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 ▶

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

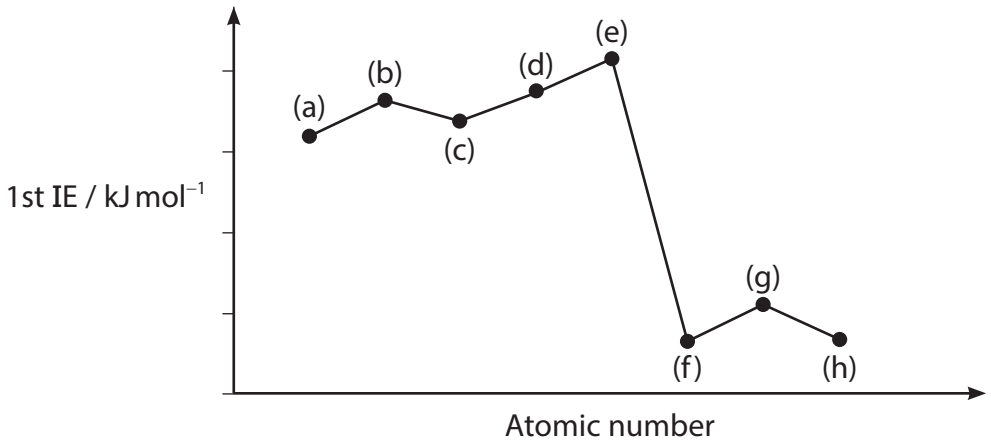
☒ **B** X

☒ **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.

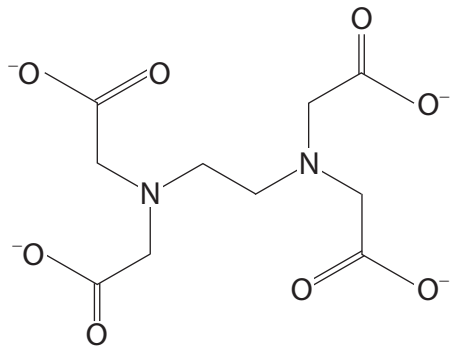
(i) Give the shape of this complex ion.

(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)

(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)

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.....

(Total for Question 3 = 18 marks)

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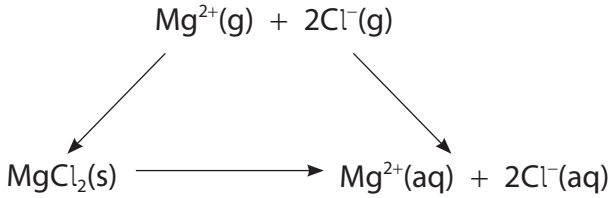
4 This question is about dissolving different compounds.

(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?



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)

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.

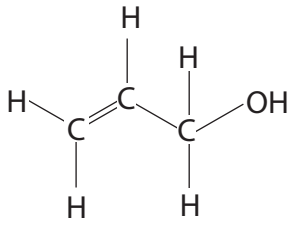
(2)

(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)

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(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)

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(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.

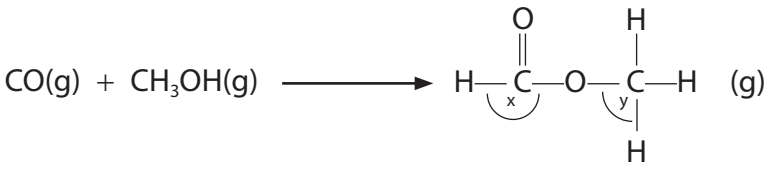
Use this information, your expression for the equilibrium constant, K_c, and the value for K_c, to find the amounts of each product at equilibrium, in moles.

(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.

$$16H^+(aq) + 2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

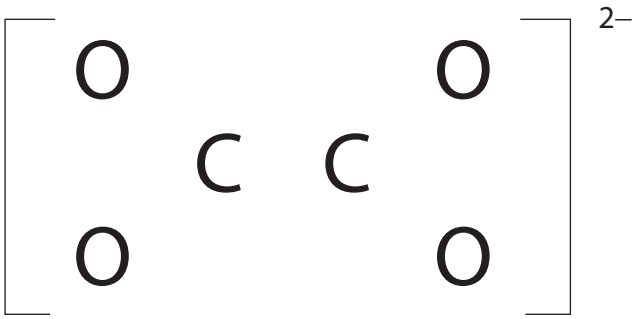
(a) Give the colour **change** at the end-point of the titration.

(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

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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)

October 2020

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

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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)

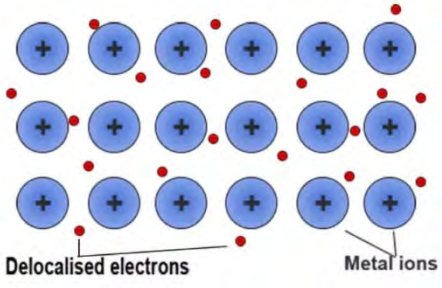
Question Number	Answer	Mark
2(a)	**The only correct answer is A** ($CH_3COOH > CH_2ClCOOH > HCl$) *B is incorrect because HCl is the only strong acid, so would have the lowest pH* *C is incorrect because $CH_2ClCOOH$ is stronger than CH_3COOH as the Cl atom stabilises the anion* *D is incorrect because 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 orbitals 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)**	<u>Example of calculation</u> (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.

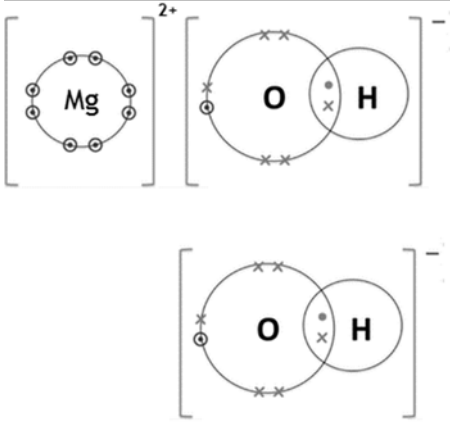
Reasoning marks may be reduced for extra incorrect chemistry.
</td><td>(6)</td></tr>
</table>

	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)	• calculation of moles of $Mg(OH)_2$	**(1)**	Example of calculation 0.174 ÷ 58.3 = 2.98456 x 10^{-3} (mol)	**(5)**
	• 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)**	<u>Example of calculation:</u> 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 $\Delta S_{surroundings}$ and ΔS_{system} are positive **(1)** • OR • ΔG is always negative **(1)** • as ΔH is negative and $\Delta S_{(system)}$ is positive **(1)**	If no marking points awarded allow 1 mark for idea that ΔS_{system} / $\Delta S_{surroundings}$ / entropy increases with correct explanation	**(2)**

