COMBINED 2017 - 20 PAPERS AND MARK SCHEMES

Write your name here

Surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐ Candidate Number ☐☐☐☐

Chemistry

COMBINED 2017 PAPERS AND MARK SCHEMES

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Tuesday 13 June 2017 – Afternoon
Time: 1 hour 45 minutes

Paper Reference
9CH0/01

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

P48058A

6/5/6/6/1/

P 4 8 0 5 8 A 0 1 2 8

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

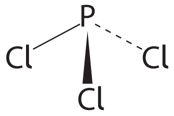
1 A phosphorus atom has mass number 31.

(a) How many of each sub-atomic particle are present in the phosphide ion, P^{3-}?

(1)

		Number of protons	Number of neutrons	Number of electrons
☒	**A**	15	16	12
☒	**B**	15	16	18
☒	**C**	16	15	12
☒	**D**	16	15	18

(b) Phosphorus(III) chloride molecules are pyramidal with a bond angle less than 109.5°.



(i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.

(2)

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(ii) Which describes the polarity of the P—Cl bond and the polarity of the phosphorus(III) chloride molecule?

(1)

		Polarity of P—Cl bond	Polarity of molecule
☒	**A**	non-polar	non-polar
☒	**B**	non-polar	polar
☒	**C**	polar	non-polar
☒	**D**	polar	polar

(c) Phosphorus has one naturally occurring isotope with mass number 31. Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3.

(2)

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(Total for Question 1 = 6 marks)

2 Magnesium nitrate decomposes on heating as shown by the equation.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

(a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

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(b) Calcium nitrate decomposes in a similar way to magnesium nitrate, but requires a higher temperature for decomposition.

Explain this observation in terms of the charge and size of the cations.

(3)

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(Total for Question 2 = 6 marks)

3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

Halogen	**Boiling temperature / °C**
chlorine	–35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine.

(2)

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(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

Potassium halide	**Products**
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

(c) Use these electrode potentials to answer the following questions.

Electrode reaction	$E^{\ominus}$ **/ V**
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$MnO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Mn^{2+}(aq) + 2H_2O(l)$	+1.23
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(i) Which species will oxidise $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$?

(1)

☒ **A** $Br_2(aq)$

☒ **B** $Cl^-(aq)$

☒ **C** $I_2(aq)$

☒ **D** $Mn^{2+}(aq)$

(ii) Write the ionic equation and calculate the $E^{\ominus}_{cell}$ value for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required.

(3)

(Total for Question 3 = 9 marks)

4 Iron and zinc are in the d-block of the Periodic Table.

(a) Which of these is the electronic configuration of an iron(II) ion, Fe^{2+}?

(1)

			3d					4s
☒ **A**	[Ar]	↑↓	↑↓	↑↓				
☒ **B**	[Ar]	↑↓	↑	↑	↑	↑		
☒ **C**	[Ar]	↑↓	↑↓					↑↓
☒ **D**	[Ar]	↑	↑	↑	↑			↑↓

(b) Iron(II) ions, $[Fe(H_2O)_6]^{2+}$, form a pale green solution but zinc ions, $[Zn(H_2O)_6]^{2+}$, form a colourless solution.

Explain why zinc ions are colourless.

(2)

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(c) Hydrated iron(II) ions react with ethanedioate ions, $C_2O_4^{2-}$, to form a complex ion.

$$[Fe(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightleftharpoons [Fe(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$$

(i) Draw a structure of the $[Fe(C_2O_4)_2(H_2O)_2]^{2-}$ ion, showing **all** of the bonds.

(2)

(ii) Explain, in terms of entropy, why this reaction is feasible.

(2)

(d) Iodide ions, I^-, react with peroxodisulfate(VI) ions, $S_2O_8^{2-}$

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

This reaction is catalysed by iron(II) ions, $Fe^{2+}(aq)$.

Write **two** ionic equations to show how iron(II) ions act as a catalyst in this reaction. State symbols are not required.

(2)

(Total for Question 4 = 9 marks)

5 This question is about enthalpy changes and entropy changes.

(a) Which is the equation for the standard enthalpy change of formation, $\Delta_f H^\ominus$, of aluminium oxide?

(1)

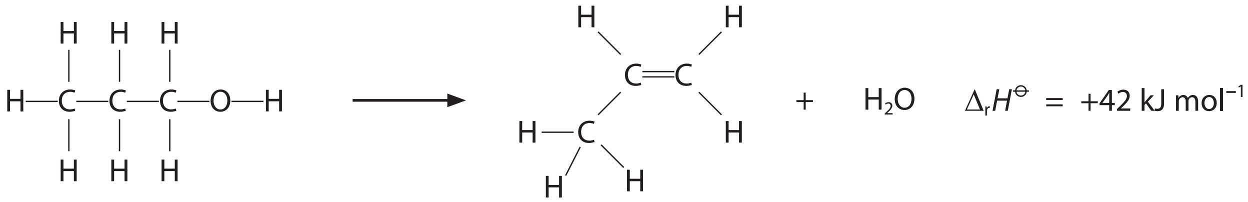
☒ **A** $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

☒ **B** $4Al(s) + 6O(g) \rightarrow 2Al_2O_3(s)$

☒ **C** $2Al(s) + 1\frac{1}{2}O_2(g) \rightarrow Al_2O_3(s)$

☒ **D** $2Al(s) + 3O(g) \rightarrow Al_2O_3(s)$

(b) Propan-1-ol is dehydrated to form propene.



The relevant mean bond enthalpies are given in the table.

Bond	**Mean bond enthalpy / kJ mol^{-1}**
C—C	347
C═C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)

(c) Which reaction has a negative value for ΔS_{system}?

(1)

☒ **A** $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

☒ **B** $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

☒ **C** $MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l) + CO_2(g)$

☒ **D** $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

(d) What is the expression for ΔS_{total}?

(1)

☒ **A** $\Delta S_{\text{surroundings}} + \dfrac{\Delta H}{T}$

☒ **B** $\Delta S_{\text{surroundings}} - \dfrac{\Delta H}{T}$

☒ **C** $\Delta S_{\text{system}} + \dfrac{\Delta H}{T}$

☒ **D** $\Delta S_{\text{system}} - \dfrac{\Delta H}{T}$

(e) Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{\text{system}} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

(Total for Question 5 = 9 marks)

6 Magnesium bromide, $MgBr_2$, is an ionic compound.

(a) (i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide. Only outer shell electrons are required.

(1)

(ii) State all the conditions under which magnesium bromide conducts electricity.

(1)

....

....

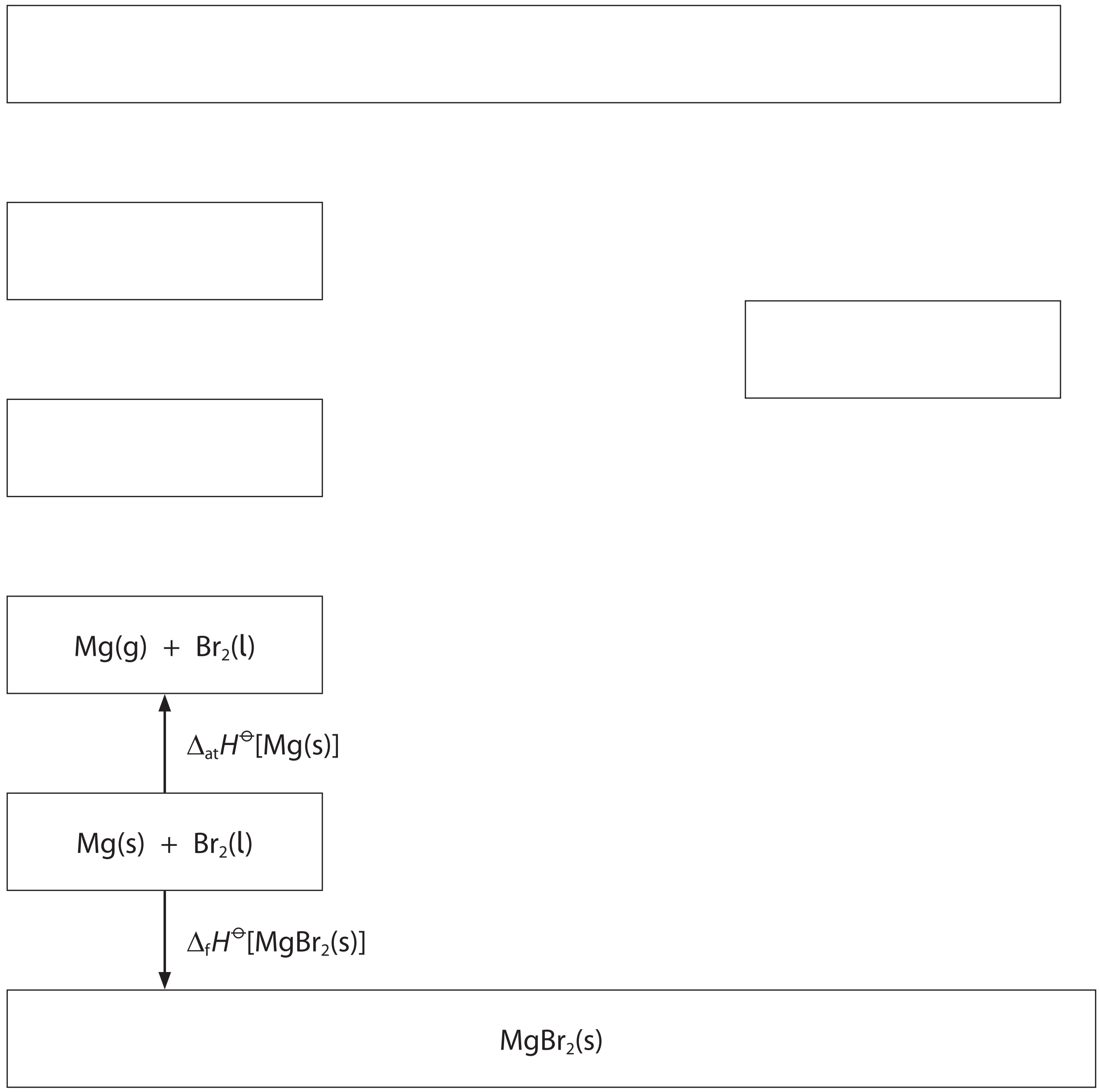
Turn over ▶

(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	**Value / kJ mol^{-1}**
enthalpy change of atomisation of magnesium, $\Delta_{at}H^{\ominus}$[Mg(s)]	+148
1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
2nd ionisation energy of magnesium, 2nd IE[Mg^+(g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{at}H^{\ominus}$[½Br_2(l)]	+112
lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	–2 440
enthalpy change of formation of magnesium bromide, $\Delta_f H^{\ominus}$[$MgBr_2$(s)]	–524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1}.

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

(ii) Write the equation, including state symbols, to show the **third** ionisation energy of magnesium.

(1)

(Total for Question 6 = 11 marks)

7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is $-53.4\ \text{kJ mol}^{-1}$.

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

Calculate the temperature change you would expect when
$25.0\ \text{cm}^3$ of $1.00\ \text{mol dm}^{-3}$ hydrochloric acid is mixed with
$25.0\ \text{cm}^3$ of $1.00\ \text{mol dm}^{-3}$ aqueous ammonia.

Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is $1.00\ \text{g cm}^{-3}$
the specific heat capacity of the solution is $4.18\ \text{J g}^{-1}\ {}^\circ\text{C}^{-1}$]

(3)

*(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	**Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}**
hydrochloric acid, HCl	–58
nitric acid, HNO_3	–58
sulfuric acid, H_2SO_4	–115
ethanoic acid, CH_3COOH	–56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

(Total for Question 7 = 9 marks)

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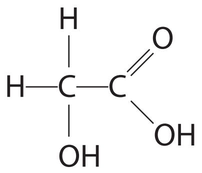
8 2-Hydroxyethanoic acid, also known as glycolic acid, $CH_2OHCOOH$, is an alpha hydroxy acid used in some skincare products.
It has a K_a value of 1.5×10^{-4} mol dm^{-3}.

The structure of glycolic acid is



(a) A solution of glycolic acid of concentration 0.1 mol dm^{-3} has a pH of 2.4

What is the approximate pH of the resulting solution after it has been diluted by a factor of 100?

(1)

☒ **A** 1.4

☒ **B** 2.4

☒ **C** 3.4

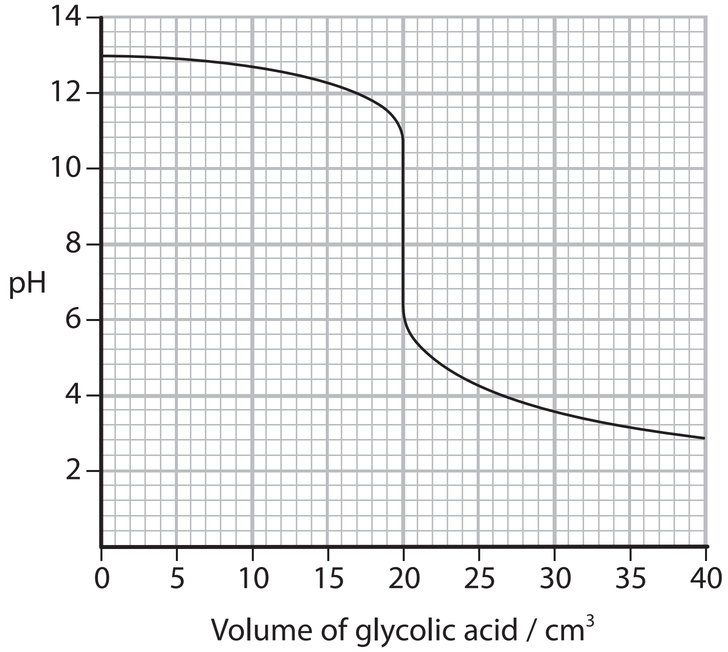
☒ **D** 4.4

(b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)

(c) The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.



(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

(ii) What is the concentration of this glycolic acid in mol dm^{-3}?

(1)

☒ **A** 0.080

☒ **B** 0.100

☒ **C** 0.125

☒ **D** 0.250

(iii) The pH of the solution containing just sodium glycolate and water is

(1)

☒ **A** 2.8

☒ **B** 6.0

☒ **C** 8.3

☒ **D** 11.0

(d) Glycolic acid has an acid dissociation constant of 1.5×10^{-4} mol dm^{-3} compared with a value of 1.7×10^{-5} mol dm^{-3} for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

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(ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed.

(1)

$CH_2OHCOOH + CH_3COOH \rightarrow$ .... + ...

(Total for Question 8 = 12 marks)

9 This question is about buffer solutions.

(a) A buffer solution is formed from disodium hydrogenphosphate, containing HPO_4^{2-} ions, and sodium dihydrogenphosphate, containing $H_2PO_4^-$ ions.

Write the **ionic** equations involving HPO_4^{2-} and $H_2PO_4^-$ ions to show how this solution acts as a buffer solution.

(2)

(b) Another buffer solution was formed by mixing 20.0 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} with 25.0 cm^3 of ethanoic acid of concentration 0.150 mol dm^{-3}.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

Calculate the pH of this buffer solution.

[K_a for ethanoic acid $= 1.74 \times 10^{-5}$ mol dm^{-3}]

(5)

(Total for Question 9 = 7 marks)

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10 Hydrogen is produced on a large scale by several different processes.

(a) One process for producing hydrogen involves reacting white-hot carbon with steam.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) \qquad \Delta H = +131\ \text{kJ mol}^{-1}$$

The expression for the equilibrium constant, K_p, is

$$K_p = \frac{p(H_2)\,p(CO)}{p(H_2O)}$$

(i) Give a reason why the partial pressure of carbon is not included in the expression.
(1)

(ii) Explain the effect of an increase in pressure on the equilibrium position of this reaction.
(2)

(iii) Explain, by reference to any change in the value of K_p, the effect of an increase in temperature on the equilibrium position of this reaction.
(2)

(iv) At 1000 K and a total pressure of 2.0 atm, 1.00 mol of steam reacted with excess carbon.

At equilibrium, 0.81 mol of hydrogen was present.

Calculate the value of K_p at 1000 K, stating any units.

(4)

(b) Carbon monoxide reacts with steam.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

At 1100 K, $K_c = 1.00$

In an experiment, 1 mol of carbon monoxide was mixed with 1 mol of steam, 2 mol of carbon dioxide and 2 mol of hydrogen.

Deduce, with reasons, the direction in which the reaction will shift to reach equilibrium.

(3)

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

Summer 2017

Pearson Edexcel GCE
in Chemistry (9CH0) Paper 1
Advanced Inorganic and Physical
Chemistry

Summer 2017
Publications Code 9CH0_01_MS_1706

General marking guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate’s response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate’s response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the mark scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	**The only correct answer is B** ***A*** *is not correct because incorrect electrons* ***C*** *is not correct because incorrect protons, neutrons and electrons* ***D*** *is not correct because incorrect protons and neutrons*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(b)(i)	An explanation that makes reference to the following points: • (pyramidal / this shape) because there are 4 pairs / 3 bond pairs and one lone pair of electrons (around central / P atom) **and** these are arranged to minimise repulsion **(1)** • (bond angle less than 109.5°) as lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion **(1)**	'ions' scores (0) overall Allow the electron pairs are arranged to minimise repulsion Allow (4) pairs of electrons with maximum separation / as far apart as possible Ignore reference to 'bonds' Ignore wrong shape Ignore repel equally Ignore repulsion between electrons There must be a comparison in M2 Allow lone pairs have greater repulsion than bond pairs Ignore just 'the lone pairs repel more' Ignore repetition of the question e.g. 'reduces the bond angle' Ignore incorrect bond angle stated (Data book value is 100.1°) Do not allow bond angle >109.5°	**(2)**

Question Number	Answer	Mark
1(b)(ii)	**The only correct answer is D** ***A*** *is not correct because both incorrect* ***B*** *is not correct because non-polar bond is incorrect* ***C*** *is not correct because non-polar molecule is incorrect*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)	• all 4 ion formulae **(1)** • all 4 *m*/*z* values **(1)** **or** • any two *m*/*z* values with corresponding ion formulae **(1)** • the other two *m*/*z* values with corresponding ion formulae **(1)**	Example of answer: ions *m*/*z* $P(^{35}Cl)_3^+$ 136 $P(^{35}Cl)_2{}^{37}Cl^+$ 138 $P^{35}Cl(^{37}Cl)_2^+$ 140 $P(^{37}Cl)_3^+$ 142 Allow any other unambiguous way of representing the formulae e.g. with brackets or in words Positive charge only needs to be shown on one of the ions Ignore mass number on P	**(2)**

(Total for Question 1 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	An explanation that makes reference to the following points: • N changes from (+)5 to (+)4 **(1)** • O changes from −2 to 0 (in O_2) **(1)** • so nitrogen / N is reduced (as the oxidation number has decreased) **and** oxygen / O (in forming O_2) is oxidised (as the oxidation number has increased) **(1)**	These numbers may be written under the formulae in the equation Allow oxidation numbers written as 5+, 4+, 2− Ignore unchanged oxidation numbers of magnesium and oxygen Allow this mark if incorrect / missing oxidation numbers in M1 and M2 Ignore general statement about redox Ignore redox explained in terms of electron gain or loss	**(3)**

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: • **Size** calcium ion / Ca^{2+} has larger (ionic) radius / is larger than magnesium ion **or** magnesium ion / Mg^{2+} has smaller (ionic) radius / is smaller than calcium ion **(1)** • **Polarising power** so calcium ion/ Ca^{2+} causes less polarisation/ distortion **or** magnesium ion/ Mg^{2+}causes more polarisation/ distortion **(1)** • **What is polarised** of the nitrate (ion / electron cloud) / NO_3^- / anion / negative ion / N—O bonds / N=O bonds / NO bonds **(1)**	Penalise omission of 'ion' **or** just 'calcium / Ca / magnesium / Mg' without charge, **or** reference to atom or molecule once only Ignore general references to ionic / covalent character Allow ionic radius increases down the group / decreases up the group Allow magnesium ions have a higher charge density (than calcium ions) Ignore atomic radius Ignore effective nuclear charge Allow the cation causes less / more polarisation if it is clear from M1 which cation is involved Do not allow this mark for carbonate / C-O bonds Do not allow mention of bond **between** cation and anion **Note** Nitrate ions are less polarised by Ca^{2+} / more polarised by Mg^{2+} scores M2 and M3	**(3)**

(Total for Question 2 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: • from chlorine to iodine / down the group, the number of electrons (in the molecule / atom) increases / changes from 34 to 106 / 17 to 53 **(1)** • so the strength of the London / instantaneous dipole-(induced) dipole forces increases / there are more London / instantaneous dipole-(induced) dipole forces **and** more energy is needed to separate the molecules **(1)**	An answer that states 'covalent bonds break' or 'bonds between atoms break' or refers to 'ions' scores (0) overall Allow reverse argument for M1 and M2 Allow iodine has more / most electron shells (than chlorine and/or bromine) Ignore 'the size of the atoms /molecules increases from chlorine to iodine' Do not allow incorrect numbers of electrons Allow iodine has the strongest London force **and** most energy is needed to separate the molecules Allow more energy is need to overcome / break the London forces / bonds instead of separate the molecules Allow dispersion forces / van der Waals forces for London forces Ignore higher temperature needed to separate the molecules Do not award dipole-dipole forces / just 'intermolecular forces'	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the following points: • iodide ions are the strongest reducing agent because iodide ions / I^- / (potassium) iodide reduces sulfur (in sulfuric acid) from +6 to 0 in sulfur / −2 in H_2S **(1)** • (whereas) bromide ions / Br^- / (potassium) bromide reduces sulfur (in sulfuric acid) from +6 to +4 **(1)** • (whereas) chloride ions / Cl^- / (potassium) chloride do not reduce sulfuric acid / sulfur / S (as there is no change in oxidation number of Cl or S) **(1)**	Allow the oxidation numbers written by the species in the table (+)6 only needs to be mentioned once in M1 or M2 Allow references to potassium halides / halogens / hydrogen halides instead of halide ions For full marks, the answer must identify iodide as the strongest reducing agent Only 1 oxidation number change is needed. If both are given, both must be correct Allow bromide ions are stronger reducing agents than chloride ions because they are oxidised from −1 to 0 Allow just ‘it is not a redox reaction’	**(3)**

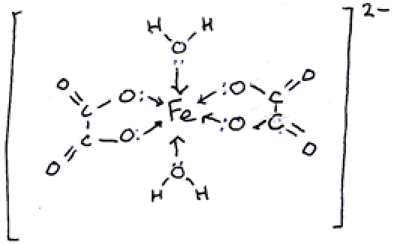
Question Number	Answer	Mark
3(c)(i)	**The only correct answer is A** ***B*** *is not correct because* Cl^- *is not an oxidising agent* ***C*** *is not correct because* I_2 *is not a powerful enough oxidising agent* ***D*** *is not correct because* Mn^{2+} is not an oxidising agent	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	- all species on correct sides of equation **and** no electrons / electrons cancelled **(1)** - balancing correct species **(1)** - $E^\ominus_{cell}$ value **(1)**	Example of ionic equation $2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$ Allow $\rightleftharpoons$ Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing Ignore state symbols Allow multiples Allow M2 for almost correct species $E^\ominus_{cell}$ (= 1.51 − 1.09) = (+)0.42 (V) No TE on incorrect equation	**(3)**

(Total for Question 3 = 9 marks)

Question Number	Answer	Mark
4(a)	**The only correct answer is B** ***A*** *is not correct because 4 of the 3d electrons should be unpaired* ***C*** *is not correct because there should not be any electrons in the 4s orbital* ***D*** *is not correct because there should not be any electrons in the 4s orbital*	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to the following points:		**(2)**
	• (zinc (ions) / Zn^{2+}) has / have a full (3)d sub-shell / $3d^{10}$ / all (3)d orbital**s** are full **(1)**	Allow zinc (ions) / Zn^{2+} do not have a partially filled / incomplete (3)d (sub-) shell / no empty (3)d orbitals Do not allow zinc atoms	
	• so d-d transitions cannot take place **or** electrons cannot move between (3)d orbitals **or** electrons cannot be promoted / excited to higher (3)d orbitals **(1)**	Ignore omission of 'd' in the 'or's, if it is included in M1 Do not allow the (3)d orbitals do not split / the (3)d subshell does not split Ignore just 'movement to different energy level'	

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	• 2 water ligands joined between O and Fe **(1)** • 2 ethanedioate ligands drawn correctly showing all the bonds **and** joined between single-bonded O atoms and Fe as shown **(1)**	<u>Example of structure</u>  Allow water ligands arranged as *cis* or *trans* Allow delocalised bonds in ethanedioate ions Allow bonds not shown in H_2O, provided the ligands are attached to Fe^{2+} through oxygen atoms Ignore bond lengths and angles Ignore wedges and dotted lines to show shape Ignore missing lone pairs and arrowheads Ignore missing square brackets and charge / incorrect charge Ignore –ve charges on ethanedioate ions / +ve charge on Fe	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(c)(ii)	An explanation that makes reference to the following points: • (there are) more particles / moles / species on the right of the equation (than on the left) **or** (there is an increase from) 3 particles on the left of the equation to 5 on the right **(1)** • so ΔS_{system} increases / is positive (and $\Delta S_{\text{surroundings}}$ is unchanged so ΔS_{total} increases) **(1)**	Do not allow incorrect numbers of particles Do not allow 3 molecules on the left and 5 molecules on the right Allow ΔS_{total} is positive / increasing Allow entropy / ΔS increases Allow there is a positive entropy change Ignore just there is an increase in disorder (from left to right) Ignore $\Delta S_{\text{surroundings}}$ changes Ignore just ‘entropy is positive’ Ignore references to free energy	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(d)	• Fe^{2+} oxidised to Fe^{3+} in reaction with $S_2O_8^{2-}$ **(1)** • Fe^{3+} reduced to Fe^{2+} in reaction with I^- **(1)**	Examples of equations $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Ignore state symbols Allow equations in either order Allow multiples Penalise uncancelled electrons once only **Note** If no other mark is awarded, allow (1) for all correct species in 2 unbalanced equations	**(2)**

(Total for Question 4 = 9 marks)

Question Number	Answer	Mark
5(a)	**The only correct answer is C** ***A*** *is not correct because standard enthalpy of formation is for making 1 moles of a compound* ***B*** *is not correct because standard enthalpy of formation is for making 1 moles of a compound* ***D*** *is not correct because* oxygen must be O_2	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(b)	• calculation of energy needed to break bonds **(1)** • calculation of energy released when bonds are made **(1)** • calculation of mean bond enthalpy of C—O **(1)**	Example of calculation Energy to break bonds: (C—C) + (C—H) + (C—O) = 347 + 413 + (C—O) = (C—O) + 760 (kJ) Energy released in forming bonds: (C=C) + (O—H) = 612 + 464 = (−)1076 (kJ) (C—O) + 760 − 1076 = 42 (C—O) = (+)358 (kJ mol^{-1}) TE on M1 and M2 If all bonds broken: Energy to break bonds = (C—O) + 4049 (kJ) Energy released in forming bonds = (−)4365 (kJ) Ignore units Correct answer with no working scores (3) Allow correct working in M1 and M2 if answers not evaluated	**(3)**

Question Number	Answer	Mark
5(c)	**The only correct answer is A** ***B*** *is not correct because all increase in entropy as disorder increases when gases are formed* ***C*** *is not correct because all increase in entropy as disorder increases when gases are formed* ***D*** *is not correct because all increase in entropy as disorder increases when gases are formed*	**(1)**

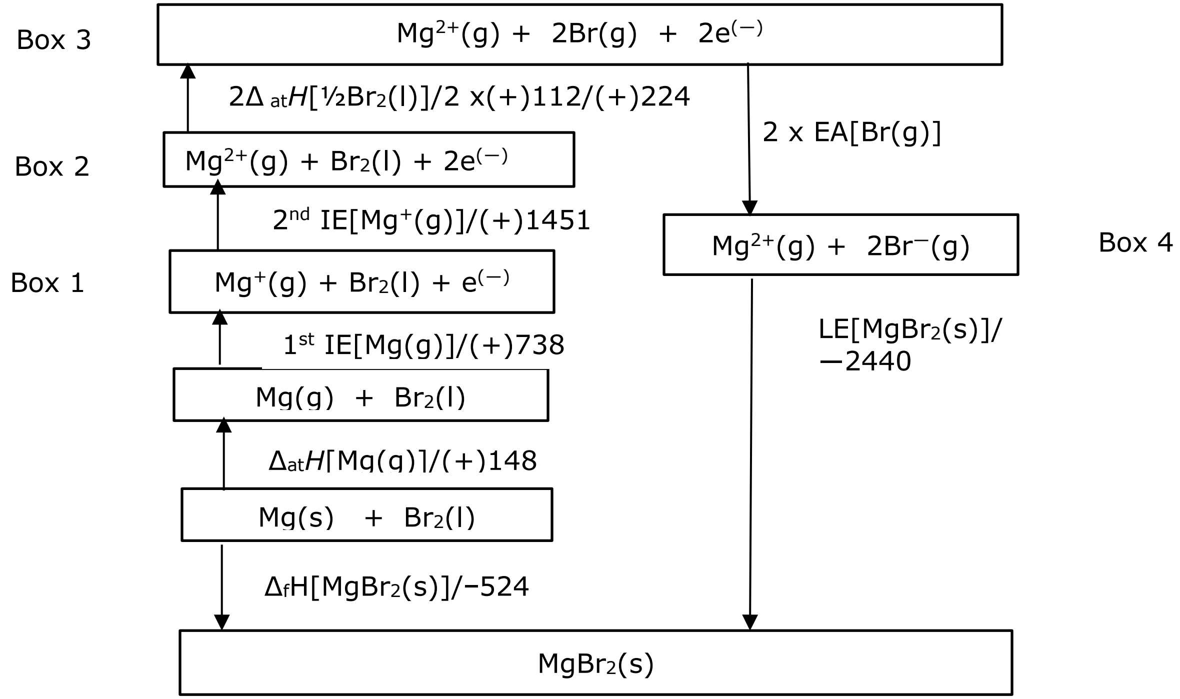
Question Number	Answer	Mark
5(d)	**The only correct answer is D** ***A*** *is not correct because* $\Delta S_{\text{surroundings}}$ *is incorrect* ***B*** *is not correct because* $\Delta S_{\text{surroundings}}$ *is incorrect* ***C*** *is not correct because sign of* $\Delta H/T$ *is incorrect*	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(e)	 • calculation of Δ*G* **(1)** • Δ*G* is positive / >0 so reaction is not feasible **(1)** • calculation of *T* **(1)**	Penalise incorrect units in M1 or M3 once only Working is not required for the calculations Example of calculation $\Delta G = 178 — (298 \times \frac{165}{1000})$ $= (+)128.83$ / 129 (kJ mol^{-1}) **or** $\Delta G = 178000 — (298 \times 165)$ $= (+)128830$ / 129000 (J mol^{-1}) Stand alone mark Allow Δ*G* must be negative for a reaction to be feasible Ignore 'so reaction is not feasible' without a reason No TE on a calculated negative value Example of calculation $\Delta G = 0$, so $\Delta H = T\Delta S_{(sys)}$ or $T = \Delta H/\Delta S_{(sys)}$ **or** $\Delta S_{total} = \Delta S_{sys} - \Delta H/T = 0$, so $T = \Delta H/\Delta S_{(sys)}$ $T = 178/0.165 = 1078.8$ / 1079 / 1080 (K) **or** $T = 178000/165 = 1078.8$ / 1079 / 1080 (K) **or** $T = 806$ (°C) Ignore SF except 1 SF	**(3)**

(Total for Question 5 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	• dot-and-cross diagram **and** charges	Example of diagram  Circles are not needed Allow no electrons or 8 electrons on outer shell of Mg Allow dots or crosses for all electrons Allow diagrams without square brackets, provided charges are shown Allow alternative ways of showing that there are 2 bromide ions Ignore inner shell electrons	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	• (conducts electricity when) molten / liquid **and** dissolved in water / (in) aqueous (solution)	Both needed for the mark Ignore gaseous Allow ‘in solution / dissolved’	**(1)**

<table>
<tr><th>Question Number</th><th>Answer and Additional Guidance</th><th>Mark</th></tr>
<tr><td>6(b)(i)</td><td>


- Correct arrows with 1st **and** 2nd IE of Mg labelled **and** correct Mg symbols with state symbols in boxes 1 and 2 or 2 and 3 **(1)**

- 2 x $\Delta_{at}H^{\ominus}[\frac{1}{2}Br_2(l)]$ / 2 x(+)112 / (+)224 **and** 2Br(g) in box 3 or 1 **and** 2 x EA[Br(g)] labelled **and** $2Br^-(g)$ in box 4 **and** correct arrows **(1)**

- LE[$MgBr_2(s)$] / −2440 labelled **and** arrow in correct direction **(1)**

Allow any unambiguous labels for the arrows with words and/or numbers – state symbols not required
Accept enthalpy change of atomisation of bromine before IEs of magnesium
Ignore missing electrons / $2e^{(-)}$ in boxes 1, 2 and 3
Allow 1 state symbol missing but penalise 2 missing, or an incorrect state symbol in boxes once only
</td><td>(3)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	• correct expression for 2 x EA(Br) in numbers or symbols **(1)** • calculation of EA(Br) **(1)**	Example of calculation 2 x EA(Br) = − (2 x +112) − (+1451) − (+738) − (+148) + (−524) − (−2440) EA(Br) = $-\frac{645}{2}$ = −322.5 /−323 (kJ mol^{-1}) Correct answer with no working scores (2) Allow for 1 mark: (+)322.5 / (+)323 (wrong sign) −266.5 /−267 (2 missing from $\Delta_{at}H$ (Br)) −645 (2 missing from EA) −533 (both 2s missing for Br) Ignore units No TE on incorrect arrows in (b)(i)	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	An explanation that makes reference to the following points: • **Nuclear charge** magnesium (atom) / Mg has more protons than sodium (atom) / Na **or** magnesium / Mg has a greater (effective) nuclear charge (than sodium / Na) **(1)** • **Shielding** (outer) electron in magnesium (atom) / Mg in the same (quantum) shell / energy level / sub-shell / orbital as in a sodium atom / Na **or** shielding in magnesium atom / Mg similar to / same as that in sodium atom / Na **(1)** • **Attraction** so the force of attraction between the nucleus and the (outer) electron is greater in magnesium (atom) / Mg (than in sodium atom / Na) **(1)**	Penalise reference to ion once only Ignore reference to atomic radius Allow correct E.C of both atoms Allow same number of (quantum) shells / energy levels in Mg and Na Allow the (outer) electron in Mg is held more tightly to the nucleus (than in Na) **Note** An answer that describes the trend across a period, without one reference to either sodium or magnesium, scores maximum (2) marks	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	• correct equation with state symbols	Examples of equations $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^{(-)}$ $Mg^{2+}(g) - e^{(-)} \rightarrow Mg^{3+}(g)$ Ignore state symbol for the electron Do not allow ⇌	**(1)**

(Total for Question 6 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	• calculation of moles used **(1)** • calculation of energy for that number of moles **(1)** • calculation of temperature change **and** gives answer to 2 SF (because a school thermometer cannot measure to 3 SF) **(1)**	Example of calculation moles used = 25.0 x 1.00/1000 = 0.0250 energy released = 0.025 x 53.4 = 1.335 (kJ) / 1335 (J) TE on moles used Ignore sign temperature change = 1335/(50.0 x 4.18) = 6.3876 = 6.4 (^{o}C / K) TE on moles and energy Allow final answer to 3 SF 6.39 (^{o}C / K) Ignore units Correct answer with no working scores (3)	**(3)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>7(b)*</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table></td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>(6)</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Comment: Look for the indicative marking points first, then consider the mark for the structure of answer and sustained line of reasoning.

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks. 3 and 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning.

	Indicative content **Hydrochloric acid and nitric acid** - (same value for) hydrochloric acid **and** nitric acid as they are strong / completely dissociated into ions (in solution) - reaction taking place is $H^+ + OH^- \rightarrow H_2O$ / $H_3O^+ + OH^- \rightarrow 2H_2O$ **Sulfuric acid** - sulfuric acid is diprotic / dibasic **or** (1 mol of) sulfuric acid provides 2 mol H^+ / produces 2 mol H_2O - so value is (almost) twice that of hydrochloric acid / nitric acid **or** reverse argument **Ethanoic acid** - ethanoic acid is weak /partially dissociated into ions (in solution) / $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ / $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ - some energy is needed to break (O-H) bond(s) to release H^+ ions (so enthalpy change of neutralisation is less than for a strong acid) **or** enthalpy change of neutralisation includes the enthalpy of dissociation of ethanoic acid so it is less exothermic	Allow correct formulae for names throughout the answer Ignore sulfuric acid as strong(est) acid Allow $HCl + NaOH \rightarrow NaCl + H_2O$ **and** $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ Allow hydrochloric acid **and** nitric acid are both monoprotic / monobasic / provide 1 mol H^+ / produce 1 mol H_2O Allow $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ Allow ethanoic acid is the weakest acid Allow some energy is needed to ionise ethanoic acid	

(Total for Question 7 = 9 marks)

Question Number	Answer	Mark
8(a)	**The only correct answer is C** ***A*** *is not correct because this is for a 100-fold increase in concentration* ***B*** *is not correct because this is for no change in concentration* ***D*** *is not correct because this is for a 10000-fold decrease in concentration*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)	• calculation of $[H^+]$ **(1)** • expression relating K_a, $[H^+]$ and $[CH_2OHCOOH]$ **(1)** • calculation of $[CH_2OHCOOH]$ **(1)**	Example of calculation $[H^+] = 10^{-pH} = 0.01 / 1 \times 10^{-2} / 10^{-2}$ (mol dm^{-3}) $K_a = \frac{[H^+]^2}{[CH_2OHCOOH]}$ **or** $[CH_2OHCOOH] = \frac{[H^+]^2}{K_a}$ Allow [HA] in M2 and M3 $[CH_2OHCOOH] = \frac{0.01^2}{1.5 \times 10^{-4}}$ $= 0.667 / 0.67$ (mol dm^{-3}) Ignore SF except 1 SF Ignore units Correct answer with no working scores (3)	**(3)**

Question Number	Answer	Additional Guidance	Mark
8(c)(i)	• named indicator **(1)** • matching colour **change** **(1)** • pH range (of indicator) / quoted range lies (completely) in the vertical region (on the titration curve) **or** indicator will change colour in the vertical / straight / steep region of the graph **or** pH range of indicator and pH range of vertical region of the graph stated, as long as they overlap **(1)**	<u>Examples of indicators and colour changes</u> phenol red – red to orange / yellow phenolphthalein ((in ethanol)) – red / pink to colourless (do not allow purple or clear) bromothymol blue – blue to yellow M2 is conditional on a correct indicator in M1 Do not allow unsuitable indicators e.g. litmus Stand alone mark Allow pK_{in} (± 1) is in the vertical jump **or** pK_{in} is nearest to the pH at the end / equivalence point **or** indicator will change colour at the end / equivalence point **or** (because it is a) titration of a weak acid with a strong base	**(3)**

Question Number	Answer	Mark
8(c)(ii)	**The only correct answer is C** ***A*** *is not correct because used the volumes the wrong way round* ***B*** *is not correct because not used the volume of glycolic acid from the graph* ***D*** *is not correct because used a 1:2 mole ratio*	**(1)**

Question Number	Answer	Mark
8(c)(iii)	**The only correct answer is C** ***A*** *is not correct because this is the pH of glycolic acid* ***B*** *is not correct because this is the pH at the end of the vertical jump in the curve* ***D*** *is not correct because this is the pH at the start of the vertical jump*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(d)(i)	An explanation that makes reference to the following points:		**(2)**
	• the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH_2OH) withdraws / attracts electrons **(1)**	Allow reference to intramolecular hydrogen bonding	
	• stabilises the anion / CH_2OHCOO^- ion **or** weakens O-H bond in acid so hydrogen **ion** / H^+ lost more easily **(1)**	Allow hydrogen **ion** / H^+ more easily dissociates	

Question Number	Answer	Additional Guidance	Mark
8(d)(ii)	($CH_2OHCOOH$ + CH_3COOH →) • CH_2OHCOO^- + $CH_3COOH_2^+$	Both correct for the mark Allow formulae in either order Allow formulae in brackets with charge outside Allow displayed formulae Do not allow $CH_3C(OH)_2^+$	**(1)**

(Total for Question 8 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)	• $HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$ **or** $HPO_4^{2-} + H_3O^+ \rightarrow H_2PO_4^- + H_2O$ **(1)** • $H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$ **(1)**	Penalise non-ionic equations, e.g. using NaOH or HCl once only Equations must show reaction of ions with H^+ / H_3O^+ and OH^- Allow $\rightleftharpoons$ Ignore state symbols Allow $H_2PO_4^- \rightarrow HPO_4^{2-} + H^+$ **and** $H^+ + OH^- \rightarrow H_2O$	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(b)	• calculation of the amount of NaOH / salt **(1)** • calculation of initial amount of acid **(1)** • calculation of the amount of acid left **(1)** • calculation of [H$^+$] **(1)** • calculation of pH **(1)**	Example of calculation amount of NaOH = amount of salt formed =0.100 x 20.0/1000 = 0.00200 initial amount of acid = 0.150 x 25.0/1000 = 0.00375 amount of acid left = 0.00375 − 0.00200 = 0.00175 total volume = 20.0 + 25.0 = 45.0 (cm^3) [salt] = 0.00200 x 1000/45.0 = 0.0444 (mol dm^{-3}) [acid] = 0.00175 x 1000/45.0 = 0.0389(mol dm^{-3}) $K_a = \frac{[H^+][salt]}{[acid]}$ so $[H^+] = K_a\frac{[acid]}{[salt]}$ [H$^+$] = 1.74 x 10^{-5} x 0.0389/0.0444 = 1.52446 x 10^{-5} (mol dm^{-3}) Allow use of moles instead of concentrations pH = −log[H$^+$] = −log(1.52446 x 10^{-5}) = 4.817 / 4.82 / 4.8 Allow TE for each step Ignore SF except 1 SF Correct answer without working score (5)	**(5)**

		Allow alternative methods, for example $\text{pH} = \text{p}K_\text{a} - \log \dfrac{[\text{acid}]}{[\text{salt}]}$ $\text{pH} = -\log 1.74 \times 10^{-5} - \log \dfrac{0.0389}{0.0444}$ pH = 4.817 / 4.82 / 4.8 scores M4 and M5 **or** $\text{pH} = \text{p}K_\text{a} + \log \dfrac{[\text{salt}]}{[\text{acid}]}$ $\text{pH} = -\log 1.74 \times 10^{-5} + \log \dfrac{0.0444}{0.0389}$ pH = 4.817 / 4.82 / 4.8 scores M4 and M5	

(Total for Question 9 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
10(a)(i)	An answer that makes reference to the following point: • carbon / solid has no (vapour / partial) pressure **or** (partial) pressure of carbon / solid is constant **or** carbon does not contribute to the overall pressure (of the system)	Allow the reaction is heterogeneous **and** (partial) pressure of a pure solid is not included (in K_p expression) Do not allow just 'because carbon is a solid' or 'carbon is not a gas'	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	An explanation that makes reference to the following points: • there are fewer moles / molecules / particles of **gas** on the left / reactant side **(1)** • so equilibrium position/ it moves / shifts to the left / reactant side **(1)**	Allow 2 moles / molecules of **gas** on right and 1 mole / molecule on left M2 is conditional on M1 **or** the idea of fewer particles on the left / decreasing the value of the quotient / Q Do not allow any indication of K_p changing	**(2)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
10(a)(iii)	An explanation that makes reference to the following points: • (forward) reaction is endothermic **and** so equilibrium constant / K_p increases as temperature increases **(1)** • so equilibrium position / it moves / shifts to the right / product side **(1)**	Ignore references to ΔG and ΔS M2 is conditional on M1 **or** endothermic or equilibrium constant increases	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>10(a)(iv)</td>
<td>
• calculation of moles of each substance at equilibrium (1)

• calculation of partial pressure of each substance (1)

• calculation of K_p (1)

• units (stand alone mark) (1)
</td>
<td>
<u>Example of calculation:</u>
<table>
<tr><th></th><th>H_2O(g)</th><th>H_2(g)</th><th>CO(g)</th></tr>
<tr><td>Initial moles</td><td>1.00</td><td>0</td><td>0</td></tr>
<tr><td>Eqm moles</td><td>1.00 – 0.81 = 0.19</td><td>0.81</td><td>0.81</td></tr>
<tr><td colspan="4">Total moles = 0.19 + 0.81 + 0.81 = 1.81</td></tr>
<tr><td>Mole fraction</td><td>0.19/1.81 = 0.10497</td><td>0.81/1.81 = 0.4475</td><td>0.81/1.81 = 0.4475</td></tr>
<tr><td>Partial pressure /atm</td><td>0.10497 x 2.0 =0.20994</td><td>0.4475 x 2.0 = 0.895</td><td>0.4475 x 2.0 =0.895</td></tr>
</table>
$$K_p = \frac{0.895 \text{ x } 0.895}{0.20994}$$
= 3.815 / 3.82 / 3.8 atm

3.8144 / 3.814 / 3.81 / 3.8 atm from 0.105 and 0.210

Correct answer with units but no working scores (4)

Allow TE for M2 and M3

Ignore SF except 1 SF
</td>
<td>(4)</td>
</tr>
</table>

Question Number	Answer	Additional Guidance	Mark
10(b)	• the quotient / Q: $\frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{2 \times 2}{1 \times 1} = 4$, which is larger than K_c **or** (since $K_c = 1$) the concentrations of the products must be equal to the concentrations of the reactants at equilibrium **(1)** • the concentrations of CO_2 and H_2 / products need to decrease **and** those of CO and H_2O / reactants need to increase **(1)** • so reaction shifts to the left **(1)**	Allow amounts / moles / (partial) pressures for concentrations Allow calculated K_c / the quotient / Q will be greater than 1 Allow shift so that there is 1.5 mol of each substance M3 conditional on some explanation	**(3)**

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 90 MARKS

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Chemistry

Advanced

Paper 2: Advanced Organic and Physical Chemistry

Monday 19 June 2017 – Morning
Time: 1 hour 45 minutes

Paper Reference
9CH0/02

You must have:
Data Booklet
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an asterisk (*****), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

1 This is a question about alkanes.

(a) What is the reaction mechanism when ethane and chlorine react in UV light?

(1)

☒ **A** electrophilic addition

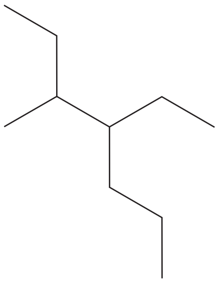
☒ **B** electrophilic substitution

☒ **C** free radical addition

☒ **D** free radical substitution

(b) What is the name of this alkane?

(1)



☒ **A** 2-ethyl-3-propylpentane

☒ **B** 4-ethyl-3-methylheptane

☒ **C** 3-methyl-4-propylhexane

☒ **D** 4-methyl-3-propylhexane

(c) Alkanes are obtained by processing crude oil.

(i) Explain why different alkanes in crude oil can be separated by fractional distillation.

(2)

....

....

....

....

(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required.

(1)

C_8H_{18} → .... + ...

(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required.

(1)

(Total for Question 1 = 6 marks)

2 Diamond, graphene and graphite are different forms of carbon.

(a) The structural feature that graphene and graphite have in common is that the carbon atoms are arranged in

(1)

☒ **A** layers with each atom bonded to four others

☒ **B** hexagonal and pentagonal rings within a layer

☒ **C** hexagonal rings within a layer

☒ **D** a three-dimensional structure

(b) The bond angles within a layer of graphene and a layer of graphite are

(1)

☒ **A** 90° and 109.5°

☒ **B** all 109.5°

☒ **C** 109.5° and 120°

☒ **D** all 120°

(c) One way in which diamond differs from graphene and graphite is that only diamond has

(1)

☒ **A** a high melting temperature

☒ **B** a precise molecular formula

☒ **C** poor electrical conductivity

☒ **D** a giant structure

(Total for Question 2 = 3 marks)

3 This is a question about halogenoalkanes and related compounds.

(a) Explain the trend in reactivity of the **primary** chloro-, bromo- and iodoalkanes with aqueous hydroxide ions.

(2)

....

....

....

....

(b) In aqueous sodium hydroxide, 1-bromoethane reacts to produce ethanol.

(i) Write the mechanism for this reaction, including all relevant curly arrows, lone pairs and dipoles. Include the transition state.

(4)

(ii) Give the reagents that are used to test that bromide ions are formed in this reaction mixture. Include the result of the test.

(2)

....

....

....

....

(c) The halogenoalkane 2-bromobutane reacts with ethanolic potassium hydroxide to produce a mixture of alkenes.

Draw the **skeletal** formulae of all the alkenes that could be produced.

(3)

(d) Explain why ethene has a boiling temperature of −104 °C, whereas ethanol has a boiling temperature of 78 °C.

(3)

....

....

....

....

....

....

(Total for Question 3 = 14 marks)

4 Traditionally, high-flying aircraft and Formula 1 racing cars have had their tyres inflated with nitrogen gas instead of air. Recently, this practice has been extended to some other cars.

(a) A car tyre is filled with nitrogen gas to a volume of 8.98 dm^3 and a pressure of 207 kPa at 20 °C.

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

(3)

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

(1)

....

....

(b) One reason for the use of nitrogen gas in car tyres is that less gas is lost from the tyres during use because nitrogen molecules are larger than oxygen molecules. A suggested explanation for this is that nitrogen atoms are larger than oxygen atoms.

Explain why a nitrogen atom is larger than an oxygen atom.

(2)

....

....

....

....

(Total for Question 4 = 6 marks)

5 This is a question about catalytic converters in car exhaust systems.

(a) When petrol is burnt in a car engine, pollutant gases including carbon monoxide and nitrogen monoxide are formed.

(i) Write the equation for the reaction between these two polluting gases that takes place on the surface of a catalytic converter. State symbols are not required.

(1)

(ii) Describe the stages by which the reaction in (a)(i) occurs in a catalytic converter.

(3)

....

....

....

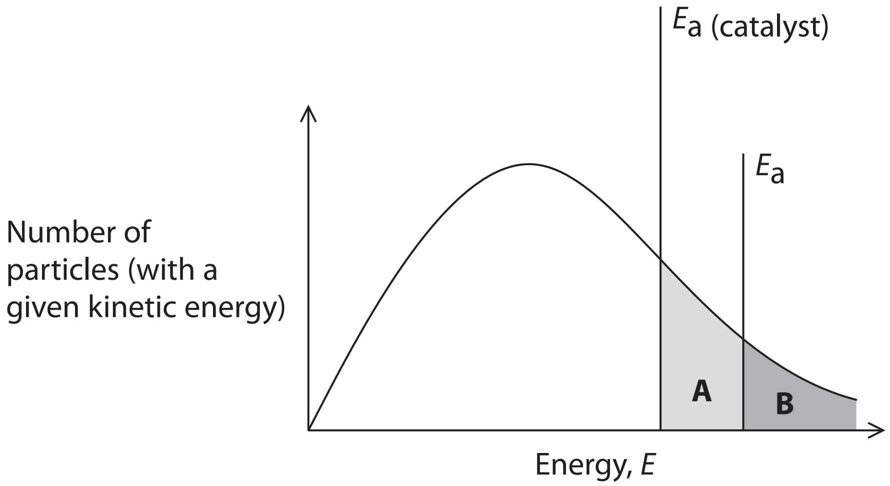
....

....

....

....

(b) Which area in the Maxwell-Boltzmann distribution diagram represents the **increase** in the number of particles with sufficient energy to react in the presence of a catalyst?



(1)

☒ **A** area A

☒ **B** area B

☒ **C** area A – area B

☒ **D** area A + area B

(c) In the UK, the exhaust emissions of a petrol-fuelled vehicle must be less than 1.00 g of carbon monoxide per kilometre.

What is the maximum number of carbon monoxide molecules that can be emitted per kilometre for a vehicle to meet this regulation?

(1)

☒ **A** 1.37×10^{22}

☒ **B** 2.15×10^{22}

☒ **C** 6.02×10^{23}

☒ **D** 1.69×10^{25}

(Total for Question 5 = 6 marks)

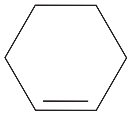
6 This is a question about polymerisation.

(a) But-1-ene and cyclohexene both form addition polymers.

Draw a section of each polymer, showing **two** repeat units.

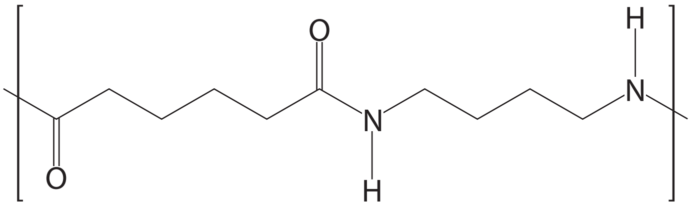
(2)

$CH_2{=}CHCH_2CH_3$ →

 →

(b) Deduce the two monomers needed to produce the polyamide shown.

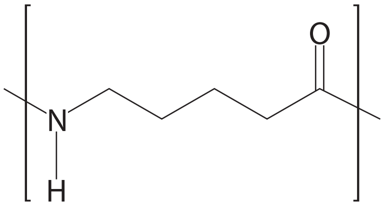
(2)



and

(c) Deduce the single monomer that could be used to produce the polyamide shown.

(1)



(d) PLA is a biodegradable polyester which is made from 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid.

(2)

(ii) State how separate samples of these two enantiomers could be distinguished in a laboratory.

(1)

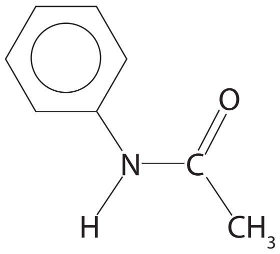
(iii) Biodegradable polyesters break down naturally.

State why this is an advantage.

(1)

(Total for Question 6 = 9 marks)

7 Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



Antifebrin

(a) Some of the following reagents can be used to produce Antifebrin from benzene.

- Aluminium chloride
- Ammonia, concentrated
- Benzene
- Ethanal
- Ethanoic acid
- Ethanol
- Ethanoyl chloride
- Hydrochloric acid, concentrated
- Hydrochloric acid, dilute
- Iron
- Nitric acid, concentrated
- Nitric acid, dilute
- Propanone
- Sodium chloride
- Sulfuric acid, concentrated
- Tin

Selecting from only these reagents, devise a **three-step** synthetic pathway to convert benzene into Antifebrin. You should include the structures of the two intermediate compounds and the reaction conditions.

(5)

(b) What is the number of peaks in a C-13 NMR spectrum of Antifebrin?

(1)

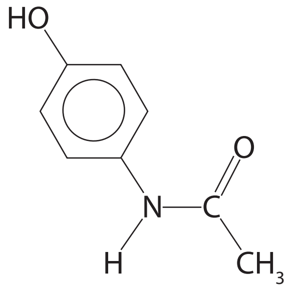
☒ **A** 5

☒ **B** 6

☒ **C** 7

☒ **D** 8

(c) Paracetamol is structurally similar to Antifebrin, but has a hydroxy group attached directly to the benzene ring.



The bromination of the benzene ring in paracetamol occurs much more readily compared to the bromination of benzene.

Explain this increased reactivity.

(2)

....

....

....

....

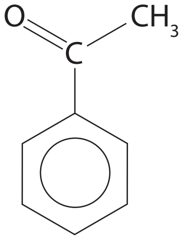
(d) A tablet with a total mass of 500 mg contained 3.10×10^{-3} mol of paracetamol.

Calculate the percentage by mass of paracetamol in the tablet, quoting your answer to an appropriate number of significant figures.

(2)

(Total for Question 7 = 10 marks)

8 Phenylethanone is an ingredient in many types of chewing gum.



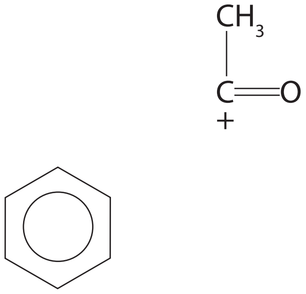
One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, CH_3COCl.

(a) (i) Write the equation for the formation of the electrophile, CH_3CO^+, from ethanoyl chloride using the catalyst aluminium chloride.

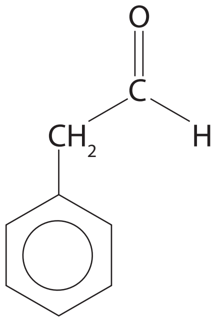
(1)

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

(4)



(b) Phenylethanone can be distinguished from its structural isomer, phenylethanal, in a number of different ways.



(i) Which would react with phenylethanone but **not** with phenylethanal?

(1)

☒ **A** acidified sodium dichromate(VI)

☒ **B** alkaline iodine solution

☒ **C** Fehling's solution

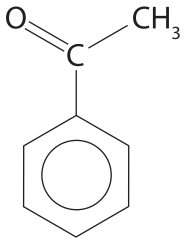
☒ **D** Tollens' reagent

(ii) Give the steps to show how 2,4-dinitrophenylhydrazine could be used to distinguish between phenylethanone and phenylethanal.

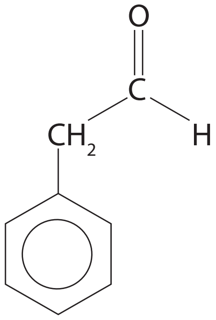
(4)

*(iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.



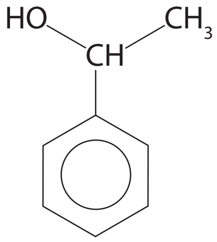
Phenylethanone



Phenylethanal

(6)

(c) The compound 1-phenylethanol can be formed from phenylethanone.



Give the reagent and conditions that would be used to form 1-phenylethanol.

(2)

....

....

....

(Total for Question 8 = 18 marks)

9 This question is about reaction kinetics.

(a) Compound **A** decomposes in a first order reaction.

Calculate the time it takes for the mass of **A** to decrease from 600 g to 37.5 g if the decomposition has a constant half-life of 14 minutes.

(1)

(b) The 'initial rates' method was used to investigate the orders of reaction with respect to reactants **X**, **Y** and **Z**. The table shows the results obtained.

Run	**Initial concentration / mol dm^{-3}**			**Initial rate / mol dm^{-3} s^{-1}**
	X	**Y**	**Z**	
1	0.00100	0.00300	0.00600	2.17×10^{-6}
2	0.00100	0.00600	0.00600	8.68×10^{-6}
3	0.00050	0.00600	0.00600	4.34×10^{-6}
4	0.00300	0.00300	0.00300	6.51×10^{-6}

(i) Calculate the orders with respect to **X**, **Y** and **Z**.

(3)

X ....

Y ....

Z ....

(ii) Give the rate equation for the reaction and hence calculate the rate constant, *k*, to an appropriate number of significant figures. Include units in your answer.

(4)

(c) The kinetics of the 'bromine clock' were investigated and the rate equation was found to be

$$\text{Rate} = k[BrO_3^-][Br^-][H^+]^2$$

(i) What is the overall reaction order?

(1)

☒ **A** First

☒ **B** Second

☒ **C** Third

☒ **D** Fourth

(ii) Calculate the concentration of bromide ions required to produce a reaction rate of 4.08×10^{-3} mol dm^{-3} s^{-1} at 298 K given that

$k = 8.00$ dm^9 mol^{-3} s^{-1}

$[BrO_3^-] = 0.200$ mol dm^{-3}

$[H^+] = 0.100$ mol dm^{-3}

(2)

(d) The rate constant for the reaction between bromoethane and aqueous hydroxide ions was determined at five different temperatures.

The results are given in the table.

Temperature (T) / K	**1 / Temperature (1 / T) / K^{-1}**	**Rate constant, *k* / $dm^3 mol^{-1} s^{-1}$**	**ln *k***
293	3.41×10^{-3}	5.83×10^{-5}	–9.75
303		1.67×10^{-4}	
313		5.26×10^{-4}	
323		1.36×10^{-3}	
333	3.00×10^{-3}	3.77×10^{-3}	–5.58

Complete the data in the table and use them to plot a graph of ln *k* against 1 / T and hence determine the activation energy, E_a, in kJ mol^{-1}.

You should include the value and units of the gradient of the line.

The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(7)

(Total for Question 9 = 18 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										*(18)* 4.0 **He** helium 2
(1)	*(2)*											*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

GCE Chemistry June 2017

Paper 9CH0/02 Advanced Organic and Physical Chemistry

Summer 2017
Publications Code 9CH0_02_1706_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

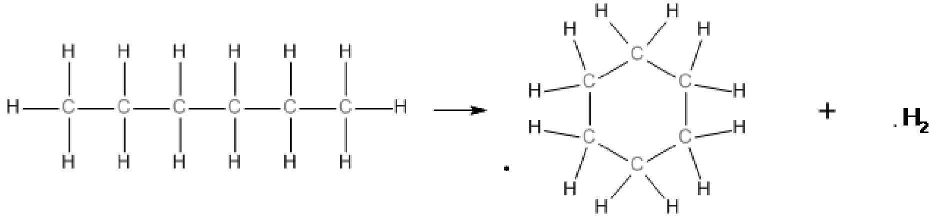
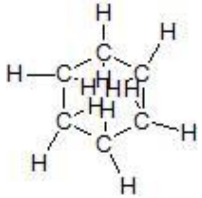
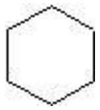
Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	**The only correct answer is D** (free radical substitution) ***A*** *is not correct because electrophilic addition would be the reaction mechanism between alkenes, such as ethene, and chlorine but the substance in the question is the alkane, ethane* ***B*** *is not correct because electrophilic substitution involves the reactions of aromatic systems but this question refers to the reaction of the alkane, ethane* ***C*** *is not correct because the mechanism of reaction between an alkane such as ethane and chlorine involves substitution and not addition*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is B** (4-ethyl-3-methylheptane) ***A*** *is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not pentane but heptane, with the consequential effect on the numbering and length of side chains* ***C*** *is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not hexane but heptane, with the consequential effect on the numbering and length of side chains* ***D*** *is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not hexane but heptane, with the consequential effect on the numbering and length of side chains*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(i)	An explanation that makes reference to the following points: • different alkanes have different boiling temperatures/points **(1)** • because of (different) chain length/molar mass /strength of intermolecular forces/ number of electrons **(1)**	Allow Volatility for boiling temperature Allow Different alkanes condense at different temperatures Ignore melting temperatures if given with boiling temperatures Ignore densities Accept London /dispersion /van der Waals forces Allow reference to size A comparison such as 'longer alkanes have higher boiling points' scores 2 Ignore any reference to surface area Do not award references to cracking Do not award reference to just weight/mass Do not award incorrect trend	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	Correct equation	<u>Example of equation:</u> $C_8H_{18} \rightarrow C_2H_4 + C_6H_{14}$ OR $C_8H_{18} \rightarrow 2C_2H_4 + C_4H_{10}$ OR $C_8H_{18} \rightarrow 3C_2H_4 + C_2H_6$ Allow $CH_2=CH_2$ for C_2H_4 Products can be given in either order Do not award equations forming H_2	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(iii)	Correct equation	Example of equation:  Accept bonds to hydrogen atoms inside the ring, e.g.  Allow skeletal or structural formulae for hexane and for cyclohexane  or $CH_3(CH_2)_4CH_3$  or $(CH_2)_6$ Ignore $C_6H_{14} \rightarrow C_6H_{12} + H_2$	**(1)**

(Total for Question 1 = 6 marks)

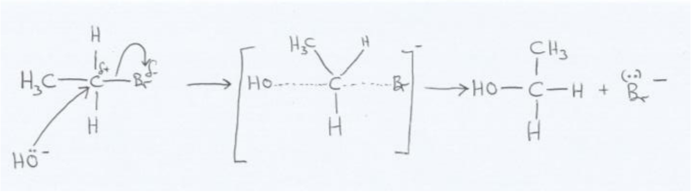
Question Number	Answer	Mark
2(a)	**The only correct answer is C** (hexagonal rings within a layer) ***A*** *is not correct because in the layers of graphite and graphene the carbon atoms are bonded to three other carbon atoms and not four* ***B*** *is not correct because graphite and graphene do not have pentagonal rings within their layers* ***D*** *is not correct because graphene is a two-dimensional structure consisting of a single layer*	**(1)**

Question Number	Answer	Mark
2(b)	**The only correct answer is D** (all 120°) ***A*** *is not correct because the angles within a layer of graphite and graphene are neither 90° nor 109.5° but are all 120°* ***B*** *is not correct because the angles within a layer of graphite and graphene are not 109.5° but are all 120°* ***C*** *is not correct because there are no angles within a layer of graphite and graphene that are 109.5° but they are all 120°*	**(1)**

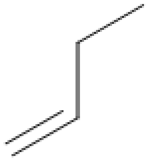
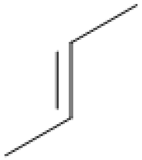
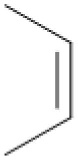
Question Number	Answer	Mark
2(c)	**The only correct answer is C** (poor electrical conductivity) ***A*** *is not correct because both graphene and graphite are similar to diamond in having a high melting temperature* ***B*** *is not correct because neither graphene nor graphite nor diamond have a precise molecular formula since they are giant molecular structures* ***C*** *is not correct because graphene, graphite and diamond are all giant molecular structures*	**(1)**

(Total for Question 2 = 3 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: • reactivity increases down Group (7) **(1)** • because (C—X) bond enthalpy decreases / because (C—X) bond gets weaker down Group 7 **(1)**	Accept reverse argument References to halogen reactivity scores (0) Do not award references to ions/halides Do not award explanation in terms of just electronegativity or C—X dipoles Ignore references to atom size, shielding etc and references to intermolecular forces No TE on incorrect reactivity trend	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	• dipole on C—Br bond **and** curly arrow from C-Br bond to Br or just beyond **(1)**	 Dipole and curly arrow may be shown on transition state	**(4)**
	• curly arrow from **lone pair** on oxygen of hydroxide ion to carbon bonded to Br **(1)**	Allow curly arrow to C$^+$ of carbocation	
	• formula of transition state with correct charge, partial bonding **(1)**	Do not award if carbocation formed as intermediate Square brackets are not essential Allow charge on Br or OH of transition state Allow longer bonds for partial bonding Ignore geometry of transition state	
	• correct final products **(1)**	Allow NaBr product if mechanism starts with NaOH Only penalise horizontal bond from the H of OH to C in the product e.g. $OH-CH_2CH_3$ Use of incorrect halogenoalkane loses this mark One mark max deducted for omission of charge on ions, including transition state S_N1 mechanism can score M1, M2 and M4 but not M3. M2 can be awarded for curly arrow from the lone pair on the oxygen of the hydroxide ion to the C+ of the carbocation intermediate	

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	Reagents: nitric acid / HNO_3 **and** silver nitrate (solution) /$AgNO_3$ **(1)** (Result) cream/off-white precipitate **(1)**	Use of hydrochloric acid/HCl OR sulfuric acid/H_2SO_4 scores **(0)** Do not award acidified silver nitrate If name and formula given then both must be correct Allow (very) **pale** yellow Do not award just white or just yellow Ignore subsequent additions of ammonia even if incorrect Result mark dependent on reagents mark or 'near miss' such as omitting to add nitric acid, using ethanolic silver nitrate, incorrect formulae	**(2)**

Question Number	Answer			Additional Guidance	Mark
3(c)	 **(1)**	 **(1)**	 **(1)**	Accept formulae in any order Award 2 if 3 correct displayed/structural formulae given Award 1 if 2 correct displayed/structural formulae given If more than 3 skeletal formulae drawn then deduct one mark for each additional formula 2-methylpropene negates a correct formula only if four formulae given View any formulae given with skeletal formula as working and ignore Ignore names even if incorrect Penalise any other alkenes such as pentenes, once only	**(3)**

Question Number	Answer	Additional Guidance	Mark
3(d)	An explanation that makes reference to the following points: • (only) ethanol has hydrogen bonding (and dipole-dipole and London forces) **(1)** • ethene (only) has (weaker) London/ instantaneous dipole –induced dipole forces **(1)** • more **energy** required to break the (stronger) intermolecular forces/hydrogen bonds in alcohols **(1)**	Ignore references to ethanol having stronger London forces Accept dispersion /van der Waals forces A comparison is needed Allow overcome for break Allow ‘heat’ for energy Accept reverse argument Do not award if the more energy required is given in response to just breaking stronger London forces for ethanol Do not award M3 for covalent bonds breaking	**(3)**

(Total for Question 3 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)(i)	• conversion of pressure, volume and temperature to correct units **(1)** • rearrangement of ideal gas equation so n=PV ÷ RT and calculation of n **(1)** • conversion of answer into mass to 2/3 SF **(1)**	<u>Example of calculation</u>: 207kPa = 207 000 Pa 8.98 dm^3 = 0.00898 m^3, 20°C = 293 K $n = \frac{207\,000 \times 0.00898}{8.31 \times 293} =$ = 0.7634… = 0.7634…. x 28 = 21.37647.. = 21.4 / 21 (g) Correct answer with no working scores 3 TE on both parts of the calculation	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	• The temperature increase will result in an increase in pressure because p is (directly) proportional to T (at constant volume and moles of gas)	Allow $p \propto T$ Reference to p=nRT/V	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to the following points: • fewer protons (in nitrogen) **(1)** • result in a weaker **nuclear** attraction because shielding is the same/electrons are in the same (sub)shell (in oxygen)/same number of electron shells **(1)**	Reference to molecule scores **(0)** Accept reverse arguments in terms of oxygen Allow weaker (effective) nuclear charge Allow smaller atomic number Do not award if incorrect numbers of protons stated or if ions referred to Do not award 'charge density' Ignore references to electron repulsion and electronegativity	**(2)**

(Total for Question 4 = 6 marks)

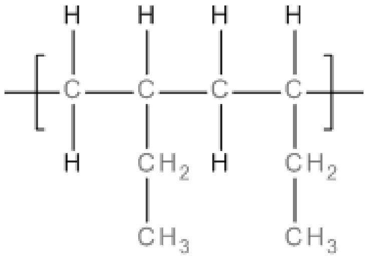
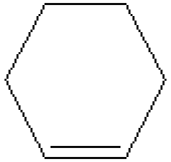
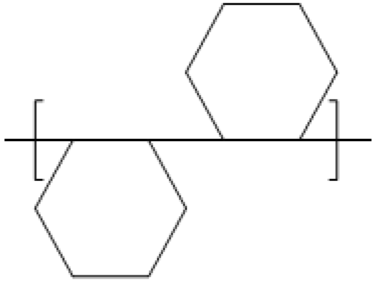
Question Number	Answer	Additional Guidance	Mark
5(a)(i)	Correct equation	$2NO + 2CO \rightarrow N_2 + 2CO_2$ Accept multiples Ignore catalysts and conditions if stated	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	A description that makes reference to the following points:	Absence of reference to the catalytic surface results in a deduction of one mark	**(3)**
	• **adsorption** of gases to catalytic surface **(1)**	Do not award absorption or “stick”	
	• weakening of bonds (and chemical reaction) on catalytic surface **(1)**	Allow bonds break (and reaction occurs) on catalytic surface Ignore the type of interaction referred to between the reactants and the catalytic surface	
	• desorption of products from catalytic surface **(1)**	Allow ‘release’ of products from catalytic surface Allow de-adsorbed	

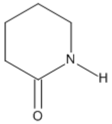
Question Number	Answer	Mark
5(b)	**The only correct answer is A** (area A) ***B*** *is not correct because this is the area representing the number of particles with sufficient energy to react in the absence of a catalyst* ***C*** *is not correct because this area subtraction does not represent the increase in the number of particles with sufficient energy to react* ***D*** *is not correct because this sum of areas represents the total number of particles with sufficient energy to react in the presence of a catalyst*	**(1)**

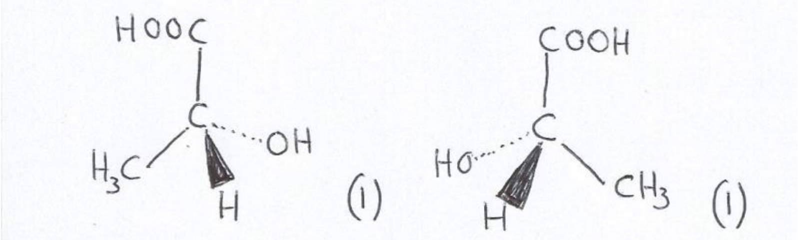
Question Number	Answer	Mark
5(c)	**The only correct answer is B** (2.15×10^{22}) ***A*** *is not correct because the molar mass of carbon dioxide has been used in the calculation instead of that of carbon monoxide* ***C*** *is not correct because this is the number of molecules that are in one mole and not one gram of carbon monoxide* ***D*** *is not correct because this is the result of incorrectly using the molar mass of carbon monoxide rather than the number of moles of carbon monoxide*	**(1)**

