Write your name here

Surname	Other names

Edexcel GCE

Centre Number	Candidate Number

Chemistry

Advanced

Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Monday 28 June 2010 – Morning
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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N 3 6 5 0 7 A 0 1 2 8

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SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 In the reaction of manganate(VII) ions with reducing agents in strongly acidic solution, the half-reaction for the reduction is

☒ **A** $MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$

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

☒ **C** $MnO_4^- + 8H^+ + 3e^- \rightarrow Mn^{2+} + 4H_2O$

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

(Total for Question 1 = 1 mark)

2 In the titration of iodine with standard sodium thiosulfate solution, starch is often used as an indicator. The starch should **not** be added until nearly all the iodine has reacted because

☒ **A** it is decomposed by high concentrations of iodine.

☒ **B** the blue complex formed is bleached by high concentrations of iodine.

☒ **C** the blue complex formed with high concentrations of iodine is insoluble and does not re-dissolve as more thiosulfate is added.

☒ **D** the starch reacts with the thiosulfate ions being added.

(Total for Question 2 = 1 mark)

3 The conditions needed for the $E^{\ominus}$ value of the standard hydrogen electrode to be exactly 0 V are

☒ **A** 1 mol dm^{-3} solution of hydrogen ions, 1 atm pressure of hydrogen, 25 °C.

☒ **B** 1 mol dm^{-3} solution of hydrogen ions, 1 atm pressure of hydrogen, room temperature.

☒ **C** 1 mol dm^{-3} solution of hydrogen ions, laboratory pressure of hydrogen, 25 °C.

☒ **D** 0.1 mol dm^{-3} solution of hydrogen ions, 1 atm pressure of hydrogen, 25 °C.

(Total for Question 3 = 1 mark)

4 The electrode potential for a cell can be used to calculate the equilibrium constant for the cell reaction. This is because

☒ **A** $E^{\ominus}_{cell}$ is proportional to $\ln K$.

☒ **B** $E^{\ominus}_{cell}$ is proportional to K.

☒ **C** $\ln E^{\ominus}_{cell}$ is proportional to $\ln K$.

☒ **D** $\ln E^{\ominus}_{cell}$ is proportional to K.

(Total for Question 4 = 1 mark)

5 Which of the following successive ionization energies (values in kJ mol^{-1}) could have come from a transition element?

☒ **A**	496	4563	6913	9544	13352	16611	20115	25941
☒ **B**	590	1145	4912	6474	8144	10496	12320	14207
☒ **C**	717	1509	3249	4940	6985	9200	11508	18956
☒ **D**	2081	3952	6122	9370	12177	15239	19999	23069

(Total for Question 5 = 1 mark)

6 Although platinum is very unreactive, it is used as a catalyst in catalytic converters in motor cars. Which of the following is true?

☒ **A** It converts nitrogen oxides and carbon monoxide to nitrogen and carbon dioxide by adsorbing the reactants on its surface so weakening their bonds.

☒ **B** It converts nitrogen oxides and carbon monoxide to nitrogen and carbon dioxide by being able to change its oxidation state.

☒ **C** It oxidizes unburnt fuel to carbon monoxide.

☒ **D** It oxidizes unburnt fuel to carbon dioxide.

(Total for Question 6 = 1 mark)

7 Which of the following gives the electronic configuration for chromium and for the Cr^{3+} ion?

		Cr	Cr^{3+}
☒	**A**	$[Ar]3d^4 4s^2$	$[Ar]3d^3 4s^0$
☒	**B**	$[Ar]3d^5 4s^1$	$[Ar]3d^2 4s^1$
☒	**C**	$[Ar]3d^5 4s^1$	$[Ar]3d^3 4s^0$
☒	**D**	$[Ar]3d^4 4s^2$	$[Ar]3d^1 4s^2$

(Total for Question 7 = 1 mark)

8 Which of the following gives the colours of solutions containing $Cr_2O_7^{2-}$, CrO_4^{2-}, hydrated Cr^{3+} and hydrated Cr^{2+}, in this order?

☒ **A** Yellow, orange, green, blue

☒ **B** Orange, yellow, green, blue

☒ **C** Orange, yellow, blue, green

☒ **D** Orange, green, yellow, blue

(Total for Question 8 = 1 mark)

9 When dichromate(VI) ions, $Cr_2O_7^{2-}$, react with iron(II) ions in acidic solution, the products are chromium(III) ions and iron(III) ions. In what ratio do the dichromate(VI) ions and the iron(II) ions react?

☒ **A** 1:6

☒ **B** 1:5

☒ **C** 2:5

☒ **D** 1:3

(Total for Question 9 = 1 mark)

10 The compound $[Pt(NH_3)_2Cl_2]$ is

☒ **A** tetrahedral with no isomers.

☒ **B** square planar with no isomers.

☒ **C** tetrahedral with two isomers.

☒ **D** square planar with two isomers.

(Total for Question 10 = 1 mark)

11 The hexaaquacopper(II) ion, $[Cu(H_2O)_6]^{2+}$, is blue because the water ligands

☒ **A** split the *p*-orbital energies and *p*-*p* electron transitions emit blue light.

☒ **B** split the *d*-orbital energies and *d*-*d* electron transitions absorb all but blue light.

☒ **C** split the *p*-orbital energies and *p*-*p* electron transitions absorb all but blue light.

☒ **D** split the *d*-orbital energies and *d*-*d* electron transitions emit blue light.

(Total for Question 11 = 1 mark)

12 If phenol and benzene are tested separately with bromine water, you would expect to see that

☒ **A** benzene and phenol would both decolorize bromine water.

☒ **B** benzene would decolorize bromine water, but phenol would not do so.

☒ **C** neither benzene nor phenol would decolorize bromine water.

☒ **D** benzene would not decolorize bromine water, but phenol would do so.

(Total for Question 12 = 1 mark)

13 An organic compound **X** is much more soluble in dilute hydrochloric acid than in water. Compound **X** forms a coloured complex with aqueous copper(II) ions.

Compound **X** could be

☒ **A** C_6H_5COOH

☒ **B** $C_6H_5NO_2$

☒ **C** $C_6H_5NH_2$

☒ **D** C_6H_5OH

(Total for Question 13 = 1 mark)

14 Which of the following shows the generation of the electrophile in the reaction of benzene with ethanoyl chloride in the presence of anhydrous aluminium chloride?

☒ **A** $CH_3COCl + AlCl_3 \rightarrow [CH_3CO]^+ + AlCl_4^-$

☒ **B** $CH_3COCl + AlCl_3 \rightarrow [CH_3CO]^- + AlCl_4^+$

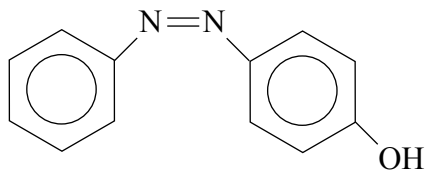
☒ **C** $CH_3CH_2Cl + AlCl_3 \rightarrow [CH_3CH_2]^+ + AlCl_4^-$

☒ **D** $CH_3COOCl + AlCl_3 \rightarrow [CH_3COO]^- + AlCl_4^+$

(Total for Question 14 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

15 Which of the following reagents and conditions would enable phenylamine to be converted to the yellow dye 4-hydroxyazobenzene in a good yield?



☒ **A** Sodium nitrite, $NaNO_2$, in concentrated HCl, between 0 °C and 10 °C; followed by an alkaline solution of phenol.

☒ **B** Sodium nitrite, $NaNO_2$, in concentrated HCl, between 0 °C and 10 °C; followed by an acidic solution of phenol.

☒ **C** Sodium nitrate, $NaNO_3$, in concentrated HCl, between 0 °C and 10 °C; followed by an alkaline solution of phenol.

☒ **D** Sodium nitrite, $NaNO_2$, in concentrated HCl, room temperature; followed by an alkaline solution of phenol.

(Total for Question 15 = 1 mark)

16 1-butylamine, $CH_3CH_2CH_2CH_2NH_2$, reacts with ethanoyl chloride to form

☒ **A** $CH_3CH_2CH_2CH_2NH_3^+Cl^-$

☒ **B** $CH_3CH_2CH_2CH_2NHCOCH_3$

☒ **C** $CH_3CH_2CH_2CH_2NHCH_2CH_3$

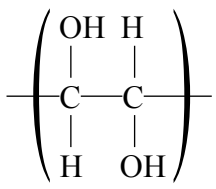
☒ **D** $CH_3CH_2CH_2CH(COCH_3)NH_2$

(Total for Question 16 = 1 mark)

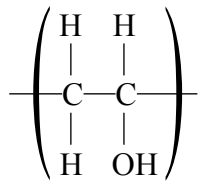
Use this space for any rough working. Anything you write in this space will gain no credit.

17 The addition polymer poly(ethenol) is water-soluble. The repeating unit of poly(ethenol) is

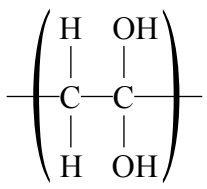
☒ **A**



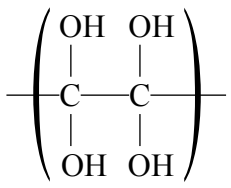
☒ **B**



☒ **C**



☒ **D**

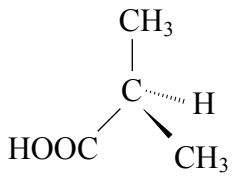


(Total for Question 17 = 1 mark)

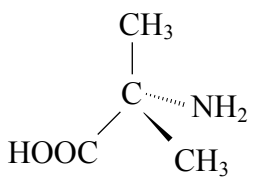
Use this space for any rough working. Anything you write in this space will gain no credit.

18 A white organic compound, **X**, is optically active and reacts with ninhydrin to give a coloured product. The structural formula of **X** could be

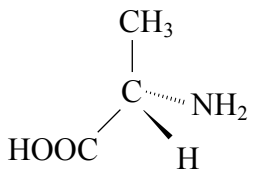
☒ **A**



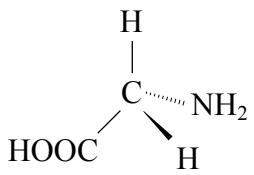
☒ **B**



☒ **C**



☒ **D**



(Total for Question 18 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

19 Glycine, H_2NCH_2COOH, is a solid that has a melting temperature of about 250 °C, and it is very soluble in water. This is because of the

☒ **A** formation of intermolecular hydrogen bonds in the solid and hydrogen bonds with water.

☒ **B** formation of $H_3N^+CH_2COO^-$ ions which interact strongly with each other in the solid and with water.

☒ **C** dissociation of the molecule to form $H_2NCH_2COO^-$ and H^+ ions in the solid and the solution.

☒ **D** protonation of the molecule to form $H_3N^+CH_2COOH$ ions in both the solid and the solution.

(Total for Question 19 = 1 mark)

20 Organic solids are often purified by recrystallization. This technique works on the basis that

☒ **A** the impurities must be insoluble in the solvent used.

☒ **B** the impurities must react with the solvent used.

☒ **C** the impurities crystallize first when the hot solution is cooled.

☒ **D** the cooled solution is saturated with the desired material but not with the impurities.

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

21 Brass is an alloy of copper, zinc and, in some cases, other metals too. There are over 30 varieties of brass for different applications.

The amount of copper in a brass can be found as follows:

- A weighed sample of brass is reacted with the minimum amount of concentrated nitric acid.
- The solution is neutralized, a portion of it pipetted into a conical flask, and excess potassium iodide solution is added.
- The iodine produced is titrated with a solution of sodium thiosulfate of known concentration.

(a) The ionic equation for the reaction between copper metal and concentrated nitric acid is shown below.

$$Cu(s) + 2NO_3^-(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$$

(i) Give the oxidation numbers of the copper and nitrogen in both the reactants and products.

(2)

Copper: from ..... **to** .....

Nitrogen: from ..... **to** .....

(ii) Write the two half-equations that can be combined to give the ionic equation shown above.

(2)

(iii) Explain why the standard electrode potentials for the two ionic half-equations that you have written give an incorrect value for E_{cell} for this reaction as described above.

(2)

.....

.....

.....

.....

(b) The solution produced contains a mixture of zinc ions and copper ions.

(i) State TWO observations that you would **see** if concentrated ammonia solution were to be added, drop by drop, to the solution until in excess.

(2)

.....

.....

.....

(ii) Copper ions can be separated from the zinc ions in the solution by adding sodium hydroxide solution in excess, followed by filtration of the mixture.

Write equations, including state symbols, for the THREE reactions that occur.

(3)

Equation 1

Equation 2

Equation 3

*(iii) Give examples of amphoteric behaviour and ligand exchange, by reference to the reactions of zinc compounds.

(3)

(c) A sample of Admiralty Brass of mass 3.00 g was treated with nitric acid and made up to a neutral solution of volume 250 cm^3. Excess potassium iodide was added to 25.0 cm^3 portions of this solution, and the liberated iodine was titrated with sodium thiosulfate solution, concentration 0.100 mol dm^{-3}. The mean titre was 33.10 cm^3.

(i) Write the ionic equation for the reaction between thiosulfate ions and iodine.

(1)

*(ii) The equation for the reaction between copper(II) ions and iodide ions is shown below.

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

Hence calculate the percentage by mass of copper in Admiralty Brass. Give your answer to **three** significant figures.

(6)

(iii) When setting up the burette, a student failed to fill the jet of the burette. Explain the effect that this would have on the value of the first titre.

If this first titre was included in the calculation of the mean titre, what effect would this have on the value for the percentage of copper in the brass?

(2)

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.....

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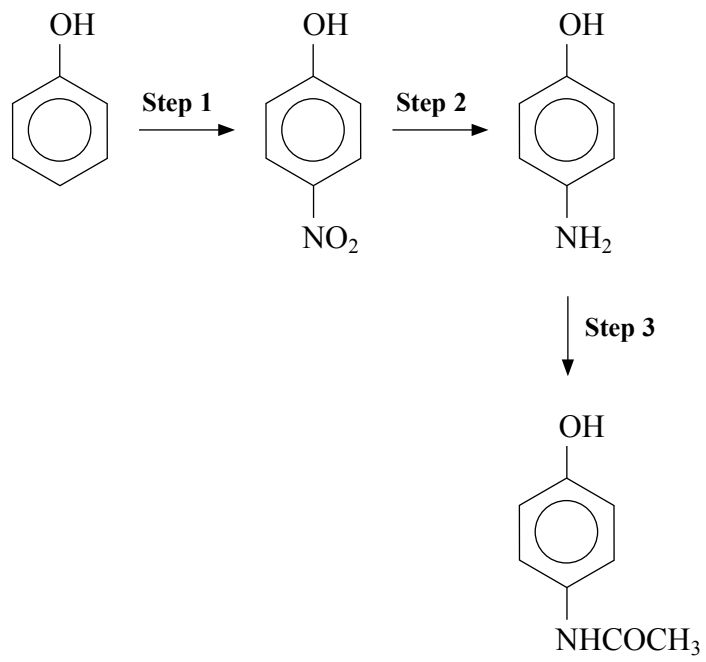
.....

(Total for Question 21 = 23 marks)

22 Paracetamol is possibly the most widely used analgesic (painkiller) in the world. It can be made from phenol as shown below.



Paracetamol

(a) The nitration of phenol in **step 1** uses dilute nitric acid at room temperature, whereas the nitration of benzene requires a mixture of concentrated nitric and sulfuric acids at about 55 °C.

(i) Give the mechanism for the nitration of **benzene**, including the equation for the reaction that produces the electrophile.

(4)

*(ii) Explain why phenol can be nitrated under much milder conditions than those required to nitrate benzene.

(2)

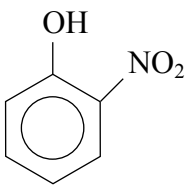
(iii) Suggest reagents that could be used for **step 2**.

(2)

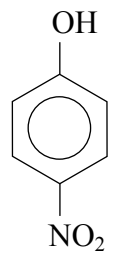
(iv) Suggest the name or formula of a reagent that could be used in **step 3**.

(1)

*(b) In the nitration of phenol, **step 1**, two compounds are produced.



2-nitrophenol



4-nitrophenol

These compounds can be separated by steam distillation, since 2-nitrophenol is volatile in steam but 4-nitrophenol is not.

Describe briefly the technique of steam distillation and give ONE advantage of steam distillation over normal distillation.

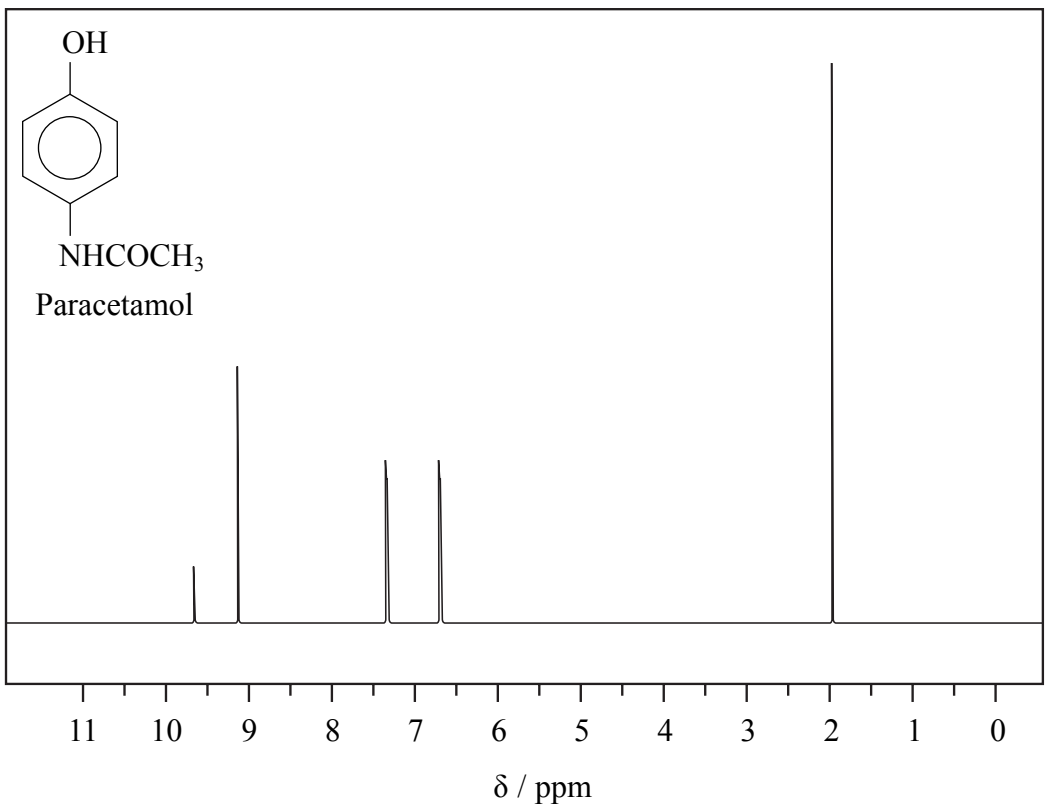
(3)

(c) The nmr spectrum of paracetamol is given below. The peaks at 6.7 and 7.4 ppm are due to the protons on the benzene ring and are both doublets.

Explain why these two peaks are doublets but all the other peaks are singlets.

[There is no need to refer to your data booklet]

(2)



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(Total for Question 22 = 14 marks)

23 More than half of the elements in the Periodic Table are transition elements. Vanadium, element 23, is a typical transition element.

(a) (i) Give TWO properties shown by vanadium **compounds** that are characteristic of transition metal chemistry, other than variable oxidation state.

(2)

(ii) Vanadium(III) ions in aqueous solution exist as $[V(H_2O)_6]^{3+}$.

Draw this ion so as to clearly show its shape. Name the type of bond between the ligand and the vanadium ion and state the feature of the ligand that enables this bond to be formed.

(3)

(b) Vanadium ions exist in oxidation states from (V) to (II).

(i) Use your data booklet (page 15) to find the standard electrode (reduction) potential for the reduction of vanadium(IV), VO^{2+}, to vanadium(III), V^{3+}.

(1)

*(ii) Explain the term **disproportionation.**

(2)

(iii) Use your answer to (b)(i), and the data below, to calculate $E^{\ominus}_{cell}$ for the formation of vanadium(V) and vanadium(III) from vanadium(IV) in acidic solution. State if the reaction is feasible under standard conditions and justify your answer.

$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l) \quad E^{\ominus} = +1.00\ V$

(2)

(Total for Question 23 = 10 marks)

TOTAL FOR SECTION B = 47 MARKS

SECTION C

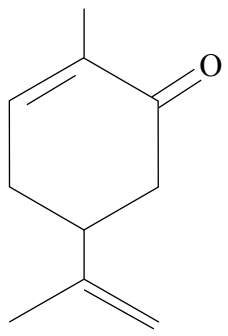
Answer ALL the questions. Write your answers in the spaces provided.

24 A major function of the chemical industry is the manufacture of perfumes and flavourings. Perfumes were originally made from natural products, such as spermaceti from whales or civetone from the civet cat. The use of synthetic equivalents is generally cheaper and the supply is more reliable, and does not require the animals to be killed which obtaining spermaceti did. Synthetic perfumes and flavourings are usually nature-identical, although naturally-occurring molecules that have stereoisomers are sometimes produced synthetically as mixtures since the stereospecific synthesis required might be difficult to achieve economically.

Some chiral molecules have a different taste depending on which enantiomer is present. The enantiomer (–)-carvone tastes and smells of spearmint, and its mirror-image, (+)-carvone, of caraway or dill. In some cases only one enantiomer has any taste; this is true for glucose. The mirror image molecule of naturally occurring glucose has no taste and cannot even be absorbed or metabolized. Many drug molecules are chiral, though paracetamol is not. The wrong isomer present in a drug may be positively damaging, which was the case with thalidomide. In order to synthesize optically-pure drug molecules, it is important to understand the mechanism of any reaction used. Using an S_N1 reaction which involves the chiral centre would result in the product mixture being racemic. It is advantageous to use stereospecific catalysts wherever possible, and industry on the whole prefers to use heterogeneous rather than homogeneous catalysts.

(a) The skeletal formula of carvone is shown below. Draw a circle around the chiral carbon atom.

(1)



(b) Explain why the synthesis of paracetamol is more efficient than the synthesis of a single enantiomer such as (–)-carvone.

(3)

(c) Carvone contains two types of functional group. For each of these, give a suitable chemical test to show its presence, and state what you would see in each case.

(4)

(d) Carvone can be reduced in a variety of ways.

(i) On reduction with hydrogen, in the presence of a platinum catalyst, 4.5 g of carvone reacted with 1.44 dm^3 of hydrogen. Use these data to deduce the skeletal formula of the reduction product.

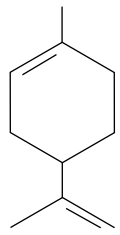
[Molar mass of carvone is 150 g mol^{-1}; molar volume of hydrogen at the temperature and pressure of the experiment is 24 dm^3 mol^{-1}.]

(3)

Working

Hence skeletal formula of reduction product.

(ii) Reduction of carvone, using hydrazine in potassium hydroxide solution, gives limonene.



How would you show from a comparison of the infra-red spectra of carvone and of limonene that this reduction had occurred? You should quote appropriate data, from the data booklet, to support your answer.

(2)

(e) (i) Draw the skeletal formula of the molecule that would be obtained if carvone were to be reacted with an excess of hydrogen bromide in an inert solvent.

(2)

(ii) If the product from (e)(i) were to be heated with ethanolic potassium hydroxide solution, elimination would occur and HBr would be lost. Would the resulting molecule necessarily be carvone? Explain your answer.

(2)

(f) *(i) Give the mechanism of one nucleophilic reaction of your choice, which **either** gives rise to a racemic mixture **or** results in the inversion of the chirality of the starting material. Explain what your mechanism predicts about the stereochemistry of the product.

(5)

(ii) Suggest why industrial chemists prefer to use heterogeneous rather than homogeneous catalysts.