Question Number	Answer		Additional Guidance	Mark
6(b)	• expression for ΔS_{system} • calculation of ΔS_{system} • expression for $\Delta S_{surroundings}$ • calculation of $\Delta S_{surroundings}$ • calculation of ΔS_{total}, correct units and comment on feasibility	**(1)** **(1)** **(1)** **(1)** **(1)**	Example of calculation ΔS_{system} = [(6x205)+(219.5)+(160.7)] − [(4x213.6)+(5x69.9) = 1610.2 − 1203.9 = (+) 406.3 (J K^{-1} mol^{-1}) $\Delta S_{surroundings} = -\Delta H/T$ = − 2778 x 10^3÷298 = −9322.14765 (J K^{-1} mol^{-1}) ΔS_{total} = 406.3 − 9322.14765 = − 8915.85 J K^{-1} 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 $CH_3CH_2OH = 1.2 – x$; $CH_3COOH = 1.2 – x$; $CH_3COOCH_2CH_3 = x$; $H_2O = x$ $K_c = \frac{(x \div vol)^2}{[(1.2-x) \div vol]^2}$ $K_c = (x^2 \div vol^2) \div ((1.2-x)^2 \div vol^2)$ $K_c = x^2 \div (1.2-x)^2$ 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)**

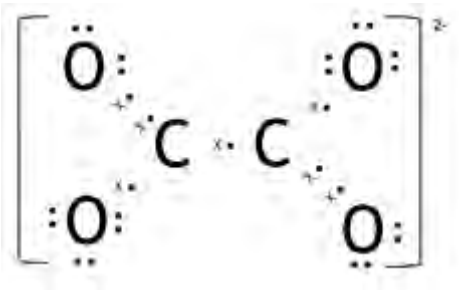
Question Number	Answer	Mark
7(b)(i)	**The only correct answer is C** (120° and 109.5°) ***A*** *is incorrect because both angles are incorrect* ***B*** *is incorrect because 90° is incorrect* ***D*** *is incorrect because 109.5° is incorrect for the left hand O−C−H angle*	**(1)**

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)**	$Pt(s) \mid C_2O_4^{2-}(aq), 2CO_2(g) \,\vdots\, [MnO_4^-(aq) + 8H^+(aq)], [Mn^{2+}(aq) + 4H_2O(l)] \mid Pt(s)$ 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)**

Question Number	Answer	Additional Guidance	Mark
8(e)(i)	• titres calculated and both ticks correct **(1)** • mean calculated **(1)**	<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="3">**16.85**</td></tr></table>Both titres to 2 dp mean = (16.90+16.80)÷2 = 16.85 (cm^3) allow TE for M2 for mean of One, Two and Three = 16.97 (cm^3)	**(2)**

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 $E^\ominus$ is more negative) forming Mn^{3+} ions OR $MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ ($E^\ominus$ = + 0.02V) **(1)** • Mn^{3+} ions then oxidise $C_2O_4^{2-}$ ions (reforming Mn^{2+}) (as $E^\ominus$ is more positive) OR $C_2O_4^{2-} + 2Mn^{3+} \rightarrow 2Mn^{2+} + 2CO_2$ ($E^\ominus$ = + 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 $E^\ominus$ is more negative Allow Mn^{3+} ions then react with $C_2O_4^{2-}$ ions (reforming Mn^{2+}) as $E^\ominus$ is more positive May be shown in equations and / or by calculating $E^\ominus$	**(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 ▶

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1/1/1/1/1/

P 6 2 6 6 9 A 0 1 3 2

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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 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)

2 This question is about alkenes.

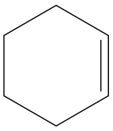
(a) Which of these has the molecular formula C_6H_{10}?

(1)

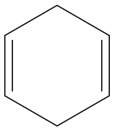
☒ **A**

☒ **B**

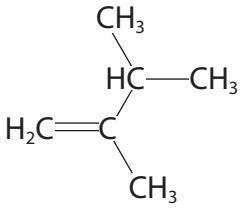
☒ **C**



☒ **D**



(b) What is the systematic name of this alkene?



(1)

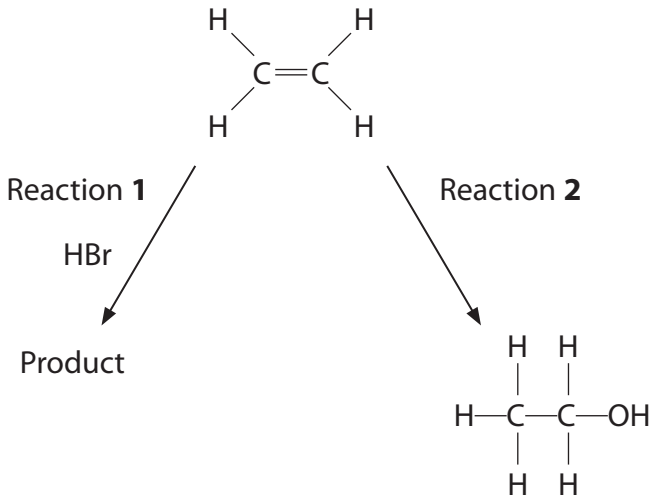
☒ **A** 2-methylpent-1-ene

☒ **B** 3-methylpent-1-ene

☒ **C** 2,3-dimethylbut-1-ene

☒ **D** 2,3-dimethylbut-3-ene

(c) Two reactions of ethene are shown.

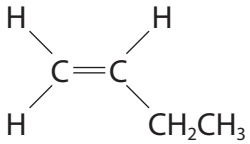


Complete the table.

(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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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.

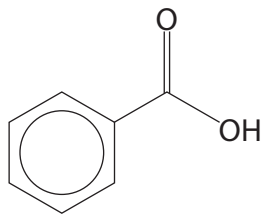
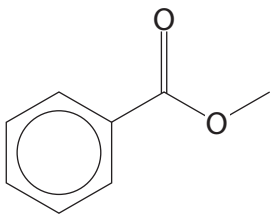
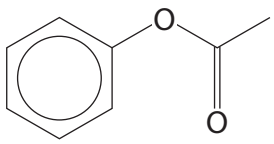
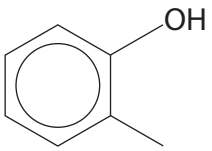
[Molar volume of gas at r.t.p. = 24.0 $dm^3\ mol^{-1}$]

(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)

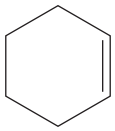
☒ **A** 2

☒ **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)

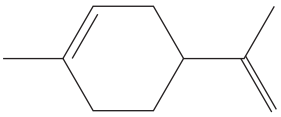
(e) Propene reacts with iodine monochloride, ICl, by an electrophilic addition mechanism.