(Total for Question 5 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	(CH_2=$CHCH_2CH_3$→)  **(1)** ( →)  **(1)**	Accept skeletal, structural or displayed formulae or combination of which is clear, e.g. $-C_2H_5$ Brackets are not essential Ignore 'n' Ignore orientation of side chains Ignore bond length Ignore where bond goes to for the ethyl groups Penalise lack of 'end-bonds' once only Award 1 mark max if only one repeat unit given for each polymer Ignore more than 2 repeat units	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(b)	• HOOC — $(CH_2)_4$ — COOH or ClOC — $(CH_2)_4$ — COCl **(1)** • H_2N — $(CH_2)_4$ — NH_2 **(1)**	Accept skeletal, structural or displayed formulae Penalise use of C_4H_8 once only Penalise missing H's once only The monomers can be in either order Do not award monofunctionality	**(2)**

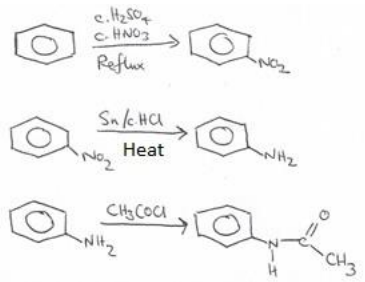
Question Number	Answer	Additional Guidance	Mark
6(c)	H_2N — $(CH_2)_4$ — COOH	Accept skeletal, structural or displayed formulae Allow H_2N — $(CH_2)_4$ — COCl Ignore connectivity Allow  Allow use of C_4H_8 here only Penalise missing hydrogens	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	Allow 	Diagram must be 3-dimensional with either wedges or dashes to score 2 marks Ignore orientation of group at the top Ignore vertical bond to H of OH group	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	• They **rotate** the plane of plane-polarised light (equally) and in opposite/different directions OR Determine in which direction they **rotate** the plane of plane-polarised light	Allow one plane	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	• Does not accumulate in the environment/does not occupy landfill	Accept answers that outline the benefit of avoiding other means of disposal such as incineration, use of toxic chemicals Ignore just less harm to environment/less harm to animal life/less pollution/less of an "eyesore"/less energy to break it down	**(1)**

(Total for Question 6 = 9 marks)

Question Number	**Answer**	**Additional Guidance**	**Mark**
7(a)		Example of synthetic pathway  The compounds used can be stated or given within equations. Ignore any unbalanced, incorrect equations or reaction mechanisms	**(5)**
	A synthetic pathway that consists of:		
	• (reagents and conditions for the nitration of benzene) conc. Nitric (HNO_3) and sulfuric acids (H_2SO_4) **and** 55°C/heat/reflux **(1)**	Allow any single value or range between 50-60°C/warm/<55 °C	
	• structure of nitrobenzene **(1)**	Intermediate marks are standalone	
	• (reduction of nitrobenzene) tin and conc. hydrochloric acid and heat/reflux **(1)**	Allow iron & c.HCl Do not award dilute Ignore subsequent addition of NaOH Penalise lack of heat once only in M1 and M3	
	• structure of phenylamine **(1)**	Penalise just the names of intermediates once only	
	• (reaction of phenylamine with) ethanoyl chloride **(1)**	Ignore heat Do not award use of $AlCl_3$	

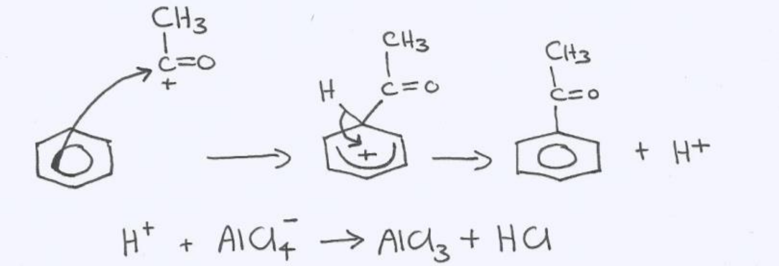
Question Number	Answer	Mark
7(b)	**The only correct answer is B** (6) ***A*** *is not correct because four carbon atoms in the aromatic ring are non-equivalent and not just three, so the correct total of non-equivalent carbon atoms and therefore peaks is six* ***C*** *is not correct because there are two sets of equivalent carbon atoms in the aromatic ring and not just one which means that the correct total of non-equivalent carbon atoms and therefore peaks is six* ***D*** *is not correct because this is the total number of carbon atoms in antifebrin but carbon atoms 2 and 6 in the aromatic ring are equivalent, as are 3 and 5, which gives a correct total of six non-equivalent carbon atoms and therefore six peaks*	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)	An explanation that makes reference to the following points: • **lone pair** (of electrons) from the **oxygen** **and** will interact with the delocalised ring of electrons / increase the (pi/π) electron density of the benzene ring **(1)** • which increases the reactivity toward electrophiles (such as bromine)/ which means that the bromine is more easily polarised **(1)**	Allow reference to the **lone pair** (of electrons) from the **nitrogen** Ignore activation of ring Do not award charge density Allow Br^+/$Br^{\delta+}$ for electrophile Allow reference to benzene as being a stronger nucleophile Do not award references to electrophilic addition	**(2)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
7(d)	• conversion of moles to mass of paracetamol **(1)** • conversion of answer into percentage to 2/3 SF **(1)**	<u>Example of calculation</u>: (mass of paracetamol = 3.10 x 10^{-3} x 151 = 0.4681 (g) % = (0.4681÷ 0.500) x 100 = 93.62%) =94 (%)/93.6 (%) Allow TE for second mark from incorrect molar mass as long as value derived from dividing by 0.500/500mg and percentage is less than 100% Correct answer without working scores 2	**(2)**

(Total for Question 7 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	Accept use of $FeCl_3$/Fe +Cl_2 Allow displayed formulae Do not award C_2H_3OCl Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)			**(4)**
	• electron pair movement from ring to electrophile **(1)** •	Do not award curly arrow that ends at the CH_3 Allow arrow starting anywhere within the hexagon	
	• formula of intermediate ion **(1)**	'Horseshoe' to cover at least three carbon atoms and face the tetrahedral carbon and with some part of the plus sign inside 'horseshoe' Allow Kekulé diagrams Do not award dotted bonds unless part of a 3D structure	
	• curly arrow from C−H bond to reform delocalised ring **(1)**		
	• correct product and equation to show regeneration of catalyst and HCl **(1)**	Could be shown in reaction mechanism Ignore curly arrows	

Question Number	Answer	Mark
8(b)(i)	**The only correct answer is B** (alkaline iodine solution) ***A*** *is not correct because this oxidising agent would react with phenylethanal and not with phenylethanone which is the wrong way round* ***C*** *is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round* ***D*** *is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: • formation of yellow/orange/red (crystalline) precipitate **(1)** • (Filter then) recrystallisation of products **(1)** • determination of melting temperature **(1)** • comparison (and hence identification) from use of database/known values **(1)**	Colour and state are both required Allow solid for ppt Ignore any conditions given with the use of 2,4-DNPH Penalise M3 if any reference to boiling temperature Award only in the context of melting temperature of the hydrazones or as a TE of boiling temperature Max 3 out of 4 if test is only carried out with one of the carbonyls	**(4)**

Question Number	Answer	Additional Guidance	Mark
***8(b)(iii)**	This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points: 6 – 4; 5-4 – 3; 3-2 – 2; 1 – 1; 0 – 0 The following table shows how the marks should be awarded for structure and lines of reasoning Number of marks awarded for structure of answer and sustained lines of reasoning: Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout – 2 Answer is partially structured with some linkages and lines of reasoning – 1 Answer has no linkages between points and is unstructured – 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). If there is no mention of protons/hydrogens in the response then deduct one structure and reasoning mark	**(6)**

Nested tables from the Answer column:

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5-4	3
3-2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained lines of reasoning
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

	Indicative content	Ignore references to C^{13} nmr Accept annotations on a structure towards crediting the following IPs Allow either a single chemical shift value or a range within the stated values Penalise incorrect chemical shifts	
	Similarities • **IP1**: aromatic hydrogens will give similar/same peaks	Both have peaks in the range 6.5-8.4 (ppm) Ignore any splitting description	
	• **IP2**: both have a peak in the range 1.7-3.0 (ppm) (due to the hydrogen of the H−C−C=O type)	Ignore any splitting pattern given for this peak to award this mark	
	Differences • **IP3** (Hydrogen environments): Phenylethanone has one less peak/hydrogen environment than phenylethanal	Allow any difference of one in the number of peaks stated	
	• **IP4** (Splitting patterns): a singlet for phenylethanone but a doublet and a triplet in phenylethanal	All these splitting patterns required for this IP	
	• **IP5** (Peak area ratios): relative peak (area) ratio in phenylethanone is 3 but in phenylethanal the peak (area) ratio is 2 to 1	Ignore the splitting pattern for this IP and ignore any peak areas given for the aryl hydrogens	
	• **IP6** (Chemical shifts): (Only) phenylethanal has an aldehyde (hydrogen) peak in the range 9 – 10.1 (ppm)	Ignore the splitting pattern for this IP	

Question Number	Answer	Additional Guidance	Mark
8(c)	• Reagent: lithium tetrahydridoaluminate((III)) /LiAlH_4 **(1)** • Conditions: (dry) ether/ethoxyethane **(1)**	Allow lithium aluminium hydride Accept sodium tetrahydridoborate /sodium borohydride/ $NaBH_4$ In water/alcohol for 2 marks Ignore reference to addition of acid after use of $LiAlH_4$ in dry ether Do not award with additional reagents Ignore heat The mark for conditions is dependent on correct reagent or near miss such as incorrect formula $LiAlH_3$/LiAlH/LiAl	**(2)**

(Total Question 8 = 18 marks)

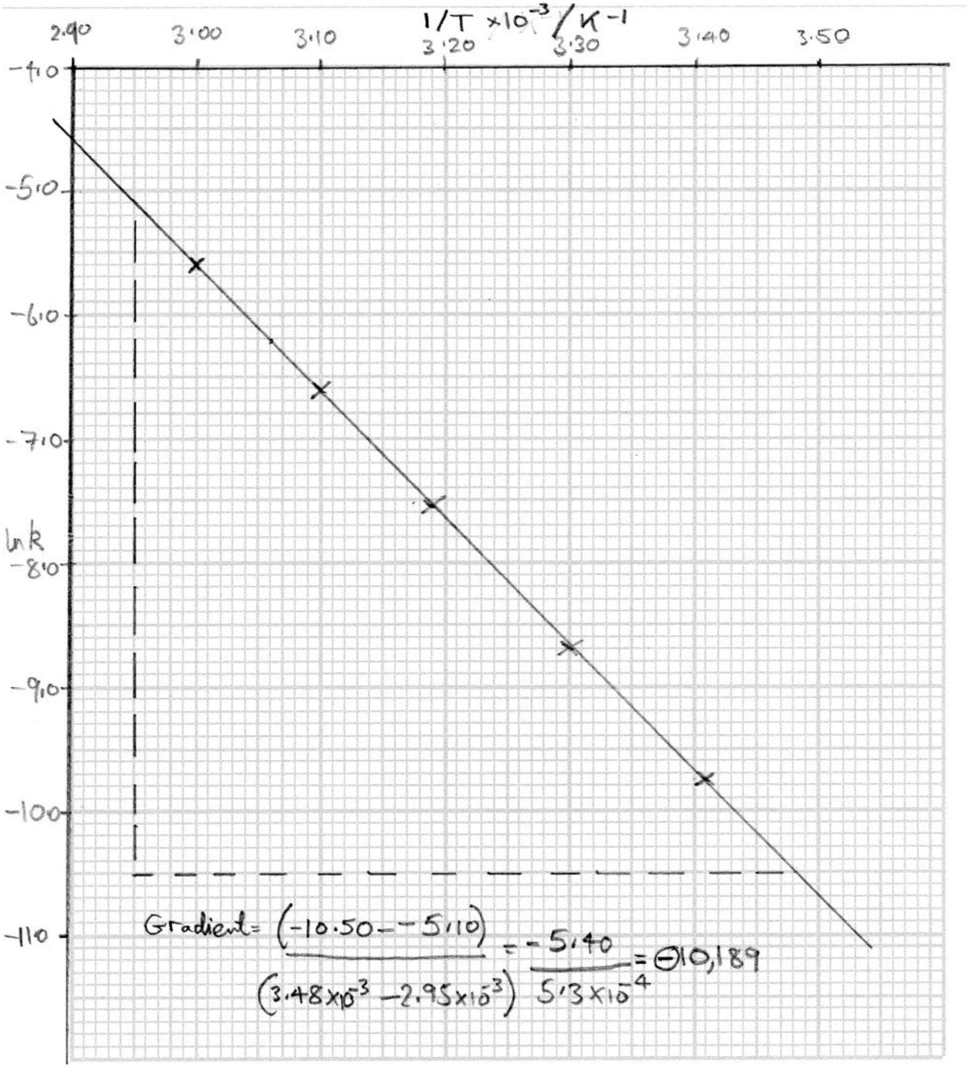
Question Number	**Answer**	**Additional Guidance**	**Mark**
9(a)	Correct answer to 2 SF	Example of calculation: (Four half-lives to decrease 600 g to 37.5 g so 4 x 14 mins) = 56 (mins) Penalise wrong units, e.g. "m"	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
9(b)(i)	Reaction Orders: • **X** First/1 **(1)** • **Y** Second/2 **(1)** • **Z** Zero/0 **(1)**	Allow "none"/"no order"	**(3)**

Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	Marking point 1 • Rate = k[X][Y]^2[Z]^0 **(1)** Marking point 2 • rearrangement of rate expression **(1)** Marking point 3 • calculation of value for k to 2/3 SF **(1)** Marking point 4 • units dm^6 mol^{-2} s^{-1} **(1)**	Reactants can be in any order Z does not have to be included in the rate equation TE from (b)(i) which will apply for all four marking points <u>Example of calculation:</u> k = rate / [X][Y]^2 k = $\frac{2.17 \times 10^{-6}}{0.00100 \times 0.00300^2}$ = 241.11 = 241/240 Any 'run' can be used No TE on incorrect rearrangement Allow units in any order Correct answer without working and with correct units to 2/3 SF scores marking points 2, 3 and 4	**(4)**

Question Number	Answer	Mark
9(c)(i)	**The only correct answer is D** (Fourth) ***A*** *is not correct because this is the individual reaction order with respect to bromate(V) ions and with respect to bromide ions but is not the overall reaction order* ***B*** *is not correct because this is the reaction order with respect to hydrogen ions but is not the overall reaction order* ***C*** *is not correct because this is the number of species in the rate equation but is not the overall reaction order*	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(c)(ii)	• rearrange rate equation so $[Br^-]$ = **(1)** • calculation of value to 2/3 SF **(1)**	Example of calculation: $[Br^-] = \frac{\text{rate}}{k\,[BrO_3^-][H^+]^2}$ $= 0.255/0.26$ (mol dm^{-3}) Correct answer without working to 2/3 SF scores 2 marks If units given then must be correct No TE on incorrect rearrangement	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(d)	Example of suitable graph  		**(7)**

	- calculation of all three 1/T values x 10^{-3} **(1)**	(3.41), 3.30, 3.19, 3.10, (3.00)	
	- calculation of all three ln k values **(1)**	(−9.75), −8.70, −7.55, −6.60, (−5.58) Allow omission of end zero Penalise more than 3SF once only	
	- axes: correct way round, labelled, suitable scale **(1)**	Plotted points must cover at least ½ the graph paper on each axis Do not award 1/t	
	- all points plotted correctly, with best-fit straight line **(1)**	Allow ±½ square	
	- calculation of gradient with sign **(1)**	Gradient = − 10200 Allow ±500 Allow this mark if the value is seen in the E_a calculation	
	- units of gradient **(1)**	K	
	- use of gradient to calculate activation energy **(1)**	E_a = 10200 x 8.31 / 1000 = (**+**) 84.8 (kJ mol^{-1}) Final answer must be positive and in the range (+) 80.6 – 88.9 (kJ mol^{-1}) Allow value given in J mol^{-1} but then these units are essential Ignore SF for gradient and activation energy values	

(Total for Question 9 = 18 marks)

TOTAL FOR PAPER = 90 MARKS

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Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Tuesday 27 June 2017 – Morning
Time: 2 hours 30 minutes

Paper Reference
9CH0/03

Candidates must have: Data Booklet
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

P48954A

6/6/6/1/

P 4 8 9 5 4 A 0 1 3 6

Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about transition metal chemistry.

(a) The **amphoteric** character of solid chromium(III) hydroxide is shown by the fact that it reacts separately with both dilute hydrochloric acid and dilute sodium hydroxide solution.

(i) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute hydrochloric acid, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

(ii) Describe the changes you would **see** when the reaction in (a)(i) is carried out.

(2)

(iii) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute sodium hydroxide solution, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

(iv) State the final appearance of the reaction mixture in (a)(iii).

(1)

(b) Dilute aqueous ammonia is added, drop by drop, to an aqueous solution of copper(II) sulfate until the aqueous ammonia is in excess.

(i) Describe what you would **see** during this experiment.

(2)

....

....

....

....

(ii) The reaction between aqueous copper(II) sulfate and **excess** aqueous ammonia is an example of a **ligand substitution** reaction.

Write an equation for the ligand substitution reaction that occurs, showing the formulae of the complex ions involved. State symbols are not required.

(2)

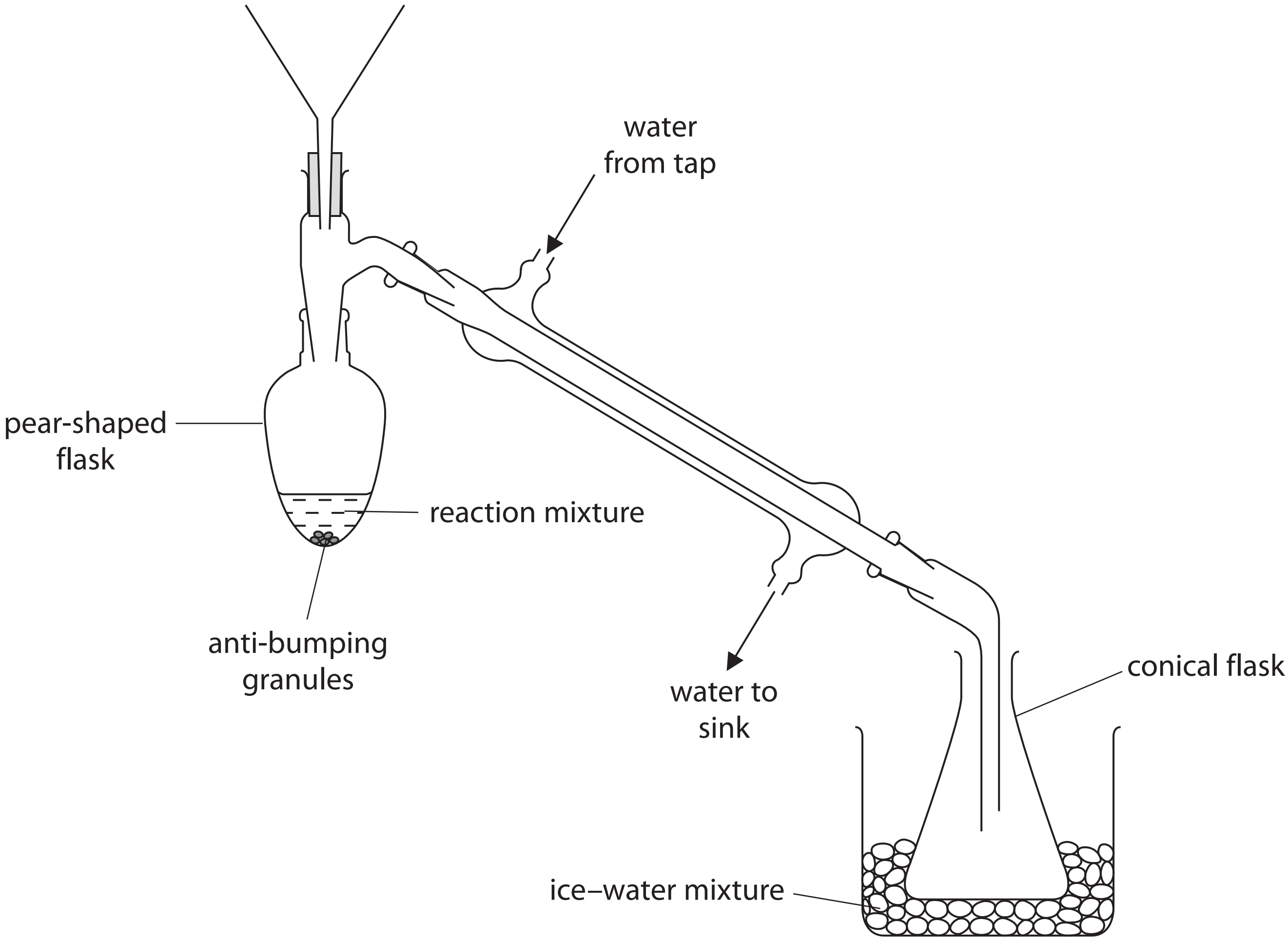
(Total for Question 1 = 11 marks)

2 This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



(a) Identify the **two** changes that must be made to the apparatus before heating the pear-shaped flask, giving a reason for each change.

(4)

....

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....

....

(b) Draw the **skeletal** formulae for 3-methylbutan-2-ol and 3-methylbutan-2-one.

(2)

3-methylbutan-2-ol

3-methylbutan-2-one

(c) Once the essential changes are made to the apparatus, the pear-shaped flask is heated. The distillate formed is collected in the conical flask.

On testing the distillate with pH paper, it is found that its pH is 2.
The student suggests that this pH is due to the formation of 3-methylbutanoic acid.

(i) Give a reason why 3-methylbutanoic acid cannot be formed in the reaction.

(1)

(ii) Deduce the **formula** of the compound that could cause the distillate to have a pH value of 2.

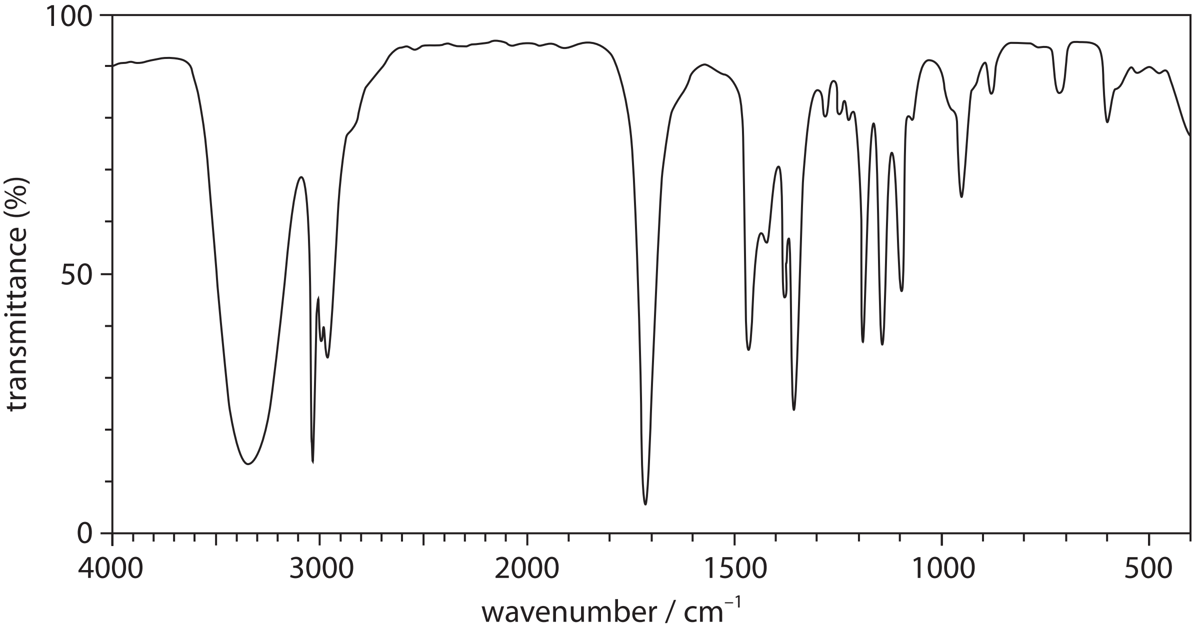
(1)

(iii) Solid sodium carbonate is added to the distillate. The sodium carbonate disappears and fizzing occurs.

Write an equation, including state symbols, for the reaction that occurs between sodium carbonate and the compound you have identified in (c)(ii).

(2)

(d) The organic mixture was separated from the aqueous layer and dried.
The infrared spectrum of the organic mixture is shown.



(i) By reference to any relevant peak(s), deduce how the infrared spectrum shows that the mixture contains 3-methylbutan-2-one.

(2)

....

....

....

....

(ii) From the infrared spectrum, the student concludes that the mixture contains another organic compound.

The mixture is redistilled and the fraction that boils in the range 93–95 °C is collected. The boiling temperature of 3-methylbutan-2-one is 94 °C.

Predict any change(s) you would see in the infrared spectrum after redistillation, justifying your answer.

(2)

....

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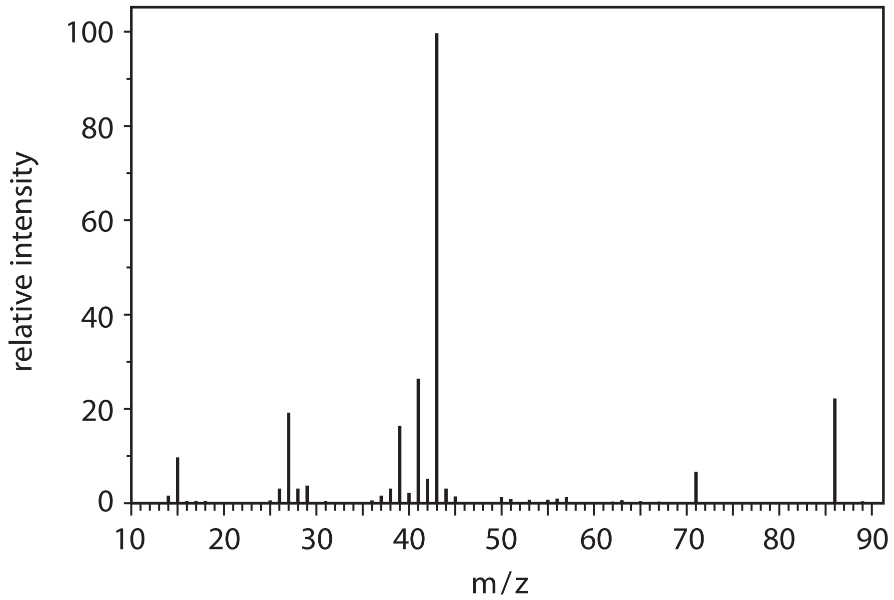
....

(e) The mass spectrum of pure 3-methylbutan-2-one is shown.



(i) State how you would find the molar mass of 3-methylbutan-2-one from the mass spectrum.

(1)

....

....

(ii) The mass spectrum shows a peak at m/z = 43.

Draw the **displayed** formulae of two fragment **ions** that might be responsible for this peak.

(2)

(f) The sample of purified 3-methylbutan-2-one is found to have a mass of 2.15 g. This mass of 3-methylbutan-2-one represents a yield of 62.5% by mass.

(i) Write an equation, using **molecular** formulae, for the oxidation of 3-methylbutan-2-ol to 3-methylbutan-2-one.
Use [O] to represent the oxidising agent.

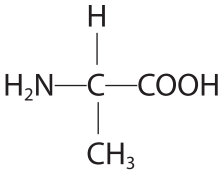
(2)

(ii) Calculate the mass of 3-methylbutan-2-ol that the student uses at the start of the preparation.

(2)

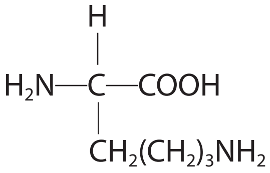
(Total for Question 2 = 21 marks)

3 Alanine and lysine are amino acids.



$$\mathrm{H_2N{-}\overset{\displaystyle H}{\underset{\displaystyle CH_3}{C}}{-}COOH}$$

alanine



$$\mathrm{H_2N{-}\overset{\displaystyle H}{\underset{\displaystyle CH_2(CH_2)_3NH_2}{C}}{-}COOH}$$

lysine

(a) Give the systematic (IUPAC) name for **lysine**.

(1)

....

(b) Draw the **structure** of the organic product formed when **lysine** reacts with the following reagents:

(3)

aqueous sodium hydroxide, NaOH(aq)

excess dilute hydrochloric acid, HCl(aq)

methanol, with warming, in the presence of a few drops of concentrated sulfuric acid.

(c) Draw the structure of a dipeptide formed when one molecule of alanine reacts with one molecule of lysine.

(1)

(d) The dipeptide formed in part (c) is hydrolysed under **acidic** conditions and the resulting mixture is analysed by column chromatography. The column uses a polar stationary phase.

Explain why lysine leaves the chromatography column after alanine.

(2)

....

....

....

....

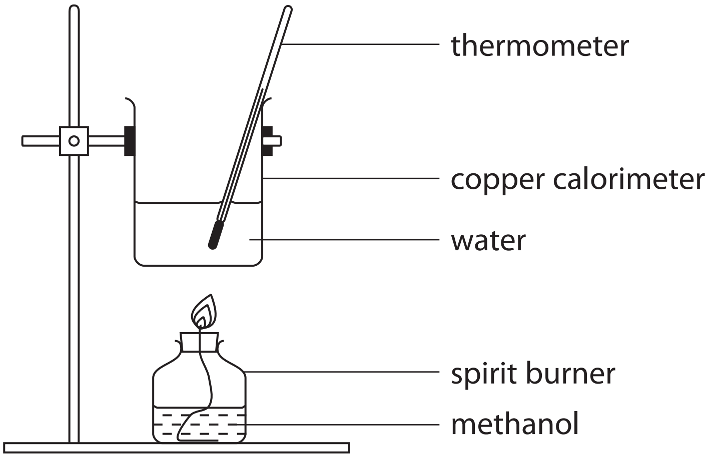
(Total for Question 3 = 7 marks)

4 This question is about the enthalpy change of combustion of methanol.

A teacher asked two students to carry out a practical task to determine the enthalpy change of combustion of methanol.
Both students were provided with the same apparatus and chemicals.
The following procedure was provided for the students.

Procedure

- Measure out 150 cm^3 of distilled water, using a 250 cm^3 measuring cylinder.
- Transfer the water to a copper calorimeter and note the initial temperature of the water (to the nearest 0.5 °C) in **Table 1**.
- Weigh the spirit burner containing methanol and record its mass in **Table 1**.
- Place the spirit burner under the copper calorimeter, as shown in the diagram.
- Ignite the spirit burner and burn the methanol, whilst stirring the water with the thermometer.
- After heating the water for three minutes, extinguish the flame and immediately record the **highest** temperature reached by the water.
- As soon as possible, reweigh the spirit burner containing the methanol and record its mass in **Table 1**.



The results of Student 1 are recorded in **Table 1**.

Mass of spirit burner plus methanol before burning / g	213.47
Mass of spirit burner plus methanol after burning / g	211.87
Mass of methanol burned / g	
Highest temperature of the water / °C	64.5
Initial temperature of the water / °C	22.0
Temperature change of the water / °C	

Table 1

(a) Complete **Table 1**, giving the values to an appropriate number of decimal places.

(2)

(b) Write the equation that represents the reaction that occurs when the standard enthalpy change of combustion of methanol, $CH_3OH(l)$, is measured. Include state symbols.

(2)

(c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1}.
Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = 4.18 J g^{-1} $°C^{-1}$
Density of water = 1.00 g cm^{-3}

(4)

(d) Student 1 compared the experimental value for the enthalpy change of combustion of methanol obtained in part (c) with the standard value given on the internet. The student's value was **less exothermic** than the standard value.

Student 1 decided to evaluate the uncertainty in the measurements made in this experiment.

(i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is ±1 cm^3.

Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in the experiment.

(1)

(ii) Compare and contrast the use of a 250 cm^3 measuring cylinder to measure out the 150 cm^3 distilled water with the use of a 25 cm^3 measuring cylinder (uncertainty ±0.2 cm^3 for each volume measurement) six times to measure the same volume.

(3)

(iii) Student 1 calculated the uncertainties in the remaining measurements. However, Student 1 realised that the measurement uncertainties did **not** explain the difference between the experimental value for the enthalpy change of combustion of methanol calculated in part (c) and the value obtained from the internet.

Other than human error, give **three** reasons for the difference in the values.

(3)

(e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0 °C.
Student 1 burned **exactly** the same mass of methanol as in the first experiment.

Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)

(f) Student 2 followed the **original** instructions provided, but extinguished the flame after **four** minutes rather than after three minutes.

Explain how the value calculated by Student 2 for the enthalpy change of combustion of methanol compared with that obtained in Student 1's first experiment.

(2)

(g) Another student, Student 3, used the results from Student 1's first experiment to find the enthalpy change of combustion of methanol. Student 3 incorrectly used a value of 46.0 g mol^{-1} for the molar mass of methanol.

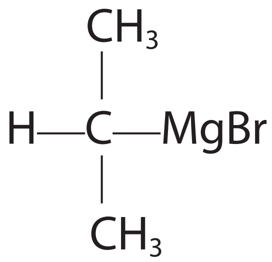
State and justify how this mistake would affect the calculated value for the enthalpy change of combustion of methanol.

(2)

(Total for Question 4 = 21 marks)

5 Grignard reagents are used in organic synthesis as a way of increasing the length of the carbon chain in a molecule.

(a) The structure of the Grignard reagent formed by the reaction between 2-bromopropane and magnesium is



On the diagram, draw the permanent dipole involving the central carbon atom.

(1)

(b) The Grignard reagent in part (a) reacts with propanal.

(i) Draw the **fully displayed** formula of the final organic product of this reaction.

(1)

(ii) Name the organic product in (b)(i).

(1)

....

(c) Identify, by using ticks, **two** boxes in the table to select appropriate terms that describe a Grignard reagent.

(2)

acid	
electrophile	
nucleophile	
oxidising agent	
reducing agent	

(d) The solvent used for Grignard reagents has to be completely **dry**.

By considering the dipole on the O—H bonds in water, predict the identity of the organic product that forms if water is added to the Grignard compound in part (a).

(1)

....

(Total for Question 5 = 6 marks)

6 A student carried out an investigation to determine the value of ***x*** in hydrated magnesium nitrate(III), $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$, using three different methods.

Method 1

- The student prepared an aqueous solution by dissolving 1.15 g of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ in distilled water, making up the solution to 250.0 cm^3 in a volumetric flask and shaking the mixture.
- The student titrated this solution against 25.0 cm^3 portions of an acidified solution of 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4(aq)$.

Method 2

- The student mixed a solution of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ with an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$.
- The student obtained a precipitate of magnesium carbonate, $MgCO_3(s)$, and determined the mass of this precipitate.

Method 3

- The student heated a known mass of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O(s)$.
- The student determined the mass of the anhydrous residue formed.

Method 1 – Titration

The student filled the burette with the solution made from $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$.

In each titration

- 25.0 cm^3 of 0.0200 mol dm^{-3} $KMnO_4$(aq) was transferred to a conical flask using a pipette.
- An excess of dilute sulfuric acid was added to the conical flask and the mixture heated.
- $Mg(NO_2)_2$(aq) was added from the burette until the end-point was reached.

The student's titration results are shown in the table (the rough titration results have **not** been included in the table).

Titration number	**1**	**2**	**3**
Final burette reading / cm^3	23.95	48.05	23.85
Initial burette reading / cm^3	0.80	24.50	0.65
Titre / cm^3			
Concordant titres (✓)			
Mean titre / cm^3			

(a) Complete the table.

(2)

(b) Deduce the colour change that the student would see at the end-point in this titration.

(1)

From .... to ....

(c) In the titration reaction, 2 mol MnO_4^- react with 5 mol NO_2^-.
Calculate the number of moles of NO_2^-, in the 250 cm^3 of solution prepared by the student and hence the value of ***x*** in $Mg(NO_2)_2 \cdot xH_2O$.
Give your answer to the nearest whole number.

(5)

(d) The half-equations for the reaction in the titration are

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$$

Use these half-equations to derive the overall ionic equation for the reaction between manganate(VII) and nitrate(III) ions in acidic conditions.
State symbols are not required.

(2)

Method 2 – Precipitation

The student used the following procedure.

- Dissolve a known mass of $Mg(NO_2)_2$**.***x*H_2O in distilled water.
- Add an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$, to obtain a precipitate of magnesium carbonate, $MgCO_3(s)$.

$$Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$$

- Weigh a piece of filter paper.
- Filter the mixture from the above reaction through the pre-weighed filter paper.
- Wash the precipitate of $MgCO_3(s)$ with distilled water.
- Dry the filter paper and precipitate in a desiccator.
- Reweigh the filter paper and the precipitate.
- Calculate the value of ***x*** from the results obtained.

The student found that the value of ***x*** calculated using **Method 2** was different from that obtained using **Method 1**. This difference occurred despite having used a pure sample of the hydrated salt and without making any errors in technique during the experiment.

The student found out from a data book that the compound magnesium carbonate is very slightly soluble in water.

(e) Explain how, if at all, the very slight solubility of magnesium carbonate in water would affect the value calculated for ***x***.

(2)

(f) The student planned to obtain any dissolved magnesium carbonate by evaporating the filtrate, and then weighing the residue.

Criticise this student's plan.

(2)

Method 3 – Thermal decomposition

NOTE: On heating, $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O(s)$ loses its water of crystallisation and **then** undergoes further decomposition to give magnesium oxide, MgO.

The student used the following procedure.

- Weigh an empty crucible.
- Add some $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O(s)$ and then reweigh the crucible plus contents.
- Heat the crucible plus contents and allow to cool.
- Weigh the crucible plus magnesium oxide residue.
- Use these data to calculate a value for $\boldsymbol{x}$.

The student's results are shown in the table.

Mass of crucible / g	18.02
Mass of crucible + $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ / g	18.84
Mass of crucible + MgO residue / g	18.27

(g) Identify how the student should ensure that the hydrated salt was fully decomposed.

(1)

....

....

(h) The student carried out an evaluation of the results obtained from **Method 3**

Identify **two** modifications to the method that would enable the student to lower the percentage uncertainty in the measurement of the mass of the solid residue.

(2)

....

....

....

....

(Total for Question 6 = 17 marks)

7 This question is about the chemistry of elements in the *d*-block of the Periodic Table.

*(a) Many of the *d*-block elements are also classified as transition metals.

Explain why two of the *d*-block elements within Period 4 (scandium to zinc) are **not** classified as transition metals.

You should include **full** electronic configurations where relevant.

(6)

(b) Under certain conditions, dichromate(VI) ions, $Cr_2O_7^{2-}$, can oxidise manganese(II) ions, Mn^{2+}.

In this reaction, dichromate(VI) ions are reduced to chromium(III) ions, in acidic conditions, according to the half-equation

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$$

In an experiment it was found that 20.0 cm^3 of 0.100 mol dm^{-3} potassium dichromate(VI) was required to oxidise 30.0 cm^3 of 0.200 mol dm^{-3} manganese(II) sulfate solution.

Use these data to calculate the final oxidation state of the manganese.

(5)

(c) A student constructed an electrochemical cell as follows:

- a half-cell was made from a strip of chromium metal and a solution of aqueous chromium(III) sulfate
- a second half-cell was made from a piece of metal, **X**, and a solution of its sulfate, **X**SO_4(aq)
- the two half-cells were connected and a current allowed to pass for some time.

Results

- the chromium electrode increased in mass by 1.456 g
- the electrode made of metal **X** decreased in mass by 1.021 g.

Use these data to determine the identity of the metal, **X**.

(4)

(Total for Question 7 = 15 marks)

8 The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, NH_3, with $CH_3CH_2CH_2Cl$ and with CH_3CH_2COCl.

(a) Draw the mechanism for the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia to form the primary amine. Include curly arrows and relevant lone pairs.

(3)

(b) Predict the mechanism for the reaction of CH_3CH_2COCl with ammonia. Include curly arrows and relevant lone pairs.

(3)

(Total for Question 8 = 6 marks)

9 The gas phase reaction between hydrogen and iodine is reversible.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) If the starting concentration of both hydrogen and iodine was **a** mol dm^{-3} and it was found that 2**y** mol dm^{-3} of hydrogen iodide had formed once equilibrium had been established, write the K_c expression in terms of **a** and **y**.

(2)

(b) The expression for the equilibrium constant in (a)(ii) can be rearranged as shown.

$$\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2 + \sqrt{K_c}}$$

In an experiment, air was removed from a 1 dm^3 flask and amounts of hydrogen and iodine gases were mixed together such that their initial concentrations were both **a** mol dm^{-3}. This mixture was allowed to reach equilibrium at 760 K. The equilibrium concentration of iodine was then measured.

The experiment was repeated for various initial concentrations, **a** mol dm^{-3}, and the results recorded in the table.

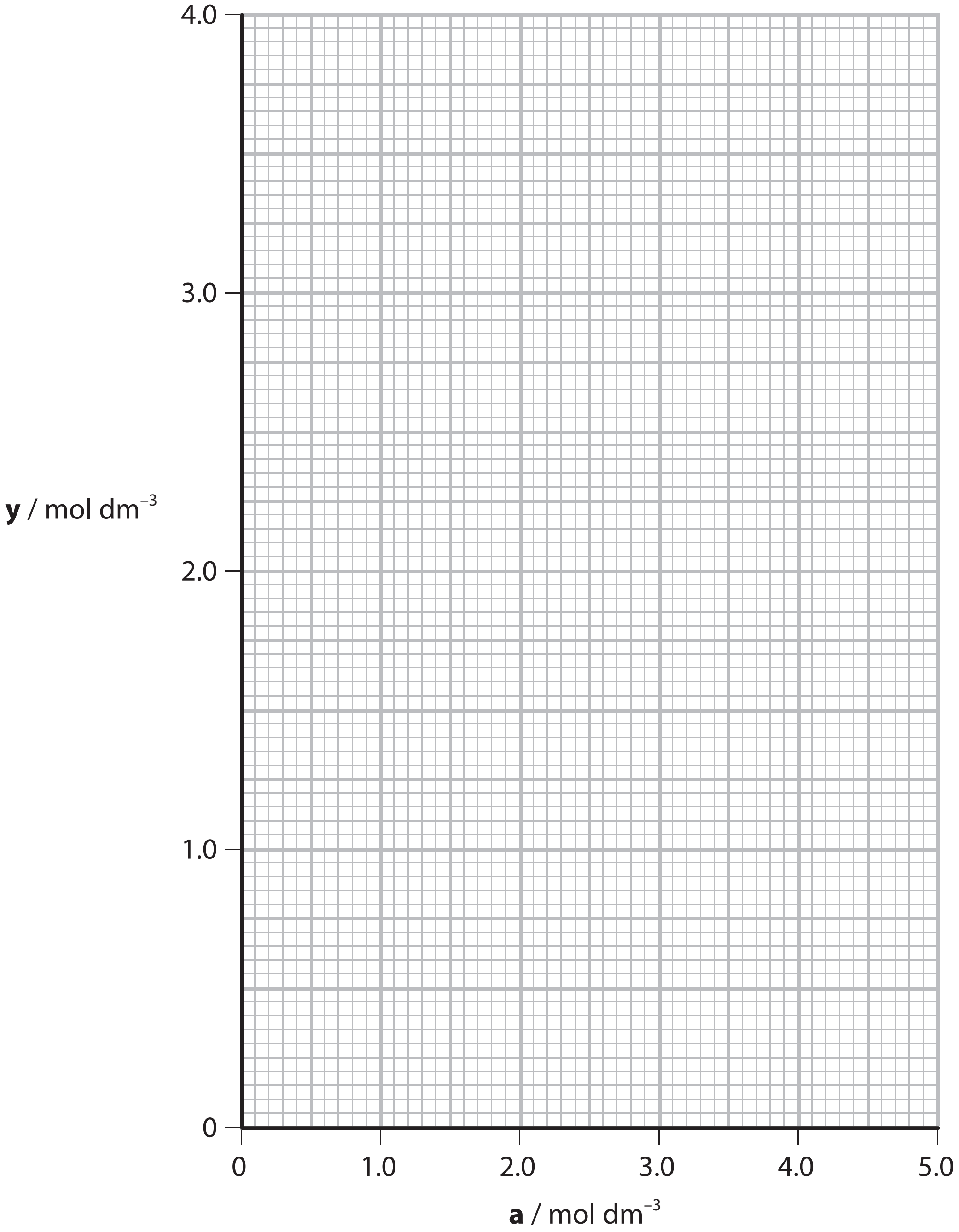
(i) Complete the table to give the two remaining values of **y** mol dm^{-3}, to **two** decimal places.

(1)

a / mol dm^{-3}	**$[I_2]_{eq}$ / mol dm^{-3}**	**y / mol dm^{-3}**
0.20	0.02	0.18
0.80	0.25	0.55
1.50	0.37	
2.10	0.57	1.53
2.80	0.65	2.15
3.80	0.87	
4.90	1.15	3.75

(ii) Plot a graph to show how **y** mol dm^{-3} varies with the initial concentrations of hydrogen and iodine, **a** mol dm^{-3}.

(2)



(iii) Determine the gradient of your graph.
Show your working on the graph.

(2)

(iv) Use your answer to (b)(iii) and the expression $\mathbf{y} = \dfrac{\mathbf{a}\sqrt{K_c}}{2 + \sqrt{K_c}}$ to calculate the value of K_c.

(2)

(c) Identify a safety issue associated with this experiment.

(1)

....

....

(d) One of the experiments in part (b) was repeated using the same molar quantities of hydrogen and iodine but in a 500 cm^3 flask instead of the 1 dm^3 flask.

Deduce the effect, if any, that this would have on the rate of reaction and on the value of K_c calculated.

(2)

....

....

....

....

(e) The equation for the reaction between hydrogen and iodine is

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

(i) Explain the effect, if any, on the value of K_c when the temperature is increased.

(2)

(ii) On your graph in (b)(ii), draw and label the line you would expect if the experiment was carried out at 1000 K instead of 760 K.

(1)

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

Summer 2017

Pearson Edexcel GCE in Chemistry (9CH0) Paper 03 General and Practical Principles in Chemistry

Summer 2017
Publications Code 9CH0_03_1706_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate’s response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate’s response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(i)	• All species and balancing correct **(1)** • All state symbols correct **(1)**	Examples of equation $Cr(OH)_3(s) + 3H_2O(l) + 3H^+(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$ **Or** $Cr(OH)_3(s) + 3H_3O^+(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$ **Or** $[Cr(OH)_3(H_2O)_3](s) + 3H^+(aq)$ on LHS as an alternative Allow correct equations for sequential protonation e.g. $[Cr(OH)_3(H_2O)_3](s) + H^+(aq) \rightarrow [Cr(H_2O)_4(OH)_2]^+(aq)$ M2 consequential on M1 being awarded, or a 'near-miss' e.g. Cl^- on both sides / one missing charge	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(ii)	A description that makes reference to the following points: • green solid / grey-green solid **(1)** • forms green solution **(1)**	Allow ppt/precipitate for solid Allow purple /violet /ruby solution Do not award yellow-green / red / blue-green bubbles etc means MP2 should not be awarded Ignore adjectives to describe green e.g. pale	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(iii)	- all species and balancing correct **(1)** - all state symbols correct **(1)**	Examples of equation $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq)$ **Or** $[Cr(OH)_3(H_2O)_3](s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq) + 3H_2O(l)$ Allow $Cr(OH)_3(s) + OH^-(aq) \rightarrow [Cr(OH)_4]^-(aq)$ **Or** $[Cr(OH)_5(H_2O)]^{2-}(aq)$ as complex ion on RHS, with rest of equation correctly balanced M2 consequential on M1 being awarded, or a 'near-miss'	**(2)**

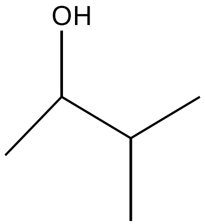
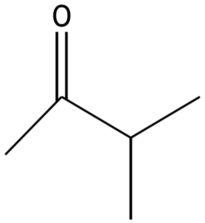
Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(iv)	An answer that makes reference to the following point: - green **and** solution	Ignore 'Qualifiers' for any colour (e.g. 'dark', 'deep', etc)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)(i)	A description that makes reference to the following points: - (blue solution initially forms pale) blue precipitate **(1)** - (which dissolves to) form dark/deep/royal blue solution **(1)**	Allow 'solid' / 'ppt' for 'precipitate' Do not award for 'blue crystals' Do not allow dark blue ppt	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)(ii)	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ • LHS of equation correct **(1)** • RHS of equation correct **(1)**	Ignore state symbols even if incorrect Ignore balanced sulfate ions Do not award just Cu^{2+} on LHS Allow $[Cu(OH)_2(H_2O)_4] + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$ Do not award for $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_6]^{2+}$ on RHS	**(2)**

(Total for Question 1 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: • (First change) Adjust so that the flow of water goes in at the bottom of the condenser and out at the top of the condenser **(1)** • (Reason) Keeps condenser full of water / water removes (any) air in the condenser / allows more efficient / better cooling / prevents 'air-lock' **(1)** • (Second change) (Replace funnel and) seal with a thermometer or a stopper **(1)** • (Reason) Prevents vapour / gas / product / reactants escaping **(1)**	First and second change can be in either order Ignore prior refluxing Ignore water bath Allow just "water should enter the condenser at the bottom" OR Just "water should leave at the top" OR Just "swap the tubes around" Allow replacing the funnel with a tap / dropping funnel Ignore thermometers used to measure boiling temperatures	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)	 **(1)**  **(1)**	Do not penalise 'connectivity' to OH unless O-H-C Allow O-H for OH Penalise non-skeletal formulae once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(i)	• 3-methylbutan-2-ol / secondary alcohols cannot be oxidised to a carboxylic acid OR • 3-methylbutanone / the product / ketones cannot be (further) oxidised	Allow only primary alcohols can be oxidised to carboxylic acids	**(1)**

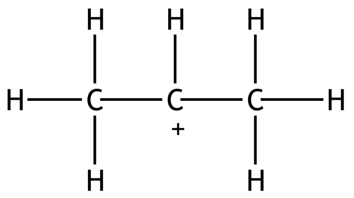
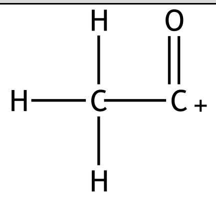
Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(ii)	• H_2SO_4	Ignore 'sulfuric acid'	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(c)(iii)	• all formulae correct **(1)** • all state symbols correct **(1)**	Example of equation: $Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$ OR $Na_2CO_3(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + H_2O(l) + CO_2(g)$ OR $Na_2CO_3(s) + 2H_2SO_4(aq) \rightarrow 2NaHSO_4(aq) + H_2O(l) + CO_2(g)$ Use of $NaCO_3$ or H_2CO_3 scores zero Allow any acid. M2 consequential on M1 being awarded, or a 'near-miss'	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(d)(i)	An explanation that makes reference to the following points: • peak at 1720 (cm^{-1}) **(1)** • shows presence of a C=O bond / carbonyl **(1)**	Allow any absorbance between 1720 to 1700 (cm^{-1}) Marks cannot be awarded if ANY incorrect other peaks are identified e.g. peak due to C=C / peak due to O-H Ignore references to alkane C-H bonds / fingerprint region Do not award just 'ketone' for MP2	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(d)(ii)	An answer that makes reference to the following points: • peak between 3750 and 3200 (cm^{-1}) will disappear / will be absent from the spectrum OR Peak(s) above 3000(cm^{-1}) will disappear / will be absent from the spectrum **(1)** • (because) 3-methylbutan-2-ol / the alcohol / O-H has now been removed **(1)**	Allow any absorbance between 3750 to 3200 (cm^{-1}) Ignore references to fingerprint region	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(e)(i)	(identify the peak at the) highest/largest *m*/*z* value	Allow Peak (furthest) to the right/last peak on the spectrum Do not award the mark for “largest peak” / “highest peak” Ignore “parent ion” / molecular ion peak / References to *m*/*z* = 86	**(1)**

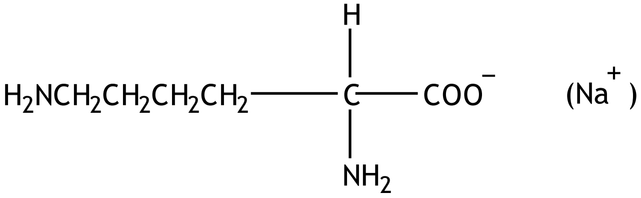
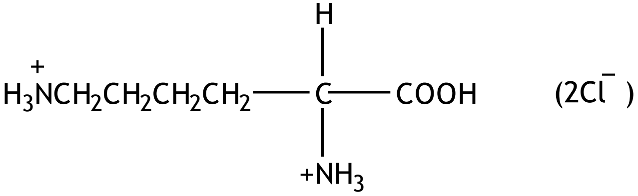
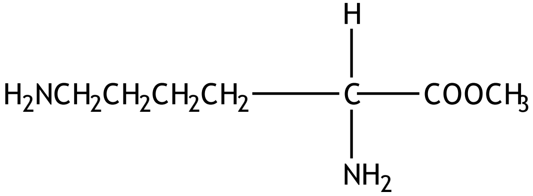
Question Number	Acceptable Answers	Additional Guidance	Mark
2(e)(ii)	 **(1)**  **(1)**	Allow positive charge anywhere on structure Ignore open bonds Penalise non-displayed formulae once only Ignore brackets around the structure Penalise missing charge once only	**(2)**

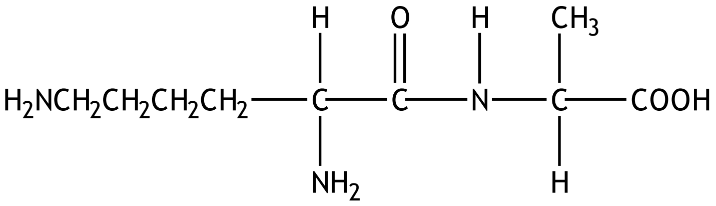
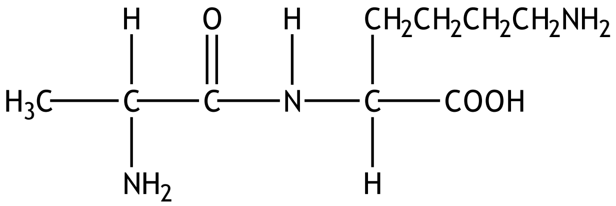
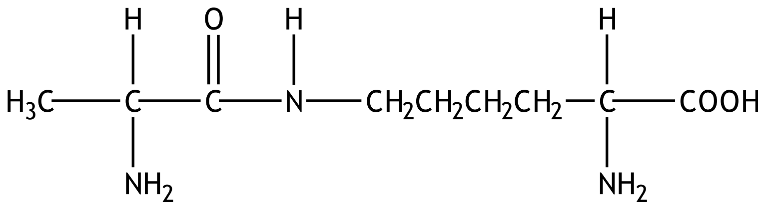
Question Number	Acceptable Answers	Additional Guidance	Mark
2(f)(i)	$C_5H_{12}O + [O] \rightarrow C_5H_{10}O + H_2O$ • left-hand side of equation correct **(1)** • right-hand side of equation correct **(1)**	**Molecular** formulae must be used throughout Allow [O] above the arrow Do not award for $C_5H_{11}OH$ as the alcohol Ignore state symbols if incorrect or conditions mentioned	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
2(f)(ii)		<u>Example of calculation</u>	**(2)**
	• calculation of moles of both of $C_5H_{10}O$ and $C_5H_{12}O$ **(1)**	Moles $C_5H_{10}O$ = $\frac{2.15}{86.0}$ = 0.025(0) (mol) **and** moles $C_5H_{12}O$ = $\frac{0.025(0)}{62.5}$ x 100 = 0.04(00)	
	• calculation of mass of $C_5H_{12}O$ **(1)**	(So) mass of $C_5H_{12}O$ = 0.04(00) x 88 = 3.52 g	
	OR		
	• calculation of theoretical mass of $C_5H_{10}O$ **and** moles of $C_5H_{10}O$ **(1)**	Theoretical mass $C_5H_{10}O$ = $\frac{2.15}{62.5}$ x 100 = 3.44 g **and** moles $C_5H_{10}O$ = $\frac{3.44}{86.0}$ = 0.04(00) = mol $C_5H_{12}O$	
	• calculation of mass of $C_5H_{12}O$ **(1)**	(So) mass of $C_5H_{12}O$ = 0.04(00) x 88 = 3.52 g Correct answer with no working scores (2) Allow TE from MP1 Award 1 mark for 3.36 g, 1.375 g or 2.2 g	

(Total for Question 2 = 21 marks)

Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
3(a)	• 2,6-diaminohexanoic acid	Allow 2,6-diamin**e**hexanoic acid Ignore any additional commas or hyphens or spaces Do not award 2,6-dia**mm**inohexanoic acid	**(1)**

Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
3(b)	- Deprotonated structure **(1)**  $H_2NCH_2CH_2CH_2CH_2-CH(NH_2)-COO^-$ (Na^+) - Protonated structure **(1)**  $^+H_3NCH_2CH_2CH_2CH_2-CH(^+NH_3)-COOH$ $(2Cl^-)$ - Ester structure **(1)**  $H_2NCH_2CH_2CH_2CH_2-CH(NH_2)-COOCH_3$	Allow displayed /structural /condensed formulae Allow NH_2– Allow –CO_2^- Allow –COONa but penalise if O–Na covalent bond is shown **Both** NH_2 groups must be protonated Allow NH_3^+– / ^+H_3N– Allow –CO_2H Allow CO_2CH_3 Allow NH_3^+– or NH_2– for each amine group Penalise wrong side chain only once If alanine used throughout then only MP3 can be awarded	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
3(c)	Any one of:  $H_2NCH_2CH_2CH_2CH_2-\underset{\underset{NH_2}{\mid}}{\overset{\overset{H}{\mid}}{C}}-\overset{\overset{O}{\Vert}}{C}-\overset{\overset{H}{\mid}}{N}-\underset{\underset{H}{\mid}}{\overset{\overset{CH_3}{\mid}}{C}}-COOH$ OR  $H_3C-\underset{\underset{NH_2}{\mid}}{\overset{\overset{H}{\mid}}{C}}-\overset{\overset{O}{\Vert}}{C}-\overset{\overset{H}{\mid}}{N}-\underset{\underset{H}{\mid}}{\overset{\overset{CH_2CH_2CH_2CH_2NH_2}{\mid}}{C}}-COOH$ OR  $H_3C-\underset{\underset{NH_2}{\mid}}{\overset{\overset{H}{\mid}}{C}}-\overset{\overset{O}{\Vert}}{C}-\overset{\overset{H}{\mid}}{N}-CH_2CH_2CH_2CH_2-\underset{\underset{NH_2}{\mid}}{\overset{\overset{H}{\mid}}{C}}-COOH$	Must be the dipeptide and not the repeat unit Allow $-CO_2H$ Allow $-H_2N$ Allow –CONH– / -COHN- unless C-H-N Allow zwitterions or cyclic dipeptides Allow skeletal / part-skeletal formulae	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)	An explanation that makes reference to the following points: • (In acidic conditions) lysine (ion) has two positive charges (whereas alanine has only one) **(1)** • (So lysine ion has) has greater attraction for the stationary phase **(1)**	Ignore comments on retention time, solubility, polarity, dipoles or intermolecular forces Allow 'greater positive charge' Allow lysine has 2 NH_2 groups that can be protonated Allow 'greater affinity for stationary phase' 'adheres better to stationary phase' 'better a**d**sorption onto stationary phase' Allow 'polar phase' for 'stationary phase' Allow reverse argument for alanine Mark points M1 and M2 independently	**(2)**

(Total for Question 3 = 7 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)	• 1.60 **(1)** • (+) 42.5 **(1)**	Do not award MP1 for "1.6" (must be to 2 D.P.) Do not award MP2 for "42.50" (must be to 1 D.P.) Penalise D.P. error once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	$CH_3OH(l) + 1.5O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ • Balanced equation **(1)** • State symbols all correct **(1)**	Do not award multiples (enthalpy change is for the complete combustion of one mole) for MP1 MP2 depends on the award of MP1 or correct species	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	- Calculation of energy change **(1)** - Calculation of moles of CH_3OH **(1)** - Calculation of energy ÷ moles CH_3OH **(1)** - ΔH final answer in kJ mol^{-1} **and** negative sign included **and** ΔH final answer to 2 or 3 S.F. **(1)**	Example of calculation (= $mc\Delta T$ = 150 x 4.18 x 42.5 =) 26647.5 (J) Moles CH_3OH = 1.60/32 (= 0.05(00)) $\frac{26647.5}{0.05(00)}$ = 532950 (J mol^{-1}) Ignore any signs at this stage −533 (kJ mol^{-1}) **Or** −530 (kJ mol^{-1}) Correct answer with no working gains full marks Penalise incorrect units for MP4 only Allow TE at each stage Allow correct rounding to 2SF or more at each stage	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(i)	(±)0.7 (%)	Allow from 1 SF up to calculator value correctly rounded where (% uncertainty =) (±) $\frac{1}{150}$ x 100 = 0.66666…7 (%) Allow $0.\dot{6}$ or $\frac{2}{3}$ Do not award 0.66/0.6	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(ii)	An answer that makes reference to the following points: • Calculation of the % uncertainty using the 25 cm^3 measuring cylinder **(1)** **Then any two from:** • % uncertainty with use of 25 cm^3 measuring cylinder is greater **(1)** • Repeated use of the small measuring cylinder will lead to greater transfer losses **(1)** • Repeated use will take more time **(1)**	Needs to show combined error in using the 25 cm^3 six times is greater than using 250 cm^3 measuring cylinder once only Award MP1 EITHER if multiplies errors: 100 x (0.2 /25) x 6 = 4.8% OR If adds errors 100 x (1.2 /150) = 0.8% Do not award (0.2 / 25) x 100 = 0.8 % Do not award 'easier' to use larger measuring cylinder	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(iii)	An answer that makes reference to any **three** of the following points: • heat/energy loss (to the surroundings) **(1)** • evaporation of methanol / water from the calorimeter **(1)** • incomplete combustion (of methanol) **(1)** • (specific) heat capacity of the calorimeter/apparatus has been ignored **(1)**	Ignore experiment carried out under non-standard conditions Ignore just 'no lid' Allow calorimeter has not been calibrated	**(3)**

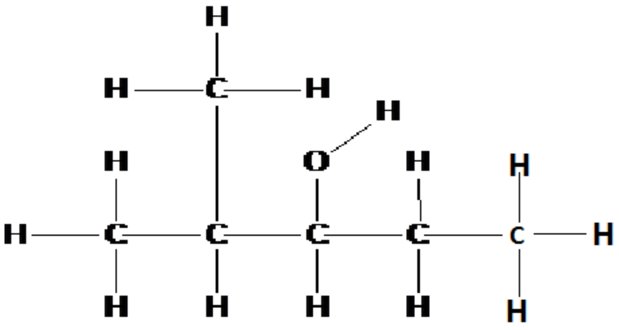
Question Number	Acceptable Answers	Additional Guidance	Mark
4(e)	An explanation that makes reference to the following points: • The second value will be less exothermic / less negative **(1)** • Some energy will be used to boil the water/boiling water is endothermic Water can only be heated to 100°C/ Temperature rise (measured) can only be (a maximum) of 40°C Greater heat losses in the 60°C to 100°C range **(1)**	Allow 'more positive' or 'smaller in magnitude' Do not accept 'greater' or 'smaller' for 'less negative' Do not award **just** "the water boils" Mark points M1 and M2 independently	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(f)	An explanation that makes reference to the following points: Either • student 2's value will be similar / the same **(1)** • (As) both the energy change **and** moles/mass (of methanol) burned will be higher/ Ratio of energy change to moles/mass (of methanol) burned will be the same/ The energy change is proportional to the moles/mass (of methanol) burned **(1)** Or • student 2's value will be less negative/ less exothermic **(1)** • greater heat loss because higher temperature/heated for longer **(1)**	Allow 'temperature change' for 'energy change' Allow 'more positive' or 'smaller in magnitude' or 'smaller' for 'less negative' Mark points MP1 and MP2 independently within each route	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(g)	An answer that makes reference to the following points: • (Calculated) value of moles (of methanol) burned will be less / too small **(1)** • The calculated value will be more exothermic / more negative **(1)**	Allow **both** marks for a calculation using M_r of 46.0 (instead of 32.0), giving a final ΔH value (approx.) of −766 (kJ mol^{-1}) Allow 'increase' or 'greater' for 'more negative' MP2 depends on MP1	**(2)**

(Total for Question 4 = 21 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
5(a)	C atom of C−Mg bond labelled as δ− **and** Mg labelled as δ+	Do not award full + or – charge Ignore δ- on Br	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(b)(i)		Ignore other structures Allow non-displayed formula	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(b)(ii)	• 2-methylpentan-3-ol	Allow 2-methyl-3-pentanol No TE on incorrect formula from 5(b)(i)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(c)	• ✓ next to nucleophile **(1)** • ✓ next to reducing agent **(1)**	If more than two boxes ticked scores (0)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)	• propane / C_3H_8	Accept name or formula or structural / skeletal / displayed formula Ignore additional inorganic products Do not award just ‘alkane’ If name and formula given then they both must be correct	**(1)**

(Total for Question 5 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)	• 23.15 **and** 23.55 **and** 23.20 completed in table **(1)** • ✓ beneath titres **1 and 3** **and** mean titre = 23.18 (cm^3) **(1)**	All three titres must be shown to 2 D.P. Allow 23.2 or 23.175 (cm^3)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(b)	(From)(pale) pink/purple (to) colourless	**Both** colours needed for the mark Do not award mauve or magenta or violet for pink/purple Ignore references to 'clear'	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)	• calculation of moles of MnO_4^- in 25.0 cm^3 **(1)** • calculation of moles of NO_2^- in mean titre **(1)** • calculation of moles of NO_2^- in 250 cm^3 **(1)** • calculation of molar mass **(1)**	Example of calculation Moles MnO_4^- = $\frac{0.02(00) \times 25.0}{1000}$ = $5(.00) \times 10^{-4}$ / 0.0005(00) (mol) Moles NO_2^- in mean titre = 2.5 x moles MnO_4^- = 1.25×10^{-3} / 0.00125 (mol) Moles NO_2^- in 250 cm^3 = moles NO_2^- in mean titre x $\frac{250}{\text{mean titre from (a)}}$ = $1.25 \times 10^{-3} \times \frac{250}{23.18}$ = 0.013481449 = 0.0135 (mol) Allow TE on mean titre from (a) Ignore SF except 1 SF • Molar mass = $2 \times \frac{1.15}{0.0135}$ = 170.3703704 (g mol^{-1}) = 170.4 (g mol^{-1})	**(5)**

	• calculation of ***x*** correctly to the nearest whole number: **(1)**	Allow TE • $\boldsymbol{x} = \frac{170.4 — 116.3}{18(.0)}$ $\boldsymbol{x} = 3.005555556$ $\boldsymbol{x} = 3$ (**must** be to nearest whole number) Allow TE from molar mass calculated Allow alternative correct methods for MP4 and MP5 Correct value of ***x*** with no working scores (1)	

Question Number	Acceptable Answers	Additional Guidance	Mark
6(d)	$2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 3H_2O$ • evidence of multiplying 1st equation by 2 **and** 2nd equation by 5 **(1)** • overall equation correct with H^+ and H_2O and $e^{(-)}$ cancelled as appropriate **(1)**	Each of the following equations score **(1)** mark overall: $2MnO_4^- + 5NO_2^- + 16H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O + 10H^+$ OR $2MnO_4^- + 5NO_2^- + 6H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O$ OR $2MnO_4^- + 5NO_2^- + 16H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 10H^+ + 3H_2O$ Ignore state symbols, even if incorrect Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(e)	An explanation that makes reference to the following: **Either** • the (calculated) value of ***x*** would be too high **(1)** • The moles of $MgCO_3$ would be too low / the moles of $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ would be too low / the M_r of $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ would be too high **(1)** **Or** • (So) the (calculated) value of ***x*** would be unchanged (so this does not explain the discrepancy) **(1)** • Only a small amount/mass of $MgCO_3$ would dissolve because it is very slightly soluble **(1)**	Allow 'amount' or 'mass' for 'moles' MP2 depends on MP1 MP2 depends on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(f)	An answer that makes reference to the following points: • the $MgCO_3$ would decompose / the residue would contain $NaNO_2$ / the residue would contain (the excess) Na_2CO_3 **(1)** • (so) the (proposed) method is not valid / appropriate / suitable **(1)**	Ignore references to just 'impurities' M2 dependent on M1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(g)	An answer that makes reference to the following point: • heat (the sample) to constant mass	Allow repetition of heating and weighing until there is no change in mass (of the sample) Ignore references to 'brown gas' etc	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(h)	An answer that makes reference to the following points: • use a larger mass (of the hydrated salt) **(1)** • Use a balance that weighs to 3 D.P. (rather than 2 D.P.) **(1)**	Ignore references to repeat measurements Allow statements such as 'use a balance that weighs to more decimal places' /'greater resolution' / ' a more precise/sensitive balance' Do not allow 'more accurate'	**(2)**

(Total for Question 6 = 17 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>***7(a)**</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general it would be expected that 5 or 6 indicative points would score 2 reasoning marks, and 3 or 4 indicative points would score 1 reasoning mark. A total of 2, 1 or 0 indicative points would score 0 marks for reasoning.