(1)

(Total for Question 24 = 23 marks)

TOTAL FOR SECTION C = 23 MARKS
TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

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

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

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June 2010

GCE

GCE Chemistry (6CH05/01)

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Summer 2010

Publications Code UA023639

Section A

Question Number	Correct Answer	Mark
1	D	**1**

Question Number	Correct Answer	Mark
2	C	**1**

Question Number	Correct Answer	Mark
3	A	**1**

Question Number	Correct Answer	Mark
4	A	**1**

Question Number	Correct Answer	Mark
5	C	**1**

Question Number	Correct Answer	Mark
6	A	**1**

Question Number	Correct Answer	Mark
7	C	**1**

Question Number	Correct Answer	Mark
8	B	**1**

Question Number	Correct Answer	Mark
9	A	**1**

Question Number	Correct Answer	Mark
10	D	**1**

Question Number	Correct Answer	Mark
11	B	**1**

Question Number	Correct Answer	Mark
12	D	**1**

Question Number	Correct Answer	Mark
13	C	**1**

Question Number	Correct Answer	Mark
14	A	**1**

Question Number	Correct Answer	Mark
15	A	**1**

Question Number	Correct Answer	Mark
16	B	**1**

Question Number	Correct Answer	Mark
17	B	**1**

Question Number	Correct Answer	Mark
18	C	**1**

Question Number	Correct Answer	Mark
19	B	**1**

Question Number	Correct Answer	Mark
20	D	**1**

Section B

Question Number	Acceptable Answers	Reject	Mark
21 (a)(i)	**Copper:** 0 to +2/2+/2^+/II/2 **(1)** **Nitrogen:** +5/5+/5^+/V/5 to +4/4+/4^+/IV/4 **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
21(a)(ii)	$Cu \rightarrow Cu^{2+} + 2e^{(-)}$ OR $Cu - 2e^{(-)} \rightarrow Cu^{2+}$ **(1)** $Cu[(H_2O)_6]^{2+}$ OK if 6 waters shown on l.h.s. $NO_3^- + 2H^+ + e^{(-)} \rightarrow NO_2 + H_2O$ OR $2NO_3^- + 4H^+ + 2e^{(-)} \rightarrow 2NO_2 + 2H_2O$ **(1)** OR $2NO_3^- + 4H^+ + 2e^{(-)} \rightarrow N_2O_4 + 2H_2O$ **(1)** Ignore the full equation if it is given as well Allow equations written as reverse of above Ignore state symbols even if wrong Allow $\rightleftharpoons$ for $\rightarrow$		**2**

Question Number	Acceptable Answers	Reject	Mark
21(a)(iii)	(electrode potential) values are for standard conditions **(1)** **nitric acid** is concentrated / not 1 mol dm^{-3} / not 1 M **(1)** Allow temperature not stated for second mark	NO_3^- are not 1 mol dm^{-3} Any reference to loss of NO_2	**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(i)	initially a (pale/light) **blue precipitate (1)** Allow blue solid Ignore white precipitate (re-dissolves in excess to form) a (deep) blue **solution (1)** Stand alone mark Accept any shade of blue except greenish-blue	Any colour (other than blue) precipitate in blue solution	**2**

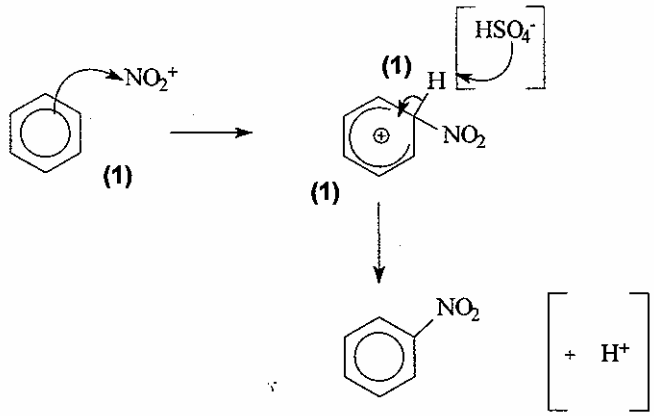
Question Number	Acceptable Answers	Reject	Mark
21(b)(ii)	$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ **(1)** $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$ **(1)** $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq)$ **(1)** If two previous equations combined correctly then **(1)** only : $Zn^{2+} + 4OH^- \rightarrow Zn(OH)_4^{2-}$ **Allow** $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow ZnO_2^{2-}(aq) + 2H_2O(l)$ OR $Zn(OH)_2(s) + 4OH^-(aq) \rightarrow Zn(OH)_6^{4-}(aq)$ OR equivalent non-ionic equations, including those with Zn^{2+} + 2NaOH etc OR Correct balanced equations starting with hexaqua or tetraqua cations ALLOW the hydroxides to be shown as e.g. $Zn(OH)_2(H_2O)_4$ (s) provided that the whole equation balances. Penalise missing /incorrect state symbols on product once only. Ignore other state symbols		**3**

Question Number	Acceptable Answers	Reject	Mark
21(b)(iii) QWC	**First 2 marks:** zinc **hydroxide/oxide** amphoteric because it reacts with alkali (to give a solution of a zincate) **(1)** and reacts with acid (to give a salt) **(1)** zinc hydroxide **is / acts as** both an acid and an alkali – scores **(1)** only **Third mark:** hexaquazinc or hydrated zinc ions exchanged water for ammonia or other named ligand **(1)** OR $Zn(H_2O)_6^{2+} + 4NH_3 \rightarrow$ etc **(1)** Allow any number of ammonias from 1 to 6 Allow balanced equations, ionic or full. Ligand exchange reaction must start with a complex ion **Note:** If zinc mentioned initially but equation refers to a correct compound then credit should be given If equations wrong but words are correct then ignore equations	Reference to zinc ions or zinc metal Do not allow deprotonation	**3**

Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ Ignore state symbols even if wrong.	Non-ionic equation.	**1**

Question Number	Acceptable Answers	Reject	Mark
21(c)(ii) **QWC**	Amount thiosulphate = 0.0331 dm^3 x 0.1 mol dm^{-3} = 0.00331 mol **(1)** = amount of copper(II) ions in 25 cm^3 portion **(1)** ∴ amount Cu = 10 x 0.00331= 0.0331 mol in total **(1)** ∴ mass Cu = 0.0331 mol x 63.5 g mol^{-1} **(1)** = 2.102 g ∴ % copper = (2.102 x 100)÷ 3.00 **(1)** = 70.1% **(1)** to **3 s.f. only** Mark consequentially but if % > 100 then (-1) If equation in (i) is incorrect but used correctly in part (ii) then all marks can be scored unless answer > 100% Correct answer can score 6 marks irrespective of the stoichiometry of the equation in (c)(i) If candidates uses 64 for molar mass of Cu final answer will be 70.6; scores max of 5	70.06 or 70.0	**6**

Question Number	Acceptable Answers	Reject	Mark
21(c)(iii)	some reagent used to fill the jet (which does not react with the iodine solution) **and so** the titre is too high **(1)** and hence the percentage value would be too high **(1)** Allow only if the titre is said to be high If the titre is thought to be too low then allow percentage value too low for 2nd mark **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	$H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_2O + HSO_4^-$ OR $H_2SO_4 + HNO_3 \rightarrow H_2NO_3^+ + HSO_4^-$ $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ Both needed OR $2H_2SO_4 + HNO_3 \longrightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ **(1)** Ignore state symbols even if wrong  arrow showing attack on the nitronium ion with arrow going to N atom, or into the C – N gap **(1)** Arrow must start at or inside ring Ignore position of + charge structure of the intermediate showing reasonable delocalisation (over at least 3 carbon atoms) **(1)** arrow **from the bond** showing the loss of H^+ from the intermediate. Removal by hydrogen sulphate ion preferable but not essential **(1)** Kekulé structures score full marks If the electrophile is incorrect then the intermediate structure mark is lost	Delocalisation mustn't go over C where NO_2^+ is attached	**4**

Question Number	Acceptable Answers	Reject	Mark
22(a)(ii) QWC	**First mark:** (lone pair of) electrons on the oxygen atom or on the OH group is delocalised / incorporated into the ring **(1)** OR the OH group is electron donating **(1)** **Second mark:** so the ring in phenol is more negative / has increased electron density / **ring** is more nucleophilic / hence more susceptible to electrophilic attack **(1)** OR the OH group activates the ring **(1)** Second mark stand alone	Reject hydroxide for first mark only Nucleophilic attack on the ring 'Makes it more reactive' on its own	**2**

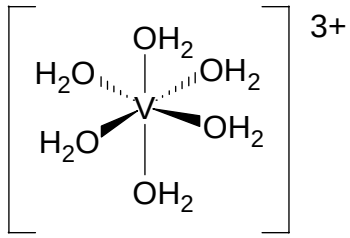
Question Number	Acceptable Answers	Reject	Mark
22(a)(iii)	tin **(1)** and **concentrated** hydrochloric acid **(1)** Formulae acceptable. If NaOH is added after HCl then ignore; if implication that HCl and NaOH are added together then second mark is lost OR iron **(1)** and **concentrated** hydrochloric acid **(1)** **2nd mark conditional on a metal** OR hydrogen **(1)** and platinum / palladium catalyst **(1)**	lithium aluminium hydride sodium borohydride Nickel Raney Nickel	**2**

Question Number	Acceptable Answers	Reject	Mark
22(a)(iv)	ethanoyl chloride OR acetyl chloride OR CH_3COCl OR equivalent displayed formula OR ethanoic anhydride OR acetic anhydride OR $(CH_3CO)_2O$ OR equivalent displayed formula Right name but wrong formula does not score Ignore minor spelling errors if the formula is correct		**1**

Question Number	Acceptable Answers	Reject	Mark
22(b) **QWC**	**First mark:** steam is passed into the mixture OR water is added and mixture boiled or distilled or heated **(1)** **Second mark:** and the 2-nitrophenol / product vapour distilled off **with the water** (and condensed) **(1)** **Advantage:** The 2-nitrophenol / product distils at a lower temperature / prevents decomposition**(1)** Stand alone	Passed over; anything that implies external heating with a steam bath or water bath any implication of fractional distillation any suggestion that separation based on differing boiling temperature water-soluble	**3**

Question Number	Acceptable Answers	Reject	Mark
22(c)	Read the whole answer to get the sense The (ring) hydrogen atoms are on carbon atoms which have **one / a** hydrogen on an **adjacent** carbon atom, so are doublets **(1)** All the other hydrogen atoms have no adjacent hydrogen (bearing carbon) atoms, so are singlets **(1)**	nearby	**2**

Question Number	Acceptable Answers	Reject	Mark
23(a)(i)	Any TWO of: complex ions / complexes **(1)** coloured ions / compounds / solutions **(1)** catalytic properties **(1)** paramagnetic **(1)** Allow coloured complexes **(2)** coloured complex compound **(1)** If a list appears with 1 or 2 correct properties followed by properties related to the element, then (1) mark only Ignore 'partially filled *d*-orbitals'	complex compounds	**2**

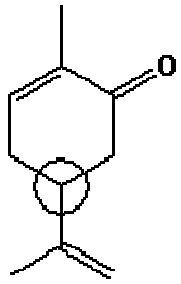
Question Number	Acceptable Answers	Reject	Mark
23(a)(ii)	 ignore absence of charge **clearly** octahedral (ignore bonds to the H in H_2O) **(1)** but allow some latitude in the symbols used to show the 3D structure. Wedges do not have to be exact – if used they are enough to show 3D if the axial bonds are lines The word 'octahedral' does not salvage a poor drawing dative (covalent) / coordinate (bond) **(1)** not just shown by an arrow lone pair (of electrons on the oxygen) **(1)** can be shown on the diagram		**3**

Question Number	Acceptable Answers	Reject	Mark
23(b)(i)	(+) 0.34 (V) OR (+) 0,34 V sign not needed		**1**

Question Number	Acceptable Answers	Reject	Mark
23(b)(ii) QWC	(simultaneous) oxidation and reduction **(1)** Allow redox of a species / substance / reactant / compound / chemical / element **(1)**		**2**

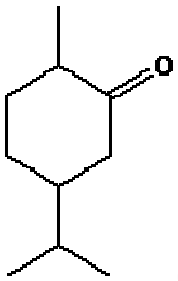
Question Number	Acceptable Answers	Reject	Mark
23(b)(iii)	− 0.66(V) **(1)** Allow TE from (b)(i) reaction not feasible **since the potential is negative** (2^{nd} mark is for an answer consistent with sign of E°) **(1)**		**2**

Section C

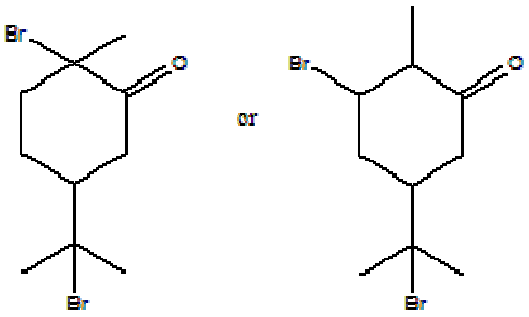
Question Number	Acceptable Answers	Reject	Mark
24(a)		Circles that encompass two atoms	**1**

Question Number	Acceptable Answers	Reject	Mark
24(b)	**First mark:** Recognition that paracetamol is not chiral / has no enantiomers / does not have optical isomers **(1)** **Second and third marks:** Any two of: there is no racemisation so the product will not be a mixture **(1)** no need to separate (the enantiomers) **(1)** do not have to discard an unwanted enantiomer / atom economy is higher **(1)** **OR** converse arguments starting from (-)-carvone.	Is not optically active	**3**

Question Number	Acceptable Answers	Reject	Mark
24(c)	(C=C): add bromine (water) **(1)** decolourises **(1)** OR $KMnO_4$ **(1)** purple → brown / colourless **(1)** (C=O): add 2,4-dnp / 2,4-dinitrophenylhydrazine/ Brady's reagent **(1)** orange or yellow or orange-red or red ppt **(1)** Ignore a negative Fehling's / Tollens' test If a positive Fehling's / Tollens' is given in addition to 2,4 DNP then third and fourth marks are lost Observation dependent on test	1,4-dnp	**4**

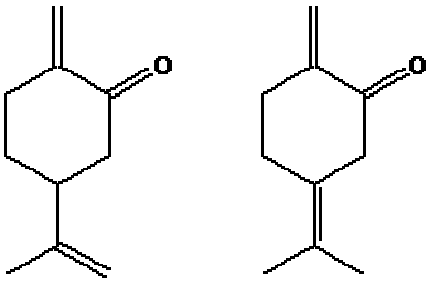
Question Number	Acceptable Answers	Reject	Mark
24(d)(i)	amount of carvone = (4.5 ÷ 150) mol = 0.03 mol **(1)** amount of hydrogen = (1.44 ÷ 24) mol = 0.06 mol (allow 1st mark for either of the mole calculations) so two double bonds are reduced **(1)** OR 2 moles H_2 : (1 mol carvone) OR 4 mole H : (1 mol carvone) If hydrogen is used it must be clear whether they are atoms or molecules This mark can be salvaged if the structure is correct and both double bonds are reduced  **(1)** stand alone Accept displayed formula if completely correct	Any structure that shows reduction of the C=O bond	**3**

Question Number	Acceptable Answers	Reject	Mark
24(d)(ii)	(a ketone/C=O) absorption / peak / trough / within the range 1680 – 1700 (cm^{-1}) **(1)** Ignore units will be seen in carvone but not in limonene / the reduction product **(1)** omission of the value for the absorption loses first mark only	1720 - 1740 cm^{-1}	**2**

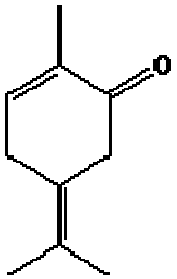
Question Number	Acceptable Answers	Reject	Mark
24(e)(i)	 for both double bonds having HBr added **(1)** ignore added hydrogens for correct orientation in **exocyclic** double bond **(1)** stand alone	Any structure retaining C=C bonds	**2**

Question Number	Acceptable Answers	Reject	Mark
24(e)(ii)	HBr can be eliminated using a hydrogen from the carbon on either side of the bromine **(1)** which would then give a double bond in a different position from that in carvone **(1)** this second mark can be answered using a skeletal / structural formula (below)	Reference to substitution	**2**

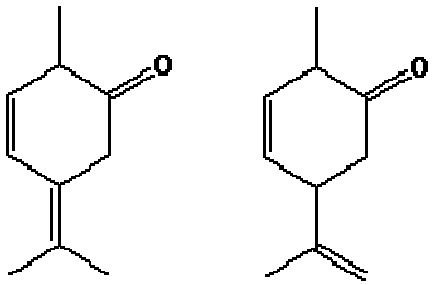
From the left-hand structure above:



From either of the structures above:



From the right-hand structure above:



Question Number	Acceptable Answers	Reject	Mark
24(f)(i) QWC	**Using an $S_N1$mechanism:** selection of a chiral starting material **(1)** curly arrow from C-X bond to X **(1)** and intermediate carbocation **(1)** curly arrow from nucleophile (can come from negative charge) **(1)** **planar intermediate** attacked from either side to give a racemic mixture **OR** **intermediate equally** attacked from either side to give a racemic mixture **(1)** **Using an S_N2 mechanism:** selection of a chiral starting material **(1)** curly arrow from nucleophile (can come from negative charge) **(1)** curly arrow from C-X bond to X **(1)** to give correct transition state **(1)** attack from opposite side to C-X bond gives inverted product can be shown on a diagram **(1)** **Using nucleophilic addition to C= O:** Selection of any aldehyde (other than methanal) or any asymmetric ketone **(1)** Curly arrow from nucleophile (can come from negative charge) to C of C=O and curly arrow from = to O **(1)** Intermediate **(1)** Arrow from O^- of intermediate to H^+ **(1)** **planar molecule** attacked from either side to give a racemic mixture **OR** **molecule equally** attacked from either side to give a racemic mixture **(1)**	If H-X used then -1	**5**

Question Number	Acceptable Answers	Reject	Mark
24(f)(ii)	heterogeneous catalysts can be filtered off OR do not appear in any liquid or gaseous products OR are easy to separate OR are stereospecific OR suited to continuous processes rather than batch processes	greater surface area	**1**

Write your name here

Surname	Other names

Edexcel GCE

Centre Number	Candidate Number

Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Friday 24 June 2011 – Morning
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

P38480A

7/7/5/3/

P 3 8 4 8 0 A 0 1 2 4

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SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Four complex ions have the following formulae:

A $Cu(edta)^{2-}$

B $Zn(H_2O)_6^{2+}$

C $Ni(NH_3)_6^{2+}$

D $CrCl_4^{2-}$

(a) Which complex ion is most likely to be tetrahedral in shape?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which complex ion is most likely **not** to be coloured?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Each of these complex ions may be formed by ligand exchange from an aqua complex. For which complex ion is the entropy change of this reaction most positive?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 1 = 3 marks)

2 When a **few drops** of aqueous ammonia are added to a solution containing $[Cr(H_2O)_6]^{3+}$ ions the product formed will be

☒ **A** $[Cr(NH_3)_6]^{3+}$

☒ **B** $Cr(H_2O)_3(OH)_3$

☒ **C** $[Cr(NH_3)_4]^{3+}$

☒ **D** $[Cr(H_2O)_2(OH)_4]^-$

(Total for Question 2 = 1 mark)

3 Which of these statements about a standard hydrogen electrode, for which $E^{\ominus} = 0$ V, is **not** correct?

☒ **A** The hydrogen gas is at a pressure of 1 atm.

☒ **B** A solution containing 1 mol dm^{-3} of $H^+(aq)$ ions is used.

☒ **C** A platinum electrode is used.

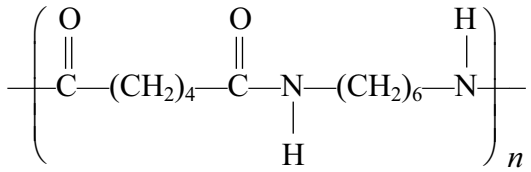
☒ **D** The temperature is kept at 20 °C.

(Total for Question 3 = 1 mark)

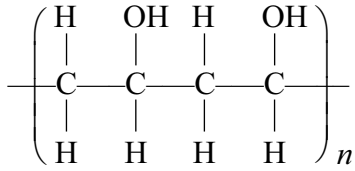
Use this space for any rough working. Anything you write in this space will gain no credit.

4 Four polymers labelled **A to D** have the following formulae:

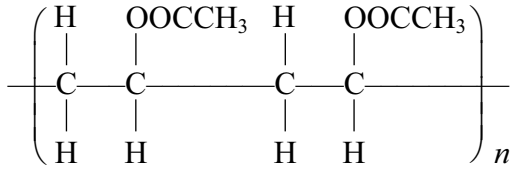
A



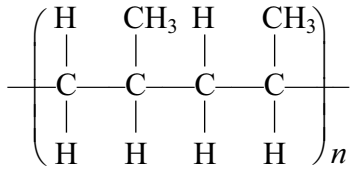
B



C



D



(a) Which polymer is most soluble in hot water?

(1)

☒ **A**

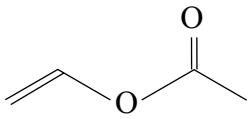
☒ **B**

☒ **C**

☒ **D**

(b) Which polymer is formed from the monomer shown below?

(1)



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which polymer is a condensation polymer?

(1)

☒ **A**

☒ **B**

☒ **C**

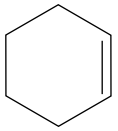
☒ **D**

(Total for Question 4 = 3 marks)

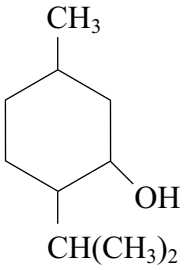
Use this space for any rough working. Anything you write in this space will gain no credit.

5 The formulae of some organic compounds labelled **A to D** are shown below.

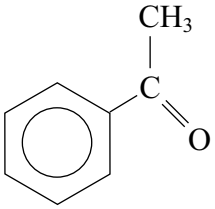
A



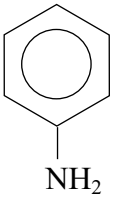
B



C



D



(a) Which compound reacts with sodium to form hydrogen?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which compound forms a green complex ion with $CuSO_4(aq)$?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which compound forms an orange precipitate with 2,4-dinitrophenylhydrazine?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 5 = 3 marks)

6 How many peaks would you expect to see in a **low resolution** proton nmr spectrum of the ester $HCOOCH_2CH_2CH_3$?

☒ **A** 8

☒ **B** 7

☒ **C** 4

☒ **D** 3

(Total for Question 6 = 1 mark)

7 In a **high resolution** proton nmr spectrum of ethyl ethanoate, $C\mathbf{H_3}COOCH_2CH_3$, the peak due to the hydrogen atoms shown **in bold** would be a

☒ **A** singlet.

☒ **B** doublet.

☒ **C** triplet.

☒ **D** quartet.

(Total for Question 7 = 1 mark)

8 Which of these compounds, whose formulae are shown below, **cannot** exist as a racemic mixture?

☒ **A** $CH_2ClCHClCOOH$

☒ **B** $HOOCCHClCOOH$

☒ **C** $CH_3CHClCOOH$

☒ **D** $CH_3CH(OH)COOH$

(Total for Question 8 = 1 mark)

9 Phenol reacts with bromine water whereas benzene reacts with bromine in the presence of iron.

(a) The mechanism for both these reactions is

(1)

☒ **A** electrophilic substitution.

☒ **B** electrophilic addition.

☒ **C** nucleophilic substitution.

☒ **D** nucleophilic addition.

(b) In the reaction of benzene with bromine, iron

(1)

☒ **A** acts as a heterogeneous catalyst.

☒ **B** acts as a homogeneous catalyst.

☒ **C** reacts with the bromine to make iron(III) bromide, $FeBr_3$.

☒ **D** allows bromine to attack the hydrogen atoms on benzene more readily.

(c) Bromine reacts more readily with phenol than with benzene because the OH group on phenol

(1)

☒ **A** is a good leaving group.

☒ **B** attracts the bromine particles more readily.

☒ **C** is a good nucleophile.

☒ **D** increases the electron density of the ring.

(Total for Question 9 = 3 marks)

---

10 Ammonia (NH_3), butylamine ($CH_3CH_2CH_2CH_2NH_2$) and phenylamine ($C_6H_5NH_2$) all form alkaline solutions in water. The order of **increasing** pH of equimolar solutions is

☒ **A** $C_6H_5NH_2 < CH_3CH_2CH_2CH_2NH_2 < NH_3$

☒ **B** $NH_3 < CH_3CH_2CH_2CH_2NH_2 < C_6H_5NH_2$

☒ **C** $C_6H_5NH_2 < NH_3 < CH_3CH_2CH_2CH_2NH_2$

☒ **D** $CH_3CH_2CH_2CH_2NH_2 < NH_3 < C_6H_5NH_2$

(Total for Question 10 = 1 mark)

---

11 The distance on a chromatogram moved by an individual amino acid, in a mixture of different amino acids, mainly depends on

☒ **A** the molar mass of the amino acid.

☒ **B** the molar mass of the solvent used.

☒ **C** the intermolecular forces between the solvent and the stationary phase.

☒ **D** the intermolecular forces between the amino acid and both the solvent and the stationary phase.

(Total for Question 11 = 1 mark)

12 Amino acids are crystalline solids with a high melting temperature because

☒ **A** each molecule has a large number of electrons.

☒ **B** each molecule forms hydrogen bonds at both ends.

☒ **C** a proton is transferred from one end of the molecule to the other.

☒ **D** their shape allows the molecules to pack close together.

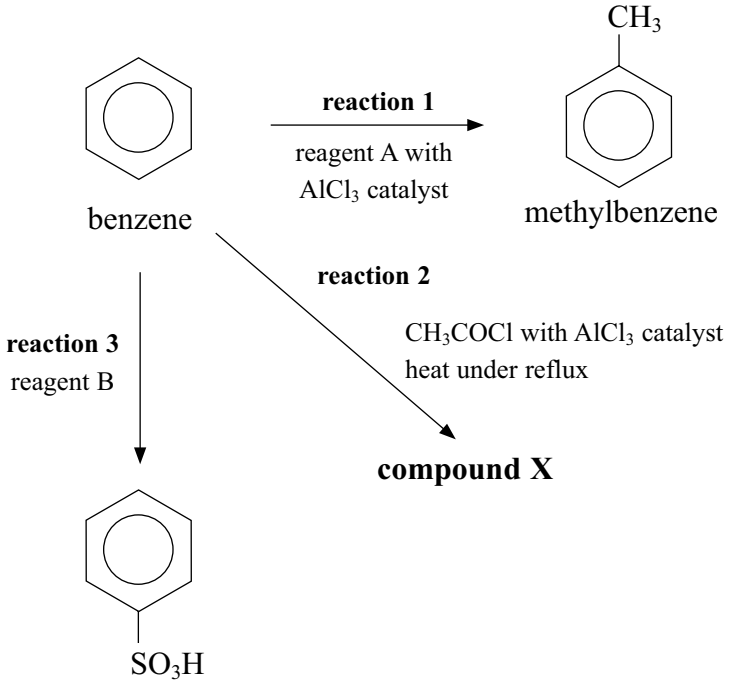
(Total for Question 12 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

13 Some reactions of benzene are shown below.



(a) (i) Suggest the formula of reagent A in **reaction 1**.

(1)

.....

(ii) Write the equation to show how the catalyst, $AlCl_3$, reacts with reagent A to form the species which attacks the benzene ring.

(1)

(iii) Draw the structure of the intermediate ion formed when the species in (ii) attacks the benzene ring.

(1)

(b) The methylbenzene formed in **reaction 1** generally reacts in a similar way to benzene but faster, as the ring is said to be activated.

(i) Explain how the presence of a methyl group activates the benzene ring.

(1)

(ii) Use your answer to (i) to explain why methylbenzene reacts faster.

(1)

(c) (i) Draw the structural formula of **compound X**, formed in **reaction 2**.

(1)

(ii) The organic product of **reaction 2** is also formed when the same reactants, but with an aluminium catalyst, are heated using microwave radiation. Suggest two reasons why this technique may be considered 'greener'.

(2)

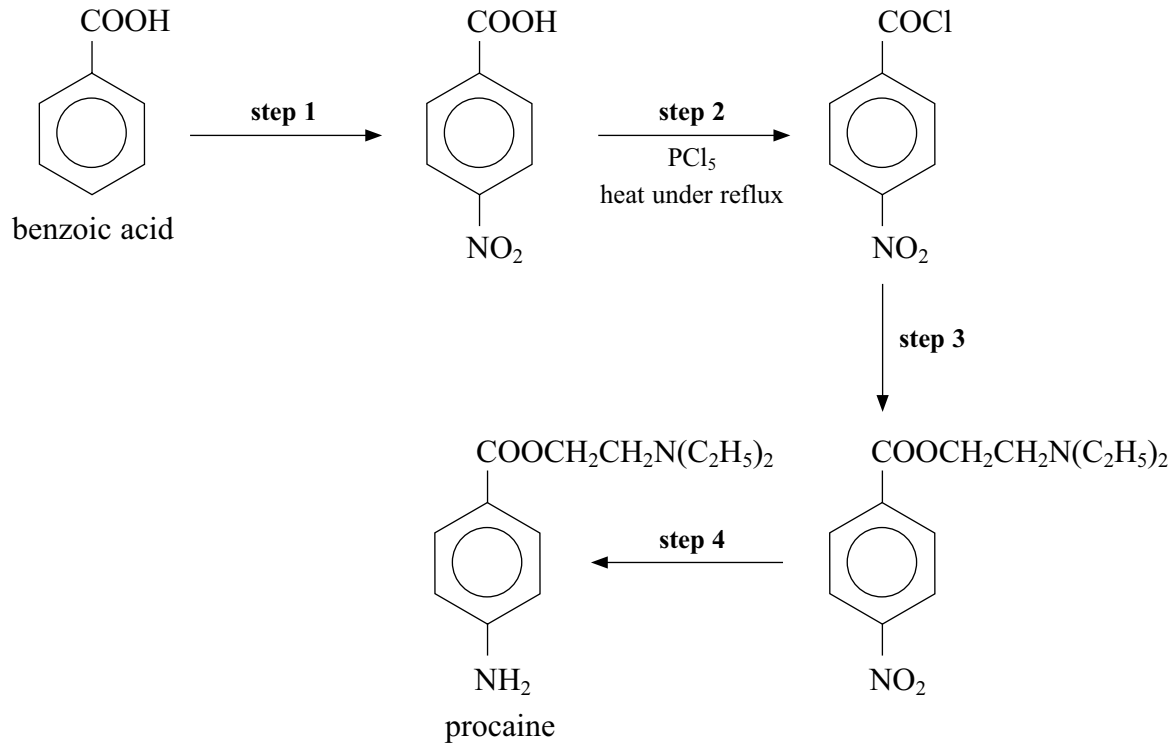
(d) Name reagent B needed for **reaction 3**.