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.

$$RBr + OH^- \rightarrow R{-}OH + Br^-$$

This reaction is first order with respect to the bromoalkane and the rate equation is

$$\text{rate} = k[RBr]^1[OH^-]^x$$

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)

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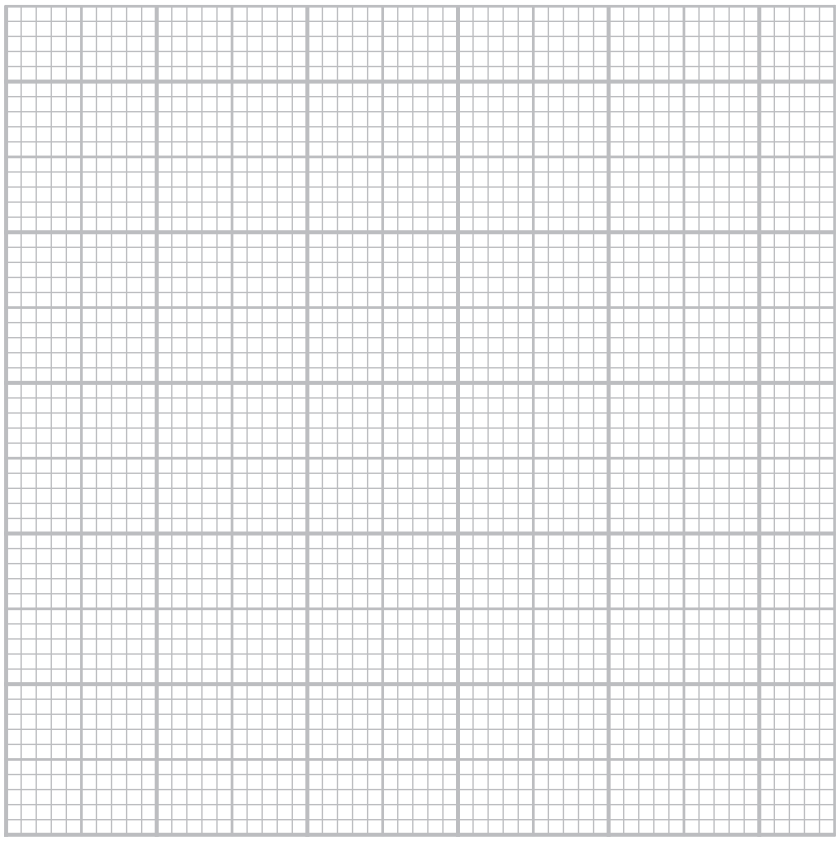
.....

.....

(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)

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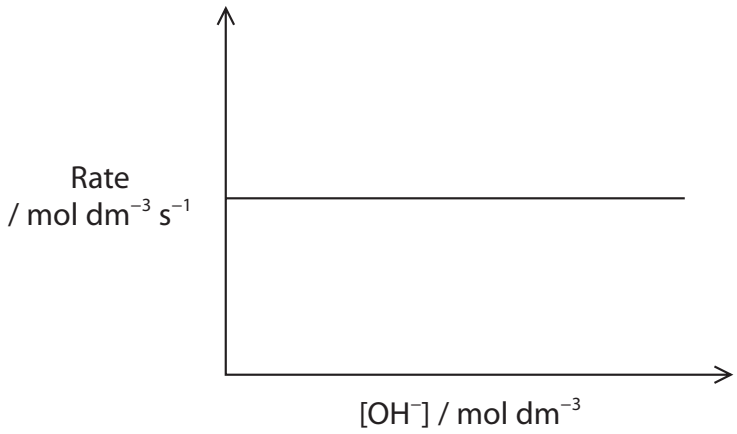
(d) The experiment was repeated using equal concentrations of RBr and varying the concentration of hydroxide ions.

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.

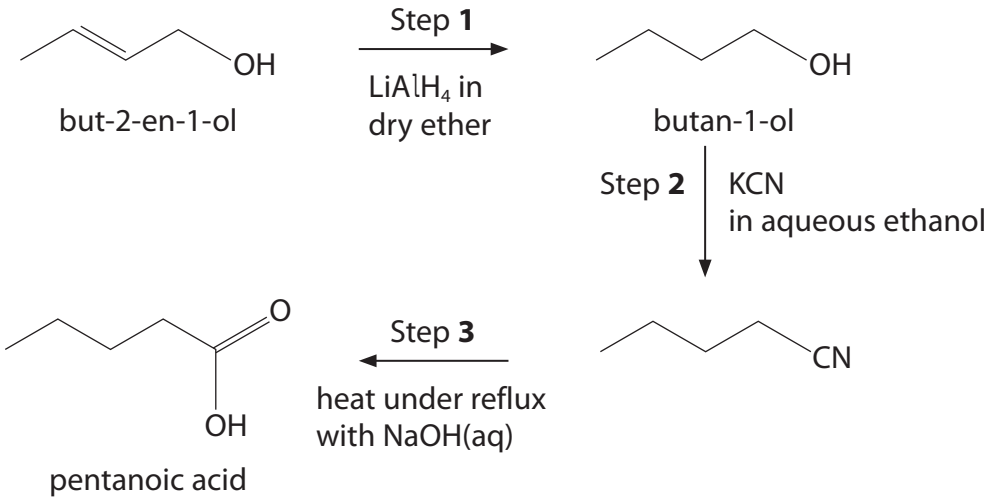
Explain why the butan-2-ol produced from a single optical isomer of 2-bromobutane, using this mechanism, is **not** optically active.

(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)

.....

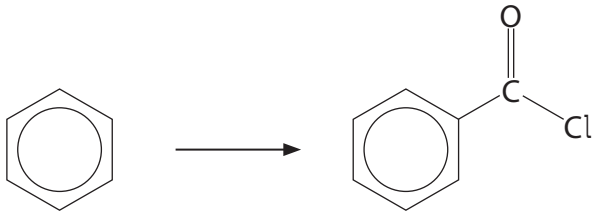
(iv) Step **3** involves the hydrolysis of a nitrile.