Reasoning marks may be subtracted for extra incorrect chemistry.</td><td>**(6)**</td></tr>
</table>

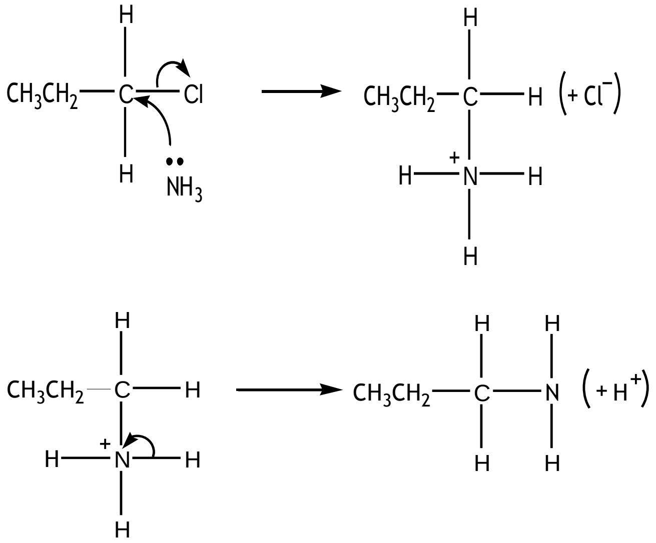
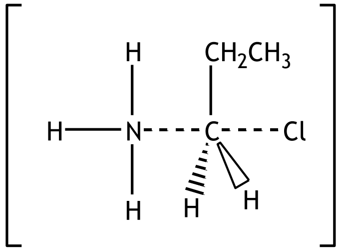
	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

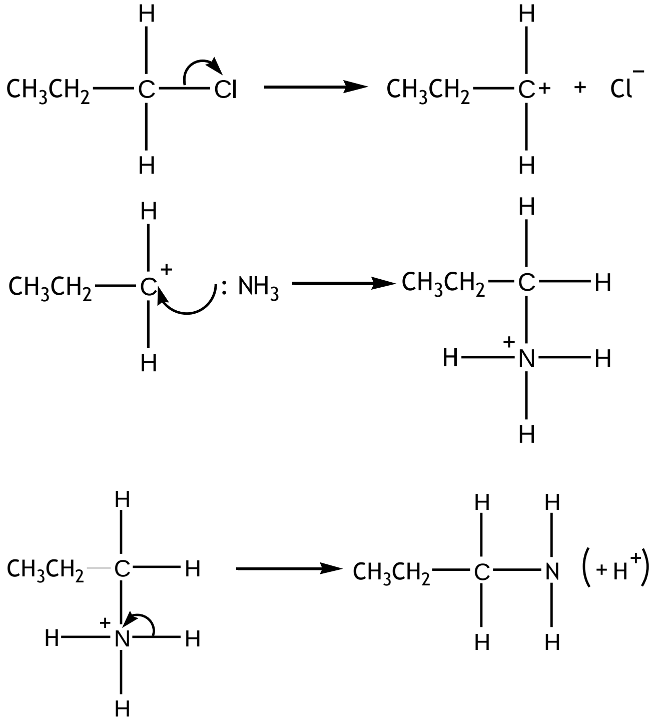
	Indicative content (IPs) **IP1:** • (transition metal) forms an **ion** with an incomplete *d* sub-shell	Allow ‘partially-filled’ for incomplete Allow *d*-orbital(s) Do not award “*d*-shell” Allow “*D*” for “*d*” throughout	
	IP2: • scandium **and** zinc are not transition metals	Allow if **only** Sc **and** Zn are used to illustrate *d*-block elements that are not transition metals	
	IP3: • Sc^{3+} **and** $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$	Allow $4s^0$ and/or $3d^0$ Penalise use of [Ar] once only	
	IP4: • Zn^{2+} **and** $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$		
	IP5: • Sc^{3+} **and** *d* sub-shell empty / *d*-orbitals empty	Allow “Sc^{3+} has no *d* sub-shell”	
	IP6: • Zn^{2+} **and** *d* sub-shell full / **ALL** *d*-orbitals are full	Allow ‘d orbital is full’ if clarified by $3d^{10}$	

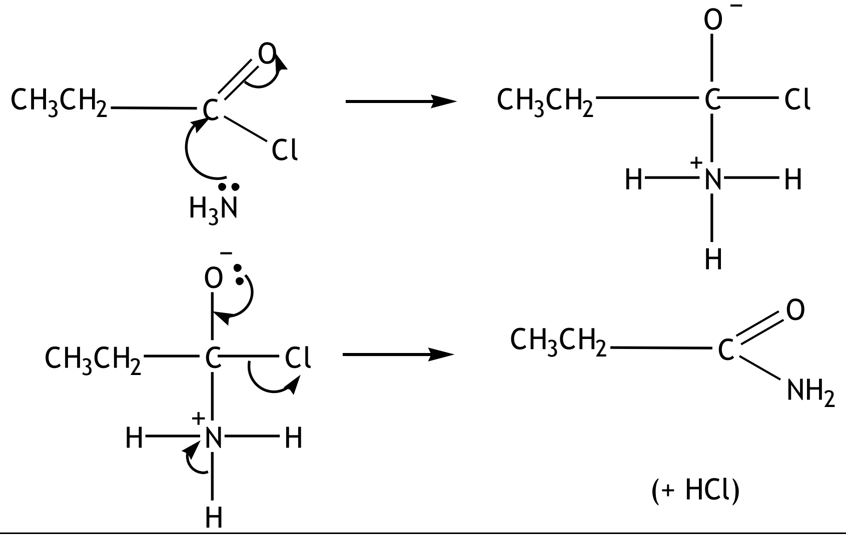
Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)	• calculation of moles of $Cr_2O_7^{2-}$ **(1)** • calculation of moles of Mn^{2+} **(1)** • deduction of whole number mole ratio of $Cr_2O_7^{2-}$: Mn^{2+} **(1)** • deduction of total number of electrons lost by 3 mol of Mn^{2+} **(1)** • deduction of final oxidation state of manganese **(1)**	<u>Example of calculation</u> • moles of $Cr_2O_7^{2-}$ **=** $\frac{0.100 \times 20.0}{1000}$ = 2(.00) x 10^{-3} (mol) • moles of Mn^{2+} **=** $\frac{0.200 \times 30.0}{1000}$ = 6(.00) x 10^{-3} (mol) • mole ratio $Cr_2O_7^{2-}$: Mn^{2+} = 1 : 3 • 3 mol Mn^{2+} lose a total of $6e^-$ • each Mn^{2+} loses $2e^-$, so final oxidation state of Mn is (+)4 / IV /Mn^{4+} MP3 and MP4 may be awarded via alternative methods e.g. use of oxidation numbers / moles of electrons correct final oxidation state with no working scores M5 only	**(5)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(c)	• calculation of moles of Cr **(1)** **MP2, 3 & 4 are only available for answers using a 3:2 mole ratio** • deduction of mole ratio of **X** to Cr^{3+} **(1)** • calculation of moles of **X** **(1)** • calculation of molar mass / A_r of **X** **and** identification of **X** accordingly **(1)**	Example of calculation Moles Cr = $\frac{1.456}{52(.0)}$ = 0.028(0) **3** mol **X** : **2** mol Cr^{3+} / Cr Allow $2Cr^{3+} + 3\mathbf{X} \rightarrow 3\mathbf{X}^{2+} + 2Cr$ Moles **X** = 0.028(0) x 1.5 = 0.042(0) Correctly multiplying by 1.5 for MP3 implies MP2 $M_r = \frac{1.021}{0.042(0)}$ = 24.3 (g mol^{-1}) **and** (so) **X** is magnesium/Mg COMMENT: If transpose 3:2 ratio, **X** has M_r = 54.7 (g mol^{-1}) and **X =** Mn so scores M1, then M3 and M4 by TE (i.e. **(3)** marks overall)	**(4)**

(Total for Question 7 = 15 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including positive charge **(1)** • third curly arrow and formation of final organic product **(1)**	Ignore correct dipoles Allow non-displayed NH_3^+ for MP2 Ignore involvement of Cl^- / NH_3 or wrong inorganic products for MP3 EITHER  Ignore depiction of transition state e.g. 	**(3)**

	OR • fission of C-Cl bond curly arrow **and** curly arrow from nitrogen in NH_3 with lone pair shown on N atom to correct carbocation **(1)** • structure of resulting nitrogen-containing intermediate including positive charge **(1)** • curly arrow resulting in breaking of an N-H bond and structure of the final organic product **(1)**	OR AWARD S_N1 mechanism 	

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including both charges **(1)** • three curly arrows and structure of final organic product **(1)**		**(3)**

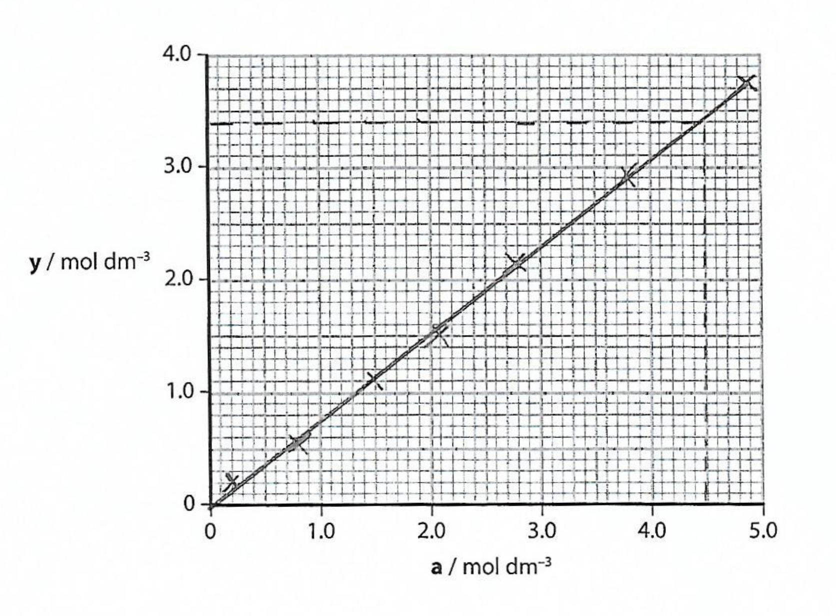
(Total for Question 8 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(i)	(K_c =) $\frac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$	Ignore missing state symbols or units Do not award round brackets	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(ii)	(K_c =) $\frac{4y^2}{(a - y)^2}$	Allow square brackets	**(2)**
	- Numerator term correct **(1)**	Allow $(2y)^2$	
	- Denominator term correct **(1)**	Allow $(a^2 - 2ay+y^2)$ or (a-y)(a-y)	

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(i)	- both values correct to 2 DP	1.13 2.93	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(ii)	- All 7 points plotted correctly **(1)**	Allow TE for incorrect values from 9(b)(i)	**(2)**
	- Appropriate straight line of best fit, drawn through the origin **(1)**	Do not allow all points above or below the line of best fit Allow line of best fit to intersect one square either side of the origin	

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(iii)	- co-ordinates correctly read off the line on graph **(1)**  - gradient correctly calculated **(1)**	At least 1 line must be shown on the graph to indicate selection of co-ordinates <u>Example of calculation</u> $\frac{3.40 - 0.00}{4.50 - 0.00}$ = gradient of graph Gradient = 0.76 Ignore SF except 1SF Do not allow units for the gradient Allow a value from 0.71 to 0.81 inclusive	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)(iv)	• $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}}$ = gradient / $\frac{y}{a}$ **(1)** • re-arrangement of expression and calculation of K_c **(1)**	<u>Example of calculation</u> $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = 0.76$ K_c = 40.1 /40 (no units) Allow TE on gradient from part (b)(iii) $K_c = [(2 \text{ x grad})/(1\text{-grad})]^2$ Correct answer with no working scores (2)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(c)	• hydrogen is flammable / explosive	Allow iodine vapour damages eyes /toxic Allow hydrogen iodide is corrosive / acidic / irritant (if qualified) / lachrymator Ignore references to high pressure Ignore references to safety precautions	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(d)	• Faster rate of reaction / increased rate **(1)** • K_c unchanged **(1)**	Ignore references to shifting position of equilibrium	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(e)(i)	An explanation that makes reference to the following points: • (K_c is) smaller / decreases / gets less **(1)** • (forward) reaction is exothermic **(1)**	Allow reverse/backwards reaction is endothermic MP2 dependent on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(e)(ii)	• straight line drawn on the graph with a less steep gradient (and goes through the origin)	Do not allow if lines cross	**(1)**

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

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Chemistry

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Tuesday 5 June 2018 – Afternoon
Time: 1 hour 45 minutes

Paper Reference
9CH0/01

Candidates must have: Data Booklet
Scientific calculator

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

P52302RA

5/5/5/5/2/1/2/

P 5 2 3 0 2 R A 0 1 2 8

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

1 An inorganic salt **A** contains one cation and one anion.
The results of two tests on salt **A** are shown in the table.

Test	Observation
Add aqueous sodium hydroxide to solid **A**. Warm the mixture. Test any gas evolved with damp red litmus paper.	A gas was evolved. The gas turned red litmus paper blue.
Add dilute nitric acid followed by aqueous silver nitrate to an aqueous solution of **A**.	A cream precipitate formed.

(a) Deduce the **name** of salt **A**.

(2)

....

(b) Describe additional tests, with the results, that will confirm the identity of the **anion** in the cream precipitate.

(2)

....

....

....

....

....

....

(Total for Question 1 = 4 marks)

2 This question is about atoms, molecules and ions.

(a) Lithium exists as two isotopes.

Complete the table to show the numbers of subatomic particles in a ^{6}Li **atom** and a ^{7}Li^{+} **ion**.

(2)

Particle	Protons	Neutrons	Electrons
^{6}Li			
^{7}Li^{+}			

(b) The mass spectrum of a diatomic molecule, X_2, has peaks at the following *m* / *z* values for the X_2^+ ion:

32, 33, 34, 35, 36

Deduce the formulae of all the species responsible for **each** of the peaks in the mass spectrum of X_2, identifying element X and showing clearly the isotopes present.

(3)

....

....

....

....

....

....

....

....

(c) Complete the table to show the maximum number of electrons which can fill each region of an atom.

(3)

Region	Maximum number of electrons
the 1s orbital	
the 2p subshell	
the third quantum shell	

(Total for Question 2 = 8 marks)

3 Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of 1.00 mol dm^{-3} HNO_3 = 25.0 cm^3

Volume of 1.05 mol dm^{-3} NaOH = 25.0 cm^3

Temperature rise = 6.8 °C

(a) Give a reason why excess sodium hydroxide was used.

(1)

....

....

....

(b) Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

[Assume: density of the reaction mixture = $1.0\,\text{g}\,\text{cm}^{-3}$
specific heat capacity of the reaction mixture = $4.18\,\text{J}\,\text{g}^{-1}\,{}^\circ\text{C}^{-1}$]

(4)

(Total for Question 3 = 5 marks)

4 This question is about transition metals.

(a) Which of these ions has the electronic configuration $[Ar]3d^5$?

(1)

☒ **A** Cr^{3+}

☒ **B** Fe^{2+}

☒ **C** Mn^{2+}

☒ **D** Mn^{3+}

(b) In which of these complex ions does the transition metal have the oxidation number +3?

(1)

☒ **A** $[Ag(CN)_2]^-$

☒ **B** $[CuCl_4]^{2-}$

☒ **C** $[Fe(CN)_6]^{3-}$

☒ **D** $[Ni(EDTA)]^{2-}$

(c) Which type or types of bonding exist **within** the complex ion $[Cr(H_2O)_6]^{3+}$?

(1)

☒ **A** dative covalent only

☒ **B** dative covalent and covalent only

☒ **C** dative covalent and ionic only

☒ **D** dative covalent, covalent and ionic

(d) Which **best** explains why $[Cu(NH_3)_2]^+$ ions are colourless?

(1)

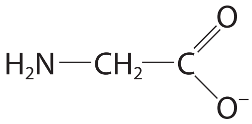
☒ **A** all complex ions having a metal ion with a +1 charge are colourless

☒ **B** no electronic transitions can take place between *d*-orbitals

☒ **C** the *d*-orbitals cannot split in energy

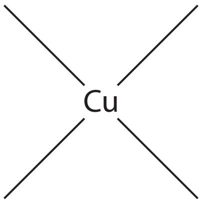
☒ **D** there are no electrons in the *d*-subshell

(e) Glycinate ions are bidentate ligands and can be represented by the structure



Complete the diagram below to show the structure of the $[Cu(NH_2CH_2COO)_2]$ complex, which is square planar.

(2)



(f) Manganate(VII) ions, MnO_4^-, react with ethanedioate ions in acid solution.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The reaction starts slowly, the rate of reaction then increases, before it decreases again. Explain this sequence.

(3)

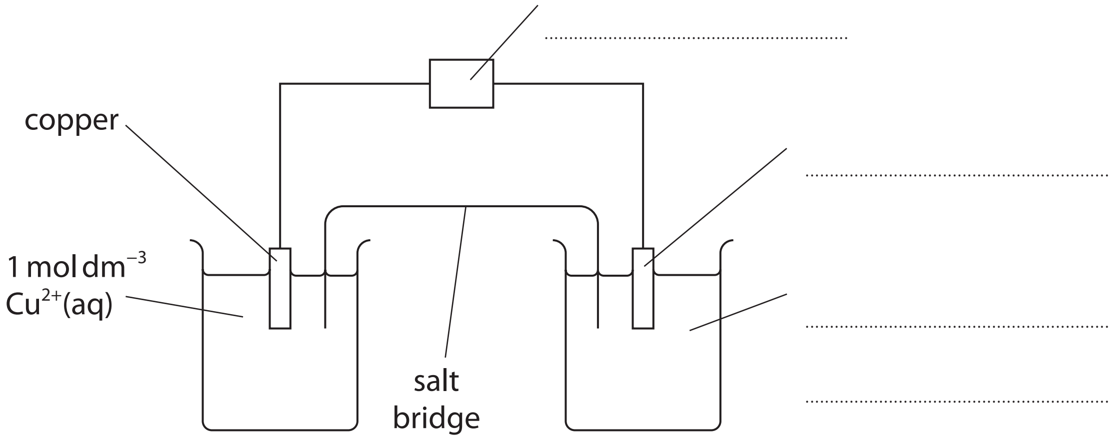
(Total for Question 4 = 9 marks)

5 An electrochemical cell is made from the electrode systems represented by these half-equations.

$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$$

$$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$$

The $E^{\ominus}_{cell}$ value is measured using the apparatus shown.



(a) Complete the diagram by adding labels on the dotted lines provided.

(3)

(b) A salt bridge is used to connect the two half-cells.

(i) State what chemical is contained in the salt bridge.

(1)

....

....

(ii) Give a possible reason why the salt bridge cannot be replaced by an unreactive metal wire.

(1)

....

....

....

(c) In this cell, the copper is oxidised and $E^{\ominus}_{\text{cell}} = +1.15\,\text{V}$.

$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) \qquad E^{\ominus} = +0.34\,\text{V}$$

$$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$$

(i) Write the overall ionic equation for the reaction taking place.
State symbols are not required.

(1)

(ii) Calculate the value of the standard electrode potential for the $Mn^{3+}(aq)\ |\ Mn^{2+}(aq)$ half-cell.

(1)

(Total for Question 5 = 7 marks)

6 This question is about the solubility of metal hydroxides.

(a) Which of these metal hydroxides is the most soluble in water?

(1)

☒ **A** barium hydroxide

☒ **B** calcium hydroxide

☒ **C** magnesium hydroxide

☒ **D** potassium hydroxide

(b) When excess magnesium hydroxide is added to water and shaken, a saturated solution is formed and the mixture reaches equilibrium.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

The equilibrium constant, K_c, for this reaction is

$$K_c = [Mg^{2+}(aq)][OH^-(aq)]^2$$

(i) Give a reason why the magnesium hydroxide is not included in the expression for K_c.

(1)

....

....

....

....

(ii) Give the units for K_c.

(1)

(iii) Calculate the enthalpy change of solution of magnesium hydroxide, using the following data.

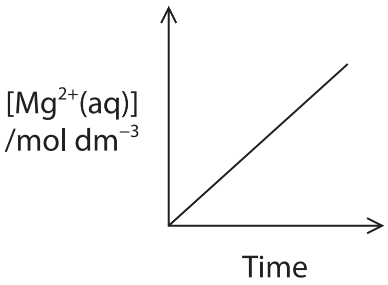
Energy or enthalpy change	Value / kJ mol^{-1}
Lattice energy of $Mg(OH)_2(s)$	−2842
$\Delta_{hyd}H$ ($Mg^{2+}(aq)$)	−1920
$\Delta_{hyd}H$ ($OH^{-}(aq)$)	−460

(2)

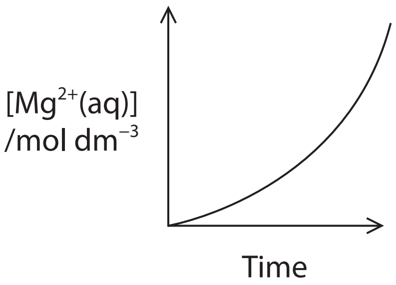
(iv) Which graph shows the change in the concentration of the $Mg^{2+}(aq)$ ions when some solid magnesium hydroxide is shaken with water and left to reach equilibrium?

(1)

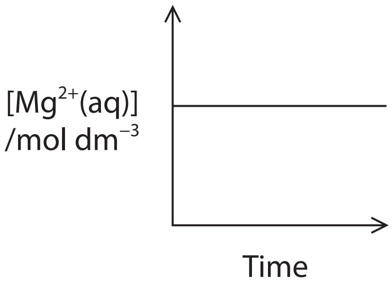
☒ **A**



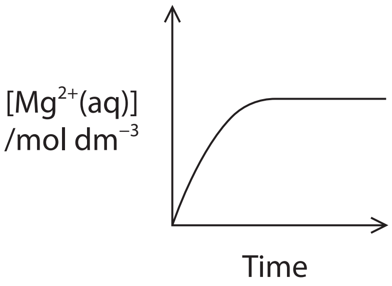
☒ **B**



☒ **C**



☒ **D**



(v) Predict the effect, if any, of adding each of the following to a saturated solution of magnesium hydroxide in contact with solid magnesium hydroxide. Justify your answers in terms of the effect on the equilibrium.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^{-}(aq)$$

(4)

Magnesium sulfate solution

Dilute hydrochloric acid

(Total for Question 6 = 10 marks)

7 Boric acid, H_3BO_3, is a weak acid with antiseptic properties.

(a) Boric acid can be prepared by reacting borax, $Na_2B_4O_7.10H_2O$, with hydrochloric acid.

Write the equation for this reaction. State symbols are not required.

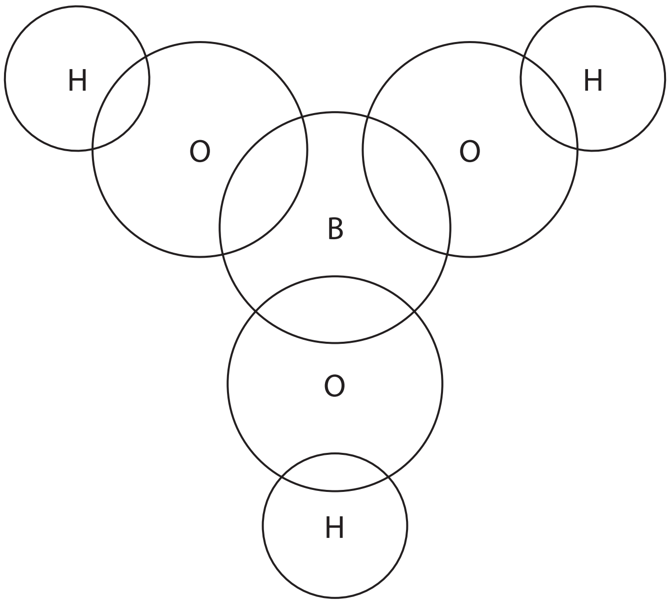
(1)

(b) The formula of boric acid can also be written as $B(OH)_3$.

(i) Complete the dot-and-cross diagram of a molecule of boric acid. Show the outer shell electrons only.

Use dots (•) for the hydrogen electrons, crosses (×) for the oxygen electrons and triangles (△) for the boron electrons.

(2)



(ii) What are the O—B—O and B—O—H bond angles in a molecule of boric acid?

(1)

		O—B—O bond angle	B—O—H bond angle
☒	**A**	109.5°	104.5°
☒	**B**	109.5°	180°
☒	**C**	120°	104.5°
☒	**D**	120°	180°

(c) Boric acid is a solid with melting temperature 171 °C.

What are the strongest interactions between the molecules in solid boric acid?

(1)

☒ **A** covalent bonds

☒ **B** hydrogen bonds

☒ **C** ionic bonds

☒ **D** London forces

(d) In aqueous solution, boric acid dissociates into ions in three stages. The equation for the first dissociation is

$$H_3BO_3(aq) \rightleftharpoons H^+(aq) + H_2BO_3^-(aq)$$

pK_a for this dissociation is 9.24

(i) Calculate the pH of a 0.0500 mol dm^{-3} solution of boric acid from the pK_a value for the first dissociation.

(3)

(ii) State any assumptions you made in your calculation in (d)(i).

(2)

....

....

....

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....

....

(e) Boric acid can undergo further dissociation.

Which is the conjugate acid of the HBO_3^{2-} ion?

(1)

☒ **A** BO_3^{3-}

☒ **B** $H_2BO_3^-$

☒ **C** H_3BO_3

☒ **D** H_3O^+

(Total for Question 7 = 11 marks)

8 This question is about ions and ionic compounds.

(a) The first three ionisation energies of calcium are shown in the table.

	First ionisation	Second ionisation	Third ionisation
Ionisation energy / kJ mol^{-1}	590	1145	4912
Orbital			

(i) Complete the table by identifying the specific orbital from which each electron is removed.

(2)

(ii) Write the equation for the **third** ionisation energy of calcium.
Include state symbols.

(1)

(iii) Explain why the difference between the second and third ionisation energies of calcium is much larger than the difference between the first and second ionisation energies.

(2)

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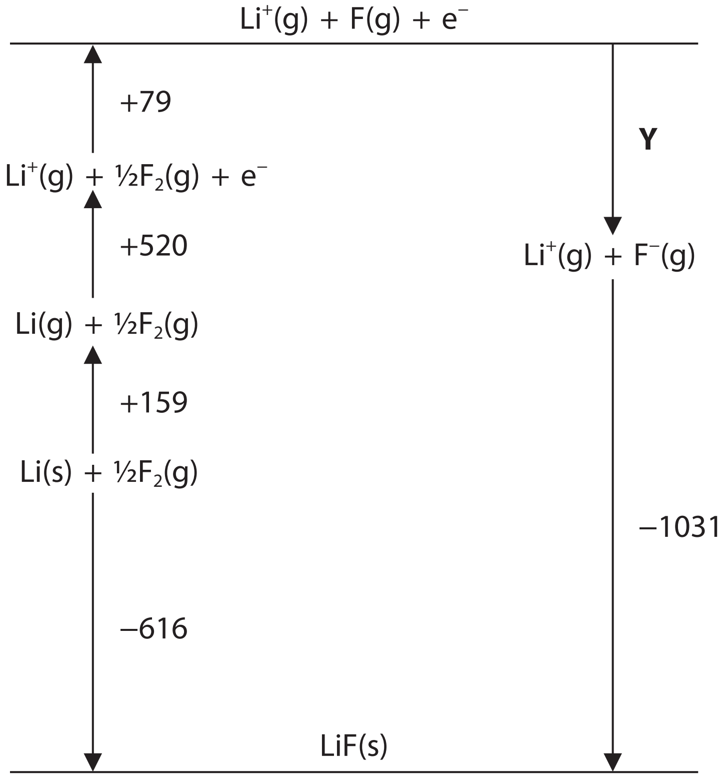
(b) The diagram, which is not drawn to scale, shows the Born-Haber cycle for lithium fluoride. The energy changes are given in kJ mol^{-1}.



What is the value for **Y**, in kJ mol^{-1}?

(1)

☒ **A** −273

☒ **B** −343

☒ **C** −432

☒ **D** −889

*(c) The table shows the theoretical and experimental lattice energy values of two compounds.

Compound	Theoretical lattice energy / kJ mol^{-1}	Experimental lattice energy / kJ mol^{-1}
lithium chloride, LiCl	–845	–848
magnesium iodide, MgI_2	–1944	–2327

Comment on the theoretical and experimental lattice energy values, giving the reasons for any differences and similarities.

(6)

(Total for Question 8 = 12 marks)

9 This question is about entropy and free energy.

(a) Complete the table by giving the sign of the entropy change of the system, ΔS_{system}, for each reaction.

(2)

Reaction	Sign of ΔS_{system}
$CO_2(s) \rightarrow CO_2(g)$	
$NaCl(s) + aq \rightarrow NaCl(aq)$	
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	

(b) Calculate the total entropy change, ΔS_{total}, for the thermal decomposition of calcium carbonate at 298 K.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

[Data: $\Delta_r H = +178\ \text{kJ mol}^{-1}$ $\quad\quad \Delta S_{\text{system}} = +160\ \text{J K}^{-1}\ \text{mol}^{-1}$]

(3)

(c) Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta_r H = -288.4\,kJ\,mol^{-1}$$

The standard molar entropy values at 298 K are given in the table.

	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
$S^\ominus$ / $J\,K^{-1}\,mol^{-1}$	+248.1	+205.0	+95.6

(i) Calculate the entropy change of the system, ΔS_{system}, for the forward reaction. Include a sign and units in your answer.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

(2)

(ii) Calculate the free energy change, ΔG, at 298 K and hence deduce whether the reaction is feasible.

(3)

(iii) In industry, the reaction is carried out at about 700 K using a vanadium(V) oxide catalyst.

Calculate the value of the equilibrium constant, *K*, at 700 K.

ΔG at 700 K is $-60\,\text{kJ}\,\text{mol}^{-1}$

(3)

(iv) The equilibrium constant has a larger value at 298 K than at 700 K. Explain why the reaction is carried out at 700 K and not at 298 K.

(2)

(Total for Question 9 = 15 marks)

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10 Yellow gold is used to make jewellery. It is an alloy of copper, gold and silver. The purity of gold is measured in carats. The higher the carat, the higher the percentage of gold in the alloy. Pure gold is 24 carat.

A sample of yellow gold is analysed using the steps below.

Step **1** Excess concentrated nitric acid is reacted with 1.250 g of the alloy. The gold does **not** react but the copper and silver do react. The half-equations are

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

$$Ag(s) \rightarrow Ag^+(aq) + e^-$$

$$2HNO_3(aq) + e^- \rightarrow NO_3^-(aq) + NO_2(g) + H_2O(l)$$

Step **2** The mixture is diluted with distilled water and the gold is filtered off.

Step **3** Excess hydrochloric acid is added to the filtrate. It reacts with the silver ions to form a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

Step **4** The silver chloride precipitate is filtered off, washed, dried and weighed. The mass of silver chloride formed is 0.706 g.

Step **5** Excess potassium iodide is added to the remaining solution. A precipitate of copper(I) iodide and a solution of iodine forms.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Step **6** The resulting mixture is titrated with 0.100 mol dm^{-3} sodium thiosulfate solution.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The titre is 39.40 cm^3.

(a) Write the equation for the reaction of copper with concentrated nitric acid, using the half-equations given in Step **1**. State symbols are not required.

(1)

(b) State the indicator used and its colour change at the end-point in the titration in Step **6**.

(2)

....

....

(c) The table shows the percentage by mass of gold in four different carats of yellow gold.

Carat	Percentage by mass of gold
9	37.5
10	41.7
14	58.3
18	75.0

Determine, using the experimental data, the carat of the sample of yellow gold that was analysed.

(6)

(Total for Question 10 = 9 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										*(18)* 4.0 **He** helium 2
(1)	*(2)*											*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

Summer 2018

Pearson Edexcel GCE
In Chemistry (9CH0) Paper 01
Advanced Inorganic and Physical Chemistry

Summer 2018
Publications Code 9CH0_01_1806_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is essential to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

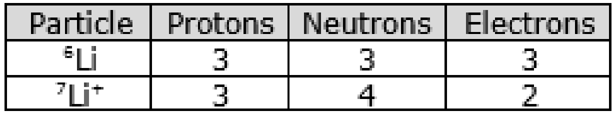
Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Acceptable Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to the following points:	Mark independently Allow names in either order Ignore symbols as well as names	(2)
	• ammonium (1)	Do not award ammonia	
	• bromide (1)	Do not award bromine Allow (1) for just NH_4Br	

Question Number	Acceptable Answer	Additional Guidance	Mark
1(b)	A description that makes reference to the following points: • add (excess) dilute ammonia / dilute NH_3 (to the precipitate) and the precipitate is insoluble /does not dissolve (1) • add (excess) concentrated (aqueous) ammonia / concentrated NH_3 (to the precipitate) and it is soluble / dissolves / forms a colourless solution (1)	Allow ammonium hydroxide for ammonia Ignore pure ammonia / ammonia with no concentration / ammonia gas Allow no change for the observation Allow 'if it dissolves it is not bromide' Allow redissolves for soluble Note If no other mark is awarded allow (1) for adding dilute and concentrated ammonia with no / incorrect observation(s) Alternative test: add concentrated sulfuric acid (1) brown fumes (1)	(2)

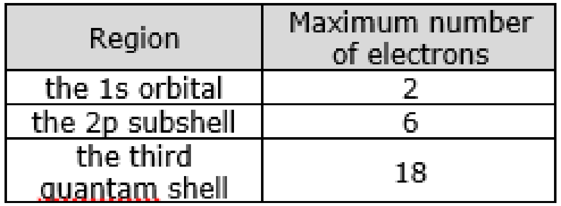
(Total for Question 1 = 4 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>2(a)</td><td>• ^{6}Li – 3 protons and 3 neutrons and 3 electrons (1)

• $^{7}Li^{+}$ – 3 protons and 4 neutrons and 2 electrons (1)</td><td><u>Example of table</u>
<table><tr><th>Particle</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>^{6}Li</td><td>3</td><td>3</td><td>3</td></tr><tr><td>$^{7}Li^{+}$</td><td>3</td><td>4</td><td>2</td></tr></table>
If no oher mark is scored, allow (1) for any 4 correct numbers

Ignore + or - signs</td><td>(2)</td></tr>
</table>

Question Number	Acceptable Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following points: • identification of oxygen / O (1) • identification of isotopes corresponding to any 3 *m*/*z* values (1) • Conditional on M2 awarded identification of isotopes corresponding to other 2 *m*/*z* values (1)	Isotopes in ions at each *m*/*z* value: (32 –) $^{16}O{=}^{16}O^{+}$ / $^{16}O_2^{+}$ (33 –) $^{16}O{=}^{17}O^{+}$ (34 –) $^{16}O{=}^{18}O^{+}$ and $^{17}O{=}^{17}O^{+}$ / $^{17}O_2^{+}$ (35 –) $^{17}O{=}^{18}O^{+}$ (36 –) $^{18}O{=}^{18}O^{+}$ / $^{18}O_2^{+}$ Allow single bonds Allow any other unambiguous ways of showing the masses of the isotopes for each *m*/*z* value e.g. 16+16, O_2^{16} Allow use of X / another symbol e.g. Cl instead of O for M2 and M3 Ignore missing charges as given in question Penalise negative charge once only	(3)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>2(c)</td><td>• 1s orbital − 2 electrons
• 2p subshell − 6 electrons
• third quantum shell − 18 electrons</td><td>(1)
(1)
(1)</td><td><u>Example of table</u>

<table>
<tr><th>Region</th><th>Maximum number of electrons</th></tr>
<tr><td>the 1s orbital</td><td>2</td></tr>
<tr><td>the 2p subshell</td><td>6</td></tr>
<tr><td>the third quantam shell</td><td>18</td></tr>
</table>
Allow $1s^2$ for 2

Allow $2p^6$ for 6

Ignore $3s^23p^63d^{10}$ for the third number

Do not award more than one number written in the box e.g. 8 or 18 in the third box</td><td>(3)</td></tr>
</table>

(Total for Question 2 = 8 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)	An answer that makes reference to the following point: • to make sure that (all) the (nitric) acid / HNO_3 / H^+ has reacted / been neutralised / is used up	Allow (nitric acid) / HNO_3 is the limiting reagent Allow so that 0.025 mol of water / H_2O forms Ignore to make sure that 1 mol of water / H_2O forms Ignore just 'to ensure that reaction is complete'	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(b)	• calculation of heat produced (1) • calculation of amount (mol) of HNO_3 (1) • calculation of enthalpy change (1) • negative sign and units and answer to 2 / 1 SF (1)	<u>Example of calculation</u> heat produced = 50.0 x 4.18 x 6.8 = 1421.2(J) / 1.4212 (kJ) amount HNO_3 used = 25.0 x 1.00/1000 = 0.025 / 2.5×10^{-2} (mol) Ignore moles NaOH and total moles calculated enthalpy change = $\frac{1421.2}{0.025}$ = 56848 (J mol^{-1}) or = $\frac{1.4212}{0.025}$ = 56.848 (kJ mol^{-1}) TE on heat produced and amount HNO_3 final answer −57 / −60 kJ mol^{-1} or −57 000 / −60 000 J mol^{-1} TE on enthalpy change Do not award 3 SF Correct final answer with sign, units and 2 or 1 SF but no working scores (4) Ignore units and sign of enthalpy change in M1 and M3	(4)

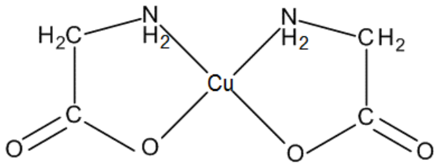
(Total for Question 3 = 5 marks)

Question Number	Answer	Mark
4(a)	The only correct answer is C *A is not correct because it is $3d^3$ not $3d^5$* *B is not correct because it is $3d^6$ not $3d^5$* *D is not correct because it is $3d^4$ not $3d^5$*	(1)

Question Number	Answer	Mark
4(b)	The only correct answer is C *A is not correct because it is +1 not +3* *B is not correct because it is +2 not +3* *D is not correct because it is +2 not +3*	(1)

Question Number	Answer	Mark
4(c)	The only correct answer is B *A is not correct because covalent is missing* *C is not correct because it has ionic is incorrect* *D is not correct because it has ionic is incorrect*	(1)

Question Number	Answer	Mark
4(d)	The only correct answer is B *A is not correct because it is not an explanation* *C is not correct because the d-orbitals can be split in energy* *D is not correct because there are ten electrons in the d-subshell*	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(e)	• 2 glycinate ligands attached to Cu through nitrogen atoms (1) • 2 glycinate ligands attached to Cu through single bonded oxygen atoms and rest of structure correct (1)	Example of structure  Allow the two ligands attached to any 2 pairs of adjacent bonds Allow *cis* or *trans* isomer / delocalised carboxylate groups / skeletal formulae Ignore bond lengths and bond angles Ignore lone pairs of electrons, charge on the copper or oxygen ions and direction of dative covalent bonds Do not award M1 if bond between Cu and H of NH_2	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
4(f)	An explanation that makes reference to the following points: • (the initial rate of reaction is slow) because both reacting species are negatively charged / repel each other or the reaction has a high activation energy / few particles have energy greater than (or equal to) the activation energy (1) • (the rate of reaction increases) because Mn^{2+} ions (are formed) and they act as a catalyst / are autocatalytic / provide an alternative route with a lower activation energy (1) • (the rate decreases) because the concentrations /amounts of the reactants decrease / the reactants are used up (1)	Allow because there is no catalyst / no Mn^{2+} ions present at the start Allow a description of how the Mn^{2+} ions are acting as a catalyst e.g. the idea of Mn^{2+} ions reacting and being regenerated Do not award 'enzyme' Allow example of one of the reagents used up / becoming a limiting factor Do not award 'the Mn^{2+} ions are used up'	(3)

(Total for Question 4 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(a)	• (high resistance) voltmeter (1)	Allow potentiometer / Wheatstone bridge / just 'V' Ignore high voltage Do not award voltameter	(3)
	• platinum /Pt (electrode) (1)	Ignore just 'inert metal' Do not award manganese / Mn	
	• manganese(II) and manganese(III) ions / Mn^{2+} and Mn^{3+} (1)	Allow any named manganese(II) salt and manganese(III) salt Ignore concentration and units	

Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(i)	• potassium nitrate / KNO_3	If name and formula are given, both must be correct If more than one substance given, all must be correct Allow potassium chloride / KCl sodium nitrate / $NaNO_3$ sodium chloride / $NaCl$ ammonium nitrate / NH_4NO_3 ammonium chloride / NH_4Cl Ignore concentration	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(ii)	• wire does not allow the flow of ions or wire (only) allows flow of electrons or salt bridge allows flow of ions or salt bridge does not allow the flow of electrons or a flow of ions is needed to complete the circuit or ions (need to) flow between the half-cells / between the solutions	Allow any indication of movement for flow in all points Allow the salt bridge donates / removes ions (to balance the charges in the solution and the wire does not do this) Ignore just 'the circuit is not complete' Ignore references to changes in potential difference / $E^\ominus$ / $E^\ominus_{cell}$	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(c)(i)	- correct equation	Example of equation $2Mn^{3+} + Cu \rightarrow 2Mn^{2+} + Cu^{2+}$ Allow multiples Allow $\rightleftharpoons$ provided equation is written in the direction shown Ignore state symbols, even if incorrect Ignore cancelled electrons e.g. $2Mn^{3+} + Cu + 2e \rightarrow 2Mn^{2+} + Cu^{2+} + 2e$ Do not award equation with uncancelled electrons	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(c)(ii)	- $\overline{E}^{\ominus}$ = 1.15 − (−0.34) = (+)1.49 (V)	Stand alone mark Correct answer with no working scores the mark	(1)

(Total for Question 5 = 7 marks)

Question Number	Answer	Mark
6(a)	The only correct answer is D *A is not correct because it is the 2nd most soluble* *B is not correct because it is the 3rd most soluble* *C is not correct because it is the least soluble*	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)(i)	An answer that makes reference to the following point: • the concentration of a solid / $Mg(OH)_2$ is constant / unchanged / changes very little	Allow magnesium hydroxide is in a different phase / state (from the aqueous ions) Ignore solids do not appear in K_c expressions / just 'it is solid' Ignore solid does not affect the concentration of the solution Ignore it is a heterogeneous equilibrium Ignore it is difficult to measure the concentration of a solid Do not award the solid does not have a concentration	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)(ii)	• mol^3 dm^{-9}	Allow dm^{-9} mol^3 mol^3/dm^9 Ignore any working before the answer	(1)

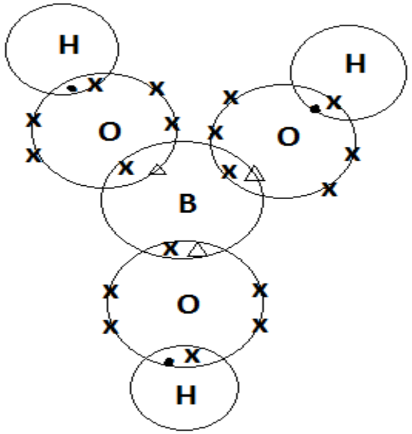
Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)(iii)	• use of $\Delta_{sol}H = \Delta_{hyd}H[Mg^{2+}(aq)] + 2\Delta_{hyd}H[OH^-(aq)] - \Delta_{latt}H[Mg(OH)_2(s)]$ (1) • calculation of $\Delta_{sol}H$ (1)	<u>Example of calculation</u> $\Delta_{sol}H = -1920 + 2(-460) - (-2842)$ Allow this shown on a Hess cycle $\Delta_{sol}H = (+)2$ (kJ mol^{-1}) Allow 2000 J mol^{-1} Correct answer with no working scores 2	(2)

Question Number	Answer	Mark
6(b)(iv)	The only correct answer is D *A is not correct because it should not be linear and should level off* *B is not correct because it should not increase in that way and should level off* *C is not correct because it should not be horizontal*	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)(v)	An answer that makes reference to the following points:	Mark independently	(4)
	Addition of magnesium sulfate solution: - equilibrium position shifts to the left / in the backwards direction (1)	Allow more magnesium hydroxide precipitates / forms	
	- because increased concentration / amount of magnesium ions / Mg^{2+}((aq)) (1)	Allow more Mg^{2+} ions present	
	Addition of dilute hydrochloric acid: - equilibrium shifts to the right / in the forwards direction (1)	Allow more magnesium hydroxide dissolves / dissociates	
	- because the hydrogen ions / H^+((aq)) react with / neutralise / removes the hydroxide ions / OH^-((aq)) (1)	Allow $H^+((aq)) + OH^-((aq)) \rightarrow H_2O((l))$ Allow magnesium hydroxide reacts with / is neutralised by acid / equation to show this Allow acid / HCl reacts with / neutralises / removes hydroxide ions Penalise reference to K_c changing once only	

(Total for Question 6 = 10 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	• correct equation	<u>Examples of equation</u> $Na_2B_4O_7.10H_2O + 2HCl \rightarrow 4H_3BO_3 + 2NaCl + 5H_2O$ or $Na_2B_4O_7.10H_2O + 2HCl \rightarrow 4B(OH)_3 + 2NaCl + 5H_2O$ Allow multiples Allow reversible arrow provided the equation is written in the direction shown. Ignore state symbols, even if incorrect	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(b)(i)	• all 6 bonding pairs correct (1) • 2 lone pairs on each O and no additional electrons on boron or hydrogen (1)	<u>Example of diagram</u>  Non-bonding electrons on O can be shown as pairs, all 4 together or as 3 and 1 Electrons in overlap regions can be on the lines or the gaps between the lines Allow (1) for electrons in correct places but incorrect symbols for electrons Ignore inner shell electrons shown on B and/or O Note If any double bonds are shown the answer scores (0)	(2)

Question Number	Answer	Mark
7(b)(ii)	The only correct answer is C *A is incorrect because 109.5^o is incorrect* *B is incorrect because 109.5^o and 180^o are incorrect* *D is incorrect because 180^o is incorrect*	(1)

Question Number	Answer	Mark
7(c)	The only correct answer is B *A is incorrect because covalent bonds are within molecules not between molecules* *C is incorrect because there are no ionic bonds* *D is incorrect because London forces are not the strongest force*	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(d)(i)	- calculation of K_a (1) - calculation of $[H^+]$ (1) - calculation of pH (1)	Example of calculation $K_a = 10^{-pK_a} = 10^{-9.24} = 5.7544 \times 10^{-10}$ (mol dm^{-3}) $[H^+] = \sqrt{K_a[H_3BO_3]} = \sqrt{5.7544 \times 10^{-10} \times 0.05}$ $= 5.364 \times 10^{-6}$ (mol dm^{-3}) TE on K_a $pH = -\log_{10}[H^+] = -\log_{10}5.364 \times 10^{-6}$ $= 5.2705 / 5.271 / 5.27 / 5.3$ TE on $[H^+]$ provided pH is >2 and <7 Accept alternative methods, for example $[H^+] = \sqrt{K_a[H_3BO_3]}$ $pH = ½pK_a - ½\log[H_3BO_3]$ (1) $= ½9.24 - ½\log0.05$ (1) $= 5.2705 / 5.271 / 5.27 / 5.3$ (1) Alternative method: $K_a = 10^{-pK_a} = 10^{-9.24} = 5.7544 \times 10^{-10}$ (mol dm^{-3}) (1) $[H^+]^2 = K_a([H_3BO_3] - [H^+])$ $= 5.7544 \times 10^{-10} \times (0.05 - [H^+])$ $[H^+] = 5.135 \times 10^{-6}$ (1) pH = 5.29 (1) Ignore SF except 1SF Correct answer without working scores 3 marks	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(d)(ii)	An answer that makes reference to the following points:	Allow $[A^-]$ for $[H_2BO_3^-]$ / [HA] for $[H_3BO_3]$ Allow any of the expressions described in words Allow approximately equal to for = (in symbols or words) Ignore reference to standard conditions Do not award two marks from the same marking point	(2)
	• $[H^+] = [H_2BO_3^-]$ or no H^+ from the (ionisation of) water / ionisation of water is negligible or H^+ is only from the acid or no H^+ from ionisation of $H_2BO_3^-$ (1)	Allow the effect of the third ionisation is negligible	
	• ionisation / dissociation of the acid is negligible / very small / insignificant or $[H_3BO_3]_{initial} = [H_3BO_3]_{equilibrium}$ or $[H_3BO_3]_{equilibrium} = 0.05$ (mol dm^{-3}) or $[H^+]/[H_2BO_{3\_}] << [H_3BO_3]$ or $[H_3BO_3]$ / acid concentration remains constant or $[H_3BO_3]_{equilibrium} = [H_3BO_3]_{initial} - [H^+]$ used in calculation in (i) (1)	Ignore partial dissociation / not completely dissociated Do not award H_3BO_3 / [HA]is completely dissociated	

Question Number	Answer	Mark
7(e)	The only correct answer is B *A is not correct because it is the conjugate base not acid* *C is not correct because it is not the conjugate acid* *D is not correct because it is not the conjugate acid*	(1)

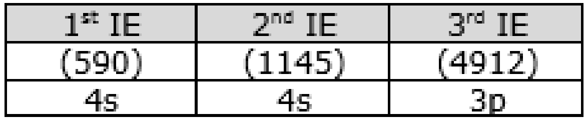
(Total for Question 7 = 11 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>8(a)(i)</td><td>

- any 2 correct (1)
- all 3 correct (2)

</td><td>

<u>Example of table</u>



<table>
<tr><th>1st IE</th><th>2nd IE</th><th>3rd IE</th></tr>
<tr><td>(590)</td><td>(1145)</td><td>(4912)</td></tr>
<tr><td>4s</td><td>4s</td><td>3p</td></tr>
</table>

Accept $3p_x$ / $3p_y$ / $3p_z$ for 3rd IE

Ignore any superscript numbers by 4s and 3p

Allow (1) for just 's, s, p' or 's, s, p' with one or more incorrect numbers in front

</td><td>(2)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>8(a)(ii)</td><td>

- correct equation

</td><td>

<u>Examples of equations</u>

$Ca^{2+}(g) \rightarrow Ca^{3+}(g) + e^{(-)}$

or

$Ca^{2+}(g) - e^{(-)} \rightarrow Ca^{3+}(g)$

Correct state symbols are required

Ignore any state symbol for the electron

</td><td>(1)</td></tr>
</table>

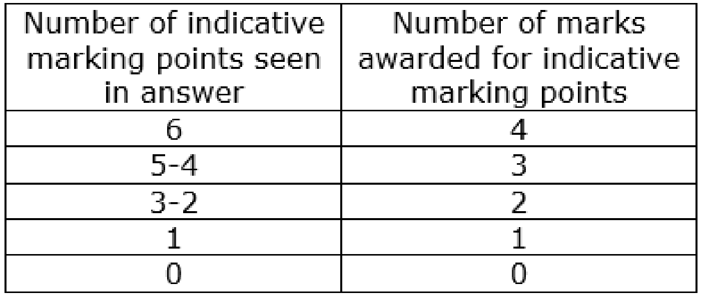
Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)(iii)	An explanation that makes reference to the following points: • (there is a much larger difference between the 2nd and 3rd ionisation energies because the) 3rd electron is lost from a shell / energy level / sub-shell / (3p) orbital closer to the nucleus or the 3rd electron is lost from a shell / energy level / sub-shell / (3p) orbital of lower energy (1) • (there is a smaller difference between the 1st and 2nd ionisation energies because the) 1st and 2nd electrons removed from the same shell / energy level / sub-level / orbital or the first two electrons experience similar shielding (from the inner electrons) or there is only a small change in electron-electron repulsion as the first two electrons are removed (1)	Ignore electron is lost from a full (sub-)shell / a full (sub-)shell is more stable Ignore just '3rd electron lost is more strongly attracted to the nucleus' Allow the same amount of shielding Allow the 3rd electron (to be lost) experiences less shielding (from inner electrons)	(2)

Question Number	Answer	Mark
8(b)	The only correct answer is B *A is incorrect because (−1031) + (79 + 520 + 159) is incorrect* *C is incorrect because (−1031) + (79 + 520) is incorrect* *D is incorrect because (−1031) + 79 +520 +159 − 616 is incorrect*	(1)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>8(c)*</td>
<td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

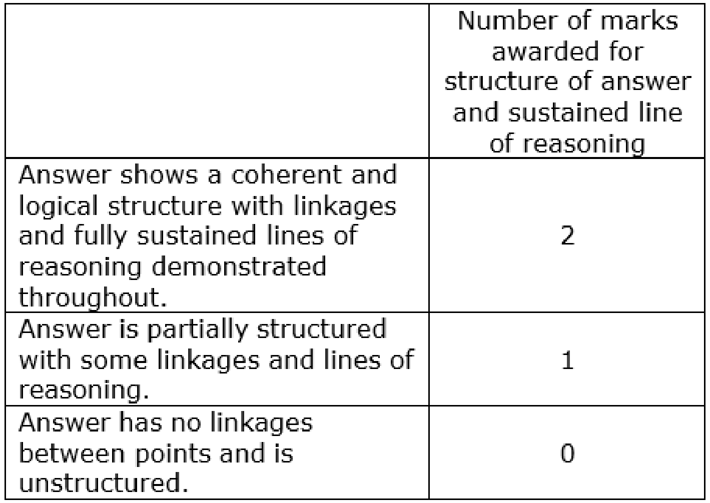
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.


<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</td>
<td>(6)</td>
</tr>
</table>



	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).
e.g.
penalise any reference to 'molecule' once only
or
penalise 'ion' not mentioned in word or formula at least once in answer, once only

Allow reverse arguments for IP3 to IP6 Ignore mention of stoichiometry Ignore references to electronegativity

	Indicative content		
	- IP1 - Ionic lithium chloride / LiCl (has very similar theoretical and experimental lattice energy values so) is (almost 100%) ionic	Allow very small amount of / no covalent character in LiCl Allow assumption that ions act as point charges / are spherical is true for LiCl	
	- IP2 - Covalency magnesium iodide / MgI_2 (has different theoretical and experimental lattice energy values so) has (some) covalent character	Allow MgI_2 more covalent character than LiCl	
	- IP3 - Charge on cations magnesium is Mg^{2+} and lithium is Li^+	Allow magnesium has 2+ charge and lithium has 1+ charge / magnesium ion has a larger charge than a lithium ion Allow charge density for charge	
	- IP4 - Polarising – what does the polarising magnesium ion/Mg^{2+} is (more) polarising / has a large(r) polarising power (than lithium ion)		
	- IP5 - Size of anion iodide ion / I^- is larger (than chloride ion / Cl^-)	Allow iodine ion / I^- is a large atom / has a large atomic radius Ignore size of cation Do not award iodide has a larger charge density	
	- IP6 – Polarisable – what is polarised iodide ion / I^- is (more easily) polarised / distorted	Allow this shown in a diagram Ignore just 'greater attraction to cation'	

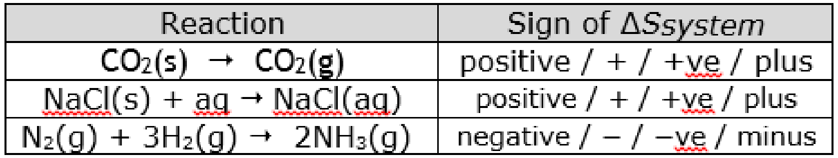
(Total for Question 8 = 12 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>9(a)</td><td>

- all 3 correct (2)
- any 2 correct (1)

</td><td>

<u>Example of table</u>



<table>
<tr><th>Reaction</th><th>Sign of Δ<i>Ssystem</i></th></tr>
<tr><td>$CO_2(s) \rightarrow CO_2(g)$</td><td>positive / + / +ve / plus</td></tr>
<tr><td>$NaCl(s) + aq \rightarrow NaCl(aq)$</td><td>positive / + / +ve / plus</td></tr>
<tr><td>$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$</td><td>negative / − / −ve / minus</td></tr>
</table>

</td><td>(2)</td></tr>
</table>

Question Number	Acceptable Answer	Additional Guidance	Mark
9(b)	• use of $\Delta S_{\text{surroundings}} = -\Delta H/T$ (1) • calculation of $\Delta S_{\text{surroundings}}$ (1) • calculation of ΔS_{total} and sign and units (1)	<u>Example of calculation</u> -(178000÷298) / -(178÷298) -597(.315) (J K^{-1} mol^{-1}) or -0.597(315) (kJ K^{-1} mol^{-1}) TE on equation with minus sign missing $\frac{160}{1000}$ + (-0.597315) = -0.437(315) kJ K^{-1} mol^{-1} or 160 + (-0.597315 x 1000) = -437.(315) J K^{-1} mol^{-1} TE on $\Delta S_{\text{surroundings}}$ Allow correct units shown once in answer for ΔS_{total} or $\Delta S_{\text{surroundings}}$ Ignore SF except 1SF Correct answer with sign and units without working scores 3 marks	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(c)(i)	• correct working (1) • correct answer and sign (1)	Example of calculation (2 x 95.6) − ((2 x 248.1) + 205.0) / (2 x 95.6) − (2 x 248.1) − 205.0 -510(.0) (J K^{-1} mol^{-1}) or -0.510 (kJ K^{-1} mol^{-1}) TE on working Ignore SF except 1SF Correct answer with sign and without working scores both marks	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(c)(ii)	• use of $\Delta G = \Delta H - T\Delta S_{\text{system}}$ (1)	Example of calculation The equation may be stated or numbers substituted directly e.g.−288.4 − (298 x −0.510) / −288400 − (298 x −510)	(3)
	• calculation of ΔG and sign and units (1)	−136(.42) kJ mol^{-1} / −136420 J mol^{-1} TE on ΔS_{system} in (i) Ignore SF except 1SF Correct answer with sign and units without working scores both marks	
	• ΔG is negative / less than 0 / <0 and so the reaction is feasible (1)	Conditional on a stated number TE on sign of ΔG: ΔG is positive / greater than 0 / >0 so the reaction is not feasible	

Question Number	Acceptable Answer	Additional Guidance	Mark
9(c)(iii)	- use of $\Delta G = -RT\ln K$ (1) - rearrangement of equation and substitution of correct values (1) - calculation of K (1)	<u>Example of calculation</u> $-60000 = -\ 8.31 \text{ x } 700 \ln K$ $(\ln K = -\Delta G/RT)$ $\ln K = \frac{-(-60000)}{(8.31 \text{ x } 700)}$ Allow $\ln K = \frac{60000}{8.31 \text{ x } 700}$ Allow ln*K* = 10.3146 / 10.315 / 10.32 / 10.3 / 10 TE on equation, provided equation involves all of Δ*G*, *K*, *R* and *T* and no others e.g. *S* $K = e^{10.315} = 3.016975\text{x } 10^4$ / 30169.75 TE on ln*K* expression / value Allow answers based on earlier correct rounding Ignore SF including 1SF Ignore units Correct answer without working scores 3 marks	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(c)(iv)	An explanation that makes reference to any two of the following points: • Yield - even though the (percentage) yield / amount of SO_3 is higher at 298 K / lower temperature (1) • Rate - the rate of reaction is slower at 298 K / lower temperature (1) • Compromise - so 700 K is a compromise between a (high) yield and (high) rate (1)	Allow reverse argument for M1 and M2 Ignore reference to changing the pressure Allow the unused reactants can be recycled to increase the yield / products are removed to increase the yield Allow the reaction does not reach equilibrium in industry so there is no effect on the yield Ignore just a reference to 'equilibrium shifting' Ignore references to activation energy Allow at 700K the amount of product per unit time is larger Ignore just '700 K is more economically viable' Note If three points are made related to yield, rate and compromise and one of these is incorrect, maximum mark is (1) for 1 correct point	(2)

(Total for Question 9 = 15 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(a)	- correct equation	Examples of equations $Cu + 4HNO_3 \rightarrow Cu^{2+} + 2NO_3^- + 2NO_2 + 2H_2O$ or $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$ Allow multiples Allow ⇌ provided equation is written in the direction shown Ignore state symbols, even if incorrect Ignore cancelled electrons Ignore Ag or Au on both sides	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(b)	- Indicator: starch (1) - Colour change: Starting colour: blue/black or blue or black Final colour: colourless (1)	M2 is conditional on starch or no indicator Ignore mention of precipitate Ignore other words to describe colour e.g. deep / dark Ignore clear	(2)

Question Number	Answer	Additional Guidance	Mark
10(c)	• calculation of moles of silver chloride (1) • calculation of mass of silver (1) • calculation of moles of Cu^{2+} (1) • calculation of mass of copper (1) • calculation of percentage of gold (1)	Example of calculation moles AgCl = 0.706/(107.9 + 35.5) = 0.00492329 / 4.92329 x 10^{-3} mass Ag = 0.00492329 x 107.9 = 0.531223 (g) moles S_2O $^{2-}$ or moles Cu^{2+} = 39.40 x 0.100 / 1000 = 0.00394 / 3.94 x 10^{-3} mass Cu = 0.00394 x 63.5 = 0.25019 (g) mass Au = 1.250 − (0.531223 + 0.25019) = 0.468587 (g) percentage of gold = 0.468587/1.250 x 100 = 37.5 (%) or percentage of silver = 0.531223/1.250 x 100 = 42.4978 / 42.5 (%) percentage of copper = 0.25019/1.250 x 100 = 20.0151 / 20 (%) percentage of gold = 100 − (42.5 + 20) = 37.5 (%) Allow TE for each step Allow final answer based on correct rounding at each stage (36.3 to 37.9%) Ignore SF except 1 SF in final answer Correct answer without working scores (5) Continued on next page	(6)

	- deduction that alloy is 9 carat gold (1)	Conditional on some correct working to show the percentage of gold If calculated % is not 37.5, allow: calculated value of carat (24 x their percentage/100) or 'less than 9 carat gold' if calculated % is less than 37.5% or nearest carat value from table or a (rough) interpolated carat value or between the two relevant carat values	

(Total for Question 10 = 9 marks)

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Write your name here

Surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐

Candidate Number ☐☐☐☐

Chemistry

Advanced

Paper 2: Advanced Organic and Physical Chemistry

Tuesday 12 June 2018 – Afternoon
Time: 1 hour 45 minutes

Paper Reference
9CH0/02

Candidates must have: Data Booklet
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an asterisk (*****), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

P52293A

5/4/5/5/2/1/

P 5 2 2 9 3 A 0 1 2 4

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

1 This question is about alkanes.

(a) The reaction of ethane and chlorine in UV radiation produces chloroethane.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

This reaction is classified as

(1)

☒ **A** addition

☒ **B** elimination

☒ **C** initiation

☒ **D** substitution

(b) The black smoke produced from the incomplete combustion of alkane fuels is

(1)

☒ **A** carbon particulates

☒ **B** oxides of nitrogen

☒ **C** oxides of sulfur

☒ **D** unburnt hydrocarbons

(c) A reaction of hexane is shown below.

This is **best** described as

(1)

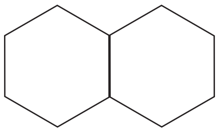
☒ **A** elimination

☒ **B** hydrogenation

☒ **C** isomerisation

☒ **D** reforming

(d) The skeletal formula of decalin is



The molecular formula of decalin is

(1)

☒ **A** $C_{10}H_{22}$

☒ **B** $C_{10}H_{20}$

☒ **C** $C_{10}H_{18}$

☒ **D** $C_{10}H_{16}$

(Total for Question 1 = 4 marks)

2 This question is about how catalysts work.

(a) Gaseous reactants attach to the catalytic surface by the process of

(1)

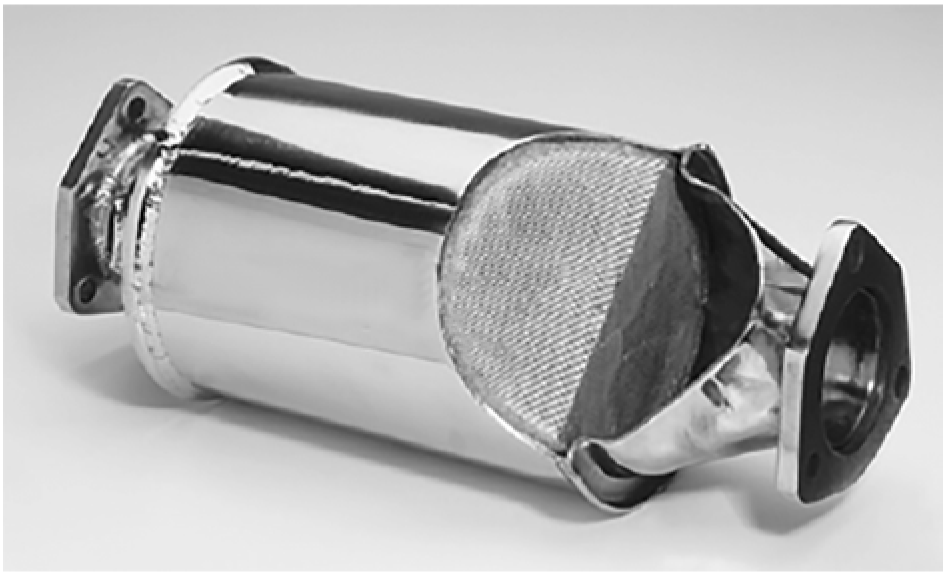
☒ **A** absorption

☒ **B** activation

☒ **C** adsorption

☒ **D** desorption

(b) Catalytic converters of car exhaust systems have internal honeycomb structures as shown.



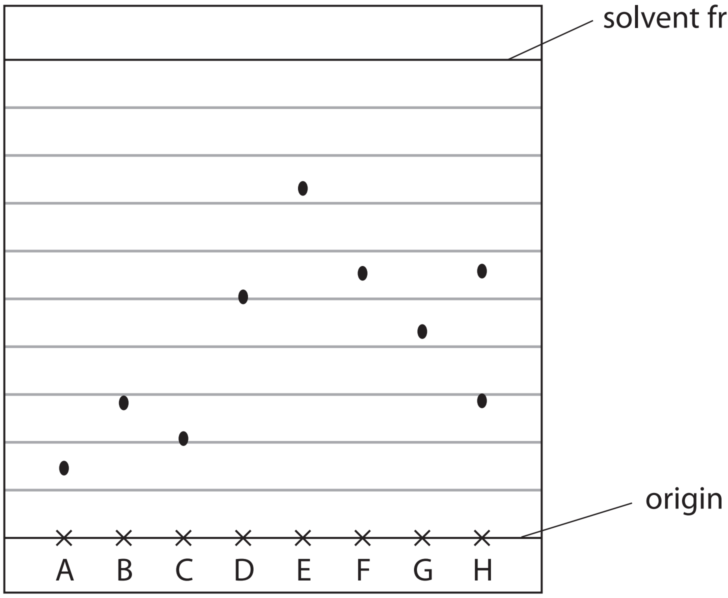
Explain why the honeycomb structure is used in a car exhaust system.

(2)

(Total for Question 2 = 3 marks)

3 Chromatography is a technique used to separate the components of a mixture.

(a) A sample of a tripeptide was hydrolysed and then placed on a thin layer chromatography (TLC) plate. Samples of possible amino acids present were also placed on the TLC plate for reference.
A simplified diagram of the developed TLC plate is shown.



A – Lysine	B – Serine	C – Histidine	D – Tyrosine
E – Isoleucine	F – Methionine	G – Proline	H – Hydrolysed tripeptide

(i) Calculate the R_f value for the amino acid lysine.
Give your answer to an appropriate number of significant figures.

(1)

(ii) Identify by **name** the two amino acids present in the tripeptide, giving a reason for the lack of a third spot.

(3)

....

....

....

....

....

....

(iii) Give **two** reasons why different amino acids have different R_f values.

(2)

(iv) In chromatography, a 'locating' reagent is often used when the components in a mixture are colourless.

Which reagent is used to locate the amino acid spots?

(1)

☒ **A** iodine

☒ **B** methyl orange

☒ **C** ninhydrin

☒ **D** phenolphthalein

(b) Gas chromatography can be used both to separate the components in a mixture and to determine the amount of each present.

(i) State why argon and nitrogen are suitable carrier gases for gas chromatography.

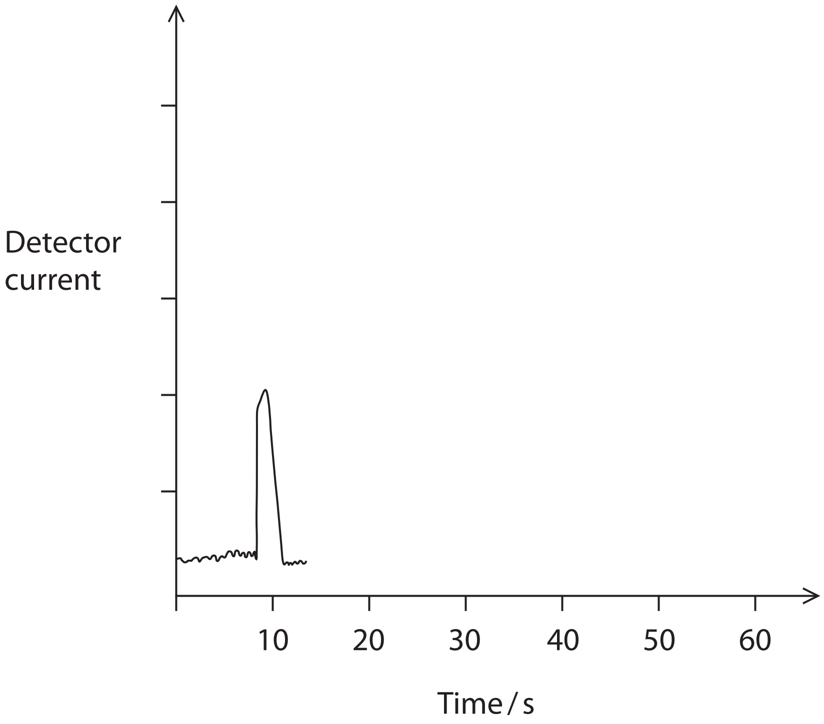
(1)

(ii) A mixture containing one part substance **X**, two parts substance **Y** and one part substance **Z** was separated by gas chromatography.

Substance **X** has a retention time of 10 seconds, substance **Y** of 15 seconds and substance **Z** of 40 seconds.

Complete the sketch of this chromatogram.

(3)



(Total for Question 3 = 11 marks)

4 Many vehicles are fitted with airbags which provide a gas-filled safety cushion to protect the occupant of the vehicle if there is a crash.

(a) The first reaction in airbags is the thermal decomposition of sodium azide, NaN_3, to form sodium and nitrogen gas.

(i) Write the equation for this decomposition of sodium azide.
State symbols are not required.

(1)

(ii) In the reaction in (a)(i), a typical airbag is inflated by about 67 dm^3 of gas. Calculate the **minimum mass** of sodium azide, in grams, needed to produce this volume of gas. Use the Ideal Gas Equation and give your answer to an appropriate number of significant figures.

For the purpose of this calculation, assume that the temperature is 300 °C and the pressure is 140 000 Pa.

(4)

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$\ldots\ldots Na + \ldots\ldots KNO_3 \rightarrow \ldots\ldots K_2O + \ldots\ldots Na_2O + \ldots\ldots N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

(3)

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(c) The third reaction in the airbag is between the metal oxides and silicon dioxide.

State the type of reaction taking place and justify why this reaction is necessary.

(3)

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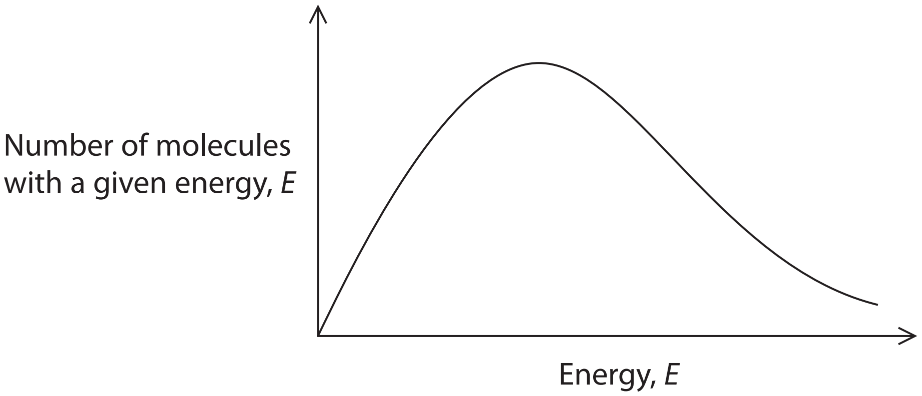
(d) The Maxwell-Boltzmann distribution diagram shows the molecular energies for the gaseous system immediately after the airbag has been deployed.



What is the change in shape of the curve when the airbag **cools**?

(1)

☒ **A** the peak would shift to the left and be higher

☒ **B** the peak would shift to the left and be lower

☒ **C** the peak would shift to the right and be higher

☒ **D** the peak would shift to the right and be lower

(Total for Question 4 = 12 marks)

5 Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

(a) Balance the ionic half-equation for the reduction of the dichromate(VI) ion. Give the colours of all of the species involved, or state colourless if appropriate.

(2)

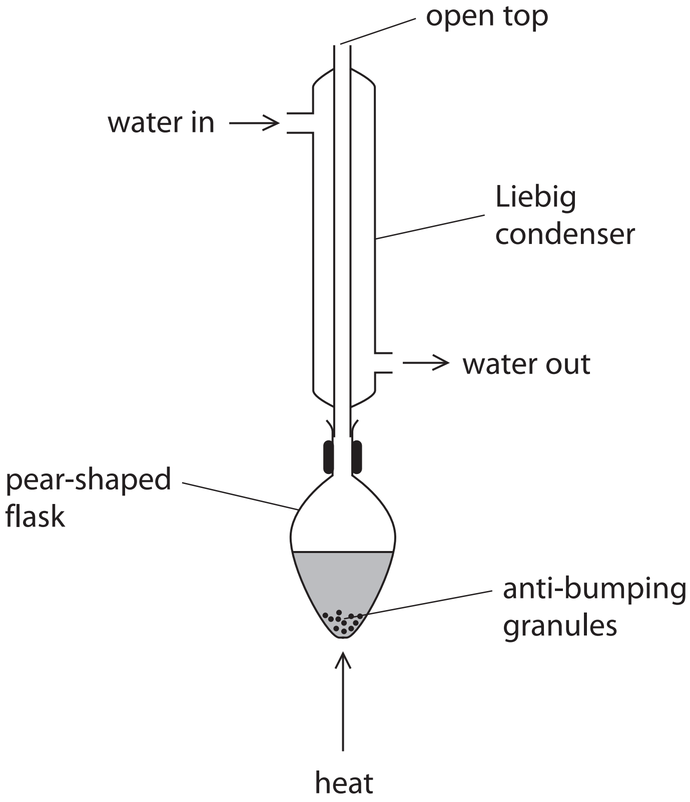
$$Cr_2O_7^{2-} \quad + \quad ....H^+ \quad + \quad ....e^- \quad \rightarrow \quad ....Cr^{3+} \quad + \quad ....H_2O$$

Colour ....

(b) Reflux apparatus can be used to carry out the oxidation of alcohols.

(i) This Liebig condenser has been set up incorrectly. Add shading to the diagram to show the water in the condenser, illustrating the effect of the incorrect water flow.

(1)



(ii) State how the granules prevent bumping.

(1)

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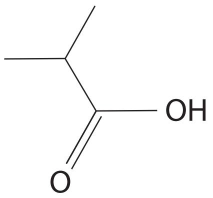
(c) The carboxylic acid shown can be produced by oxidation of an alcohol under reflux.



Which alcohol would be oxidised under reflux to produce this carboxylic acid?

(1)

☒ **A** 1,1-dimethylethanol

☒ **B** 2-methylpropan-1-ol

☒ **C** 2-methylbutan-1-ol

☒ **D** propan-2-ol

(d) Using the apparatus for distillation instead of reflux is not an efficient way to produce ethanoic acid from ethanol. Explain why.