(1)

(Total for Question 13 = 9 marks)

14 This question is about synthetically produced painkillers and anaesthetics.

(a) The local anaesthetic procaine can be synthesised from benzoic acid. The simplified route is shown below.



(i) Suggest the two reagents needed for **step 1**.

(2)

.....

.....

(ii) Draw the apparatus needed to heat under reflux in **step 2**.

(3)

(iii) Suggest why the reagents for the reaction in **step 2** are

(2)

heated .....

.....

under reflux .....

.....

(iv) Give the structural formula for the organic reagent needed in **step 3**.

(1)

(v) What type of reaction is taking place in **step 4**? Suggest the reagents used.

(2)

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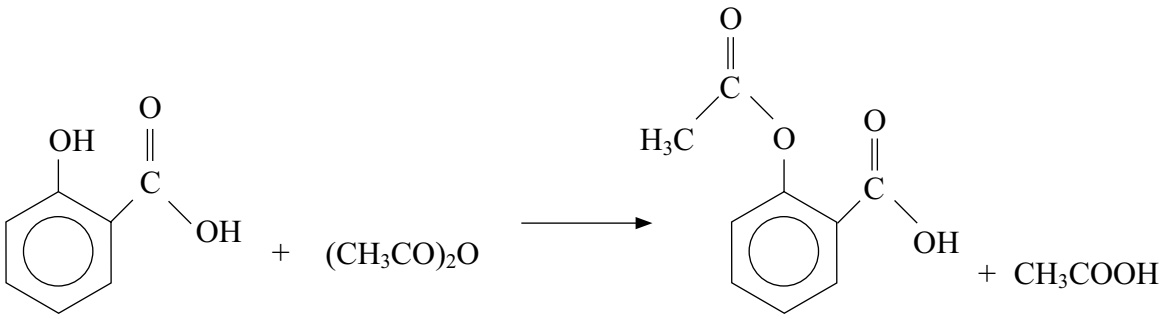
(b) A student produced a sample of aspirin by the esterification of 9.40 g of 2-hydroxybenzoic acid with excess ethanoic anhydride.



2-hydroxybenzoic acid ethanoic anhydride aspirin

After purification by recrystallization, 7.77 g of aspirin was obtained.

[M_r of 2-hydroxybenzoic acid = 138, M_r of aspirin = 180]

(i) Calculate the percentage yield obtained.

(3)

*(ii) Outline how to purify a solid, such as aspirin, by recrystallization, using water as the solvent.

(4)

(iii) Explain what effect recrystallization has on the final yield.

(1)

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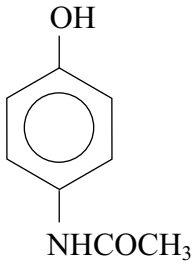
(c) Paracetamol is found in many non-prescription painkillers, often in conjunction with other compounds such as codeine.



paracetamol

(i) Suggest, by name or formula, a reagent that could be used to form paracetamol from 4-aminophenol.

(1)

(ii) Suggest why sales of non-prescription painkillers, often containing paracetamol and codeine, are limited to 32 tablets.

(1)

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.....

(iii) Explain why paracetamol is only slightly soluble in water although it can form hydrogen bonds with water.

(1)

.....

.....

.....

(Total for Question 14 = 21 marks)

15 Hydrogen gas can be used as a fuel in car engines by being burnt in a combustion reaction or reacted with oxygen in a fuel cell to produce electricity.

(a) Write half-equations for the reaction of hydrogen gas at the anode and oxygen gas at the cathode in the fuel cell.

(2)

Anode

Cathode

(b) Describe one advantage of using hydrogen in fuel cells rather than burning the hydrogen directly.

(1)

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.....

.....

(c) Other fuels, such as ethanol, can also be used in fuel cells. By considering the possible sources of ethanol and hydrogen, explain why some scientists believe the use of such cells could provide a more sustainable source of energy for cars, compared with fossil fuels.

(3)

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(Total for Question 15 = 6 marks)

16 This question is about the transition metal iron and some of its compounds.

(a) Give the electronic configuration of the Fe^{3+} ion and use this to define what is meant by a transition element.

(2)

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*(b) Iron will act as a surface catalyst in some gaseous reactions. Outline the processes that take place during such catalysis and suggest two reasons to explain why the catalyst speeds up the reaction.

(4)

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(c) One of the components of rust, found on objects made from iron, is iron(III) hydroxide, $Fe(OH)_3$. Use items 17, 19 and 44 from the Standard Electrode Potential table in your data booklet to show how it is able to form in two steps, writing an equation for each step.

(4)

(d) Haemoglobin is a complex containing iron(II) ions.

Describe how nitrogen atoms in the haemoglobin bond to the iron(II) ions.

(2)

.....

.....

.....

.....

(Total for Question 16 = 12 marks)

TOTAL FOR SECTION B = 48 MARKS

SECTION C

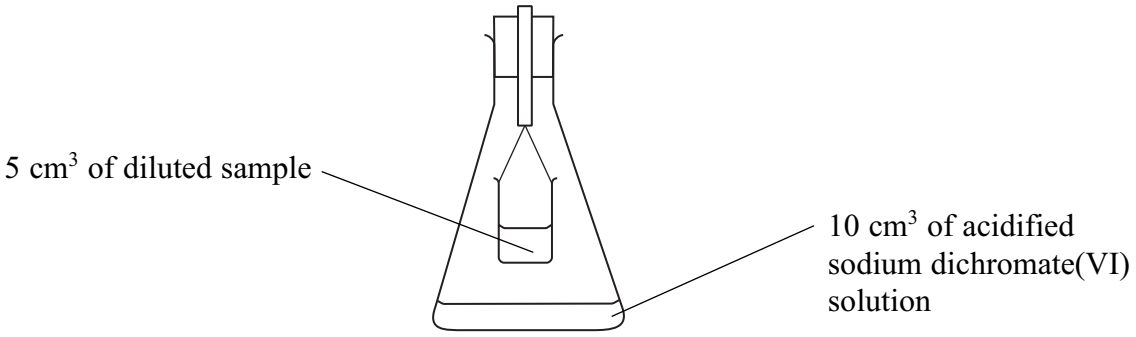
Answer ALL the questions. Write your answers in the spaces provided.

17

Alcoholic drinks contain ethanol, CH_3CH_2OH, in aqueous solution. The percentage of alcohol in a drink can be determined by a redox titration, whilst the amount of alcohol present on the breath of someone who has consumed such a drink can be estimated using a breathalyser.

The earliest breathalysers used the colour change that occurs when dichromate(VI) ions react with ethanol to measure the amount of alcohol. Later models measure the current from a fuel cell. Cheaper versions of these meters are available for drivers to buy for self-testing. Some police forces also use fuel cell breathalysers in conjunction with infrared breath analysers, which can determine the amounts of alcohol from an infrared spectrum.

In an experiment to find out the concentration of ethanol in a drink, a small beaker containing 5.00 cm^3 of a diluted sample of the drink is suspended above 10.0 cm^3 of excess acidified sodium dichromate(VI) solution, of concentration 0.0800 mol dm^{-3}, and left for 24 hours in a warm place.



The ethanol vaporizes and reacts with some of the acidified sodium dichromate(VI) ions. Excess potassium iodide is then added to the unreacted acidified sodium dichromate(VI), forming iodine, $I_2(aq)$.

The $I_2(aq)$ is then titrated with a solution of sodium thiosulfate, $Na_2S_2O_3$, of concentration 0.0250 mol dm^{-3}.

(a) Ethanol and dichromate(VI) ions in acidic solution react in the mole ratio 3:2.

(i) Complete the two half-equations below. State symbols are **not** required.

(2)

$$Cr_2O_7^{2-} \rightarrow Cr^{3+}$$

$$CH_3CH_2OH \rightarrow CH_3COOH$$

(ii) Use either the half-equations in (i) or that the mole ratio of CH_3CH_2OH:$Cr_2O_7^{2-}$ is 3:2 to construct the ionic equation for the reaction between ethanol and acidified dichromate(VI) ions. State symbols are **not** required.

(1)

*(iii) The iodine formed in the experiment reacted completely with 34.40 cm^3 of the 0.0250 mol dm^{-3} sodium thiosulfate solution. Use this information, the fact that the mole ratio of CH_3CH_2OH:$Cr_2O_7^{2-}$ is 3:2 and the equations below, to calculate the concentration of the ethanol in the 5.00 cm^3 of the diluted sample of the drink.

(6)

$$Cr_2O_7^{2-} + 14H^+ + 6I^- \rightarrow 2Cr^{3+} + 3I_2 + 7H_2O$$

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

(iv) The solution used in the experiment was made by adding 10.0 cm^3 of the drink to a 100 cm^3 volumetric flask, making up the remainder of the volume using distilled water. Use the information and your final answer to (a)(iii) to calculate the concentration, in mol dm^{-3}, of ethanol in the undiluted drink.

(1)

(v) Suggest why the sample was suspended above the acidified sodium dichromate(VI) solution, rather than simply being mixed with it.

(1)

(vi) Suggest two reasons why the apparatus was left in a **warm** place for **24 hours**. What would be the effect on the final result if this procedure were not followed?

(3)

(vii) Do you think that this experiment gives a reliable result? Explain your answer.

(1)

*(b) (i) Explain how each type of breathalyser, mentioned in the passage, shows the amount of ethanol present.

(3)

Earliest type.....

.....

.....

Fuel cell.....

.....

.....

Infrared.....

.....

.....

(ii) Suggest why infrared breathalysers do not use the OH absorption to detect the amount of alcohol on the breath.

(1)

.....

.....

.....

(iii) Suggest why some police forces use infrared breathalysers together with fuel cell breathalysers.

(1)

(iv) Suggest **one** advantage and **one** disadvantage of buying a personal breathalyser.

(2)

(Total for Question 17 = 22 marks)

TOTAL FOR SECTION C = 22 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)											(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

* Actinide 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
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

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Mark Scheme (Results)

June 2011

GCE Chemistry (6CH05) Paper 01
General Principles of Chemistry II

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June 2011
Publications Code UA027569

General Marking Guidance

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

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.

Section A (multiple choice)

Question Number	Correct Answer	Mark
1 (a)	D	**1**

Question Number	Correct Answer	Mark
1 (b)	B	**1**

Question Number	Correct Answer	Mark
1 (c)	A	**1**

Question Number	Correct Answer	Mark
2	B	**1**

Question Number	Correct Answer	Mark
3	D	**1**

Question Number	Correct Answer	Mark
4 (a)	B	**1**

Question Number	Correct Answer	Mark
4 (b)	C	**1**

Question Number	Correct Answer	Mark
4 (c)	A	**1**

Question Number	Correct Answer	Mark
5 (a)	B	**1**

Question Number	Correct Answer	Mark
5 (b)	D	**1**

Question Number	Correct Answer	Mark
5 (c)	C	**1**

Question Number	Correct Answer	Mark
6	C	**1**

Question Number	Correct Answer	Mark
7	A	**1**

Question Number	Correct Answer	Mark
8	B	**1**

Question Number	Correct Answer	Mark
9 (a)	A	**1**

Question Number	Correct Answer	Mark
9 (b)	C	**1**

Question Number	Correct Answer	Mark
9 (c)	D	**1**

Question Number	Correct Answer	Mark
10	C	**1**

Question Number	Correct Answer	Mark
11	D	**1**

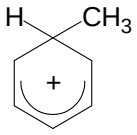
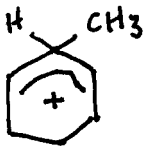
Question Number	Correct Answer	Mark
12	C	**1**

TOTAL FOR SECTION A = 20 MARKS

Section B

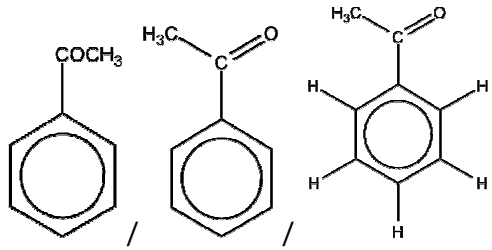
Question Number	Acceptable Answers	Reject	Mark
13 (a)(i)	CH_3Cl / CH_3Br / CH_3I Ignore name and state symbols Allow displayed formula	Name alone	**1**

Question Number	Acceptable Answers	Reject	Mark
13 (a)(ii)	$CH_3Cl + AlCl_3 \rightarrow CH_3^+ + AlCl_4^-$ Allow $CH_3^{\delta+}$ $AlCl_4^{\delta-}$ and other halogens Ignore state symbols and curly arrows	$CH_3^{\delta+}$-$AlCl_3^{\delta-}$ + Cl^-	**1**

Question Number	Acceptable Answers	Reject	Mark
13 (a)(iii)	 Ignore curly arrows and use of wedges/dashes Ignore attempts to complete mechanism if intermediate is correct Must show reasonable delocalisation over at least 3 carbon atoms Allow positive charge anywhere inside benzene ring Allow delocalization shown as dashed line e.g  Allow correct Kekulé structure	Complete circle of delocalization 'Upside down' delocalization e.g. 	**1**

Question Number	Acceptable Answers	Reject	Mark
13 (b)(i)	(Methyl group) donates/increases electron density to the ring/feeds electrons into ring Allow the methyl group is electron releasing	Donates **lone** pair of electrons Ring becomes more electronegative Just 'inductive effect'	**1**

Question Number	Acceptable Answers	Reject	Mark
13 (b)(ii)	(Methylbenzene) is more susceptible to electrophilic attack/attack by **positive** species/makes it a stronger nucleophile Ignore comments about ring stability Allow methyl group stabilizes carbocation		**1**

Question Number	Acceptable Answers	Reject	Mark
13 (c)(i)	 $C_6H_5COCH_3$ / / / Allow displayed or skeletal formulae or Kekulé		**1**

Question Number	Acceptable Answers	Reject	Mark
13 (c)(ii)	**Any 2 from 4** Lower energy input (to heat reaction)/less heat losses/more efficient heating **(1)** Electrical energy can be obtained from renewable resources whereas gas is non renewable **(1)** Easier separation of catalyst/(easier to) re-use catalyst **(1)** Involves less chlorine/chlorine compounds **(1)** Ignore any comments regarding carbon dioxide level/global warming	Faster reaction because using a catalyst Just 'uses less fuel' Just uses less toxic/harmful chemicals	**2**

Question Number	Acceptable Answers	Reject	Mark
13 (d)	Fuming sulfuric acid / oleum / sulfur trioxide (dissolved) in concentrated sulfuric acid Allow fuming H_2SO_4 /$H_2S_2O_7$ / SO_3 (dissolved) in concentrated H_2SO_4	Just sulfuric acid or sulfur trioxide	**1**

Question Number	Acceptable Answers	Reject	Mark
14 (a)(i)	Conc. Nitric acid **(1)** Conc. Sulfuric acid **(1)** Allow correct formulae Ignore state symbols Sulfuric acid and nitric acid with no mention of concentrated scores (1)		**2**

Question Number	Acceptable Answers	Reject	Mark
14 (a)(ii)	Pear shaped/round bottomed flask & heat source **(1)** Allow vertical arrow with or without the word heat Allow water bath as a heat source Liebig condenser, shown vertically **(1)** (Water) flow shown correctly into a jacket **(1)** Ignore thermometers unless stoppered Penalise (one for each): Stopper/sealed Gaps between flask and condenser Condenser inner tube extends into liquid in flask	Conical flask in diagram or label	**3**

Question Number	Acceptable Answers	Reject	Mark
14 (a)(iii)	Heat Speed up reaction / to overcome the activation energy / provide energy to break bonds / because activation energy for the reaction is high **(1)** Under reflux Prevent escape of reactants / products Or As they may be flammable / harmful / volatile **(1)**	Just to provide energy for the reaction to start Just to increase the yield/make reaction go to completion	**2**

Question Number	Acceptable Answers	Reject	Mark
14 (a)(iv)	$HOCH_2CH_2N(C_2H_5)_2$ Allow $OHCH_2CH_2N(C_2H_5)_2$ Allow displayed or skeletal formulae		**1**

Question Number	Acceptable Answers	Reject	Mark
14 (a)(v)	Reduction **(1)** Allow redox Tin / iron / zinc **and** (conc./dilute) hydrochloric acid **(1)** Accept correct names or formulae for both alternatives Ignore references to tin as a catalyst Ignore conditions Allow $NaBH_4$ in alkali (Pd catalyst)	Addition of NaOH unless clearly after the reduction Hydrogen gas and nickel (catalyst) $LiAlH_4$	**2**

Question Number	Acceptable Answers	Reject	Mark
14 (b)(i)	Moles of 2-hydroxy benzoic acid = 9.4/138 **(1)** (= 0.0681) So theoretical yield of aspirin = 0.0681 x 180 **(1)** = 12.26 g % yield = 100 x 7.77/12.26 = 63.4% **(1)** Or Moles of 2-hydroxy benzoic acid = 9.4/138 **(1)** (= 0.0681) Moles of aspirin = 7.77/180 **(1)** (=0.0432) % yield = 100 x 0.0432/0.0681 = 63.4/63% **(1)** Correct answer with no working 3 marks Allow 1 max. if *M*r values are transposed 108%	100 x 7.77/9.40 = 82.7%	**3**

Question Number	Acceptable Answers	Reject	Mark
14 *(b)(ii)	Dissolve/add to impure solid in min. volume / amount **(1)** of hot solvent / water **(1)** (Filter whilst hot) Allow to cool **and** filter off product / (re)crystallize **and** filter off product **(1)** Wash with cold / small amount of solvent / water (then dry) **(1)**	Just 'small/little amount of water' Named solvents other than water – penalise once	**4**

Question Number	Acceptable Answers	Reject	Mark
14 (b)(iii)	It reduces yield as some product remains in solution Allow stated and explained errors due to transfer e.g. left on filter paper	Just 'transfer errors'	**1**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(i)	CH_3COCl / $(CH_3CO)_2O$ / ethanoyl chloride / ethanoic anhydride If both name and formula are given then both must be correct Allow acetyl chloride / acetic anhydride Ignore any additional information Allow displayed formulae	Ethanoic acid	**1**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(ii)	(Lessen) risk of overdose / as paracetamol is toxic in larger doses/ as paracetamol is harmful in larger doses / reduce risk of taking medication over a longer time period than necessary / reduce risk of addiction		**1**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(iii)	Net forces between paracetamol and water are less than the forces between water and water and / or paracetamol and paracetamol Allow benzene / ring doesn't interact with water Allow benzene ring is hydrophobic / non polar / only forms London forces / can't form hydrogen bonds	Just paracetamol / benzene ring is large / steric hindrance	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (a)	Either Anode $H_2 - 2e^{(-)} \rightarrow 2H^+$ **(1)** Cathode $O_2 + 4H^+ + 4e^{(-)} \rightarrow 2H_2O$ **(1)** Or Anode $H_2 + 2OH^- - 2e^{(-)} \rightarrow 2H_2O$ **(1)** Cathode $O_2 + 2H_2O + 4e^{(-)} \rightarrow 4OH^-$ **(1)** Electrons can be on either side of the equation Allow multiples Allow equilibria signs Ignore state symbols		**2**

Question Number	Acceptable Answers	Reject	Mark
15 (b)	One advantage e.g. quieter, more efficient (energy transfer), no NO_x formed Ignore references to carbon dioxide and / or water as only product	Just easier to control	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (c)	Ethanol can be obtained from biomass / plants / fermentation / ethanol is a bio fuel **(1)** hydrogen from (electrolysis of) water using a non-fossil source of energy **(1)** these are renewable / fossil fuels are a finite resource **(1)** Allow for third mark so less burning/use of fossil fuels hence lower carbon emissions / less impact on greenhouse effect		**3**

Question Number	Acceptable Answers	Reject	Mark
16 (a)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 (4s^0)$ **(1)** Accept $[Ar]3d^5(4s^0)$ (Ion) has an incompletely filled (3)d-orbital / sub-shell / unpaired d electron **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
***16 (b)**	Gases adsorb onto / bind to catalyst (surface) **(1)** Allow gases are absorbed onto surface Then react **and** desorb / leave **(1)** Reaction could be faster because Any two • These processes lower the activation energy (by providing an alternative route so a greater proportion of molecules react) • Bonds in reactant(s) are weakened • Reactants may be positioned in more favourable orientations • Reactants can migrate towards each other on surface • Increases likelihood of molecules coming into contact / colliding • Adsorption onto surface means more reactant molecules in a given space	Just 'bonds in reactants are broken'	**4**

Question Number	Acceptable Answers	Reject	Mark
16 (c)	E_{cell} for reaction is (+) 0.84 (V) (so will work) / E_{cell} for item 44 is more positive than for item 19 / illustrate using anti-clockwise rule **(1)** $2Fe + O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4OH^-$ or $2Fe + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$ **(1)** E_{cell} for reaction is (+)0.96 (V) (so will work) / E_{cell} for item 44 is more positive than for item 17 / illustrate using anti-clockwise rule **(1)** $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$ **(1)**	Just 'because of the anti-clockwise rule'	**4**

Question Number	Acceptable Answers	Reject	Mark
16 (d)	Lone pair(s) (from nitrogen(s)) **(1)** Forms dative / dative covalent / coordinate bond (with Fe^{2+}) **(1)**		**2**

TOTAL FOR SECTION B = 48 MARKS

Section C

Question Number	Acceptable Answers	Reject	Mark
17 (a)(i)	$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ **(1)** $CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$ **(1)** Allow multiples Ignore state symbols		**2**

Question Number	Acceptable Answers	Reject	Mark
17 (a)(ii)	$3CH_3CH_2OH + 2\ Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$ Allow hydrogen ions and water molecules not cancelled e.g. $3CH_3CH_2OH + 2\ Cr_2O_7^{2-} + 28H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O + 12H^+$ $3CH_3CH_2OH + 2\ Cr_2O_7^{2-} + 16H^+ + 3H_2O \rightarrow 3CH_3COOH + 4Cr^{3+} + 14H_2O$ $3CH_3CH_2OH + 2\ Cr_2O_7^{2-} + 28H^+ + 3H_2O \rightarrow 3CH_3COOH + 4Cr^{3+} + 14H_2O + 12H^+$	Equations with electrons	**1**

Question Number	Acceptable Answers	Reject	Mark
***17 (a)(iii)**	Moles of thiosulfate = 34.40/1000 x 0.025 = 8.6 x 10^{-4} (mol) **(1)** So moles I_2 = 4.3 x 10^{-4} (mol) **(1)** So moles of dichromate unreacted = 4.3 x 10^{-4} / 3 = 1.433 x 10^{-4} (mol) **(1)** So moles of dichromate reacted with ethanol = 8 x 10^{-4} – 1.43 x 10^{-4} = 6.567 x 10^{-4} (mol) **(1)** So moles of ethanol = 6.567 x 10^{-4} x 3/2 mol = 9.85 x 10^{-4} (mol) **(1)** Concentration = 9.85 x 10^{-4} /0.005 = 0.197 (mol dm^{-3}) **(1)** Correct answer (0.197) with no working 6 marks Allow 4 max. for missing subtraction in step 4 and gaining answer of 0.043(0)		**6**

Question Number	Acceptable Answers	Reject	Mark
17 (a)(iv)	0.197 x 10 = 1.97 (mol dm^{-3}) Allow answer to (a) (iii) x 10		**1**

Question Number	Acceptable Answers	Reject	Mark
17 (a)(v)	To prevent other (non volatile) substances (in the drink) from reacting with the dichromate ions		**1**

Question Number	Acceptable Answers	Reject	Mark
17 (a)(vi)	because it allows the ethanol to evaporate (allowing it to mix with the dichromate) **(1)** make sure all ethanol reacts **(1)** Concentration / results would have been lower than the actual value **(1)**		**3**

Question Number	Acceptable Answers	Reject	Mark
17 (a)(vii)	No, as only one sample titrated so no evidence that results are repeatable / no, as not all the ethanol has evaporated/no, as the dichromate may have reacted with something else/ no, as not all the ethanol has reacted Allow only 1 titration carried out		**1**

Question Number	Acceptable Answers	Reject	Mark
***17 (b)(i)**	Early breathalysers: (the extent to which) dichromate turns **green (1)** Fuel cells: (more alcohol means larger) current / quantity of electricity **(1)** Infrared breathalysers: (more alcohol means greater) absorbance **(1)** Ignore reference to specific bonds provided they are present in ethanol	Just colour change Just 'potential difference measured' Just 'voltage measured' Just 'gives a peak'	**3**

Question Number	Acceptable Answers	Reject	Mark
17 (b)(ii)	Water (in the breath) also has an OH bond Allow other named molecules on the breath provided they have an OH bond		**1**

Question Number	Acceptable Answers	Reject	Mark
17 (b)(iii)	Additional evidence is more reliable Or Police often use IR as well as fuel cell breath test to provide sufficient evidence to prosecute (without need for blood test) Or Fuel cell breathalysers are portable and determine whether or not to check with IR at the police station	Answers only related to accuracy	**1**

Question Number	Acceptable Answers	Reject	Mark
17 (b)(iv)	Advantage It could check if you are below the legal limit / safe to drive **(1)** Disadvantage It may not be sensitive enough to give an accurate reading / may give a value that does not closely match police value OR It encourages people to drink and drive **(1)**		**2**

TOTAL FOR SECTION C = 22 MARKS

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Centre Number	Candidate Number

Chemistry

Advanced

Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Tuesday 19 June 2012 – Afternoon
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

P39309A

7/7/5/5/3/

P 3 9 3 0 9 A 0 1 2 0

PEARSON

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The acid used in a standard hydrogen electrode to provide a 1 mol dm^{-3} solution of hydrogen ions is

☒ **A** ethanoic acid.

☒ **B** phosphoric(V) acid.

☒ **C** sulfuric acid.

☒ **D** hydrochloric acid.

(Total for Question 1 = 1 mark)

2 To measure the standard electrode potential for the $Ag^+(aq)|Ag(s)$ electrode, the most suitable chemical for the solution in a salt bridge to connect the two half cells is

☒ **A** potassium chloride.

☒ **B** potassium iodide.

☒ **C** potassium nitrate.

☒ **D** potassium sulfate.

(Total for Question 2 = 1 mark)

3 For any reversible reaction, ln K is proportional to

☒ **A** both ΔS_{total} and E_{cell}.

☒ **B** ΔS_{total} but not E_{cell}.

☒ **C** E_{cell} but not ΔS_{total}.

☒ **D** neither E_{cell} nor ΔS_{total}.

(Total for Question 3 = 1 mark)

4 This question is about a titration to determine the iron content of a tablet. The iron(II) ions in the tablet are oxidized to iron(III) ions by acidified manganate(VII) ions which are reduced to manganese(II) ions.