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)

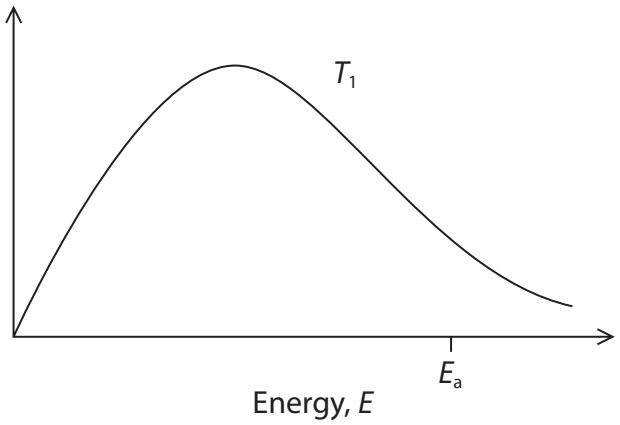
(Total for Question 8 = 10 marks)

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

1	2										3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1									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							

Key: relative atomic mass / atomic symbol / name / atomic (proton) number

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 2: Advanced Organic and Physical Chemistry

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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.

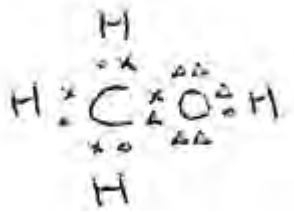
The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ 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.

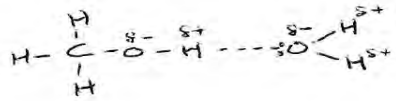
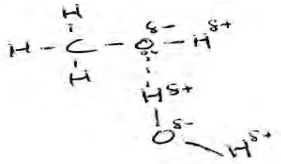
Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex 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.

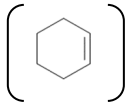
Question Number	Answer	Additional Guidance	Mark
1(a)	• all bonding pairs of electrons correct **(1)** • 2 lone pairs of electrons on oxygen **(1)**	Example of diagram  Allow any symbols for electrons, including all dots or all crosses Allow electrons either side of a line for a bond e.g. x • Electrons 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° **(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)**	<u>Examples of diagrams</u>   Any bond angle labelled as 180° must be between the correct bonds 180° must be drawn at about 180°, 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)

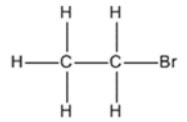
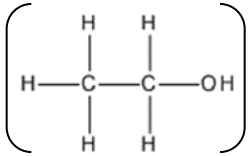
(Total for Question 1 = 7 marks)

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)**

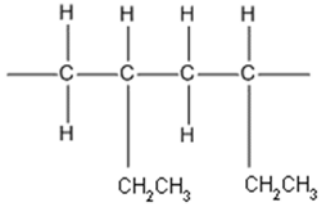
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>2(c)</td><td>

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 x 6.02 x10^{23} = 7.525 x 10^{23} TE on moles but-1-ene Ignore SF except 1 SF Do not award M2 for mass x 6.02 x10^{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)**

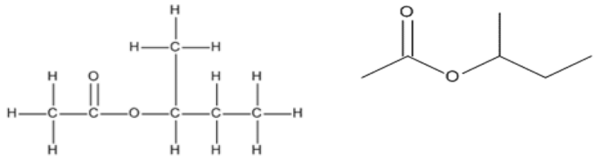
Question number	Answer	Mark
3(a)(ii)	**The only correct answer is D** (cannot tell from this information) *A is incorrect because there are 3 reactant species but the overall order of a reaction can only be determined by experiment* *B is incorrect because there is 1 bromate ion and 5 bromide ions but 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)**	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)	**(3)**
	• calculation of moles of O_2	**(1)**	moles of O_2 = $\frac{0.031138 \times 3}{2}$ = 0.046707 / 4.6707×10^{-2} (mol) TE on moles of $KBrO_3$	
	• calculation of volume of O_2	**(1)**	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 $pV = nRT$	

(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:** • **T**: structure of butan-2-ol **(1)** • **U**: structure of butanone **(1)** • **V**: structure of 1-methylpropyl ethanoate **(1)** **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)** • **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)**	<u>Examples of structures</u> Ignore names, even if incorrect **T**: $CH_3CH_2CHOHCH_3$ Ignore connectivity of OH group in displayed formula **U**: $CH_3CH_2COCH_3$ **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 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	**(6)**

(Total for Question 4 = 8 marks)

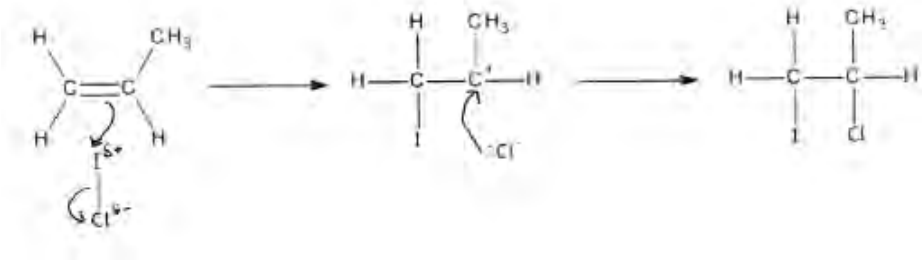
Question number	Answer	Mark
5(a)	**The only correct answer is D** (C_6H_{14}) *A is incorrect because this has general formula C_nH_n and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}* *B is incorrect because this has general formula C_nH_{2n-2} and non-cyclic, saturated hydrocarbons 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)**

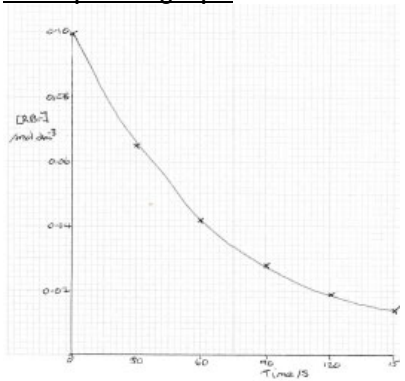
Question number	Answer	Additional Guidance	Mark
5(d)(ii)	• calculation of x **(1)** • calculation of y **(1)** • structure of cyclopentene **(1)**	<u>Example of calculation</u> (volume of CO_2 = 125 (cm^3) so x = 125/25) = 5 (25 + 25(5 + (y/4)) − 75 = 125) y = 8  Allow the skeletal formula of any cyclic C_5H_8 compound with C=C e.g. a methylcyclobutene TE on x and y for a cyclic hydrocarbon	**(3)**