(2)

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(Total for Question 5 = 7 marks)

6 This is a question about the hydrolysis of halogenoalkanes.

(a) Devise an experiment, giving outline details only, that would enable the relative rates of hydrolysis of halogenoalkanes to be compared.

(5)

(b) Explain the trend in the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

(2)

(c) The product of the hydrolysis of 2-bromobutane is butan-2-ol. Both molecules are chiral.

State what is meant by the term chiral, using three-dimensional diagrams of the enantiomers of butan-2-ol to illustrate your answer.

(3)

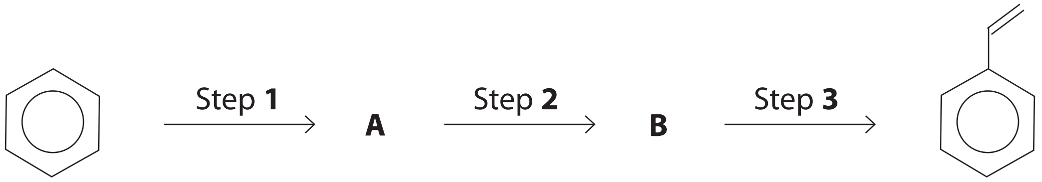
*(d) Compare and contrast the mechanism of hydrolysis, using aqueous potassium hydroxide, of the primary halogenoalkane, RCH_2X, with that of the tertiary halogenoalkane, R_3CX. Include diagrams of any intermediate or transition state.

Curly arrows are not required.

(6)

(Total for Question 6 = 16 marks)

7 Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.



(a) Some of the following compounds can be used to make phenylethene from benzene.

Aluminium chloride	Chloroethane	Ethanal	Ethanol
Ethanoic acid	Ethanoyl chloride	Ethene	Ether
Hydrochloric acid, concentrated	Lithium tetrahydridoaluminate(III)	Phosphoric acid, concentrated	Sulfuric acid, concentrated

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step.

(5)

(b) Which reagent could produce a diol from phenylethene?

(1)

☒ **A** acidified potassium dichromate(VI)

☒ **B** acidified potassium manganate(VII)

☒ **C** aqueous sodium hydroxide

☒ **D** steam

(c) Draw a section of the polymer, polystyrene, showing **two** repeat units.

(1)

(d) Give one advantage and one disadvantage of the disposal of polystyrene by incineration.

(2)

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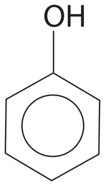
(e) Calculate the percentage by mass of carbon in phenylethene, giving your answer to an appropriate number of significant figures.

(2)

(Total for Question 7 = 11 marks)

8 Phenol is a feedstock in the production of many organic molecules.



(a) Phenol reacts with bromine water.

(i) Complete the equation for the reaction of phenol with excess bromine water, using the **skeletal** formula of the organic product.

(2)

(ii) Compare and contrast the bromination of phenol with the bromination of benzene.

(3)

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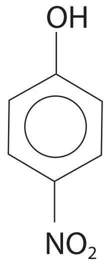
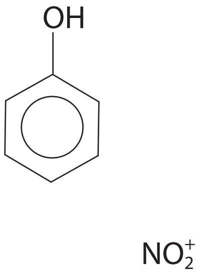
(b) Phenol can be nitrated to produce 4-nitrophenol.



(i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, NO_2^+, and phenol to produce 4-nitrophenol.

(3)



(ii) What is the mass, in grams, of 4-nitrophenol produced from 0.94 g of phenol if the yield of this isomer is 15%?

(1)

☒ **A** 0.14

☒ **B** 0.21

☒ **C** 0.68

☒ **D** 1.39

(iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

(1)

(Total for Question 8 = 10 marks)

9 This question is about the reaction kinetics of an 'iodine clock' reaction.

One example of an 'iodine clock' reaction that involves the iodate(V) ions and iodide ions in acidic solution is

$$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

(a) State why the order of reaction with respect to iodide ions cannot be five, even though 5 mol of iodide ions are shown in the equation.

(1)

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(b) A series of experiments was carried out by a student to determine the order of reaction with respect to iodate(V) ions. The concentrations of the iodide ions and the acid were in large excess and the volume of the iodate(V) solution was varied.
The total volume of the reaction mixture was kept constant by the addition of suitable volumes of deionised water.
The following results were obtained:

Experiment Number	1	2	3	4	5	6
Volume of iodate(V) solution / cm^3	10.0	7.0	5.0	3.0	2.0	1.0
Time (t) / s	180	260	357	606	900	800
(1000/t) / s^{-1}	5.56				1.11	1.25

(i) In experiment 6, the student forgot to add deionised water to keep the total volume the same for each experiment.
State why the total volume should be kept the same.

(1)

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....

(ii) Complete the table and use the results from experiments 1, 2, 3, 4 and 5 to plot a graph of 1000/t against volume of iodate(V) ions.

(4)

(iii) Deduce the order of reaction with respect to the iodate(V) ions. Justify your answer.

(2)

(c) A different version of the 'iodine clock' reaction involves mixing hydrogen peroxide with aqueous solutions of potassium iodide, sodium thiosulfate and starch.

The main reaction is

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

The reaction is first order with respect to hydrogen peroxide and iodide ions but zero order with respect to hydrogen ions.

(i) In one experiment, the following data were obtained:

Reactants	Initial concentration / mol dm^{-3}
$H_2O_2(aq)$	1.50×10^{-3}
$I^-(aq)$	2.10×10^{-3}
$H^+(aq)$	2.10×10^{-3}

Initial rate = 1.24×10^{-3} mol dm^{-3} s^{-1}

Write the rate equation and hence deduce the value of the rate constant, *k*, from these data. Include units and give your answer to an appropriate number of significant figures.

(2)

(ii) Explain the purpose of the starch present in the reaction mixture when starch is neither in the rate equation, nor in the reaction equation.

(2)

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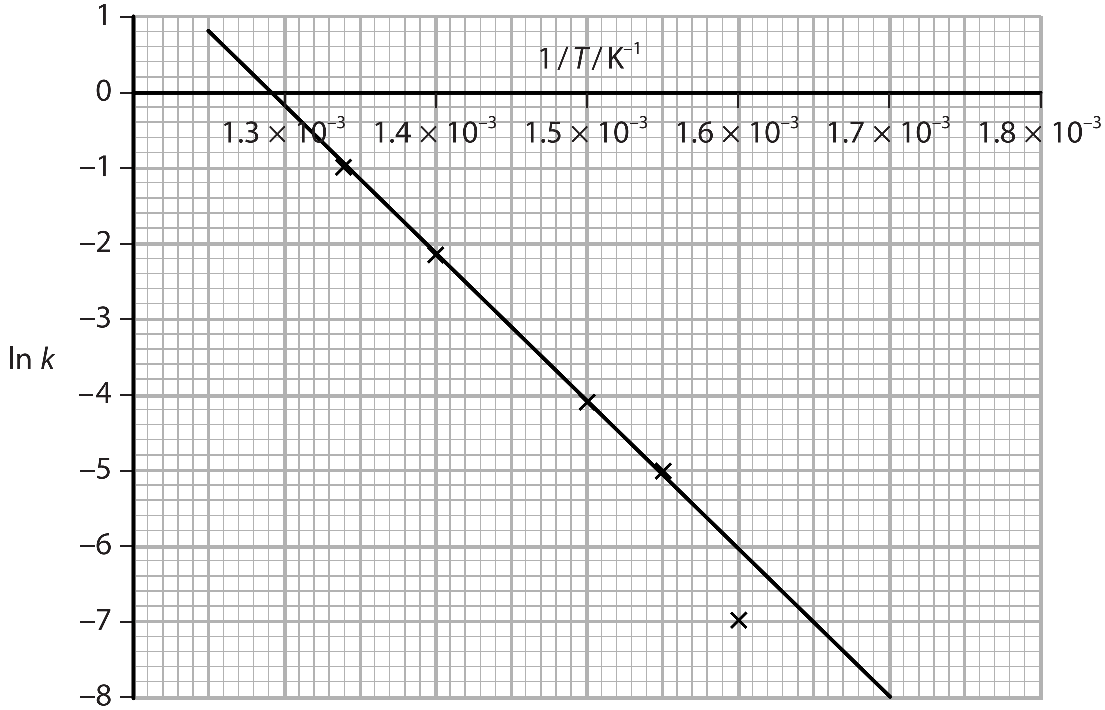
(d) Another 'iodine clock' reaction produced data that enabled the following graph of ln *k* against 1/*T* to be drawn.



(i) The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \left[\frac{1}{T}\right] + \text{constant}$$

From the gradient of the graph, determine the activation energy, E_a, for this reaction.

Include a sign and units in your answer.

(3)

(ii) Give a reason for the point at ln *k* = −7 **not** being included in the line drawn on the graph.

(1)

....

....

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

Summer 2018

Pearson Edexcel GCE Chemistry
In Chemistry (9CH0) Paper 02
Advanced Organic Physical Chemistry

Summer 2018
Publications Code 9CH0_02_1806_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate’s response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate’s response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

he mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Acceptable Answer	Mark
1(a)	The only correct answer is D *A is incorrect because it is not an addition reaction* *B is incorrect because no multiple bond is formed* *C is incorrect because initiation is only the first stage in the mechanism of the reaction*	(1)

Question Number	Acceptable Answer	Mark
1(b)	The only correct answer is A *B is incorrect because oxides of nitrogen are not black solids* *C is incorrect because oxides of sulfur are not black* *D is incorrect because unburnt hydrocarbons are not black solids*	(1)

Question Number	Acceptable Answer	Mark
1(c)	The only correct answer is D *A is incorrect because no alkenes are produced* *B is incorrect because hydrogen is formed* *C is incorrect because the molecular formulae of the organic compounds are not the same*	(1)

Question Number	Acceptable Answer	Mark
1(d)	The only correct answer is C *A is incorrect because* there are not 22 hydrogen atoms *B is incorrect because* there are not 20 hydrogen atoms *D is incorrect because* there are not 16 hydrogen atoms	(1)

(Total for Question 1 = 4 marks)

Question Number	Acceptable Answer	Mark
2(a)	The only correct answer is C *A is incorrect because gaseous reactants attach only to the surface* *B is incorrect because this happens after adsorption* *D is incorrect because this is detachment of the products from the surface*	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
2(b)	An explanation that makes reference to the following:		(2)
	• increase surface (area) / more active sites (1)	Do not award aBsorption Ignore reference to rate of reaction / remove pollutants	
	• (honeycomb structure) allows gases to flow through (the exhaust) (1)	Do not award if comments are made that refer to the structure acting like a filter for the particulates or other substances	

(Total for Question 2 = 3 marks)

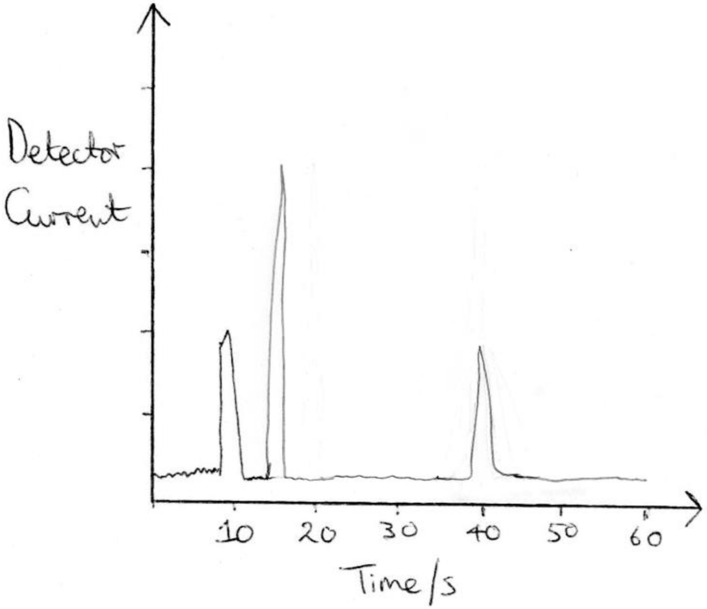
Question Number	Acceptable Answer	Additional guidance	Mark
3(a)(i)	- Answer to 2 SF	<u>Example of calculation:</u> R_f= $\frac{1.5}{10} = 0.15$ Allow 0.14 – 0.16 Do not award 3SF, e.g. 0.140/0.150/0.160 Do not award an answer with units	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
3(a)(ii)	An answer that makes reference to the following: - serine (1) - methionine (1) - (reason) one amino acid is present twice (in the tripeptide) OR Another amino acid has the same R_f value as either serine or methionine (1)	Allow for 1 mark out of the first two for F and B Allow 'there are two serine amino acids/ there are two methionine amino acids' Do not award if given with any other amino acid stated in the question Ignore reference to another amino acid not given in the table	(3)

Question Number	Acceptable Answer	Additional guidance	Mark
3(a)(iii)	An answer that makes reference to the following: • amino acids have different solubility / adsorption to the stationary phase (1) • amino acids have different solubility in the mobile phase (1)	Allow reverse arguments Do not award react with the stationary phase Allow "TLC plate" for stationary phase Allow interact with/affinity for/form different intermolecular forces with the stationary or mobile phase Allow "solvent" for mobile phase Ignore references to molecular mass/size	(2)

Question Number	Answer	Mark
3(a)(iv)	The only correct answer is C *A is incorrect because* this is a test for starch *B is incorrect because* this is a strong acid-weak base indicator *D is incorrect because* this is a weak acid-strong base indicator	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
3(b)(i)	A statement that makes reference to • gases are inert / do not react (with the components of the mixture)	Ignore references to intermolecular bonding / stability Do not award for not an oxidising agent	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
3(b)(ii)	A sketch that includes • peak at 15 seconds and 40 seconds (1) • (peak at 15 seconds) with height at approximately twice that of the peak at 10 seconds (1) • (peak at 40 seconds with) height at approximately the same height as that of the peak at 10 seconds (1) Exemplar sketch 	Penalise additional peaks Max 1 for the differences in height if both peaks are not at correct positions	(3)

(Total for Question 3 = 11 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
4(a)(i)	correct equation	<u>Example of equation</u>: $2NaN_3 \rightarrow 2Na + 3N_2$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
4(a)(ii)	• conversion of volume and temperature to correct units (1) • rearrangement of ideal gas equation so n=*pV* ÷ *RT* and calculation of $n(N_2)$ in moles (1) • evaluation of $n(NaN_3)$ (1) • answer converted into mass to 2/3 SF (1) Allow TE at each stage	<u>Example of calculation</u>: 67 dm^3 = 0.067 m^3, 300°C = 573 K $n(N_2) = \frac{140\ 000 \times 0.067}{8.31 \times 573} =$ = 1.9699…..(mol) $n(NaN_3)$ = (2/3 x 1.9699…..=) 1.313…. (mol) m= (1.313 …. x 65 = 85.3629..=) = 85.4 / 85 (g) Correct answer without working scores (4)	(4)

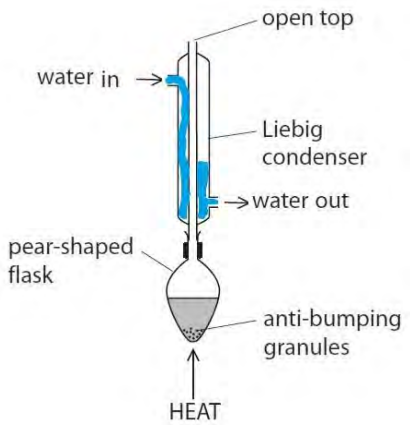
Question Number	Acceptable Answer	Additional guidance	Mark
4(b)	An answer that makes reference to the following points: • Nitrogen (is reduced) from +5 to 0 (1) • Sodium (is oxidised) from 0 to +1 (1) • Balanced equation (1)	Look for oxidation numbers annotated on the equation Do not award potassium oxidised Penalise omission of "+" sign, once only Example of balanced equation: $10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$ Allow multiples	(3)

Question Number	Acceptable Answer	Additional guidance	Mark
4(c)	An answer that makes reference to the following points: • Neutralisation reaction / acid base reaction (1) • Sodium and/or potassium oxides are caustic / corrosive (1) • Salts (silicates) formed are inert / unreactive (1)	Allow salt formation Allow "metal oxides" Ignore "harmful" / "alkaline" Allow "not harmful"/ "not caustic" Ignore "neutral"	(3)

Question Number	Acceptable Answer	Mark
4(d)	The only correct answer is A *B is incorrect because the peak would shift to the left and be higher* *C is incorrect because the peak would shift to the left not to the right* *D is incorrect because the peak would be shift to the left not to the right*	(1)

(Total for Question 4 = 12 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
5(a)	• Balanced equation (1) • Appropriate colours (1)	Example of equation: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow \mathbf{2}Cr^{3+} + 7H_2O$ Allow multiples Orange colourless green colourless Allow 'No colour' for colourless Do not award 'blue' for 'green' Do not award 'clear' for colourless Do not award if any spaces left blank Ignore any colour given for electrons Ignore any shades of colour	(2)

Question Number	Acceptable Answer	Additional guidance	Mark
5(b)(i)	A diagram with any shading that is not 100%	An example of a suitable diagram:  Allow shaded area to show 'air pockets'	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
5(b)(ii)	An answer that makes reference to the following prevention of uncontrolled boiling by: • distributing the heat more evenly or • providing a surface for bubbles to form/allow smaller bubbles to form/provides nucleation sites for bubbles	Do not award provide surface area for reaction Ignore reference to mixing the reagents/provide smooth boiling	(1)

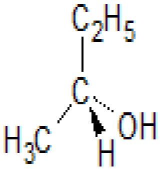
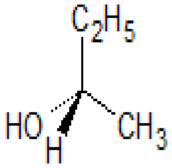
Question Number	Acceptable Answer	Mark
5(c)	The only correct answer is B *A is incorrect because not a systematic name* *C is incorrect because it has five carbons* *D is incorrect because it has only three carbons*	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
5(d)	An explanation that makes reference to the following • ethanol would be oxidised to ethanal (1) • because ethanal has a low boiling temperature or ethanal will distil before ethanoic acid can be formed (1)	Allow aldehyde for ethanal Allow ethanal will be formed Allow ethanal is (more) volatile Accept reverse argument in terms of reflux condensing ethanal for oxidation to ethanoic acid	(2)

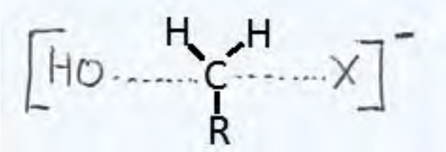
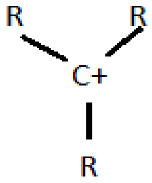
(Total for Question 5 = 7 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
6(a)	An answer that gives reference to the following - (M1) use of ethanol (as a solvent) (1) - (M2) use of silver nitrate (solution) (1) - (M3) equal amounts used of each halogenoalkane (1) - (M4) measure the time taken for precipitate to form (1) - (M5) use a water bath (to control a raised temperature) (1)	Allow "alcohol" Do not award ammoniacal silver nitrate Ignore use of nitric acid Allow equal volumes/equal stated volumes Allow "time for cross to disappear" Do not award for a colour to form. M4 dependent on M2 or near miss. If hydroxide (ions) used for hydrolysis then measuring the reaction is too quick, so no M4. The solution would need to be acidified before the addition of silver nitrate if M2 is to be awarded. If hydrochloric acid is used, then only M1, M3 and M5 can be scored	(5)

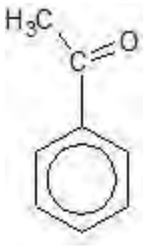
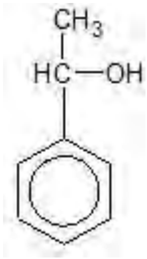
Question Number	Acceptable Answer	Additional guidance	Mark
6(b)	An explanation that makes reference to the following • the reaction rate is in the order 1-chlorobutane<1-bromobutane<1-iodobutane (1) • because the C-Cl bond is stronger than the C-Br bond which is stronger than the C-I bond (1)	Accept reverse arguments Incorrect trend scores (0) Allow 'the C-Cl bond is the strongest' Ignore any reasoning given Do not award if reference is made to the bonding of the halide (ion)	(2)

Question Number	Acceptable Answer	Additional guidance	Mark
6(c)	 (1)  (1) Forms (two) isomers which are non-superimposable (1)	Diagram must be 3-dimensional, i.e. include 'wedges'. Allow Br instead of OH Ignore attachment of −OH, CH_3 and C_2H_5 groups Standalone mark Allow a chiral carbon has four different groups attached (so they are non-superimposable) Do not award has four different 'molecules' attached	(3)

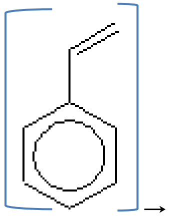
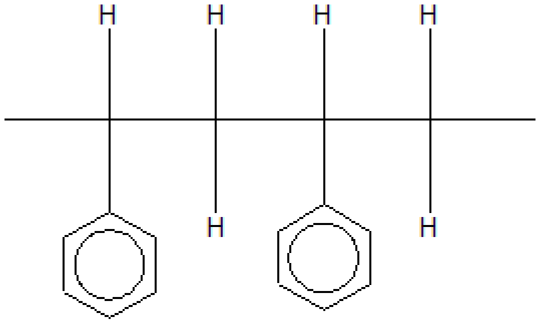
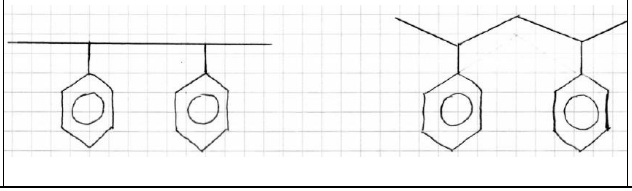
<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>6(d)</td>
<td>
<p>This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p>
<p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p>
<p>The following table shows how the marks should be awarded for indicative content.</p>
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
<p>The following table shows how the marks should be awarded for structure and lines of reasoning</p>
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>
<p>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).</p>
<p>In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</p>
<p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p>
</td>
<td>(6)</td>
</tr>
</table>

	Indicative content	More than one indicative marking point may be made within the same comment or explanation	
	• (similarity)(both) are nucleophilic substitution (1)	Words needed at least once provided S_N1 and S_N2 are given	
	• Hydrolysis mechanism for RCH_2X/primary is S_N2 via a transition state and R_3CX/tertiary is S_N1 via a carbocation/intermediate (1)		
	• RCH_2X and OH^- in the RDS (1)	Allow "both/two species in the RDS"	
	• R_3CX only in the RDS (1)	Allow correct rate equations for IP3 and IP4	
	• (RCH_2X forms a transition state with OH^-) diagram, including dotted lines and charge (1)	 Allow "-" either on the "OH" or the "X" Ignore point of attachment of OH Ignore dipoles within structure	
	• (R_3CX forms a carbocation / intermediate) diagram, including charge (1)	 Ignore shape Ignore references to comparative rates of reaction between 1° and 3° even if incorrect Ignore references to optical activity.	

(Total for Question 6 = 16 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following: synthetic pathway that consists of: (Step 1) • (acylation of benzene) using ethanoyl chloride (1) • use of aluminium chloride (and heat) (1) (Step 2) • (reduction of) A with $LiAlH_4$ in ether (dry) (1) (Step 3) • (dehydration of) B with (conc.) phosphoric acid/H_3PO_4 (1) (Intermediates) • identification of A as phenylethanone and B as (1-)phenylethanol   (1)	The compounds used can be stated or given within equations. Only award if part of a Friedel-Crafts reaction Only award if given to reduce an aromatic carbonyl or carboxylic acid Allow (conc.) sulfuric acid/ H_2SO_4 Only award if given to dehydrate an aromatic alcohol Accept formulae for names, but if both given, then both must be correct This also applies to reagents Do not award use of other reagents not in the table.	(5)

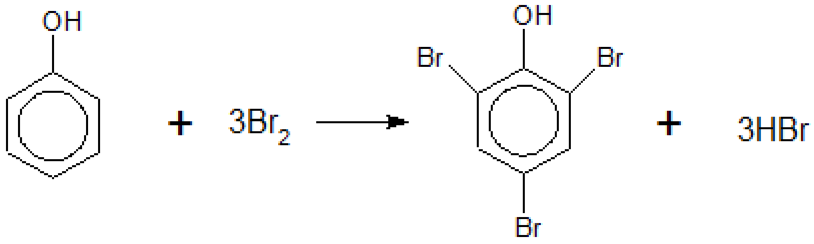
Question Number	Acceptable Answer	Mark
7(b)	The only correct answer is B *A is incorrect because this is an oxidising agent for alcohols not alkenes* *C is incorrect because this would not react* *D is incorrect because this would only produce an alcohol*	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(c)	 	Accept skeletal, structural or displayed formulae Accept any orientation of benzene ring Ignore brackets Ignore 'n' / '2n' / '$^{n}/_{2}$' Allow syndiotactic and atactic forms Allow more than two units, as long as all correct. Neither of these diagrams scores Both have missing CH$_2$ 	(1)

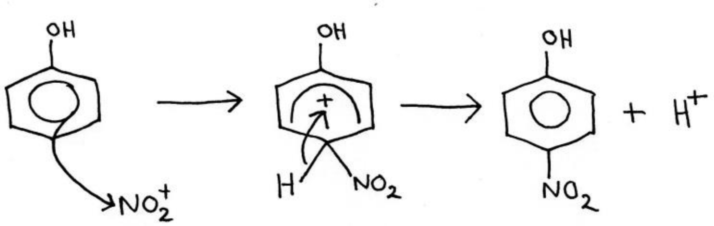
Question Number	Acceptable Answer	Additional Guidance	Mark
7(d)	An answer that makes reference to the following: An advantage • release of energy/avoids landfill (1) A disadvantage • release of toxic fumes (of polycyclic aromatics) (1)	Allow used to generate electricity Allow Release of benzene/carbon monoxide Release of carbon dioxide because of global warming / it's a greenhouse gas/ reduces recycling Release of carbon particulates increases respiratory problems Do not award damages the ozone layer Do not award references to acid rain Ignore just 'harmful' fumes	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(e)	• calculation of M_r of phenylethene (1) • answer converted into percentage to 2 or 3 SF (1)	<u>Example of calculation</u>: (M_r of phenylethene = 104 % = (96 ÷ 104 x 100 = 92.30769..%) =92 (%)/92.3 (%) Allow TE on incorrect M_r as long as answer not >100% Correct answer without working scores (2)	(2)

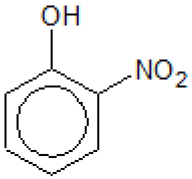
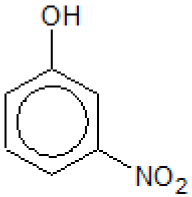
(Total for Question 7 = 11 marks)

Question Number		Additional Guidance	Mark
8(a)(i)	 • Structure of 2,4,6-tribromophenol (1) • Balanced equation (1)	Ignore state symbols even if incorrect Do not award $C_6H_3OBr_3$ M2 dependent on M1	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to the following: Similarity • Both electrophilic substitution (1) Any two from: Contrast • No need of a halogen carrier with phenol (1) • oxygen's lone pair of electrons interacts with the benzene ring of delocalised electrons so electrophilic attack more likely (1) • Tri-substitution of phenol compared to mono for benzene (1) • Bromination of phenol requires bromine in aqueous solution but benzene requires liquid bromine (1) • Bromination of phenol requires room temperature but benzene requires heating (under reflux) / reflux (1)	Ignore comments of ease of reaction Should be stated clearly as a similarity Accept reverse argument Allow Fe/$FeBr_3$/$AlBr_3$ with benzene Do not award just 'catalyst' Allow reference to OH group Allow 'bromine' for 'electrophilic' Do not award for nucleophilic attack Allow "multiple-" for "tri-"	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to • Electron pair movement from ring to electrophile (1) • Formula of intermediate ion (1) • Curly arrow from C-H bond to reform delocalised ring and correct final structure with H^+ also formed (1)	Allow arrow that starts from anywhere within the hexagon but it must go to the nitrogen of the ion 'Horseshoe' to cover at least three carbon atoms, facing the tetrahedral carbon and part of the + sign to be inside the 'horseshoe' Do not award '+' charge on the tetrahedral carbon Do not award dotted bonds unless part of a 3D structure Curly arrow to go from the bond to anywhere inside the ring Accept the drawing of HSO_4^- to remove the H from the ring as long as H_2SO_4 is given as the product instead of H^+ Exemplar mechanism  Do not penalise attachment of OH/NO_2 to benzene ring Penalise incorrect product: 1 mark	(3)

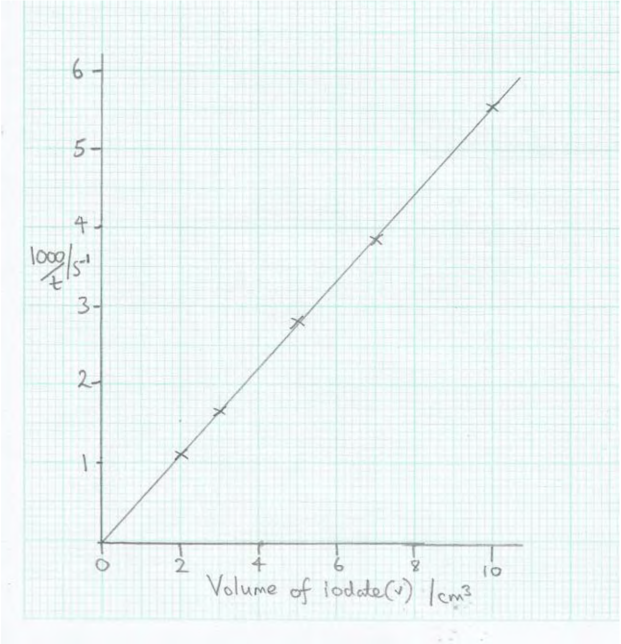
Question Number	Acceptable Answer	Mark
8(b)(ii)	The only correct answer is B *A is incorrect because this is 15% of the mass of the starting material* *C is incorrect because this is the percentage of the starting mass over the max mass of product* *D is incorrect because this is 100% yield and not 15%*	(1)

Question Number		Additional Guidance	Mark
8(b)(iii)	 and 	Ignore connectivity of OH/NO_2	(1)

(Total for Question 8 = 10 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(a)	A statement that makes reference to the following: • The chance of five or more ions colliding in the rate determining step is negligible	Allow 'at the same time' for the RDS	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(b)(i)	A statement that makes reference to the following: • So that the volume of iodate(V) ions is proportional to the concentration.	Allow the volume of iodate(V) ions can be used instead of the concentration in plotting the graph. Ignore reference to "fair tests".	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(b)(ii)	• calculation of all three 1000/t values (1) • axes: correct way round, labelled and including units (1) • suitable scale (1) • all points plotted correctly, with best-fit straight line through the origin (1)	(5.56) 3.85, 2.80, 1.65, (1.11) Do not award 2.8 or ≥3SF Do not award use of T for t Plotted points must cover at least ½ the graph paper on each axis Allow ±½ square Ignore plotting of experiment 6 Exemplar graph  	(4)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(b)(iii)	An answer that makes reference to the following: • first order (with respect to iodate(V) ions) (1) • because straight line goes through the origin / rate is (directly) proportional to concentration (1)	Mark independently Allow "volume" for "concentration" Do not award references of proportionality to time Ignore references to half life	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(c)(i)	• value of rate constant to 2 or 3 SF (1) • units of rate constant (1)	<u>Example of calculation:</u> (Rate=$k[H_2O_2][I^-]$ so k= rate ÷ ($[H_2O_2][I^-]$) $=1.24\text{x}10^{-3} \div (1.50\text{x}10^{-3}\text{x}2.10\text{x}10^{-3})$ =393.65...) = 390/394 $dm^3\ mol^{-1}\ s^{-1}$ Accept units in any order No TE on incorrect rate equation	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(c)(ii)	An explanation that makes reference to • starch is an indicator (to react with the iodine) (1) • the time taken for the formation of the blue-black complex (can be used to calculate the reaction rate) (1)	Do not award references to iodide/I^- Allow Reacts with iodine/produces a blue-black colour when the reaction is complete. Allow Changes colour when all the thiosulfate is used up. Allow indication of 'time taken'	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(d)(i)	• calculation of gradient of straight line (1) • numerical value of E_a (1) • sign and units (1)	Example of calculation Gradient = −19500 Allow ±500 $-E_a$ = −19500 x 8.31 / 1000 = 162 ± 5 + and kJ mol^{-1} Accept +162000 $Jmol^{-1}$ Final answer with or without working scores (3) Allow TE for incorrect gradient as long as the final value is not negative Ignore SF except 1SF	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(d)(ii)	An answer that makes reference to the following: • (Reason) anomalous point	Allow description of Allow 'outlier'	(1)

(Total for Question 9 = 16 marks)

Write your name here

Surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number	Candidate Number

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Wednesday 20 June 2018 – Morning
Time: 2 hours 30 minutes

Paper Reference
9CH0/03

Candidates must have: Data Booklet
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

P52304A

5/1/1/1/

P 5 2 3 0 4 A 0 1 3 2

Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about some halogens and their compounds.

(a) The intermolecular attractions between halogen molecules are London forces.

(i) Describe how London forces form between halogen molecules.

(3)

(ii) The boiling temperatures of chlorine and bromine are shown in the table.

Halogen	Boiling temperature / °C
chlorine	–34
bromine	59

Explain why bromine has a higher boiling temperature than chlorine.

(2)

(b) A student carries out experiments to determine the order of reactivity of three halogens: bromine, chlorine and iodine.
The student is provided with aqueous solutions of the following five substances:

- bromine
- iodine
- potassium chloride
- potassium bromide
- potassium iodide.

The student has **no** access to chlorine gas or chlorine water.
The student uses cyclohexane, an organic solvent, to identify the halogen present at the end of each experiment.

The student carries out the **smallest** number of experiments required to determine the order of reactivity of the halogens.

Describe the experiments and the expected observations.

Include in your answer **ionic** equations for any reactions that occur.

State symbols are **not** required.

(5)

(Total for Question 1 = 10 marks)

2 This question is about lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$.
Lactic acid is used to make biodegradable polymers.

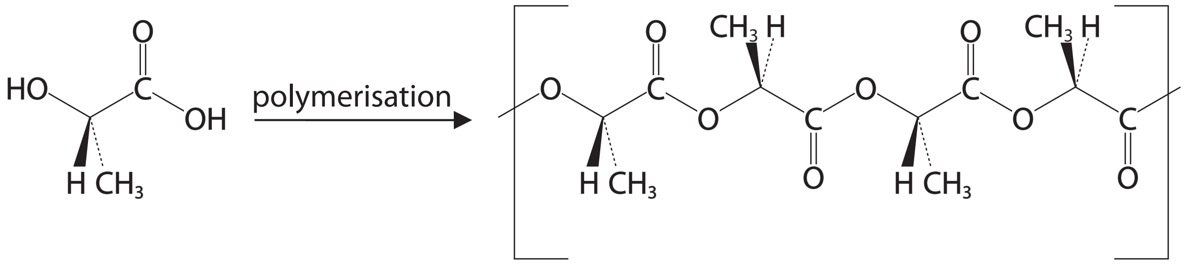
(a) Lactic acid can be made in a two-step synthesis starting from ethanal, CH_3CHO.

Devise a reaction scheme for a two-step synthesis.

Include in your answer all reagents and conditions, the type of reaction occurring at each step, and a balanced equation for each reaction.
State symbols are **not** required.

(7)

(b) Polymerisation of lactic acid forms poly(lactic acid) as shown in the diagram.



(i) State the type of polymerisation occurring in this reaction.

(1)

....

(ii) **On the diagram**, draw a circle around the repeat unit of the polymer.

(1)

(Total for Question 2 = 9 marks)

3 This question is about the identification of a Group 2 carbonate.

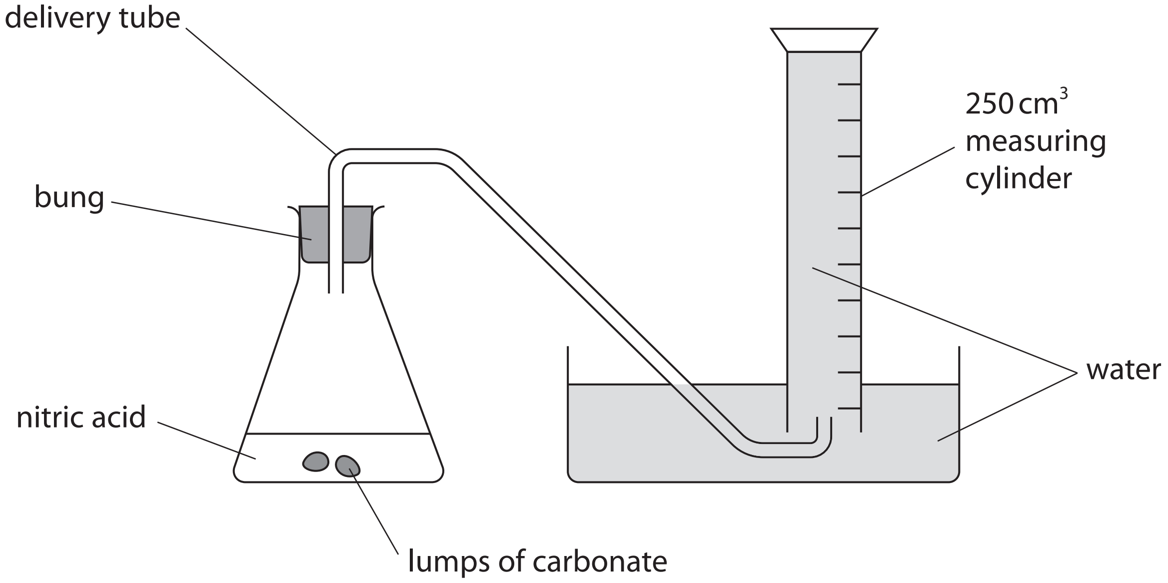
A chemistry teacher found a bottle containing lumps of a white solid. The original label was missing from the bottle. However, someone had written 'Group 2 carbonate' on the bottle. The lumps of the anhydrous white solid were pure and dry.

The chemistry teacher tried to identify the carbonate with the help of three students. The three students worked under identical conditions and shared the same weighing balance.

Student **1** recognised that if an acid is added to a carbonate, carbon dioxide is evolved. The student decided to measure the volume of carbon dioxide evolved when the Group 2 carbonate reacts with excess nitric acid.

The student knew that 1 mol of a Group 2 carbonate produces 1 mol of carbon dioxide.

Student **1** set up the apparatus shown below.



- Student **1** weighed out some of the Group 2 carbonate and added it to a 250 cm^3 conical flask.
- Student **1** then added 100 cm^3 of 0.200 mol dm^{-3} nitric acid to the conical flask and replaced the bung.
- Student **1** measured the volume of gas collected in the inverted measuring cylinder at room temperature and pressure (r.t.p.) when all the Group 2 carbonate had reacted.
- Student **1** obtained the results shown in Table 1.

Measurement		Value
Mass of weighing bottle and carbonate	/ g	13.247
Mass of empty weighing bottle	/ g	12.431
Mass of carbonate used	/ g	....
Volume of acid used	/ cm^3	100
Volume of gas collected	/ cm^3	225

Table 1

(a) Complete Table 1 to show the mass of the carbonate used.

(1)

(b) Calculate the amount, in moles, of carbon dioxide collected in the measuring cylinder at r.t.p.

(1)

(c) Calculate the molar mass of the Group 2 carbonate to an appropriate number of significant figures and hence deduce the identity of the Group 2 metal.

(4)

(d) Student **2** carried out the same experiment as Student **1**, using the same mass of the Group 2 carbonate.
Student **2** made no errors in their measurements or calculations but obtained a value for the molar mass which was 10 g mol^{-1} greater than the value obtained by Student **1**.

(i) Explain **one** procedural error which could have resulted in Student **2** obtaining a molar mass greater than that of Student **1**.

(2)

(ii) It was later discovered that Student **2** had used 110 cm^3 of 0.200 mol dm^{-3} dilute nitric acid, instead of 100 cm^3 of 0.200 mol dm^{-3} dilute nitric acid.

Give a reason why this mistake would **not** have affected Student **2**'s result.

No calculation is required.

(1)

(iii) The teacher noticed that Student **2** had used the Group 2 carbonate in powdered form rather than in lumps.
Explain how, if at all, this would affect the rate of reaction and the final volume of gas produced in the reaction.

(2)

(e) Student **3** suggested a different experiment.
Student **3** realised that, by heating the carbonate, carbon dioxide would be lost and an oxide would remain.
Student **3** decided to measure the change in mass of the carbonate and to use this information to calculate its molar mass.

- Student **3** weighed an empty test tube.
- Using a spatula, Student **3** added some of the carbonate to the test tube.
- The test tube containing the carbonate was then weighed.
- The test tube and its contents were heated to constant mass.
- The results obtained by Student **3** are shown in Table 2.

Measurement		Value
Mass of carbonate + test tube	/ g	20.447
Mass of oxide + test tube	/ g	20.205
Mass of empty test tube	/ g	19.996

Table 2

(i) Write an equation, including state symbols, for the thermal decomposition of a Group 2 carbonate, MCO_3, where M represents the metal.

(1)

(ii) Using Student **3**'s results, calculate the molar mass of the Group 2 carbonate.

(3)

(f) Student **3** used the same balance as Student **1**.

Give a reason why the mass of the carbonate measured by Student **3** has a greater percentage uncertainty than that measured by Student **1**.

(1)

(g) Student **3** noticed that on heating the test tube some solid was lost. Explain how this would affect the calculated value for the molar mass of the Group 2 carbonate.

(2)

(Total for Question 3 = 18 marks)

4 This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

(a) Tetramethylsilane (TMS) is a compound used as a standard when recording both ^1H and ^{13}C NMR spectra.

(i) Give the structural formula of TMS.

(1)

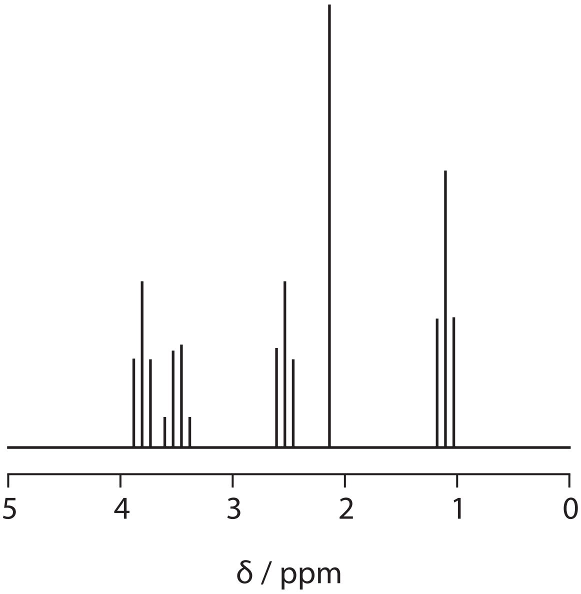
(ii) TMS is an inert and non-toxic compound. State **two** other reasons why TMS is suitable for use as a standard when recording NMR spectra.

(2)

(b) (i) Draw the structural formulae of the **two** esters with formula $C_6H_{12}O_2$ that each have only **two** peaks, both singlets, in their high resolution **proton** NMR spectra. The relative peak areas are 3:1 for both esters.

(2)

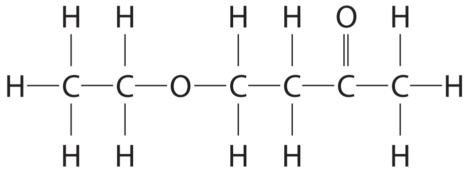
(ii) The high resolution **proton** NMR spectrum of another isomer of $C_6H_{12}O_2$ is shown.



The ratios of the number of protons for the five sets peaks in the spectrum are given in the table.

δ / ppm	3.8	3.5	2.6	2.2	1.2
Ratio of the number of protons	2	2	2	3	3

Show that **all** these data are consistent with the displayed formula shown. Refer to the five chemical shifts and explain **two** of the splitting patterns.



$CH_3CH_2OCH_2CH_2COCH_3$

(5)

(c) (i) There are three other isomers of $C_6H_{12}O_2$ which are carboxylic acids with **five** peaks in their **carbon-13** NMR spectra.

Draw the structural formula of **two** of these isomers.

(2)

(ii) Draw the **skeletal** formula of a cyclic diol isomer of $C_6H_{12}O_2$ that has only **two** peaks in its **carbon-13** NMR spectrum.

(1)

(Total for Question 4 = 13 marks)

5 This question is about the properties of transition elements, their ions and their complexes.

(a) Give the oxidation state of vanadium in the compound NH_4VO_3.

(1)

....

(b) Excess zinc powder is added to an acidified solution of the compound NH_4VO_3. Using the data in the table, explain the sequence of reactions that takes place.

In your answer, include a description of what you would **see**, and the relevant ionic equations with their calculated $E^\ominus_{cell}$ values. State symbols are not required.

(7)

Electrode system	$E^\ominus$ / V
$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$	−1.18
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	−0.26
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$VO_3^-(aq) + 4H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + 2H_2O(l)$	+1.00
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76

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(c) Explain how vanadium(V) oxide acts as a catalyst in one step of the contact process. The equation for this step is

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(2)

*(d) Describe the reactions of separate portions of aqueous copper(II) ions with aqueous sodium hydroxide solution, with excess aqueous ammonia solution and with concentrated hydrochloric acid.

In your answer you should link observations with equations which include the formulae of any copper-containing complex ions. Include state symbols.

(6)

(Total for Question 5 = 16 marks)

6 This question is about the analysis of an unknown carboxylic acid **X** by three students.

The students analyse the mass spectrum of **X** and find that it has a molecular ion peak at *m*/*z* = 116.

The three students each propose a different structural formula for compound **X**.

Structure 1 $HOOCCH{=}CHCOOH$

Structure 2 $HOCH_2CH{=}CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(a) The students are given the infrared spectrum of **X**.

(i) State **two** wavenumber ranges of the infrared absorptions providing evidence that compound **X** is a carboxylic acid. Include the bonds responsible.

(2)

(ii) One of the students suggests that this infrared spectrum and the data in the Data Booklet **alone** could be used to identify which of the three proposed structures is **X**.

Show that this student's suggestion is correct. Include relevant infrared data in your answer.

(3)

(b) The students decide to carry out an acid-base titration to obtain further information about compound **X**.
Each student uses solid sodium hydroxide, NaOH, to prepare a solution of concentration 0.140 mol dm^{-3}.

Calculate the mass, in grams, of solid sodium hydroxide that each student should weigh out to prepare 250.0 cm^{3} of a 0.140 mol dm^{-3} solution.

(2)

(c) Each of the students makes up 250.0 cm^3 of 0.140 mol dm^{-3} sodium hydroxide solution in a volumetric flask and titrates this solution with the same solution of **X** of known concentration.

Student A

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution and pipettes a volume of 10.0 cm^3 of the solution into a conical flask
- fills a burette with the solution of **X** and carries out a titration
- repeats the procedure until obtaining concordant results
- obtains a mean titre of 10.20 cm^3.

Student B

- dissolves the sodium hydroxide in distilled water and transfers the solution to a volumetric flask
- adds more distilled water to the volumetric flask and mixes the solution
- notices that the volumetric flask has been filled with distilled water several cm^3 beyond the graduation mark
- realises the mistake, removes the extra solution and discards it
- pipettes 10.0 cm^3 of the sodium hydroxide solution into a conical flask and titrates this with the solution of **X**.

Student C

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution
- washes a conical flask thoroughly with distilled water and pipettes 10.0 cm^3 of the sodium hydroxide solution into the wet conical flask
- titrates the contents of the conical flask with the solution of **X**.

(i) Explain how, if at all, Student **B**'s mistake affects the value of the titre.

(2)

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(ii) Explain how, if at all, Student **C**'s use of a wet conical flask affects the value of the titre.

(2)

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(iii) Student **A** uses three pieces of apparatus to measure volumes in this experiment.

- The burette has an uncertainty of ±0.05 cm^3 for each volume reading
- The volumetric flask has an uncertainty of ±0.30 cm^3 for the volume
- The pipette has an uncertainty of ±0.04 cm^3 for the volume

Show by calculation which volume measurement has the lowest percentage uncertainty.

(3)

(d) Student **A** calculates the correct value for the molar mass of compound **X**, using the mean titre of 10.20 cm^3. The results indicate that **X** has **structure 1**.

Structure 1 $HOOCCH{=}CHCOOH$

Structure 2 $HOCH_2CH{=}CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(i) Write the equation for the reaction between **structure 1** and sodium hydroxide solution. State symbols are not required.

(2)

(ii) Deduce the value that would have been obtained for the mean titre if the structural formula of **X** had been **structure 2**.
Justify your answer.

(2)

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(e) The students could have identified the three structures using chemical tests.

Complete the table to show whether or not the suggested structures react with bromine water and when heated with acidified potassium dichromate(VI).

Use a tick (✓) if a reaction occurs.

Use a cross (✗) if no reaction occurs.

(2)

Structure	Test with bromine water	Test with acidified potassium dichromate(VI)
$HOOCCH{=}CHCOOH$		
$HOCH_2CH{=}CHCH_2COOH$		
$CH_3CH_2CH_2CH_2CH_2COOH$		

(f) The structure HOOCCH═CHCOOH has two stereoisomers.

(i) Draw the structures of these stereoisomers.

(2)

***E*-isomer**

***Z*-isomer**

(ii) State why HOOCCH═CHCOOH has *E*/*Z* isomers.

(2)

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(Total for Question 6 = 24 marks)

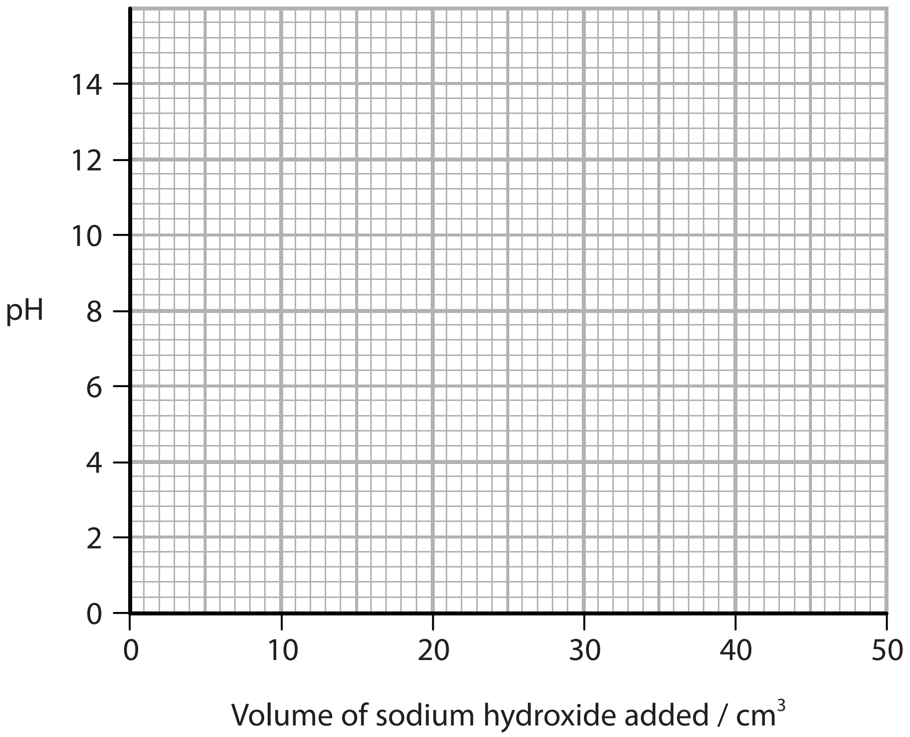
7 This question is about weak acids.

(a) A weak acid, HX, has a K_a value of 5.25×10^{-5} mol dm^{-3}. A solution was formed by mixing 10.5 cm^3 of 0.800 mol dm^{-3} dilute sodium hydroxide with 25.0 cm^3 of 0.920 mol dm^{-3} HX(aq).
Calculate the pH of the solution formed, showing all your working.

(5)

(b) (i) Propanoic acid, CH_3CH_2COOH, is a weak acid.
On the grid below, sketch the change in pH during the addition of 50.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide solution to 25.0 cm^3 of 0.100 mol dm^{-3} propanoic acid solution.

(4)



(ii) Explain how you would use the graph in (b)(i) to obtain the value of the acid dissociation constant, K_a, for propanoic acid.
You are **not** expected to calculate this value.

(2)

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(Total for Question 7 = 11 marks)

8 This question is about an experiment to determine the equilibrium constant, K_c, for an esterification reaction producing propyl ethanoate.
The equation for the reaction is

$$\underset{\text{ethanoic acid}}{CH_3COOH(l)} + \underset{\text{propan-1-ol}}{CH_3CH_2CH_2OH(l)} \rightleftharpoons \underset{\text{propyl ethanoate}}{CH_3COOCH_2CH_2CH_3(l)} + H_2O(l)$$

In an experiment to determine the equilibrium constant, K_c, the following steps were carried out.

- 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube. In this pre-equilibrium mixture, there is 0.111 mol of water
- The mixture was left for one week, at room temperature and pressure, to reach equilibrium
- The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
- 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3}, using phenolphthalein as the indicator
- The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

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(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)

(ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of $H^+(aq)$ ions. Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

(c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid. Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

(ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

Moles of propan-1-ol at equilibrium ....

Moles of propyl ethanoate at equilibrium ....

Moles of water at equilibrium ....

(d) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$

(1)

(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

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(iii) Calculate the value of K_c.
Give your answer to an appropriate number of significant figures.

(2)

(e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.
Give a possible explanation for this observation.

(2)

(f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

(2)

(g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l) \qquad \Delta_r H^\ominus = +21.4\,\text{kJ mol}^{-1}$$

Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

(2)

(Total for Question 8 = 19 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported
but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

Summer 2018

Pearson Edexcel GCE
In Chemistry (9CH0) Paper 03
General and Practical Principles in Chemistry

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Summer 2018
Publications Code 1806_9CH0_03_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in bold indicate that the meaning of the phrase or the actual word is essential to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(i)	An answer that makes reference to the following points: setting up of the dipole • uneven distribution of electrons / (random) movement of electrons / (random) fluctuations of electrons (1) type of dipole • (results in an) instantaneous dipole / temporary dipole (in the first molecule) (1) induction of a second dipole • causes/induces a (second) dipole on another molecule (1)	M1 & M3 could be scored for an appropriate diagram Allow "Change in electron density" Allow "transient dipole" / "oscillating dipole" Do not award for "permanent dipole" Allow neighbouring molecule / adjacent molecule Do not award for "permanent dipole"	(3)

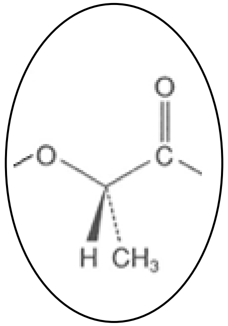
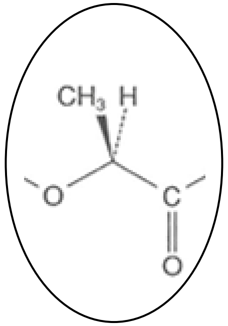
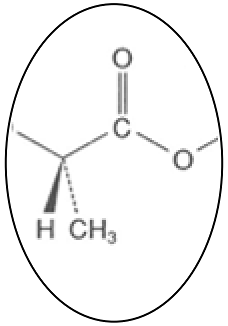
Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(ii)	An explanation that makes reference to the following points: relative number of electrons • bromine has more electrons (than chlorine) / bromine has one more shell of electrons (than chlorine) (1) relative strength of intermolecular forces • (so) bromine has stronger (London) forces (between molecules) / more (heat) energy is needed to overcome the London forces between bromine molecules / greater temporary dipole − induced dipole forces (1)	Allow reverse arguments Allow correct formulae Bromine has 35/70 electrons and chlorine has 17/34 electrons Ignore comments about protons, molecular mass etc Do not award "more outer shells" Ignore comments about 'points of contact' Allow more (London) forces Allow "bonds between molecules" Award (0) marks overall if any implication that covalent bonds are broken (on boiling)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)	An answer that makes reference to the following points: mixing of 1st pair of solutions • mix Br_2 with KCl (1) mixing of 2nd pair of solutions • mix Br_2 with KI or mix I_2 with KBr (1) colours of halogen (in cyclohexane) • colour seen for experiment 1/ bromine is orange / yellow and colour seen for experiment 2/ iodine is purple / pink / violet / lilac (1) correct ionic equation • $Br_2 + 2I^- \rightarrow 2Br^- + I_2$ (1) • use of ONLY two correct experiments as above (1)	Ignore any reference to any additional reactions, e.g. with silver nitrate Award mark if correct ionic equation is given Ignore colours before the addition of cyclohexane Do not award brown Do not award red Allow multiples Ignore state symbols even if incorrect	(5)

(Total for Question 1 = 10 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: (1st Step)	Ignore references to other conditions / solvent in step 1	(7)
	• HCN (and KCN) (1)	Allow HCN and CN^- / H^+ and CN^- / H^+ and KCN or KCN and H_2SO_4 / KCN and HCl or HCN at pH 8 − 9 M1 can be scored for the appearance of HCN in M3	
	• Nucleophilic addition (1)	Do not award additional incorrect reaction types e.g. nitrification	
	• $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ (1)	Allow skeletal formulae in equations	
	(2nd Step)	M4, 5 & 6 dependent on the formation of any nitrile in step 1	
	• Any identified (dilute) strong acid / H^+ (1)	Allow sodium hydroxide followed by acid Do not award conc. acid / just "acidify" / just "acid"	
	• Heat (under reflux) / reflux (1)	Allow warm	
	• Hydrolysis (1)	Do not award additional incorrect reaction types Allow two equations involving NaOH and H^+	
	• $CH_3CH(OH)CN + 2H_2O + H^+ \rightarrow CH_3CH(OH)COOH + NH_4^+$ or $CH_3CH(OH)CN + 2H_2O \rightarrow CH_3CH(OH)COOH + NH_3$ (1)	Allow $CH_3CH(OH)CN + 2H_2O + HCl \rightarrow CH_3CH(OH)COOH + NH_4Cl$	

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)(i)	• Condensation (polymerisation)	Ignore esterification or addition-elimination Do not award addition	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)(ii)	• Repeat unit circled on diagram as follows:  or 	Allow any repeat unit e.g  Do not award circle containing more than one repeat unit	(1)

(Total for Question 2 = 9 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	0.816 / 8.16 x 10^{-1} (g)		(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	• calculation of moles of CO_2	<u>Example of calculation</u>: (moles CO_2 = $\frac{225}{24000}$ =) 0.009375 Allow 9.375 x 10^{-3} / 9.38 x 10^{-3} / 9.4 x 10^{-3} Ignore SF except 1SF	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(c)	• moles of MCO_3 (1) • method for calculation of molar mass of MCO_3 (1) • molar mass final answer to 1, 2 or 3 SF (1) • consequential identification of Group 2 metal by name or formula (1) NOTE Alternative method can score 3 MAX Calculation of moles of CO_3^{2-} (1) (Calculation of mass of CO_3^{2-}) Deduction of mass of M by subtraction (1) Calculation of Ar of M to 1, 2 or 3 SF AND Identification of group 2 metal (1)	Example of calculation: Moles of MCO_3 = moles CO_2 = 0.009375 (mol) Molar mass of MCO_3 = $\frac{0.816}{0.009375}$ (= 87.04 (g mol^{-1})) M2 subsumes mark for M1 = 87.0 / 87 / 90 (g mol^{-1}) NOTE M3 mark subsumes mark for M2 and M1 (87.0 − 60) = 27 AND Mg / Magnesium / $MgCO_3$ Allow TE on answers to parts (a) and (b), with Metal consequential on calculated molar mass but M must be a Group 2 element Moles CO_3^{2-} = 0.009375 (Mass of CO_3^{2-} = 0.009375 x 60 = 0.5625 g) Mass of M = 0.2535 g Ar = 0.2535/0.009375 = 27.0 / 27 / 30 (g mol^{-1}) AND Mg / Magnesium / $MgCO_3$	(4)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)(i)	An explanation that makes reference to the following points: • the bung was not replaced quickly enough (1) • (So) CO_2 / gas lost (to the surroundings) (1)	Allow bung not fitting tightly resulting in leaks Ignore references to CO_2 dissolving Ignore references to other types of gas leak Allow 'smaller volume of gas collected' / lower reading of gas volume Mark points M1 and M2 independently	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)(ii)	An answer that makes reference to the following point: The acid was (already) in excess (and more acid won't affect this)	Allow The carbonate is the limiting reactant / the acid is not the limiting reactant	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)(iii)	An explanation that makes reference to the following points: • rate of reaction is faster and powder has greater surface area (1) • no effect on (final) volume of gas and moles of (metal) carbonate are unchanged or because the rate is faster more gas will be lost before the bung is replaced so the (final) volume will be less (1)	Mark points M1 and M2 independently Both parts of statement needed Both parts of statement needed Allow mass / amount for moles Allow reactant for metal carbonate	(2)

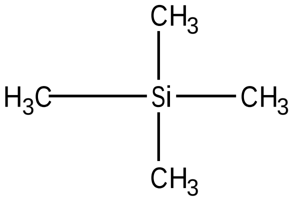
Question Number	Acceptable Answers	Additional Guidance	Mark
3(e)(i)	• balanced equation with state symbols	Example of equation: $MCO_3(s) \rightarrow MO(s) + CO_2(g)$ Allow a correct equation for the decomposition of any Group 2 carbonate	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(e)(ii)	• subtractions to obtain masses (1) • calculation of moles of CO_2 (1) • calculation of molar mass of MCO_3 (1)	Example of calculation: (mass of CO_2 = 20.447 − 20.205) = 0.242 AND (mass of MCO_3 = 20.447 − 19.996) = 0.451 moles of $CO_2 = \frac{0.242}{44}$ = 0.0055(0) (mol) / 5.5(0) x 10^{-3} (mol) ALLOW TE from M2 to M3 Mr of $MCO_3 = \frac{0.451}{0.0055(0)}$ = 82 (g mol^{-1}) Correct answer with or without working scores 3 Ignore SF except 1 Ignore attempts to identify the metal	(3)

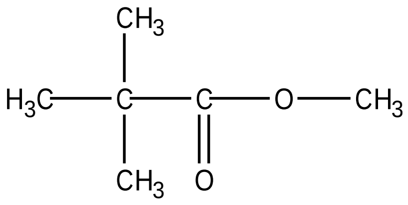
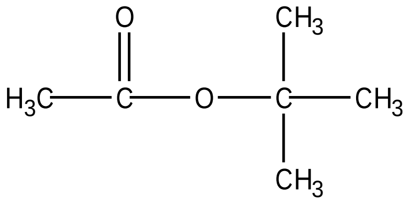
Question Number	Acceptable Answers	Additional Guidance	Mark
3(f)	An answer that makes reference to the following point: Student 3 used a smaller mass / less (and the uncertainty of the balance was the same) or Student 1 used a larger mass / more (and the uncertainty of the balance was the same)	Allow calculations comparing the two percentage errors: e.g. Student 1:- (0.001/0.816) x 100% = 0.12% and Student 3:- 0.001/0.451 x 100% = 0.22%	(1)

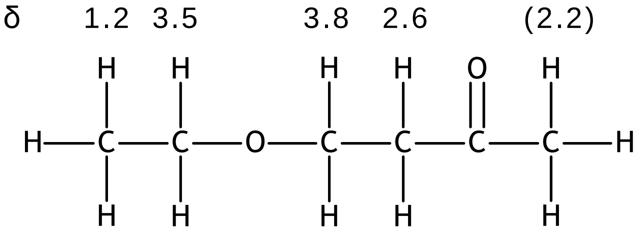
Question Number	Acceptable Answers	Additional Guidance	Mark
3(g)	An explanation that makes reference to the following points: • more CO_2 (would appear to be) given off (1) • (So) calculated molar mass is smaller (1) OR • Less MO would appear to have been formed (1) • Calculated molar mass would be greater (1)	M2 dependent on M1 M2 dependent on M1	(2)

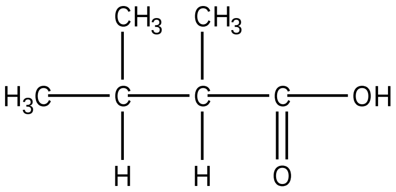
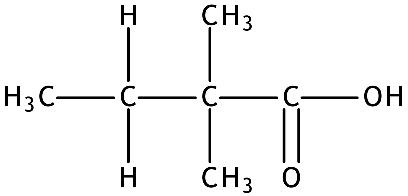
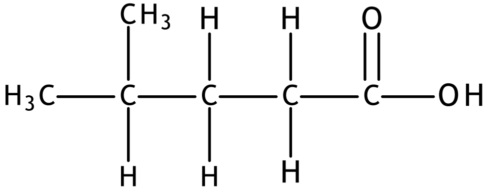
(Total for Question 3 = 18 marks)

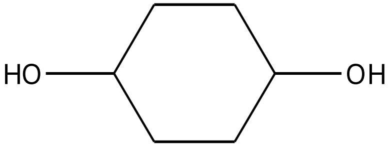
Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(i)	$(CH_3)_4Si$	Allow partially or fully displayed formula Ignore connectivity 	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to any **two** of the following: • single peak / all H or all C in same environment / no splitting pattern (1) • (TMS) peak to the right / upfield / out of the way of other peaks / peak doesn't overlap with other peaks (1) • (TMS) low boiling temperature / volatile / can be easily removed (1) • gives a strong signal so only a small amount needed (1)	Allow 12 H or 4 C in the same environment Ignore references to inertness / non-toxicity / cost / non-polar(ity) Ignore chemical shift = 0 12 H / 4 C are equivalent so gives a strong signal scores 2 marks	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)(i)	$C(CH_3)_3COOCH_3$ or  (1) $CH_3COOC(CH_3)_3$ or  (1)	Allow displayed or skeletal formulae	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points:		(5)
	- the chemical shift δ 2.2 identified (1)	$CH_3C=O$ / methyl attached to C=O	
	- four remaining chemical shifts identified (2)	Identifies 2 or 3 chemical shifts correctly scores 1  	
	- two splitting patterns given and explained (2)	1 specific splitting patterns explained scores 1	

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)(i)	Any two of the following $(CH_3)_2CHCH(CH_3)COOH$ /  (1) $CH_3CH_2C(CH_3)_2COOH$ /  (1) $(CH_3)_2CHCH_2CH_2COOH$ /  (1)	Allow displayed or skeletal formulae	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)(ii)		Do not award other types of structure	(1)

(Total for Question 4 = 13 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
5(a)	+5	Allow 5+ / +V / V+ / (V) / 5 Do not award V^+	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
5(b)	A description that makes reference to the following points: M1 and M2 **–**colours Yellow → blue → green → violet / lavender / purple / mauve 2 or 3 colours linked to correct species / oxidation states / reactions (1) 4 colours linked to correct species / oxidation states / reactions (1) M3 - statement Statement that sequence is from +5 to +4 to +3 to +2 or (step-wise) reduction / zinc is a reducing agent (1) M4, M5 and M6 - equations These three equations, with appropriate $E^\ominus$ values $Zn + 2VO_3^- + 8H^+ \rightarrow Zn^{2+} + 2VO^{2+} + 4H_2O$ and $E^\ominus$ = (+)1.76 (V) (1) $Zn + 2VO^{2+} + 4H^+ \rightarrow Zn^{2+} + 2V^{3+} + 2H_2O$ and $E^\ominus$ = (+)1.1(0) (V) (1) $Zn + 2V^{3+} \rightarrow Zn^{2+} + 2V^{2+}$ and $E^\ominus$ = (+)0.5(0) (V) (1) M7 **–** stops at V^{2+} No (further) reduction (feasible) to V metal / V(0) or $Zn + V^{2+} \rightarrow Zn^{2+} + V$ not feasible or $E^\ominus = -0.42$ (V) (1)	M3 can be implied from species in explanation or equations Allow multiples Ignore state symbols even if incorrect 3 correct equations with incorrect $E^\ominus$ scores 2 2 correct equations with incorrect $E^\ominus$ scores 1 3 correct $E^\ominus$ with incorrect equations scores 1	(7)

Question Number	Acceptable Answers	Additional Guidance	Mark
5(c)	A explanation that makes reference to the following points:	Ignore any references to heterogeneous catalysis	(2)
	M1		
	V changes (its oxidation state / oxidation number) from +5 to +4 (as it oxidises the sulfur dioxide)	Allow Forms V_2O_4 / VO_2 (as an intermediate)	
	OR	Do not award VO^{2+} or VO_3^- or VO_2^+	
	The oxidation number of V decreases in the reaction		
	OR		
	Vanadium is reduced in the reaction with SO_2		
	OR		
	V_2O_5 oxidises the SO_2 / S		
	OR		
	$V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ (1)		
	M2		
	(Then) returns to +5 (oxidation state / oxidation number) by reacting with oxygen	Allow (re-) forms V_2O_5	
	OR		
	$2\ V_2O_4 + O_2 \rightarrow 2\ V_2O_5$ (1)		

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*5(d)</td>
<td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5−4</td><td>3</td></tr>
<tr><td>3−2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general it would be expected that 5 or 6 indicative points would score 2 reasoning marks, and 3 or 4 indicative points would score 1 reasoning mark. A total of 2, 1 or 0 indicative points would score 0 marks for reasoning.