(a) The mole ratio of iron(II) to manganate(VII) ions in the reaction is

(1)

	Fe^{2+}	MnO_4^-
☒ **A**	1	5
☒ **B**	2	5
☒ **C**	5	2
☒ **D**	5	1

(b) A 0.200 g tablet is dissolved to make exactly 100 cm^3 of solution. 10 cm^3 of this solution is found to contain 5.38×10^{-5} mol of iron(II) ions.

The percentage by mass of iron (A_r = 55.8) in the tablet is

(1)

☒ **A** $\dfrac{5.38\times10^{-5}\times55.8}{0.200}\times\dfrac{100}{10}\times100\%$

☒ **B** $\dfrac{5.38\times10^{-5}}{55.8\times0.200}\times\dfrac{100}{10}\times100\%$

☒ **C** $\dfrac{5.38\times10^{-5}\times55.8}{0.200}\times\dfrac{10}{100}\times100\%$

☒ **D** $\dfrac{5.38\times10^{-5}\times0.200}{55.8}\times\dfrac{10}{100}\times100\%$

(Total for Question 4 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

5 Some fuel cells are used to produce energy from the combination of hydrogen and oxygen. The half-equations for a hydrogen-oxygen fuel cell in alkaline solution are

$$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq) \qquad E^{\ominus} = -0.83\ V$$

$$\tfrac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightleftharpoons 2OH^-(aq) \qquad E^{\ominus} = +0.40\ V$$

(a) The equation for the cell reaction is

(1)

☒ **A** $3H_2O(l) + \tfrac{1}{2}O_2(g) \rightarrow H_2(g) + 4OH^-(aq)$

☒ **B** $H_2(g) + 4OH^-(aq) \rightarrow 3H_2O(l) + \tfrac{1}{2}O_2(g)$

☒ **C** $H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$

☒ **D** $H_2O(l) \rightarrow H_2(g) + \tfrac{1}{2}O_2(g)$

(b) From the data above, E_{cell} for the reaction in the hydrogen-oxygen fuel cell is

(1)

☒ **A** –0.43 V

☒ **B** +0.43 V

☒ **C** –1.23 V

☒ **D** +1.23 V

(c) An advantage of operating a hydrogen fuel cell over a conventional jet engine for powering an aeroplane is

(1)

☒ **A** it is 100% efficient.

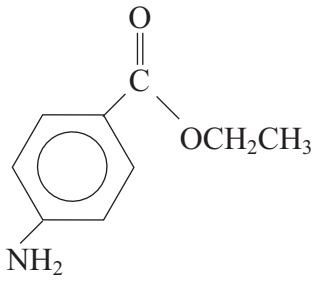
☒ **B** it does not produce greenhouse gas emissions.

☒ **C** it does not produce emissions which damage the ozone layer.

☒ **D** hydrogen is easier to transport.

(Total for Question 5 = 3 marks)

6 Benzocaine is used as a local anaesthetic.



Separate samples of a solution of benzocaine are added to 2,4-dinitrophenylhydrazine, hot aqueous sodium hydroxide, and dilute hydrochloric acid.

Which chemicals react with benzocaine?

☒ **A** All three

☒ **B** Only sodium hydroxide and hydrochloric acid

☒ **C** Only hydrochloric acid

☒ **D** Only sodium hydroxide

(Total for Question 6 = 1 mark)

7 In the first commonly used breathalyser, acidified potassium dichromate(VI) was used which was reduced to chromium(III) by alcohol.

The colour change seen when alcohol was present in a motorist's breath is from

☒ **A** orange to green.

☒ **B** orange to yellow.

☒ **C** yellow to green.

☒ **D** yellow to orange.

(Total for Question 7 = 1 mark)

8 For which of the following are both tests acceptable evidence for a driver to be successfully prosecuted for excess alcohol in the blood in many countries?

☒ **A** A dichromate(VI) breath analyser and a blood test.

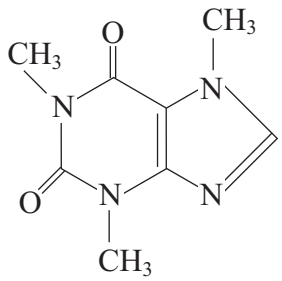
☒ **B** A dichromate(VI) breath analyser and a fuel cell breath analyser.

☒ **C** A dichromate(VI) breath analyser and an infrared breath analyser.

☒ **D** An infrared breath analyser and a blood test.

(Total for Question 8 = 1 mark)

9 The structural formula of caffeine, $C_8H_{10}O_2N_4$, is shown below.



(a) How many main peaks would you expect in the proton nuclear magnetic resonance spectrum of caffeine?

(1)

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(b) At which of the following wavenumbers is an absorption peak **not** present in the infrared spectrum of caffeine?

(1)

☒ **A** 3600 cm^{-1}

☒ **B** 2925 cm^{-1}

☒ **C** 1690 cm^{-1}

☒ **D** 1660 cm^{-1}

(c) The parent ion peak of caffeine in the mass spectrum of caffeine would be at m/e ratio

(1)

☒ **A** 101

☒ **B** 102

☒ **C** 193

☒ **D** 194

(d) Intermolecular forces between caffeine molecules would include

(1)

☒ **A** London forces only.

☒ **B** London forces and hydrogen bonds.

☒ **C** London forces and permanent dipole forces.

☒ **D** London forces, permanent dipole forces, and hydrogen bonds.

(Total for Question 9 = 4 marks)

10 (a) The principal advantage of combinatorial chemistry over traditional methods for developing pharmaceuticals is that

(1)

☒ **A** very small amounts of compounds are used.

☒ **B** many more compounds can be made in a given time.

☒ **C** compounds formed are more powerful drugs.

☒ **D** compounds formed have fewer side effects.

(b) A refinement of combinatorial chemistry involves initially attaching compounds firmly to polymer beads. The type of attachment is most likely to be by

(1)

☒ **A** metallic bonds.

☒ **B** covalent bonds.

☒ **C** London forces.

☒ **D** permanent dipole forces.

(Total for Question 10 = 2 marks)

11 Four reactions involving the transition elements copper and chromium are given below.

1 $Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$

2 $[Cu(H_2O)_4(OH)_2](s) + 4NH_3(aq) \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+}(aq) + 2OH^{-}(aq) + 2H_2O(l)$

3 $[Cr(H_2O)_3(OH)_3](s) + 3OH^{-}(aq) \rightarrow [Cr(OH)_6]^{3-}(aq) + 3H_2O(l)$

4 $[Cr(H_2O)_3(OH)_3](s) + 3H^{+}(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$

(a) Which reaction produces a dark blue solution?

(1)

☒ **A** **1**

☒ **B** **2**

☒ **C** **3**

☒ **D** **4**

(b) Which two reactions show the amphoteric behaviour of a metal hydroxide?

(1)

☒ **A** **1** and **2**

☒ **B** **2** and **3**

☒ **C** **2** and **4**

☒ **D** **3** and **4**

(c) Predict, without calculation, which reaction has the most negative value for ΔS_{system}.

(1)

☒ **A** **1**

☒ **B** **2**

☒ **C** **3**

☒ **D** **4**

(Total for Question 11 = 3 marks)

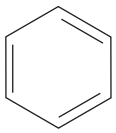
TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

12 This question is about benzene and its compounds.

(a) A Kekulé structure of benzene suggests the molecule consists of alternate double and single carbon to carbon bonds.



The standard enthalpy change of hydrogenation of a carbon to carbon double bond is -120 kJ mol^{-1}.

(i) Calculate the standard enthalpy change of hydrogenation of benzene for the Kekulé structure.

(1)

.....

*(ii) The actual standard enthalpy change of hydrogenation of benzene is -208 kJ mol^{-1}.

Use this information and your answer to (i), to calculate the difference in stability of benzene and the Kekulé structure.

What does this tell us about the bonding in benzene?

Explain how this influences the type of chemical reactions that benzene undergoes.

(4)

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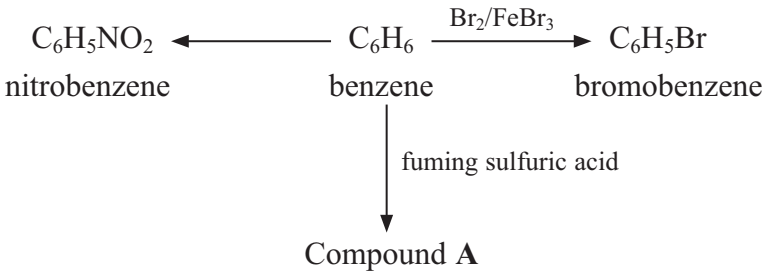
(b) The flow chart shows some typical reactions of benzene.



(i) Identify the two chemicals needed to make nitrobenzene from benzene.

(2)

.....

.....

(ii) Classify the type of reagent required in all three reactions.

(1)

.....

(iii) Show, with appropriate diagrams, the mechanism for the reaction of benzene with bromine, in the presence of iron(III) bromide, to form bromobenzene. Include the formation of the ion attacking the benzene molecule.

(4)

(iv) Give the structural formula and the name for compound **A**.

(2)

Name .....

(c) (i) Explain why phenol, C_6H_5OH, and methoxybenzene, $C_6H_5OCH_3$, are much more reactive than benzene with bromine.

(3)

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.....

(ii) Write the equation for the reaction between phenol and bromine water. State symbols are **not** required.

(2)

(d) Diphenylmethane, $(C_6H_5)_2CH_2$, is often added to soap to create the pleasant smell of geraniums. It can be made from benzene and one other reagent, using a suitable catalyst.

Identify the other starting material and the catalyst by name or formula.

(2)

.....

.....

(Total for Question 12 = 21 marks)

13 This question is about 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$.

(a) Write an equation for the reaction between 1,2-diaminoethane and **excess** dilute hydrochloric acid.

(2)

(b) When an aqueous solution of nickel(II) ions is added to 1,2-diaminoethane, a complex ion forms.

$$3H_2NCH_2CH_2NH_2 + Ni(H_2O)_6^{2+} \rightarrow Ni(H_2NCH_2CH_2NH_2)_3^{2+} + 6H_2O$$

(i) Suggest the colour of this complex.

(1)

.....

(ii) Without using the data booklet, suggest why the complex formed is more stable than $Ni(H_2O)_6^{2+}$ by considering the appropriate entropy change.

(2)

.....

.....

.....

.....

(iii) This complex can exist as two structures, which are non-superimposable mirror images.

Suggest the physical property that would enable you to distinguish between these two structures.

(1)

.....

.....

(c) 1,2-diaminoethane reacts with butane-1,2-dioyl dichloride, $ClOCCH_2CH_2COCl$, to form a polymer.

(i) Draw a displayed formula for this polymer showing one repeat unit.

(2)

(ii) Give, and explain, the name for this type of polymerization reaction.

(2)

*(iii) State and explain the intermolecular forces between two of these polymer chains.

(5)

(Total for Question 13 = 15 marks)

14 An organic compound **X** contains carbon, hydrogen, oxygen and nitrogen.

0.132 g of **X** is burned completely in oxygen to produce 0.072 g of water, 0.176 g of carbon dioxide and 24.0 cm^3 of nitrogen.

[Molar volume of nitrogen under the conditions of the experiment = 24 000 $cm^3\ mol^{-1}$]

(a) Calculate the empirical formula of compound **X**.

(5)

(b) The molar mass of **X** is 132 g mol^{-1}. Deduce the molecular formula for **X**. Show how you arrived at your answer.

(1)

(c) When **X** is refluxed with concentrated hydrochloric acid for several hours, cooled and neutralized, there is only one organic product, **Y**, which has the molecular formula $C_2H_5O_2N$.

One mole of **Y** will react with either one mole of hydrochloric acid or one mole of sodium hydroxide solution.

When **Y** is sprayed with a solution of ninhydrin and heated, a purple colour is observed.

(i) Use **all** the information above to deduce the functional groups present in **Y** and to classify the type of compound it is. Justify your answer.

(3)

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.....

(ii) Deduce the displayed formula for **Y** and give its name.

(2)

Name of **Y**.....

(iii) Hence give the structural formula for **X**.

(1)

(Total for Question 14 = 12 marks)

TOTAL FOR SECTION B = 48 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

15

Some unusual oxidation states

You will probably have seen manganese in its common oxidation states during your study of chemistry. Manganese(II) sulfate occurs as very pale pink crystals in the hydrated form. Manganese(IV) oxide is a black powder which is often used as a catalyst. Potassium manganate(VII) occurs as very dark purple crystals and forms a purple aqueous solution, which is a powerful oxidizing agent.

You are less likely to have seen compounds containing the other oxidation states of manganese, which are manganese(VI), manganese(V), manganese(III) and manganese(I). However, compounds containing each of these four oxidation states can be prepared.

Manganese(VI)

Manganese(VI), in MnO_4^{2-}, can be prepared in a reverse disproportionation reaction, by reacting manganate(VII) ions with manganese(IV) oxide in alkali.

Equation 1

$$2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq) \rightarrow 3MnO_4^{2-}(aq) + 2H_2O(l) \quad E^{\ominus}_{cell} = -0.03V$$

The reaction is not thermodynamically favourable under standard conditions. However, the E_{cell} value can be made positive by increasing the concentration of hydroxide ions so that green manganate(VI) ions form.

Manganese(V)

Manganese(V) can be formed by adding a little potassium manganate(VII) to very concentrated (12 mol dm^{-3}) aqueous sodium hydroxide. The solution slowly becomes blue as manganate(V) ions, $MnO_3^-(aq)$, form. The ionic half-equations are:

Equation 2

$$MnO_4^-(aq) + H_2O(l) + 2e^- \rightarrow MnO_3^-(aq) + 2OH^-(aq)$$

Equation 3

$$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$$

Manganese(III)

A deep red solution containing manganese(III) ions is formed by the oxidation of manganese(II) hydroxide by potassium manganate(VII) in acid solution. The ionic equation for the reaction is:

Equation 4

$$MnO_4^-(aq) + 4Mn(OH)_2(s) + 16H^+(aq) \rightarrow 5Mn^{3+}(aq) + 12H_2O(l)$$

Manganese(I)

Manganese(I) ions are not stable in aqueous solution, but do form stable complex ions. They can be made by reducing hexacyanomanganate(II) ions, $Mn(CN)_6^{4-}$, to hexacyanomanganate(I) ions, $Mn(CN)_6^{5-}$.

(a) (i) Give the formula of manganese(IV) oxide.

(1)

(ii) How do catalysts speed up reactions?

(2)

(iii) Explain how transition metal ions can act as homogeneous catalysts.

(2)

(b) (i) Suggest why the preparation of manganate(VI) ions, MnO_4^{2-}, in **equation 1**, may be described as a reverse disproportionation reaction by considering the relevant oxidation states.

(2)

(ii) The two half-equations which are combined to form **equation 1** are

$$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq) \qquad E^{\ominus} = +0.56\ V$$

$$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq) \qquad E^{\ominus} = +0.59\ V$$

Explain, by reference to these half-equations, why increasing the concentration of hydroxide ions alters the electrode potential to make the preparation of manganate(VI) ions more likely.

(3)

.....

.....

.....

.....

(c) Use equations **2** and **3** to answer the following questions.

(i) Identify the gas formed in the preparation of manganate(V) ions.

(1)

.....

(ii) By appropriately combining these two equations, write the ionic equation for the formation of manganate(V) ions from manganate(VII) ions.

(2)

(iii) Identify the main hazard and state how you would minimize the associated risk in this preparation of manganate(V) ions.

(2)

.....

.....

.....

.....

(d) Identify the reagents you would use to make manganese(II) hydroxide for the preparation of manganese(III) ions.

(2)

.....

.....

(e) (i) Draw a dot and cross diagram to show the electron arrangement in the cyanide ion, CN^-.

(2)

(ii) Explain how the cyanide ion acts as a ligand.

(2)

.....

.....

.....

.....

(iii) Suggest the name of the shape of the hexacyanomanganate(I) ion.

(1)

.....

(Total for Question 15 = 22 marks)

TOTAL FOR SECTION C = 22 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)											(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

* Actinide 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
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

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Mark Scheme (Results)

Summer 2012

GCE Chemistry (6CH05) Paper 01

General Principles of Chemistry II Transition Metals and Organic Chemistry (Including synoptic assessment)

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Summer 2012
Publications Code UA031866

General Marking Guidance

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

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.

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	D		**1**
2	C		**1**
3	A		**1**
4(a)	D		**1**
4(b)	A		**1**
5(a)	C		**1**
5(b)	D		**1**
5(c)	C		**1**
6	B		**1**
7	A		**1**
8	D		**1**
9(a)	D		**1**
9(b)	A		**1**
9(c)	D		**1**
9(d)	C		**1**
10(a)	B		**1**
10(b)	B		**1**
11(a)	B		**1**
11(b)	D		**1**
11(c)	A		**1**
		Total for section A	**20 marks**

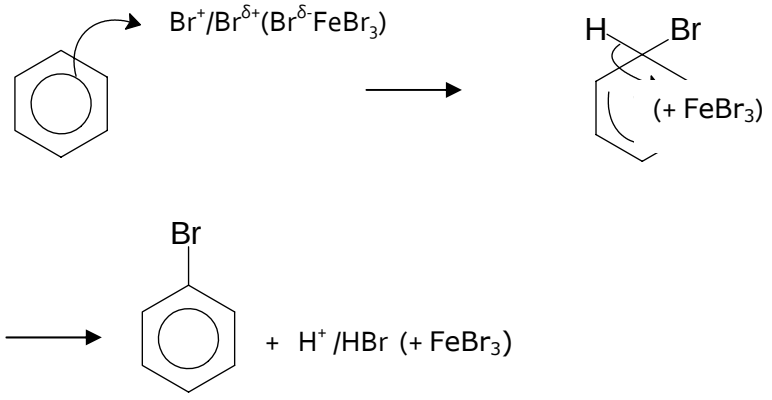
Section B

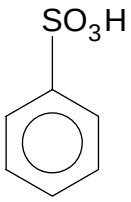
Question Number	Acceptable Answers	Reject	Mark
12(a)(i)	(3 x -120) = -360 (kJ mol^{-1}) IGNORE ∆H, and case of letters in units e.g allow Kj	No sign or + sign in answer, ie 360/+360 Any other wrong units ∆E	**1**

Question Number	Acceptable Answers	Reject	Mark
***12(a)(ii)**	• (Bonding in) benzene/it is more **stable** (than Kekule) by **152** kJ mol^{-1} (consequential on (a)(i)) **(1)** IGNORE sign • **π /p/double bond electrons** are delocalized (around the ring) OR six **p electrons** shared between six (ring) carbon atoms OR delocalized because of overlap of **p orbitals** OR resonance hybrid of C=C's and C-C's **(1)** • **Substitution** reactions (rather than addition) **(1)** NOTE: **Nucleophilic** substitution negates the substitution mark because it is wrong additional information • Maintains/regains delocalized system OR maintains/regains stability OR maintains/regains stabilization energy **(1)**	Attack by electrophiles with no mention of substitution	**4**

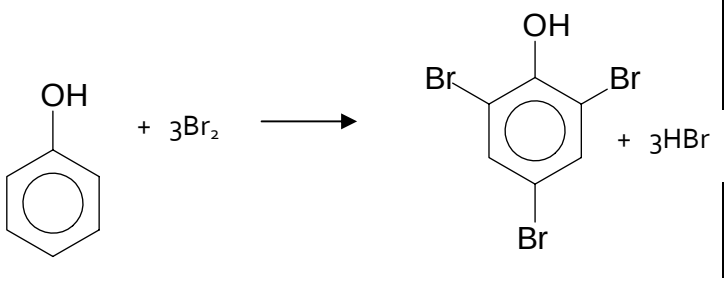
Question Number	Acceptable Answers	Reject	Mark
12(b)(i)	Concentrated nitric acid/HNO_3 **(1)** Concentrated sulfuric acid/H_2SO_4 **(1)** Allow conc or c. in place of 'concentrated' ALLOW Concentrated nitric acid and sulfuric acid OR Concentrated HNO_3 and H_2SO_4 **(2)** Second mark depends on nitric acid Max. (1) if no mention of concentrated Nitric acid and concentrated sulfuric acid scores (1) NOTE: conc. HNO_3 and H_2SO_4(aq) scores (1) but conc. HNO_3 and conc H_2SO_4(aq) scores (2)	Concentrated hydrochloric acid	**2**

Question Number	Acceptable Answers	Reject	Mark
12(b)(ii)	Electrophile/electrophilic ALLOW Electrophyl(e)	Acid Base Oxidizing agent Reducing agent	**1**

Question Number	Acceptable Answers	Reject	Mark
12(b)(iii)	$Br_2 + FeBr_3 \rightarrow FeBr_4^- + Br^+$ OR $Br\text{-}Br + FeBr_3 \rightarrow Br^{\delta+}\ldots..Br^{\delta-}FeBr_3$ **(1)** IGNORE state symbols even if wrong  Arrow from benzene ring electrons (from **inside** the hexagon) to $\mathbf{Br^+/Br^{\delta+}}(\ldots..Br^{\delta-}FeBr_3)$ **(1)** Correctly drawn intermediate with delocalization covering at least three carbon atoms, but not the carbon atom bonded to the bromine with the positive charge shown inside the hexagon The bonds to H and Br may be dotted **(1)** Arrow from or close to **bond** to H to centre of ring **and** H^+/HBr as a product **(1)** ALLOW Kekulé structure for benzene and intermediate **Each marking point is independent**	lack of charges	**4**

Question Number	Acceptable Answers	Reject	Mark
12(b)(iv)	 OR $C_6H_5SO_3H$ accept: displayed $-SO_3H$ $-SO_3^-H^+$ $-SO_2OH$ If two formulae are given both must be correct **(1)** Penalise if bond **clearly** goes to O or H rather than S **Benzenesulfonic acid** **(1)** ALLOW **phenyl sulfonic acid**	Benzenesulfuric acid/benzosulfonic acid/benzylsufonic acid	**2**

Question Number	Acceptable Answers	Reject	Mark
12(c)(i)	**Non-bonding/lone pair** electron**s** from **oxygen**... **(1)** ...are delocalized/incorporated/donated into the ring (electron system) (Could be shown in diagram) OR increases electron density on the ring **(1)** makes it (the ring) more susceptible to electrophilic attack/makes it (the ring) a better nucleophile **(1)**	…from methyl/methoxy Makes it more electronegative	**3**

Question Number	Acceptable Answers	Reject	Mark
12(c)(ii)	 **(1)** organic formula **(1)** balancing ALLOW • Condensed structural formulae, for example $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$ **(1)** **(1)** balancing • multiples • substitution to any positions IGNORE: H_2O Position of bond to OH NOTE: Correct balanced equations giving mono and disubstitution phenols score **1 mark**		**2**

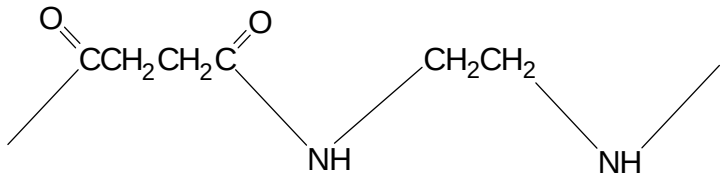
Question Number	Acceptable Answers	Reject	Mark
12(d)	(Chloromethyl)benzene/chloromethylbenzene/ chlorophenylmethane/ benzyl chloride OR dichloromethane **(1)** ALLOW phenylchloromethane Aluminium chloride **(1)** ACCEPT formulae eg C_7H_7Cl, $C_6H_5CH_2Cl$, CH_2Cl_2, $AlCl_3$ ACCEPT other halogen carriers eg $FeCl_3$/iron**(III)** chloride/$ZnCl_2$ ACCEPT bromine in place of chlorine for either/both marks Correct formula and wrong name or correct name and wrong formula or any other wrong additional information loses mark	CH_2Cl	**2**

Question Number	Acceptable Answers	Reject	Mark
13(a)	$H_2NCH_2CH_2NH_2 + 2HCl \rightarrow H_3N^+CH_2CH_2NH_3^+ + 2Cl^-$ **(1)** organic product Positive charges can be on nitrogens Balancing with **HCl** and **Cl^-** **(1)** Chloride ions can be at ends of product ie $ClH_3NCH_2CH_2NH_3Cl$ for right hand side, with or without charges, but if given charges must balance $H_2NCH_2CH_2NH_2 + 2H^+ \rightarrow H_3N^+CH_2CH_2NH_3^+$ **(2)** Reaction with 1 mol HCl for 1 max If molecular formulae used 1 max IGNORE state symbols even if wrong	Covalent bond to Cl, (-Cl)	**2**

Question Number	Acceptable Answers	Reject	Mark
13 (b)(i)	Blue or green or blue-green or lavender ALLOW qualification of blue or green e.g. dark blue, but not with another colour e.g. blue purple	Any other colour e.g. Purple Violet	**1**

Question Number	Acceptable Answers	Reject	Mark
13(b)(ii)	The entropy change of the **system** is positive **(1)** Because there is an increase in the number of particles/entities/moles/molecules OR The number of particles/entities/moles goes from four to seven OR Complex with three molecules goes to a complex with six molecules **(1)** Second mark depends on a positive entropy change	Additional incorrect numbers molecules/ atoms from four to seven	**2**

Question Number	Acceptable Answers	Reject	Mark
13(b)(iii)	They will **rotate** the **plane of plane-** polarised light (equally in opposite directions) Allow They will **rotate** the **plane** of polarised light (equally in opposite directions) OR They will **rotate plane-** polarised light (equally in opposite directions)	Optically active Reflect/ bend/ refract	**1**

Question Number	Acceptable Answers	Reject	Mark
13(c)(i)	 Amide linkage correct **(1)** Further detail correct, including trailing bonds **(1)** IGNORE brackets ALLOW multiple units Second mark dependent on correct amide link ALLOW fully correct structural formulae for 1 ~~(~~$OCCH_2CH_2CONHCH_2CH_2NH$~~)~~ Can start with NH group		**2**

Question Number	Acceptable Answers	Reject	Mark
13(c)(ii)	Condensation **(1)** Hydrogen chloride/HCl/water/H_2O or another **small** molecule/is produced/lost/formed/removed (as well as the polymer) **(1)** Mark independently	Addition/elimination	**2**

Question Number	Acceptable Answers	Reject	Mark
***13(c)(iii)**	**Types of force** Hydrogen bonds **and** (permanent) dipole(-permanent dipole) forces **and** London/van der Waals'/dispersion forces OR Explanation e.g temporary/induced dipoles **(1)** All three needed for 1st mark (which is given even if the forces are later explained incorrectly) **Hydrogen bonds** (Between) the hydrogen atoms on the nitrogen atoms and ... OR (Between) N-H and ... **(1)** ... (the lone pair of electrons on) oxygen/ nitrogen atoms **(1)** These marks can be shown by a diagram **Permanent dipole-permanent dipole forces** Because the C=O / carbon-oxygen bond/the C-N bond is polar/a dipole OR N and/or O are electronegative atoms This mark can be shown by a diagram providing the polarity of the bond is shown **(1)** **London forces** Polymer has large number of/many electrons OR Explanation e.g temporary/induced/fluctuating dipoles **(1)**	Just p.d.- p.d Just v d W Large molecular mass alone	**5**