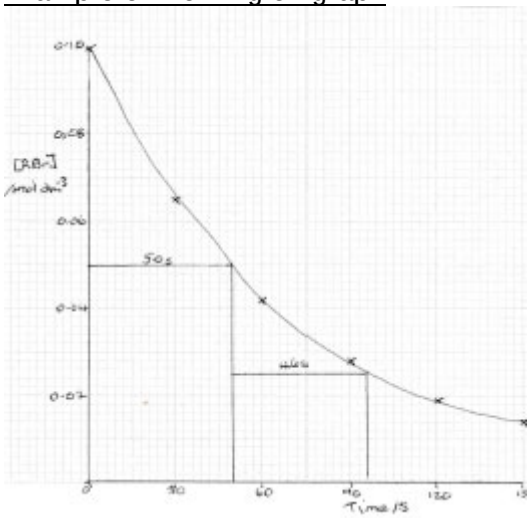
Question Number	Answer	Additional Guidance	Mark
5(e)	• dipole on I-Cl **and** correct major product **(1)** • curly arrow from C=C to I **and** curly arrow from I-Cl to, or just beyond, Cl **(1)** • intermediate **(1)** • lone pair on Cl^- **and** curly arrow from **lone pair** to C^+ **(1)**	Example 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 $Br_2 = \frac{30.6 \times 0.200}{1000} = 0.00612 / 6.12 \times 10^{-3}$ moles of limonene = $\frac{0.00612}{2} = 0.00306 / 3.06 \times 10^{-3}$ 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 = $\frac{0.41616}{0.500} \times 100$ (= 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)**

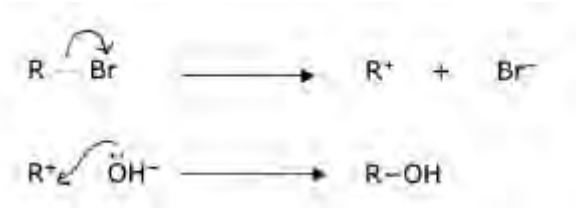
(Total for Question 5 = 15 marks)

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)**	<u>Example of graph</u>  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-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)**	Example of mechanism  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)**

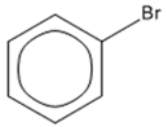
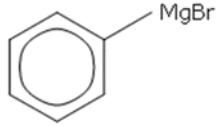
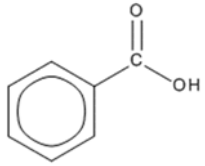
(Total for Question 6 = 13 marks)

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)**

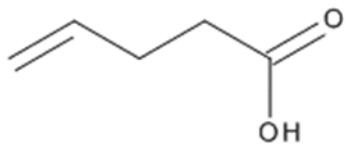
Question Number	Answer	Additional Guidance	Mark
7(a)(iv)	• hydrochloric acid / HCl / H^+	Allow any (dilute) strong acid Ignore concentration of acid Do not award any weak acid	**(1)**

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)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>8(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>

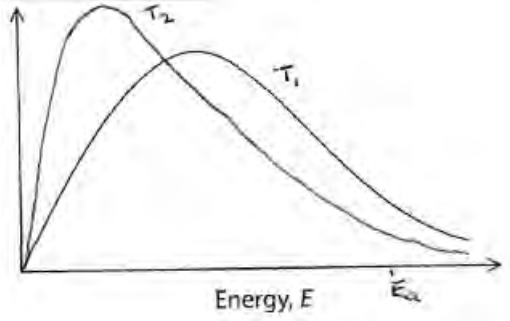
The following table shows how the marks should be awarded for structure and lines of reasoning.</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that 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	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.	
		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. Mention of splitting on the ^{13}C spectra Deduct 1 reasoning mark if the similarity in IP1 has not been explicitly mentioned	

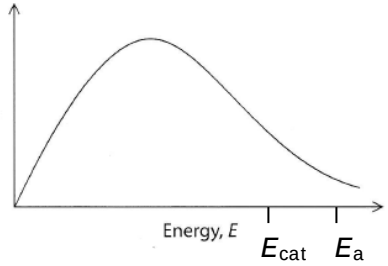
	Indicative content • **IP1 -** Similarity **both** ^{1}H NMR spectra have a peak (which is a singlet with relative peak area 1) for OH • **IP2 -** ^{13}C spectra 3 peaks for propan-1-ol **and** 2 peaks for propan-2-ol • **IP3 -** ^{1}H spectra number of peaks 4 peaks for propan-1-ol **and** 3 peaks for 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 • **IP5 -** ^{1}H splitting pattern for propan-1-ol 2 triplets, 1 sextet / split into 6 and 1 singlet • **IP6 -** ^{1}H splitting pattern for propan-2-ol 1 doublet, 1 septet / split into 7 and 1 singlet	All IP can be shown on clearly labelled diagrams of structures and/or spectra Allow carbon environments for peaks Ignore any reference to peak areas 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 Allow hextet for sextet Ignore missing singlet if this has been given in similarity 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	<u>Example of label</u>  Allow other clear labels for E_{cat}	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(b)	• substitution of numbers into expression **(1)** • evaluation of k_2/k_1 or ln k_2/k_1 **and** $1/T_1 - 1/T_2$ **(1)** • rearrangement of expression **(1)** • evaluation of expression **(1)** • answer given to 2/3 SF **and** corresponding units **(1)**	Example of calculation $\ln \frac{4.87 \times 10^{-3}}{1.50 \times 10^{-3}} = \frac{-E_a}{8.31}\left(\frac{1}{338} - \frac{1}{328}\right)$ $k_2/k_1 = 3.2467$ 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 $(-)9.0201 \times 10^{-5}$ 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 E_a = 108 493 TE on $\ln (k_2/k_1)$ and $1/T_1 - 1/T_2$ = (+)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)	**(5)**

(Total for Question 9 = 11 marks)
Total for Paper = 90 Marks

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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 ▶

P62670A

1/1/1/1/1/1

P 6 2 6 7 0 A 0 1 3 2

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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)

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(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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(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)

(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)

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(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)

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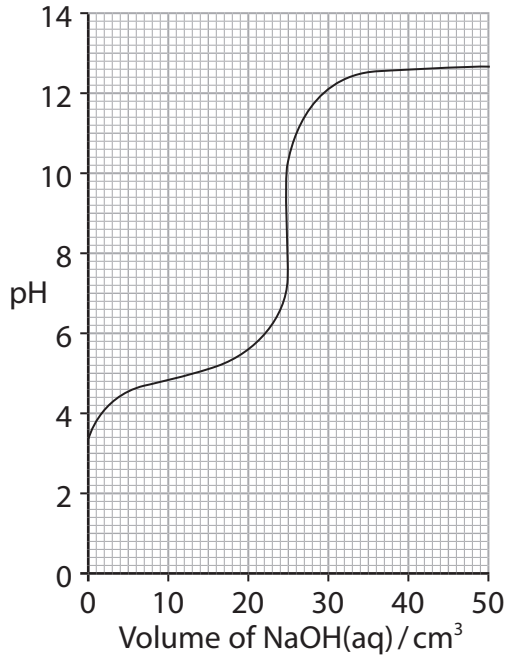
(c) The sketch shows the pH changes during a titration of 25.0 cm^3 of ethanoic acid with sodium hydroxide of the same concentration.