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</td>
<td>(6)</td>
</tr>
</table>

Indicative content (IPs)	Allow omission of square brackets throughout
IP1: • $[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow [Cu(OH)_2(H_2O)_4](s) + 2H_2O(l)$	Allow for IP1 $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ Only penalise incorrect or missing state symbols in this equation (IP1)
IP2: • blue ppt / blue solid (when $[Cu(OH)_2(H_2O)_4](s)$ is formed)	
IP3: • $[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 4H_2O(l)$	Allow for IP3 $Cu^{2+}(aq) + 4NH_3\ (aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$ $[Cu(OH)_2(H_2O)_4](s) + 4NH_3\ (aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 2H_2O(l) + 2OH^-(aq)$ $[Cu(OH)_2(H_2O)_4](s) + 6NH_3\ (aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 2NH_4^+\ (aq)\ 2H_2O(l) + 2OH^-(aq)$ Ignore formation of initial precipitate $Cu(OH)_2(s)$ Do not award $[Cu(NH_3)_6]^{2+}(aq)$
IP4: • Deep blue solution / dark blue solution (when $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ is formed)	
IP5: • $[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightarrow [CuCl_4]^{2-}(aq) + 6H_2O(l)$	
IP6: • Yellow / green (solution when $[CuCl_4]^{2-}(aq)$ is formed)	Do not award 'yellow precipitate' Allow equilibrium sign ⇌ in any reaction Ignore any initial colours, even if incorrect

(Total for Question 5 = 16 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)(i)	An answer that makes reference to the following points: • 3300 — 2500 (cm^{-1}) and O-H (bond) (1) • 1725 — 1700 (cm^{-1}) and C=O (bond) (1)	Allow any value(s) within the range 3300 — 2500 (cm^{-1}) Allow -OH Allow any value(s) within the range 1725 — 1700 (cm^{-1}) Allow 1320 – 1210 (cm^{-1}) and C-O	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)(ii)	An answer that makes reference to the following points: • structures 1 and 2 will have an absorption at Either C=C at 1669 — 1645 (cm^{-1}) or C—H in an alkene at 3095 — 3010 (cm^{-1}) (1) • only structure 2 will have an absorption due to the presence of an alcohol / O—H at 3750 —3200 (cm^{-1}) (1) • structure 3 will have none of these absorptions / will not show C=C absorption / C-H absorption for an alkene (1)	Reject C=C at 3010 (cm^{-1})	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(b)	• calculation of moles of NaOH (1) • calculation of mass of NaOH (1)	<u>Example of calculation</u>: (moles NaOH = $0.140 \times \frac{250}{1000}$) = 0.035(0) (mol) = 40(.0) x 0.035(0) = 1.4(0) (g) Correct answer with or without working scores 2 marks Allow TE for M2 on moles of NaOH Alternative route, allow M1 for conversion of concentration to 5.6 g dm^{-3} Ignore SF	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(i)	An explanation that makes reference to the following points: • (because the) sodium hydroxide has been diluted (1) • (the titre will be) smaller (1)	Allow Fewer moles of sodium hydroxide present / some sodium hydroxide will have been removed M2 dependent on M1	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(ii)	An explanation that makes reference to the following points: M1 no effect (on the titre) (1) M2 because the (number of) moles of sodium hydroxide is unaffected (1)	M2 depends on M1 Allow base / alkali / hydroxide (ions) Allow amount / mass of sodium hydroxide is unaffected	(2)

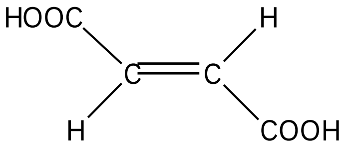
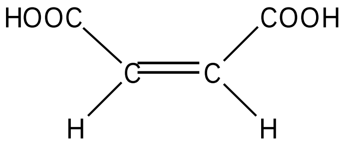
Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(iii)	• calculation of percentage uncertainty in burette volume (1) • calculation of percentage uncertainty in volumetric flask volume and in pipette volume (1) • identification of volume with the lowest percentage uncertainty (1)	Example of calculation: $\frac{2 \text{ x } (\pm)0.05}{10.20}$ x 100% = (±)0.980392156% $\frac{(\pm)0.30}{250.0}$ x 100% = (±)0.12% and $\frac{(\pm)0.040}{10.0}$ x 100% = (±)0.4% Volumetric flask has the lowest uncertainty Allow TE for identification in M3 Allow ANY number of SF in answer, from 1 SF up to calculator value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(d)(i)	• left-hand side of equation correct (1) • right-hand side of equation correct (1)	<u>Example of equation</u> $HOOCCH{=}CHCOOH + 2NaOH \rightarrow NaOOCCH{=}CHCOONa + 2H_2O$ ALLOW use of molecular formulae or ionic equation: $C_4H_4O_4 + 2NaOH \rightarrow Na_2C_4H_2O_4 + 2H_2O$ $HOOCCH{=}CHCOOH + 2OH^- (+ 2Na^+) \rightarrow {}^-OOCCH{=}CHCOO^- + 2H_2O (+ 2Na^+)$ ALLOW Multiples Correct charges Do not award if O−Na covalent bond drawn IGNORE State symbols, even if incorrect	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(d)(ii)	An answer that makes reference to the following points: • (New mean titre) = 20.4(0) (cm^3) / double (the original value) (1) • For structure 2, mole ratio / reacting ratio is 1:1 (with NaOH) (1)	Mark M1 and M2 independently Allow structure 2 has 1 COOH / 1 acid group	(2)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>6(e)</td><td>
<table>
<tr><th>Structure</th><th>Test with Br_2 water</th><th>Test with acidified $K_2Cr_2O_7$</th></tr>
<tr><td>$HOOCCH=CHCOOH$</td><td>✓</td><td>x</td></tr>
<tr><td>$HOCH_2CH=CHCH_2COOH$</td><td>✓</td><td>✓</td></tr>
<tr><td>$CH_3CH_2CH_2CH_2CH_2COOH$</td><td>x</td><td>x</td></tr>
</table>
Left hand column correct (1)
Right hand column correct (1)
</td><td>3 correct ticks with no crosses scores 1

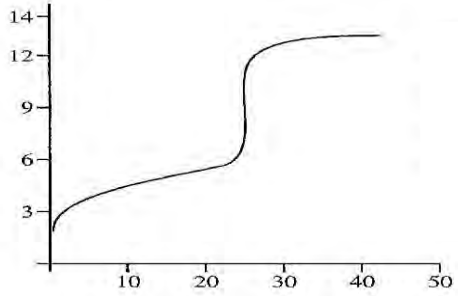
Ignore descriptions of result in terms of colour (changes) / reactions occurring</td><td>(2)</td></tr>
</table>

Question Number	Acceptable Answers	Additional Guidance	Mark
6(f)(i)	• *E*-isomer:  (1) • *Z*-isomer:  (1)	ALLOW skeletal or displayed structures ALLOW −CO_2H IGNORE Connectivity to the −COOH group IGNORE bond angles Award one mark if correct structures are drawn, but *E*- and *Z*-isomers labelled the wrong way round Award 1 mark if incorrect molecule used but *E* - and *Z*- isomers are correct	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(f)(ii)	An answer that makes reference to the following points: • restricted / limited rotation (about the C=C double bond) (1) • each carbon atom in the double bond is attached to (two) different atoms / different groups (of atoms) / to a H (atom) and a COOH group (1)	Allow "no rotation" Do not award the carbons are attached to 2 "different molecules" Mark points M1 and M2 independently	(2)

(Total for Question 6 = 24 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)		Example of calculation:	(5)
	• calculates moles of X^- / NaOH present in the mixture (1)	(moles of X^- = mol NaOH = $\frac{0.8(00) \text{ x } 10.5}{1000}$) = 0.0084(0) / $8.4(0) \text{ x } 10^{-3}$ (mol)	
	• calculates moles of HX which remain unreacted (1)	(moles of HX − mol NaOH = $\frac{0.92(0) \text{ x } 25.0}{1000}$ − 0.0084(0) = 0.023(0) − 0.0084(0)) = 0.0146 / $1.46 \text{ x } 10^{-2}$ (mol)	
	• calculates / shows ratio of [HX] to [X^-] OR ratio of moles of HX : X^- (as total V cancels) (1)	[HX] = $\frac{0.0146}{0.0355}$ and [X^-] = $\frac{0.0084(0)}{0.0355}$ = 0.411 and 0.237 (mol dm^{-3}) Allow use of the ratio of the moles as above (as total V cancels)	
	• re-arranges K_a or pK_a expression correctly and substitutes appropriate values (1)	$[H^+] = K_a \times \frac{[HX]}{[X^-]} = 5.25 \times 10^{-5} \times \frac{0.411}{0.237}$ $[H^+] = 9.10443038 \times 10^{-5}$ (mol dm^{-3})	
	• final pH to 2 or 3SF (1)	pH = 4.04 Allow use of pH expression to get answer: pH = pK_a − log $\frac{[HX]}{[X^-]}$ or pK_a + log $\frac{[X^-]}{[HX]}$ ALLOW TE M5 for calculation of pH from any [H^+] Correct answer with no working scores (5)	

Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(i)	A sketch graph which shows the following: • a starting pH between 2 and 4 (inclusive) (1) • correct general shape and ends at pH = 12-13 (1) • (any) vertical at 25 cm^3 (1) • vertical between pH = 6 - 7 and pH = 10 − 12 (1)	 Vertical must be no more than 5 pH units within these ranges	(4)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: • (Read off) pH at half-neutralisation (point) / pH at 12.5 (cm^3) OR pH at half-equivalence (point) (1) • As pH = pK_a / $[H^+] = K_a$ / $K_a = 10^{-pH}$ (1)	May be shown on the sketch graph ALLOW read equivalence vol, add same volume of (propanoic) acid and measure pH M2 dependent on mentioning half equivalent / 12.5 cm^3	(2)

(Total for Question 7 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)	Any one from: Catalyst / speeds up reaction / increases rate / increases rate of attainment of equilibrium / lowers activation energy	Ignore any mention of protonation or mechanism for catalysis Do not award additional incorrect types of reaction	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(i)		Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only Example of calculation:	(2)
	• calculation of moles of H^+ in 25.0 cm^3 (1)	(moles NaOH = $0.200 \times \frac{23.60}{1000}$) = 0.00472 (mol) (= mol H^+ in 25.0 cm^3)	
	• calculation of moles of H^+ in 250 cm^3 flask (1)	(= 10 x 0.00472) = 0.0472 (mol) (in 250 cm^3) Allow TE for M2 on moles of NaOH Correct answer with or without working scores 2 marks	

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(ii)	• subtracts moles of H^+ in HCl from answer to (b)(i)	Example of calculation: 0.0472 − 0.00400 = 0.0432 (mol) Allow TE on answer to part (b)(i)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(c)(i)	- calculation of moles of CH_3COOH that have reacted	Example of calculation: (0.105 — 0.0432) = 0.0618 Allow TE on part (b)(ii) unless negative value	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(c)(ii)	- calculation of equilibrium moles of $CH_3CH_2CH_2OH$ (1) - calculation of equilibrium moles of $CH_3COOCH_2CH_2CH_3$ (1) - calculation of equilibrium moles of H_2O (1)	Example of calculation: 0.0800 — 0.0618 = 0.0182 0.0618 0.111 + 0.0618 = 0.1728 Allow TE on answer to part (c)(i) unless negative value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(d)(i)	$(K_c =) \quad \frac{[CH_3COOCH_2CH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2CH_2OH]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(d)(ii)	An explanation that makes reference to the following points: • Same number of moles/molecules on both sides of the equation (1) • (so) volume / V cancels in K_c expression (1)	2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel Allow same number of terms on top and bottom of K_c expression Allow units cancel out Allow "all divided by the same volume"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(d)(iii)	• calculates value of K_c (1) • final value of K_c quoted to 2 or 3 SF (1)	<u>Example of calculation</u> $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ = 14 / 13.6 (no units) Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression	2

Question Number	Acceptable Answers	Additional Guidance	Mark
8(e)	An explanation that makes reference to the following points: • the equilibrium shifts to the left or the mixture absorbs carbon dioxide from the atmosphere (1) • so the mixture is (becoming more) acidic / the acid reforms (1)	Mark independently Allow no longer alkaline Do not award just "pH decreases"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(f)	An explanation that makes reference to the following points: • carry out / repeat experiment and leave for longer than a week (1) • the titre value / K_c value will remain unchanged (if equilibrium has been established) (1)	Ignore pH probes / checking pH Allow repeat experiment and check titres within first week Allow moles / concentration are unchanged Ignore just "results unchanged"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(g)	An answer that makes reference to the following points: • K_c value will be greater than that calculated in (d)(iii) (1) • because the (forward) reaction is endothermic or backward / reverse reaction is exothermic (1)	M2 depends on M1 Ignore References to the equilibrium position shifting to the right (with increasing temperature)	(2)

(Total for Question 8 = 19 marks)

TOTAL FOR PAPER = 120 MARKS

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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐

Candidate Number ☐☐☐☐

Tuesday 4 June 2019

Afternoon (Time: 1 hour 45 minutes) | Paper Reference **9CH0/01**

Chemistry

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Candidates must have: Data Booklet
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ~~☒~~
and then mark your new answer with a cross ☒.

1 This question is about atoms, molecules and ions.

(a) The numbers of subatomic particles in an ^{18}O atom are

(1)

☒ **A** 8 protons, 10 neutrons and 8 electrons

☒ **B** 9 protons, 9 neutrons and 9 electrons

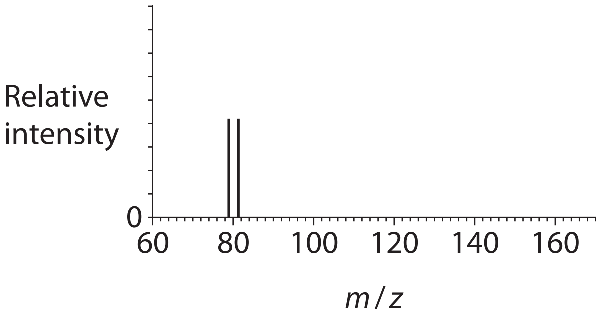
☒ **C** 10 protons, 8 neutrons and 10 electrons

☒ **D** 18 protons, 18 neutrons and 18 electrons

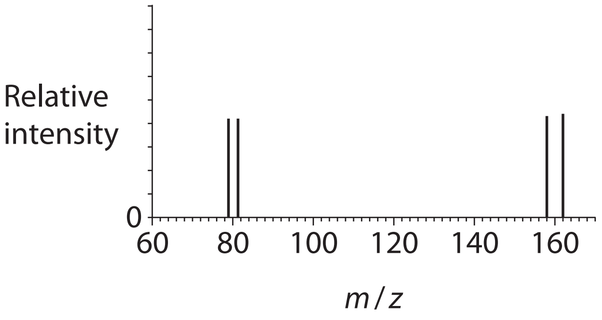
(b) The mass spectrum of a sample of bromine **molecules** with approximately equal proportions of the ^{79}Br and ^{81}Br isotopes is

(1)

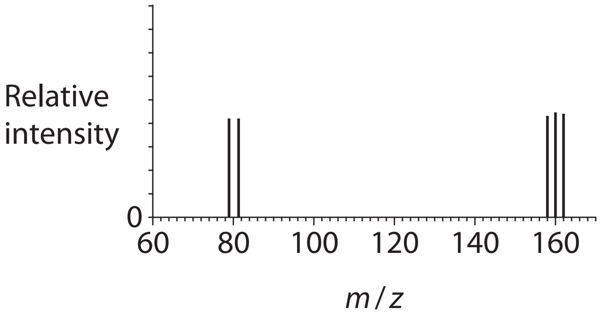
☒ **A**



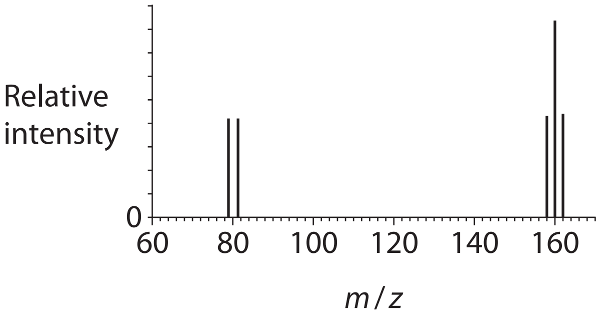
☒ **B**



☒ **C**



☒ **D**



(c) The total number of electrons in **all** the occupied **p** orbitals in a chloride ion, Cl^-, is

(1)

☒ **A** 5

☒ **B** 6

☒ **C** 12

☒ **D** 18

(d) Which of these isoelectronic ions has the largest ionic radius?

(1)

☒ **A** N^{3-}

☒ **B** O^{2-}

☒ **C** Na^+

☒ **D** Al^{3+}

(Total for Question 1 = 4 marks)

2 This question is about some redox reactions of chlorine, bromine and iodine.

(a) An **excess** of aqueous potassium bromide was added to chlorine water and the solution turned orange.

(i) Write an equation for this reaction. State symbols are not required.

(1)

(ii) Silver nitrate solution was added to the mixture in (a) and excess dilute ammonia solution was then added to the precipitate formed. Only some of the precipitate dissolved.

Deduce why only **some** of the precipitate dissolved.

(3)

(iii) Aqueous potassium bromide was added to aqueous iodine, instead of chlorine water. There was no reaction.

Give a reason why no reaction occurred.

(1)

(b) Chlorine undergoes disproportionation when it reacts with **hot** aqueous sodium hydroxide solution.

(i) Complete the ionic equation for this reaction.
State symbols are not required.

(1)

$$\ldots\ldots\ Cl_2 + \ldots\ldots\ OH^- \rightarrow \ldots\ldots\ Cl^- + \ldots\ldots\ ClO_3^- + \ldots\ldots\ H_2O$$

(ii) Explain, in terms of oxidation numbers, why this is a disproportionation reaction.

(2)

(Total for Question 2 = 8 marks)

3 The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

(a) An experiment was carried out to determine the enthalpy change of neutralisation for the reaction between propanoic acid and sodium hydroxide.

The equation for this reaction is

$$CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow CH_3CH_2COO^-Na^+(aq) + H_2O(l)$$

50.0 cm^3 of sodium hydroxide solution, of concentration 1.00 mol dm^{-3}, was placed in a polystyrene cup. The initial temperature was measured.

(i) Which piece of equipment has the **smallest** measurement uncertainty for the measurement of 50.0 cm^3 of sodium hydroxide solution?

(1)

		Equipment	Measurement uncertainty for **each** reading
☒	**A**	burette	±0.05 cm^3
☒	**B**	50 cm^3 measuring cylinder	±1 cm^3
☒	**C**	25 cm^3 pipette	±0.06 cm^3
☒	**D**	50 cm^3 pipette	±0.08 cm^3

(ii) 50.0 cm^3 of propanoic acid solution, of concentration 1.00 mol dm^{-3}, was added and thoroughly mixed with the sodium hydroxide solution in the polystyrene cup.

The maximum temperature rise was 6.5 °C.

Calculate the enthalpy change of neutralisation for propanoic acid, in kJ mol^{-1}, giving your answer to the **nearest whole number**.

[Assume density of the mixture = 1.00 g cm^{-3}, specific heat capacity of the mixture = 4.18 J g^{-1} °C^{-1}]

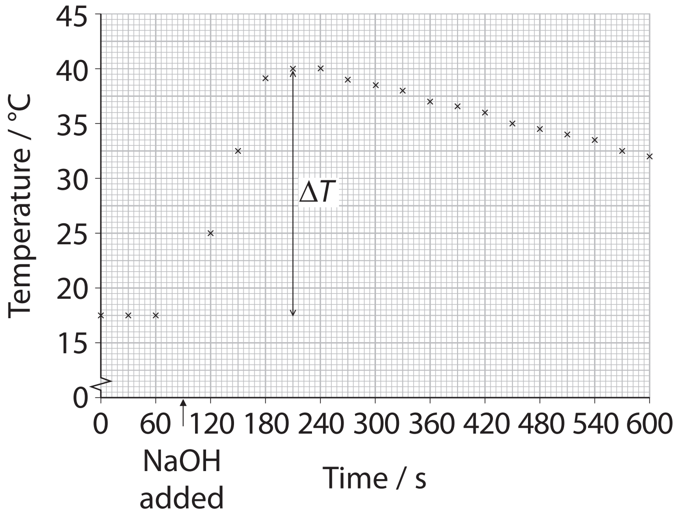
(3)

(b) Another experiment was carried out with a solution of ethanoic acid and sodium hydroxide solution of the same concentration.

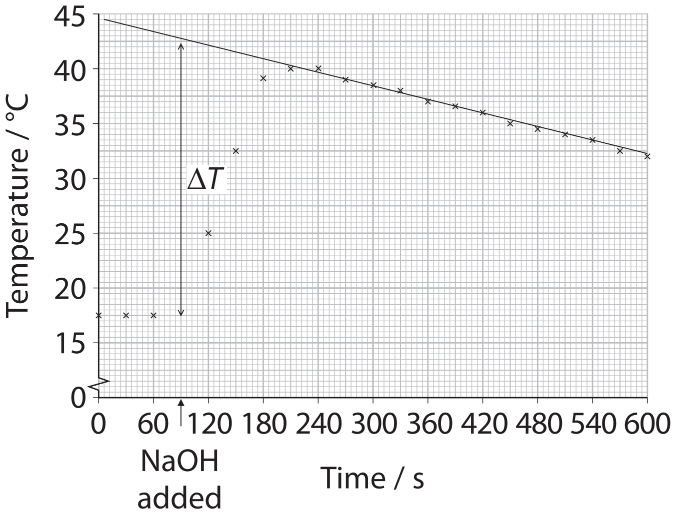
(i) Which graph shows the correct way that the maximum temperature rise should be determined?

(1)

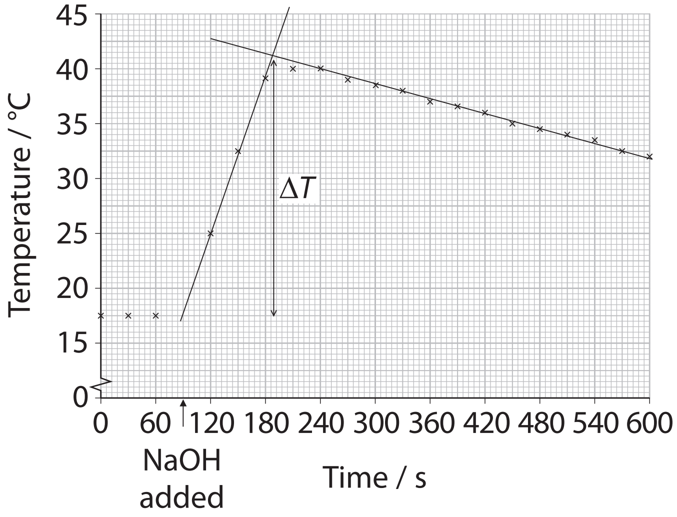
☒ **A**



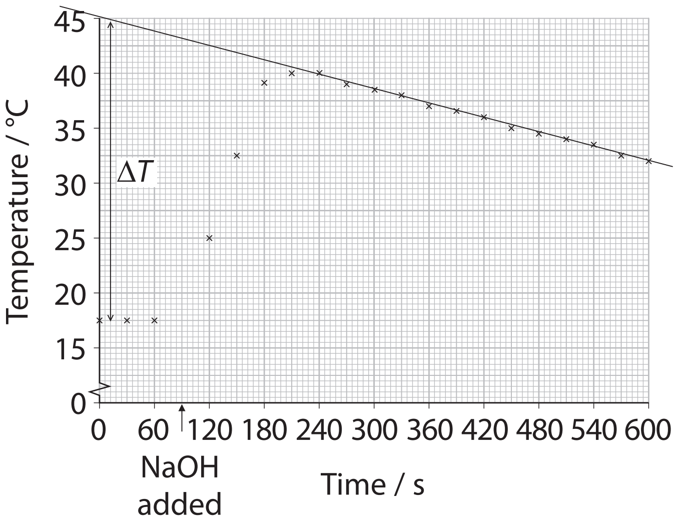
☒ **B**



☒ **C**



☒ **D**



(ii) Explain why the data book value for the standard enthalpy change of neutralisation of ethanoic acid with sodium hydroxide is −55.2 kJ mol^{-1} but the value for hydrochloric acid is −57.1 kJ mol^{-1}.

(2)

(Total for Question 3 = 7 marks)

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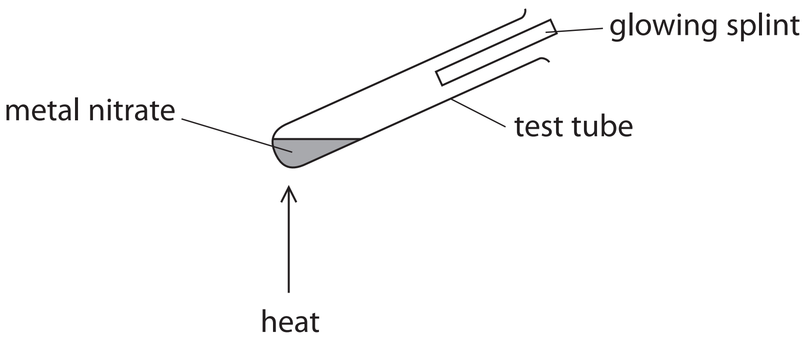
4 Thermal decomposition is the breaking down of a substance by heat.

(a) An experiment was carried out to investigate the thermal decomposition of a metal nitrate using the apparatus shown.



(i) The glowing splint is used as a test for one of the gases given off in this experiment.

Identify this gas and the positive result of the test.

(1)

(ii) Give the name and appearance of the other gas given off in this experiment when a Group 2 nitrate is heated.

(1)

(iii) Write the equation for the decomposition if the Group 1 compound, sodium nitrate, was used in this experiment.
State symbols are not required.

(1)

(iv) Describe the apparatus that would be used to compare the decomposition of metal carbonates. Include how the rate of decomposition would be compared.

(2)

(b) Explain why magnesium carbonate decomposes much more readily on heating than barium carbonate.

(3)

(Total for Question 4 = 8 marks)

5 This is a question about catalysis.

(a) The reaction between iodide ions and peroxodisulfate ions is catalysed by iron(II) ions.

$$2I^- + S_2O_8^{2-} \xrightarrow{Fe^{2+}} I_2 + 2SO_4^{2-}$$

(i) Give a reason why the reaction between iodide ions and peroxodisulfate ions has a high activation energy and is therefore very slow without a catalyst.

(1)

(ii) Explain, with the aid of two equations, how the iron(II) ions catalyse this reaction. State symbols are not required.

(3)

(b) The oxidation of sulfate(IV) ions to sulfate(VI) ions is catalysed by cobalt(II) ions in **acidic** solution. The role of cobalt(II) ions is similar to that of iron(II) ions in (a).

$$SO_3^{2-} + \tfrac{1}{2}O_2 \xrightarrow{Co^{2+}} SO_4^{2-}$$

Deduce two ionic equations to show how cobalt(II) ions catalyse the reaction in **acidic** solution. State symbols are not required.

(2)

(c) The rate of oxidation of ethanedioate ions by manganate(VII) ions starts slowly and then rapidly increases.

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

What is the catalyst in this reaction?

(1)

☒ **A** CO_2

☒ **B** H^+

☒ **C** Mn^{2+}

☒ **D** MnO_4^-

(d) The trend in the strength of gaseous adsorption by three transition elements is

tungsten > platinum > silver

Silver is not suitable as a replacement for platinum in a catalytic converter because the adsorption of gases is too weak to allow significant chemical reaction.

Give a possible reason why tungsten would also **not** be a suitable replacement for platinum in a catalytic converter. Refer to the mechanism of heterogenous catalysis in your answer.

(1)

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(Total for Question 5 = 8 marks)

6 This is a question about water.

(a) Water might be expected to have a lower boiling temperature than hydrogen sulfide but it actually has a higher boiling temperature.

Comment on this statement by referring to the intermolecular forces in both these substances.

A detailed description of how the intermolecular forces arise is not required.

(4)

(b) Explain why both water and carbon dioxide molecules have polar bonds but only water is a polar molecule.

(4)

(c) Pure water ionises to form H_3O^+ and OH^- ions, although only to a very small extent.
Draw the dot-and-cross diagrams of these ions.
Use dots (•) for the hydrogen electrons and crosses (**×**) for the oxygen electrons.

(2)

(d) An equation for the ionisation of water is

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The expression for the ionic product of water is

$$K_w = [H^+(aq)]\,[OH^-(aq)]$$

The value of K_w at 310 K is $2.40 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$

(i) Calculate the pH of water at 310 K.

Give your answer to **two** decimal places.

(2)

(ii) Predict, with a reason, whether water is acidic, alkaline or neutral at 310 K.

(2)

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....

(iii) Predict, with a reason, the sign of the enthalpy change for the ionisation of water.

(1)

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(Total for Question 6 = 15 marks)

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***7** Colour is often used in chemistry to identify substances.

Compare and contrast the origin of the colour of a copper(II) complex with the origin of the colour of the copper(II) ion in a flame test.

You do not need to state any specific colours.

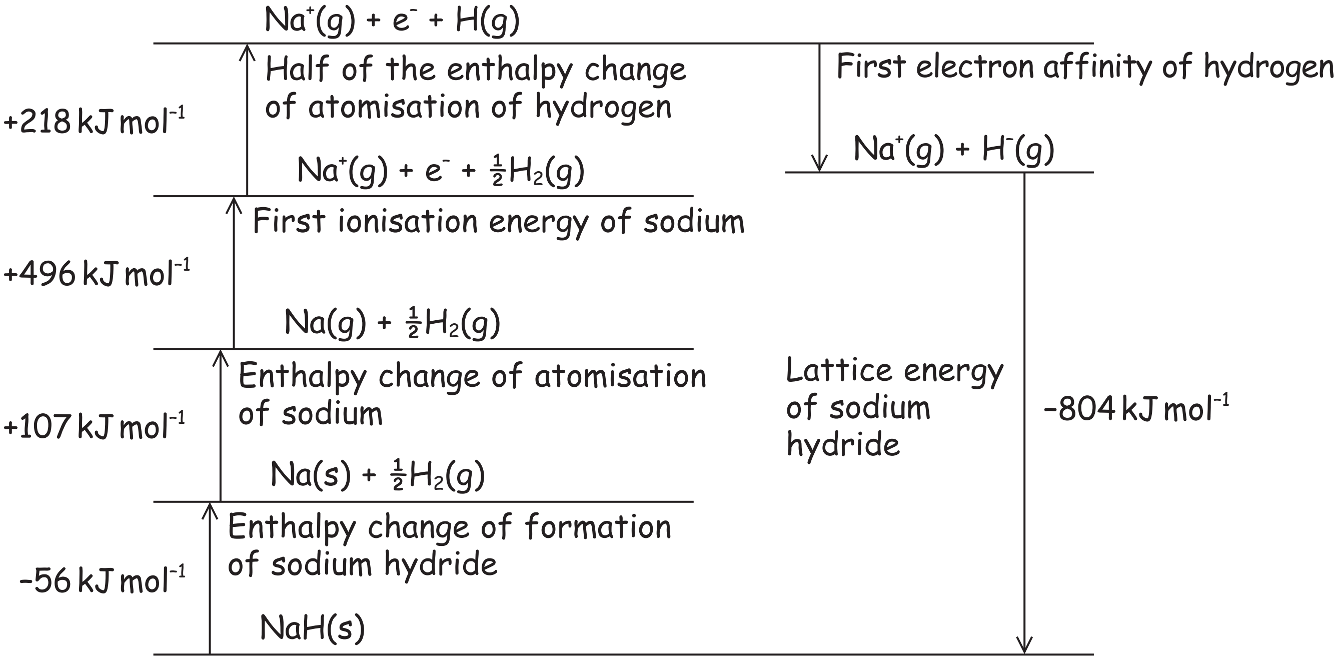
(6)

(Total for Question 7 = 6 marks)

8 Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

(a) In order to calculate the first electron affinity of hydrogen, a student was asked to draw a Born-Haber cycle for sodium hydride.

The cycle had **two** errors but the numerical data were correct.



(i) Identify and correct the **two** errors in this Born-Haber cycle.

(2)

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(ii) Calculate the first electron affinity, in kJ mol^{-1}, of hydrogen, using the values given in the cycle.

(1)

(b) The equation for the formation of sodium hydride is

$$Na(s) + \tfrac{1}{2}H_2(g) \rightarrow NaH(s) \qquad \Delta_f H^{\ominus} = -56\,kJ\,mol^{-1}$$

The standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for this reaction is $-76.5\,J\,K^{-1}\,mol^{-1}$.

(i) Deduce the feasibility of this reaction at 298 K by calculating the free energy change, ΔG.

(2)

....

....

(ii) Calculate the temperature at which $\Delta G = 0$.

(1)

Turn over ▶

(c) The sodium hydride is crushed in the presence of water to release the hydrogen gas for a fuel cell.

The overall equation for the reaction occurring in the fuel cell is

$$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$$

In an alkaline fuel cell the oxidation half-equation is

$$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$$

Deduce the reduction half-equation for the alkaline fuel cell.

State symbols are not required.

(1)

(d) Lattice energies provide an indication of ionic bond strength.

Which are the lattice energies of the hydrides NaH, KH and MgH_2?

(1)

	Lattice energy / kJ mol^{-1}		
	Sodium hydride, NaH	Potassium hydride, KH	Magnesium hydride, MgH_2
☒ **A**	–804	–711	–1018
☒ **B**	–804	–711	–2718
☒ **C**	–804	–911	–1018
☒ **D**	–804	–911	–2718

(Total for Question 8 = 8 marks)

9 This is a question about buffer solutions.

(a) A buffer solution always

(1)

☒ **A** keeps the pH less than 7.

☒ **B** contains equimolar amounts of acid and its conjugate base.

☒ **C** keeps the pH constant if small quantities of acid or base are added.

☒ **D** resists changes in pH if small quantities of acid or base are added.

(b) A buffer solution with a pH of 3.90 is required.
Calculate the **mass**, in grams, of sodium ethanoate that should be added to 50.0 cm^3 of an ethanoic acid solution of concentration 0.800 $mol\,dm^{-3}$ to form this buffer solution.

Give your answer to an appropriate number of significant figures.

[K_a for ethanoic acid = $1.74 \times 10^{-5}\,mol\,dm^{-3}$]

(5)

(c) One of the systems controlling the pH of blood is the carbonic acid-hydrogencarbonate buffer system.

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Explain how this buffer system helps to control the pH of blood when extra carbon dioxide is present due to strenuous exercise.

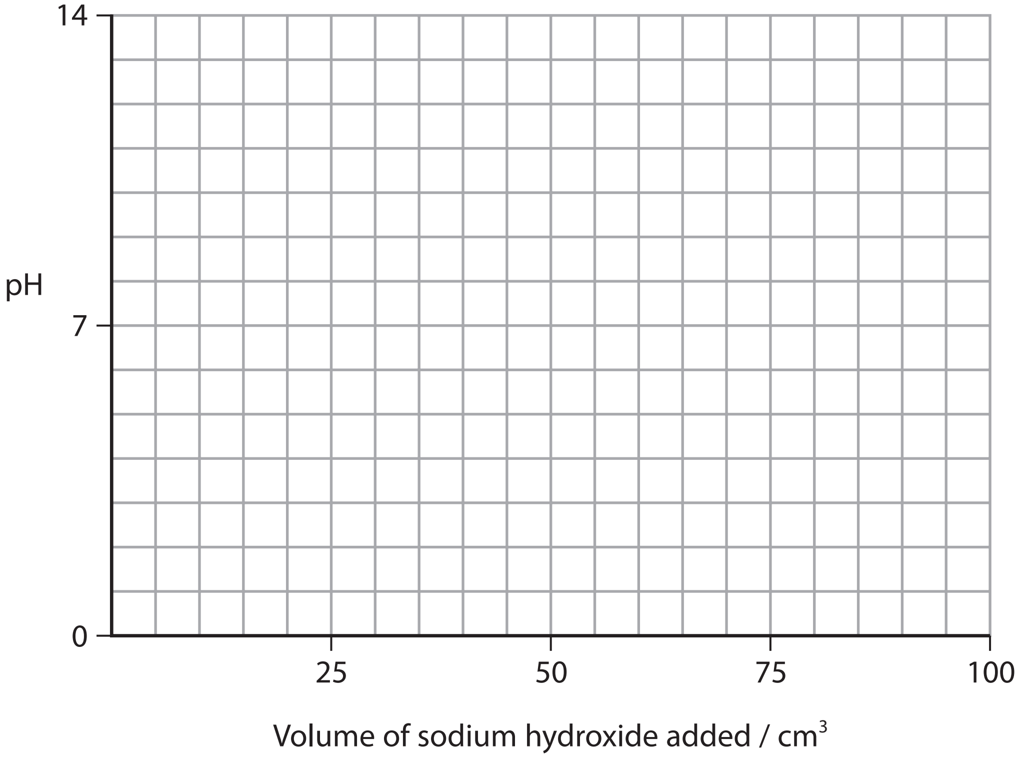
(3)

(d) A weak acid-strong base titration curve can be used to demonstrate buffer action.

(i) Draw a titration curve for the addition of
100 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} to
40.0 cm^3 of propanoic acid solution of concentration 0.100 mol dm^{-3}
which has a pH of 3.0.

Show the part of the curve that demonstrates buffer action.

(4)



(ii) Describe, without calculation, how you would use your curve to determine the value of K_a for propanoic acid.

(2)

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(Total for Question 9 = 15 marks)

10 This question is about equilibrium systems.

(a) Sulfur dioxide and oxygen form an equilibrium with sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The composition of an equilibrium mixture at 698 K and a total pressure of 2.40 atm is shown in the table.

Substance	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
Number of moles /mol	0.0160	0.0120	0.772

(i) Calculate the value of K_p at this temperature.

Include units, if appropriate.

(5)

(ii) Calculate the number of sulfur dioxide molecules present in this equilibrium mixture.

(1)

(iii) Deduce, by referring to K_p, how the number of sulfur dioxide molecules will change if more oxygen is added to the equilibrium mixture.

(2)

....

....

....

....

(b) An equilibrium exists in aqueous solution between the chromate(VI) ions and the dichromate(VI) ions.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

Explain any change in the position of equilibrium if a few drops of sodium hydroxide solution are added to this equilibrium system.

(2)

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(c) The equilibrium for the reaction between hydrogen gas and an oxide of iron is

$$Fe_3O_4(s) + 4H_2(g) \rightleftharpoons 3Fe(s) + 4H_2O(g)$$

The K_c expression for this equilibrium is

(1)

☒ **A** $K_c = \dfrac{[Fe] \times [H_2O]}{[Fe_3O_4] \times [H_2]}$

☒ **B** $K_c = \dfrac{[Fe]^3 \times [H_2O]^4}{[Fe_3O_4] \times [H_2]^4}$

☒ **C** $K_c = \dfrac{[H_2O]}{[H_2]}$

☒ **D** $K_c = \dfrac{[H_2O]^4}{[H_2]^4}$

(Total for Question 10 = 11 marks)

TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							
* Lanthanide series			140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71	
* Actinide series			232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103	

Elements with atomic numbers 112-116 have been reported but not fully authenticated

Mark Scheme Results)

Pearson Edexcel Advanced Level In Chemistry (9CH0) Paper 01 Advanced Inorganic and Physical Chemistry

Summer 2019
Publications Code 9CH0_01_1906_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	**The only correct answer is A** ***B*** *is not correct because oxygen atoms do not have this number of protons* ***C*** *is not correct because oxygen atoms do not have this number of protons* ***D*** *is not correct because oxygen atoms do not have this number of protons*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is D** ***A*** *is not correct because there are no peaks for bromine molecules* ***B*** *is not correct because the peak for the* $^{79}Br\text{-}^{81}Br^{+}$ *molecular ion is missing* ***C*** *is not correct because the peak for the* $^{79}Br\text{-}^{81}Br^{+}$ *molecular ion is not twice the height of the other molecular ion peaks*	**(1)**

Question Number	Answer	Mark
1(c)	**The only correct answer is C** ***A*** *is not correct because this is only the number of electrons in the 3p orbitals of the chlorine atom* ***B*** *is not correct because this is only the number of electrons in the 3p orbitals of the chloride ion* ***D*** *is not correct because this is the total number of electrons in the chloride ion, not just those in the p orbitals*	**(1)**

Question Number	Answer	Mark
1(d)	**The only correct answer is A** ***B*** *is not correct because oxygen has more protons to exert an attractive force to reduce the ionic radius* ***C*** *is not correct because sodium has more protons to exert an attractive force to reduce the ionic radius* ***D*** *is not correct because aluminium has more protons to exert an attractive force to reduce the ionic radius*	**(1)**

(Total Question 1 = 4 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)(i)	• equation	Example of equation $Cl_2 + 2KBr \rightarrow Br_2 + 2KCl$ Accept ionic equation $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An answer that makes reference to the following points:		**(3)**
	• **(M1)** the precipitate is a mixture of silver chloride and silver bromide **or** not all of the bromide ions were oxidised **(1)**	Allow Some bromide ions are still present/bromide ions were in excess/both chloride and bromide ions are present	
	• **(M2)** silver chloride/AgCl dissolves in dilute ammonia **(1)**	Do not award references to Cl^- dissolving	
	• **(M3)** silver bromide/AgBr does not dissolve in dilute ammonia **(1)**	Silver bromide only dissolves in concentrated ammonia	

Question Number	Answer	Additional Guidance	Mark
2(a)(iii)	An answer that makes reference to the following point: • iodine is a weaker oxidising agent than chlorine **or** iodine cannot oxidise bromide ions **or** iodine is a stronger reducing agent	Accept reverse arguments Ignore Just references to reactivity/displacement e.g. iodine is less reactive/cannot displace	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)(i)	• balanced equation	<u>Example of equation</u> $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)(ii) **Clip with 2(b)(i)**	An explanation that makes reference to the following points: • oxidation number for chlorine changes from 0 to -1 so it is **reduced** **(1)** • oxidation number for chlorine changes from 0 to +5 so it is **oxidised** **(1)**	Ignore general definitions of disproportionation Accept oxidation numbers and their changes shown with equation Allow 1 out of 2 marks for three correct oxidation numbers of the chlorine	**(2)**

(Total Question 2 = 8 marks)

Question Number	Answer	Mark
3(a)(i)	**The only correct answer is D** ***A** is not correct because the measurement uncertainty is doubled as there are two burette readings* ***B** is not correct because this gives the largest measurement uncertainty* ***C** is not correct because the measurement uncertainty is doubled as the pipette is used twice*	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)		Example of calculation	**(3)**
	• calculation of Q **(1)**	Q=(100 x 4.18 x 6.5=) = 2717 (J) / 2.717 kJ	
	• calculation of enthalpy change **(1)**	ΔH= 2.717 ÷ 0.05= (−)54.340	
	• answer to nearest whole number **and** with negative sign **(1)**	= −54 (kJ mol^{-1})	
		Allow TE at each stage Correct answer with no working scores (3)	

Question Number	Answer	Mark
3(b)(i)	**The only correct answer is B** ***A*** *is not correct because there is no extrapolation to the largest temperature increase carried out* ***C*** *is not correct because the extrapolation is at the wrong time* ***D*** *is not correct because the extrapolation extends beyond the time of addition of alkali*	**(1)**

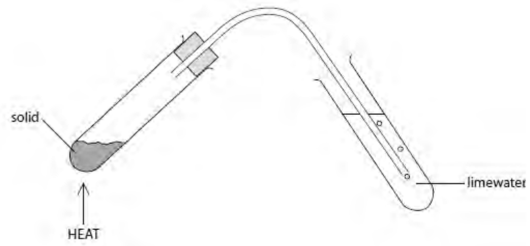
Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An explanation that makes reference to • ethanoic acid is a weak(er) acid / only partially ionised/dissociated **(1)** • (some) **energy** is used to fully/completely ionise the ethanoic acid **(1)**	Allow hydrochloric acid is a strong(er) acid/fully ionised Do not award 'more NaOH will react so more energy given off'	**(2)**

(Total Question 3 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)(i)	An answer that makes reference to the following point: • (Identity of gas is) oxygen/O_2 **and** (test result is that the splint) relights	Do not award just 'O' Allow 'rekindle'/'reignites'	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to the following point: • (Identity of gas is) nitrogen dioxide **and** (appearance is) brown (gas/fumes)	If name and formula given then both must be correct Allow NO_2 Do not award NO or N_2O_4 Do not award if liquid referred to Do not award if two gases are given unless one of the gases stated is colourless oxygen Ignore shades of colour	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(a)(iii)	• equation	<u>Example of equation</u> $2NaNO_3 \rightarrow 2NaNO_2 + O_2$ Accept multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(a)(iv)	An description that makes reference to following points: • use of a delivery tube to bubble gas into limewater **(1)** • compare the time taken for the limewater to go cloudy **(1)**	Allow annotated diagrams to illustrate the marking points Example of a diagram that could be given credit  Do not award if the apparatus setting would not be feasible such as • missing cork/bung or gaps around delivery tube • horizontal tube with limewater in • bung in the test tube with limewater Allow TE from an incorrect/unsuitable method Allow Any length of time, e.g. 10 minutes	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to	Accept reverse arguments Penalise omission of ion once only	**(3)**
	• the magnesium ion/cation is smaller (than the barium ion/cation) **(1)**	Allow magnesium ion/cation has a higher charge density Do not award reference to just atom	
	• which polarises the (large) carbonate (ion)/anion **(1)**	Accept 'which distorts the carbonate electron cloud' Do not award if molecules of carbonate are referred to	
	• and weakens the carbon-oxygen bond (C-O/C=O) bonds **(1)**	Allow 'weakens the bonds **in** the carbonate ion' Allow 'less energy needed to break the C-O bond' Do not award if the bonds referred to are the ionic bonds between the metal ion and the carbonate ion	

(Total Question 4 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	An answer that makes reference to the following point: • the two negative ions repel each other	Reference to both charge and repulsion needed	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	An explanation that makes reference to the following points: • equation with oxidation of iron(II) ions **(1)** • equation with reduction of iron(III) ions **(1)** • (catalysis is possible because) variable oxidation state/iron has more than one oxidation state/number **or** both steps now involve oppositely charged ions **(1)**	<u>Example of equations</u> $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $2Fe^{3+} + 2I^{-} \rightarrow 2Fe^{2+} + I_2$ Allow multiples Ignore state symbols even if incorrect Allow one mark if the two correct equation are given in the wrong order Allow reference to iron being oxidised and reduced Allow reference to the iron ions being positive and so not repelled	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(b)	• equation with oxidation of cobalt(II) ions • equation with reduction of cobalt(III) ions	Example of equations $2Co^{2+} + ½O_2 + 2H^+ \rightarrow 2Co^{3+} + H_2O$ $2Co^{3+} + SO_3^{2-} + H_2O \rightarrow 2Co^{2+} + SO_4^{2-} + 2H^+$ Allow multiples Ignore state symbols even if incorrect	**(2)**

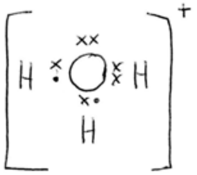
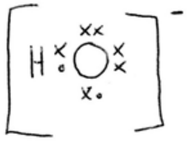
Question Number	Answer	Mark
5(c)	**The only correct answer is C** ***A*** *is not correct because only* Mn^{2+} *is an autocatalyst for this reaction* ***B*** *is not correct because only* Mn^{2+} *is an autocatalyst for this reaction* ***D*** *is not correct because only* Mn^{2+} *is an autocatalyst for this reaction*	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(d)	Tungsten • (because) adsorption is too strong and so desorption would be too slow	Ignore references to oxidation or reactivity series or cost Do not award ‘a**b**sorption’	**(1)**

(Total Question 5 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following points: • **(M1)** (a lower boiling temperature is expected) because water has fewer electrons than hydrogen sulfide **(1)** • **(M2)** water has weaker/less London forces **(1)** • **(M3)** (a higher boiling temperature occurs because) water has hydrogen bonding **(1)** • **(M4)** hydrogen bonding is stronger than London forces and requires more **energy** to break (and results in a higher boiling temperature) **(1)**	Accept water has 10 electrons but hydrogen sulfide has 18 electrons (per molecule) Ignore reference to Mr/size of atom Allow van der Waals'/dispersion forces/ instantaneous dipole-induced dipole Accept reverse arguments Ignore references to permanent dipole-dipole forces	**(4)**

Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that makes reference to the following points: • **(M1)** oxygen is more electronegative than hydrogen **and** carbon **(1)** • **(M2)** which results in a polar bond with oxygen δ− so carbon **and** hydrogen δ+ **(1)** • **(M3)** carbon dioxide is a symmetrical/linear molecule and so the dipole moments/vectors cancel **(1)** • **(M4)** the lone pairs of electrons of oxygen/ the V-shape of the water molecule mean that the dipole moments/ vectors do not cancel **(1)**	Accept supporting diagrams which illustrate the following: Accept electronegativity values stated Allow oxygen has a greater force of attraction for the bonded electron pairs than hydrogen **or** carbon Penalise the failure to refer to carbon and hydrogen once only Allow 'symmetrical so dipoles/ polar bonds cancel' Allow angular/bent for V-shape Penalise reference to just 'charges' once only in M3 and M4 if dipoles not stated or shown in the answer	**(4)**

Question Number	Answer	Additional Guidance	Mark
6(c)	Two diagrams • oxonium ion **(1)** • hydroxide ion **(1)**	Examples of suitable diagrams   Ignore inner 'shell' of two electrons Ignore missing brackets Ignore covalent circles Penalise all dots or all crosses or use of other symbols for electrons once only Penalise omission of charges once only	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	• square root of K_w at 310K to get $[H^+]$ **(1)** • calculation of pH to 2 decimal places **(1)**	<u>Example of calculation</u>: $[H^+] = (\sqrt{2.40 \times 10^{-14}}) = 1.549..\times10^{-7}$ (mol dm^{-3}) pH = ($-\log 1.549..\times10^{-7}$) = (6.809894379) = 6.81 Correct answer with no working scores (2) Allow TE from incorrect $[H^+]$ as long as answer is in the pH range 6.00 – 7.00 inclusive	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	An answer that makes reference to the following points: • **(M1)** neutral **(1)** • **(M2)** because $[H^+(aq)] = [OH^-(aq)]$ /equal amounts of H^+ and OH^- ions **(1)**	Acidic or alkaline scores (0) Allow both $[H^+]$ and $[OH^-]$ have increased equally (from 298 K to 310 K) M2 dependent on M1	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	An answer that makes reference to the following point: • positive / + sign because K_w increases as the temperature increases	Allow 'positive because' bond breaking requires energy or equilibrium shifts to the right or there is greater/more ionisation/dissociation Ignore 'endothermic'	**(1)**

(Total Question 6 = 15 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*7</td>
<td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
</table>
</td>
<td>
Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning.
For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

More than one indicative marking point may be made within the same comment or explanation
</td>
<td>(6)</td>
</tr>
</table>

	Answer is partially structured with some linkages and lines of reasoning	1	Deduct a reasoning mark if no comparison made	
	Answer has no linkages between points and is unstructured	0	Penalise the use of ‘atom’ instead of ion once only against any indicative point Ignore incorrect colours	
	Indicative content Similarities • **(IP1)** the differences in energy levels determines the colour of the flame test and complex ion		This can be mentioned separately or as a comparison	
	Differences Flame test • **(IP2) heat** (energy) results in electron promotion		Allow electrons excited by **heat**	
	• **(IP3)** return of an (excited) electron to a lower (energy) state		Allow electron is ‘de-excited’ to a lower (energy) state Do not award if d-d transitions stated	
	Complex ion • **(IP4)** d orbital**s** are split (in energy by the ligands)		Allow d subshell splitting Do not award singular “d orbital” splitting	
	• **(IP5) light** (energy) is needed for electron promotion			
	• **(IP6)** the colour not absorbed is the colour seen		Accept “The colour seen is complimentary to that absorbed” Allow ‘colour reflected is the colour seen’ Do not award if colour attributed to ‘fall’ of electron to lower energy d orbital Do not award ‘emission of light’	

(Total Question 7 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)(i)	An answer that makes reference to the following points: • identification and correction of the first error **(1)** • identification and correction of the second error **(1)**	Allow corrections to be made on the diagram Error 1 – arrow for enthalpy change of formation should go down/be reversed Error 2 – the word 'half ' should be deleted from the enthalpy change of atomisation of hydrogen	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	• calculation of first electron affinity of hydrogen	<u>Example of calculation</u> 1st EA= −(218+496+107)−56 +804 = −73 (kJ mol^{-1}) Allow a TE 1st EA = +39(kJ mol^{-1}) if the first arrow reversed direction is not identified	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td colspan="4">Penalise incorrect or missing units in (b)(i) and (b)(ii) once only</td></tr>
<tr><td>8(b)(i)</td><td>• calculation of Δ<i>G</i> (1)
• Δ<i>G</i> is negative/ <0 and so reaction is feasible (1)</td><td><u>Example of calculation</u>
$\Delta G = -56 - (298 \text{ x } \frac{-76.5}{1000})$
$= -33.203$ (kJ mol^{-1})
or
$\Delta G = -56000 - (298 \text{ x } -76.5)$
$= -33203$ (J mol^{-1})

Ignore SF except 1

Allow ≤0 and so reaction is feasible
Standalone mark
Allow TE on own Δ<i>G</i> calculated value</td><td>(2)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	• calculation of *T*	<u>Example of calculation</u> $\Delta G = 0$, so $\Delta H = T\Delta S_{(\text{system})}$ or $T = \Delta H/\Delta S_{(\text{system})}$ T = 56/0.0765 = 732 K **or** T = 56000/76.5 = 732 K **or** T = 459°C Ignore SF except 1 SF Do not award −732K TE on incorrect values penalised already in (b)(i)	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(c)	- reduction half-equation	Example of half equation $\frac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$ Allow multiples Ignore state symbols even if incorrect	**(1)**

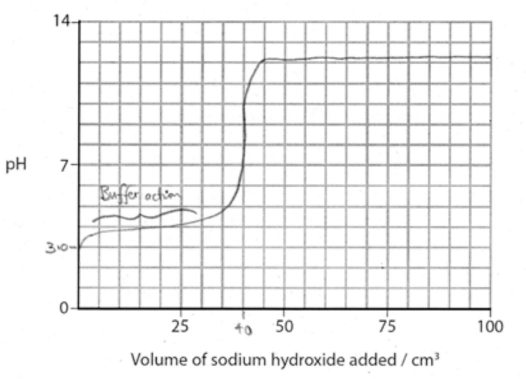
Question Number	Answer	Mark
8(d)	**The only correct answer is B** (-804, -711, -2718) ***A*** *is not correct because the lattice energy of magnesium hydride is not exothermic enough* ***C*** *is not correct because the lattice energy of potassium hydride should be less exothermic than sodium hydride and also that the lattice energy of magnesium hydride is not exothermic enough* ***D*** *is not correct because the lattice energy of potassium hydride should be less exothermic than sodium hydride*	**(1)**

(Total Question 8 = 8 marks)

Question Number	Answer	Mark
9(a)	**The only correct answer is D** (resists changes in pH if small quantities of acid or base are added) **A** *is not correct because buffer solutions can be alkaline or acidic* **B** *is not correct because buffers do not always contain equal numbers of moles of the acid and its conjugate base* **C** *is not correct because a buffer does not prevent any change in pH*	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(b)	- **(M1)** calculation of $[H^+]$ **(1)** - **(M2)** rearrangement of K_a and calculation of ethanoate concentration **(1)** - **(M3)** calculation of the number of moles of ethanoate in the buffer volume **(1)** - **(M4)** calculation of the mass of sodium ethanoate in the buffer volume **(1)** - **(M5)** answer to 2/3 SF **(1)**	Example of calculation $[H^+] = 10^{-3.9} = 1.2589.. \times 10^{-4}$ (mol dm^{-3}) $[CH_3COO^-] = (\frac{\underline{1.74 \times 10^{-5} \times 0.800}}{1.2589.. \times 10^{-4}}) =$ =0.11057.. (mol dm^{-3}) n=(0.11057.. x 0.05 =) 5.5285..x 10^{-3} (mol) m=(5.5285..x 10^{-3} x 82=) 0.453339.. m=0.45/ 0.453 (g) Award this mark only if there has been some attempt at calculation using an M_r TE at each stage If Henderson-Hasselbalch equation used **(M1)** for calculation of $pK_a = 4.759$ **(M2)** for rearrangement and calculation of ethanoate concentration Remaining marking points as above	**(5)**

Question Number	Answer	Additional Guidance	Mark
9(c)	An answer that makes reference to the following points:		**(3)**
	• carbon dioxide dissolved in the blood forms carbonic acid (and so this concentration increases) **(1)**	Can be shown in an equation Do not award ‘CO_2 reacts with H^+ to form carbonic acid’	
	• the equilibrium will shift to the right and produces more H^+/acid ions **(1)**	Allow Carbonic acid (partially) dissociates to produce H^+ Do not award ‘CO_2 reacts with H^+ so equilibrium shifts to the right to produce more $H^{+\prime}$’	
	• the (high) concentration of hydrogencarbonate ions suppress the ionisation of carbonic acid (to help to control pH) **or** the (large) reservoir/excess of hydrogencarbonate ions combine with the H^+ ions (to help to control blood pH) **(1)**		
		Ignore general comments about the effects of adding acid and/or alkali to a buffer which do not relate to carbon dioxide	

Question Number	Answer	Additional Guidance	Mark
9(d)(i)		Exemplar graph 	**(4)**
	- general shape of weak acid-strong base curve **(1)**	Ignore missing initial rise in pH Vertical part must cover 3-5 pH units between 6 – 11 The curve should reach pH~12-13 by 10cm^3 after vertical section	
	- curve starts at pH of 3.0 and ends at pH of 12-13 **(1)**	The curve must start at zero and continue to 100 cm^3	
	- vertical part of the curve at 40 cm^3 **(1)**		
	- labelling of area indicating buffer action **(1)**	Allow buffering area to be labelled anywhere between ~5 and 35 cm^3 inclusive	

Question Number	Answer	Additional Guidance	Mark
9(d)(ii)	An answer that makes reference to • determine the pH at the point when half of the acid is neutralised **(1)** • $K_a = 10^{-pH}$ / $K_a = 10^{-pK_a}$ **(1)**	Standalone marks Allow 'pH at half-equivalence point' Allow 'pH at half neutralisation point' Accept description in words such as inverse log of minus pH or value is pK_a and so inverse log of minus value gives K_a Allow $pK_a = -\log K_a$ Ignore any calculation	**(2)**

(Total Question 9 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
10(a)(i)	• **(M1)** calculation of mole fractions **(1)** • **(M2)** calculation of partial pressures **(1)** • **(M3)** expression of K_p **(1)** • **(M4)** calculation of value of K_p **(1)** • **(M5)** units **(1)**	<u>Example of calculation</u> $X_{SO_2} = 0.0160 \div 0.8 = 0.02(0)$ $X_{O_2} = 0.0120 \div 0.8 = 0.015$ $X_{SO_3} = 0.772 \div 0.8 = 0.965$ $P_{SO_2} = 0.02(0) \times 2.40 = 0.048$ $P_{O_2} = 0.015 \times 2.40 = 0.036$ $P_{SO_3} = 0.965 \times 2.40 = 2.316$ $K_p = \frac{(\boldsymbol{P}_{SO_3})^2}{(\boldsymbol{P}_{SO_2})^2 \times \mathbf{P}_{O_2}}$ Do not award square brackets $K_p = \frac{2.316^2}{0.048^2 \times 0.036} =$ $K_p = 64668.4..../6.46684.. \times 10^4$ $K_p = 65000/6.5 \times 10^4/64700/6.47 \times 10^4$ Ignore SF except 1 atm^{-1} Correct final answer without working scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	• calculation of the number of molecules	Example of calculation N=(n x L = 0.0160 x 6.02 x 10^{23}) = 9.632 x 10^{21} Ignore SF except 1SF Do not award if any units are given	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(a)(iii)	An answer that makes reference to the following points: • to ensure that K_p stays the same/ quotient stays the same **or** only temperature changes the value of K_p **(1)** • the number of (sulfur dioxide) molecules decreases **Either** because the equilibrium shifts to the right or because one of the denominators (oxygen) has increased so the other denominator (sulfur dioxide) has to decrease **(1)**	Standalone marks Allow concentration changes have no effect on the value of K_p Allow 'moles' for molecules	**(2)**

Question Number	Answer	Additional Guidance	Mark
10(b)	An explanation that makes reference to the following points: • equilibrium position shifts to the left **(1)** • (because) the hydroxide ions combine with/neutralise the H^+ ions to remove them from the equilibrium **(1)**	'Equilibrium moves to the right' scores (0) Allow Hydroxide ions react with H^+ ions to make water/ hydroxide ions react with H^+ ions to reduce their number/concentration Ignore reference to 'more products formed'	**(2)**

Question Number	Answer	Mark
10(c)	**The only correct answer is D** $K_c = \frac{[H_2O]^4}{[H_2]^4}$ **A** is not correct because the solids should not be included in the expression and the powers of the remaining substituents have been omitted **B** is not correct because the solids should not be included in the expression **C** is not correct because the powers of the substituents have been omitted	**(1)**

(Total Question 10 = 11 marks)

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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐ Candidate Number ☐☐☐☐

Tuesday 11 June 2019

Afternoon (Time: 1 hour 45 minutes)
Paper Reference **9CH0/02**

Chemistry

Advanced

Paper 2: Advanced Organic and Physical Chemistry

Candidates must have: Scientific calculator
Data Booklet
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an asterisk (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

1 This question is about some reactions of alcohols.

(a) (i) Which alcohol **cannot** be oxidised by acidified potassium dichromate(VI)?

(1)

☒ **A** hexan-2-ol

☒ **B** 2-methylpentan-2-ol

☒ **C** hexan-3-ol

☒ **D** 2-methylpentan-3-ol

(ii) Which alcohol reacts with iodine in the presence of alkali to form a yellow solid?

(1)

☒ **A** hexan-2-ol

☒ **B** 2-methylpentan-2-ol

☒ **C** hexan-3-ol

☒ **D** 2-methylpentan-3-ol

(b) Which reagent is used with iodine to prepare iodoalkanes from alcohols?

(1)

☒ **A** red phosphorus

☒ **B** concentrated phosphoric acid

☒ **C** sulfur

☒ **D** concentrated sulfuric acid

(Total for Question 1 = 3 marks)

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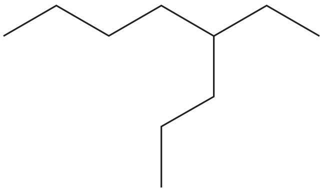
2 This question is about alkanes and their reactions.

(a) What is the IUPAC name for this alkane?



(1)

☒ **A** 4-ethyloctane

☒ **B** 5-ethyloctane

☒ **C** 3-propylheptane

☒ **D** 5-propylheptane

(b) What is the name of the process that could be used to produce propane, C_3H_8, from decane, $C_{10}H_{22}$?

(1)

☒ **A** substitution

☒ **B** reforming

☒ **C** fractional distillation

☒ **D** cracking

(c) A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.

$$C_3H_8(g) + Br_2(l) \rightarrow C_3H_7Br(l) + HBr(g)$$

(i) The first step of the reaction involves

(1)

☒ **A** heterolytic bond fission to form free radicals

☒ **B** heterolytic bond fission to form ions

☒ **C** homolytic bond fission to form free radicals

☒ **D** homolytic bond fission to form ions

(ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (c).

(2)

(iii) A source from the internet gave the percentage yield for this reaction as 31.0%. The best explanation for the low percentage yield of 1-bromopropane in this reaction is

(1)

☒ **A** bromine is very unreactive

☒ **B** a gaseous reactant always gives a low yield

☒ **C** the reaction is very slow

☒ **D** the reaction produces a mixture of organic products

(iv) Calculate the volume of propane, in dm^3, measured at room temperature and pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.
Give your answer to an appropriate number of significant figures.

[Molar gas volume at r.t.p. = $24.0\,dm^3\,mol^{-1}$]

(3)

(Total for Question 2 = 9 marks)

3 This question is about compounds of Group 5 elements.

(a) Phosphorus forms two chlorides with the formulae PCl_3 and PCl_5.

(i) Explain the shape of the PCl_3 molecule. The bond angle is not required.

(3)

(ii) Draw a diagram to show the three-dimensional shape of the PCl_5 molecule in the gas phase.

Include bond angles and the name of the shape.

(3)

(iii) Explain why phosphorus forms PCl_5 but nitrogen does not form NCl_5.

(2)

(b) Nitrogen trichloride, NCl_3, has a boiling temperature of 344 K, and nitrogen trifluoride, NF_3, has a boiling temperature of 144 K.

Explain this difference in boiling temperatures, by referring to all the intermolecular forces present.

(5)

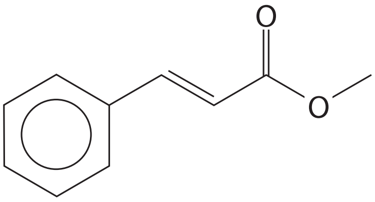
(c) Which of these compounds produces hydrogen chloride when it reacts with PCl_5?

(1)

- ☒ **A** propanal
- ☒ **B** propan-1-ol
- ☒ **C** propanone
- ☒ **D** propyl propanoate

(Total for Question 3 = 14 marks)

4 Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.



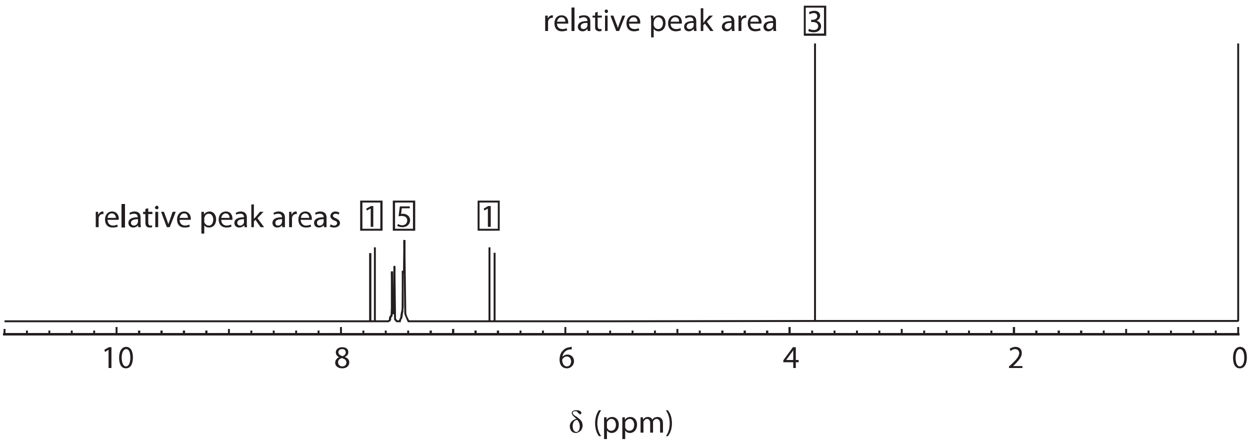
methyl cinnamate

(a) Calculate the mass of carbon in 2.34 g of methyl cinnamate.

(2)

(b) A sample of methyl cinnamate was analysed by high resolution proton NMR spectroscopy.

A simplified spectrum is shown.



(i) Name the compound responsible for the peak at a chemical shift of 0 ppm, stating its purpose.

(2)

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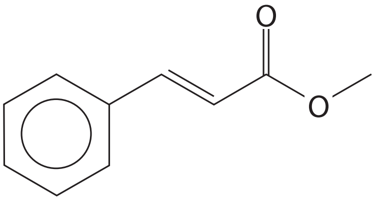
(ii) Identify the proton environment that causes the peak at a chemical shift of 3.8 ppm by circling it on the diagram shown. Fully justify your answer.

(3)



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(c) Methyl cinnamate undergoes an addition reaction in the dark with bromine.

(i) Draw the mechanism for the reaction between methyl cinnamate and bromine, Br_2.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

Turn over ▶

(ii) Deduce the number of optical isomers of the addition product that can exist.

(1)

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 8

(iii) When plane-polarised light is passed through an optical isomer, the plane of polarisation is

(1)

☒ **A** diffracted

☒ **B** reflected

☒ **C** refracted

☒ **D** rotated

(Total for Question 4 = 13 marks)

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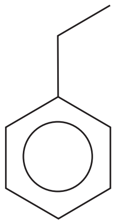
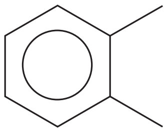
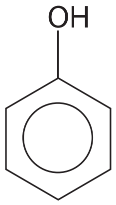
5 This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



ethylbenzene



xylene



phenol

(a) Ethylbenzene can be formed by the reaction of a chloroalkane with benzene, catalysed by aluminium chloride, $AlCl_3$.

(i) Draw the **displayed** formula of the chloroalkane required for this reaction.

(1)

(ii) Draw the mechanism for this reaction.
Include equations showing the role of the catalyst and how it is regenerated.

(5)

(iii) Explain whether phenol is likely to be less or more reactive than benzene with the chloroalkane from (a)(i).

(3)

(b) A student carried out an experiment to determine the molar mass of xylene.

The student's sample of xylene vapour had a mass of 0.271 g.

At a temperature of 165 °C and a pressure of 118 kPa, this sample had a volume of 70.5 cm^3.

Use the Ideal Gas Equation to calculate the molar mass, in g mol^{-1}, of this sample.

Give your answer to an appropriate number of significant figures.

You **must** show your working.

(4)

(c) The time taken for a compound to pass through the column in gas chromatography is called the retention time.

Explain why different compounds will have different retention times in the same column, under the same conditions.

(2)

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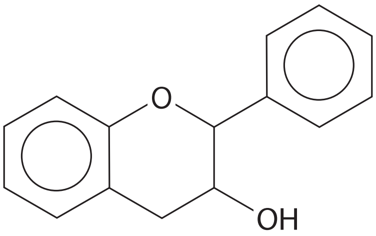
(Total for Question 5 = 15 marks)

Turn over ▶

6 The compound flavan-3-ol is found in tea, fruit and wine.



(a) Clearly label all the chiral carbon atoms in flavan-3-ol.

(1)

(b) Give the molecular formula for flavan-3-ol.

(1)

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*(c) A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.

Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell.

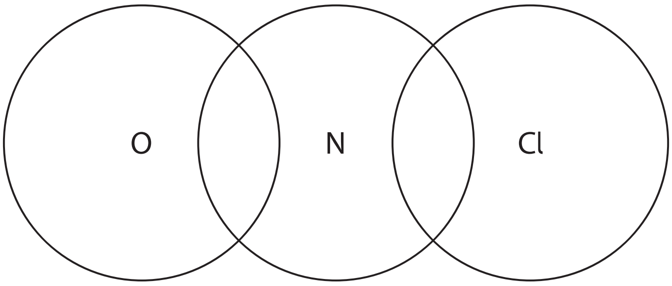
(6)

(Total for Question 6 = 8 marks)

7 Nitrogen monoxide and chlorine react together to form nitrosyl chloride.

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

(a) Draw a dot-and-cross diagram for nitrosyl chloride, showing only the outer shell electrons.



(2)

(b) The rate equation for the formation of nitrosyl chloride is

Rate = $k[NO]^2[Cl_2]$

(i) Complete the table by adding the missing values.

Experiment	[NO] / mol dm^{-3}	[Cl_2] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	0.122	0.241	1.09×10^{-2}
2		0.482	8.72×10^{-2}
3	0.366		4.91×10^{-2}

(2)

(ii) Calculate the rate constant, *k*, using data from Experiment 1.
Include units with your answer.

(3)

(iii) Explain how using a catalyst increases the rate constant, *k*.

(2)

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(iv) The heterogeneous catalyst palladium was suggested for use in this reaction. Explain how impurities in the gaseous reactants could make the catalyst less effective.

(3)

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(Total for Question 7 = 12 marks)

8 Gentian violet is a purple crystalline solid used as an antifungal treatment.

It can be synthesised from dimethylphenylamine, $C_6H_5N(CH_3)_2$.

(a) The dimethylphenylamine used in the synthesis can be made by the stepwise reaction of phenylamine with chloromethane.

Step **1** $2C_6H_5NH_2 + CH_3Cl \rightarrow C_6H_5NH(CH_3) + C_6H_5NH_3^+Cl^-$

Step **2** $2C_6H_5NH(CH_3) + CH_3Cl \rightarrow C_6H_5N(CH_3)_2 + C_6H_5NH_2^+(CH_3)Cl^-$

The reaction mechanism for Step **1** between phenylamine and chloromethane is the same as that in the reaction between ammonia and chloromethane.

(i) What is the reaction type and mechanism in Step **1**?

(1)

☒ **A** electrophilic addition

☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

☒ **D** nucleophilic substitution

(ii) Draw the mechanism for the reaction in Step **1**.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

(iii) Describe, in outline, how a sample of a solid, such as gentian violet, is purified by recrystallisation.
Specific details of the solvent used are not required.

(4)

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(b) The rate constant for the reaction between a solution of gentian violet and aqueous sodium hydroxide was determined at different temperatures.

Temperature (T) / K	1 / Temperature ($1/T$) / K^{-1}	Rate constant, k / $dm^3\,mol^{-1}\,s^{-1}$	ln k
283.5	3.53×10^{-3}	2.71×10^{-3}	–5.91
287.5	3.48×10^{-3}	3.55×10^{-3}	
291.5		4.75×10^{-3}	–5.35
295.0	3.39×10^{-3}	6.10×10^{-3}	–5.10
298.5	3.35×10^{-3}	7.60×10^{-3}	–4.88

(i) Complete the data in the table.

(1)

(ii) Plot a graph and use it to determine the activation energy for the reaction in $kJ\,mol^{-1}$.

You should include the value and units of the gradient of the line.