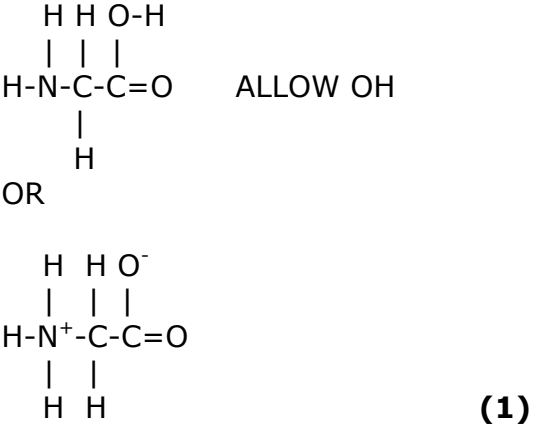
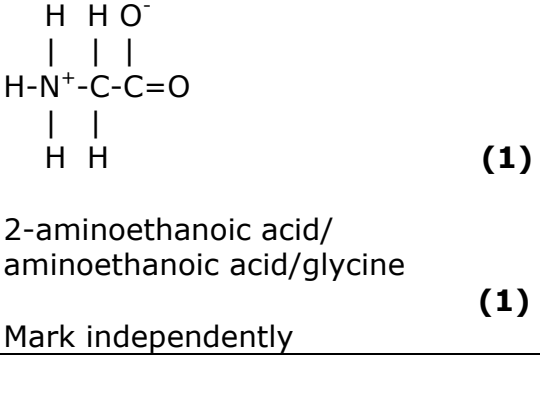
Question Number	Acceptable Answers	Reject	Mark
14(a)	**Route 1 by mol of H, C and N** $\frac{0.072}{18}$ = 0.004 mol water OR 0.008 mol H(atoms) **And** $\frac{0.176}{44}$ = 0.004 mol carbon (dioxide) **(1)** $\frac{24.0}{24000}$ = 0.001 mol nitrogen N_2 OR 0.002 mol N(atoms) **(1)** Mass of H + mass of C + mass of N = 0.008 + 0.004 x 12 + 0.028 **(1)** = 0.084 g mass of oxygen = 0.132 – (0.008 + 0.004 x 12 + 0.028) = 0.048 g amount of oxygen = $\frac{0.048}{16}$ = 0.003 mol **(1)** empirical formula is $C_4H_8O_3N_2$ **(1)** **Route 2 by mass of H, C and O calculated in one step** mass of H = 2/18 x 0.072 = 0.008 g **(1)** mass of C = 12/44 x 0.176 = 0.048 g **(1)** mass of N = 24/24000 x 28 = 0.028 g **(1)** mass of O = 0.132 – (0.008 + 0.048 + 0.028) = 0.048 g moles of O = 0.003 **(1)** moles of H = 0.008		**5**

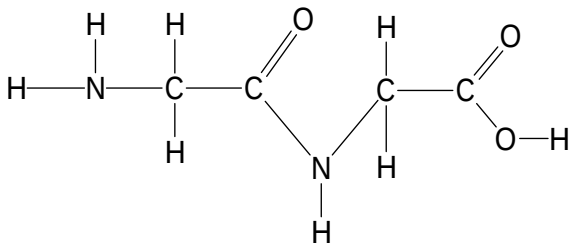
	moles of C = 0.004 moles of N = 0.002 empirical formula is $C_4H_8O_3N_2$ **(1)** **Route 3 Percentage by mass of each element in 0.132 g** First three marks by either method above. Then percentages are: H – 6.06 C – 36.36 N – 21.21 So O is 100 – (6.06 + 36.36 + 21.21) = 100 – 63.63 = 36.37 Mole ratios O – 2.27 – allow = or – 0.02 **(1)** H – 6.06, C – 3.03, N – 1.515 Dividing by smallest gives H – 4, C – 2, N – 1, O – 1.5 empirical formula is $C_4H_8O_3N_2$ **(1)** **The following transferred errors are allowed:** If nitrogen gas taken as N, first two marks can still be awarded for all methods Then mass of nitrogen is 0.014 g This gives mass of oxygen as 0.062 g and amount of oxygen as 0.003875 mol **(1)** now empirical formula is $C_4H_8O_4N$ **(1)** **OR** percentage method: N – 10.61% O – 46.97%		

	Mole ratio N – 0.7575 O – 2.935 **(1)** empirical formula is $C_4H_8O_4N$ **(1)** **Transferred error for hydrogen** Two from first three marks still awarded Then amount of hydrogen is 0.004 mol This gives 0.003125 mol oxygen empirical formula is $C_4H_4O_3N_2$ **(1)** **Both the above nitrogen and hydrogen errors** Award 1 mark for correct mass of carbon or correct moles of carbon Then mass of nitrogen is 0.014 g Then mass of hydrogen is 0.004 g This gives 0.004125 mol oxygen **(1)** Empirical formula is $C_4H_4O_4N$ **(1)**		

Question Number	Acceptable Answers	Reject	Mark
14(b)	**(12 x 4 + 1 x 8 + 16 x 3 + 14 x 2)**n = 132 n = 1 So molecular formula is $C_4H_8O_3N_2$ Some element of working must be shown TE from (a) of nitrogen error can be given **only if**: **(12 x 4 + 1 x 8 + 16 x 4 + 14)**n = 132 n = 0.98 (which is approximately 1) TE from (a) of hydrogen error can be given **only if**: **(12 x 4 + 1 x 4 + 16 x 3 + 14 x 2)**n = 132 n = 1.03 (which is approximately 1) TE from (a) of nitrogen and hydrogen error can be given **only if**: **(12 x 4 + 1 x 4 + 16 x 4 + 14)**n = 132 n = 1.015/1.02 (which is approximately 1)		**1**

Question Number	Acceptable Answers	Reject	Mark
14(c)(i)	**Y** reacts with HCl/acid so it is an amine /contains NH_2 /CO_2^- **(1)** It reacts with alkali/NaOH so it is a carboxylic acid/contains CO_2H/NH_3^+ **(1)** It forms a purple colour/reacts with ninhydrin so it is an amino acid **(1)** OR As it is an amine/contains NH_2 /CO_2^- it will react with HCl/acid **(1)** As it is a carboxylic acid/contains CO_2H/NH_3^+ it will react with alkali/NaOH **(1)** As it is an amino acid so it forms a purple colour/reacts with ninhydrin **(1)** Each marking point is independent and requires both the functional group and the test **NOTE:** It is an amino acid so it reacts with acid and alkali (with neither of first two points) **(1)**	Just ... it is a base Just ... it is an acid ...it is amphoteric (alone)	**3**

Question Number	Acceptable Answers	Reject	Mark
14(c)(ii)	 ALLOW OH OR  **(1)** 2-aminoethanoic acid/ aminoethanoic acid/glycine **(1)** Mark independently	C-H-O if bond is clearly to H **1**- aminoethanoic acid	**2**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(iii)	$H_2NCH_2CONHCH_2CO_2H$ Or $NH_2CH_2CONHCH_2CO_2H$ Or $HOCOCH_2NHOCCH_2NH_2$ ALLOW  Or reversed displayed formula ALLOW ionic formulae with H_3N^+ and CO_2^-		**1**

TOTAL FOR SECTION B = 48 MARKS

Question Number	Acceptable Answers	Reject	Mark
15(a)(i)	MnO_2((s))	Anything else eg MnO_4^-	**1**

Question Number	Acceptable Answers	Reject	Mark
15(a)(ii)	• They provide alternative routes/mechanisms for reactions • With lower activation energies/E_a OR catalysts lower activation energy /E_a • So a greater proportion of /more particles/reactants have sufficient energy/E_a (to react)/greater frequency of/more successful collisions All three points **2** any two points **1** All points stand alone and can be in any order IGNORE references to adsorption/surfaces Provide alternate route with lower activation energy scores one mark NOTE: The term activation energy could be described rather than stated		**2**

Question Number	Acceptable Answers	Reject	Mark
15(a)(iii)	Transition metals form various/variable oxidation states **(1)** They are able to **donate and receive** electrons/they are able to **oxidize and reduce**/they are able to be **oxidized and reduced** /ions contain **partially filled** (sub-)shells of **d electrons** **(1)** ALLOW Energy differences between the oxidation states are small (for second mark) OR Reduce reactant with more positive/higher electrode potential **(1)** Then oxidize reactant with more negative/lower electrode potential **(1)** Or other way round: Oxidize reactant with lower electrode potential etc	They change oxidation state Any mention of providing a surface/adsorption loses second mark Formation of intermediates (alone)	**2**

Question Number	Acceptable Answers	Reject	Mark
15(b)(i)	Two (less stable) oxidation states/one higher and one lower oxidation state of **the same/an element** react to form one(more stable) oxidation state ALLOW The reverse reaction is a disproportionation in which (one oxidation state of) the **same/an element** and it EITHER: reacts to give one higher and one lower oxidation state/two oxidation states OR is both oxidized and reduced **(1)** Correct oxidation states +7 and +4 to +6 Mn(VII) and Mn(IV) to Mn(VI) ALLOW Mn^{7+} and Mn^{4+} to Mn^{6+} **(1)** Mark independently		**2**

Question Number	Acceptable Answers	Reject	Mark
15(b)(ii)	(When the hydroxide ion concentration is increased) the equilibrium (of the second half equation) moves to the left/back **(1)** *E* becomes less positive/more negative/decreases/reduces **(1)** Therefore E_{cell} becomes positive (so reaction feasible) **(1)** ALLOW confusion between E, $E^{\ominus}$, E_{cell} if meaning is clear		**3**

Question Number	Acceptable Answers	Reject	Mark
15(c)(i)	Oxygen/oxygen gas/O_2/O_2(g)	O (alone) Anything else	**1**

Question Number	Acceptable Answers	Reject	Mark
15(c)(ii)	$2MnO_4^-(aq) \rightarrow 2MnO_3^-(aq) + O_2(g)$ Entities **(1)** balancing **(1)** Correct equation with H_2O and/or OH^- on both sides (even if in brackets) max. 1 IGNORE state symbols ACCEPT multiples ACCEPT $\rightleftharpoons$ for arrow Reverse equation max. 1 No signs on entities max. 1	Equations including electrons	**2**

Question Number	Acceptable Answers	Reject	Mark
15(c)(iii)	**(Hazard –)** the sodium hydroxide/alkali is corrosive/caustic/burns (skin)/attacks the skin OR attacks the cornea/eye/causes blindness **(1)** IGNORE Harmful/Irritant/toxic/hazardous/concentrated **(Minimize Risk by –)** wear gloves OR (full) eye protection/goggles/safety glasses **(1)** Protection **must** relate to **sodium hydroxide** e.g. sodium hydroxide is irritant so wear gloves / eye protection **scores 1 mark** This means 'This experiment is dangerous so wear eye protection' **score zero** IGNORE lab coats and/or fume cupboards (Oxygen) gas given off so container must not be sealed **(2)**	MnO_4^- is toxic Cl_2 is toxic	**2**

Question Number	Acceptable Answers	Reject	Mark
15(d)	Manganese**(II)**/manganous sulfate (solution) **(1)** ALLOW any named soluble manganese**(II)** salt – chloride, bromide, iodide, nitrate Sodium hydroxide (solution) **(1)** ALLOW any named soluble hydroxide ACCEPT formulae Mark independently except contradiction eg NaOH + HCl (0)	Mn^{2+}(aq) alone Ammonia unless dilute **and** added dropwise	**2**

Question Number	Acceptable Answers	Reject	Mark
15(e)(i)	 Accept dots, crosses, mixture of both Triple bond **(1)** Non-bonding electrons **(1)** IGNORE presence/absence of negative charge But if positive charge max 1 Second mark dependent on first IGNORE correct inner shell electrons on either or both atoms	 If not paired Incorrect inner shell electrons 1 max	**2**

Question Number	Acceptable Answers	Reject	Mark
15(e)(ii)	The non-bonding / lone pair of electrons on the carbon **(1)** ALLOW non-bonding/lone pair of electrons on the nitrogen Forms a **dative covalent/coordinate** bond (to central metal ion) **(1)** Mark independently		**2**

Question Number	Acceptable Answers	Reject	Mark
15(e)(iii)	Octahedral/octahedron ALLOW Oct**o**hedral Oct**e**hedral	Tetrahedral/hexagonal/square planar/(trigonal) bipyramid	**1**

TOTAL FOR SECTION C = 22 MARKS

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Chemistry

Advanced

Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Wednesday 19 June 2013 – Morning
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

P41651A

10/5/5/7/

P 4 1 6 5 1 A 0 1 3 2

PEARSON

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The following data are provided.

	$E^{\ominus}$ / V
$ClO^-(aq) + H_2O(l) + e^- \rightleftharpoons \frac{1}{2}Cl_2(aq) + 2OH^-(aq)$	+0.40
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

What is the value of $E^{\ominus}_{cell}$ in which the following disproportionation reaction occurs?

$$Cl_2(aq) + 2OH^-(aq) \rightarrow ClO^-(aq) + Cl^-(aq) + H_2O(l)$$

☒ **A** $+\frac{1.36}{2} - 0.40$ V

☒ **B** $+\frac{1.36}{2} + 0.40$ V

☒ **C** $+ 1.36 - 0.40$ V

☒ **D** $+ 1.36 + 0.40$ V

(Total for Question 1 = 1 mark)

2 Which of the following is always proportional to $E^{\ominus}_{cell}$ for a chemical reaction?

☒ **A** $\Delta H_{reaction}$

☒ **B** ΔS_{system}

☒ **C** $\Delta S_{surroundings}$

☒ **D** ΔS_{total}

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

3 The electrode system based on the half-equation below has the standard electrode potential +1.51 V.

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$ $\quad E^{\ominus} = +1.51$ V

Which of the following statements about this electrode system is correct?

☒ **A** Changing the concentration of $Mn^{2+}(aq)$ would cause a change in the electrode potential.

☒ **B** $Mn^{2+}(aq)$ is acting as an oxidizing agent.

☒ **C** The electrode used is made of manganese.

☒ **D** When connected to a standard hydrogen electrode, the resulting cell voltage would be +0.51 V.

(Total for Question 3 = 1 mark)

4 Consider the following reaction.

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

Which of the following ions could catalyse this reaction?

☒ **A** Zn^{2+}

☒ **B** Al^{3+}

☒ **C** Fe^{2+}

☒ **D** Na^+

(Total for Question 4 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

5 EDTA ions form a complex with aqueous nickel(II) ions as shown by the equation

$$[Ni(H_2O)_6]^{2+}(aq) + (EDTA)^{4-}(aq) \rightleftharpoons Ni(EDTA)^{2-}(aq) + 6H_2O(l)$$

Aqueous nickel(II) ions also form a complex ion with ammonia as shown by the equation

$$[Ni(H_2O)_6]^{2+}(aq) + 6NH_3(aq) \rightleftharpoons [Ni(NH_3)_6]^{2+}(aq) + 6H_2O(l)$$

Aqueous nickel(II) ions form a more stable complex with EDTA ions than with ammonia because

☒ **A** six ammonia ligands cause steric hindrance around the central nickel(II) ion.

☒ **B** EDTA ions carry a negative charge whereas ammonia molecules do not.

☒ **C** there is a large increase in entropy when aqueous nickel(II) ions react with EDTA ions, but not when aqueous nickel(II) ions react with ammonia.

☒ **D** ammonia molecules tend to evaporate from the solution of the complex whereas EDTA ions do not.

(Total for Question 5 = 1 mark)

6 The hydrolysis of a transition metal cation can be represented by the following equation

$$[M(H_2O)_6]^{n+}(aq) + H_2O(l) \rightleftharpoons [M(H_2O)_5OH]^{(n-1)+}(aq) + H_3O^+(aq)$$

In this reaction

☒ **A** the solvent H_2O is acting as an acid by donating a proton to the metal cation.

☒ **B** the pH of the solution will be lower if the value of n is 2 instead of 3.

☒ **C** the equilibrium position lies further to the right if the value of n is 3 instead of 2.

☒ **D** the oxidation state of the metal in the cation has decreased from n to (n – 1).

(Total for Question 6 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

7 In aqueous solution, manganate(VI) ions disproportionate into manganate(VII) ions and manganese(IV) oxide when carbon dioxide is bubbled through the solution. The ionic equation for the reaction is

$$3MnO_4^{2-}(aq) + 4H^+(aq) \rightarrow 2MnO_4^-(aq) + MnO_2(s) + 2H_2O(l)$$

The role of the carbon dioxide is to

☒ **A** lower the pH of the solution.

☒ **B** raise the pH of the solution.

☒ **C** oxidize the manganate(VI) ions.

☒ **D** reduce the manganate(VI) ions.

(Total for Question 7 = 1 mark)

---

8 Which of the following shows the correct oxidation states of **chromium** in the ions given?

	$[Cr(OH)_6]^{3-}$	CrO_4^{2-}	$[Cr(H_2O)_6]^{2+}$
☒ **A**	−3	−2	+2
☒ **B**	−3	+10	+2
☒ **C**	+3	+8	+6
☒ **D**	+3	+6	+2

(Total for Question 8 = 1 mark)

---

9 Transition metals are often used as heterogeneous catalysts. Which of the following processes does **not** occur during such a catalysed reaction?

☒ **A** Adsorption of reactant molecules on the surface of the metal.

☒ **B** Bond breaking in the reactant molecules.

☒ **C** Desorption of product molecules from the surface of the metal.

☒ **D** An overall change in the oxidation number of the metal.

(Total for Question 9 = 1 mark)

---

10 Consider the equation below.

$$[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 6H_2O(l)$$

This reaction is best described as

☒ **A** acid-base.

☒ **B** redox.

☒ **C** addition.

☒ **D** ligand exchange.

(Total for Question 10 = 1 mark)

11 Which of the following will **not** reduce an acidified solution of potassium dichromate(VI)?

☒ **A** $(CH_3)_2C(OH)CH_3$

☒ **B** $FeSO_4$

☒ **C** $CH_3CH_2CH(OH)CH_3$

☒ **D** Zn

(Total for Question 11 = 1 mark)

12 The total number of isomers of dibromobenzene, $C_6H_4Br_2$, containing a benzene ring is

☒ **A** 2

☒ **B** 3

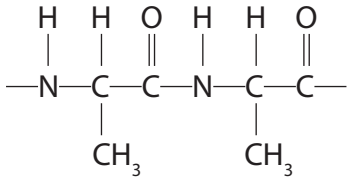
☒ **C** 4

☒ **D** 5

(Total for Question 12 = 1 mark)

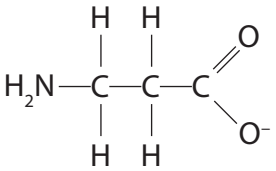
Use this space for any rough working. Anything you write in this space will gain no credit.

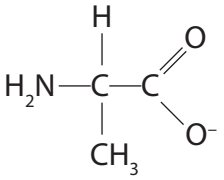
13 A section of the polypeptide made from a single amino acid is shown below.

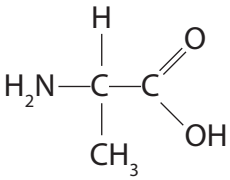


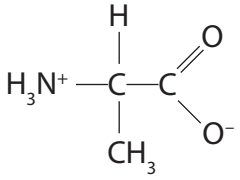
The polypeptide was heated with excess dilute sodium hydroxide solution until no further change took place.

Which of the following products is formed?

☒ **A** 

☒ **B** 

☒ **C** 

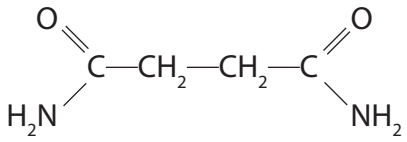
☒ **D** 

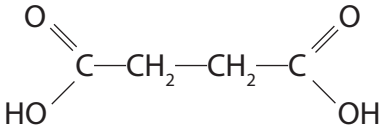
(Total for Question 13 = 1 mark)

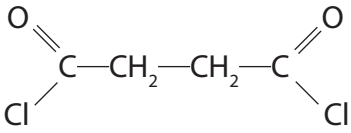
Use this space for any rough working. Anything you write in this space will gain no credit.

14 Which of the following pairs of compounds could form a polyamide?

☒ **A** $Cl—CH_2—CH_2—Cl$ and $H_2N—CH_2—CH_2—NH_2$

☒ **B** $HO—CH_2—CH_2—OH$ and 

☒ **C**  and $CH_3—CH_2—NH_2$

☒ **D**  and $H_2N—CH_2—CH_2—NH_2$

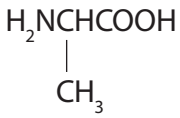
(Total for Question 14 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

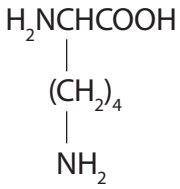
15 Which of the following amino acids is optically active and produces an approximately neutral solution when dissolved in water?

☒ **A** H_2NCH_2COOH

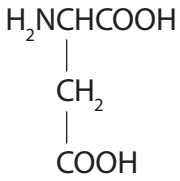
☒ **B**



☒ **C**



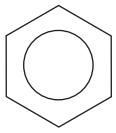
☒ **D**



(Total for Question 15 = 1 mark)

16 Which of the following is **not** planar?

☒ **A**



☒ **B** CCl_4

☒ **C** BF_3

☒ **D** $[Pt(NH_3)_2Cl_2]$

(Total for Question 16 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

17 A 50 cm^3 sample of a gaseous hydrocarbon required exactly 250 cm^3 of oxygen for complete combustion. A volume of 150 cm^3 of carbon dioxide was produced.

[All volume measurements were made at the same temperature and pressure.]

Which of the following is the correct formula of the hydrocarbon?

☒ **A** C_3H_4

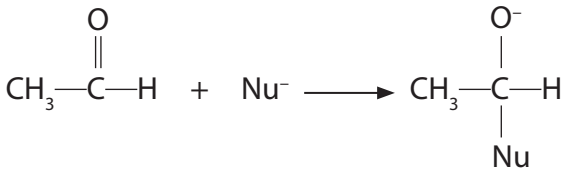
☒ **B** C_3H_8

☒ **C** C_5H_{10}

☒ **D** C_5H_{12}

(Total for Question 17 = 1 mark)

18 The first step of a nucleophilic addition reaction to a carbonyl group by a nucleophile, Nu^-, is shown below.



The above step is possible because the

☒ **A** nucleophile bonds to the δ+ carbon atom and the carbonyl oxygen accepts an electron pair from the double bond.

☒ **B** nucleophile bonds to the δ+ carbon atom and the carbonyl oxygen accepts one electron from the double bond.

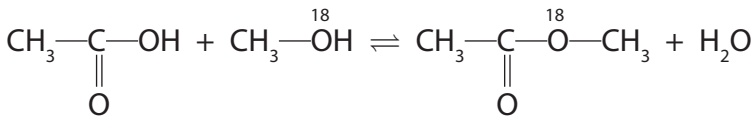
☒ **C** methyl group donates electrons to the carbonyl carbon atom.

☒ **D** C═O bond is weak.

(Total for Question 18 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

19 In a reaction carried out between ethanoic acid and methanol, the methanol was labelled with the ^{18}O isotope. The ^{18}O was found to be in the organic product of the reaction



From the above information it can be deduced that the mechanism involves

☒ **A** free radical substitution.

☒ **B** breaking the C—O bond in the ethanoic acid.

☒ **C** nucleophilic attack by ethanoic acid on methanol.

☒ **D** breaking the C—^{18}O bond in methanol.

(Total for Question 19 = 1 mark)

20 The hydride ion, H^-, is a strong reducing agent, a good nucleophile and a strong base.

Which of the following changes could **not** be brought about by the hydride ion?

☒ **A** CH_3CHO to CH_3CH_2OH

☒ **B** C_2H_5Br to C_2H_6

☒ **C** $CH_2{=}CH_2$ to C_2H_6

☒ **D** CH_3COOH to CH_3COO^-

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

21 Hydrogen-oxygen fuel cells can operate in acidic or alkaline conditions.
One such commercial cell uses porous platinum electrodes in contact with concentrated aqueous potassium hydroxide solution, KOH(aq).

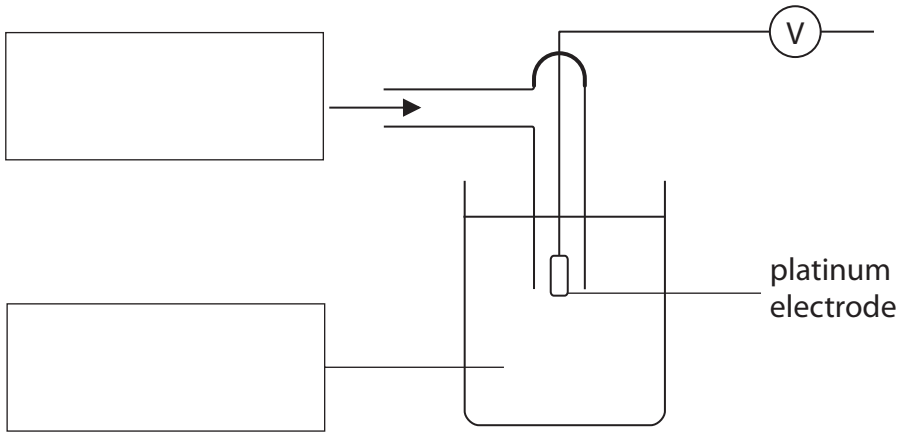
(a) Use relevant standard electrode potential values, on pages 15 and 17 of the Data Booklet, to complete the table below in which two $E^{\ominus}$ values are missing.

(2)

Half-equation	$E^{\ominus}$ / V
$2H_2O(l) + 2e^- \rightleftharpoons 2OH^-(aq) + H_2(g)$	−0.83
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	

(b) (i) Fill in the boxes to identify, by name or formula, the substances used in the **standard** hydrogen electrode.

(2)



(ii) State **three** conditions that are necessary for a standard hydrogen electrode.

(2)

1. .....

2. .....

3. .....

(c) Write appropriate half-equations and use them to derive an overall equation for the reaction which occurs when an **alkaline** hydrogen-oxygen fuel cell operates.

(2)

(d) Use the $E^{\ominus}$ values from the table in part (a) to calculate the $E^{\ominus}_{cell}$ for a hydrogen-oxygen fuel cell operating in alkaline conditions.

(1)

(e) Suggest why the $E^{\ominus}_{cell}$ for a hydrogen-oxygen fuel cell, operating in **acidic** conditions, is identical to that of an alkaline fuel cell.

(1)

.....

.....

(f) Give **one** reason (other than cost implications) why the platinum electrodes are made by coating porous material with platinum rather than by using platinum rods.

(1)

.....

.....

(g) Suggest **one** disadvantage of using a hydrogen-oxygen fuel cell compared with a rechargeable battery when providing electrical energy for a motor vehicle.

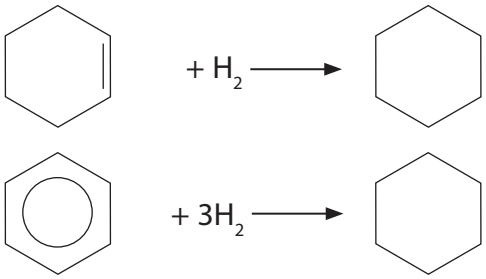
(1)

.....