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} $^oC^{-1}$]

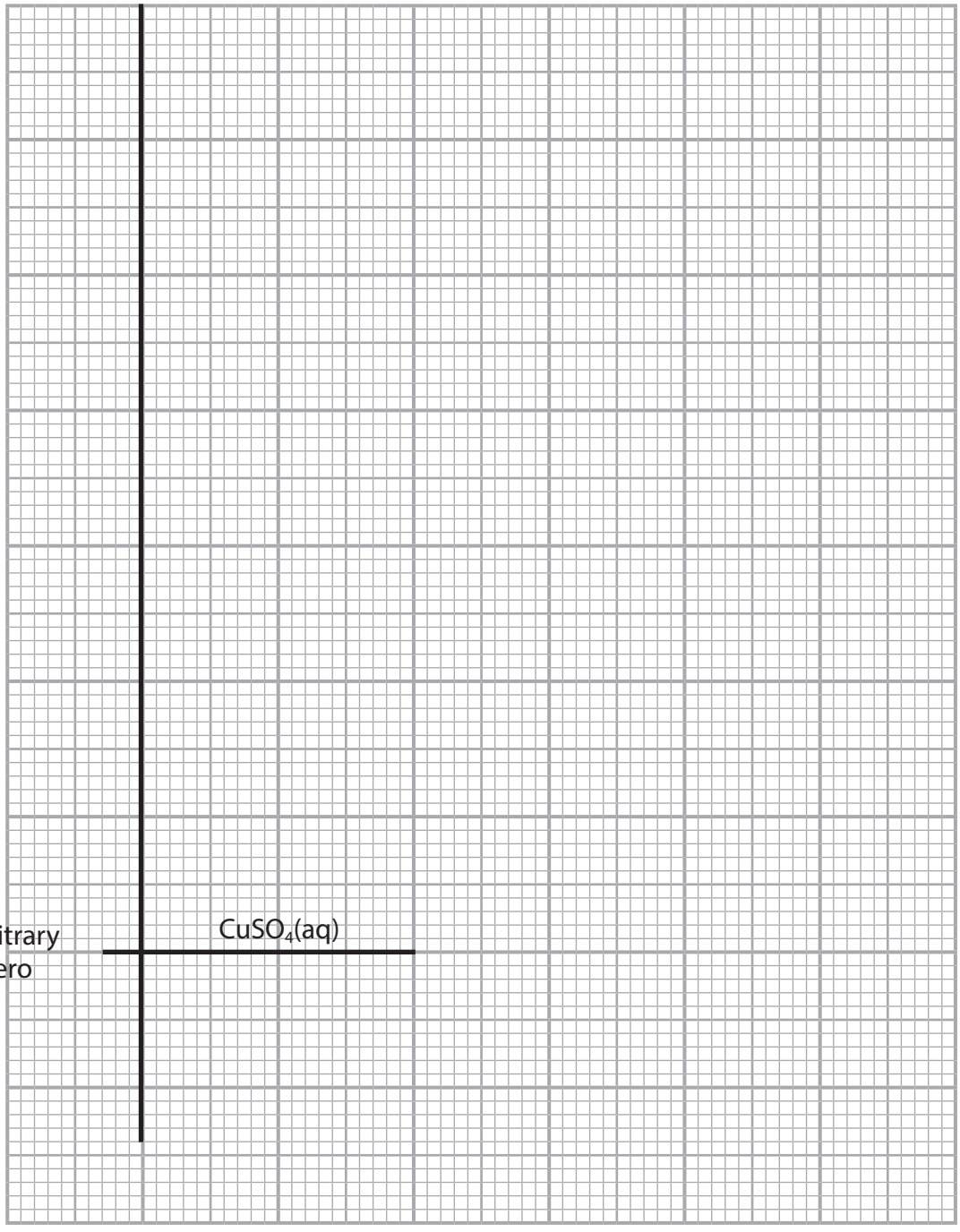
(3)

(c) The reaction of anhydrous copper(II) sulfate with water is shown.

$$CuSO_4(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_2 = -84.5\ kJ\ mol^{-1}$$

(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.

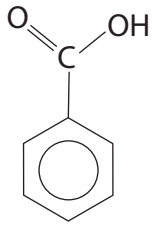
Step **7** The impure benzoic acid was filtered under reduced pressure.

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)

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(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)

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(e) Explain why the addition of hydrochloric acid in Step **6** results in the precipitation of benzoic acid.

(2)

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(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)

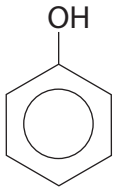
(h) The melting temperature range of the purified benzoic acid in Step **9** was 116–121 °C.

Compare this result with the literature value, giving a reason for any differences.

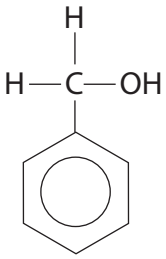
(2)

(Total for Question 5 = 14 marks)

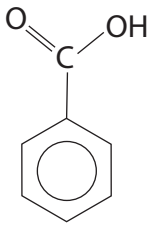
6 This is a question about the analysis of three aromatic substances with —OH groups.



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)

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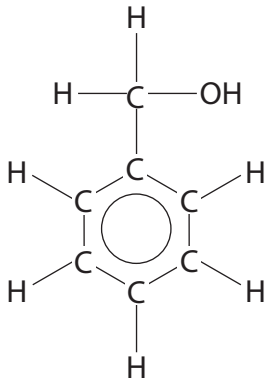
(c) Spectroscopy is an effective means of distinguishing between molecules.

(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

$$Pt(s) \mid H_2O_2(aq), [2H^+(aq)+O_2(g)] \,\vdots\, [Cr_2O_7^{2-}(aq)+14H^+(aq)], [2Cr^{3+}(aq)+7H_2O(l)] \mid Pt(s)$$

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)

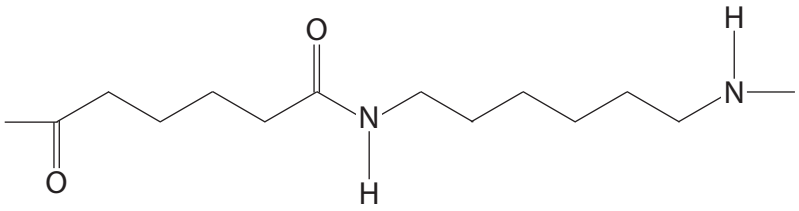
(c) Write the equation for the reaction between propanoyl chloride and pentylamine. Include the name of the amide formed.