The Arrhenius equation can be shown as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(6)

Gradient

Activation energy

(Total for Question 8 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										(18) 4.0 **He** helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

Pearson Edexcel Advanced Level In Chemistry (9CH0) Paper 02 Advanced Organic and Physical Chemistry

Summer 2019
Publications Code 9CH0_02_1906_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)(i)	**The only correct answer is B** (2-methylpentan-2-ol) **A** *is not correct because it is a secondary alcohol* **C** *is not correct because it is a secondary alcohol* **D** *is not correct because it is a secondary alcohol*	**(1)**

Question Number	Answer	Mark
1(a)(ii)	**The only correct answer is A** (hexan-2-ol) **B** *is not correct because it is a tertiary alcohol* **C** *is not correct because it does not contain a* CH_3CHOH *group* **D** *is not correct because it does not contain a* CH_3CHOH *group*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is A** (red phosphorus) **B** *is not correct because it will not form iodoalkanes with iodine and alcohols* **C** *is not correct because it will not form iodoalkanes with iodine and alcohols* **D** *is not correct because it will not form iodoalkanes with iodine and alcohols*	**(1)**

(Total Question 1 = 3 marks)

Question Number	Answer	Mark
2(a)	**The only correct answer is A** (4-ethyloctane) *B is incorrect because the position of the ethyl group should be shown by counting in the direction that gives the lowest possible number* *C is incorrect because the longest carbon chain has 8 carbons* *D is incorrect because the longest carbon chain has 8 carbons and because the position of the alkyl group should be shown by counting in the direction that gives the lowest possible number*	**(1)**

Question Number	Answer	Mark
2(b)	**The only correct answer is D** (cracking) *A is incorrect because substitution would exchange atoms/groups in the reactant for other atoms/groups* *B is incorrect because reforming would produce branched/cyclic alkanes* *C is incorrect because fractional distillation would separate a mixture of alkanes*	**(1)**

Question Number	Answer	Mark
2(c)(i)	**The only correct answer is C (homolytic bond fission to form free radicals)** *A is incorrect because such bond fission would produce ions* *B is incorrect because the first step of the reaction produces free radicals by homolytic fission* *D is incorrect because the first step of the reaction produces free radicals*	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	122.9æ(122.9 + 80.9) x 100 **or** 122.9æ(44.0 + (2 x 79.9)) x 100 **or** (122.9æ203.8) x 100 (1) = 60.304% (1)	Allow 123æ(123+81) = 60.29% Award M1 only if final answer given as decimal 0.603 rather than % Allow TE for M2 for only one incorrect A_r value Ignore SF Correct answer with or without working scores (2)	**(2)**

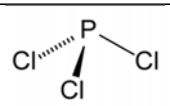
Question Number	Answer	Mark
2(c)(iii)	**The only correct answer is D** (the reaction produces a mixture of organic products) *A is incorrect because bromine is very reactive* *B is incorrect because gaseous reactants do not necessarily give a poor yield* *C is incorrect because the kinetics of the reaction do not affect the yield*	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(c)(iv)	Amount of 1-bromopropane (1) So moles of propane required (1) So volume of propane required to 2 or 3 SF (1) **Alternative route** Target mass of 1-bromopropane required to produce 14.7 g (with a 31.0% yield) (1) Moles of propane required to produce the required mass of 1-bromopropane (1) So volume of propane required to 2 or 3 SF (1)	14.7/122.9 = 0.11961 (mol) (0.11961/31) x 100 = 0.38584 (mol) = 0.38584 x 24.0 = 9.2601 (dm^3) = 9.3 / 9.26 (dm^3) Allow 14.7/123 = 0.11951 (mol) (0.11951/31) x 100 = 0.38552 (mol) = 0.38552 x 24.0 = 9.2526 (dm^3) = 9.3 / 9.25 (dm^3) $14.7 \times \frac{100}{31.0} = 47.4$ g $\frac{47.4}{122.9} = 0.3857$ (mol) 0.3857 x 24.0 = 9.3 / 9.26 (dm^3) Award (2) for a final answer of 0.890 / 0.89 (dm^3) (incorrect use of 31.0%) Answer assuming 100% yield scores (2) for final answer of 2.87 / 2.9 (dm^3) Penalise incorrect units in M3 Do not award M3 if Ideal Gas Eqtn used for propane volume Penalise incorrect rounding once only **Correct answer to 2 or 3 SF with or without working scores (3)**	**(3)**

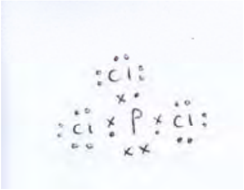
(Total Question 2 = 9 marks)

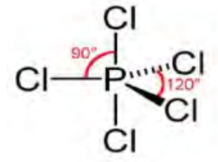
Question Number	Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to • **M1** PCl_3 is (trigonal) pyramidal (1) • **M2** has 3 bond pairs and 1 lone pair (around central P atom) (1) • **M3** electron pairs repel to positions of minimum repulsion / maximum separation (1)	Marking points 1 and 2 may be shown on diagrams (see below) Award M1 for correct name of shape even if diagram(s) incorrect Ignore lone pair – bond pair repulsions > bond pair – bond pair repulsions Answer must state or imply somewhere that (electron) pairs repel Do not award if specifically stated that 'bonds repel' or 'atoms repel' Ignore any references to bond angles even if incorrect	**(3)**

Example of diagram for award of M1 (a lone pair may also be shown on the P atom)



Example of diagram for award of M2
(must show 3 bond pairs and 1 lone pair)



Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	• **M1** Diagram showing trigonal bipyramidal shape, with 3D emphasised by use of two wedges or one hatch and one wedge in the central plane (1) • **M2** 90˚ and 120˚ angles labelled (1) • **M3** trigonal bipyramidal (1)	 M2 dependent on correct M1 Ignore 180° Do not award M2 if any incorrect bond angle is shown M3 stand alone mark Both words required Award "trigonal bipyramid"	**(3)**

Question Number	Answer	Additional Guidance	Mark
3(a)(iii)	An answer that makes reference to the following points: • phosphorus can expand its octet / can expand its (outer) shell / can accommodate more than 8 electrons / can accommodate 10 electrons / has available (3d-) orbitals (for promotion of electrons) (1) • nitrogen does not have (2)d-orbitals / can only accommodate eight electrons (in its outer shell) (1)	**Comment** Award reference to P accommodating 18 electrons Ignore comparisons of size / radius of P and N atoms	**(2)**

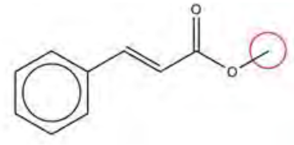
Question Number	**Answer**	**Additional Guidance**	**Mark**
3(b)	An explanation that makes reference to the following points:	Allow reverse arguments	**(5)**
	• **M1** London forces are greater in NCl_3 (1)	Award van der Waals' / induced dipole etc	
	• **M2** as NCl_3 has more electrons / as Cl (atom) has more electrons (than F atom) (1)	Award NCl_3 has 58 electrons whereas NF_3 has 34 electrons Ignore comparisons of M_r Do not award M2 if comparison of "**ionic** radii"	
	• **M3 (**permanent) dipole-dipole forces / "permanent dipoles" / "dipole forces" stronger in NF_3 (than NCl_3) (1)	Award for M3 (permanent) dipole-dipole forces only in NF_3	
	• **M4** as F is more electronegative than Cl (1)	Electronegativity difference 1.0 between N and F / No electronegativity difference between N and Cl / N-F is a more polar bond than N-Cl	
	• **M5** **either** London forces predominate / London forces are more significant **or** more (heat) energy needed to overcome the intermolecular forces between NCl_3 molecules (than NF_3 molecules) (1)	Award (0) for M5 if any mention of: Ionic bonds breaking in either NF_3 or NCl_3 **Breaking of** N-F and / or N-Cl covalent bonds scores (0) for M5 Note If hydrogen bonding mentioned, can only award M1, M2 and M5 max Ignore polarisation of ions	

Question Number	Answer	Mark
3(c)	**The only correct answer is B** (propan-1-ol) **A** *is not correct because it does not give hydrogen chloride when* PCl_5 *is added* **C** *is not correct because it does not give hydrogen chloride when* PCl_5 *is added* **D** *is not correct because it does not give hydrogen chloride when* PCl_5 *is added*	**(1)**

(Total Question 3 = 14 marks)

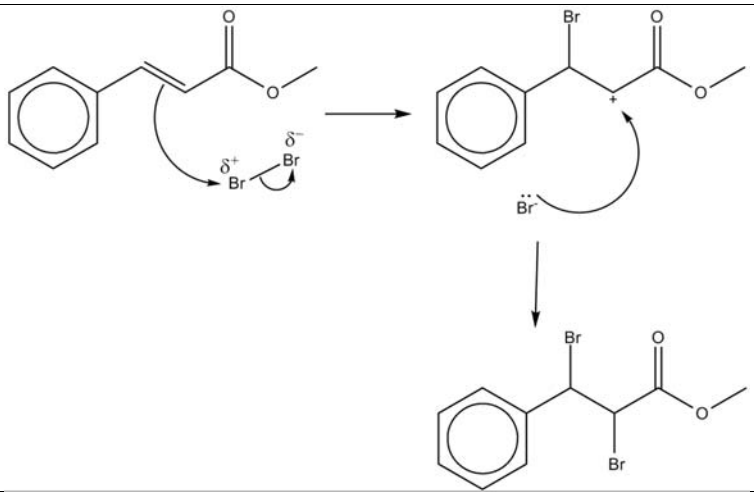
Question Number	Answer	Additional Guidance	Mark
4(a)	- calculation of molar mass of methyl cinnamate (1) - calculation of mass of carbon (1)	Example of calculation molar mass = 162 (g mol^{-1}) 2.34 x (120/162) = 1.73333 = 1.73 (g) TE on incorrect molar mass for M2 **Correct answer with no working scores 2 marks** Ignore SF except 1	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that makes reference to the following points: - peak due to tetramethylsilane (1) - so (chemical) shifts (due to other hydrogen atoms) can be compared (1)	Allow TMS / $Si(CH_3)_4$ Name must be correct if given Allow “a reference” / “a standard” “calibration” Ignore “to allow other molecules to be compared”	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points: • **M1** circle around –CH_3 group in -OCH_3 (1) • **M2** singlet as no neighbouring hydrogen atoms (1) • **M3** peak area of 3 means there are 3 hydrogen atoms in this environment (1)	Allow 'protons' for hydrogen atoms  Award whole -OCH_3 circled Do not award if C=O included in circle M1 is a stand alone mark Award "has no adjacent hydrogen atoms" Award "no hydrogens on adjacent carbon" Ignore "there is no adjacent C atom" Award "(relative) peak area of three for a –CH_3 group" For M3 must relate to (relative) peak area / integral Ignore references to chemical shift value for ester δ = 3.0 to 4.0 (ppm) Ignore references to relative heights of peaks **Comment** M2 and / or M3 dependent on -CH_3 group being included in the circled group	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	• **M1** arrow from double bond to (δ+)Br in Br_2 (1) • **M2** arrow from bond in Br_2 to $Br^{\delta-}$ (1) • **M3** structure of carbocation (1) • **M4** arrow from **lone pair** on Br^- to C^+ in carbocation **and** final product (1)	Example of mechanism **See below** Penalise lack of dipole only once in M1 and M2 Award C^+ in intermediate on either C from the double bond Do not award M3 if four bonds are shown on carbocation Br atoms can be shown either upwards or downwards in final product Award (0) if just electrophilic substitution mechanism given. If **both** electrophilic substitution and addition shown allow 2 max Penalise errors in structure of methyl cinnamate once only in either M3 or M4 Do not award **M4** if the two Br atoms have been added to the same carbon atom in the addition product Penalise use of half arrows once only	**(4)**

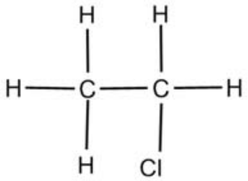
Example of mechanism

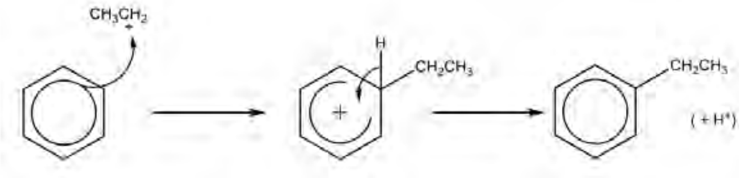


Question Number	Answer	Mark
4(c)(ii)	**The only correct answer is C** (4) **A** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms* **B** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms* **D** *is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms*	**(1)**

Question Number	Answer	Mark
4(c)(iii)	**The only correct answer is D** (rotated) **A** *is not correct because diffracted is the wrong term* **B** *is not correct because reflected is the wrong term* **C** *is not correct because refracted is the wrong term*	**(1)**

(Total Question 4 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)		Do not award skeletal or structural formulae	**(1)**

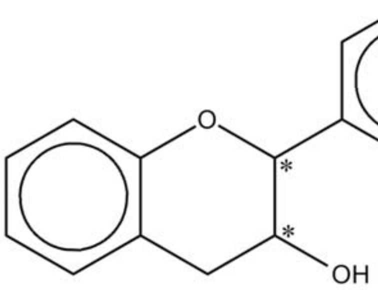
Question Number	Answer	Additional Guidance	Mark
5(a)(ii)		<u>Example of mechanism</u> Penalise incorrect halogenoalkane in (a)(i) only	**(5)**
	- **M1 equation** to show formation of electrophile (1)	$CH_3CH_2Cl + AlCl_3 \rightarrow CH_3CH_2^+ + AlCl_4^-$ Ignore any curly arrows given in the equation	
	- **M2** curly arrow from anywhere on the central ring to positive carbon (1)	Allow curly arrow from anywhere within the hexagon Do not award if curly arrow to CH_3 carbon in $CH_3CH_2^+$ Do not award if curly arrow to $C_2H_5^+$	
	- **M3** structure of intermediate (1)	Horseshoe facing the tetrahedral carbon and covering at least three carbon atoms Some part of the positive charge in the horseshoe Do not award dotted lines unless clearly part of a 3D structure	
	- **M4** curly arrow from C-H bond to reform the ring (1)		
	- **M5 equation** showing regeneration of catalyst (1)	$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$ Ignore regeneration step if part of the mechanism **Mechanism**  Allow TE from (a)(i)	

Question Number	**Answer**	**Additional Guidance**	**Mark**
5(a)(iii)	An explanation that makes reference to the following points: Phenol is likely to be more reactive because		**(3)**
	• **M1 lone pair** on **oxygen** (atom of –OH group) delocalises / is incorporated into the (benzene) ring / donated to the ring (1)		
	• **M2** which increases the electron density (of the ring) (1)	Do not award M2 if mention of “charge density” / “electronegativity” Ignore references to “the ring becomes more negative”	
	• **M3** making the ring / phenol more susceptible to electrophilic attack (1)	Award “making the ring more nucleophilic” / “making the ring more susceptible to attack by a positive ion” Ignore references to “activation of the ring ”	

Question Number	Answer	Additional Guidance	**Mark**
5(b)		Example of calculation	**(4)**
	• **M1** conversion of pressure and temperature (1)	118 000 (Nm^{-2}) and 438 (K)	
	• **M2** conversion of volume units (1)	70.5×10^{-6} / 7.05×10^{-5} (m^3)	
	• **M3** rearrangement of gas equation and calculation of *n* (1)	$n = \frac{pV}{RT}$ $n = \frac{(118000 \times 70.5 \times 10^{-6})}{(8.31 \times 438)}$ $n = 2.2855777 \times 10^{-3}$ (mol)	
	• **M4** calculation of the molar mass with the final answer given to **2 or 3 SF** (1)	$\frac{0.271}{2.2855777 \times 10^{-3}}$ = 118.5696 = 119 / 120 (g mol^{-1}) If use $M_r = \frac{mRT}{pV}$ (since $n = \frac{m}{M_r}$) can score both **M3 and M4** $M_r = \frac{0.271 \times 8.31 \times 438}{118\,000 \times 70.5 \times 10^{-6}}$ M_r = 118.5695 M_r = 119 / 120 (g mol^{-1}) Award TE at each stage Ignore units even incorrect	

Question Number	Answer	Additional Guidance	Mark
5(c)	An explanation that makes reference to the following points: EITHER • retention time depends on the polarity **or** attraction / affinity / solubility / of the component for the stationary phase (1) • The greater attraction / affinity / solubility / of the component for the stationary phase the greater the retention time (1) OR • retention time depends on the boiling temperature of the compound (1) • higher boiling temperature compounds spend less time in the gas phase / mobile phase so have longer retention time (1)	Allow 'solid phase' or 'liquid phase' for 'stationary phase' Allow 'retention time depends interaction with stationary phase' Ignore attractions to the mobile / gas phase Ignore comments related to mass of compounds	**(2)**

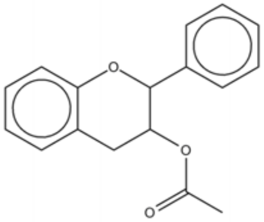
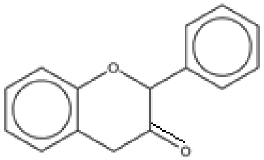
(Total Question 5 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)			**(1)**

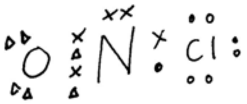
Question Number	Answer	Additional Guidance	Mark
6(b)	$C_{15}H_{14}O_2$	Allow symbols in any order e.g. $H_{14}O_2C_{15}$	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*6(c)</td>
<td>
<p>This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p>
<p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p>
<p>The following table shows how the marks should be awarded for indicative content.</p>
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
<p>The following table shows how the marks should be awarded for structure and lines of reasoning</p>
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
</table>
</td>
<td>
<p>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning.
For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).</p>
<p>Typically</p>
<table>
<tr><th>Number of IPs</th><th></th><th>Reasoning mark</th></tr>
<tr><td>6 or 5</td><td>scores</td><td>2</td></tr>
<tr><td>4 or 3</td><td>scores</td><td>1</td></tr>
<tr><td>2 or 1 or 0</td><td>scores</td><td>0</td></tr>
</table>
</td>
<td>(6)</td>
</tr>
</table>

Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

	Indicative content • **IP1** any mention of **oxidation** of ethanol **or oxidation** of flavan-3-ol (by oxygen in the air) • **IP2** for formation of **either** ethanoic acid **or** ethanal (from ethanol) • **IP3** for formation of ethyl ethanoate (from the reaction between ethanol and ethanoic acid) • **IP4** for structure / name of flavan-3-one • **IP5** for (-OH group on) flavan-3-ol forms an ester with ethanoic acid • **IP6** correct structure of the ester formed between flavan-3-ol and ethanoic acid  **This is the structure of the ester formed between flavan-3-ol and ethanoic acid**	Allow names or formulae **but** if both are given **both** must be correct  **Comment** For correct structure of the ester formed between flavan-3-ol and ethanoic acid award both **IP5** and **IP6** Do not award IP4 if the product is described as an aldehyde	

(Total Question 6 = 8 marks)

Question Number	**Answer**	**Additional Guidance**	**Mark**
7(a)	• electrons for double bond, single bond and lone pair around N (1) • rest of electrons on Cl and O (1)	Example of dot-and-cross diagram  Allow any combination of dots/crosses/triangles for electrons Allow bond pairs in double bond shown horizontally Ignore lines drawn between atoms to show covalent bonds	**(2)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
7(b)(i)	• concentration of NO in experiment 2 (1) • concentration of Cl_2 in experiment 3 (1)	Example of calculation 0.244 0.121 Do not award 0.1205 **Both** values must be to **3SF**	**(2)**

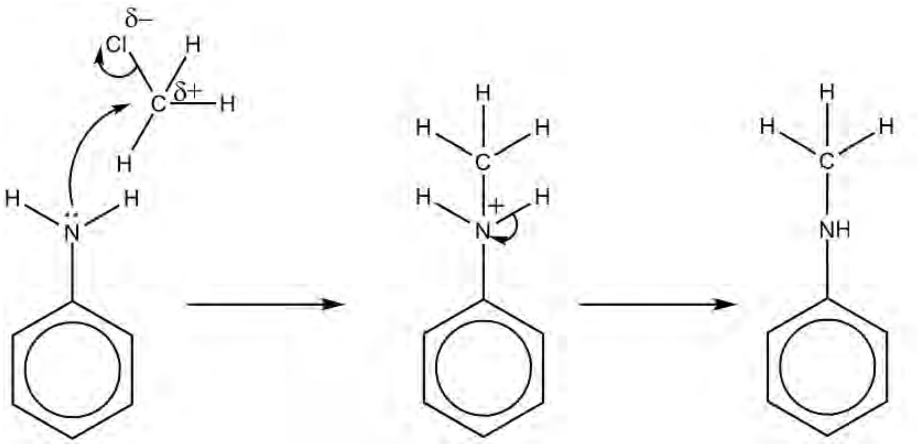
Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	- **M1** rearrangement of rate equation to find *k* (1)	Example of calculation $k = \frac{\text{rate}}{[\text{NO}]^2[\text{Cl}_2]}$	**(3)**
	- **M2** calculation of *k* (1)	$\frac{1.09 \times 10^{-2}}{(0.122 \times 0.122 \times 0.241)}$ =3.03871 = 3.04 Ignore SF Correct numerical answer for *k* scores both M1 and M2	
	- **M3** correct units for *k* (1)	$\text{dm}^6\ \text{mol}^{-2}\ \text{s}^{-1}$ Allow units in any order M3 stand alone mark	

Question Number	Answer	Additional Guidance	Mark
7(b)(iii)	An explanation that makes reference to the following points: *k* increases because • the catalyst provides an alternative pathway of lower activation energy (1) • so a greater proportion of molecules / more molecules have energy greater than the activation energy (so faster reaction) (1)	Award 'particles' instead of 'molecules' Do not award "atoms" instead of 'molecules'	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(b)(iv)	An explanation that makes reference to the following points: Catalysts will be less effective because		**(3)**
	• **M1** impurities **ad**sorb onto (catalyst) surface **or** impurities occupy active sites **or** impurities bond / bind to (catalyst) surface (1)	Do not award "**ab**sorb" for M1 Ignore impurities "react"	
	• **M2** impurities prevent bond weakening in the reactants **or** less surface area (of catalyst) / fewer active sites available for reaction (1)	Allow 'no active sites available'	
	• **M3** impurities form strong bonds (to surface) **or** impurities less likely to desorb (from surface) (1)	Allow 'impurities remain on surface'	

(Total Question 7 = 12 marks)

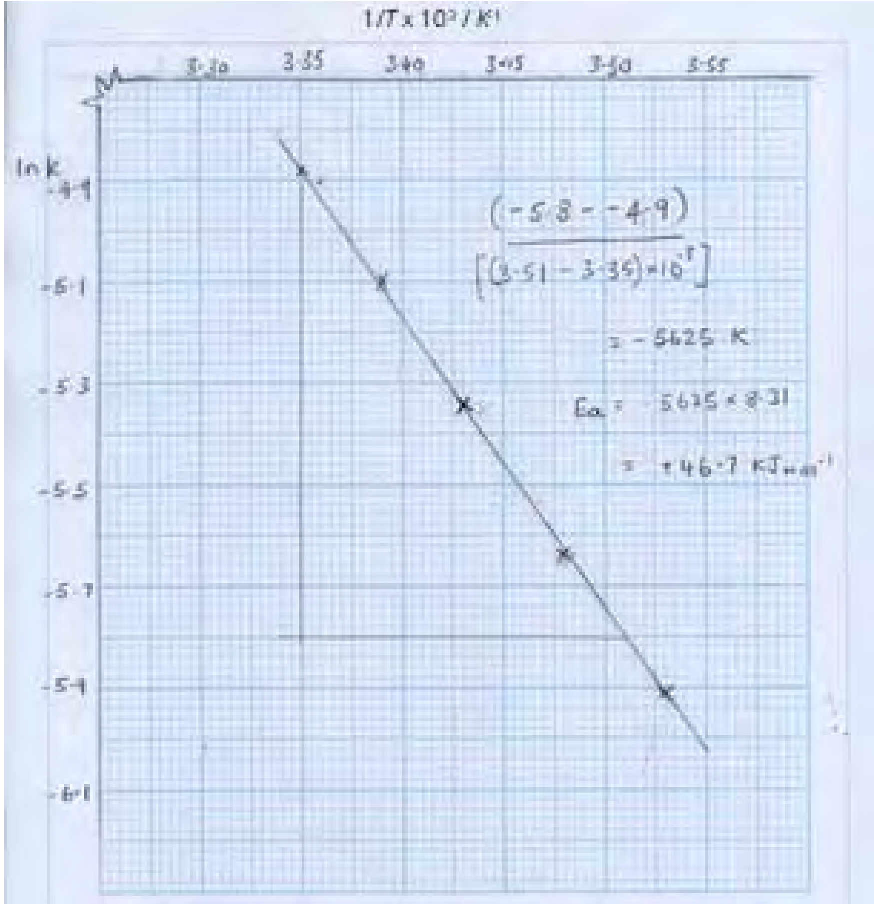
Question Number	Answer	Mark
8(ai)	**The only correct answer is D** (nucleophilic substitution) **A** *is not correct because it is not electrophilic or addition* **B** *is not correct because it is not electrophilic* **C** *is not correct because it is not addition*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	- **M1** arrow from lone pair on nitrogen atom to carbon atom (1) - **M2** dipole shown **and** arrow from C–Cl bond to Cl or just beyond (1) - **M3** formula of intermediate including the **+** charge on the N atom (1) - **M4** arrow from N-H bond to N$^+$ and formula of organic product (1)	Example of mechanism  (+ H$^+$ / HCl) **Comment** M2 is a stand alone mark Allow access to full marks for correct use of other halogenomethanes Ignore any SN2 transition states Ignore use of a second molecule of phenylamine behaving as a base	**(4)**

Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	An answer that makes reference to the following points: • **M1** dissolve (impure product) in a **minimum** volume of **hot** solvent (1) • **M2** cool (in ice) **or** leave to recrystallise (1) • **M3** filter using vacuum filtration / Buchner filtration / filter under suction (1) • **M4** dry solid in desiccator / between filter papers (1)	Allow any named solvent Ignore hot filtration after M1 Allow dry in a **warm** oven Ignore references to rinsing Do not award M4 if drying agent added to the crystals / solution	**(4)**

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	• calculation of missing 1/*T* value **and** calculation of missing ln *k* value	Example of calculation 3.43×10^{-3} -5.64 Ignore SF	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)		Example of calculation and graph	**(6)**
	• **M1** axes correct way round and labelled with units on *x*-axis (1)	award 1/T x 10^{3} / K^{-1} **or** 1/T / 10^{-3} K^{-1} or 1/T / K^{-1} (10^{-3}) Do not award 1/T x 10$^{\mathbf{-3}}$ / K^{-1} Do not award **M1** if units given for ln *k* on *y*-axis Do not award small "t" for "T"	
	• **M2** suitable scale, must be uniform (1)	Points must cover at least half the graph paper in each direction	
	• **M3** all points plotted correctly, with straight line of best fit (1)		
	• **M4** calculation of gradient, including minus sign (1)	-5775 (± 400) Award gradient value between -5375 to -6175	
	• **M5** units of gradient (1)	**K**	
	• **M6** calculation of activation energy with units (1)	(+)48.0 / (+)48 kJ mol^{-1} ; allow TE for gradient outside range Award E_a values (+)44.7 to (+)51.3 kJ mol^{-1} Award E_a if correct in J mol^{-1} Do not award M6 if given in just "kJ" or "J" Ignore SF Do not award M6 if final answer is a negative E_a value See next page for graph	
	Comment If ln*k* plotted with most negative value at the top or -ln*k*, then all marks can still be scored, but gradient should still be negative	**Comment** If 1/*T* (*y*-axis) plotted against ln *k* (*x*-axis) Can only award **M2, M3** and TE for **M4** If either or both variables incorrect, then only **M2** can be scored	

		Example of suitable graph and gradient  	

(Total Question 8 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

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Candidate surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐ Candidate Number ☐☐☐☐

Wednesday 19 June 2019

Morning (Time: 2 hours 30 minutes)

Paper Reference **9CH0/03**

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Candidates must have: Scientific calculator
Data Booklet
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about acids and bases.

(a) State what is meant by a Brønsted-Lowry acid.

(1)

....

(b) Identify the acid-base conjugate pairs in this reaction.

(1)

$$CH_3COOH \quad + \quad HCOOH \quad \rightarrow \quad CH_3COOH_2^+ \quad + \quad HCOO^-$$

....

(c) Write the expression that defines the pH of a solution.

(1)

(d) Calculate the concentration of hydrogen ions, in mol dm^{-3}, in a solution with a pH of 2.76

(1)

(e) Explain why the pH of a 1×10^{-8} mol dm^{-3} solution of nitric acid, HNO_3, is not 8.

[Ionic product of water, $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}]

(2)

(Total for Question 1 = 6 marks)

Turn over ▶

2 This question is about the $Ag^+(aq)|Ag(s)$ half-cell.

(a) A student was asked to plan an experiment to measure the standard electrode potential of the $Ag^+(aq)|Ag(s)$ half-cell.

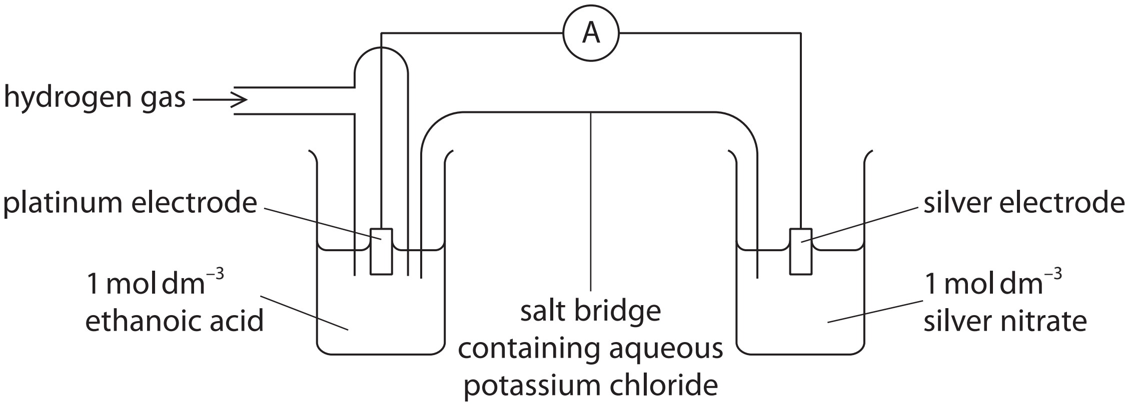
(i) State the conditions of temperature and pressure under which standard electrode potentials are measured.

(1)

....

....

(ii) The student drew the diagram shown.



Identify **three** mistakes in this diagram and the modifications that should be made to correct them.

(3)

Mistake in diagram	Modification needed to correct mistake

(b) The standard electrode potential, $E^{\ominus}$, of the $Ag^+(aq)|Ag(s)$ half-cell is +0.80 V.

The effect of changing the concentration of the ions on the value of the electrode potential, E, in this half-cell is calculated using the equation

$$E = E^{\ominus} + \frac{RT}{96500} \times \ln[Ag^+(aq)]$$

where T is the temperature in kelvin and R is the gas constant.

The electrode potential of a $Ag^+(aq)|Ag(s)$ half-cell was measured at 20 °C and found to be +0.72 V.

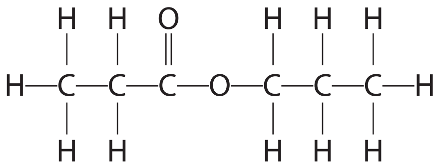
Calculate the concentration of silver ions, in mol dm^{-3}, in this half-cell.

(3)

(Total for Question 2 = 7 marks)

3 This question is about esters with the molecular formula $C_6H_{12}O_2$.

(a) Propyl propanoate has the structure shown.



Devise a synthetic pathway to prepare propyl propanoate starting with 1-bromopropane as the **only** organic compound.

Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

(5)

(b) Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed. It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

....

....

....

....

....

....

(Total for Question 3 = 8 marks)

4 Compound **C** is a pink crystalline solid containing two cations and one anion.

(a) Three tests were carried out on **C**. The observation made for each test was recorded in the table.

(i) Complete the statements in the inference column by writing the names or formulae of the species.

(6)

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid **C** and the mixture warmed The gas evolved was tested with damp red litmus paper	The red litmus paper turned blue	The gas evolved was .... One of the cations in **C** is ....
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of **C**	The pink solution turned blue	The other cation in **C** is .... The formula of the complex ion in the blue solution is ....
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of **C**	A white precipitate formed	The white precipitate is .... The anion in **C** is ....

(ii) Use the results of the tests in (a)(i) to give a formula of **C**.
Do not include water of crystallisation.

(1)

....

(b) Write the **ionic** equation for the reaction between the cation in **C** and sodium hydroxide producing the gas in **Test 1**.
State symbols are not required.

(1)

(c) State the type of reaction occurring in **Test 2**.

(1)

....

(d) Give a reason why dilute hydrochloric acid is needed in **Test 3**.

(1)

....

....

....

....

(Total for Question 4 = 10 marks)

5 This question is about redox reactions.

(a) Name the ion with formula PO_3^{3-}. Include the relevant oxidation number.

(1)

....

(b) State what happens to a reducing agent during a reaction, in terms of oxidation number **and** electrons.

(1)

....

....

(c) Identify the species that is the strongest reducing agent from the list of standard electrode potentials in the Data Booklet.

(1)

....

(d) Manganese(IV) oxide, MnO_2, and manganate(VII) ions, MnO_4^-, react in alkaline solution to form manganate(VI) ions, MnO_4^{2-}.

(i) Write the **ionic** equation for this reaction.
State symbols are not required.

(2)

(ii) Give a reason why this reaction is **not** disproportionation.

(1)

....

....

....

....

(e) Sodium tetrahydridoborate(III), $NaBH_4$, is used in organic chemistry. It is an alternative reagent to lithium tetrahydridoaluminate(III) for the reduction of carbonyl compounds.

(i) Draw a dot-and-cross diagram of the BH_4^- ion.

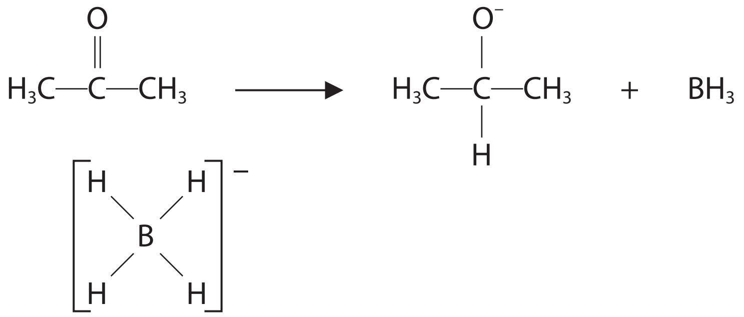
Use crosses (×) for the boron electrons, dots (•) for the hydrogen electrons and triangles (△) for the additional electron forming the negative ion.

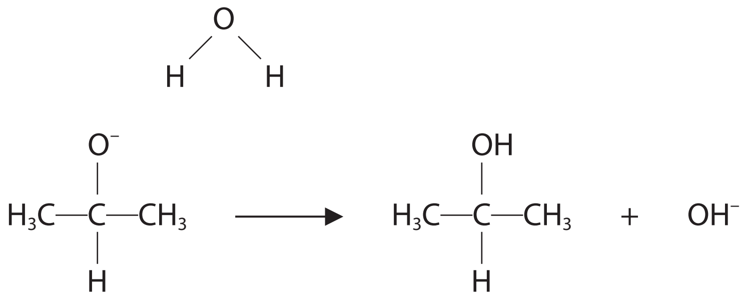
(1)

(ii) The BH_4^- ions reduce carbonyl compounds to alcohols in aqueous solution.

Complete the mechanism for the reduction of propanone to propan-2-ol by adding curly arrows, and any relevant lone pairs and dipoles.

(4)





(Total for Question 5 = 11 marks)

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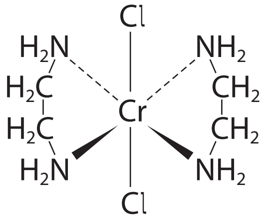
6 This question is about transition metals and their ions.

(a) The **shape** of a complex ion formed from Cr^{3+} ions is shown.



(i) State the coordination number of Cr^{3+} in this complex ion.

(1)

....

(ii) State the overall charge on this complex ion.

(1)

....

(b) The complex ions of transition metals have different colours in aqueous solution.

Two factors that affect the colour of the solution are the oxidation number of the central metal ion, and the ligands present.

Give examples to illustrate these factors by referring to complex ions of iron and/or copper. Include the formula and colour of each complex.

An explanation of why transition metal ions are coloured is **not** required.

(3)

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(c) Tungsten wire catalyses the decomposition of ammonia.

$$2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$$

In an experiment, the following results were obtained.

Time /s	Partial pressure of ammonia / kPa
0	0.350
100	0.335
200	0.319
300	0.303
400	0.287
500	0.271

(i) Plot a graph of partial pressure of ammonia against time.

(2)

(ii) Deduce the rate equation for this reaction by using your graph in (c)(i). Justify your answer.

(2)

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(iii) Use the graph to calculate the rate constant. Include units in your answer.

(2)

(iv) Describe the stages in the catalytic decomposition of ammonia by tungsten.

(3)

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(Total for Question 6 = 14 marks)

7 A group of students analysed a hydrated salt with the formula $KH_3(C_2O_4)_{\mathbf{y}}.\mathbf{z}H_2O$ where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

(a) **Experiment 1** – to determine the value of **y**

One student was provided with a 0.0235 mol dm^{-3} solution of the salt.

25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.

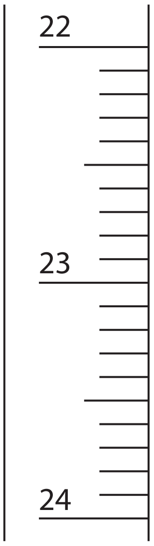
Each portion was titrated with 0.0203 mol dm^{-3} potassium manganate(VII).

The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



(ii) Explain why this student should use a mean titre of 23.15 cm^3 and not 23.43 cm^3 in the calculation.

(2)

....

....

....

....

(iii) The uncertainty in each burette reading is ±0.05 cm^3.

Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

(iv) The equation for the reaction is

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $KH_3(C_2O_4)_{\mathbf{y}}.\mathbf{z}H_2O$.

Use the mean titre of 23.15 cm^3 and other data from **Experiment 1**.

You **must** show your working.

(4)

Turn over ▶

(b) **Experiment 2** – to determine the value of **z**

Another student wrote an account of the method for this experiment.

A crucible was weighed.

A sample of the hydrated salt was added to the crucible and it was reweighed.

The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.

The crucible and contents were weighed again.

Results

Mass of crucible = 19.56g

Mass of crucible + $KH_3(C_2O_4)_y.zH_2O$ = 22.97g

Mass of crucible + $KH_3(C_2O_4)_y$ = 22.52g

(i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the formula $KH_3(C_2O_4)_y.zH_2O$.

You must use the data from **Experiment 2** and your value of **y** in (a)(iv).

You **must** show your working.

(3)

(ii) A third student carried out Experiment 2 and calculated a value of **z** that was lower than expected.

This student evaluated the experiment and gave two suggestions for **z** being lower.

Suggestion **1**
"Some of the crystals jumped out of the crucible while it was being heated."

Suggestion **2**
"It was difficult to tell when all the water of crystallisation had been lost."

Evaluate these two suggestions to decide whether they could account for the lower value of **z** obtained from the experimental results.

Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

(5)

(Total for Question 7 = 17 marks)

Turn over ▶

8 1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.

$$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

(a) The steps for the preparation of impure 1-bromobutane are summarised.

Step **1** Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 cm^3 of butan-1-ol.

Step **2** Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.

Step **3** Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.

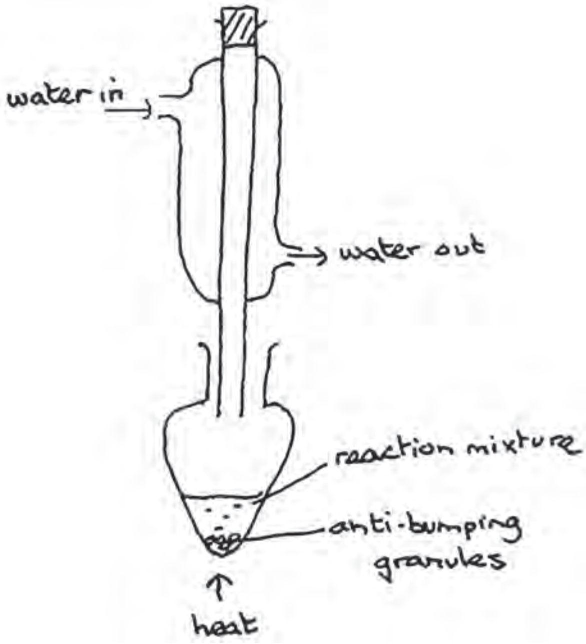
Step **4** Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.

Step **5** Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

(i) Parts of the method are given in **bold** type in Steps **2**, **3** and **4**.
Give a reason why each of these parts is necessary.

(3)

(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**. There are three errors in the apparatus shown in the diagram. Assume the apparatus is suitably clamped.



Identify the three errors, including the effect of each error.

(3)

(iii) The student corrected the errors.
While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.

Explain why the brown vapour forms.

(2)

(b) The distillate collected in Step **5** is a mixture consisting of two layers.
There is an aqueous layer and a layer containing impure 1-bromobutane.

Data

Densities:

water	1.00 g cm^{-3}
butan-1-ol	0.81 g cm^{-3}
1-bromobutane	1.27 g cm^{-3}

Boiling temperature of 1-bromobutane = 102 °C

The steps for the purification of the 1-bromobutane are summarised.

Step **6** Transfer the mixture from Step **5** to a separating funnel and remove the aqueous layer.

Step **7** Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel. Remove the aqueous layer.

Step **8** Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.

Step **9** Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.

Step **10** Collect the 1-bromobutane layer from Step **9** in a small conical flask. Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.

Step **11** Decant the 1-bromobutane into a clean pear-shaped flask and redistil it. Measure the volume of 1-bromobutane produced.

(i) State the position of the aqueous layer in the separating funnel at the start of Step **6**. Justify your answer.

(1)

....

....

(ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in the mixture in Step **7**.

Give the reasons for carrying out Steps **8**, **9** and **10**.

(3)

....

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(iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step **11**.

(1)

....

(iv) The volume of 1-bromobutane collected was 12.0 cm^3.

Calculate the number of molecules of 1-bromobutane produced in this experiment.

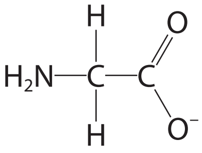
Give your answer to an appropriate number of significant figures.

(2)

(Total for Question 8 = 15 marks)

9 Some organic compounds contain metals.

(a) Glycinate ions are formed from the amino acid glycine.



glycinate ion

(i) Explain the effect, if any, of an aqueous solution containing glycinate ions on plane-polarised monochromatic light.

(2)

(ii) A hot aqueous solution of glycine is added to a hot solution of copper(II) ethanoate.
When the mixture is cooled, crystals of copper(II) glycinate are formed.

Write the equation for this reaction.
State symbols are not required.

(2)

(iii) In an experiment, the crystals are filtered, weighed and the percentage yield calculated.

Student **1** obtained a yield of 102.6%.

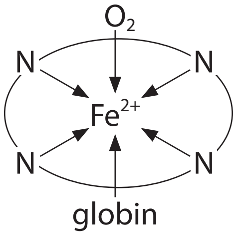
Student **2** obtained a yield of 56.4%.

The expected yield is 82% and the students carried out the calculation correctly.

Discuss possible reasons for the yields obtained by these students.

(4)

(b) Haemoglobin is an iron(II) complex. It carries oxygen around the body.
Part of the structure of haemoglobin is shown.



The four nitrogen atoms are part of a multidentate ligand in the haem group.

Explain why inhaling carbon monoxide can be fatal.

(2)

Turn over ▶

*(c) Grignard reagents contain a metal.

Discuss how Grignard reagents are formed and used in adding one or more carbon atoms to the carbon chain in 1-bromopropane to produce primary, secondary and tertiary alcohols and a carboxylic acid.

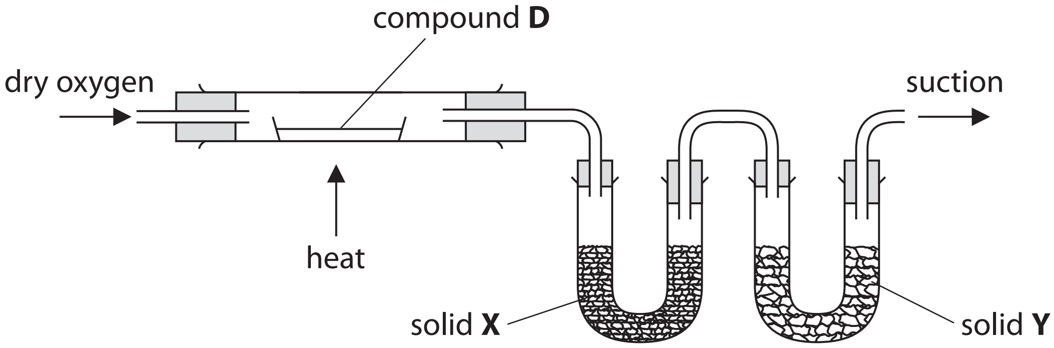
Include a suitable example for each reaction and give reagents, conditions and products. You may include equations in your answer.

(6)

(Total for Question 9 = 16 marks)

10 Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

(a) A sample of **D** was burned completely in the apparatus shown.
Solid **X** absorbed the water formed in the combustion.
Solid **Y** absorbed the carbon dioxide.



(i) The masses of solids **X** and **Y** increased during the experiment.

Explain the effect, if any, on the changes in mass of **X** and **Y** if the oxygen gas was not dry.

(3)

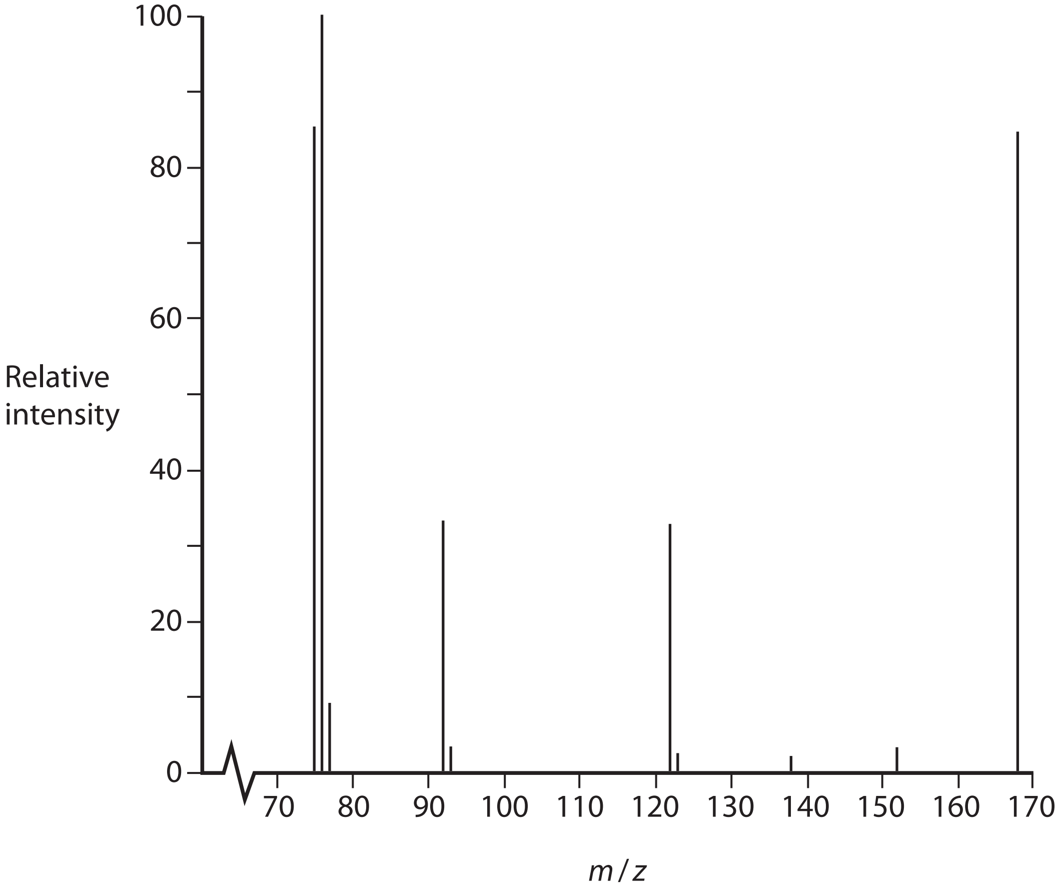
(ii) On combustion in dry oxygen, 3.36 g of **D** produced 0.72 g of water and 5.28 g of carbon dioxide.
This sample of **D** also contained 0.56 g of nitrogen.

Use these data to calculate the empirical formula of compound **D**.

You **must** show your working.

(5)

(b) Part of the mass spectrum of **D** is shown.



Deduce the molecular formula of **D**. Justify your answer.

(2)

(c) Compound **D** contains a benzene ring.

(i) Give the molecular formula of the species that causes the peak at $m/z = 76$ in the mass spectrum of **D**.

(1)

(ii) Draw the structures of the **three** possible isomers of **D** containing a benzene ring.

(2)

(iii) The ^{13}C NMR spectrum of compound **D** has four peaks.

Identify the structure of **D**. Justify your answer by labelling the different carbon environments in **all** the structures drawn in (c)(ii).

(3)

(Total for Question 10 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						
* Lanthanide series			140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71	
* Actinide series			232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103	

Mark Scheme (Results)

Summer 2019

Pearson Edexcel Advanced Level In Chemistry (9CH0) Paper 03 General and Practical Principles in Chemistry

Summer 2019
Publications Code 9CH0_03_1906_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

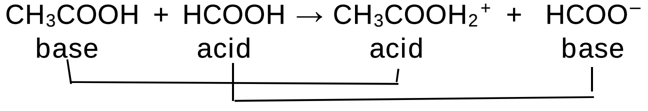
Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)	• (a Brønsted-Lowry acid is a) proton donor	Allow donates / gives away protons / H^+ (ions) / hydrogen ions Allow releases / loses protons / H^+ / hydrogen ions Do not award 'donates H_3O^+ (ions)'	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)	• correct acid-base pairs identified **and** linked	<u>Examples of acid-base pairs</u> $CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$ base 2/B2 acid 1/A1 acid 2/ A2 base 1/B1 **or** $CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$ base acid acid base **or** $CH_3COOH + HCOOH \rightarrow CH_3COOH_2^+ + HCOO^-$ base / B acid / A conjugate acid / CA conjugate base / CB Allow any clear identification of acid and base **and** connection between the correct pairs	**(1)**

Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
1(c)	- (pH =) –log$[H^+(aq)]$ **or** (pH =) –log$[H_3O^+(aq)]$	Allow $\log_{10}$ / lg for log Ignore missing (aq) Do not award –log conc H^+ Do not award round brackets / no brackets for concentration but allow round brackets around the square brackets e.g. –log($[H^+(aq)]$)	**(1)**

Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
1(d)	- calculation of $[H^+(aq)]$	<u>Example of calculation</u> $[H^+(aq)] = 10^{-pH} = 10^{-2.76}$ $= 1.7378 \times 10^{-3}$ / 1.738×10^{-3} / 1.74×10^{-3} / 1.7×10^{-3} / 0.0017378 / 0.001738 / 0.00174 / 0.0017 (mol dm^{-3}) Ignore units even if incorrect Correct answer to 2 or more SF with no working scores (1)	**(1)**

Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
1(e)	An explanation that makes reference to the following points: • $[H^+]$/ $[H_3O^+]$/ concentration of hydrogen ions from water is $1(.0) \times 10^{-7}$ (mol dm^{-3}) **(1)** • so total $[H^+]$ is greater than $1(.0) \times 10^{-7}$ (mol dm^{-3}) / is 1.1×10^{-7} (mol dm^{-3}) **or** the pH cannot be more than 7 / alkaline (for an acid) **or** concentration of hydrogen ions from water is not negligible / cannot be ignored **or** 10^{-8} is only the concentration of ions from the acid, it doesn't include those from the water **(1)**	Penalise reference to nitric acid as a weak acid in M2 only Allow $[H^+]$ from water = $\sqrt{1(.00) \times 10^{-14}}$ / $\sqrt{K_w}$ Allow this shown as part of a calculation Allow $[H_3O^+]$/ concentration of hydrogen ions for $[H^+]$ Allow $[H^+]$ is greater than 1×10^{-8} (mol dm^{-3}) Allow $[H^+]$ cannot be less than $[OH^-]$ / $[OH^-]$ cannot be more than $[H^+]$ Allow the addition of nitric acid to water decreases pH by increasing $[H^+]$ Allow pH is 6.96 Allow pH 8 / >7 is alkaline Allow acid must have pH below 7 Do not award $10^{-14}/10^{-8} = 10^{-6}$ so pH = 6 for M2 only Allow water also dissociates to form H^+ ions	**(2)**

(Total for Question 1 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)(i)	- correct temperature **and** pressure	Examples of values Temperature: 298 K / 25^{o}C Pressure: 1 atm / 1 bar 100 kPa/ 1 x 10^5 Pa / 101 kPa / 1.01 x 10^5 Pa / 1 x 10^5 Nm^{-2} / 1.01 x 10^5 Nm^{-2} Values **and** units are needed Ignore reference to concentration even if incorrect	**(1)**

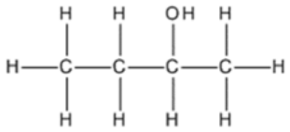
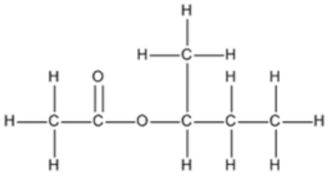
Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)(ii)		The mistakes can be in any order Ignore any other errors Ignore reasons for replacements	(3)
	• ammeter / symbol for ammeter **and** replace with (high resistance) voltmeter / symbol for voltmeter **(1)**	Allow replace with potentiometer / Wheatstone bridge Do not award voltameter	
	• ethanoic acid **and** replace with solution that is 1.0 mol dm^{-3} with respect to $H^+(aq)$ **(1)**	Allow replace with (1.0 / 1.16-1.18 mol dm^{-3}) hydrochloric acid / HCl / nitric acid / HNO_3 **or** Allow 0.5 mol dm^{-3} sulfuric acid / H_2SO_4 Ignore just 'replace with a strong acid'	
	• potassium chloride / chemical in salt bridge **and** replace with potassium nitrate / KNO_3 / sodium nitrate / $NaNO_3$ **(1)**	Allow replace chloride with a nitrate anion Ignore replace with a different anion that will not react with Ag^+	

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)	- substitution of correct values into expression **(1)** - calculation of $\ln[Ag^+(aq)]$ **(1)** - calculation of $[Ag^+(aq)]$ **(1)**	Example of calculation $0.72 = 0.80 + \frac{8.31 \times 293}{96500} \times \ln[Ag^+(aq)]$ $\ln[Ag^+(aq)] = (0.72 - 0.80) \times \frac{96500}{8.31 \times 293}$ $= -3.1707$ $[Ag^+(aq)] = e^{\ln[Ag+(aq)]}$ $= 0.041976$ / 4.1976×10^{-2} (mol dm^{-3}) TE on $\ln[Ag^+(aq)]$ Ignore SF except 1 SF Correct answer with no working scores full marks Expression can be rearranged before substitution of values	**(3)**

(Total for Question 2 = 7 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	A synthetic pathway that includes:	Allow names or formulae for reagents but if both are given, both must be correct Allow correct species in unbalanced equations Allow any combination of structural, displayed or skeletal formulae for the intermediates Penalise missing H once only Ignore conditions e.g. heat / reflux	**(5)**
	Conversion to alcohol - (aqueous ethanolic) potassium / sodium hydroxide **(1)**	Allow hydroxide ions / OH^- Ignore concentration Do not award just ethanol / ethanolic	
	- name or structure of propan-1-ol **(1)**	Stand alone mark e.g. $CH_3CH_2CH_2OH$ Allow propanol if correct structure shown somewhere	
	EITHER ROUTE 1 **Conversion to carboxylic acid** - (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **(1)**	Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl	
	- name or structure of propanoic acid **(1)**	Stand alone mark e.g. CH_3CH_2COOH	
	Formation of ester - react propan-1-ol and propanoic acid together **and** using (concentrated) sulfuric acid (catalyst) **(1)**	Stand alone mark for C_3 compounds Allow (concentrated hydrochloric) acid / H^+ / H_3O^+ instead of sulfuric acid Ignore concentration of acid	
	PTO for ROUTE 2	Ignore incorrect structure of ester e.g. with H or O missing	

	OR ROUTE 2 **Conversion to acyl chloride** • (oxidise some of the propan-1-ol using) potassium dichromate((VI)) **and** (dilute) sulfuric acid **and** add phosphorus(V) chloride to propanoic acid **(1)** • name or structure of propanoyl chloride **(1)** **Formation of ester** • react propan-1-ol and propanoyl chloride together **(1)**	Allow acidified potassium dichromate((VI)) / $Cr_2O_7^{2-}$ **and** H^+ Allow acidified manganate((VII)) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH_3CH_2COCl Stand alone mark for C_3 compounds Ignore incorrect structure of ester e.g. with H or O missing	

Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	**Identifications** • structure of alcohol **B** **(1)** • structure of ester **A** **(1)** **Justification** • butan-2-ol / $CH_3CH_2CHOHCH_3$ is the **only** alcohol (with formula $C_4H_{10}O$) that (undergoes elimination and) produces (but-1-ene and) but-2-ene **(1)**	Allow any combination of structural, displayed or skeletal formulae / correct species in unbalanced equations Allow structures not labelled **A** and **B** Penalise missing H once only <u>Examples of identification</u> **(B)**  Ignore connectivity of the OH group unless horizontal **(A)**  Ignore incorrect name for **A** TE on incorrect alcohol Allow butan-2-ol can form a double bond either side of the C with OH / between the 1st and 2nd carbon atoms and the 2nd and 3rd carbon atoms – this can be shown on diagram / equation Allow OH must be on the 2nd carbon atom / secondary alcohol to form but-1-ene and but-2-ene Allow butan-1-ol gives but-1-ene **and** 2-methylpropan-1-ol / 2-methylpropan-2-ol gives (2-)methylpropene Allow the other alcohols (with formula $C_4H_{10}O$) do not give but-2-ene	**(3)**

(Total for Question 3 = 8 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(i)	**Test 1** • (gas is) ammonia / NH_3 **(1)** • (cation is) ammonium / NH_4^+ **(1)** **Test 2** • (cation is) cobalt(II) / Co^{2+} / $[Co(H_2O)_6]^{2+}$ **(1)** • (complex ion is) $[CoCl_4]^{2-}$ **(1)** **Test 3** • (precipitate is) barium sulfate / $BaSO_4$ **(1)** • (anion is) sulfate((VI)) / SO_4^{2-} **(1)**	If name and formula are given, both must be correct Mark independently Do not award gas is ammonium / NH_4 Do not award cation is ammonia / NH_3^+ Oxidation number of cobalt is needed in the name but allow cobalt **with** Co^{2+} Charge is needed on the ion Allow +2 and −2 for the charges on the ions Allow brackets around Cl Ignore missing square brackets in complex ions Do not award $[CoCl_6]^{4-}$ **Note** If cation in Test 2 is identified as copper(II) / Cu^{2+}, do not award M3 but M4 can be awarded as TE for $[CuCl_4]^{2-}$ Oxidation number of sulfate is not needed but if given must be correct e.g. do not award sulfate(IV)	**(6)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(ii)	- correct formula	Examples of correct formula $(NH_4)_2Co(SO_4)_2$ $(NH_4)_2SO_4.CoSO_4$ Allow NH_4, Co and SO_4 in any order Allow multiples Allow any combination of Co^{2+} / NH_4^+ / SO_4^{2-} that gives a neutral complex TE on the **three** ions identified in (a)(i) Ignore missing dot in second formula Ignore any amount of water of crystallisation	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	- correct equation	Example of equation $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ Allow multiples Allow Na^+ on both sides if crossed through Ignore state symbols even if incorrect	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	• ligand exchange	Allow ligand substitution / ligand replacement Ignore change in co-ordination number Do not award ligand change Do not award any other type of reaction in addition to correct answer e.g. reduction / acid-base / deprotonation	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)	An answer that makes reference to the following point: • to react with / remove any carbonate / sulfite / sulfate(IV) (ions)	Allow equation for the reaction with acid e.g. $2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$ Allow to prevent any other ions forming a precipitate (with barium ions / Ba^{2+}) Allow to rule out the possibility of carbonate / sulfite / sulfate(IV) ions giving a false result Ignore just 'to remove impurities / other (an)ions' / 'react with precipitates' Ignore to dissolve barium carbonate / sulfite Ignore reference to hydrogencarbonate	(1)

(Total for Question 4 = 10 marks)

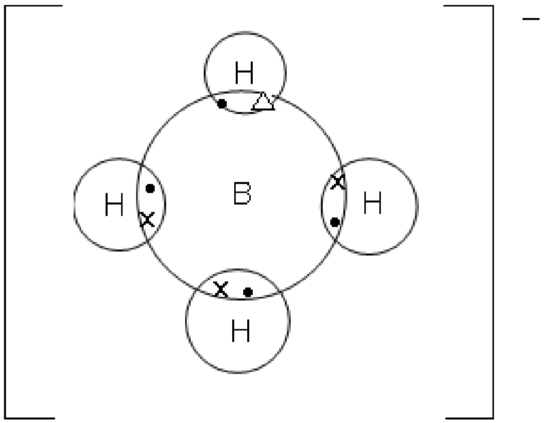
Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
5(a)	- phosphate(III) (ion)	Name **and** oxidation number are required Allow gap between name and oxidation number Allow phosphate and +3 Ignore missing brackets around oxidation number Do not award phosphorus / trioxide / phosphite(III)	**(1)**

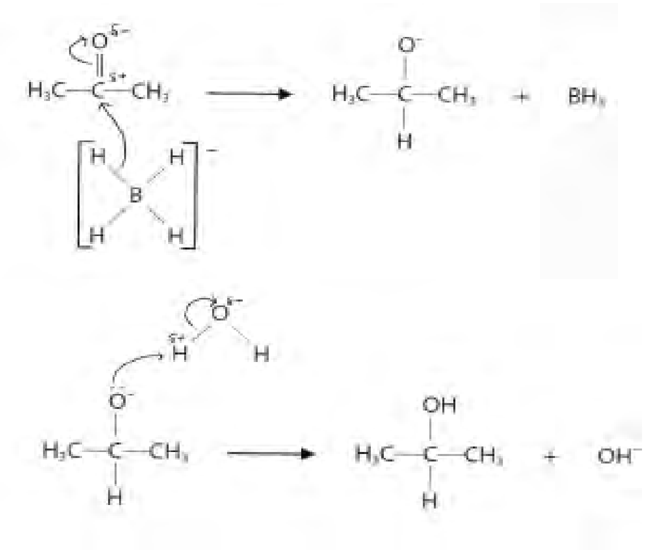
Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
5(b)	- (a reducing agent) increases in oxidation number **and** loses electron(s)	Allow oxidation number becomes more positive / gets larger Allow donates / gives electrons / number of electrons decreases Ignore a reducing agent decreases the oxidation number of another substance	**(1)**

Question Number	**Acceptable Answers**	**Additional Guidance**	**Mark**
5(c)	- Na / sodium	Do not award Na^+	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)(i)	• MnO_2, MnO_4^-, OH^- and MnO_4^{2-} species correct in a single equation **(1)** • H_2O on right **and** balancing **(1)**	Example of equation $MnO_2 + 2MnO_4^- + 4OH^- \rightarrow 3MnO_4^{2-} + 2H_2O$ Ignore state symbols, even if incorrect Do not award M1 if H^+ is on the left Allow cancelled electrons Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(d)(ii)	An answer that makes reference to: • 2 different species are oxidised and reduced (to form the same species) **or** there is not 1 species that is being oxidised and reduced **or** 2 different oxidation states are not produced from one oxidation state **or** only 1 oxidation state / +6 is formed as a product **or** Mn changes from +4 and +7 to +6 (only)	This mark can be awarded even if (i) is incorrect Allow manganate(VI) / MnO_4^{2-} is oxidised and reduced in the reverse reaction Allow Mn in the same species is not being oxidised and reduced Ignore just 'Mn is not simultaneously oxidised and reduced' Ignore this is reverse disproportionation / comproportionation Do not award O / H is oxidised / reduced Do not award molecules / compounds for species	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
5(e)(i)	- dot-and-cross diagram	Example of diagram  Electrons must have the correct symbols i.e. 3 bonds with • and x and 1 bond with • and Δ Circles do not need to be shown Allow missing brackets but charge needs to be shown Allow charge anywhere on or close to diagram Ignore lines representing covalent bonds e.g. $\underline{x}$ • Ignore missing atom labels / inner shell of 2 electrons on B	**(1)**

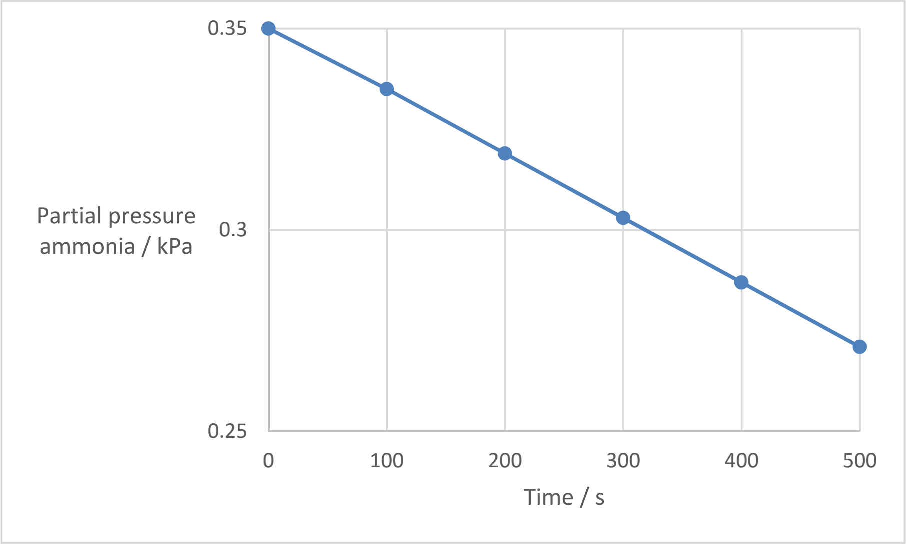
Question Number	Acceptable Answers	Additional Guidance	Mark
5(e)(ii)	• curly arrow from B-H bond to C of C=O Allow curly arrow from B-H bond to H **and** curly arrow from H to C **(1)** • dipole on C=O **and** curly arrow from C=O bond to or just beyond O **(1)** • lone pair on O^- **and** curly arrow from lone pair to H of H_2O **(1)** • curly arrow from O-H bond to O **and** dipole on H-O bond **(1)**	<u>Example of mechanism</u>  Allow curly arrow from any B-H bond Ignore lone pair on O in H_2O Penalise half-headed curly arrow once only	**(4)**

(Total for Question 5 = 11 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)(i)	- six / 6		**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)(ii)	- 1+ / +1	Allow + / one positive charge Ignore positive / plus	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(b)	Oxidation state: • Two ions of the **same metal** (iron or copper) with different oxidation states and the same ligands with appropriate colours **(1)** Ligands: • formula and colour of complex with first ligand **(1)** • formula and colour of complex with second ligand **(1)**	Ignore ions of metals other than iron or copper Ignore use of precipitates instead of complex ions Ignore names of complex ions, even if incorrect Penalise additional incorrect species / colours once only Examples of ions $[Fe(H_2O)_6]^{2+}$ is green **and** $[Fe(H_2O)_6]^{3+}$ is yellow / orange / red/ brown $[CuCl_4]^{2-}$ is yellow **and** $[CuCl_2]^{-}$ is colourless $[Cu(H_2O)_6]^{2+}$ is (pale) blue **and** $[CuCl_4]^{2-}$ is yellow $[Cu(H_2O)_6]^{2+}$ is (pale) blue **and** $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(H_2O)_2(NH_3)_4]^{2+}$ is a **darker** blue than in the aqua ion $[CuCl_4]^{2-}$ is yellow and $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(H_2O)_2(NH_3)_4]^{2+}$ is (deep / dark) blue Allow any correct example of the **same metal** in the same oxidation state with different ligands and their corresponding colours, including colourless – the metal can be different to that in M1 **Note** Formulae **and** colours must be correct but ignore missing square brackets e.g. Do not award mention of green for $[CuCl_4]^{2-}$ Do not award $[Cu(NH_3)_6]^{2+}$ Ignore qualifications of colour e.g. pale / dirty	**(3)**

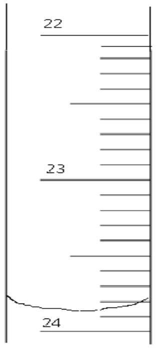
Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(i)	- axes with time on x axis **and** labelled, including units **and** suitable scale **(1)** - **all** points plotted correctly **and** best fit line **(1)**	Example of graph  Allow y axis labelled with partial pressure / pressure and unit Do not allow partial pressure axis starting at 0 Both axes must cover at least half the graph paper Allow ± ½ square M2 can be awarded if axes the wrong way around in M1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(ii)	• rate = *k* / rate = *k* x *p*(NH_3)^0 **(1)** • (zero / 0 order) because the rate is independent of the partial pressure of ammonia / rate is constant **or** because the graph is a straight line / linear **(1)**	Allow r for rate Allow −rate = *k* / rate = *k*[NH_3]^0 Ignore [H_2]^0 or [N_2]^0 Conditional on M1 Allow because the gradient is constant	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(iii)	• calculation of gradient of graph / rate / rate constant **(1)** • corresponding units for rate constant **(1)**	Example of calculation $\frac{(0.271 - 0.350}{500} = (-)\frac{0.079)}{500}$ *k*= 1.58 x 10^{-4} / 0.000158 Allow any value in the range 1.50 to 1.65 x 10^{-4} 1.58 x 10^{-4} / 0.000158 kPa s^{-1} Allow 158 x 10^{-6} kPa s^{-1} / 0.158 Pa s^{-1} / 1.58 x 10^{-1} Pa s^{-1} Do not award units of mol dm^{-3} s^{-1} Ignore SF except 1 SF Ignore negative value for *k* Correct answer with corresponding units and no working scores (2)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)(iv)	A description that makes reference to the following points: • adsorption of ammonia / reactant onto surface of tungsten / catalyst **(1)** • breaking bonds in ammonia / reactant **or** breaking N-H bonds **(1)** • desorption of nitrogen and hydrogen / products / gases from surface of tungsten / catalyst **(1)**	Ignore reference to heterogeneous / homogeneous / active sites Allow gas for ammonia Allow adsorb / adsorp for adsorption Ignore "stick" Do not award absorption Allow bonds weaken instead of break Ignore mention of atoms / radicals Allow products released / detached from catalyst surface Allow de-adsorbed / desorped for desorption Do not award desorption of ammonia	**(3)**

(Total for Question 6 = 14 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(i)	• bottom of meniscus between 23.8 and 23.9 (cm^3) **(1)** • meniscus curved downwards **(1)**	Example of diagram  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(ii)	An explanation that makes reference to the following points: • 23.15 (cm^3) should be used as it is the mean of the concordant titres / titres 2 and 4 /23.10 and 23.20 (cm^3) **(1)** • 23.43 (cm^3) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) **(1)**	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm^3 Allow (23.1(0) + 23.2(0))/2 = 23.15 (cm^3) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean) Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) should not be used / are used (in the mean)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(iii)	• calculation of percentage uncertainty	Example of calculation $\frac{2 \times 0.05}{23.20} \times 100$ = (±)0.431 / 0.43 / 0.4 (%) Ignore SF including 1 SF Correct answer with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(iv)	- calculation of moles of MnO_4^- **(1)** - calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)** - calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)** - calculation of **y** to nearest whole number **(1)**	<u>Example of calculation</u> moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol) moles $C_2O_4^{2-}$ in 25.0 cm^3 = 4.6995 x 10^{-4} x 5/2 = 0.0011749 / 1.1749 x 10^{-3} (mol) TE on moles MnO_4^- moles $C_2O_4^{2-}$ in 1.00 dm^3 = 1.1749 x 10^{-3} x $\frac{1000}{25.0}$ = 0.046995 / 4.6995 x 10^{-2} (mol) TE on moles $C_2O_4^{2-}$ in 25.0 cm^3 Ratio moles salt : moles $C_2O_4^{2-}$ = 0.0235 : 0.046995 = 1 : 1.9998 **y** = 2 TE on moles $C_2O_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in 25.0 cm^3 = 0.0235 x 25.0/1000 = 5.875 x 10^{-4} (1) Ratio moles salt : moles $C_2O_4^{2-}$ = 5.875 x 10^{-4} : 1.1749 x 10^{-3} = 1 : 1.9998 **y** = 2 TE on moles salt and $C_2O_4^{2-}$ in 25.0 cm^3 (1) Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(i)	• calculation of mol of anhydrous salt **(1)** • calculation of mol H_2O **(1)** • calculation of ***z*** to nearest whole number **(1)**	<u>Example of calculation</u> mol anhydrous salt = 2.96/218.1 = 0.013572 / 1.3572 x 10^{-2} (mol) TE on M_r of anhydrous salt from value of **y** in (a)(iv) or an assumed value of ***y*** Allow 0.013578 from M_r 218 mol H_2O (= 0.45/18) = 0.025 / 2.5 x 10^{-2} (mol) Ratio mol salt : mol H_2O = 0.013572 : 0.025 = 1 : 1.842 **z** = 2 TE on moles anhydrous salt and moles H_2O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise **y** and **z** not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible • value of ***z*** increases **and** because it appears that more mass / mol / water is lost (than expected) **(1)** • (this can be prevented by) placing a lid on the crucible **or** heat more gently / carefully **(1)** Not all water of crystallisation lost • less mass / mol /water is lost (than expected) **(1)** • (this can be prevented by) heating to constant mass **or** description of heating to constant mass **(1)** • so this accounts for the lower value of ***z*** / value of ***z*** decreases **(1)**	Ignore just 'loss in mass / mol' Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent Conditional on M3	**(5)**

(Total for Question 7 = 17 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(i)	An answer that makes reference to the following points: • cool the mixture because the reaction (with concentrated sulfuric acid / H_2SO_4) is (very) exothermic / releases (a lot of) heat **(1)**	Ignore reaction is violent / to prevent splashing / to slow down the reaction / to stop reactants evaporating Do not award to quench the reaction / reference to explosion	**(3)**
	• anti-bumping granules are added to prevent violent / sudden / localised boiling **or** to prevent superheating / large bubbles forming **or** to promote smooth / even / controlled boiling **or** to promote the formation of small bubbles **or** to provide nucleation centres / (rough) surface for bubble formation **(1)**	Ignore to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants / to distribute heat more evenly / any reference to rate / to promote smooth heating	
	• heating under reflux is used to prevent the loss of any volatile substances / volatile reactants / volatile products / organic compound / named organic compound **or** to make sure the vapour / gas condenses **or** to prevent vapour escaping **(1)**	Allow so that the reaction goes to completion Ignore just ‘to prevent gas escaping’ / just ‘to prevent loss of reactants / products’ / just ‘reactants / products are volatile’ / ‘because 1-bromobutane / butan-1-ol is flammable’ / to increase yield / reference to safety Do not award for reference to oxidation or reduction	