.....

(Total for Question 21 = 12 marks)

22 (a) Equations for the catalytic hydrogenation of cyclohexene and of benzene are shown below.



(i) What is the type of reaction in both of these hydrogenations?

(1)

.....

*(ii) The enthalpy of hydrogenation of benzene might be expected to be −360 kJ mol^{-1}. Explain why this is **not** the actual value.

(2)

.....

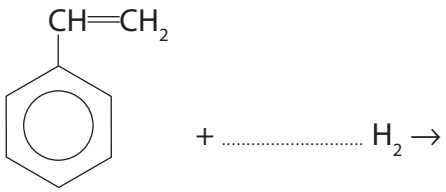
.....

.....

.....

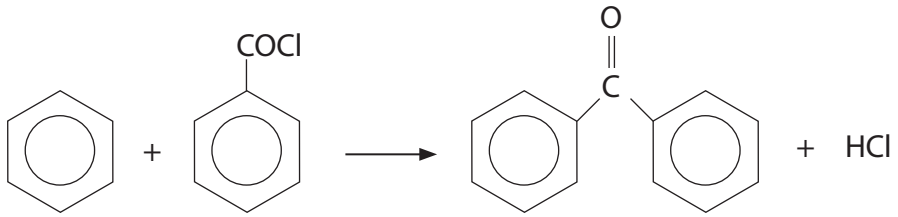
(iii) Complete the following equation for the total hydrogenation of phenylethene. Suggest a value for the enthalpy change of this reaction.

(3)



$\Delta H =$ ..... kJ mol^{-1}

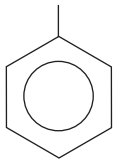
(b) The compound benzophenone is used as a sunscreen. It can be prepared from benzene, in the presence of aluminium chloride by the following reaction.



benzene + compound **A** benzophenone

(i) Complete the diagram below by showing the **displayed** formula of the –COCl group in compound **A**.

(1)



(ii) Classify the type and mechanism of the reaction between benzene and compound **A**.

(1)

.....

(iii) Give the names of the two chemists associated with the type of reaction described in (b)(ii).

(1)

..... and .....

(iv) Give the mechanism for the reaction between benzene and compound **A** in the presence of an aluminium chloride catalyst.

Start by showing the equation for the generation of the species which then attacks the benzene ring.

(4)

Equation to show generation of species attacking the benzene ring:

Rest of the mechanism:

(v) Suggest the essential property of a substance that will be used as a sunscreen.

(1)

.....

.....

(c) (i) The identity of a sample of benzophenone can be confirmed by recording its infrared and proton nmr spectra.

Identify **two** different bonds that would produce an absorption in the infrared spectrum of benzophenone. Use the Data Booklet to suggest the wavenumber of each of these absorptions.

(4)

.....

.....

.....

.....

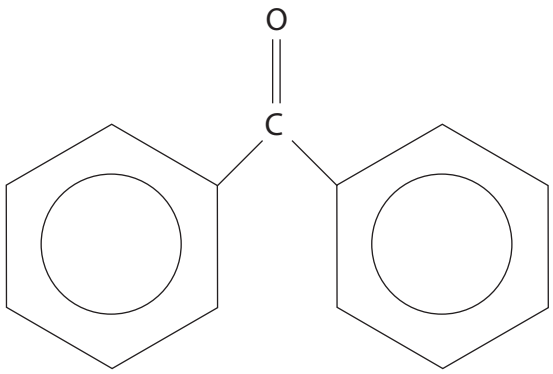
.....

.....

(ii) In benzophenone there are three different hydrogen environments, X, Y and Z, that produce signals in the ratio 2:2:1 respectively in the proton nmr spectrum.

Identify, **on the structure drawn below**, the positions of all the hydrogen atoms in each environment, labelling the different environments **X**, **Y** and **Z**.

(2)



benzophenone

(Total for Question 22 = 20 marks)

23 A scientist investigated the typical behaviour of primary amines.

(a) Amines such as butylamine, $CH_3CH_2CH_2CH_2NH_2$, and phenylamine, $C_6H_5NH_2$, both behave as bases.

(i) Which feature of an amine molecule allows it to act as a base?

(1)

.....

.....

(ii) The scientist reacted butylamine with two different acids.

Give the **formulae** of the salts that are formed when butylamine reacts with

(2)

sulfuric acid, H_2SO_4 .....

ethanoic acid, CH_3COOH .....

(b) Phenylamine, $C_6H_5NH_2$, is formed by the reduction of nitrobenzene, $C_6H_5NO_2$.

Give the reagents that are used for this reduction.

(2)

.....

.....

(c) Phenylamine was reacted with a mixture of sodium nitrite, $NaNO_2$, and hydrochloric acid at a temperature between 0 °C and 5 °C. A diazonium ion was formed. In a second step, the scientist reacted the diazonium ion with phenol, under suitable conditions. A precipitate of 4-hydroxyazobenzene (4-hydroxyphenylazobenzene) was formed.

(i) Draw the structure of the diazonium ion, clearly displaying the functional group present in the ion.

(1)

(ii) Draw the structural formula of 4-hydroxyazobenzene.

(1)

(iii) State a condition, other than a suitable temperature, required for the reaction of the diazonium ion with phenol and give a use for 4-hydroxyazobenzene.

(2)

Condition required:

.....

Use for 4-hydroxyazobenzene:

.....

(d) The scientist repeated the first step in experiment (c), but the temperature was allowed to rise above 10 °C. Under these conditions, the diazonium ion reacted with water to produce phenol. An unreactive gas, of molar mass 28.0 g mol^{-1}, was also formed along with one other product.

Use this information to write the equation for the reaction of the diazonium ion with water.

(2)

(e) The impure sample of 4-hydroxyazobenzene formed in part (c) may be purified by recrystallization. During this process

- the solid is dissolved in the minimum volume of hot solvent
- the mixture is then filtered whilst still hot
- the filtrate is cooled in an ice bath to produce crystals of 4-hydroxyazobenzene
- the crystals are removed by filtration and dried.

(i) Why is the "minimum volume of hot solvent" used?

(1)

.....

.....

.....

(ii) The impure 4-hydroxyazobenzene may contain both insoluble and soluble impurities. Describe how

(2)

I. insoluble impurities are removed during recrystallization

.....

.....

.....

II. soluble impurities are removed during recrystallization

.....

.....

.....

(iii) How would you check the purity of 4-hydroxyazobenzene after recrystallization, other than by using spectroscopy?

(1)

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.....

(Total for Question 23 = 15 marks)

TOTAL FOR SECTION B = 47 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

24

Titanium is the seventh most abundant metal in the Earth's crust and occurs principally as rutile (impure titanium(IV) oxide, TiO_2).

Early attempts to extract the metal from its oxide by reduction with heated carbon failed because the compound titanium carbide is formed. In 1910, however, pure titanium was made by heating titanium(IV) chloride with sodium.

Titanium has a high melting temperature and a density of 4.50 g cm^{-3}. Titanium is as strong as steel, but is about 40% less dense and is therefore suitable for use in the aircraft industry. Titanium metal resists corrosion as it has an impervious coating of titanium(IV) oxide. The metal adheres well to bone, is not rejected by the body and is in demand for the manufacture of replacement joints.

Titanium has two common oxidation states, +3 and +4. Solutions containing the $[Ti(H_2O)_6]^{3+}(aq)$ ion, such as titanium(III) chloride, are purple in colour and are readily oxidized by the oxygen in air to colourless titanium(IV) ions. An aqueous solution of titanium(III) chloride is a strong reducing agent. Titanium(IV) chloride, $TiCl_4$, is a colourless liquid with a boiling temperature of 136 °C. This compound is used, in conjunction with organic compounds of aluminium, as a catalyst for the polymerization of propene to poly(propene). Titanium(IV) chloride is hydrolysed by water to give titanium(IV) oxide, TiO_2 and hydrogen chloride gas.

Titanium(IV) oxide is a white, non-toxic solid at room temperature. It is used as a white pigment in paint, largely replacing toxic lead compounds which were used previously. Titanium(IV) oxide reacts with concentrated sulfuric acid to form a salt and water. Titanium(IV) oxide also reacts with aqueous potassium hydroxide solution, under suitable conditions, to form a compound with formula $K_2Ti(OH)_6$.

(a) (i) Write the equation for the reaction which occurs during the manufacture of titanium from titanium(IV) chloride as described in the article above. State symbols are not required.

(1)

(ii) Explain, by stating the changes of oxidation numbers, why the reaction in (i) is classified as a redox reaction.

(2)

.....

.....

.....

.....

(b) Complete the electronic configurations of

(2)

Ti [Ar] .....

Ti^{3+} [Ar] .....

Ti^{4+} [Ar] .....

(c) Use your answer to (b) to explain why titanium is

(i) a *d*-block element

(1)

.....

.....

.....

(ii) a transition element

(1)

.....

.....

.....

*(d) (i) Explain why the hexaaquatitanium(III) ion, $[Ti(H_2O)_6]^{3+}$, is coloured.

(3)

(ii) Explain briefly why titanium(IV) compounds are colourless.

(1)

*(e)(i) Titanium(IV) oxide has a melting temperature of 1830 °C. Use this data, plus information in the article at the start of the question, to compare the structure and bonding in titanium(IV) oxide with that in titanium(IV) chloride. Hence explain why these two compounds change state at very different temperatures.

(4)

(ii) Give the term used to describe an oxide, such as titanium(IV) oxide, which can react with both acids and bases.

(1)

(iii) Using information in the article, write the equation for the reaction between titanium(IV) oxide and aqueous potassium hydroxide solution. State symbols are not required.

(1)

(iv) Titanium(IV) chloride is one of the catalysts used in the polymerization of propene to form poly(propene).

Give the displayed formula of the repeat unit of poly(propene).

(1)

(f) The concentration of a solution of titanium(III) chloride can be determined by titration with a solution of hydrogen peroxide, H_2O_2, in acidic conditions. The end-point of the reaction is when the solution of titanium(III) chloride in the flask goes colourless.

(i) Complete the ionic half-equation to show the reduction of hydrogen peroxide.

(1)

$H_2O_2 + 2H^+ +$ ..... $\rightarrow$ .....

*(ii) One mole of hydrogen peroxide reacts with two moles of titanium(III) chloride.

In an experiment, 5.00 cm^3 of a sample of titanium(III) chloride solution was transferred to a volumetric flask and made up to 250 cm^3 of an aqueous solution. A 25.0 cm^3 portion of this diluted solution was acidified and titrated with a 0.0200 mol dm^{-3} solution of hydrogen peroxide, H_2O_2. The mean titre was 22.50 cm^3.

Calculate the concentration of the **original** titanium(III) chloride solution, in mol dm^{-3}.

(3)

(iii) Use information in the article to suggest why this titration gives a value that is lower than the true value for the concentration of titanium(III) chloride solutions.

(1)

.....

.....

(Total for Question 24 = 23 marks)

TOTAL FOR SECTION C = 23 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)		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

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

edexcel

Mark Scheme (Results)

Summer 2013

GCE Chemistry 6CH05/01
General Principles of Chemistry II

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Summer 2013
Publications Code UA035576

General Marking Guidance

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

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

Using the Mark Scheme

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

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

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

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

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

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

Section A

Question Number	Correct Answer	Mark
1	C	**1**

Question Number	Correct Answer	Mark
2	D	**1**

Question Number	Correct Answer	Mark
3	A	**1**

Question Number	Correct Answer	Mark
4	C	**1**

Question Number	Correct Answer	Mark
5	C	**1**

Question Number	Correct Answer	Mark
6	C	**1**

Question Number	Correct Answer	Mark
7	A	**1**

Question Number	Correct Answer	Mark
8	D	**1**

Question Number	Correct Answer	Mark
9	D	**1**

Question Number	Correct Answer	Mark
10	D	**1**

Question Number	Correct Answer	Mark
11	A	**1**

Question Number	Correct Answer	Mark
12	B	**1**

Question Number	Correct Answer	Mark
13	B	**1**

Question Number	Correct Answer	Mark
14	D	**1**

Question Number	Correct Answer	Mark
15	B	**1**

Question Number	Correct Answer	Mark
16	B	**1**

Question Number	Correct Answer	Mark
17	B	**1**

Question Number	Correct Answer	Mark
18	A	**1**

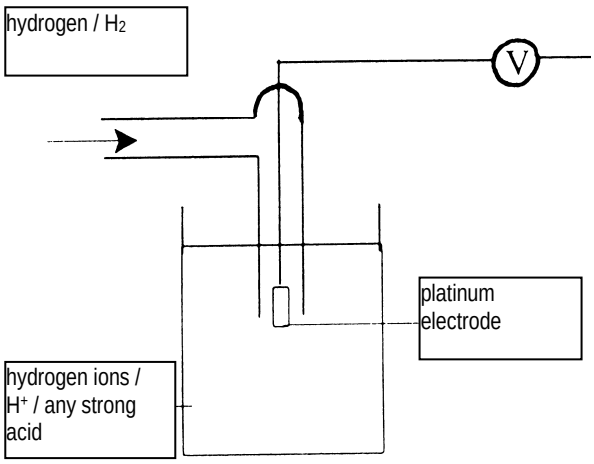
Question Number	Correct Answer	Mark
19	B	**1**

Question Number	Correct Answer	Mark
20	C	**1**

Total for Section A = 20 Marks

Section B

Question Number	Acceptable Answers	Reject	Mark
21(a)	<table><tr><th>Half-equation</th><th>$E^{\ominus}$ / V</th></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td>+0.4(0)</td></tr><tr><td></td><td>+1.23</td></tr></table> **(1)** for each correct value Penalise omission of + once only	**+2.46**	**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(i)	 **First mark**: Hydrogen / $H_2(g)$ / H_2 **(1)** IGNORE Any pressure value quoted **Second mark:** Name or formula of any strong acid (e.g. HCl / H_2SO_4) ALLOW hydrogen ions / $H^+(aq)$ / H^+ **(1)** IGNORE Any acid concentration value quoted IGNORE State symbols for ANY formula of hydrogen and / or acid, even if incorrect IGNORE any references to platinum	H(g) / H for hydrogen gas 'HCL' / HSO_4 Just 'acidic'	**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(ii)	• 1 atm / 100 kPa / 101 kPa /1 bar • 1 mol dm^{-3} ($[H^+]$ / [HCl]) ALLOW '1 molar' / '1M' • 298 K / 25 ^oC ALLOW "^oK" All **THREE** conditions correct = **2** marks Any **TWO** conditions correct = **1** mark IGNORE References to 'standard conditions' References to Pt/catalyst ALLOW 0.5 mol dm^{-3} H_2SO_4 INSTEAD of the 1 mol dm^{-3} ($[H^+]$ / [HCl])	Wrong pressure units Incorrect concentration units (eg '1 mol' / 1 mol^{-1} dm^3 for $[H^+]$) 273 K / 0^oC / 'room temperature'	**2**

Question Number	Acceptable Answers	Reject	Mark
21(c)	**First mark:** Mentions / some evidence for the use of BOTH equations 1 AND 3 from the table in any way, even if reversed or left unbalanced eg $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ AND $4OH^-(aq) + 2H_2(g) \rightarrow 4H_2O(l) + 4e^-$ **(1)** ALLOW $\rightleftharpoons$ for $\rightarrow$ **Second mark:** (Adds the above half-equations cancelling $4e^-$ to get) $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ OR $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ **(1)** ALLOW $\rightleftharpoons$ for $\rightarrow$ but must have H_2 and O_2 on left Mark the second scoring point independently Award this mark if the correct equation is seen, no matter how it is derived ALLOW MULTIPLES OF EQUATIONS IN ALL CASES IGNORE any state symbols, even if incorrect ALLOW equilibrium sign $\rightleftharpoons$ used in **ANY** of the above equations instead of the full arrows	Equations involving H^+ **If** e^- / OH^- / H^+ / two surplus H_2O molecules remain in this final equation **(0)** for 2nd mark	**2**

Question Number	Acceptable Answers	Reject	Mark
21(d)	$E^{\ominus}_{cell}$ = +0.40 — (—0.83) (V) = (+)1.23 (V) + sign NOT required in final answer Correct answer with or without working scores (1) No ECF from any incorrect $E^{\ominus}$ values used	**−**1.23 (V)	**1**

Question Number	Acceptable Answers	Reject	Mark
21(e)	Reaction / equation is the same OR Reaction / equation for both is $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ALLOW ⇌ for → IGNORE state symbols even if incorrect ALLOW statements such as 'they both produce water from hydrogen and oxygen' / 'reactants and products are the same' ALLOW multiples of the **equation**	'Electrode potentials don't change' **Just** same product / water is produced **Just** same reactants are oxidized and reduced Same reaction but in **reverse** scores **(0)**	**1**

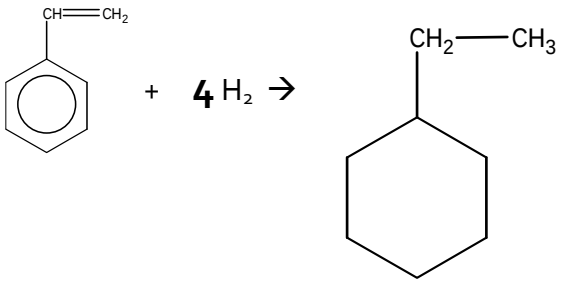
Question Number	Acceptable Answers	Reject	Mark
21(f)	To **increase** the **surface area** /to increase the number of active sites		**1**

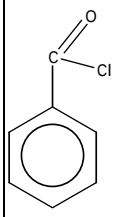
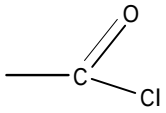
Question Number	Acceptable Answers	Reject	Mark
21(g)	Storage (problems) OR hydrogen / oxygen / the gases have to be stored under pressure OR Leakage (of hydrogen / of oxygen /of gas) OR Transport(ation) problems OR Hard to carry / lack of portability OR Hydrogen flammable / inflammable OR Hydrogen explosive OR (Fuel cell) costly / expensive OR Needs (regular) re-filling OR Needs continual replenishment of H_2 and O_2 OR Lack of availability (of hydrogen / fuel) OR Hydrogen is made from fossil fuels / hydrogen is made by electrolysis / hydrogen is made from Natural Gas / hydrogen is made from non-renewable resources ALLOW water is a Greenhouse gas / Fuel cell(s) have short(er) life-span / Fuel cells have to be (regularly) replaced IGNORE references to just 'danger' or just 'safety' or just 'hazardous' Any arguments in terms of **voltage** output References to cannot be recharged	'Fuel cell can only be used once' scores (**0**)	**1**

Total for Question 21 = 12 Marks

Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	Addition / reduction / free-radical addition IGNORE references to 'hydrogenation'	'redox' 'electrophilic addition' 'nucleophilic addition'	**1**

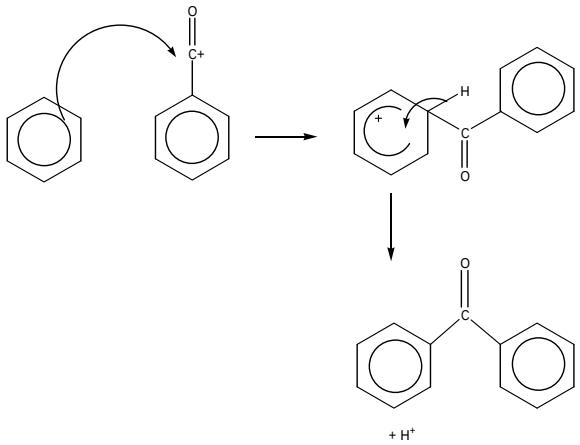
Question Number	Acceptable Answers	Reject	Mark
22(a)(ii)	**First mark:** **Delocalization** (of π/p electrons in benzene ring) **(1)** IGNORE reference to 'resonance' **Second mark:** Results in more **energy** needed to **break** the **bonds** in benzene (compared with three separate π bonds) **(1)** ALLOW confers **stability** on the molecule / makes benzene **more stable** (than expected) IGNORE Reference to carbon-carbon bond lengths Values of any enthalpy changes Mark the two points independently		**2**

Question Number	Acceptable Answers	Reject	Mark
22(a)(iii)	 + **4** H_2 → (ΔH =) **— 328 (**kJ mol^{-1}) **First mark**: For "4" **Second mark**: Product as above / correct skeletal formula of product ALLOW Side chain written as $-C_2H_5$ **Third mark**: **—**328 (kJ mol^{-1}) **NOTE** **One** H_2 added showing a CQ correct product with only side chain reduced and cq ΔH = **—**120 **(**kJ mol^{-1}) scores **(2)** **Three** H_2 added showing a CQ correct product with only the benzene ring reduced and cq ΔH = **—**208 (kJ mol^{-1}) scores **(2)** **Five** H_2 added with fully correct product drawn and ΔH = **—**448 (kJ mol^{-1}) scores **(2)** **Three and a half** H_2 added showing a fully correct product and ΔH = **—**268/**—**293(.3)(kJ mol^{-1}) scores **(2)** **NOTE** Mark scoring points independently		**3**

Question Number	Acceptable Answers	Reject	Mark
22(b)(i)	 Mark awarded for displaying 		**1**

Question Number	Acceptable Answers	Reject	Mark
22(b)(ii)	Electrophilic substitution **BOTH** words needed IGNORE references to 'acylation' and /or 'Friedel-Crafts'		**1**

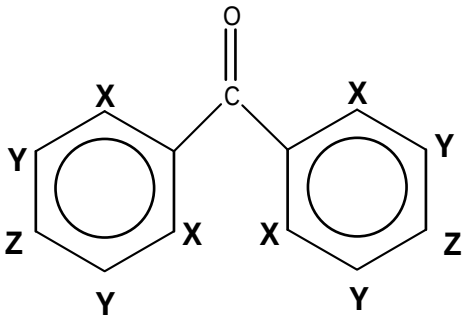
Question Number	Acceptable Answers	Reject	Mark
22(b)(iii)	Friedel **and** Crafts **BOTH** names are needed for this mark		**1**

Question Number	Acceptable Answers	Reject	Mark
22(b)(iv)	**First mark:** **C_6H_5COCl** + $AlCl_3$ → **$C_6H_5CO^+$** + $AlCl_4^-$ **(1)** **+** can be anywhere on the C_6H_5CO in the equation for the first mark  $(AlCl_4^- + H^+ \rightarrow HCl + AlCl_3)$ **NOTE:** If ethanoyl chloride or any other acid chloride or the generic RCOCl is used **instead** of benzoyl chloride, no first mark can be awarded but the 2nd, 3rd and 4th marks can be awarded consequentially **Second mark**: First curly arrow, as shown, to start from inside the hexagon to the correct C+ carbon (i.e. not to the benzene ring) Note the + must be on the C of the C=O/CO for this mark **(1)** **Third mark:** Intermediate correctly drawn **(1)** **NOTE** + can be shown anywhere in the ring or at the C atom where electrophile is bonded. The 'horseshoe' in the intermediate to cover at least three carbon atoms **Fourth mark:** Second curly arrow as shown from C—H bond to reform the ring, not from the H atom in this bond **(1)** **NOTE** Products do not have to be shown nor the equation for regeneration of the catalyst given		**4**

Question Number	Acceptable Answers	Reject	Mark
22(b)(v)	Absorbs / reflects / blocks / protects from / shields against / **uv** (light/ radiation) IGNORE 'non-toxic' / references to IR	**adsorbs** uv light	**1**

Question Number	Acceptable Answers	Reject	Mark
22(c)(i)	Any **TWO** of the following (1) for identifying the bond by formula as shown and (1) for wavenumber in each matching pair **UNITS** are not required **NOTE** ALLOW Correct wavenumber range, or any number within the correct range, **for C=O** Mark identification of the bond and the wavenumber independently (eg a correct bond with a wrong wavenumber, or vice-versa, scores one of the two marks in each case) IGNORE nmr values / chemical shifts		**4**

Bond	Wavenumber range/wavenumber (cm^{-1})
C=C	1600 / 1580 / 1500 / 1450 **All four values needed**
C=O	1700 – 1680
C-H	3030
C-H	750 / 700 **Both values needed**

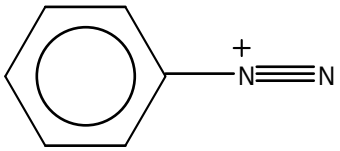
Question Number	Acceptable Answers	Reject	Mark
22(c)(ii)	 **First mark** **EITHER** Identifies correctly the **three** different proton environments ALLOW If the three different proton environments are only shown on one of the benzene rings **NOTE** On right-hand ring, clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments and /or On left-hand ring, anti-clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments **OR** Identifies proton Z correctly on both benzene rings **(1)** **Second mark** Fully correct labelling both rings using the letters **X**, **Y** and **Z** **NOTE** **X** and **Y** labels are interchangeable, **Z** is not **(1)**		**2**

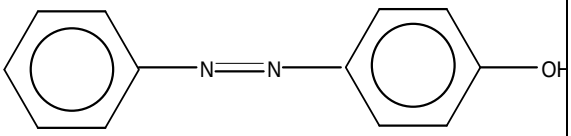
Total for Question 22 = 20 Marks

Question Number	Acceptable Answers	Reject	Mark
23(a)(i)	**Lone pair** (of electrons on the nitrogen atom) ALLOW non-bonded pair (of electrons on the nitrogen atom)	**Lone pairs** **Spare pair**	**1**

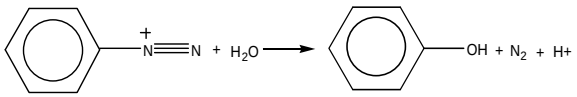
Question Number	Acceptable Answers	Reject	Mark
23(a)(ii)	**(with H_2SO_4)** $(C_4H_9NH_3^+)_2SO_4^{2-}$ **(1)** ALLOW $C_4H_9NH_3^+HSO_4^-$ **(with CH_3COOH)** $C_4H_9NH_3^+CH_3COO^-$ **(1)** **CHARGES** not essential Cation and anion can be in either order Max **(1)** if formula of the amine is incorrect in either case ALLOW (1) if only the correct cation is given in each case (i.e. the anion has been omitted in both cases) **NOTE** The correct ions can be shown separately Eg $(C_4H_9NH_3^+)_2$ **+** SO_4^{2-}		**2**

Question Number	Acceptable Answers	Reject	Mark
23(b)	Tin / Sn ALLOW Iron / Fe **(1)** (concentrated) **hydrochloric acid** **NOTE** If they write 'HCl', there must be some indication of concentrated Eg 'conc HCl' / 'concentrated HCl' ALLOW HCl(aq) (Followed by addition of alkali to liberate the free amine) **(1)** Mark the two points independently **NOTE** Do not allow 2nd mark if there is a suggestion that the acid and alkali are added together simultaneously	$LiAlH_4$ **Just 'HCl'** **'dilute'** hydrochloric acid / sulfuric acid	**2**

Question Number	Acceptable Answers	Reject	Mark
23(c)(i)	 **NOTE** If the above structure is drawn, the + charge must be on the N connected directly to the benzene ring ALLOW $—N=N^+$ on ring IGNORE Cl^-	N_2^+ on ring	**1**