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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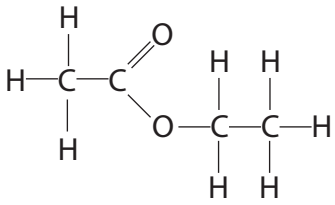
(Total for Question 9 = 9 marks)

10 Ethyl ethanoate is an ester.



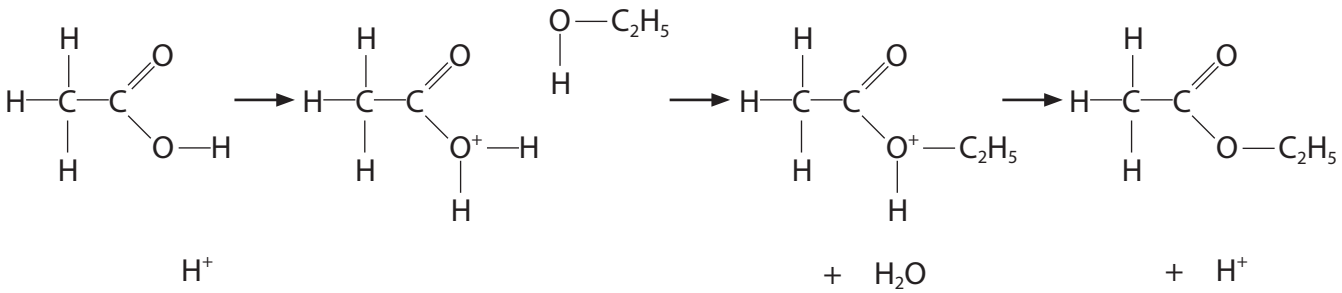
(a) One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

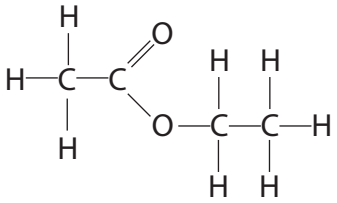
An incomplete simplified mechanism for this reaction is shown.

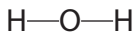
(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(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



and 

Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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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 J mol^{-1} K^{-1}
Temperature, T	298 K
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	–6.0 kJ mol^{-1}
Standard molar entropy of ethanoic acid, S^{O}	159.8 J K^{-1} mol^{-1}
Standard molar entropy of ethanol, S^{O}	160.7 J K^{-1} mol^{-1}
Standard molar entropy of water, S^{O}	69.9 J $K^{-1}mol^{-1}$

(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

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(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

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
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

* Lanthanide series

* Actinide series

Mark Scheme (Results)

October 2020

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 3: General and Practical Principles in Chemistry

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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)**

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	An answer that includes • two ticks and two crosses as shown	<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)	**(1)**

<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 / cm^3</td><td>13.00</td><td>25.50</td><td>37.90</td><td>50.00</td></tr>
<tr><td>Initial burette reading / cm^3</td><td>0.25</td><td>13.00</td><td>25.50</td><td>37.90</td></tr>
<tr><td>Titre / cm^3</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>

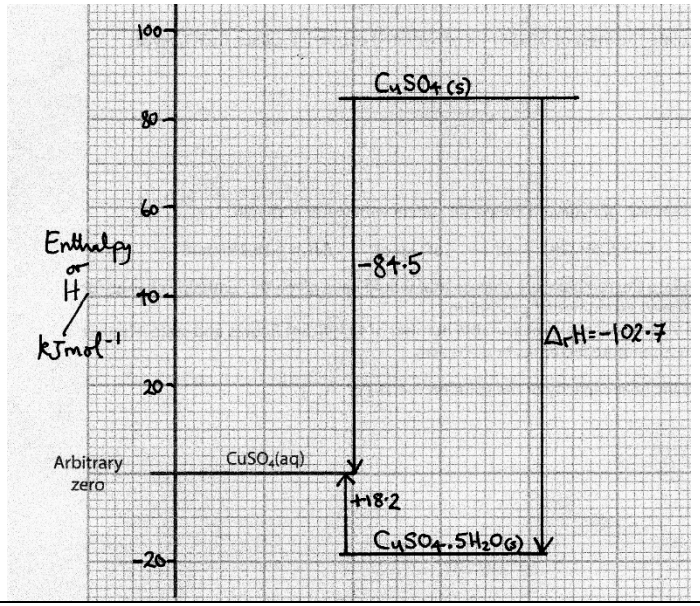
Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	• calculation of percentage measurement uncertainty	<u>Example of calculation</u> (%= ((0.05 x 4) ÷ 12.40 x 100) = 1.6%/1.61% / 2% Ignore SF Do not award 1.65% rounded to 2%	**(1)**

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)**	Example of calculation $M_r(CuSO_4.5H_2O)$= 249.6 (g mol^{-1})	**(2)**
	• mass of 0.0250 mol hydrated copper(II) sulfate	**(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	

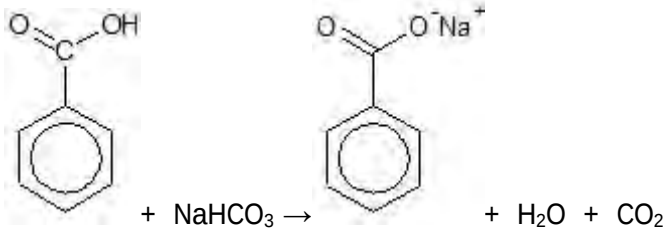
Question Number	Answer		Additional Guidance	Mark
4(b)	• evaluation of Q	**(1)**	Example of calculation Q =(ΔH x n)=18.2 x 0.025 = 0.455(kJ) or 455 **J**	**(3)**
	• rearrangement to give ΔT	**(1)**	ΔT=Q ÷(m x c) = 455 ÷ (45.00 x 4.18) = 2.4189…(^oC)	
	• Answer to 1 or 2SF and temperature change	**(1)**	ΔT = 2/2.4 ^oC/ K **and** decrease Allow -2/2.4 ^oC/ K Correct final answer without working scores (3) TE throughout	

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	• 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)**	Allow energy for 'enthalpy' Ignore horizontal axis Do not award enthalpy change/ΔH 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>  	**(3)**

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)

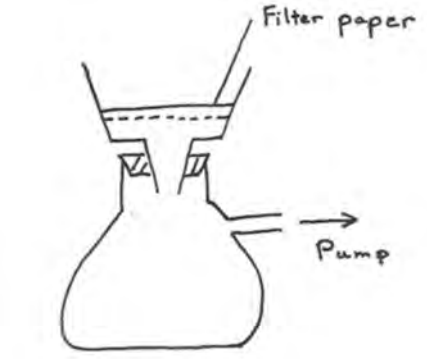
Question Number	Answer	Additional Guidance	Mark
5(a)	• formula of sodium benzoate **(1)** • remainder of equation **(1)**	Example of equation  Accept C_6H_5COONa and/or $C_6H_5COO^{(-)}Na^{(+)}$ Allow omission of charges Allow Kekulé structures Do not award O–Na Ignore state symbols even if incorrect Standalone mark	**(2)**