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to the following points:	Allow answers shown on annotated diagram e.g. gap circled Ignore any additional errors Ignore additional suggested modifications even if incorrect	**(3)**
	• there is a gap between the condenser and the flask / seal the joint between the flask and condenser **and** so vapour / gas / reactants / products will escape **(1)**	Do not award just 'the apparatus is not sealed' unless it is clear it means between the condenser and flask Allow so this will lower the yield of product / 1-bromobutane	
	• the water is flowing the wrong way through the condenser / the water should go in at the bottom (and out at the top) **and** so it doesn't fill with water / is only part filled /there is an airlock **(1)**	Ignore condenser is fitted the wrong way up Allow so there will be inefficient condensation / cooling	
	• there is a stopper on the condenser / there should not be a stopper on the condenser **and** so there will be a build-up of pressure (if the gap between condenser and flask is closed) **(1)**	Allow so the stopper will blow off / there will be an explosion / it will be dangerous	

Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)(iii)	An explanation that makes reference to the following points: • (brown vapour / it) is bromine / Br_2 **(1)** • bromide ions / Br^- / HBr oxidised (by concentrated sulfuric acid) **(1)**	Stand alone mark Do not award just 'Br' Do not award any other brown gas in addition to bromine Allow bromide ions / Br^- / HBr reduce sulfuric acid / act as a reducing agent Ignore sodium bromide / NaBr is oxidised Ignore just 'redox reaction' Do not award bromine is oxidised Do not award oxidation by anything other than sulfuric acid	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to the following: • aqueous layer is on the top **and** because water / it has a lower density than 1-bromobutane	Allow 'it' for aqueous layer Allow because 1-bromobutane has a higher density than water Ignore reference to butanol unless in a third layer Do not award water is 'lighter' Do not award reference to three layers	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: Step **8** • (aqueous sodium hydrogencarbonate / $NaHCO_3$) reacts with / neutralises / removes the (hydrochloric) acid / H^+ (ions) in the mixture **(1)** Step **9** • (the tap is opened) to release the carbon dioxide / gas (formed) **or** to allow the carbon dioxide / gas to escape **or** to prevent the build-up of pressure **(1)** Step **10** • (anhydrous sodium sulfate is added) to remove / absorb water **(1)**	Do not award reacts with incorrect acid e.g. H_2SO_4 / HBr / ethanoic acid Ignore removes water Do not award an incorrect gas e.g. hydrogen Allow (anhydrous) sodium sulfate is a drying agent / added to dry the product Do not award dehydration / reacts with water	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(iii)	• starting temperature 99 or 100 or 101 (°C) **and** final temperature 103 or 104 or 105 (°C)	Do not award just one value / 102 (°C) Do not award 102 (°C) with another temperature	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(iv)	• calculation of mol of 1-bromobutane **(1)** • calculation of number of molecules **and** answer to 2/3 SF **(1)**	Example of calculation mol of 1-bromobutane = $\frac{12.0 \times 1.27}{136.9}$ = 0.11132 (mol) Do not award 0.1 number of molecules = 0.11132 x 6.02 x 10^{23} = 6.7 x 10^{22} / 6.70 x 10^{22} TE on a calculated mol 1-bromobutane using M_r Correct answer to 2 or 3 SF with no working scores (2)	**(2)**

(Total for Question 8 = 15 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(i)	An explanation that makes reference to the following points: • glycinate ions / they do not contain a carbon atom with four different atoms / groups attached **or** the glycinate ion is superimposable on its mirror image **(1)** • so there will be no effect (on plane-polarised monochromatic light) **(1)**	An answer that states there will be an effect scores (0) Allow not chiral / achiral / has no enantiomers / has no asymmetric carbon atom Allow the carbon atom attached to NH_2 is only attached to 3 different atoms / groups / is not attached to 4 different atoms / groups Ignore glycinate ions are not optically active / do not exhibit optical isomerism Do not award it is a racemic mixture / there are equal amounts of the two isomers / four different molecules attached M2 is conditional on M1 Do not award the (monochromatic) light will not be polarised	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(ii)	• correct formula of one of the copper species **(1)** • rest of equation correct **(1)**	Example of equation $(CH_3COO)_2Cu + 2\ NH_2CH_2COOH \rightarrow (NH_2CH_2COO)_2Cu + 2CH_3COOH$ Allow $Cu(CH_3COO)_2$ / $Cu(NH_2CH_2COO)_2$ Allow both charges shown e.g. $(CH_3COO^-)_2Cu^{2+}$ Allow displayed / skeletal formulae for organic substances but not molecular formulae Ignore state symbols, even if incorrect Do not award M1 if covalent bond between Cu and O in any species but M2 can still score	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
9(a)(iii)	An answer that makes reference to any **four** of the following points:	Ignore reference to weighing errors for both students	**(4)**
	Student **1** / higher yield		
	• the crystals were not dry / still damp when they were weighed **(1)**	Allow the student did not subtract the mass of filter paper / product container Do not award the crystals contain water of crystallisation / are (partially) hydrated	
	• there are impurities in the crystals **(1)**	Allow a specific impurity e.g. glycine	
	Student **2** / lower yield		
	• reaction was incomplete **(1)**	Allow the reaction reached equilibrium / side reactions occur / by-products form	
	• not all of the copper(II) glycinate had crystallised / some is left in solution **(1)**	Ignore just 'the solution has not cooled enough'	
	• description of a specific handling loss **(1)**	Allow any specific example e.g. some crystals left on the walls of the container / beaker / flask / lost during filtration / lost during transfer Ignore just 'transfer error' / lost when handling	

Question Number	Acceptable Answers	Additional Guidance	Mark
9(b)	An explanation that makes reference to any **TWO** of the following points:		**(2)**
	• carbon monoxide replaces / takes the place of the oxygen molecule **(1)**	Allow carbon monoxide displaces the oxygen molecule Allow ligand substitution / exchange reaction between oxygen and carbon monoxide	
	• (and may be toxic because) it binds strongly to the Fe^{2+} (ion) **(1)**	Allow carbon monoxide forms a stronger bond / binds more tightly to / has a stronger affinity for Fe^{2+} Allow reduces the amount of oxygen that can bind to Fe^{2+} Allow carbon monoxide binds (almost) irreversibly / permanently to Fe^{2+} Allow CO forms a more stable complex ion with Fe^{2+} / has a larger equilibrium constant / K Ignore CO bonds more easily to Fe^{2+} Ignore just 'CO bonds more strongly to haemoglobin'	
	• effect on the body **(1)**	Allow prevents oxygen being carried to the cells / organs / around the body / blood Allow reduces the amount of oxygen that can be carried to the cells / organs / around the body / blood	

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>9(c)*</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning.
For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td>(6)</td>
</tr>
</table>

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

	Indicative content		
	• **IP1 - Reagents and conditions** magnesium **and** dry ether / dry ethoxyethane / dry $(CH_3CH_2)_2O$	This may be shown as part of any specific reaction. Ignore errors in an equation to make the Grignard.	
	• **IP2 - Hydrolysis of product** add dilute (hydrochloric) acid / $H^+(aq)$ /HCl(aq) (to hydrolyse the intermediate / protonate …O−)	This only needs to be mentioned once Do not award this point if acid is clearly added at the same time as magnesium / dry ether / a reactant	
	• **IP3 – Primary alcohol** react with methanal to form butan-1-ol / $CH_3CH_2CH_2CH_2OH$		
	• **IP4 – Secondary alcohol** react with ethanal to form pentan-2-ol / $CH_3CH_2CH_2CH(OH)CH_3$	Allow other specific aldehydes with corresponding product	
	• **IP5 – Tertiary alcohol** react with propanone to form 2-methylpentan-2-ol / $CH_3CH_2CH_2C(CH_3)(OH)CH_3$	Allow other specific ketones with corresponding product	
	• **IP6 – Carboxylic acid** react with carbon dioxide to form butanoic acid / $CH_3CH_2CH_2COOH$		

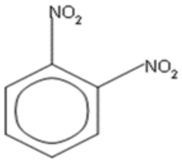
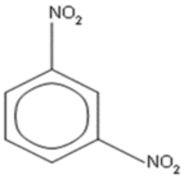
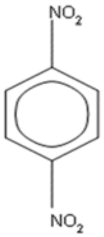
(Total for Question 9 = 16 mark)

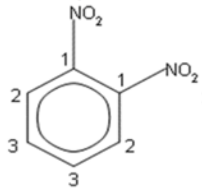
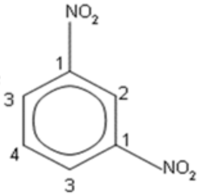
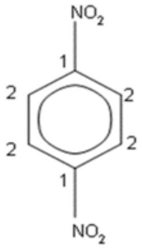
Question Number	Acceptable Answers	Additional Guidance	Mark
10(a)(i)	An explanation that makes reference to the following points: • (the increase in mass of) **X** will increase **and** (the increase in mass of) **Y** will stay the same **(1)** • because **X** will also absorb the water / moisture in the oxygen **(1)** • (**Y** stays the same) because the water / moisture has already been absorbed by **X** **(1)**	Allow greater change in mass for **X** if it is clear that it is an increase Allow **X** reacts with the water in oxygen Do not award **X** absorbs oxygen Allow because **Y** only absorbs carbon dioxide / CO_2 Allow because **Y** does not absorb water Allow because the amount of carbon dioxide / CO_2 does not change	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(a)(ii)	- calculation of mol C/ CO_2 **(1)**	<u>Example of calculation</u> mol CO_2 = 5.28/44 = 0.12 = mol C **or** mass C = 5.28 x 12/44 = 1.44 (g) mol C = 1.44/12 = 0.12	**(5)**
	- calculation of mol H **(1)**	mol H_2O = 0.72/18 = 0.04 mol H = 2 x mol H_2O = 0.08 **or** mass H = 0.72 x 2/18 = 0.08 mol H = 0.08 x 1 = 0.08	
	- calculation of mol N **(1)**	mol N_2 = 0.56/28 = 0.02 mol N = 2 x mol N_2 = 0.04 **or** mass N = 0.56 mol N = 0.56/14 = 0.04	
	- calculation of mol O **(1)**	mass O = 3.36 – (12 x 0.12 + 1 x 0.08 + 14 x 0.04) = 1.28 (g) mol O = 1.28/16 = 0.08 TE on masses of C, H and N	
	- empirical formula **(1)**	(0.12 C : 0.08 H : 0.04 N : 0.08 O) $C_3H_2NO_2$ Allow symbols in any order TE on incorrect moles but the ratio must be a whole number and include C, H, N and O if no O, only M1, M2 and M3 can be awarded Ignore use of O_2 / O / N_2 / N in the ‘words’ Correct empirical formula with some working at each stage scores (5) but correct empirical formula with no working scores M5 only	

Question Number	Acceptable Answers	Additional Guidance	Mark
10(b)	• molecular ion is at *m*/z = 168 **or** 168 is equal to the M_r of **D** / twice the empirical formula / 2 x 84 / 168÷2 = 84 / M_r of empirical formula is 84 **(1)** • (so the molecular formula is) $C_6H_4N_2O_4$ **(1)**	Allow 168 shown on spectrum along with the rest of the explanation Do not award M1 for any other value Stand alone mark Ignore structural / displayed / skeletal formula Do not award $C_6H_4N_2O_4^+$	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(c)(i)	• $C_6H_4^+$	Allow $H_4C_6^+$ Do not award just C_6H_4	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(c)(ii)	- 3 correct formulae **(2)**	Examples of formulae    Allow (1) for any 2 correct formulae Allow (2) for three disubstituted benzenes with incorrect substituents / (1) for any two disubstituted benzenes with incorrect substituents Allow incorrectly displayed formulae of NO_2 groups **In (c)(ii) and (iii):** Allow Kekule structures Allow hydrogen atoms shown on benzene Ignore connectivity of NO_2 groups Penalise missing circle in benzene once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
10(c)(iii)	• **D** identified as 1,3-dinitrobenzene **and** 4 different carbon environments labelled **(1)** • 3 different carbon environments labelled on 1,2-dinitrobenzene **(1)** • 2 different carbon environments labelled on 1,4-dinitrobenzene **(1)**	Examples of identification    These labels may be shown on the structures in (c)(ii) The identification of **D** can be assumed if it is the only structure with 4 carbon environments labelled Allow any form of identification of the carbon environments e.g. numbers, letters, equivalent carbon environments circled TE on disubstituted benzene substituents in (ii) Penalise only half the carbon environments labelled once only	**(3)**

(Total for Question 10 = 16 marks)

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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number	Candidate Number

Tuesday 2 June 2020

Afternoon (Time: 1 hour 45 minutes)

Paper Reference **9CH0/01**

Chemistry

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Candidates must have: Scientific calculator
Data Booklet
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

P62668A

1/1/1/1/1/1

P 6 2 6 6 8 A 0 1 2 4

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 (a) Which equation shows the third ionisation energy of aluminium?

(1)

☒ **A** $Al(g) \rightarrow Al^{3+}(g) + 3e^-$

☒ **B** $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$

☒ **C** $Al^{3+}(g) + 3e^- \rightarrow Al(g)$

☒ **D** $Al^{3+}(g) + e^- \rightarrow Al^{2+}(g)$

(b) Which element in this table is in Group 2?

	Ionisation energy / kJ mol^{-1}			
Element	First	Second	Third	Fourth
W	1086	2353	4621	6223
X	653	1592	2987	4740
Y	590	1145	4912	6474
Z	496	4563	6913	9544

(1)

☒ **A** W

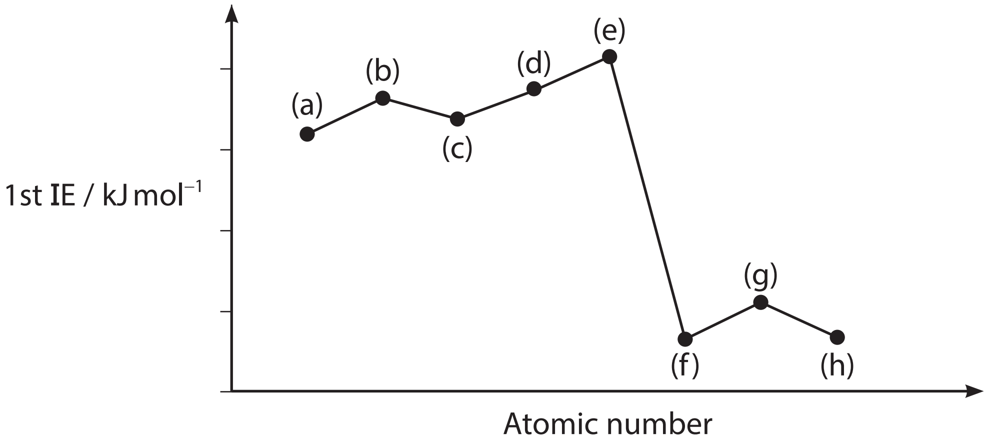
☒ **B** X

☒ **C** Y

☒ **D** Z

(c) The graph shows the first ionisation energies (IE) of eight successive elements from the first 20 elements in the Periodic Table.

Which letter represents the first ionisation energy of oxygen?



(1)

☒ **A** (a)

☒ **B** (b)

☒ **C** (c)

☒ **D** (h)

(d) Give the formula of a stable **ion** that is isoelectronic with the magnesium ion, Mg^{2+}.

(1)

....

(e) A student stated that 'the elements scandium and zinc are d-block elements but are not transition metals'.

Discuss this statement, using appropriate electronic configurations to support your answer.

(4)

(Total for Question 1 = 8 marks)

2 This question is about acids and bases.

(a) What is the order of **decreasing** pH for 0.100 mol dm^{-3} solutions of these three acids?

(1)

☒ **A** $CH_3COOH > CH_2ClCOOH > HCl$

☒ **B** $HCl > CH_3COOH > CH_2ClCOOH$

☒ **C** $CH_2ClCOOH > CH_3COOH > HCl$

☒ **D** $HCl > CH_2ClCOOH > CH_3COOH$

(b) A solution of methanoic acid, HCOOH, has a concentration of 0.240 mol dm^{-3} and a pH of 2.20.

Calculate the value of pK_a for methanoic acid.

(3)

(c) Which of these mixtures would form a buffer solution with a pH **below** 7?

(1)

☒ **A** NaOH(aq) and excess HCl(aq)

☒ **B** NaOH(aq) and excess CH_3COOH(aq)

☒ **C** excess NaOH(aq) and HCl(aq)

☒ **D** excess NaOH(aq) and CH_3COOH(aq)

(d) Bromothymol blue, methyl orange and phenolphthalein are indicators used in titrations.

Which, if any, of these indicators could be used for a titration of ammonia, NH_3(aq), with ethanoic acid, CH_3COOH(aq)?

(1)

☒ **A** bromothymol blue

☒ **B** methyl orange

☒ **C** phenolphthalein

☒ **D** none of these three indicators

(Total for Question 2 = 6 marks)

3 This question is about transition metals and transition metal complexes.

(a) Describe the bonding in the element chromium and use your answer to justify why it has such a high melting temperature.

You may find it helpful to draw a labelled diagram.

(4)

(b) When chromium(III) sulfate dissolves in water, a green solution containing the $[Cr(H_2O)_6]^{3+}$ ion forms.

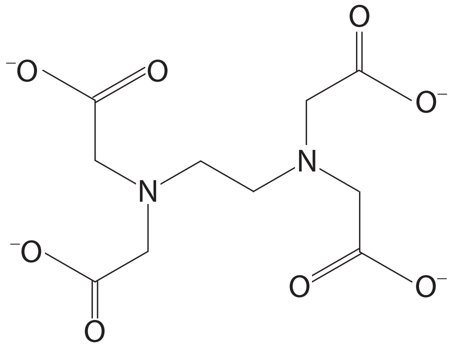
(i) Give the shape of this complex ion.

(1)

(ii) Explain why the chromium complex ion is coloured.

(3)

(c) The ligand ethylenediaminetetraacetate, $EDTA^{4-}$, has the structure shown.



When a solution of $EDTA^{4-}$ is added to a solution of $[Cr(H_2O)_6]^{3+}$ ions, a new complex ion is formed.

$$[Cr(H_2O)_6]^{3+} + EDTA^{4-} \rightleftharpoons [Cr(EDTA)]^{-} + 6H_2O$$

The equilibrium constant for this equilibrium is 2.51×10^{23} dm^3 mol^{-1}.

By considering the equilibrium for this reaction and changes in entropy, comment on the value of the equilibrium constant. No calculations are required.

(3)

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....

....

(d) Aqueous vanadium(II) chloride, $VCl_2(aq)$, can be oxidised by bubbling gaseous chlorine, $Cl_2(g)$, through the solution in the absence of air.

40.0 cm^3 of 0.100 mol dm^{-3} VCl_2 solution was oxidised by 144 cm^3 of chlorine gas, at room temperature and pressure (r.t.p.).
The chlorine was reduced to chloride ions, according to the half-equation

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

[Molar volume of a gas at r.t.p. = 24.0 dm^3 mol^{-1}]

(i) Use these data to calculate the final oxidation state of vanadium.
You **must** show your working.

(5)

(ii) State the initial and final colours you would see as the chlorine bubbles through the aqueous vanadium(II) chloride, $VCl_2(aq)$.

(2)

....

....

(Total for Question 3 = 18 marks)

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4 This question is about dissolving different compounds.

(a) Which of these compounds is the most soluble in water?

(1)

☒ **A** barium sulfate

☒ **B** calcium sulfate

☒ **C** magnesium sulfate

☒ **D** strontium sulfate

(b) What is the value, in kJ mol^{-1}, for the standard enthalpy change of solution of magnesium chloride?

$$\begin{tikzcd}
& Mg^{2+}(g) + 2Cl^{-}(g) \arrow[dl] \arrow[dr] & \\
MgCl_2(s) \arrow[rr] & & Mg^{2+}(aq) + 2Cl^{-}(aq)
\end{tikzcd}$$

Lattice energy $MgCl_2(s)$ = –2526 kJ mol^{-1}

Hydration enthalpy of $Cl^{-}(g)$ = – 381 kJ mol^{-1}

Hydration enthalpy of $Mg^{2+}(g)$ = –1921 kJ mol^{-1}

(1)

☒ **A** +157

☒ **B** –157

☒ **C** +224

☒ **D** –224

*(c) The solubility of two compounds in different solvents was investigated.
A summary of the findings is shown.

Compound	Soluble in water	Soluble in hexane
2-methylpentane	X	✓
potassium bromide	✓	X

Explain the findings of the investigation by considering the interactions between the compounds and each of the solvents.

(6)

(Total for Question 4 = 8 marks)

Turn over ▶

5 This question is about the chemistry of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$.

(a) Group 2 nitrates decompose when heated.

(i) State **two** observations you would see when hydrated magnesium nitrate is heated.

(2)

(ii) Explain the trend in thermal stability of Group 2 nitrates.

(3)

(b) In an experiment, a sample of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$, with a mass of 0.765 g, was dissolved in water and reacted with an excess of sodium hydroxide solution, NaOH(aq).
The precipitate of magnesium hydroxide, $Mg(OH)_2$, produced was removed and dried. The mass of the dried sample was 0.174 g.

(i) Draw dot-and-cross diagrams for the ions in magnesium hydroxide.
Show the outer electrons only.

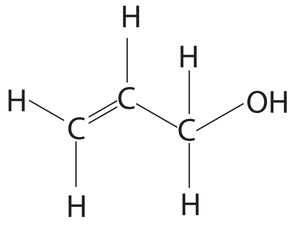
(2)

(ii) Use the experimental data to calculate the value for x in the formula $Mg(NO_3)_2.xH_2O$.
You **must** show all your working.

(5)

(Total for Question 5 = 12 marks)

6 Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.



(a) A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.

(i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C bond as they could use the value for a C–C bond and multiply it by two.
Explain why the student is **incorrect**.

(2)

....

....

....

....

(ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.

$$C_3H_6O(g) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$$

Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / kJ mol^{-1}	347	612	358	805	464	413	498

(3)

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

(b) Chemists are researching a process to make ethanol and ethene directly from carbon dioxide and water.

$$4CO_2(g) + 5H_2O(l) \rightarrow CH_3CH_2OH(l) + C_2H_4(g) + 6O_2(g) \quad \Delta H^\ominus = +2778 \text{ kJ mol}^{-1}$$

	$CO_2(g)$	$H_2O(l)$	$CH_3CH_2OH(l)$	$C_2H_4(g)$	$O_2(g)$
$S^\ominus$ / J K^{-1} mol^{-1}	213.6	69.9	160.7	219.5	205.0

Calculate $\Delta S^\ominus_{total}$ for the reaction and hence determine whether the reaction is feasible under standard conditions.

(5)

(Total for Question 6 = 12 marks)

7 A mixture of ethanoic acid, ethanol and a catalyst was left for several days to reach equilibrium.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

The equilibrium constant, K_c, **under these conditions**, was 0.28.

(a) (i) Write the expression for the equilibrium constant, K_c.

(1)

(ii) The initial amounts of ethanol and ethanoic acid used were 1.2 mol of each reactant.

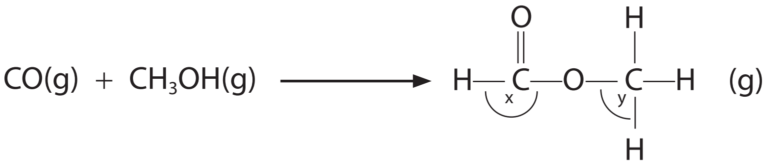
Use this information, your expression for the equilibrium constant, K_c, and the value for K_c, to find the amounts of each product at equilibrium, in moles.

(3)

Amount of $CH_3COOCH_2CH_3$ = ...

Amount of H_2O = ...

(b) Another ester, methyl methanoate, can be formed by the reaction between methanol and carbon monoxide in the gaseous phase.



(i) The two O–C–H bond angles, x and y, in the ester are approximately

(1)

☒ **A** 180° and 90°

☒ **B** 120° and 90°

☒ **C** 120° and 109.5°

☒ **D** 109.5° and 109.5°

(ii) The reaction often forms an equilibrium mixture.

Which could be the units for the equilibrium constant, K_p?

(1)

☒ **A** mol dm^{-3}

☒ **B** dm^3 mol^{-1}

☒ **C** atm

☒ **D** atm^{-1}

(iii) Describe what effect, if any, increasing the pressure would have on the equilibrium constant, K_p. Justify your answer.

(2)

....

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(Total for Question 7 = 8 marks)

8 Tablets containing potassium manganate(VII), $KMnO_4$, are dissolved in water forming an antiseptic solution to treat skin conditions. The manufacturers claim that each tablet contains 400 mg of $KMnO_4$.

To check the claim, the titration procedure outlined was carried out.

- Five tablets were dissolved in distilled water to make 100.0 cm^3 of solution.
- Some of the $KMnO_4$ solution was used to fill a burette.
- 25.0 cm^3 of sodium ethanedioate solution, $Na_2C_2O_4(aq)$, of concentration 0.200 mol dm^{-3}, was added to a conical flask and warmed.
- Sulfuric acid, of concentration 2 mol dm^{-3}, was also added to the conical flask.
- The $KMnO_4$ solution was added to the flask from the burette, until the end-point.

The equation for the reaction between MnO_4^- ions from the $KMnO_4$ and $C_2O_4^{2-}$ ions from the sodium ethanedioate solution is shown.

$$16H^+(aq) + 2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

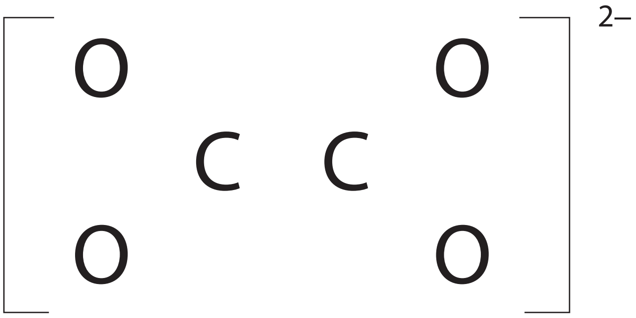
(a) Give the colour **change** at the end-point of the titration.

(1)

....

(b) (i) Complete the dot-and-cross diagram for the ethanedioate ion. Show the outer electrons only.

(2)



(ii) Determine the oxidation number of carbon in the ethanedioate ion, $C_2O_4^{2-}$.

(1)

....

(c) Give the reason why sulfuric acid was also added to the conical flask.

(1)

....

....

(d) This redox reaction could be used in an electrochemical cell.

The cell half-equations are

$$2CO_2(g) + 2e^- \rightleftharpoons C_2O_4^{2-}(aq)$$

$$8H^+(aq) + MnO_4^-(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$$

Write a cell diagram for this cell using the conventional representation.

(2)

(e) The results of the titration are shown.

Run	Trial	1	2	3
Final volume / cm^3	17.50	34.10	17.20	34.10
Initial volume / cm^3	0.00	17.30	0.00	17.20
Titre / cm^3	17.50		17.20	
Concordant titres (✓)				
Mean titre / cm^3				

(i) Complete the table.

(2)

(ii) The equation for the reaction between MnO_4^- ions from the $KMnO_4$ and $C_2O_4^{2-}$ ions from the sodium ethanedioate solution is shown.

$$16H^+(aq) + 2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

Use this equation and your mean titre from (e)(i) to calculate the mass, in mg, of $KMnO_4$ in **one** tablet.

Give your answer to an appropriate number of significant figures.

(5)

(iii) A textbook suggested the conical flask should be heated during the titration, as the reaction between the MnO_4^- ions and the $C_2O_4^{2-}$ ions is slow.

Use these electrode potentials and your knowledge of homogeneous catalysis to deduce why the heating is very important at the start of the titration, but less important as the titration proceeds. Justify your answer.
You may include equations in your justification.

Electrode system	$E^\ominus$ / V
$2CO_2(g) + 2e^- \rightleftharpoons C_2O_4^{2-}(aq)$	+0.64
$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$	+1.49
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(4)

(Total for Question 8 = 18 marks)

TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

October 2020

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 1: Advanced Inorganic and Physical Chemistry

October 2020
Publications Code 9CH0_01_2010_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	**The only correct answer is B** ($Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$) **A** *is not correct because it is the equation for the first three ionisation energies* **C** *is not correct because an ion is gaining electrons* **D** *is not correct because an ion is gaining an electron*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is C** (Y) **A** *is not correct because there is a steady increase in ionisation energies* **B** *is not correct because there is a steady increase in ionisation energies* **D** *is not correct because there is a large increase after the first ionisation energy, so Z is a Group 1 element*	**(1)**

Question Number	Answer	Mark
1(c)	**The only correct answer is C** (c) **A** *is not correct because it is carbon* **B** *is not correct because it is nitrogen* **D** *is not correct because it is aluminium*	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
1(d)	• N^{3-} / O^{2-} / F^{-} / Na^{+} / Al^{3+}	Do not award Ne, C^{4-}, Si^{4+}	**(1)**

Question Number	**Answer**	**Additional guidance**	**Mark**
1(e)	A discussion that makes reference to the following points: • both elements / atoms have the last added electron in the d-subshell / d orbital (so are d-block elements) **(1)** • but neither forms a (stable) ion with an incomplete d-subshell / d orbital (so are not transition metals) **(1)** • Zn^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ (so d subshell is full) **(1)** • Sc^{3+} is $1s^2 2s^2 2p^6 3s^2 3p^6$ (so d subshell is empty) **(1)**	Do not award just ‘contains d electrons’ Allow ‘transition elements form a (stable) ion with an incomplete d-subshell / d orbital’ Allow $[Ar]3d^{10}$ Allow [Ar]	**(4)**

(Total Question 1 = 8 marks)

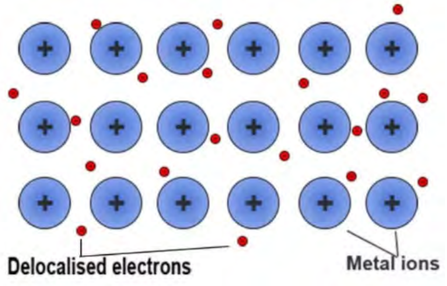
Question Number	Answer	Mark
2(a)	**The only correct answer is A** ($CH_3COOH > CH_2ClCOOH > HCl$) *B is incorrect because HCl is the only strong acid, so would have the lowest pH* *C is incorrect because $CH_2ClCOOH$ is stronger than CH_3COOH as the Cl atom stabilises the anion* *D is incorrect because the stronger the acid the lower the pH, hence these are in reverse order*	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)	- calculation of $[H^+]$ **(1)** - use of K_a expression to calculate K_a **(1)** - calculation of pK_a **(1)**	Example of calculation $[H^+] = 10^{-2.20} = 6.3096 \times 10^{-3}$ (mol dm^{-3}) $K_a = (6.3096 \times 10^{-3})^2 / 0.240$ $= 1.6588 \times 10^{-4}$ $pK_a = -\log [1.6588 \times 10^{-4}] = 3.7802$ ignore SF except 1SF ignore units allow TE throughout correct answer with no working scores 3	**(3)**

Question Number	Answer	Mark
2(c)	**The only correct answer is B** (NaOH(aq) and excess CH_3COOH(aq)) ***A*** *is incorrect because the solutions would not form a buffer* ***C*** *is incorrect because the solutions would not form a buffer* ***D*** *is incorrect because the solutions would not form a buffer*	**(1)**

Question Number	Answer	Mark
2(d)	**The only correct answer is D** (none of these three indicators) ***A*** *is incorrect because both acid and base are weak so pH range at equivalence is too narrow for bromothymol blue to change colour* ***B*** *is incorrect because both acid and base are weak so pH range at equivalence is too narrow for methyl orange to change colour* ***C*** *is incorrect because both acid and base are weak so pH range at equivalence is too narrow for phenolphthalein to change colour*	**(1)**

(Total Question 2 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points (Structure consisting of) • lattice of positive ions / regular arrangement of positive ions **(1)** • (in sea of) delocalised electrons **(1)** • strong forces of attraction between ions and delocalised electrons (so high melting temperature) **(1)** • so lots of (heat) energy needed to break attraction between ions and delocalised electrons / metallic bonds **(1)**	M1 and M2 can be scored by use of a labelled diagram, but if both given both must be correct For example  Allow charge on ion of 2+ or 3+ Diagram should show at least 4 ions (for M1) a number of electrons roughly consistent with charge on ions and random (for M2) The attraction between ions and delocalised electrons only needs to be mentioned once in M3 and M4 Allow ‘lots of energy needed to separate the ions’	**(4)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
3(b)(i)	• octahedral	Allow octahedron / octahedral Ignore diagrams Do not award octagonal	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
3(b)(ii)	An explanation that makes reference to the following points • (ligand / water molecule causes) d orbital**s** to split (into 2 energy levels) **(1)** • light/energy (in the visible region) absorbed to promote electrons (to higher d orbitals) **(1)** • the remaining light / unabsorbed light / complementary colour / green light is transmitted **(1)**	Allow d subshell for d orbitals Do not award d orbital splits Allow (some light) energy is absorbed when d-d electron transitions occur Do not award ‘emitted’ or transmission linked to electrons returning to ground state Allow reflected / emerged	**(3)**

Question Number	Answer	Additional Guidance	Mark
3(c)	An answer that makes reference to the following points: • (the equilibrium constant is large) so the equilibrium lies well / far to the right hand side / $[Cr(EDTA)]^-$ is more stable **(1)** • as ΔS_{system} is positive / increases entropy (of the system) **(1)** • as 2 mol of reactants form 7 mol of products **(1)**	Allow forward reaction is very feasible / spontaneous / goes (virtually) to completion Allow an increase in the number of moles / particles / molecules if number of moles is given, they must be correct i.e. do not award 2 moles to 6 moles Do not award just ‘2 molecules form 7 molecules’ Do not award M3 if M2 states ‘entropy decreases’	**(3)**

Question Number	Answer	Additional guidance	Mark
3(d)(i)	- calculation of moles of VCl$_2$(aq) **(1)** - calculation of moles of Cl$_2$(g) **(1)** - deduction of whole number ratio of V^{2+} : Cl$_2$ **(1)** - deduction of electrons lost per vanadium ion **(1)** - deduction of final oxidation number of V **(1)**	Example of calculation (40/1000) x 0.100 = 4 x 10^{-3} / 0.004 (mol) (144/24000) = 6 x 10^{-3} / 0.006 (mol) 2V^{2+} : 3Cl$_2$ allow V^{2+} : 1.5Cl$_2$ 6 electrons lost by 2V^{2+}, so 3 lost per V^{2+}, (+)5 Allow TE throughout Correct answer with no working scores M5 only	**(5)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
3(d)(ii)	• purple / lilac / violet **(1)** • to yellow (solution) **(1)**	Ignore references to blue / green / turquoise or similar, as intermediate colours, regardless of order If no final oxidation state given in (d)(i) do not award M2 Allow lavender / mauve for M1 Mark consequentially from (d)(i) Do not award colourless Use list principle for additional inappropriate intermediate colours e.g. red / pink For consequential marking from (d)(i) V(IV) – blue ; V(III) – green If both colours are given but the wrong way round, allow 1 mark out of 2	**(2)**

(Total Question 3 = 18 marks)

Question Number	Answer	Mark
4(a)	**The only correct answer is C** (magnesium sulfate) ***A*** *is incorrect because Group 2 sulfates decrease in solubility down Group 2* ***B*** *is incorrect because Group 2 sulfates decrease in solubility down Group 2* ***D*** *is incorrect because Group 2 sulfates decrease in solubility down Group 2*	**(1)**

Question Number	Answer	Mark
4(b)	**The only correct answer is B** (–157) ***A*** *is incorrect because this is the value if the cycle is used in the opposite direction* ***C*** *is incorrect because this is the value if the hydration enthalpy for the chloride ion is not multiplied by 2* ***D*** *is incorrect because this is the value if the cycle is used in the opposite direction and the hydration enthalpy for the chloride ion is not multiplied by 2*	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*4(c)</td><td>This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

In general, an answer with 5 or 6 IPs would score 2 reasoning marks, 3 or 4 IPs would score 1 reasoning mark, 0, 1 or 2 IPs would score 0 reasoning marks.

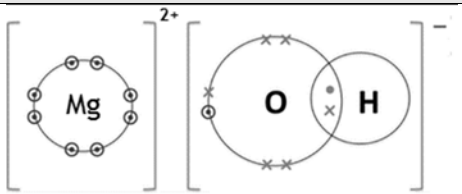
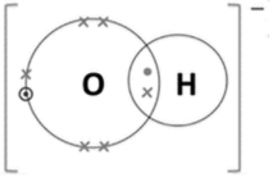
Reasoning marks may be reduced for extra incorrect chemistry.</td><td>(6)</td></tr>
</table>

	Indicative content - 2-methylpentane is insoluble in water as it cannot hydrogen bond to water (as none of the hydrogen atoms are electropositive) - 2-methylpentane is soluble in hexane as London forces in both compounds (are similar in strength / size) - so (resultant) forces in mixture are similar in magnitude to those in each liquid - potassium bromide is soluble in water as its ions are hydrated when dissolved - the enthalpy change of hydration is greater than / close to / compensates for the energy needed to break apart the lattice - potassium bromide is insoluble in hexane as any (London) forces that form between it and hexane would be smaller in magnitude than the forces between the ions	If there is no specific reference to types of intermolecular forces / interaction in IPs 1 and 2 then allow 1 IP for idea of 'like dissolves like' e.g. 2-methylpentane dissolves in hexane as they are both non-polar / does not dissolve in water as water is polar scores 1IP if both IP1 and IP2 not awarded Allow van der Waals / dispersion forces / instantaneous dipole-induced dipole Allow both form only London forces Ignore references to entropy Do not award if water is shown as split into ions	

(Total Question 4 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	Any two observations from • solid dissolves / melts **(1)** • condensation on sides of test tube **(1)** • brown gas/ brown fumes/ brown NO_2(g) produced **(1)** • white solid / powder forms **(1)**	Do not award magnesium dissolved / just 'solid disappears' Allow 'steam given off' Ignore NO_2 / O_2 / gas given off/ bubbles/ effervescence / gas relights a glowing splint Allow red-brown Ignore 'precipitate' Ignore 'magnesium oxide forms' Do not award 'Mg^{2+} forms'	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	An answer that makes reference to the following points: • Nitrates increase in stability down Group 2 as ionic radius increases (as you go down group) **(1)** • so polarising ability of metal (ion) decreases / distorts (the electron cloud of) the anion less **(1)** • weakening of N-O bonds (in nitrate ion) is less **(1)**	Allow charge density decreases as you go down Group 2 Do not award **just** 'atomic radius increases' There has to be a mention of ions somewhere in M1 or M2 Allow reverse argument	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	• magnesium ion (1) • hydroxide ion (1)	  Allow all dots or all crosses Allow M1 for magnesium ion outer shell shown with no electrons Allow M2 even if only 1 hydroxide ion is shown Ignore inner shells Ignore absence of square brackets and circles Ignore any indication of 2 hydroxide ions e.g. 1 hydroxide ion with ‘2’ preceding it Penalise missing charges once only	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)		Example of calculation	**(5)**
	- calculation of moles of $Mg(OH)_2$ **(1)**	0.174 ○58.3 = 2.98456 x 10^{-3} (mol)	
	- calculation of mass of $Mg(NO_3)_2$ **(1)**	2.98456 x 10^{-3} x 148.3 = 0.44261 (g)	
	- calculation of mass of H_2O **(1)**	0.765 - 0.44261 = 0.32239 (g)	
	- calculation of moles of H_2O **(1)**	0.32239○18 = 0.017911 (mol)	
	- deduction of $Mg(NO_3)_2$: H_2O ratio (and hence formula) **(1)**	0.017911○2.98456 x 10^{-3} = 6.0011 1:6, (so $Mg(NO_3)_2.6H_2O$)	
	OR		
	- Calculation of moles of $Mg(OH)_2$ **(1)**	0.174 ○58.3 = 2.98456 x 10^{-3} (mol)	
	- deduction of moles of $Mg(NO_3)_2.xH_2O$ **(1)**	1:1 so = 2.98456 x 10^{-3} (mol)	
	- expression for / calculation of molar mass of $Mg(NO_3)_2.xH_2O$ **(1)**	148.3 + 18x / 0.765 ○2.98456 x 10^{-3} = 256.3	
	- expression for moles of $Mg(NO_3)_2.xH_2O$ in terms of mass and molar mass / calculation mass of water in 1 mole **(1)**	0.765○(148.3 + 18x) = 2.98456 x 10^{-3} (mol) / 256.3 - 148.3 = 108	
	- calculation of x (and hence formula) **(1)**	0.32239 = 0.0537x, so x = 0.32239○0.0537 = 6.0035 / 108○18 so x = 6 ; (so $Mg(NO_3)_2.6H_2O$) Correct answer with no working scores M5 only. Ignore SF from M1 to M4, allow TE throughout	

(Total Question 5 = 12 marks)

Question Number	Answer	Additional guidance	Mark
6(a)(i)	An explanation that makes reference to the following points • C=C bond is weaker than 2 x C-C bond **(1)** • as it consists of a pi and a sigma bond (rather than 2 sigma bonds)**(1)**	Ignore pi bond formed by sideways / less effective orbital overlap	**(2)**

Question number	Answer	Additional guidance	Mark
6(a)(ii)	• calculation of energy required to break reactant bonds **(1)** • calculation of energy release when product bonds form **(1)** • calculation of enthalpy change **(1)**	Example of calculation: 5(C-H) + (C=C)+(C- C)+(C-O)+(O-H)+4(O=O) 5(413) + (612) + (347) + (358) + (464) + (4x498) = 5838 (kJ mol^{-1}) 6(C=O) + 6(O-H) (6x805) + (6x464) = 7614 (kJ mol^{-1}) 5838 – 7614 = –1776 (kJ mol^{-1}) Ignore SF except 1 SF Allow TE from M1 and M2 Correct answer no working scores 3	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(a)(iii)	An explanation that makes reference to one of the following points EITHER • ΔS_{total} is always positive (1) **(1)** • As both $\Delta S_{\text{surroundings}}$ and ΔS_{system} are positive **(1)** • OR • ΔG is always negative **(1)** • as ΔH is negative and $\Delta S_{\text{(system)}}$ is positive **(1)**	If no marking points awarded allow 1 mark for idea that ΔS_{system} / $\Delta S_{\text{surroundings}}$ / entropy increases with correct explanation	**(2)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
6(b)	• expression for ΔS_{system} **(1)** • calculation of ΔS_{system} **(1)** • expression for $\Delta S_{\text{surroundings}}$ **(1)** • calculation of $\Delta S_{\text{surroundings}}$ **(1)** • calculation of ΔS_{total}, correct units and comment on feasibility **(1)**	<u>Example of calculation</u> $\Delta S_{\text{system}} = [(6x205)+(219.5)+(160.7)] - [(4x213.6)+(5x69.9)$ $= 1610.2 - 1203.9 = (+)\ 406.3\ (\text{J K}^{-1}\ \text{mol}^{-1})$ $\Delta S_{\text{surroundings}} = -\Delta H/T = -\ 2778\ \text{x}\ 10^3 \bigcirc 298$ $= -9322.14765\ (\text{J K}^{-1}\ \text{mol}^{-1})$ $\Delta S_{\text{total}} = 406.3 - 9322.14765$ $= -\ 8915.85\ \text{J K}^{-1}\ \text{mol}^{-1}$, (negative) so not feasible Ignore SF except 1 SF. Allow TE and KJ throughout	**(5)**

(Total for Question 6 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	• $K_c = \frac{[CH_3COOCH_2CH_3(l)][H_2O(l)]}{[CH_3COOH(l)][CH_3CH_2OH(l)]}$	Ignore omission of state symbols Do not award round brackets	**(1)**

Question Number	Answer	Additional Guidance	**Mark**
7(a)(ii)	• expression for equilibrium amounts in terms of x **(1)** • use equilibrium amounts in K_c expression and rearrangement to find amount of product / express as correct quadratic expression **(1)** • calculation of amount of product **(1)**	<u>Example of calculation</u> Amounts CH_3CH_2OH = 1.2 – x; CH_3COOH = 1.2 – x; $CH_3COOCH_2CH_3$ = x; H_2O = x $K_c = \frac{(x \bigcirc vol)^2}{[(1.2-x) \bigcirc vol]^2}$ $K_c = (x^2 \bigcirc vol^2) \bigcirc ((1.2-x)^2 \bigcirc vol^2)$ $K_c = x^2 \bigcirc (1.2-x)^2$ so $x^2 = K_c \times (1.2-x)^2$ $x = \sqrt{} K_c \times (1.2-x)$ x=0.63498○1.52915; x= 0.41525 = 0.42 (So amounts of each product = 0.42 (mol)) Allow use of quadratic equation for M2 Allow M2 for expression without inclusion of volume Correct answer with no working scores 3 marks Ignore SF except 1 SF Ignore negative amounts Allow alternative methods Allow TE throughout (a)(ii) for use of x / $(1.2-x)^2$ in K_c expression	**(3)**

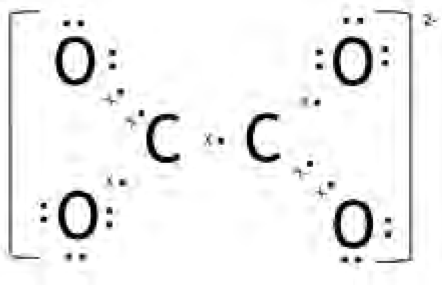
Question Number	Answer	Mark
7(b)(i)	**The only correct answer is C** (120° and 109.5°) ***A*** *is incorrect because both angles are incorrect* ***B*** *is incorrect because 90° is incorrect* ***D*** *is incorrect because 109.5° is incorrect for the left hand O−C−H angle*	**(1)**

Question Number	Answer	Mark
7(b)(ii)	**The only correct answer is D** (atm^{-1}) ***A*** *is incorrect because it is the inverse of the units for* K_C ***B*** *is incorrect because it is the units for* K_C ***C*** *is incorrect because it is the inverse of the units for* K_p	**(1)**

(Total Question 7 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
7(b)(iii)	An explanation that makes reference to the following points • K_p will remain unchanged **(1)** • equilibrium moves to right-hand side (to keep K_p constant) / only temperature affects K_p **(1)**	Allow answers in terms of quotient Do not award M2 if K_p is described as changing Ignore comments related to rate	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(a)	- colourless to (permanent pale/light) pink	Do not award purple for pink	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	- double C=O bond on left and right hand side **(1)** - rest of diagram **(1)**		**(2)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	- (+) 3	Allow 3+ / +III / III+ / III / three Ignore working out Do not award ± 3	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(c)	to provide the hydrogen ions (needed as a reactant in the balanced equation) / to prevent formation of MnO_2 / to prevent (brown) precipitate forming	Allow reaction needs acidic conditions Do not award 'acts as a catalyst' / just 'ensures reaction go to completion'	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
8(d)	- both platinum symbols and salt bridge **(1)** - rest of diagram **(1)**	$\mathrm{Pt(s)} \mid \mathrm{C_2O_4^{2-}(aq)\,,\,2CO_2(g)} \;\vdots\vdots\; \mathrm{[MnO_4^{-}(aq) + 8H^{+}(aq)],\ [Mn^{2+}(aq) + 4H_2O(l)]} \mid \mathrm{Pt(s)}$ Allow solid lines for salt bridge Allow half cells shown correctly on opposite side Ignore omission of square brackets / state symbols if neither marked scored allow 1 mark for all four ‘redox’ species in ROOR order, separated by commas or dashed lines, but not solid lines	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>**8(e)(i)**</td>
<td>
• titres calculated and both ticks correct **(1)**
• mean calculated **(1)**
</td>
<td>
<table>
<tr><td>Run</td><td>Trial</td><td>One</td><td>Two</td><td>Three</td></tr>
<tr><td>Final volume / cm^3</td><td>17.50</td><td>34.10</td><td>17.20</td><td>34.10</td></tr>
<tr><td>Initial volume /cm^3</td><td>0.00</td><td>17.30</td><td>0.00</td><td>17.20</td></tr>
<tr><td>Titre / cm^3</td><td>17.50</td><td>16.8**0**</td><td>17.20</td><td>16.9**0**</td></tr>
<tr><td>Concordant titres (✓)</td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td>Mean titre /cm^3</td><td colspan="4">**16.85**</td></tr>
</table>
Both titres to 2 dp
mean = (16.90+16.80)O2 = 16.85 (cm^3)
allow TE for M2 for mean of One, Two and Three = 16.97 (cm^3)
</td>
<td>**(2)**</td>
</tr>
</table>

Question Number	**Answer**	**Additional Guidance**	**Mark**
8(e)(ii)	• calculation of moles of $Na_2C_2O_4$(aq) **(1)** • calculation of moles of $KMnO_4$ in titre **(1)** • calculation of moles of $KMnO_4$ in 100 cm^3 **(1)** • calculation of M_r for $KMnO_4$ **(1)** • calculation of mass of 1 tablet in mg to 2 or 3SF **(1)**	<u>Example of calculation</u> (25.0÷1000) x 0.200 = 0.005 / 5.00 x 10^{-3} (mol) 5.00 x 10^{-3} x 2÷5 = 0.002 / 2.00 x 10^{-3} (mol) 2.00 x 10^{-3} x (100÷16.85) = 0.011869 (mol) 158 0.011869 x 158 = 1.8754 g (1.8754÷5) x 1000 = 375.07 mg = 380 / 375 (mg) Correct answer with or without working scores 5 marks 0.38 g scores 4 marks (M5 not awarded) TE at each stage and on mean titre 379 mg from 0.012 scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
8(e)(iii)	An explanation that makes reference to the following points • (reaction is slow initially) as MnO_4^- and $C_2O_4^{2-}$ are (both) negative (ions) so will repel (each other) **(1)** • when (sufficient) Mn^{2+} ions form they (auto) catalyse the reaction **(1)** • Mn^{2+} ions will reduce MnO_4^- ions (as $E^⦵$ is more negative) forming Mn^{3+} ions OR $MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ ($E^⦵ = + 0.02V$) **(1)** • Mn^{3+} ions then oxidise $C_2O_4^{2-}$ ions (reforming Mn^{2+}) (as $E^⦵$ is more positive) OR $C_2O_4^{2-} + 2Mn^{3+} \rightarrow 2Mn^{2+} + 2CO_2$ ($E^⦵ = + 0.85V$) **(1)**	Allow 'heat is required to overcome high activation energy when catalyst is absent' Allow Mn^{2+} ions will react with MnO_4^- ions as $E^⦵$ is more negative Allow Mn^{3+} ions then react with $C_2O_4^{2-}$ ions (reforming Mn^{2+}) as $E^⦵$ is more positive May be shown in equations and / or by calculating $E^⦵$	**(4)**

(Total Question 8 = 18 marks)

TOTAL FOR PAPER = 90 MARKS

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Candidate surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐

Candidate Number ☐☐☐☐

Monday 8 June 2020

Afternoon (Time: 1 hour 45 minutes)

Paper Reference **9CH0/02**

Chemistry

Advanced
Paper 2: Advanced Organic and Physical Chemistry

Candidates must have: Scientific Calculator
Data Booklet
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

1 This question is about methanol, CH_3OH.

(a) Draw a dot-and-cross diagram to show the bonding in a molecule of methanol. Show outer shell electrons only.

(2)

(b) Predict which bond has the shortest bond length in a molecule of methanol.

(1)

....

(c) Methanol is soluble in water.

(i) State the strongest type of intermolecular force that occurs between molecules of methanol and water.

(1)

....

(ii) Draw a labelled diagram to show the interaction named in (c)(i) between one molecule of methanol and one molecule of water.
Include any relevant lone pairs and dipoles in your diagram.

(3)

(Total for Question 1 = 7 marks)

Turn over ▶

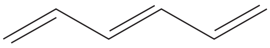
2 This question is about alkenes.

(a) Which of these has the molecular formula C_6H_{10}?

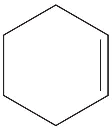
(1)

☒ **A**

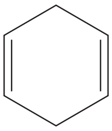
☒ **B**



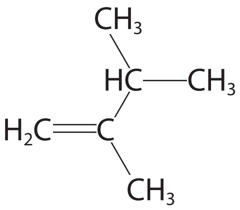
☒ **C**



☒ **D**



(b) What is the systematic name of this alkene?



(1)

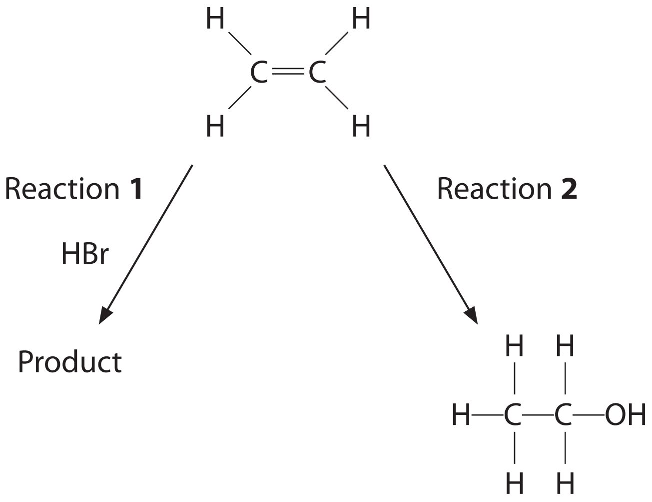
☒ **A** 2-methylpent-1-ene

☒ **B** 3-methylpent-1-ene

☒ **C** 2,3-dimethylbut-1-ene

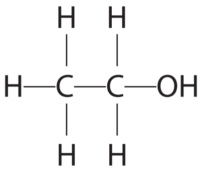
☒ **D** 2,3-dimethylbut-3-ene

(c) Two reactions of ethene are shown.

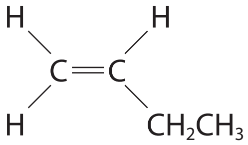


Complete the table.

(3)

Reaction	Reagent and condition	Product
1	HBr at room temperature	
2		

(d) But-1-ene has the structure



(i) Draw the structure of the polymer formed when but-1-ene polymerises. Include **two** repeat units.

(1)

(ii) Calculate the number of molecules in 70.0 g of but-1-ene.
[Avogadro constant = 6.02×10^{23} mol^{-1}]

(2)

(Total for Question 2 = 8 marks)

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Turn over ▶

3 This question is about the compound potassium bromate, $KBrO_3$.

(a) These bromate ions react with bromide ions in acidic solution.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

(i) Explain, in terms of oxidation numbers, whether or not this is a disproportionation reaction.

(2)

(ii) What is the overall order of this reaction?

(1)

☒ **A** 3

☒ **B** 6

☒ **C** 12

☒ **D** cannot tell from this information

(b) Potassium bromate decomposes on heating.

$$2KBrO_3 \rightarrow 2KBr + 3O_2$$

Calculate the maximum volume of oxygen, in dm^3, measured at room temperature and pressure (r.t.p.), that could be produced from the complete decomposition of 5.20 g of potassium bromate.

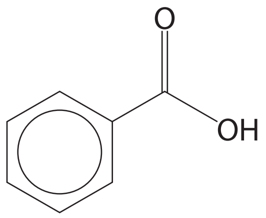
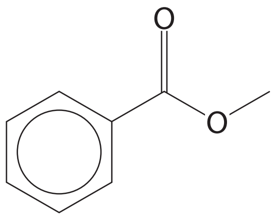
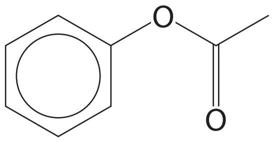
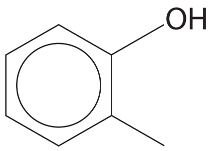
[Molar volume of gas at r.t.p. = 24.0 $dm^3\ mol^{-1}$]

(3)

(Total for Question 3 = 6 marks)

4 This question is about the identification of some organic compounds.

(a) The skeletal formulae of four organic compounds are shown.

Compound **P**  	Compound **Q** 
Compound **R**  	Compound **S** 

(i) Which of these compounds can be hydrolysed to form methanol as one of the products?

(1)

☒ **A** Compound **P**

☒ **B** Compound **Q**

☒ **C** Compound **R**

☒ **D** Compound **S**

(ii) Which of these compounds produces carbon dioxide when it reacts with aqueous sodium hydrogencarbonate?

(1)

☒ **A** Compound **P**

☒ **B** Compound **Q**

☒ **C** Compound **R**

☒ **D** Compound **S**

(b) Compound **T**, $C_4H_{10}O$, is oxidised by acidified potassium dichromate(VI) to form compound **U**, C_4H_8O.

U gives an orange precipitate with 2,4-dinitrophenylhydrazine (Brady's reagent) but does **not** give a red precipitate when heated with Fehling's solution.

T reacts with ethanoyl chloride to form compound **V**, $C_6H_{12}O_2$.

Deduce the structures of compounds **T**, **U** and **V**. Justify your answers.

(6)

(Total for Question 4 = 8 marks)

5 This question is about hydrocarbons.

(a) Which of these molecular formulae represents a non-cyclic, saturated hydrocarbon?

(1)

☒ **A** C_6H_6

☒ **B** C_6H_{10}

☒ **C** C_6H_{12}

☒ **D** C_6H_{14}

(b) How many **structural** isomers are there with the molecular formula C_5H_{12}?

(1)

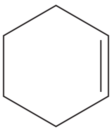
☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

(c) How many σ bonds and π bonds are there in one molecule of cyclohexene?



(1)

		σ bonds	π bonds
☒	**A**	5	2
☒	**B**	6	1
☒	**C**	15	2
☒	**D**	16	1

(d) When hydrocarbons undergo complete combustion, there is a change in the total volume of gases.

(i) Ethane burns in excess oxygen.

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

All gas volumes are measured at the same temperature and pressure when water is a gas.

What is the **increase** in the total volume when 100 cm^3 of ethane is burned in excess oxygen?

(1)

☒ **A** 50 cm^3

☒ **B** 100 cm^3

☒ **C** 200 cm^3

☒ **D** 500 cm^3

(ii) A combustion experiment was carried out using conditions under which water was a liquid.

A cyclic hydrocarbon, C_xH_y, was mixed with excess oxygen and ignited. Under the conditions of the experiment, this hydrocarbon was gaseous and had a volume of 25 cm^3.

The equation for the complete combustion of C_xH_y is

$$C_xH_y(g) + (x + \frac{y}{4})O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$$

The total gas volume **decreased** by 75 cm^3.
The remaining gases were shaken with aqueous sodium hydroxide and the total gas volume **decreased** by a further 125 cm^3.

All gas volumes were measured at the same temperature and pressure.

Suggest the identity of the cyclic hydrocarbon by calculating the molecular formula of C_xH_y.
Include the **skeletal formula** of the cyclic hydrocarbon.

(3)

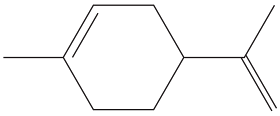
(e) Propene reacts with iodine monochloride, ICl, by an electrophilic addition mechanism.

Draw the mechanism for the reaction between propene and iodine monochloride to form the **major** product.

Include the dipole on the ICl molecule, curly arrows and any relevant lone pairs of electrons.

(4)

(f) Limonene is obtained from the oil in lemon peel and it is the only alkene present.



0.500 g of the oil reacted with exactly 30.6 cm^3 of a solution of bromine dissolved in cyclohexane with a concentration of 0.200 mol dm^{-3}.

Calculate the percentage by mass of limonene in the oil.
Give your answer to an appropriate number of significant figures.

Assume that there is nothing else in the oil that reacts with bromine.

(4)

(Total for Question 5 = 15 marks)

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6 A bromoalkane, RBr, reacts with aqueous hydroxide ions in a nucleophilic substitution reaction.

$$\text{RBr} + \text{OH}^- \rightarrow \text{R—OH} + \text{Br}^-$$

This reaction is first order with respect to the bromoalkane and the rate equation is

$$\text{rate} = k[\text{RBr}]^1[\text{OH}^-]^x$$

where x is the order of the reaction with respect to hydroxide ions.

In an experiment, a sample of the bromoalkane was added to a large excess of aqueous sodium hydroxide and the concentration of the bromoalkane was determined at regular time intervals.

Results

Time / s	[RBr] / mol dm^{-3}
0	0.100
30	0.065
60	0.042
90	0.028
120	0.019
150	0.014

(a) This experiment is carried out using the bromoalkane dissolved in ethanol and the hydroxide ions dissolved in water.

Give a reason why a solution of hydroxide ions dissolved in pure ethanol should **not** be used.

(1)

....

....

....

(b) Plot a graph of [RBr] against time.

(3)

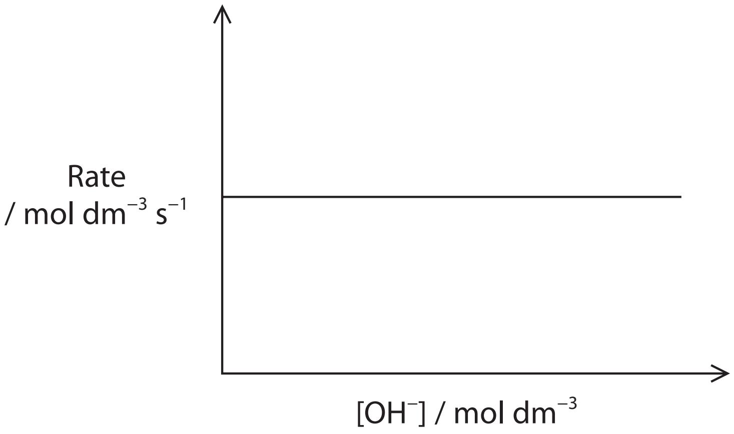
(c) Explain how the graph shows that the reaction is first order with respect to RBr. Include the values of two consecutive half-lives.

You **must** show your working for the half-lives on the graph.

(2)

(d) The experiment was repeated using equal concentrations of RBr and varying the concentration of hydroxide ions.

A graph was plotted of the results.



(i) Deduce the value of x in the rate equation.

$$\text{rate} = k[\text{RBr}]^1[\text{OH}^-]^x$$

(1)

....

(ii) Give the mechanism for the reaction that is consistent with the orders of reaction with respect to R—Br and hydroxide ions.
Include curly arrows and relevant lone pairs.

(3)

(e) 2-bromobutane can react with aqueous hydroxide ions by an S_N1 mechanism.

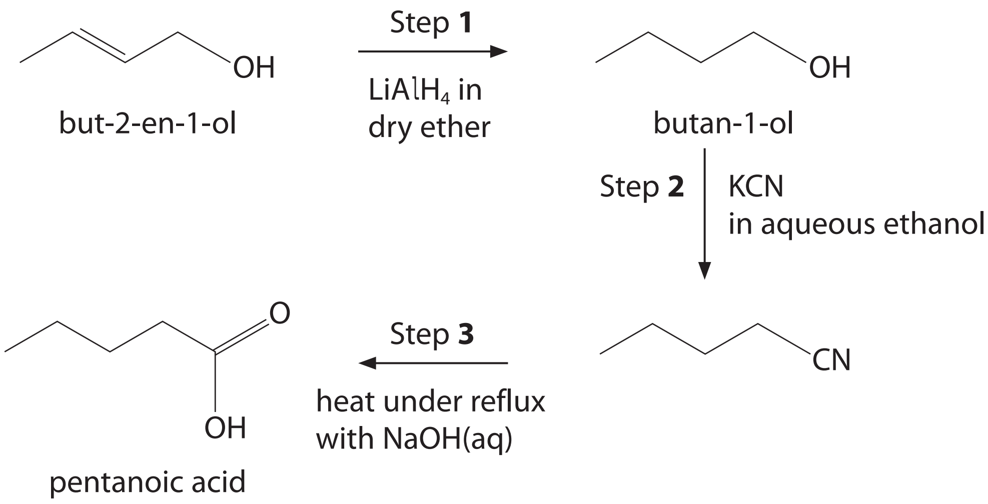
Explain why the butan-2-ol produced from a single optical isomer of 2-bromobutane, using this mechanism, is **not** optically active.

(3)

(Total for Question 6 = 13 marks)

7 This question is about the synthesis of organic compounds.

(a) A student suggested the following plan for the synthesis of pentanoic acid from but-2-en-1-ol.



(i) $LiAlH_4$ is a source of hydride ions, H^-.

Give a possible reason why $LiAlH_4$ cannot be used to reduce alkenes.

(1)

....

....

....

(ii) Give a suitable reagent and condition for Step **1**.

(2)

....

(iii) Step **2** is incorrect because alcohols can only be converted to nitriles via an intermediate compound.
Identify a suitable intermediate compound by name or formula.

(1)

....

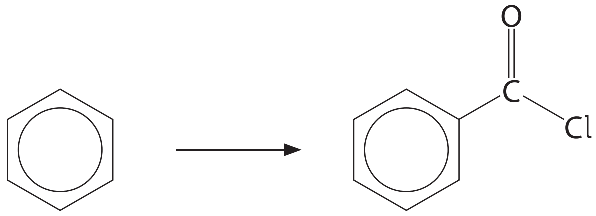
(iv) Step **3** involves the hydrolysis of a nitrile.

Give the additional reagent that should be added after heating under reflux with aqueous sodium hydroxide, to produce pentanoic acid.

(1)

....

(b) Devise a four-step synthesis, involving the use of a Grignard reagent, to convert benzene into benzoyl chloride.



Include the reagents and conditions for each step in the synthesis and the structures of the intermediates.

(7)

(Total for Question 7 = 12 marks)

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8 This question is about the analysis of organic compounds.

(a) **X** is an organic compound.

(i) The accurate relative atomic masses, A_r, of the four elements that could make up **X** are shown in the table.

Element	A_r
hydrogen, H	1.0078
carbon, C	12.0000
nitrogen, N	14.0031
oxygen, O	15.9949

X gives a molecular ion peak at $m/z = 100.0522$ on its mass spectrum.

Which is the molecular formula of **X**?

(1)

☒ **A** C_7H_{16}

☒ **B** $C_6H_{12}O$

☒ **C** $C_6H_{14}N$

☒ **D** $C_5H_8O_2$

(ii) The infrared spectrum of **X** contains major absorption wavenumber ranges at 3300–2500 cm^{-1}, 1725–1700 cm^{-1} and 1669–1645 cm^{-1}.

Identify the two functional groups in **X**.

(2)

....

....

(iii) **X** has an unbranched carbon chain and does **not** exhibit geometric isomerism.

Draw the **skeletal formula** of **X**.

(1)

*(b) There are similarities and differences in the ^{13}C NMR spectra and the high resolution ^{1}H NMR spectra of isomeric organic compounds.

Compare the NMR spectra of propan-1-ol with those of propan-2-ol.

Include the number of peaks, relative peak areas and splitting patterns, where appropriate.

Chemical shift values are **not** required.

(6)

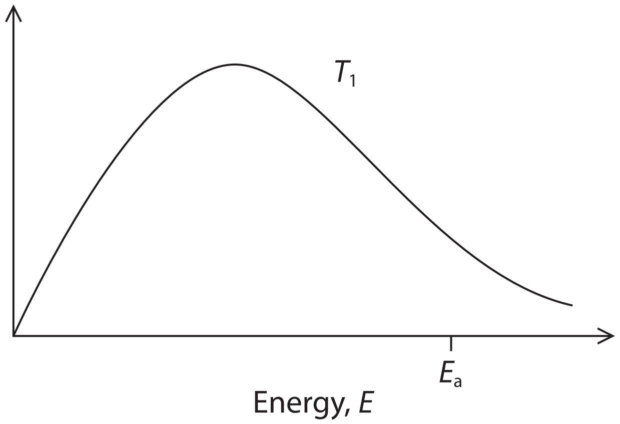
(Total for Question 8 = 10 marks)

9 This question is about the effect of temperature on the rate of decomposition of nitrogen(V) oxide.

$$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$$

(a) The diagram shows the Maxwell-Boltzmann distribution of molecular energies for nitrogen(V) oxide at a temperature T_1.

E_a is the activation energy of this reaction.



(i) Give the label for the vertical axis. **(1)**

....

(ii) Draw a second curve on the same set of axes for the same gas at a **lower** temperature, T_2. **(2)**

(iii) Explain, in terms of collisions and energy, why lowering the temperature decreases the rate of reaction. **(2)**

....

....

....

....

....

(iv) A catalyst is added to the gas.

Label the diagram above with the symbol E_{cat} to show a possible activation energy for the reaction in the presence of a catalyst. **(1)**

(b) The rate constant for the decomposition of nitrogen(V) oxide was determined at two temperatures.

Temperature / K	Rate constant / s^{-1}
328	1.50×10^{-3}
338	4.87×10^{-3}

Calculate the activation energy for this reaction.

Include units and give your answer to an appropriate number of significant figures.

You should **not** attempt to use any graphical method to answer this question.