Question Number	Acceptable Answers	Reject	Mark
23(c)(ii)			**1**

Question Number	Acceptable Answers	Reject	Mark
23(c)(iii)	**(Conditions)** (Presence of) NaOH / KOH / alkali /OH^- **(1)** ALLOW 'Alkaline (conditions)' or 'base' or 'high pH' IGNORE Any references to temperature **(Use)** Dye / pigment / colouring / indicator / in foodstuff / in paint / methyl orange **(1)** IGNORE Any reference to medicines		**2**

Question Number	Acceptable Answers	Reject	Mark
23 (d)	 ALLOW The +sign to be on either N atom in the benezenediazonium ion OR $C_6H_5N_2^+ + H_2O \rightarrow C_6H_5OH + N_2 + H^+$ OR $C_6H_5N_2Cl + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ OR $C_6H_5N_2^+ + 2H_2O \rightarrow C_6H_5OH + N_2 + H_3O^+$ OR $C_6H_5N_2^+Cl^- + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ **NOTE** —C_6H_5 can be written or drawn **First mark** for **N_2** **(1)** **Second mark** for rest of the equation correct **(1)** IGNORE State symbols, even if incorrect		**2**

Question Number	Acceptable Answers	Reject	Mark
23(e)(i)	(Otherwise) too much (product) remains in solution OR If excess (solvent) is used, crystals might not form ALLOW To avoid losing (too much) product (in the filtrate when crystallization occurs) / 'to maximize the yield'/ 'will crystallize better from a concentrated solution'/ 'will recrystallize (better) when cold' IGNORE References to a 'saturated solution' or references to 'dilution' or references to the time taken for crystals to form		**1**

Question Number	Acceptable Answers	Reject	Mark
23(e)(ii)	**(Insoluble impurities removed)** By **hot** filtration / During the **first** filtration / During the **second** step in the process **(1)** **(Soluble impurities removed)** By remaining in solution / Left in filtrate / Removed when washed (with cold solvent) **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
23(e)(iii)	Measure the melting temperature / melting point **and** compare with data / known value (from a data book / literature / Internet /data base) (BOTH points needed for the mark) OR The melting point is sharp (Just this statement is needed for the mark) ALLOW Any form of chromatography IGNORE References to any types of spectroscopy	**(0)** if reference to determination of the boiling point is made	**1**

Total for Question 23 = 15 Marks

Question Number	Acceptable Answers	Reject	Mark
24(a)(i)	$TiCl_4 + 4Na \rightarrow 4NaCl + Ti$ IGNORE State symbols, even if incorrect ALLOW Multiples Reversible arrows		**1**

Question Number	Acceptable Answers	Reject	Mark
24(a)(ii)	Ti **reduced** as oxidation number decreases from **+4 to 0**/ changes from **+4 to 0** **(1)** Na **oxidized** as oxidation number increases from **0 to +1** /changes from **0 to +1** **(1)** ALLOW Correct oxidation numbers only for one mark **NOTE** Max (1) if no + sign included ALLOW **'4+'** and/or **'1+'** given instead of **+4** and **+1** **NOTE** If any of the oxidation numbers are wrong, award max (1) for the idea that during oxidation the oxidation number increases **AND** during reduction the oxidation number decreases IGNORE References to loss and /or gain of electrons		**2**

Question Number	Acceptable Answers	Reject	Mark
24(b)	(Ti [Ar]) $3d^2\ 4s^2$ / $4s^2\ 3d^2$ **(1)** (Ti^{3+} [Ar]) $3d^1$ / $3d^1\ 4s^0$ (Ti^{4+} [Ar]) 'nil' / $3d^0\ 4s^0$ /$3d^0$ space left blank by candidate BOTH Ti^{3+} and Ti^{4+} correct for second mark **(1)** Mark CQ on Ti electron configuration for the second mark ALLOW Upper case (e.g. 'D' for 'd' in electronic configurations) Subscripts for numbers of electrons Full correct electronic configurations $1s^2$, $2s^2$.....		**2**

Question Number	Acceptable Answers	Reject	Mark
24(c)(i)	**(d-block element)** **EITHER** Ti has (two) electrons in the 3d subshell / Ti has a partially filled d-subshell / Ti has a partially filled d-orbital / Ti has electrons in d-orbital(s) / Ti has electrons in d-subshell (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital **OR** (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital	**Outer / highest energy** electrons are in a d-orbital / **Outer / highest energy** electrons are in a d-subshell Electrons in the 'd-block'/ 'electrons in the d-shell'	**1**

Question Number	Acceptable Answers	Reject	Mark
24(c)(ii)	(transition element) Forms one (or more stable) **ions** / forms **Ti^{3+}** (ions) which have incomplete d-orbital(s) / an incomplete d-subshell / a partially filled d-subshell / an unpaired d electron IGNORE References to variable oxidation states		**1**

Question Number	Acceptable Answers	Reject	Mark
24(d)(i)	**First mark:** d-subshell splits /d-orbital**s** split (in energy by ligands) /d energy level(s) split(s) **(1)** **Second mark:** **absorbs light** (in visible region) **(1)** **Third mark:** Electron transitions from lower to higher energy / electron(s) jump from lower to higher energy OR Electron(s) promoted (within d) **(1)** Mark independently **NOTE** Maximum of (1) mark (i.e. the first mark only) if refers to electrons falling back down again	d-**orbital /** d-**shell** splits absorbs **purple** light	**3**

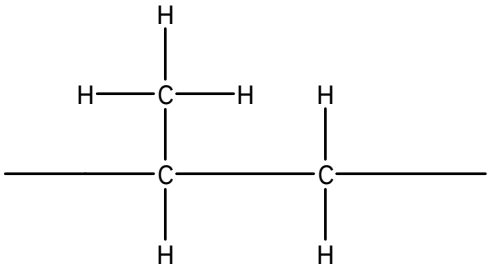
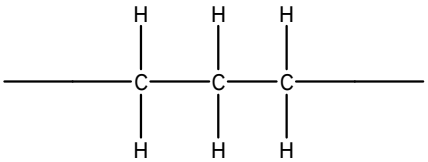
Question Number	Acceptable Answers	Reject	Mark
24(d)(ii)	No d-electrons / empty d-subshell		**1**

Question Number	Acceptable Answers	Reject	Mark
24(e)(i)	**TiO_2** **'Structure' mark** **EITHER** Giant (structure) **OR** Lattice (structure) IGNORE Whether stated as ionic or covalent for this mark **(1)** **TiO_2** **'Bonding' mark** EITHER **Strong** (electrostatic) attraction between ions ALLOW **Strong** ionic bonds / ionic bonds require a lot of energy to break **OR** **Strong** covalent bonds/covalent bonds require a lot of energy to break **(1)** **$TiCl_4$** **'Structure' mark** (Simple) molecules / (small) molecules **/**molecular **(1)** **$TiCl_4$** **'Bonding' mark** **Weak** London / dispersion / van der Waals' forces (between molecules) / London /dispersion / van der Waals' forces (between molecules) require little energy to break	TiO_2 (small) molecule**s** / simple molecular For TiO_2 mention of any type of intermolecular forces between molecules of TiO_2 $TiCl_4$ giant structure Covalent bonds broken (on melting) in $TiCl_4$ Ionic bonding in $TiCl_4$ Hydrogen bonding **(0)** for this mark	**4**

	NOTE If candidates assumes TiO_2 and $TiCl_4$ are both simple molecular, can score last mark for saying that the **named** intermolecular forces in TiO_2 are stronger that those in $TiCl_4$ IGNORE (Permanent) dipole-dipole forces **(1)** Mark the four scoring points independently		

Question Number	Acceptable Answers	Reject	Mark
24(e)(ii)	Amphoteric ALLOW Recognisable spellings		**1**

Question Number	Acceptable Answers	Reject	Mark
24(e)(iii)	$TiO_2 + 2H_2O + 2KOH \rightarrow K_2Ti(OH)_6$ OR $TiO_2 + 2H_2O + 2OH^- \rightarrow Ti(OH)_6^{2-}$ IGNORE state symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
24(e)(iv)	 **MUST** have continuation bonds at each end ALLOW CH_3 IGNORE n and any brackets	 **Two** (or more) repeat units shown	**1**

Question Number	Acceptable Answers	Reject	Mark
24(f)(i)	(H_2O_2 + $2H^+$ +) **$2e^{(-)}$ → $2H_2O$** **BOTH** $2e^{(-)}$ **and 2**H_2O needed for the mark		**1**

Question Number	Acceptable Answers	Reject	Mark
24(f)(ii)	(Moles H_2O_2 = $\frac{0.0200 \times 22.50}{1000}$ =) 4.5×10^{-4} mol H_2O_2 **(1)** (Moles Ti^{3+} reacting in 25.0 cm^3) = 9.0×10^{-4} mol Ti^{3+} (Moles Ti^{3+} in 250 cm^3) = 9.0×10^{-3} mol Ti^{3+} **(1)** (Original concentration of Ti^{3+} = $\frac{9.0 \times 10^{-3}}{0.00500}$ =) 1.8 (mol dm^{-3}) **(1)** 1.8 (mol dm^{-3}) with or without working scores **(3)** **NOTES:** If mole ratio H_2O_2 : Ti^{3+} is 1:1 final answer for concentration of Ti^{3+} is 0.9 (mol dm^{-3}) scores **(2)** overall If mole ratio H_2O_2 : Ti^{3+} is 2:1 final answer for concentration of Ti^{3+} is 0.45 (mol dm^{-3}) scores **(2)** overall If candidate forgets to multiply no. of moles of Ti^{3+} by 10 then answer is 0.18 (moldm-3) this scores **(2)** If volume of H_2O_2 used is 25.0 no first mark, but can score **(2**) if final answer CQ is 2(.0) (mol dm^{-3})		**3**

Question Number	Acceptable Answers	Reject	Mark
24 (f)(iii)	(It/titanium(III)/Ti^{3+}) **oxidized** (by oxygen in the air) ALLOW 'It is a **strong** reducing agent'	Hydrolysis	**1**

Total for Question 24 = 23 Marks

Total for Paper = 90 Marks

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Edexcel GCE

Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Wednesday 19 June 2013 – Morning
Time: 1 hour 40 minutes

Paper Reference
6CH05/01R

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

P42985A

7/6/7/

P 4 2 9 8 5 A 0 1 2 8

PEARSON

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 In nitric(V) acid, HNO_3, the oxidation number of the nitrogen is +5.
This means that the **nitrogen** in nitric acid

☒ **A** has five electrons in its outer shell.

☒ **B** is an ion with a charge of +5.

☒ **C** would have a charge of +5 if its bonding electrons were transferred completely.

☒ **D** forms five covalent bonds in total.

(Total for Question 1 = 1 mark)

2 What are the components of the half-cell required to measure the standard reduction potential of the following system?

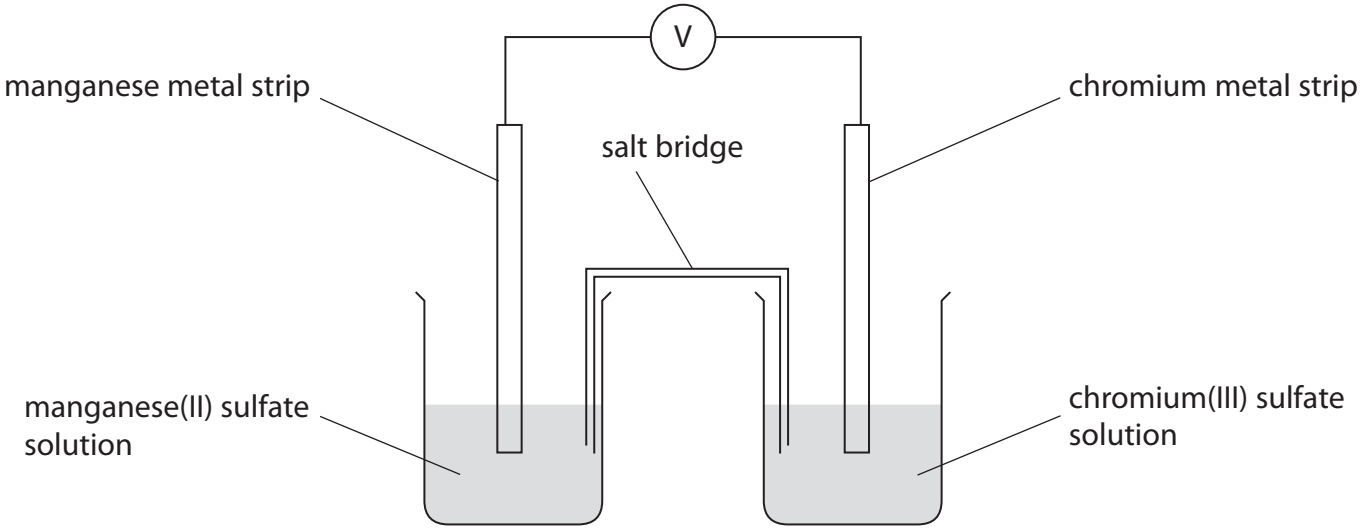
$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$$

	Ion(s) in the solution	Metal electrode
☒ **A**	Fe^{2+}	iron
☒ **B**	Fe^{3+}	iron
☒ **C**	Fe^{2+} and Fe^{3+}	iron
☒ **D**	Fe^{2+} and Fe^{3+}	platinum

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

3 The following cell is set up:



The standard electrode potential of the chromium(III)/chromium half cell is −0.74 V and that of the manganese(II)/manganese half cell is −1.19 V. Thus the emf of the cell, as shown in the diagram, under standard conditions is

☒ **A** +1.93 V

☒ **B** +0.45 V

☒ **C** −0.45 V

☒ **D** −1.93 V

(Total for Question 3 = 1 mark)

---

4 The equation for the reaction of iron and nickel(II) ions in aqueous solution is

$$Fe(s) + Ni^{2+}(aq) \rightarrow Fe^{2+}(aq) + Ni(s)$$

Under standard conditions the value of the equilibrium constant, K_c, for this reaction is greater than 1. Hence, for this reaction,

☒ **A** $\Delta S^{\ominus}_{total}$ and $E^{\ominus}_{reaction}$ are both positive.

☒ **B** $\Delta S^{\ominus}_{total}$ is positive and $E^{\ominus}_{reaction}$ is negative.

☒ **C** $\Delta S^{\ominus}_{total}$ is negative and $E^{\ominus}_{reaction}$ is positive.

☒ **D** $\Delta S^{\ominus}_{total}$ and $E^{\ominus}_{reaction}$ are both negative.

(Total for Question 4 = 1 mark)

5 Chlorine is prepared in the laboratory by the reaction of potassium manganate(VII) with concentrated hydrochloric acid. The ionic half-equations and their standard electrode potentials are

$$\tfrac{1}{2}Cl_2(g) + e^- \rightleftharpoons Cl^-(aq) \quad E^{\ominus} = +1.36\ V$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l) \quad E^{\ominus} = +1.51\ V$$

(a) Concentrated hydrochloric acid is preferred to 1 mol dm^{-3} hydrochloric acid because

☒ **A** it lowers the activation energy of the reaction.

☒ **B** the reaction is thermodynamically unfavourable under standard conditions.

☒ **C** it increases the rate of reaction.

☒ **D** it increases the equilibrium constant, K_c, for the overall reaction.

(b) From the half-equations it may be deduced that

☒ **A** 1 mol of manganate(VII) ions reacts with 5 mol of chloride ions.

☒ **B** 5 mol of manganate(VII) ions reacts with 1 mol of chloride ions.

☒ **C** 1 mol of manganate(VII) ions reacts with 2.5 mol of chlorine.

☒ **D** 2.5 mol of manganate(VII) ions reacts with 1 mol of chlorine.

(Total for Question 5 = 2 marks)

6 The electronic structure of the chromium(III) ion, Cr^{3+}, is

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

(Total for Question 6 = 1 mark)

7 In the manufacture of sulfuric acid, sulfur dioxide is converted to sulfur trioxide using a catalyst of vanadium(V) oxide:

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

The electronic configuration of vanadium is [Ar] $3d^3\ 4s^2$, so the mechanism for this reaction is most likely to involve a sequence in which vanadium(V) is converted to

☒ **A** vanadium(VI) by oxygen then back to vanadium(V) by sulfur dioxide.

☒ **B** vanadium(VI) by sulfur dioxide then back to vanadium(V) by oxygen.

☒ **C** vanadium(IV) by oxygen then back to vanadium(V) by sulfur dioxide.

☒ **D** vanadium(IV) by sulfur dioxide then back to vanadium(V) by oxygen.

(Total for Question 7 = 1 mark)

8 Titanium has the electronic structure $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$. Which of the following compounds is **unlikely** to exist?

☒ **A** K_3TiF_6

☒ **B** K_2TiF_6

☒ **C** $K_2Ti_2O_5$

☒ **D** K_2TiO_4

(Total for Question 8 = 1 mark)

9 All metal hydroxides dissolve in acid. When aqueous solutions of sodium hydroxide and ammonia are added separately to samples of chromium(III) hydroxide, in both cases the solid dissolves to form a green solution. How should these reactions be classified?

	sodium hydroxide	ammonia
☒ **A**	amphoteric	amphoteric
☒ **B**	amphoteric	ligand exchange
☒ **C**	ligand exchange	amphoteric
☒ **D**	ligand exchange	ligand exchange

(Total for Question 9 = 1 mark)

10 The ligands that form complex ions are either neutral, like NH_3, or negatively charged, like CN^-. Nickel(II) ions, Ni^{2+}, form complexes with both these ligands. The bonding between Ni^{2+} and the ligands in these complexes is

	NH_3	CN^-
☒ **A**	dative covalent	dative covalent
☒ **B**	ionic	dative covalent
☒ **C**	dative covalent	ionic
☒ **D**	ionic	ionic

(Total for Question 10 = 1 mark)

11 When excess aqueous ammonia is added to a solution containing $Zn^{2+}(aq)$ ions, a colourless solution is formed. This solution is colourless because

☒ **A** zinc does not form complex ions.

☒ **B** the d orbitals of Zn^{2+} in the complex formed are not split into different energy levels.

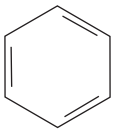
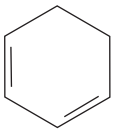
☒ **C** the energy difference between the d orbitals of Zn^{2+} in the complex formed does not correspond to the visible region of the spectrum.

☒ **D** the d orbitals of Zn^{2+} in the complex formed are full.

(Total for Question 11 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

12 Bromine reacts with benzene on heating in the presence of a catalyst and with cyclohexa-1,3-diene in the cold. The types of reaction involved are

	bromine with benzene 	bromine with cyclohexa-1,3-diene 
☒ **A**	addition	addition
☒ **B**	addition	substitution
☒ **C**	substitution	addition
☒ **D**	substitution	substitution

(Total for Question 12 = 1 mark)

13 Phenylamine, $C_6H_5NH_2$, and benzene react with bromine in a similar way, but phenylamine reacts much faster. This increased rate of reaction is most likely due to the effect that the

☒ **A** electronegativity of the nitrogen has on the benzene ring.

☒ **B** electronegativity of the nitrogen has on the bromine molecule.

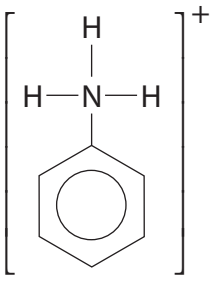
☒ **C** lone pair of electrons of the nitrogen has on the benzene ring.

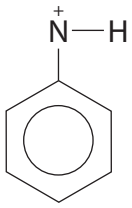
☒ **D** lone pair of electrons of the nitrogen has on the bromine molecule.

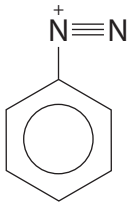
(Total for Question 13 = 1 mark)

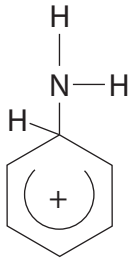
Use this space for any rough working. Anything you write in this space will gain no credit.

14 When dilute nitric(V) acid, HNO_3, reacts with phenylamine, the ion formed is

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 14 = 1 mark)

15 Methylamine, CH_3NH_2, is **very** soluble in water. This is because it

☒ **A** forms hydrogen bonds with water.

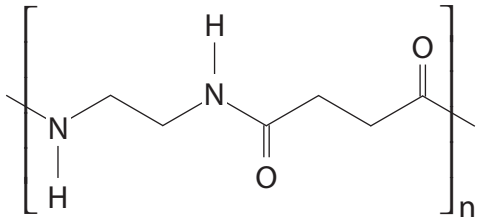
☒ **B** forms London forces with water.

☒ **C** exists mainly as ions in aqueous solution.

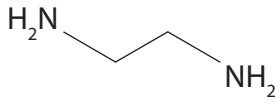
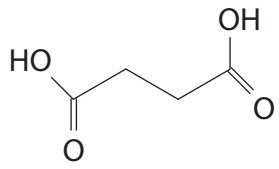
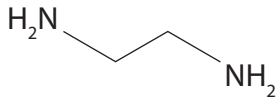
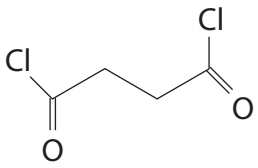
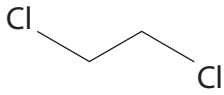
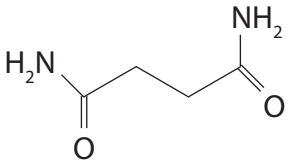
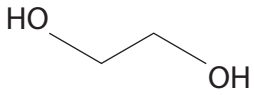
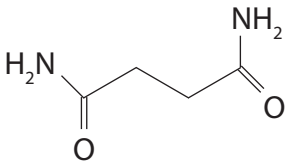
☒ **D** exists as a zwitterion.

(Total for Question 15 = 1 mark)

16 The structure below shows the repeating pattern of a polymer.



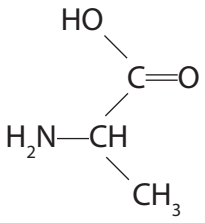
Which of the following pairs of compounds could react **rapidly** to form this polymer?

☒ **A**		
☒ **B**		
☒ **C**		
☒ **D**		

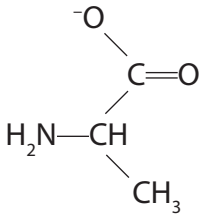
(Total for Question 16 = 1 mark)

17 Which of the following structures best represents the amino acid, alanine, in an aqueous solution with a pH of 12?

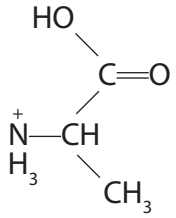
☒ **A**



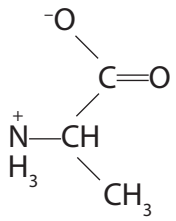
☒ **B**



☒ **C**



☒ **D**



(Total for Question 17 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

18 Which of the following is true for **all** amino acids?

All amino acids

☒ **A** exist as optical isomers.

☒ **B** are neutral in solution.

☒ **C** are essential to life.

☒ **D** are crystalline solids at room temperature.

(Total for Question 18 = 1 mark)

19 Which of the following physical methods of chemical analysis is used in modern breathalysers?

☒ **A** Infrared spectroscopy

☒ **B** Mass spectrometry

☒ **C** Nuclear magnetic resonance

☒ **D** Ultraviolet spectroscopy

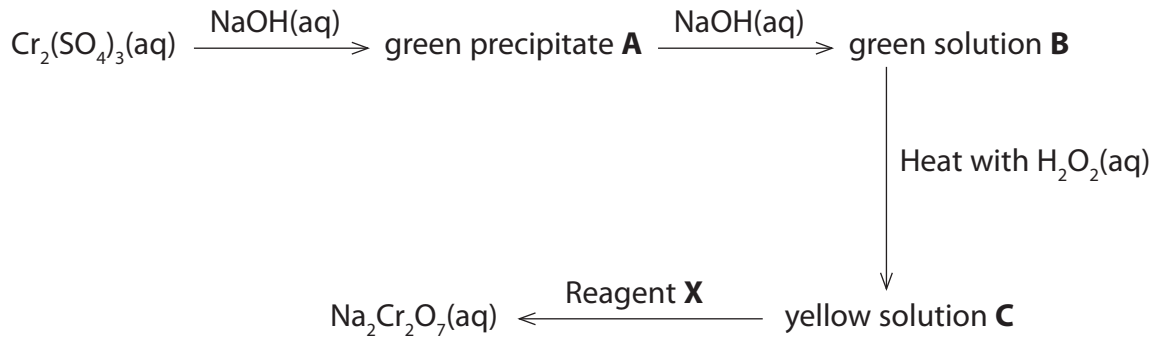
(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

20 Sodium dichromate(VI) may be prepared from chromium(III) sulfate using the sequence outlined below.



(a) (i) Complete the table below, giving the **formula** of the chromium containing species.

(4)

Substance	**Formula of chromium containing species**
$Cr_2(SO_4)_3(aq)$	
Green precipitate **A**	
Green solution **B**	
Yellow solution **C**	

(ii) Complete the half equation for the reduction of hydrogen peroxide, $H_2O_2(aq)$.

(1)

H_2O_2 + ... → ..... OH^-

(iii) Identify reagent **X**

(1)

.....

(iv) Write an **ionic** equation for the conversion of solution **C** to $Na_2Cr_2O_7$. State symbols are not required.

(1)

(b) Chromium also exists in a +2 oxidation state. Use the Data booklet to determine the feasibility of the disproportionation of chromium(III) in aqueous solution into chromium(II) and dichromate(VI).

In your answer, show both half equations and the overall equation for the proposed disproportionation. Calculate $E^{\ominus}_{cell}$ for this reaction and use this value to predict the feasibility of this reaction.

(4)

(Total for Question 20 = 11 marks)

21 Hydrogen combines rapidly with oxygen in the presence of a platinum catalyst:

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$$

The reaction is highly exothermic.

(a) Use the thermochemical data from the data booklet to obtain the enthalpy change for this reaction under standard conditions.

(1)

..... kJ mol^{-1}

(b) The same reaction occurs, also with a platinum catalyst, in a fuel cell.

(i) Write the two ionic half equations which occur in an **alkaline** fuel cell. Include state symbols.

(3)

Equation 1

Equation 2

(ii) The alkali in an alkaline fuel cell serves the same purpose as the acid in an acid fuel cell. State this purpose.

(1)

.....

.....

*(iii) Platinum catalyses both the direct combination of hydrogen with oxygen and the reactions in the fuel cell. By considering the way in which the catalyst lowers the activation energy, suggest two **similarities** in these processes.

(2)

Similarity 1 .....

.....

.....

Similarity 2 .....

.....

.....

(c) The use of hydrogen as a fuel, both in fuel cells and in direct combustion reactions, is seen as an important potential alternative to fossil fuels.

(i) State what is considered to be the main advantage of hydrogen compared with fossil fuels, bearing in mind that most hydrogen is obtained from fossil fuels.

(1)

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.....

*(ii) Explain the main advantage of using a fuel cell over direct combustion of hydrogen.

(2)

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(iii) State a disadvantage of using a hydrogen fuel cell compared with direct combustion of hydrogen.