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% / 77.7 % 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)

<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><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
<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>
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
</td>
<td>(6)</td>
</tr>
</table>

	Indicative content • **IP1** formulae and colour of first complex ion • **IP2** formulae and colour of second complex ion • **IP3** definition of ligand • **IP4** definition of and example(s) of coordination number • **IP5** shape of complex ion(s) • **IP6** the chloride ion is larger (than the oxygen in water ligand or nitrogen in the ammonia ligand)	Accept any six indicative content points More than one indicative marking point may be made within the same comment or explanation $[Co(H_2O)_6]^{2+}$ allow $[Co(NH_3)_6]^{2+}$ or $[Co(EDTA)]^{2-}$ or $[Co(en)_3]^{2+}$ **and** pink or yellow/brown for the hexaamine complex $[CoCl_4]^{2-}$ allow $[Co(OH)_4]^{2-}$ **and** blue Atom/ion/molecule/species dative covalently bonded/ coordinately bonded to a central metal ion which can be shown on a diagram The number of dative covalent bonds (to a central metal ion) **and** Six and/or four respectively which may be in a diagram Octahedral and/or tetrahedral respectively and can be a diagram. If two given then both must be correct Allow chloride ions are large and only fit four around the metal ion Do not award 'molecule' when referring to chlorine Accept reverse argument	

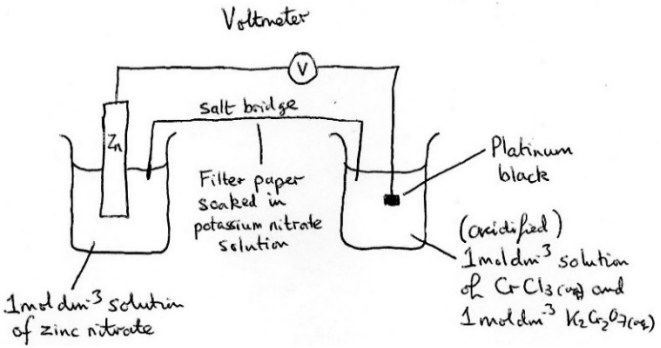
Total Question 7 = 6 marks)

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)**	$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$	**(3)**
	• reduction half equation	**(1)**	$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	
	• overall equation	**(1)**	$Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$ 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	

Question Number	Answer	Additional Guidance	Mark
8(c)	A diagram that includes • (**M1**) (high resistance) voltmeter/V **(1)** • (**M2**) salt bridge to complete circuit **(1)** • (**M3**) filter paper soaked in (saturated) potassium nitrate/KNO_3 solution **(1)** (**M4**) zinc electrode of zinc metal and suitable zinc salt **(1)** • (**M5**) platinum (black) electrode **(1)** • (**M6**) suitable chromium salts **(1)** • (**M7**) all solutions to be 1 mol dm^{-3} (wrt ions) **(1)**	Example of diagram  Salt bridge must dip into the solutions Allow sodium chloride/potassium chloride for potassium nitrate e.g. $ZnSO_4$ e.g. $CrCl_3$ / $K_2Cr_2O_7$ 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	**(7)**

(Total Question 8 = 15 marks)

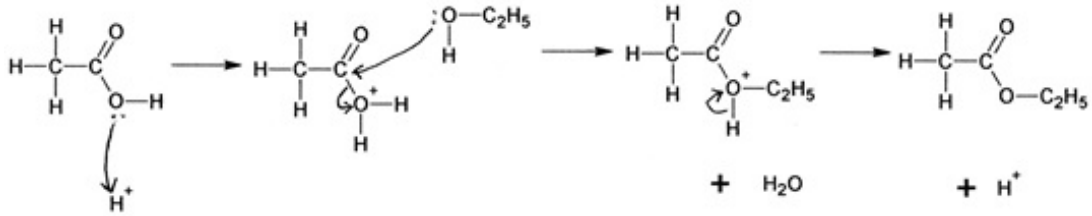
Question Number	Answer	Additional Guidance	Mark
9(a)	An answer that makes reference to • (similarity) both are reduction reactions **(1)** • (difference 1) reagents for preparation of phenylamine are tin and (conc.) hydrochloric acid **(1)** • (difference 2) reagents for preparation of butylamine are 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)**

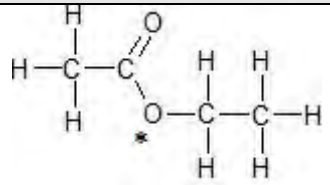
Question Number	Answer	Additional Guidance	Mark
9(b)	An answer that makes reference to: • (similarity) both are basic because they have a lone pair of electrons on the nitrogen atom which accepts a proton **(1)** • (difference 1)in $C_6H_5NH_2$ the lone pair of electrons of the nitrogen atom becomes 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)**	$C_2H_5COCl + C_5H_{11}NH_2 \rightarrow C_2H_5CONHC_5H_{11} + HCl$ 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	**(2)**
	• name **(1)**	N-pentylpropanamide Do not award N-pentylpropylamine	

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)	• (**M1**) calculation of ΔG **(1)** • (**M2**) correct equation **(1)** • (**M3**) rearrangement of equation **(1)** • (**M4**) calculation of ΔS_{system} **(1)** • (**M5**) rearrangement of equation so $S_{(\text{ethyl ethanoate})}$ = **(1)** • (**M6**) calculation of $S_{(\text{ethyl ethanoate})}$ with sign and units **(1)**	<u>Example of calculation</u> $\Delta G = -RT \ln K = -8.31 \times 298 \times \ln 4.0$ $= -3433$ (J mol^{-1}) $\Delta G = \Delta H - T\Delta S_{system}$ $\Delta S_{system} = (\Delta H - \Delta G) \div T$ $\Delta S_{system} = (-6.0 \times 10^3 - (-3433)) \div 298$ $= -8.614\ldots.$ (J mol^{-1} K^{-1}) ($\Delta S_{system} = \Sigma S_{(\text{products})} - \Sigma S_{(\text{reactants})}$) $S_{(\text{ethyl ethanoate})} = \Delta S + \Sigma S_{(\text{reactants})} - S_{(water)}$ $S_{(\text{ethyl ethanoate})} = (-8.614 + (159.8+160.7) - 69.9)$ $= +242/240$ J mol^{-1} K^{-1} Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	**(6)**

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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