The Arrhenius equation relating two rate constants, k_1 and k_2, at two different temperatures, T_1 and T_2, can be expressed as

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

(5)

(Total for Question 9 = 11 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Pearson
Edexcel

Mark Scheme (Results)

October 2020

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 2: Advanced Organic and Physical Chemistry

October 2020
Publications Code 9CH0_02_ 2010_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

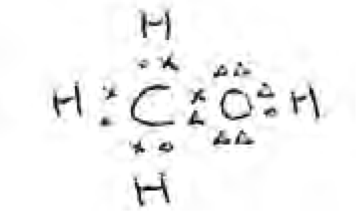
/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

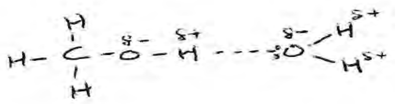
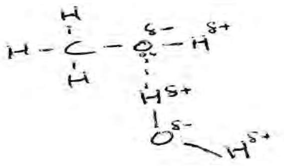
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

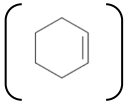
Question Number	Answer	Additional Guidance	Mark
1(a)	• all bonding pairs of electrons correct **(1)** • 2 lone pairs of electrons on oxygen **(1)**	Example of diagram  Allow any symbols for electrons, including all dots or all crosses Allow electrons either side of a line for a bond e.g. x • Electrons can be in overlapping circles, on the lines, inside the lines or in the gaps between the lines Non-bonding electrons on O can be shown as 2 pairs, all 4 together or as 3 and 1 Ignore inner shell electrons	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(b)	• O−H	Allow this shown on diagram in (a) Allow OH Do not award −O−H	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(i)	• hydrogen bonding		**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	• at least one lone pair shown on the oxygen atom in water or methanol **and** involved in the hydrogen bond **(1)** • hydrogen bond shown between an H in one molecule and an O on the other molecule **and** O–H---O / O---H–O bond angle at (about) 180^{o} **(1)** • at least one δ+ shown on either H atom in water or attached to O in methanol **and** at least one δ– shown on any O atom **(1)**	Examples of diagrams   Any bond angle labelled as 180^{o} must be between the correct bonds 180^{o} must be drawn at about 180^{o}, not just labelled Ignore all other bond angles Only 1 correct dipole needs to be shown No TE on c(i) If 2 hydrogen bonds shown, 1 with correct bond angle and 1 incorrect, do not award M2	**(3)**

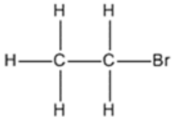
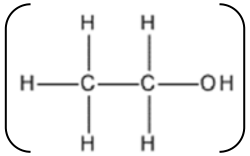
(Total for Question 1 = 7 marks)

Question number	Answer	Mark
2(a)	**The only correct answer is C**  *A is incorrect because this has molecular formula* C_6H_{12} *B is incorrect because this has molecular formula* C_6H_8 *D is incorrect because this has molecular formula* C_6H_8	**(1)**

Question number	Answer	Mark
2(b)	**The only correct answer is C** (2,3-dimethylbut-1-ene) *A is incorrect because the longest chain has 4 carbon atoms* *B is incorrect because the longest chain has 4 carbon atoms* *D is incorrect because the C=C should have the lowest number*	**(1)**

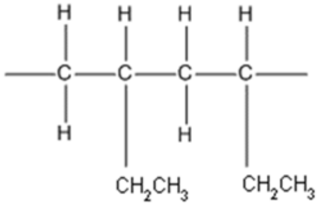
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>2(c)</td>
<td>

product in Reaction 1 (1)
reagent in Reaction 2 (1)
condition in Reaction 2 (1)

</td>
<td>
<u>Example of table</u>
<table>
<tr><th>Reaction</th><th>Reagent and condition</th><th>Product</th></tr>
<tr><td>1</td><td>(HBr at
room temperature)</td><td></td></tr>
<tr><td>2</td><td>steam / $H_2O(g)$
and
acid / H^+</td><td></td></tr>
</table>
Allow structural / skeletal / molecular formula / name for (1-)bromoethane

Allow water / H_2O and heat instead of steam

Allow specific acid e.g. (concentrated) phosphoric acid / sulfuric acid
Ignore any specific temperature and pressure
Do not award acid if mention of any reagent other than steam / water e.g. acidified dichromate
</td>
<td>(3)</td>
</tr>
</table>

Question Number	Answer	Additional Guidance	Mark
2(d)(i)	- 2 repeat units with extension bonds	Example of two repeat units  The extension bonds can be solid / dotted / dashed Allow C_2H_5 for the side chains Allow ethyl groups on carbon atoms: 1 and 3, 2 and 4, 1 and 4 or 2 and 3 Allow skeletal formula / any combination of structural or displayed formulae Ignore brackets / n Ignore connectivity of vertical CH_2CH_3 groups	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(d)(ii)	• calculation of moles of but-1-ene **(1)** • calculation of number of molecules of but-1-ene **(1)**	Example of calculation moles of but-1-ene = $\frac{70.0}{56.0}$ = 1.25 (mol) molecules of but-1-ene = $1.25 \times 6.02 \times 10^{23}$ = 7.525×10^{23} TE on moles but-1-ene Ignore SF except 1 SF Do not award M2 for mass x 6.02×10^{23} Correct answer with no working scores (2)	**(2)**

(Total for Question 2 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to the following points: • oxidation numbers of Br identified as (+)5 for BrO_3^-, −1 for Br^- and 0 for Br_2 **(1)** • this is not disproportionation because: two different species of bromine / reactants are oxidised and reduced / not one species oxidised and reduced **or** only one species containing bromine is produced / two different species containing bromine in two different oxidation states are not produced **(1)**	These may be shown in the equation Allow 5+ / V / 1− / −I Do not award any change in oxidation numbers of oxygen and or hydrogen Allow bromine is oxidised and reduced in the reverse reaction Allow this is reverse disproportionation / comproportionation	**(2)**

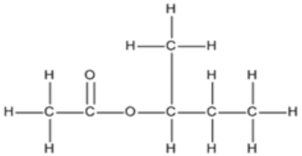
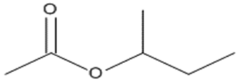
Question number	Answer	Mark
3(a)(ii)	**The only correct answer is D** (cannot tell from this information) *A is incorrect because there are 3 reactant species but the overall order of a reaction can only be determined by experiment* *B is incorrect because there is 1 bromate ion and 5 bromide ions but the overall order of a reaction can only be determined by experiment* *C is incorrect because there are 12 reactant particles but the overall order of a reaction can only be determined by experiment*	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)	- calculation of moles of $KBrO_3$ **(1)** - calculation of moles of O_2 **(1)** - calculation of volume of O_2 **(1)**	Example of calculation moles of $KBrO_3$ = $\frac{5.20}{(39.1 + 79.9 + (3 \times 16.0))}$ = $\frac{5.20}{167(.0)}$ = 0.031138 / 3.1138×10^{-2} (mol) moles of O_2 = $\frac{0.031138 \times 3}{2}$ = 0.046707 / 4.6707×10^{-2} (mol) TE on moles of $KBrO_3$ volume of O_2 = 0.046707 x 24 = 1.12096 (dm^3) TE on moles of O_2 Do not award incorrect unit e.g. dm^{-3} Correct answer with no working scores (3) Ignore SF except 1 SF Ignore use of $pV = nRT$	**(3)**

(Total for Question 3 = 6 marks)

Question number	Answer	Mark
4(a)(i)	**The only correct answer is B** (Compound **Q**) *A is incorrect because this is not hydrolysed* *C is incorrect because this is hydrolysed to form phenol and ethanoic acid* *D is incorrect because this is not hydrolysed*	**(1)**

Question number	Answer	Mark
4(a)(ii)	**The only correct answer is A** (Compound **P**) *B is incorrect because it is an ester and does not react with sodium hydrogencarbonate* *C is incorrect because it is an ester and does not react with sodium hydrogencarbonate* *D is incorrect because it is not acidic enough to react with sodium hydrogencarbonate*	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	**Structures:**	<u>Examples of structures</u> Ignore names, even if incorrect	**(6)**
	- **T**: structure of butan-2-ol **(1)**	**T**: $CH_3CH_2CHOHCH_3$ Ignore connectivity of OH group in displayed formula	
	- **U**: structure of butanone **(1)**	**U**: $CH_3CH_2COCH_3$	
	- **V**: structure of 1-methylpropyl ethanoate **(1)**	**V**:   Allow skeletal formulae or any combination of displayed and structural formulae Do not award C_4H_9 from alcohol Allow butyl ethanoate if **T** is butan-1-ol	
	Justification:		
	- **U** is a ketone because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** does not give a precipitate with Fehling's solution **(1)**	Allow **U** is a carbonyl compound because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** is not an aldehyde as it does not give a precipitate with Fehling's solution	
	- **T** is a secondary alcohol because it was oxidised to / formed a ketone **(1)**		
	- **V** is an ester as alcohols react with acyl chlorides / ethanoyl chloride to form esters **(1)**		

(Total for Question 4 = 8 marks)

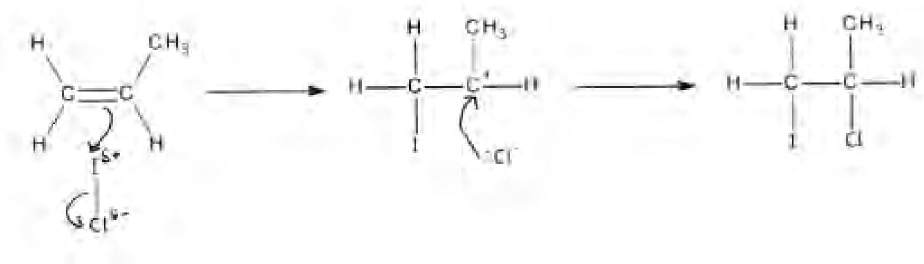
Question number	Answer	Mark
5(a)	**The only correct answer is D** (C$_6$H$_{14}$) *A is incorrect because this has general formula C_nH_n and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}* *B is incorrect because this has general formula C_nH_{2n-2} and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}* *C is incorrect because this has general formula C_nH_{2n} and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}*	**(1)**

Question number	Answer	Mark
5(b)	**The only correct answer is B** (3) *A is incorrect because the structural isomers of C_5H_{12} are pentane, 2-methylbutane and 2,2-dimethylpropane* *C is incorrect because the structural isomers of C_5H_{12} are pentane, 2-methylbutane and 2,2-dimethylpropane* *D is incorrect because the structural isomers of C_5H_{12} are pentane, 2-methylbutane and 2,2-dimethylpropane*	**(1)**

Question number	Answer	Mark
5(c)	**The only correct answer is D** (16σ bonds and 1π bond) *A is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond* *B is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond* *C is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond*	**(1)**

Question Number	Answer	Mark
5(d)(i)	**The only correct answer is A** (50 cm^3) *B is incorrect because this is the increase in volume from 200 cm^3 of ethane* *C is incorrect because this is the volume of CO_2 formed* *D is incorrect because this is the total volume of CO_2 and H_2O formed*	**(1)**

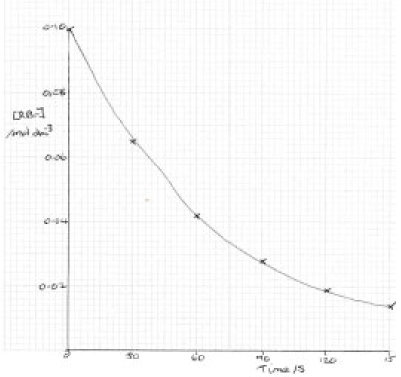
Question number	Answer	Additional Guidance	Mark
5(d)(ii)	• calculation of x **(1)** • calculation of y **(1)** • structure of cyclopentene **(1)**	Example of calculation (volume of CO_2 = 125 (cm^3) so x = 125/25) = 5 (25 + 25(5 + (y/4)) − 75 = 125) y = 8  Allow the skeletal formula of any cyclic C_5H_8 compound with C=C e.g. a methylcyclobutene TE on x and y for a cyclic hydrocarbon	**(3)**

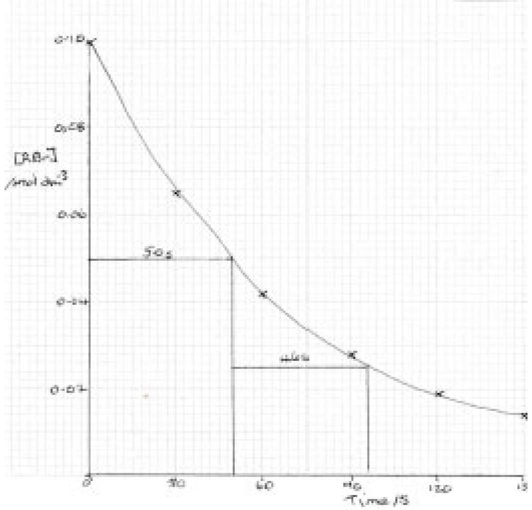
Question Number	Answer	Additional Guidance	Mark
5(e)	• dipole on I-Cl **and** correct major product **(1)** • curly arrow from C=C to I **and** curly arrow from I-Cl to, or just beyond, Cl **(1)** • intermediate **(1)** • lone pair on Cl^- **and** curly arrow from **lone pair** to C^+ **(1)**	Example of mechanism  Do not award $C^{\delta+}$ on intermediate Allow curly arrow from lone pair to $C^{\delta+}$ if penalised in M3 **Notes** If minor product formed, M2, M3 (with I on other carbon atom) and M4 can score If dipole shows $Cl^{\delta+}$ or no dipole shown and Cl joining first, M2 can score for curly arrow from C=C to Cl **and** curly arrow from Cl-I to, or just beyond, I and M4 can score for lone pair on I^- **and** curly arrow from lone pair to C^+	**(4)**

Question Number	Answer	Additional Guidance	Mark
5(f)	• calculation of moles of Br_2 **(1)** • calculation of moles of limonene **(1)** • calculation of mass of limonene **(1)** • calculation of percentage of limonene **and** answer given to 2 or 3 SF **(1)**	Example of calculation moles of Br_2 = $\frac{30.6 \times 0.200}{1000}$ = 0.00612 / 6.12×10^{-3} moles of limonene = $\frac{0.00612}{2}$ = 0.00306 / 3.06×10^{-3} TE on moles of Br_2 molar mass of limonene = 136 (g mol^{-1}) **and** mass of limonene in oil = 0.00306 x 136 = 0.41616 (g) TE on moles of Br_2 percentage of limonene = $\frac{0.41616}{0.500}$ x 100 (= 83.232(%)) = 83/83.2(%) TE on mass of limonene provided answer is less than 100% with 0.500 as denominator Correct answer with no working scores (4)	**(4)**

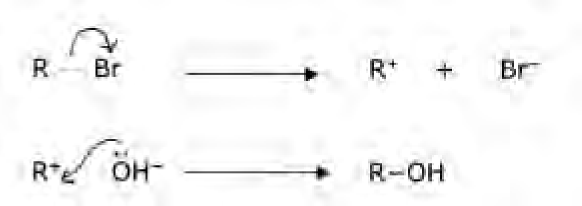
(Total for Question 5 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following point: - (hydroxide ions in ethanol would give an) elimination reaction	Allow an alkene would form Ignore references to solubility in ethanol / ethanol is a (co-)solvent Ignore just 'causes another reaction'	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)	- both axes labelled, including units **(1)** - suitable scales and points taking up at least half the graph paper in both directions **(1)** - points plotted correctly **and** smooth curve through the points **(1)**	Example of graph  Allow T / t for time with units Allow just 'concentration' with units Do not award RBr without square brackets Allow ± half square Do not award point-to-point straight lines	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(c)	• first half-life 50 s **and** second half-life 50 s **(1)** • reaction is first order because the half-lives are (almost) the same **(1)**	Example of working on graph  Allow ± 6 s for both half-lives Do not award M1 if no working is shown on the graph Allow rate ∝ [RBr] / rate = k[RBr] for first order Conditional on 2 half-lives within 12 s **or** the second half-life is (about) twice the first half-life	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	- zero (order0 / 0 (order)	Allow x = 0 / rate is proportional to $[OH^-]^0$ / rate = $k[R\text{-}Br][OH^-]^0$	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	- curly arrow from R-Br bond to, or just beyond, Br - **(1)** - R^+ **and** Br^- **(1)** - lone pair on O of OH^- **and** curly arrow from lone pair to R^+ **(1)**	<u>Example of mechanism</u>  Ignore dipole on RBr	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(e)	An explanation that makes reference to the following points: • a racemic mixture / racemate is formed **or** equal amounts / an equimolar mixture of both optical isomers forms **(1)** • intermediate / carbocation is (trigonal) planar around the reaction site / C^+ / central carbon **(1)** • (equal probability of) attack (by nucleophile / hydroxide ions) from either side / above and below / both sides / opposite sides (of the plane) **(1)**	Allow enantiomers / D-L isomers / (+) and (-) isomers Allow the two isomers rotate the plane of plane-polarised light in opposite directions and cancel out Ignore just 'mixture is not optically active' / 'mixture does not rotate the plane of plane-polarised light' Allow the intermediate / carbocation is planar (around the reaction site) Do not award 'the molecule is planar'	**(3)**

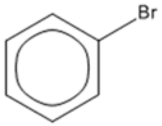
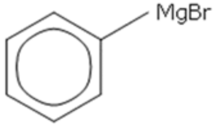
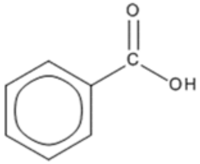
(Total for Question 6 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	An answer that makes reference to the following point: • the hydride ion will not attack / will be repelled by regions of high electron density	Allow the reduction by $LiAlH_4$ is a nucleophilic addition / alkenes do not undergo nucleophilic reactions / H^- is a nucleophile Allow alkenes react with H^+ / $H^{\delta+}$ / H• Allow the hydride ion will not attack a pi-bond / C=C Allow like charges repel Ignore hydride ions cannot reduce alkenes Ignore hydride ions can only reduce carbonyl compounds	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	An answer that makes reference to the following points: • hydrogen / H_2 **(1)** • nickel / Ni **or** platinum / Pt / palladium / Pd **(1)**	Mark independently Ignore reference to temperature	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	• 1-bromobutane / $CH_3CH_2CH_2CH_2Br$	If name and formula are given, both must be correct Allow Cl or I instead of Br Allow skeletal or displayed formulae	**(1)**

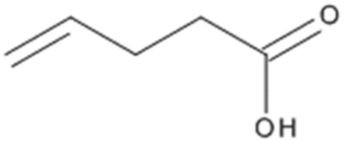
Question Number	Answer	Additional Guidance	Mark
7(a)(iv)	• hydrochloric acid / HCl / H^+	Allow any (dilute) strong acid Ignore concentration of acid Do not award any weak acid	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(b)	**Step 1** • bromine **and** iron / iron(III) bromide **or** chlorine and aluminium chloride **(1)** •  **(1)** **Step 2** • magnesium **and** dry ether **(1)** •  **(1)** **Step 3** • carbon dioxide followed by a dilute acid **(1)** •  **(1)** **Step 4** • phosphorus(V) chloride / phosphorus pentachloride **(1)**	Allow names or formulae for reagents but if both are given, both must be correct Allow these drawn as a reaction scheme with reagents and conditions on arrows and intermediates in unbalanced equations The marks for the intermediate structures are stand-alone Allow carbon dioxide and dilute acid Ignore just carbon dioxide and water	**(7)**

(Total for Question 7 = 12 marks)

Question number	Answer	Mark
8(a)(i)	**The only correct answer is D** ($C_5H_8O_2$) A *is incorrect because C_7H_{16} has a molecular ion m / z = 100.1248* B *is incorrect because $C_6H_{12}O$ has a molecular ion m / z = 100.0885* C *is incorrect because $C_6H_{14}N$ has a molecular ion m / z = 100.1123*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	• alkene / C=C **(1)** • carboxylic acid / COOH **(1)**	The functional groups can be in any order Ignore just ‘double bond’ Ignore just C=O and OH	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	• skeletal formula of **X**	<u>Example of skeletal formula</u>  Ignore bond lengths and bond angles	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning.	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	**(6)**

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

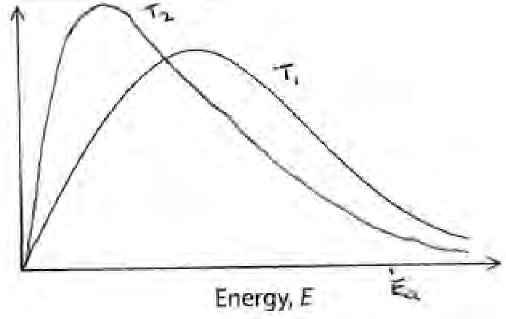
General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).
e.g.
Mention of splitting on the ^{13}C spectra

Deduct 1 reasoning mark if the similarity in IP1 has not been explicitly mentioned

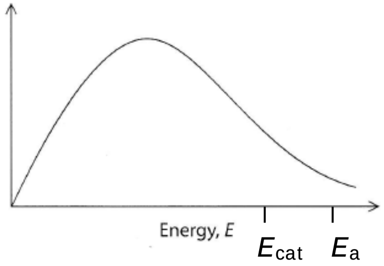
	Indicative content	All IP can be shown on clearly labelled diagrams of structures and/or spectra	
	• **IP1 -** Similarity **both** ^{1}H NMR spectra have a peak (which is a singlet with relative peak area 1) for OH		
	• **IP2 -** ^{13}C spectra 3 peaks for propan-1-ol **and** 2 peaks for propan-2-ol	Allow carbon environments for peaks Ignore any reference to peak areas	
	• **IP3 -** ^{1}H spectra number of peaks 4 peaks for propan-1-ol **and** 3 peaks for propan-2-ol		
	• **IP4 -** ^{1}H spectra relative peak areas (relative) peak areas 3 : 2 : 2 : 1 for propan-1-ol, 6 : 1 : 1 for propan-2-ol	Allow 3 : 2 : 2 and 6 : 1 if peak areas for OH given in similarity Allow ratios in any order e.g. 1 : 2 : 2 :3	
	• **IP5 -** ^{1}H splitting pattern for propan-1-ol 2 triplets, 1 sextet / split into 6 and 1 singlet	Allow hextet for sextet Ignore missing singlet if this has been given in similarity	
	• **IP6 -** ^{1}H splitting pattern for propan-2-ol 1 doublet, 1 septet / split into 7 and 1 singlet	Allow heptet for septet Ignore missing singlet if this has been given in similarity	

(Total for Question 8 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)(i)	• fraction / proportion / number of molecules / particles with energy, *E*	Allow fraction / proportion / number of molecules / particles Allow label written on y axis on diagram	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	• peak for T_2 to the left of T_1 **(1)** • peak for T_2 higher than T_1 **and** asymptote lower than T_1 line and not touching the x axis **(1)**	Example of diagram  Ignore missing label from added line Do not award M2 if added line curves upwards at the end	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	An explanation that makes reference to the following points: • (at a lower temperature the) molecules / particles / collisions have lower (kinetic) energy **(1)** • so fewer molecules / particles / collisions have energy greater than (or equal to) the activation energy / E_a **(1)**	Ignore molecules / particles move more slowly Allow fewer molecules / particles have (enough energy to overcome) the activation energy Allow this shown as labelled shading on the diagram Ignore just 'fewer successful collisions'	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(a)(iv)	• E_{cat} labelled anywhere between the energy corresponding to the highest point of the peak and to the left of E_a	Example of label  Allow other clear labels for E_{cat}	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(b)		Example of calculation	**(5)**
	- substitution of numbers into expression **(1)**	$\ln \frac{4.87 \times 10^{-3}}{1.50 \times 10^{-3}} = \frac{-E_a}{8.31}\left(\frac{1}{338} - \frac{1}{328}\right)$	
	- evaluation of k_2/k_1 or $\ln k_2/k_1$ **and** $1/T_1 - 1/T_2$ **(1)**	$k_2/k_1 = 3.2467$ or $\ln k_2/k_1 = 1.1776$ Allow 487/150 for $\ln k_2/k_1$ **and** $1/T_1 - 1/T_2 = (-)9.0201 \times 10^{-5}$ Allow (−)5/55432 for $(-)9.0201 \times 10^{-5}$	
	- rearrangement of expression **(1)**	e.g. $E_a = \frac{1.1776 \times 8.31}{9.0201 \times 10^{-5}}$ or $\frac{E_a}{R} = \frac{1.1776}{9.0201 \times 10^{-5}}$ / = 13056	
	- evaluation of expression **(1)**	$E_a = 108\ 493$ TE on $\ln (k_2/k_1)$ and $1/T_1 - 1/T_2$	
	- answer given to 2/3 SF **and** corresponding units **(1)**	= (+)108 000 / 110 000 J mol^{-1} or (+)108 / 110 kJ mol^{-1} Do not award negative value Expression may be rearranged before any evaluation Correct answer to 2/3 SF and units with no working scores (5)	

(Total for Question 9 = 11 marks)

Total for Paper = 90 Marks

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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
Level 3 GCE

Centre Number ☐☐☐☐☐ Candidate Number ☐☐☐☐

Wednesday 17 June 2020

Morning (Time: 2 hours 30 minutes) | Paper Reference **9CH0/03**

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Candidates must have: Data Booklet
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

Pearson

Answer ALL questions.

1 Aqueous sodium carbonate and aqueous sodium sulfate are both colourless solutions.

(a) Give the reagent and the observation to show the presence of carbonate ions.

(2)

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(b) Give the reagent and the observation to show the presence of sulfate ions.

(2)

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....

(Total for Question 1 = 4 marks)

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2 This question is about flame tests for Group 1 and 2 metal ions.

(a) (i) State the colour of the flame produced by separate samples of potassium and strontium ions.

(1)

Potassium ions ....

Strontium ions ....

(ii) Give a reason why carrying out a flame test on a mixture of potassium chloride and strontium chloride does not clearly show that two different metal ions are present.

(1)

....

....

....

(b) In the first stage of the flame test, the nichrome wire is dipped into concentrated hydrochloric acid and then heated in a Bunsen flame.

In the second stage, this nichrome wire is dipped into fresh hydrochloric acid and then into the metal salt to be tested before being reheated in the Bunsen flame.

(i) Give **two** reasons why the wire is made of nichrome and not iron.

(2)

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....

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....

(ii) Give a reason why the wire is dipped into acid and then heated in the first stage.

(1)

....

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....

(iii) State why **fresh** concentrated hydrochloric acid is used in the second stage of the flame test.

(1)

....

....

(iv) State why **hydrochloric acid** is used in the second stage of the flame test.

(1)

....

....

(c) Explain, with reference to electron transitions, the formation of the colour in a flame test.

(3)

....

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....

(Total for Question 2 = 10 marks)

3 This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

(a) A student weighed about 4.00 g of sodium hydroxide pellets and added them to a beaker containing 50 cm^3 of deionised water.

The mixture was stirred with a glass rod to dissolve the pellets and to give a homogenous solution.

The solution was poured through a funnel into a 250.0 cm^3 volumetric flask and deionised water was added up to the mark and then the flask was shaken.

(i) Describe how you would ensure that all the sodium hydroxide was transferred to the volumetric flask.

(2)

(ii) A student adds deionised water above the mark and shakes the flask.

State why the procedure has to be restarted rather than using a teat pipette to remove the excess water.

(1)

(b) Two students each cleaned a burette, then poured sodium hydroxide solution into their burettes.

(i) Student 1 used a funnel to pour sodium hydroxide solution into the burette.

Give **two** steps needed before the student takes the initial burette reading.

(2)

....

....

....

....

(ii) Student 2 cleaned the burette by rinsing it with deionised water immediately before filling it with the sodium hydroxide solution.

Give the effect, if any, on the value of the first titre. Justify your answer.

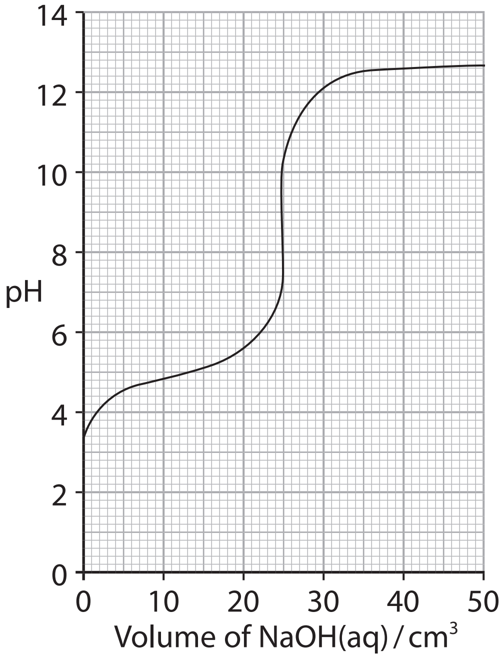
(1)

....

....

....

(c) The sketch shows the pH changes during a titration of 25.0 cm^3 of ethanoic acid with sodium hydroxide of the same concentration.



The ideal indicator for this titration will change colour on the addition of a very small volume of sodium hydroxide solution at a titre value very close to the equivalence point of the reaction.

(i) Assess the suitability of methyl red as an indicator for this titration. Make use of the Data Booklet in answering this question.

(4)

(ii) Complete the table, with a tick (✓) or a cross (✗), to show whether or not the indicator would be suitable for use in this titration.

(1)

Indicator	pH range	Tick or Cross
Bromocresol purple	5.2 – 6.8	
Thymol blue	8.0 – 9.6	
Thymolphthalein	8.3 – 10.6	
Alizarin yellow R	10.1 – 13.0	

(d) Each student used a pipette to measure 25.0 cm^3 of the ethanoic acid solution into four separate conical flasks and added an indicator.

The results of one student's titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	13.00	25.50	37.90	50.00
Initial burette reading / cm^3	0.25	13.00	25.50	37.90
Titre / cm^3				
Concordant titres (✓)				

(i) Complete the table.

(1)

(ii) The low titre for titration **4** was queried by the teacher. The student had wanted to refill the burette and continue the titration but had been told the measurement uncertainty would increase if this was done.

Calculate the total percentage measurement uncertainty if the burette had been refilled to 0.00, and then a further 0.30 cm^3 had been added from the burette, to the conical flask.

The measurement uncertainty for each burette reading is ±0.05 cm^3.

(1)

(e) The teacher carried out the experiment and obtained the following results.

Mass of sodium hydroxide used to make 250.0 cm^3 solution = 3.80 g

Volume of ethanoic acid solution = 25.00 cm^3

Mean titre of sodium hydroxide = 11.90 cm^3

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Calculate the concentration of the ethanoic acid solution in **g dm^{-3}**.
Give your answer to an appropriate number of significant figures.

(5)

(Total for Question 3 = 18 marks)

4 Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.
An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

The following outline procedure was carried out.

Step **1** 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.

Step **2** 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.

Step **3** The temperature change was recorded.

Step **4** Steps **1** to **3** were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

(a) Calculate the mass of 0.0250 mol of hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

(2)

(b) The reaction of hydrated copper(II) sulfate with water is shown.

$$CuSO_4.5H_2O(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_1 = +18.2\,kJ\,mol^{-1}$$

Calculate the temperature change that would have given this enthalpy change for the stated experimental procedure.
Give your answer to a measurable number of significant figures and state whether the temperature increases or decreases.

[Specific heat capacity of the solution = 4.18 J g^{-1} °C^{-1}]

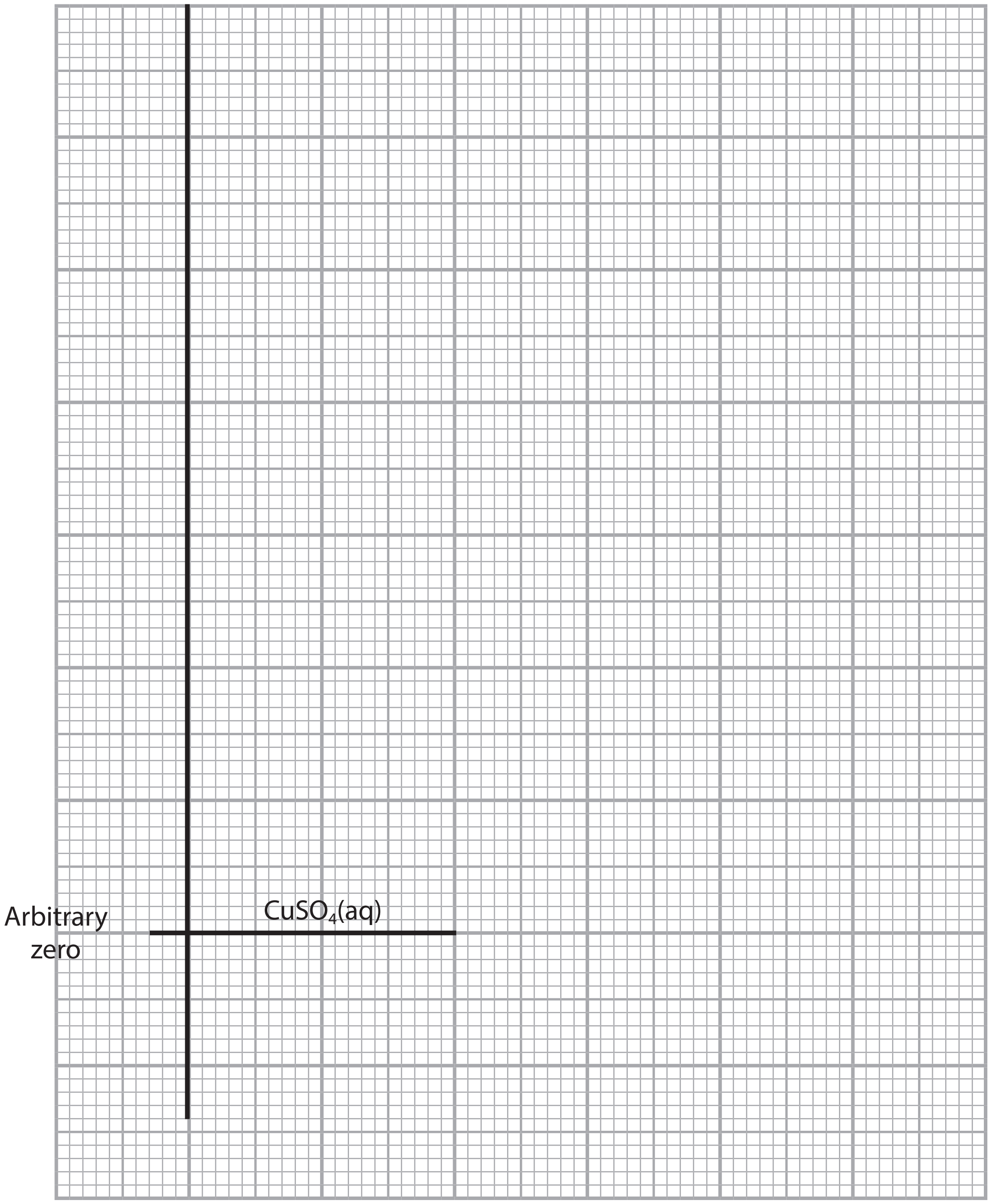
(3)

(c) The reaction of anhydrous copper(II) sulfate with water is shown.

$$CuSO_4(s) \quad + \quad aq \quad \rightarrow \quad CuSO_4(aq) \qquad \Delta H_2 = -84.5\,kJ\,mol^{-1}$$

(i) Draw to scale, on the graph paper, a labelled enthalpy level diagram which shows the enthalpy changes for the reactions of water with hydrated copper(II) sulfate (ΔH_1) and anhydrous copper(II) sulfate (ΔH_2).

(3)



(ii) Use your enthalpy level diagram in (c)(i) to determine the enthalpy change, $\Delta_r H$, for the reaction

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4.5H_2O(s)$$

You **must** show your working on the diagram.

(1)

$\Delta_r H$ ....

(d) State why the enthalpy change for the reaction of one mole of anhydrous copper(II) sulfate with five moles of water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$, cannot be measured directly.

(1)

....

....

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....

(Total for Question 4 = 10 marks)

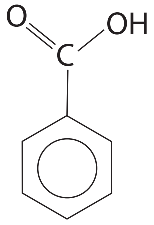
5 This question is about extracting benzoic acid from a mixture of benzoic acid, C_6H_5COOH, and phenol, C_6H_5OH.

The following steps were carried out.

Step **1**	A suitable mass of the mixture was placed in a separating funnel and some ether added. The funnel was shaken to dissolve the mixture.
Step **2**	Aqueous sodium hydrogencarbonate was added to the separating funnel, and the contents shaken.
Step **3**	Once the reaction was complete, the two layers were allowed to separate.
Step **4**	The lower aqueous layer was removed and placed in a beaker.
Step **5**	The ether layer in the separating funnel was washed with deionised water and the washings added to the beaker.
Step **6**	Hydrochloric acid was added to the aqueous solution in the beaker to precipitate the benzoic acid.
Step **7**	The impure benzoic acid was filtered under reduced pressure.
Step **8**	The impure benzoic acid was purified by recrystallisation.
Step **9**	The melting temperature of the purified benzoic acid was measured and compared with the literature value of 122 °C.

(a) Complete the equation for the reaction between benzoic acid and sodium hydrogencarbonate.

(2)



+ .... → .... + ... + ...

(b) In Step **2** there is a pressure build-up in the separating funnel.

Describe how you would lower the pressure.

(1)

....

....

....

(c) State why, in Step **4**, the aqueous layer was the lower of the two layers.

(1)

(d) Give a reason why, in Step **5**, the ether layer was washed with deionised water.

(1)

(e) Explain why the addition of hydrochloric acid in Step **6** results in the precipitation of benzoic acid.

(2)

(f) Draw a diagram of the apparatus used in Step **7** to filter under reduced pressure.

(2)

(g) Benzoic acid can be purified in Step **8** because of its high solubility in hot water and low solubility in cold water.

Calculate the maximum number of benzoic acid molecules that can dissolve in 50.0 cm^3 of cold water if the solubility is 1.70 g per 1000 cm^3.

(3)

(h) The melting temperature range of the purified benzoic acid in Step **9** was 116–121 °C.

Compare this result with the literature value, giving a reason for any differences.

(2)

....

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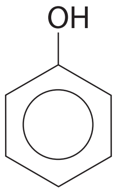
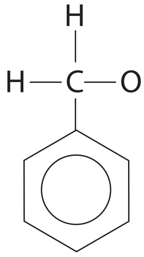
....

(Total for Question 5 = 14 marks)

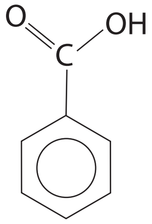
6 This is a question about the analysis of three aromatic substances with —OH groups.



phenol



phenylmethanol



benzoic acid

(a) Write the equation for the **complete** combustion of phenol.
State symbols are not required.

(2)

(b) When burned in air, these aromatic compounds undergo **incomplete** combustion.

(i) Calculate the percentage composition by mass of carbon in both phenylmethanol and benzoic acid.

(3)

(ii) Give the expected observation when these aromatic compounds undergo incomplete combustion.

(1)

(iii) Identify another **type** of organic compound which will also produce the same observation as in (b)(ii).

(1)

(iv) These combustion experiments must be carried out in a fume cupboard.

Explain why the front window of the fume cupboard must be below the safety line even with the exhaust fan switched on.

(2)

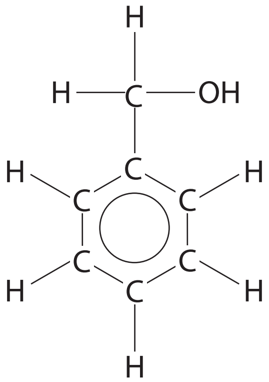
(c) Spectroscopy is an effective means of distinguishing between molecules.

(i) Compare and contrast the infrared spectra of phenol, phenylmethanol and benzoic acid.
Include relevant bonds and their wavenumber ranges using the Data Booklet.

(5)

(ii) Predict the number of peaks present, and their chemical shifts, in the ^{13}C nuclear magnetic resonance (NMR) spectrum of phenylmethanol. Use the information in the Data Booklet to help you.

(3)



phenylmethanol

(iii) Give the formula of a fragment ion, with its *m*/*z* value, that you would expect to be present in the mass spectrum of benzoic acid but **not** in the mass spectrum of phenol or the mass spectrum of phenylmethanol.

(2)

(Total for Question 6 = 19 marks)

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***7** “Cobalt(II) ions combine with substances in solution to form complex ions with different coordination numbers.”

Discuss this statement by referring to **two** complex ions containing cobalt(II).

Include

- reference to any difference in colour
- a definition of any terms used
- an explanation of the different shapes

(6)

(Total for Question 7 = 6 marks)

8 This is a question about chromium(III) and chromium(VI) compounds.

(a) Describe the observations when aqueous sodium hydroxide is added drop by drop until in excess to a solution of chromium(III) ions.

(2)

....

....

(b) The chromium(III) complex, $[Cr(OH)_6]^{3-}$, can be oxidised to chromate(VI) ions, CrO_4^{2-}, by hydrogen peroxide solution.

(i) Deduce the oxidation half-equation for this reaction, which takes place in alkaline conditions. State symbols are not required.

(2)

(ii) If the solution of chromate(VI) ions is then acidified, the colour of the solution changes to orange as dichromate(VI) ions form.

Write the equation for this change. State symbols are not required.

(1)

(iii) In acidic conditions, dichromate(VI) ions can also be reduced to chromium(III) ions using hydrogen peroxide.

The value of $E^{\ominus}_{cell} = +0.65\,V$ for which the cell diagram is

$$Pt(s) \mid H_2O_2(aq), [2H^+(aq)+O_2(g)] \,\vdots\vdots\, [Cr_2O_7^{2-}(aq)+14H^+(aq)], [2Cr^{3+}(aq)+7H_2O(l)] \mid Pt(s)$$

Deduce from the cell diagram the oxidation and the reduction half-equations, and thus the overall equation for this reaction.
State symbols are not required.

(3)

(c) Draw a labelled diagram of the apparatus that you would use to measure the standard emf of a cell with a zinc-zinc(II) electrode system and a chromium(III)-dichromate(VI) electrode system.

Include the **formulae** of all the compounds required and the concentrations of the solutions.

(7)

(Total for Question 8 = 15 marks)

9 This question is about amines.

(a) Phenylamine is an aromatic amine and butylamine is an aliphatic amine.

Phenylamine can be prepared from nitrobenzene.

Butylamine can be prepared from butanenitrile.

$$C_3H_7CN \rightarrow C_4H_9NH_2$$

Compare and contrast these two preparations of amines.

(3)

(b) Compare and contrast the basicity of phenylamine and butylamine.

(3)

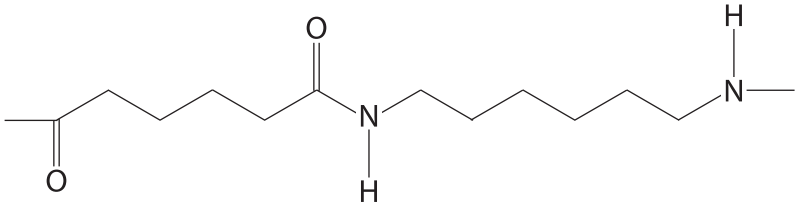
(c) Write the equation for the reaction between propanoyl chloride and pentylamine. Include the name of the amide formed.

State symbols are not required.

(2)

Name of amide ....

(d) A section of a polyamide is shown.



Identify, by name or formula, the amine monomer that reacts to form this polyamide.

(1)

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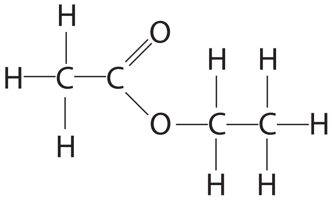
(Total for Question 9 = 9 marks)

10 Ethyl ethanoate is an ester.



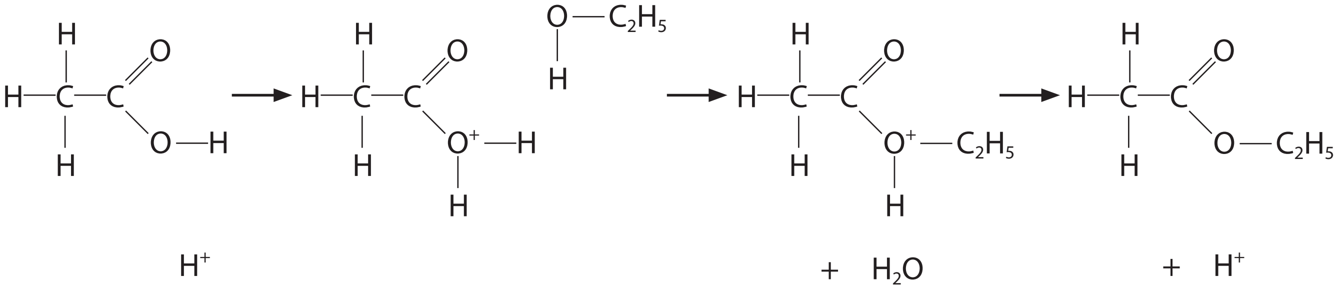
(a) One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

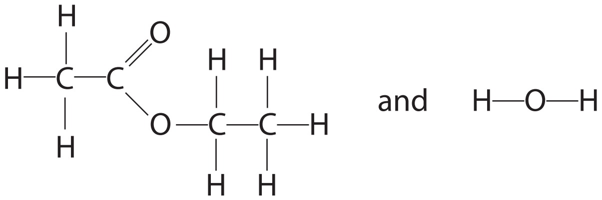
An incomplete simplified mechanism for this reaction is shown.

(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)



(ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O.
The products of the esterification are



Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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....

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....

....

(iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, ΔG, and the data in the table.

Include sign and units in your answer.

Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, R	$8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Temperature, T	$298\ \text{K}$
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	$-6.0\ \text{kJ mol}^{-1}$
Standard molar entropy of ethanoic acid, S°	$159.8\ \text{J K}^{-1}\ \text{mol}^{-1}$
Standard molar entropy of ethanol, S°	$160.7\ \text{J K}^{-1}\ \text{mol}^{-1}$
Standard molar entropy of water, S°	$69.9\ \text{J K}^{-1}\text{mol}^{-1}$

(6)

(b) Ethyl ethanoate can also be formed by reacting ethanol with ethanoyl chloride, CH_3COCl.

Identify **three** differences in the esterification reaction when ethanoyl chloride is used instead of ethanoic acid.

(3)

(Total for Question 10 = 15 marks)

TOTAL FOR PAPER = 120 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

Mark Scheme (Results)

October 2020

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 3: General and Practical Principles in Chemistry

October 2020
Publications Code 9CH0_03_2010_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to: • addition of (dilute/strong) name/formula of acid **(1)** • effervescence/bubbling/fizzing **(1)**	Allow weak acids If formula given then must be correct Allow Gas given off which turns limewater cloudy Do not award just 'gas/ CO_2 given off' Do not award incorrect observations such as precipitate forming due to addition of acid M2 dependent on M1 or 'near miss'	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to: • addition of barium chloride/nitrate (solution) **(1)** • white precipitate forms **(1)**	Accept formulae $BaCl_2$/$Ba(NO_3)_2$ Ignore addition of acids such as HCl or HNO_3 but do not award M1 if addition of sulfuric acid Allow white solid If ppt identified then must be correct M2 dependent on M1 or 'near miss'	**(2)**

(Total Question 1 = 4 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)(i)	An answer that makes reference to: • (potassium ions) lilac **and** (strontium ions) crimson / red	Allow scarlet Ignore 'shades' except Do not award 'brick red' / 'orange-red'	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An answer that makes reference to: • the crimson/red colour will mask/hide/obscure the (lighter) lilac colour	Allow 'one colour will hide the other' Allow only one colour seen Allow difficult to distinguish the two colours Allow TE from colours in (a)(i) Do not award colour from chloride ions Do not award idea of new colour resulting from both Ignore reference to impurities	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)(i)	An answer that makes reference to: • nichrome produces no colour (when heated in the flame test) **or** iron can produce a colour/sparks **(1)** • nichrome is inert/ stable to heat/unreactive **or** iron reacts with oxygen/air and or hydrochloric acid **(1)**	Allow does not change the flame colour Ignore references to melting/cost Ignore reference to nichrome not being a transition element	**(2)**

Question Number	Answer	Additional Guidance	Mark
2(b)(ii)	An answer that makes reference to: • (the wire is heated) to remove the residue of any previous sample being tested	Allow ‘to clean the wire’ Ignore ‘to sterilise/sanitise/disinfect the wire’	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)(iii)	An answer that makes reference to: • the acid can become contaminated with residue from previous tests (which can give incorrect results)		**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)(iv)	An answer that makes reference to: • (concentrated hydrochloric acid) forms volatile chlorides	Allow (the wire is moistened) to enable some of the solid metal salt to become attached/stick to the wire (and then tested in the Bunsen flame) Do not award reference to bonding or reacting or adsorb or absorb with the wire	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(c)	An explanation that makes reference to: • electrons are excited/ promoted (by heat to higher energy levels / orbitals) **(1)** • electrons fall from the excited state (to their ground state/to lower energy levels) **(1)** • electrons release energy/photons as (visible) light/ in visible region **(1)**	Lack of reference to 'electrons' results in a maximum of (2) for an otherwise correct answer Allow raised/jump/moved up for 'excited' Allow return/drop/de-excite for 'fall' Allow Wavelength/ frequency/ radiation for 'energy' Do not award reflected for 'release' Do not award colour for 'energy'	**(3)**

(Total Question 2 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)(i)	A description that makes reference to two of the following: • rinse the glass rod (into the beaker) **or** rinse beaker (several times) **or** rinse the funnel **(1)** • transfer the washings to the (volumetric) flask **(1)**	Ignore reference to weighing	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	An answer that makes reference to: • removal of the excess solution will remove some of the dissolved sodium hydroxide (so that the exact concentration will be unknown) **or** the concentration won't be known because the total volume will be more than 250cm^3	Allow 'not just removing deionised water' Ignore just 'decrease the concentration'	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	An answer that makes reference to any **two** of the following: • the tip of the burette must be filled with solution **(1)** • remove the funnel **(1)** • ensure the burette is held vertical **(1)** • eyes are level with the bottom of the meniscus **(1)**	Allow 'jet space' for tip Allow just 'remove air bubbles' Allow 'upright' for vertical Allow 'take readings at eye-level' Allow 'read from the bottom of the meniscus' Ignore reference to clamping and use of stand	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An answer that makes reference to • the titre will be larger because **either** there is water left in the burette **or** the sodium hydroxide solution will be diluted/lower	Allow the titre will be larger because the burette should have been rinsed with sodium hydroxide	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An assessment that includes • (**M1**) the vertical part of the graph is at ~7 – 10/ the mid-point is at 8.5-8.8 **(1)** • (**M2**) the mid-point of the colour change of methyl red is 5.1 **(1)** • (**M3**) pH range of methyl red does not lie (completely) within the vertical range of the pH curve (so it is not suitable) **(1)** • (**M4**) the colour change will be complete before the equivalence point is reached **(1)**	Allow 'equivalence point/end-point' for 'the vertical part of the graph/ the mid-point' Allow methyl red changes colour in the range/ has a pH range 4.2 – 6.3/ pK_{in} 5.1 Allow, after stating M1 and M2, 'this means that methyl red is unsuitable' Allow end-point/neutralisation point for equivalence point Do not award colour change to red Ignore references to choice of other indicators	**(4)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>3(c)(ii)</td><td>An answer that includes
• two ticks and two crosses as shown</td><td>
<table>
<tr><th>Indicator</th><th>pH range</th><th>Tick or Cross</th></tr>
<tr><td>Bromocresol purple</td><td>5.2 – 6.8</td><td>x</td></tr>
<tr><td>Thymol blue</td><td>8.0 – 9.6</td><td>✓</td></tr>
<tr><td>Thymolphthalein</td><td>8.3 – 10.6</td><td>✓</td></tr>
<tr><td>Alizarin yellow R</td><td>10.1 – 13.0</td><td>x</td></tr>
</table>
Do not award blank boxes for (x)</td><td>(1)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>3(d)(i)</td><td>• completed table</td><td>Exemplar table
<table>
<tr><td>Titration number</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Final burette reading / cm³</td><td>13.00</td><td>25.50</td><td>37.90</td><td>50.00</td></tr>
<tr><td>Initial burette reading / cm³</td><td>0.25</td><td>13.00</td><td>25.50</td><td>37.90</td></tr>
<tr><td>Titre / cm³</td><td>12.75</td><td>12.50</td><td>12.40</td><td>12.10</td></tr>
<tr><td>Concordant titres (✓)</td><td></td><td>✓</td><td>✓</td><td></td></tr>
</table>
COMMENT
Allow 12.5/ 12.4 /12.1
Do not award additional ticks</td><td>(1)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	• calculation of percentage measurement uncertainty	Example of calculation (%= ((0.05 x 4) ÷ 12.40 x 100) = 1.6%/1.61% / 2% Ignore SF Do not award 1.65% rounded to 2%	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(e)	- (**M1**) calculation of number of moles of NaOH weighed out **(1)** - (**M2**) concentration of NaOH solution **(1)** - (**M3**) number of moles of NaOH in titre **(1)** - (**M4**) molar concentration of CH_3COOH solution **(1)** - (**M5**) concentration in g dm^{-3} of CH_3COOH solution to 2/3SF **(1)**	<u>Example of calculation</u> n(NaOH)= 3.80 ÷ 40 = 0.095/ 9.5 x 10^{-2} (mol) [NaOH]= 0.095÷0.250=0.38(mol dm^{-3}) n(NaOH) = 0.38 x 0.0119 = 0.004522/ 4.522 x 10^{-3} (mol) [CH_3COOH] = 4.522 x 10^{-3} ÷ 0.025 = 0.18088 (mol dm^{-3}) [CH_3COOH] = 0.18088 x 60 = 10.8528 (g dm^{-3}) = 10.9 / 11 (g dm^{-3}) Do not award 10.90 (g dm^{-3}) Correct answer without working scores (5) Accept steps in a different order, e.g. moles x 60 before dividing by 0.025 TE throughout Penalise incorrect units in M5 only	**(5)**

(Total Question 3 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)	- molar mass of hydrated copper(II) sulfate **(1)** - mass of 0.0250 mol hydrated copper(II) sulfate **(1)**	Example of calculation $M_r(CuSO_4.5H_2O)$= 249.6 (g mol^{-1}) m($CuSO_4.5H_2O$)= 6.24 (g) Answer to 2 / 3SF Correct answer with no working scores (2) TE from incorrect M_r	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(b)	- evaluation of Q **(1)** - rearrangement to give Δ*T* **(1)** - Answer to 1 or 2SF and temperature change **(1)**	Example of calculation Q =(Δ*H* x n)=18.2 x 0.025 = 0.455(kJ) or 455 **J** Δ*T*=Q ÷(m x c) = 455 ÷ (45.00 x 4.18) = 2.4189…(^{o}C) Δ*T* = 2/2.4 ^{o}C/ K **and** decrease Allow -2/2.4 ^{o}C/ K Correct final answer without working scores (3) TE throughout	**(3)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>4(c)(i)</td>
<td>

- labelled y axis, including units, with appropriate scale **(1)**
- direction and placement of enthalpy changes, +18.2 and −84.5 **(1)**
- Entities with state symbols **(1)**

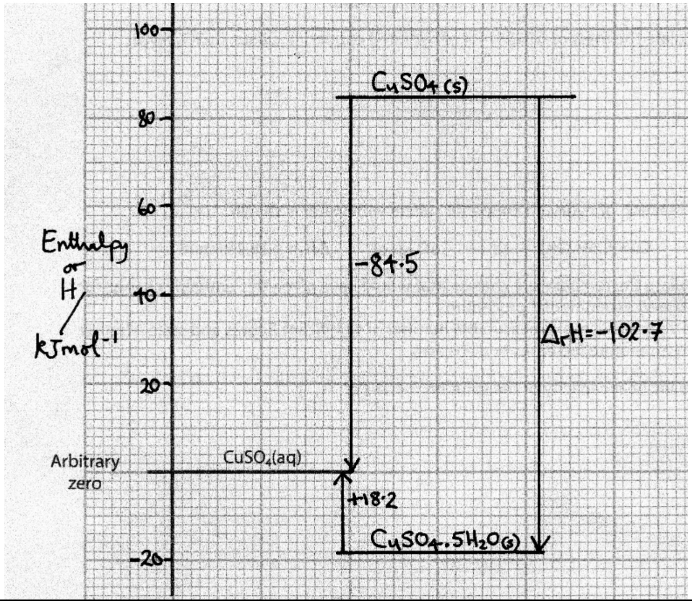
</td>
<td>

Allow energy for ‘enthalpy’
Ignore horizontal axis
Do not award enthalpy change/Δ*H* for y axis

Allow ΔH_1 and ΔH_2 for respective values
Arrows must be shown and in the correct direction
Ignore activation energy ‘curves’
Do not award double-headed arrows

Ignore inclusion of ‘+ aq’

<u>Example of diagram</u>

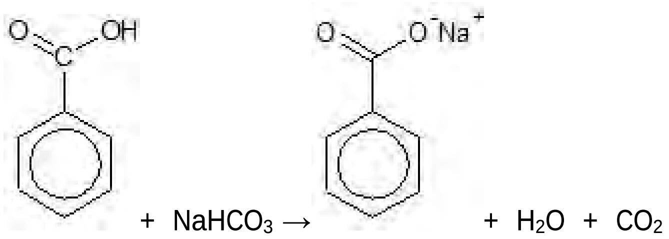


</td>
<td>(3)</td>
</tr>
</table>

Question Number	Answer	Additional Guidance	Mark
4(c)(ii)	• Use of Hess's law to calculate $\Delta_r H$ shown on the diagram	Value from diagram = −102.7 (kJ mol^{-1}) Allow $\Delta_r H = \Delta H_2 - \Delta H_1 = -84.5 - (+18.2) = -102.7$ (kJ mol^{-1}) Allow −103 (kJ mol^{-1}) Do not award if no working shown on the diagram	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(d)	An answer that makes reference to • Cannot react exactly 5 mol of water with 1 mol of anhydrous copper(II) sulfate	Cannot measure the temperature (change) for a **solid** Description that states more (than 5) water molecules will attach to some $CuSO_4$ while less (than 5) water molecules will attach to other $CuSO_4$ ACCEPT reasonable ideas such as some water may evaporate (due to exothermic reaction) Ignore heat loss to surroundings if given as an alternative reason Do not award heat is needed to start the reaction	**(1)**

(Total Question 4 = 10 marks)

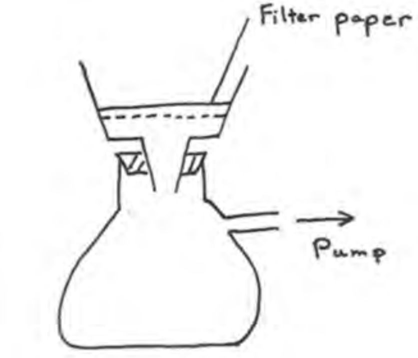
Question Number	Answer	Additional Guidance	Mark
5(a)		Example of equation  + $NaHCO_3$ → + H_2O + CO_2	**(2)**
	- formula of sodium benzoate **(1)**	Accept C_6H_5COONa and/or $C_6H_5COO^{(-)}Na^{(+)}$ Allow omission of charges Allow Kekulé structures Do not award O–Na	
	- remainder of equation **(1)**	Ignore state symbols even if incorrect Standalone mark	

Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that makes reference to: - invert the funnel **and** then open the tap	Allow Just removal of stopper/bung/lid/top Ignore shaking	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(c)	An answer that makes reference to • (Water is) more dense (than ether/than the organic layer)	Accept reverse argument Ignore references to immiscibility Do not award references to water being insoluble	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(d)	An answer that makes reference to: • some sodium benzoate has dissolved in the ether (instead of the aqueous sodium carbonate)	Ignore to increase the yield of sodium benzoate Ignore to remove the product from the ether	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(e)	An explanation that makes reference to: • The benzoate ion is protonated by the hydrochloric acid **(1)** • benzoic acid is less soluble (in water) than the sodium salt **(1)**	Allow HCl/acid reacts to form benzoic acid Allow benzoic acid is insoluble	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(f)	A labelled diagram that includes • Buchner/side-armed flask connected to vacuum/ pump/ water aspirator **(1)** • funnel with flat filter paper **(1)**	Example of diagram  Do not award fluted filter paper Do not award water flow into the flask	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(g)	Method 1 • (**M1**) mass of benzoic acid in 50 cm^3 **(1)** • (**M2**) no. of moles of benzoic acid in 50 cm^3 **(1)** OR Method 2 • (**M1**) moles of benzoic acid in 1000 cm^3 **(1)** • (**M2**) no. of moles of benzoic acid in 50 cm^3 **(1)** then • (**M3**) evaluation of the number of molecules of benzoic acid in 50 cm^3 **(1)**	Example of calculation m=(1.70 x 0.05=)0.0850 (g) n=(0.0850 ÷ 122=) 6.967 … x 10^{-4} (mol) n=(1.70 ÷ 122 =) 0.01393… (mol) n=(0.01393… x 0.05 =) 6.967 … x 10^{-4} (mol) N= (6.967 …x 10^{-4} x 6.02 x 10^{23}=) =4.19 x 10^{20} / 4.2 x 10^{20} Ignore sf except 1sf Penalise excessive (6+) SF Allow use of 6.0 x 10^{23} to give 4.18 x 10^{20} for (3) Correct final answer without working scores (3) TE throughout	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(h)	A comparison that makes reference to • (melting temperature) is a (wide) range/ not sharp **(1)** • (it is lower) because impurities are present **(1)**	Ignore just lower for M1 Allow water/phenol is present Allow 'it is not pure'	**(2)**

(Total Question 5 = 14 marks)

Question Number	Answer	Additional Guidance		Mark
6(a)	• correct formula (phenol) **(1)** • • balanced equation **(1)**	Example of equation $C_6H_5OH + 7O_2 \rightarrow 6CO_2 + 3H_2O$ Allow C_6H_6O Do not award [O] Ignore state symbols even if incorrect		**(2)**

Question Number	Answer	Additional Guidance	Mark
6(b)(i)	• mass of carbon in both substances **(1)** • molar masses of both substances **(1)** • calculation of percentages by mass of carbon **(1)**	Example of calculation (12 x 7 =) 84 Phenylmethanol 108 and Benzoic acid 122 Phenylmethanol (84 ÷ 108) x100 = 78%/ 77.8%/ 77.78% / $77.\dot{7}\%$ Benzoic acid (84 ÷ 122) x 100 = 68.85%/ 68.9%/69% Ignore sf except 1 Allow TE on incorrect M_r values Allow (2) for 11.1% and 9.8% calculated using 12 not 84 Allow ‘rescue’ (1) for one substance completely correct	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	A description that makes reference to: - black smoke	Allow Black fumes/soot/(yellow) smoky flame / grey smoke Ignore carbon particulates Do not award carbon monoxide/yellow flame	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)(iii)	An answer that makes reference to - Alkenes	Allow Cycloalkenes/cycloalkanes/alkynes/ carbon-carbon double bonds Ignore Ethene/named alkenes/named alkynes Do not award benzene/arenes	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)(iv)	An explanation that makes reference to - (window) above the safety line means the exhaust system is not strong enough to draw in the fumes **(1)** - so the toxic fumes will escape (into the laboratory) **(1)**	Allow reverse argument Allow reference to exhaust/fan not able to prevent gas escaping Allow poisonous/harmful/irritant/ carbon monoxide/soot for 'toxic fumes' Ignore reference to protection from splashing etc	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	An answer that makes reference to • (**M1**) (similarity) all have arene C–H absorptions Either 3030 (cm^{-1}) **or** 750 and/or 700 (cm^{-1}) **(1)** • (**M2**) only phenol and phenylmethanol have O–H 3750 – 3200 (cm^{-1}) **(1)** • (**M3**) only benzoic acid has O–H 3300 – 2500 (cm^{-1}) **(1)** • (**M4**) only benzoic acid has C=O 1700 – 1680 (cm^{-1}) **(1)** • (**M5**) only phenylmethanol has alkane C–H absorptions either 2962 – 2853 (cm^{-1}) or 1485 – 1365 (cm^{-1}) **(1)**	Bond and wavenumber ranges necessary for each mark Do not award 880/830/780 (cm^{-1}) Do not award –OH / C–OH by penalising once only in M2 and M3 All 5 correct bonds with no wavenumber ranges scores (3) 4 correct etc scores (2) and 3 correct etc scores (1) All 5 correct wavenumber ranges with no bonds or incorrect bonds scores (3) 4 correct etc scores (2) and 3 correct etc scores (1) Penalise any additional peaks once only Ignore references to different fingerprint regions	**(5)**

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	An answer that makes reference to • five peaks (in the ^{13}C NMR spectrum) **(1)** • (four) aromatic peaks within the chemical shift range of 165 – 105 (ppm) **(1)** • (one) peak (for the C–OH) within the chemical shift range of 75 – 55 (ppm) **(1)**	Allow any range within the stated ranges Penalise single values as opposed to ranges once only Accept annotations on diagram Penalise additional peaks once only when three or more types of peak are stated	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(c)(iii)	An answer that makes reference to • suitable formula of fragment ion **(1)** • matching *m*/*z* value **(1)**	<u>Example of a suitable formula</u> $C_6H_5COO^+$ or $C_6H_5CO^+$ Do not award $C_7H_5O_2^+$ or $C_7H_5O^+$ *m*/*z* = 121 or 105 Allow $COOH^+$ (1) Do not award bond to the fragment, e.g. $-COOH^+$ *m*/*z* = 45 (1) No TE on incorrect fragment ions such as CH_3^+	**(2)**

(Total Question 6 = 19 marks)

Question Number	Answer	Additional Guidance	Mark
***7**	This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points: 6 – 4; 5-4 – 3; 3-2 – 2; 1 – 1; 0 – 0 The following table shows how the marks should be awarded for structure and lines of reasoning Number of marks awarded for structure of answer and sustained lines of reasoning: Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout – 2 Answer is partially structured with some linkages and lines of reasoning – 1 Answer has no linkages between points and is unstructured – 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages). Penalise incorrect chemistry such as bond angles of 90^o for tetrahedral complexes or incorrect oxidation number by deducting a reasoning mark	**(6)**

Indicative content table (from the Answer column):

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5-4	3
3-2	2
1	1
0	0

Structure and lines of reasoning table (from the Answer column):

	Number of marks awarded for structure of answer and sustained lines of reasoning
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

	Indicative content	Accept any six indicative content points More than one indicative marking point may be made within the same comment or explanation	
	- **IP1** formulae and colour of first complex ion	$[Co(H_2O)_6]^{2+}$ allow $[Co(NH_3)_6]^{2+}$ or $[Co(EDTA)]^{2-}$ or $[Co(en)_3]^{2+}$ **and** pink or yellow/brown for the hexaamine complex	
	- **IP2** formulae and colour of second complex ion	$[CoCl_4]^{2-}$ allow $[Co(OH)_4]^{2-}$ **and** blue	
	- **IP3** definition of ligand	Atom/ion/molecule/species dative covalently bonded/ coordinately bonded to a central metal ion which can be shown on a diagram	
	- **IP4** definition of and example(s) of coordination number	The number of dative covalent bonds (to a central metal ion) **and** Six and/or four respectively which may be in a diagram	
	- **IP5** shape of complex ion(s)	Octahedral and/or tetrahedral respectively and can be a diagram. If two given then both must be correct	
	- **IP6** the chloride ion is larger (than the oxygen in water ligand or nitrogen in the ammonia ligand)	Allow chloride ions are large and only fit four around the metal ion Do not award ‘molecule’ when referring to chlorine Accept reverse argument	

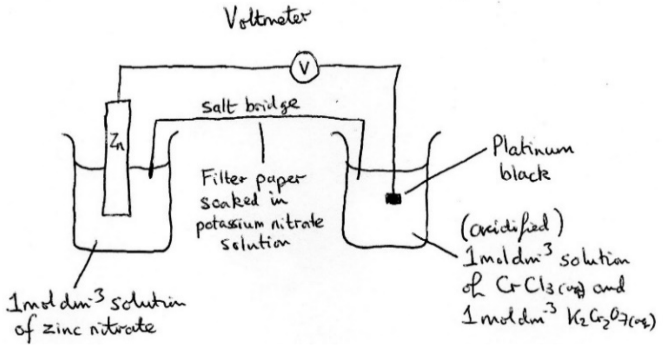
Total Question 7 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	A description that makes reference to • green ppt. **(1)** • ppt dissolves (in excess NaOH) to give a green solution **(1)**	Accept 'green solid' Allow 'grey-green ppt Do not award blue-green Ignore shades M2 dependent upon M1 or near-miss	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	• four correct species **(1)** • balancing and the correct number of electrons **(1)**	<u>An example of equation</u> $[Cr(OH)_6]^{3-} + 2OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ Accept multiples	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	• equation	<u>An example of equation</u> $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ Accept $\rightleftharpoons$ / multiples	**(1)**

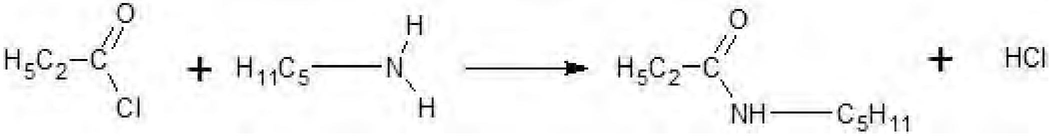
Question Number	Answer	Additional Guidance	Mark
8(b)(iii)	- oxidation half equation **(1)** - reduction half equation **(1)** - overall equation **(1)**	$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$ $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$ for M3 do not award if H^+/ e^- left on both sides Accept multiples Allow ⇌ Ignore state symbols even if incorrect Oxidation and reduction half equations scores (2) if not identified but in correct order Award (1) only for M1 and M2 if half equations are not in correct order No TE on incorrect half equations	**(3)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
8(c)	A diagram that includes	Example of diagram  	**(7)**
	• (**M1**) (high resistance) voltmeter/V **(1)**		
	• (**M2**) salt bridge to complete circuit **(1)**	Salt bridge must dip into the solutions	
	• (**M3**) filter paper soaked in (saturated) potassium nitrate/KNO_3 solution **(1)**	Allow sodium chloride/potassium chloride for potassium nitrate	
	(**M4**) zinc electrode of zinc metal and suitable zinc salt **(1)**	e.g. $ZnSO_4$	
	• (**M5**) platinum (black) electrode **(1)**		
	• (**M6**) suitable chromium salts **(1)**	e.g. $CrCl_3$ / $K_2Cr_2O_7$	
	• (**M7**) all solutions to be 1 mol dm^{-3} (wrt ions) **(1)**	if $Cr_2(SO_4)_3$ is used then M7 can only be awarded if its concentration is 0.5 mol dm^{-3} Allow electrodes drawn the other way round Ignore temperature is 298 K Penalise use of just names once only	

(Total Question 8 = 15 marks)

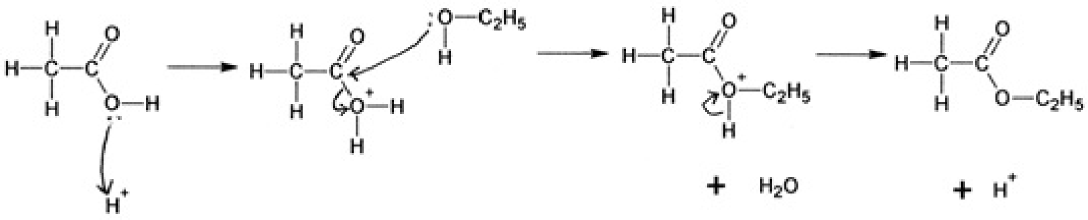
Question Number	Answer	Additional Guidance	Mark
9(a)	An answer that makes reference to • (similarity) both are reduction reactions **(1)** • (difference 1) reagents for preparation of phenylamine are tin and (conc.) hydrochloric acid **(1)** • (difference 2) reagents for preparation of butylamine are either Hydrogen gas **and** nickel catalyst **or** lithium tetrahydridoaluminate(III) **and** (dry) ether **(1)**	Ignore both require hydrogen Allow Iron for tin Do not award dilute hydrochloric acid/ sulfuric acid Lithium aluminium hydride / Lithal / $LiAlH_4$	**(3)**

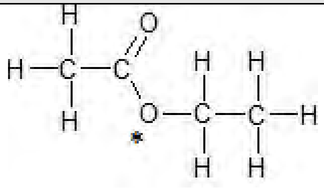
Question Number	Answer	Additional Guidance	Mark
9(b)	An answer that makes reference to: • (similarity) both are basic because they have a lone pair of electrons on the nitrogen atom which accepts a proton **(1)** • (difference 1)in $C_6H_5NH_2$ the lone pair of electrons of the nitrogen atom becomes incorporated with the delocalised ring of electrons and so is less able to accept a proton hence a weaker base **(1)** • (difference 2) the alkyl group/ C_4H_9 is electron-releasing / positively inductive and means the lone pair of electrons of the nitrogen atom are more able to accept a proton hence a stronger base**(1)**	Diagrams can be used to score Comparison of basicity/nitrogen's lone pair of electrons/proton acceptance only need to be mentioned once.	**(3)**

Question Number	Answer	Additional Guidance	**Mark**
9(c)	• equation **(1)** • name **(1)**	$C_2H_5COCl + C_5H_{11}NH_2 \rightarrow C_2H_5CONHC_5H_{11} + HCl$ or  Allow skeletal/structural/combination of formulae Allow $C_2H_5COCl + 2C_5H_{11}NH_2 \rightarrow C_2H_5CONHC_5H_{11} + HCl + C_5H_{11}NH_3Cl$ Do not award molecular formulae N-pentylpropanamide Do not award N-pentylpropylamine	**(2)**

Question Number	Answer	Additional Guidance	**Mark**
9(d)	• amine monomer structure or name	$H_2N(CH_2)_6NH_2$ / 1,6-diaminohexane Accept any mixture of displayed, structural or skeletal formulae Do not award molecular formulae or $H_2N\ C_6H_{12}\ NH_2$ If name and formula given then both must be correct	**(1)**

(Total Question 9 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
10(a)(i)	• oxygen lone pair and curly arrow to the H^+ **(1)** • curly arrow from oxygen lone pair on the ethanol to the carbon of the C = O **(1)** • curly arrow from C-O bond to oxygen of water molecule (**1)** • curly arrow from O–H bond back to the O^+ oxygen **(1)**	Example of reaction mechanism  Penalise additional curly arrows for each marking point Penalise missing lone pair on oxygen once only in M1 and M2	**(4)**

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	- correct oxygen identified **(1)** - the single bond C–O in the carboxylic acid breaks rather than the one in ethanol **or** the oxygen in ethanol acts as the nucleophile (to attack the carbon of the carboxylic acid group and so ends up in the ester) **(1)**	 Allow 'loss of OH from the carboxylic acid'	**(2)**

Question Number	Answer	Additional Guidance	Mark
10(a)(iii)		<u>Example of calculation</u>	**(6)**
	- (**M1**) calculation of ΔG **(1)**	$\Delta G = -RT \ln K = -8.31 \text{ x } 298 \text{ x } \ln 4.0$ $= -3433$ (J mol^{-1})	
	- (**M2**) correct equation **(1)**	$\Delta G = \Delta H - T\Delta S_{system}$	
	- (**M3**) rearrangement of equation **(1)**	$\Delta S_{system} = (\Delta H - \Delta G) \div T$	
	- (**M4**) calculation of ΔS_{system} **(1)**	$\Delta S_{system} = (-6.0 \text{ x } 10^3 - (-3433)) \div 298$ $= -8.614....$ (J mol^{-1} K^{-1})	
	- (**M5**) rearrangement of equation so $S_{(\text{ethyl ethanoate})} =$ **(1)**	$(\Delta S_{system} = \sum S_{(\text{products})} - \sum S_{(\text{reactants})})$ $S_{(\text{ethyl ethanoate})} = \Delta S + \sum S_{(\text{reactants})} - S(water)$	
	- (**M6**) calculation of $S_{(\text{ethyl ethanoate})}$ with sign and units **(1)**	$S_{(\text{ethyl ethanoate})} = (-8.614 + (159.8+160.7) - 69.9)$ $= +242/240$ J mol^{-1} K^{-1}	
		Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	

Question Number	Answer	Additional Guidance	Mark
10(b)	A comparison that makes reference to: (with ethanoyl chloride) • the reaction is irreversible compared to reversible **(1)** • hydrogen chloride is the by-product rather than water **(1)** • the reaction is very fast/occurs at room temperature so an acid catalyst is not needed **(1)**	Accept reverse arguments Allow steamy fumes for 'HCl'	**(3)**

(Total Question 10 = 15 marks)

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