(1)

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(iv) Suggest **two** advantages of using an ethanol fuel cell rather than a hydrogen fuel cell.

(2)

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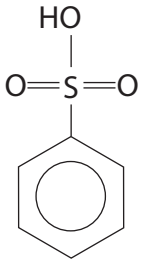
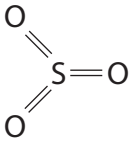
(Total for Question 21 = 13 marks)

22 (a) Benzenesulfonic acid (structure I) may be prepared from benzene. The reaction is a typical electrophilic substitution in which the electrophile is sulfur trioxide (structure II).



Structure I



Structure II

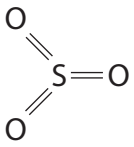
(i) Identify the reagent used as the source of sulfur trioxide in this preparation.

(1)

.....

(ii) On the formula of sulfur trioxide below, show the partial charges on each atom and explain how they arise.

(2)



Structure II

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(iii) Suggest why sulfur trioxide is an effective electrophile.

(1)

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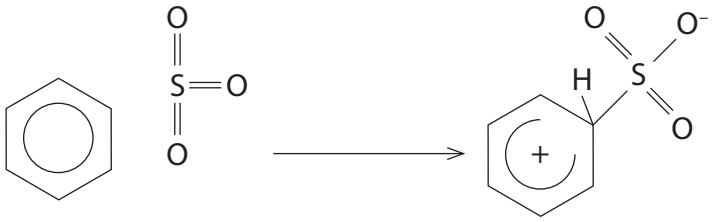
.....

(b) The mechanism for the electrophilic substitution reaction between benzene and sulfur trioxide to form benzenesulfonic acid is similar to that for the nitration of benzene.

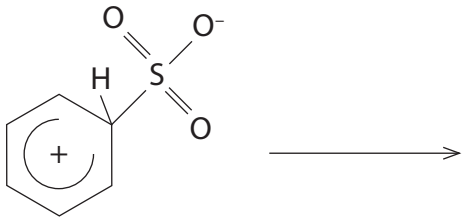
(i) Complete the first step of this mechanism by adding two curly arrows.

(2)



(ii) The mechanism for the formation of benzenesulfonic acid has two further steps. Complete the mechanism, showing curly arrows where appropriate.

(3)

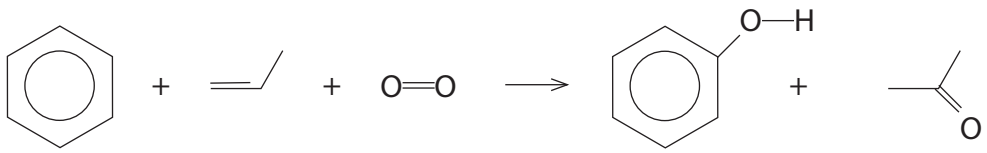


(c) At one time the main industrial use for benzenesulfonic acid was in the manufacture of phenol in a two-stage process. In the first stage, benzenesulfonic acid was reacted with sodium hydroxide forming an intermediate organic compound along with sodium sulfite, Na_2SO_3, and water. In the second stage, the intermediate organic compound was reacted with hydrochloric acid to form phenol.

(i) Write the two equations for the manufacture of phenol by this method. State symbols are not required.

(2)

(ii) Nowadays, phenol is manufactured using the Hock process which is summarised below.



Suggest why the Hock process is preferred.

(2)

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(Total for Question 22 = 13 marks)

23 (a) The following data were obtained from experiments on solutions of aqueous amines of the same concentration.

Amine	Formula	pH of solution
Butylamine	$CH_3CH_2CH_2CH_2NH_2$	11.9
Dibutylamine	$(CH_3CH_2CH_2CH_2)_2NH$	12.1
Phenylamine (aniline)	$C_6H_5NH_2$	8.8

(i) Identify the feature of the amine molecules that causes the solutions to be alkaline.

(1)

.....

.....

(ii) Write the equation for the reaction that occurs when butylamine is dissolved in water. State symbols are not required.

(1)

*(iii) Suggest why the dibutylamine solution is more alkaline than the butylamine solution.

(2)

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*(iv) Suggest why the phenylamine solution is much less alkaline than the butylamine solution.

(2)

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.....

(b) When butylamine is added to an aqueous solution of copper(II) sulfate, initially a pale blue precipitate is formed. When excess butylamine is added, the precipitate dissolves to form a deep blue solution.

Complete the equations below. State symbols are not required.

(4)

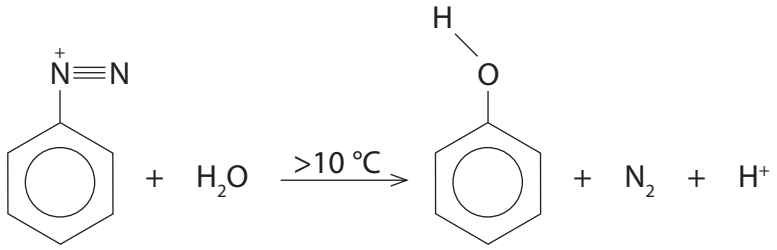
I Formation of the pale blue precipitate

$Cu(H_2O)_6^{2+} + 2C_4H_9NH_2 \rightarrow$

II The overall equation for the formation of the deep blue solution

$Cu(H_2O)_6^{2+} + 4C_4H_9NH_2 \rightarrow$

*(c) When phenylamine is treated with a mixture of sodium nitrite, $NaNO_2$, and hydrochloric acid at about 5 °C, the resulting solution contains the benzenediazonium ion. If the temperature of this solution is allowed to rise above 10 °C, the benzenediazonium ion reacts to form phenol:



By considering the role of the water molecule in this reaction, state the type and mechanism occurring and explain why it is unusual in benzene chemistry.

(2)

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(Total for Question 23 = 12 marks)

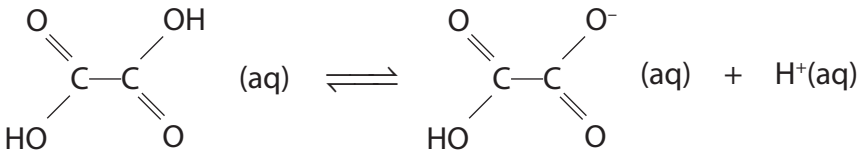
TOTAL FOR SECTION B = 49 MARKS

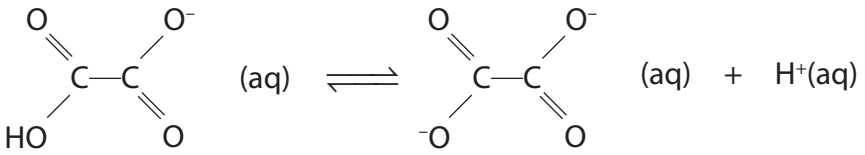
SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

24

Ethanedioic acid (also known as oxalic acid) is a dicarboxylic acid. Like sulfuric acid, it has two replaceable hydrogen atoms so it dissociates in two stages which are shown below. Acids like these are called 'dibasic'.





As is always the case with dibasic acids, the first dissociation occurs to a far greater extent than the second. Ethanedioic acid is a carboxylic acid but, because there are two carboxyl groups, it is a much stronger acid than ethanoic acid.

Ethanedioic acid is toxic, mainly due to the precipitation of calcium ethanedioate in the kidneys. As it occurs in many plants, the toxicity of ethanedioic acid has caused a number of deaths notably during the First World War when people in England used rhubarb leaves, which contain significant concentrations of the compound, as a vegetable substitute. As it is a reducing agent, the concentration of ethanedioic acid is usually determined by titration with a solution of potassium manganate(VII) of known concentration.

The ethanedioate ion, which is formed when ethanedioic acid dissociates fully, is a bidentate ligand. The ethanedioate ion together with 1,2-diaminocyclohexane, another bidentate ligand, forms a complex with platinum(II) called oxaliplatin which has the same geometry as cisplatin. Oxaliplatin is an anti-cancer drug, which has been used to treat cancers that have become resistant to cisplatin.

Ethanedioic acid has numerous uses, from cleaning and rust removal to the purification of metals. Although it can be prepared from ethene in a two stage process, it is usually manufactured by the oxidation of carbohydrates or glucose using nitric acid, or air, in the presence of vanadium(V) oxide.

(a) (i) Suggest why the presence of the second carboxylic acid group increases the extent of the **first** dissociation of ethanedioic acid compared with the dissociation of ethanoic acid.

(2)

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.....

(ii) Explain, by referring to the equilibria in the passage, why the second dissociation of a dibasic acid occurs to a lesser extent than the first.

(1)

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(b) In an experiment to determine the proportion of ethanedioic acid in rhubarb leaves, 250 g of leaves was crushed and boiled in a solution of sodium carbonate. The resulting mixture was filtered and the filtrate transferred, along with washings from the mixture, to a 250 cm^3 volumetric flask. The solution was acidified with sulfuric acid, made up to the mark and mixed thoroughly. 25.0 cm^3 portions of the solution were pipetted into a conical flask, about 25 cm^3 of sulfuric acid added and the mixture titrated against a solution of potassium manganate(VII) of concentration 0.0200 mol dm^{-3}. The mean titre was 28.55 cm^3. The relevant ionic half equations for the reaction are

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

$$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$

(i) State the colour change that occurs at the end-point of the titration.

(1)

.....

*(ii) Calculate the percentage by mass of ethanedioic acid in rhubarb leaves.

(5)

(c) (i) Explain the term 'bidentate'.

(1)

.....

.....

(ii) Draw a diagram of the oxaliplatin(II) complex, showing clearly the geometry and charge of the complex and how the ligands are attached to the central ion.

(3)

(d) (i) Suggest a two step **laboratory** synthesis of ethanedioic acid from ethene. Indicate the intermediate compound formed and the reagents required.

(3)

(ii) Suggest why it is preferable from an environmental perspective that ethanedioic acid is manufactured from carbohydrates and glucose rather than from ethene.

(1)

(iii) A sample of ethanedioic acid, manufactured from glucose, was contaminated with a small amount of propanoic acid.

High resolution nmr may be used to distinguish propanoic acid from ethanedioic acid.

Describe the high resolution nmr spectra of both propanoic acid and ethanedioic acid. Do **not** include chemical shift data in your answer.

(4)

(Total for Question 24 = 21 marks)

TOTAL FOR SECTION C = 21 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

* Actinide 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
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

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Mark Scheme (Results)

Summer 2013

GCE Chemistry 6CH05/01R
General Principles of Chemistry II

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Summer 2013
Publications Code UA035574

General Marking Guidance

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

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

Using the Mark Scheme

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

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

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

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

Quality of Written Communication

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

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

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	C		**1**

Question Number	Correct Answer	Reject	Mark
2	D		**1**

Question Number	Correct Answer	Reject	Mark
3	B		**1**

Question Number	Correct Answer	Reject	Mark
4	A		**1**

Question Number	Correct Answer	Reject	Mark
5(a)	C		**1**
(b)	A		**1**

Question Number	Correct Answer	Reject	Mark
6	C		**1**

Question Number	Correct Answer	Reject	Mark
7	D		**1**

Question Number	Correct Answer	Reject	Mark
8	D		**1**

Question Number	Correct Answer	Reject	Mark
9	B		**1**

Question Number	Correct Answer	Reject	Mark
10	A		**1**

Question Number	Correct Answer	Reject	Mark
11	D		**1**

Question Number	Correct Answer	Reject	Mark
12	C		**1**

Question Number	Correct Answer	Reject	Mark
13	C		**1**

Question Number	Correct Answer	Reject	Mark
14	A		**1**

Question Number	Correct Answer	Reject	Mark
15	A		**1**

Question Number	Correct Answer	Reject	Mark
16	B		**1**

Question Number	Correct Answer	Reject	Mark
17	B		**1**

Question Number	Correct Answer	Reject	Mark
18	D		**1**

Question Number	Correct Answer	Reject	Mark
19	A		**1**

Total for Section A = 20 Marks

Section B

Question Number	Acceptable Answers	Reject	Mark
20(a)(i)	$Cr_2(SO_4)_3(aq) = Cr(H_2O)_6^{3+}$ ALLOW $Cr^{3+}(aq)$ / Cr^{3+} **(1)** A = $Cr(H_2O)_3(OH)_3$ / $Cr(OH)_3$ **(1)** B = $Cr(H_2O)_2(OH)_4^-$ / $Cr(OH)_4^-$ / $Cr(OH)_6^{3-}$ **(1)** C = CrO_4^{2-} **(1)** IGNORE SO_4^{2-} and/or Na+		**4**

Question Number	Acceptable Answers	Reject	Mark
20(a)(ii)	$H_2O_2 + 2e^{(-)} \rightarrow 2OH^-$		**1**

Question Number	Acceptable Answers	Reject	Mark
20(a)(iii)	Sulfuric acid / H_2SO_4 ALLOW Name or formula of any strong acid (e.g. HCl) IGNORE H^+ and 'an acid' Dilute or concentrated		**1**

Question Number	Acceptable Answers	Reject	Mark
20(a)(iv)	$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ ALLOW Equation showing Na^+ and anion on both sides IGNORE State symbols even if incorrect	Non-ionic equations	**1**

Question Number	Acceptable Answers	Reject	Mark
20(b)	**First mark for both half equations** Mentions / some evidence for the use of BOTH half equations in any way even if reversed or left unbalanced $Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$ ($E^\ominus = -0.41$ V) $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$ $\rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ ($E^\ominus = +1.33$ V) **(1)** **Second mark for** $8Cr^{3+}(aq) + 7H_2O(l) \rightarrow 6Cr^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq)$ **(1)** **Third mark for** $E^\ominus_{cell} = -0.41 - 1.33 = -1.74$ (V) For **second** and **third marks,** ALLOW reverse equation and $E^\ominus_{cell} = +1.74$ (V) (for **reverse** reaction) **(1)** ALLOW 1.74 (V) only if 'positive' stated in words elsewhere **Fourth mark for** EITHER Disproportionation / (proposed) reaction / "it is" **not feasible** (because its $E^\ominus_{cell}$ is negative) OR Reverse of disproportionation **is feasible** (because its $E^\ominus_{cell}$ is positive) **(1)** IGNORE state symbols even if incorrect ALLOW $\rightleftharpoons$ instead of $\rightarrow$ Third and fourth marks can be awarded CQ on incorrect half equation(s) and stated $E^\ominus$ values		**4**

Total for Question 20 = 11 Marks

Question Number	Acceptable Answers	Reject	Mark
21(a)	−285.8 / −286 (kJ mol^{-1})		**1**

Question Number	Acceptable Answers	Reject	Mark
21(b)(i)	$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^{(-)}$ **(1)** $O_2(g) + 2H_2O(l) + 4e^{(-)} \rightarrow 4OH^-(aq)$ **(1)** **For state symbols mark:** Two of the four stated equations (see the two equations above and the two equations below) must be quoted even if reversed or unbalanced. All state symbols must be correct in **both** equations for correct species for the state symbol mark (penalise once only) **(1)** Both equations for an **acid** fuel cell score max 2 (1 for correct equations and 1 for states) e.g. $H_2(g) \rightarrow 2H^+(aq) + 2e^{(-)}$ OR $H_2(g) - 2e^{(-)} \rightarrow 2H^+(aq)$ $O_2(g) + 4H^+(aq) + 4e^{(-)} \rightarrow 2H_2O(l)$ ALLOW Equation multiples Equations in reverse direction Any order of equations Reversible arrows		**3**

Question Number	Acceptable Answers	Reject	Mark
21(b)(ii)	Electrolyte / to allow the movement of ions (between electrodes) ALLOW Movement of hydrogen ions/ oxonium ions / hydroxonium ions / hydronium ions / H^+ / H_3O^+ / hydroxide ions / OH^- (between electrodes) IGNORE References to electron transfer	Catalyst Just 'conducts electricity' Movement of other ions / charged species	**1**

Question Number	Acceptable Answers	Reject	Mark
21(b)(iii)	Any two of Both involve breaking / weakening bonds OR Both involve active site(s) (on the catalyst surface) OR **Ad**sorption **(2)** IGNORE Lowers the activation energy Both heterogeneous References to surface area or "surface for the reaction" References to orientation of reactant molecules "Reaction pathway is similar"	**Ab**sorption	**2**

Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	Water is the **only** product (at the point of use) / **no** oxide(s) of carbon IGNORE Reference to efficiency and/or high energy density Greener	**Less** oxide(s) of carbon	**1**

Question Number	Acceptable Answers	Reject	Mark
21(c)(ii)	**Any two from:** Fuel cell is more efficient / 70% efficient ALLOW Any % between 70% and 100% It produces electricity directly OR **Less** heat loss Releasing energy in a more controlled manner **(2)** IGNORE References to safety	Any mention of carbon emissions	**2**

Question Number	Acceptable Answers	Reject	Mark
21(c)(iii)	**Either** High cost / expensive OR Cost of catalyst OR Short life-span IGNORE References to liquefaction and / or storage of hydrogen / size / weight		**1**

Question Number	Acceptable Answers	Reject	Mark
21(c)(iv)	**Any two from** Ethanol renewable / sustainable / carbon neutral / availability of raw materials / low(er) carbon footprint / made from natural processes e.g. fermentation or biomass Less explosive / less flammable / safe(r) Easier to store / pressure not needed for storage / easier to transfer Fuel tank light(er) / small(er) New petrol stations not required ALLOW Reverse arguments for hydrogen IGNORE Reference to cost References to energy density		**2**

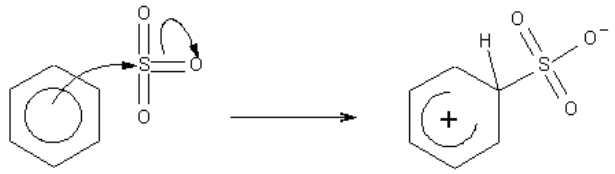
Total for Question 21 = 13 Marks

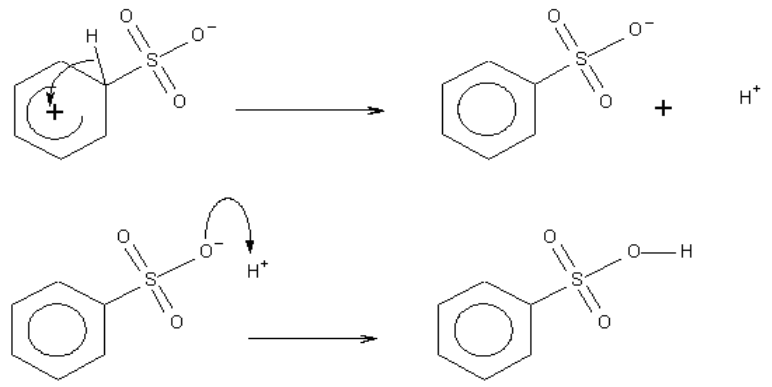
Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	**Fuming** sulfuric acid / **fuming** H_2SO_4 / oleum / $H_2S_2O_7$	Conc. (for fuming) Fuming dilute sulfuric acid **Just** sulfuric acid **Just** H_2SO_4	**1**

Question Number	Acceptable Answers	Reject	Mark
22(a)(ii)	Sulfur is δ+ and on at least one oxygen δ- **(1)** Oxygen is (much) more electronegative than sulfur ALLOW Oxygen is very electronegative **(1)**	Full + or – charge(s) 1/3 – on each oxygen	**2**

Question Number	Acceptable Answers	Reject	Mark
22 (a)(iii)	The sulfur trioxide can accept a pair of electrons OR (Three oxygen atoms so) sulfur has a large δ or partial / slight positive charge OR π bonds allow S—O bonds to be polarized more easily ALLOW Electron-deficient sulfur	An electron	**1**

Marks for (b)(i) and (b)(ii) can be awarded from either of the two annotated diagrams on item

Question Number	Acceptable Answers	Reject	Mark
22(b)(i)	 First curly arrow as shown to start inside the hexagon to the S atom **(1)** Second curly arrow from bond to O (i.e. not from the S atom itself) **(1)** ALLOW Second curly arrow to any of the three O atoms in SO_3 IGNORE A full + charge on S		**2**

Question Number	Acceptable Answers	Reject	Mark
22 (b)(ii)	 Curly arrow as shown from the C-H bond to reform the ring in first line, not from the H atom in this bond **(1)** Intermediate anion formed in first line (H^+ does not have to be shown) **(1)** Last line with curly arrow and correct structure of benzenesulfonic acid **(1)** ALLOW Use of H_2SO_4 for H^+ with HSO_4^- as other product in final step The marks for (b)(ii) may be awarded from annotations on the right hand structure given in question in (b)(i) If contradictory arrows drawn on structure in question (b)(ii), then penalise any such inconsistency The three marks for the two steps in (b)(ii) can be shown in one step / diagram / structure ALLOW $-SO_3H$ undisplayed	Use of H_2O for H^+ $-HSO_3$	**3**

Question Number	Acceptable Answers	Reject	Mark
22(c)(i)	$C_6H_5SO_3H + 3NaOH \rightarrow C_6H_5ONa + Na_2SO_3 + 2H_2O$ **(1)** ALLOW Charges on $C_6H_5O^-Na^+$ $C_6H_5ONa + HCl \rightarrow C_6H_5OH + NaCl$ **(1)** ALLOW $C_6H_5O^- + HCl \rightarrow C_6H_5OH + Cl^-$ OR $C_6H_5O^- + H^+ \rightarrow C_6H_5OH$	Charges on $C_6H_5SO_3H$	**2**

Question Number	Acceptable Answers	Reject	Mark
22(c)(ii)	**Any two from:** (Both) products useful / both are useful / propanone is useful So less waste / high(er) atom economy Fewer steps / one step / does not require many steps (in Hock synthesis) Continuous rather than a batch process **(2)** IGNORE "Only one waste product in Hock" Comments relating to hazardousness of reactants / safety / energy requirements References to yield References to efficiency References to rate	Cheaper	**2**

Total for Question 22 = 13 Marks

Question Number	Acceptable Answers	Reject	Mark
23(a)(i)	Lone pair(s) (of electrons on the nitrogen) ALLOW Non-bonded pair(s)	Spare pair	**1**

Question Number	Acceptable Answers	Reject	Mark
23(a)(ii)	$CH_3CH_2CH_2CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+ + OH^-$ ALLOW $\rightarrow$ for $\rightleftharpoons$ IGNORE state symbols even if incorrect Right hand ions must be shown separately ALLOW $C_4H_9NH_2$	Reject near misses	**1**

Question Number	Acceptable Answers	Reject	Mark
23(a)(iii)	**Any two of:** Butyl / alkyl groups are electron donating / are electron pushing / are electron releasing Two (alkyl) groups in dibutylamine (but only one in butylamine) **Lone pair** (of electrons) on the nitrogen more readily available / higher electron density on the nitrogen or NH_2 or amine group / N more delta negative / N or NH_2 accepts a proton more readily **(2)** Stand alone marks Accept reverse argument for butylamine IGNORE 'electronegativity of nitrogen increasing'		**2**

Question Number	Acceptable Answers	Reject	Mark
23(a)(iv)	**First mark** For the idea of the **lone pair** being withdrawn towards the ring e.g. Lone pair pulled into the ring Lone pair (of electrons) on the nitrogen overlap Lone pair interacts with π electrons / lone pair interacts with delocalized electrons of the (benzene) ring Lone pair (of electrons) on the nitrogen donated to the (benzene) ring **(1)** NOTE The reference to the lone pair may be found in a later part of the answer and credited **Second mark** EITHER For the idea of the **lone pair** being less available OR The **nitrogen** (atom) must be specified as below e.g. Lone pair is less readily available Nitrogen (atom) has lower electron density N (atom) or lone pair is less able to accept protons / H^+ **(1)** ALLOW N is less δ^- for second mark		**2**

Question Number	Acceptable Answers		Mark
23(b)	I $(Cu(H_2O)_6^{2+} + 2C_4H_9NH_2) \rightarrow Cu(H_2O)_4(OH)_2 + 2C_4H_9NH_3^+$ ALLOW I $(Cu(H_2O)_6^{2+} + 2C_4H_9NH_2) \rightarrow Cu(OH)_2 + 2C_4H_9NH_3^+ + 4H_2O$ **(2)** II $(Cu(H_2O)_6^{2+} + 4C_4H_9NH_2) \rightarrow Cu(H_2O)_2(C_4H_9NH_2)_4^{2+} + 4H_2O$ ALLOW II $(Cu(H_2O)_6^{2+} + 4C_4H_9NH_2) \rightarrow Cu(C_4H_9NH_2)_4^{2+} + 6H_2O$ **(2)** Each correct equation scores 2 marks: 1 mark for the formula of the copper complex ion and 1 mark for the rest of the equation being correct Ligands can be in either order IGNORE state symbols even if incorrect IGNORE (lack of) square brackets around complex ions		**4**

Question Number	Acceptable Answers	Reject	Mark
23(c)	Reaction is a nucleophilic substitution **(1)** It is unusual because benzene normally reacts with electrophiles / by electrophilic substitution OR Positive charge withdraws electrons from the ring (making it susceptible to nucleophilic attack) OR Expect nucleophiles to be repelled by the electron density of the ring **(1)**		**2**

Total for Question 23 = 12 Marks

Total for Section B = 49 Marks

Section C

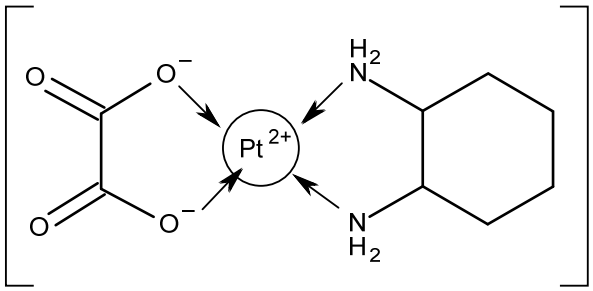
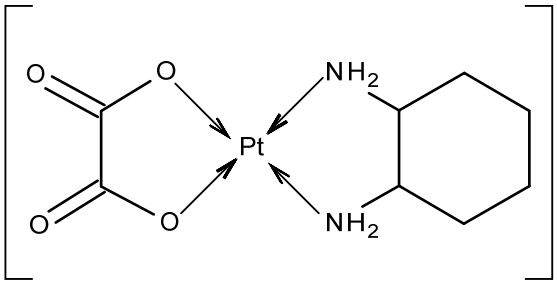
Question Number	Acceptable Answers	Reject	Mark
24(a)(i)	The electron withdrawing effect of the (extra) COOH group / oxygen atoms **(1)** Increases the stability of the (hydrogenethanedioate) ion ALLOW Weakens the OH bond **(1)** IGNORE Reference to OH bond becoming more polar		**2**

Question Number	Acceptable Answers	Reject	Mark
24(a)(ii)	H^+ ions formed (in first dissociation) shifts (second equilibrium) to the left ALLOW H^+ formed suppresses (second) ionization		**1**

Question Number	Acceptable Answers	Reject	Mark
24(b)(i)	Colourless to (pale) pink ALLOW purple for pink	Clear for colourless	**1**

Question Number	Acceptable Answers	Reject	Mark
24(b)(ii)	Amount of MnO_4^- = 28.55 x 10^{-3} x 0.0200 (= 5.71 x 10^{-4} mol) **(1)** Amount of $C_2O_4^{2-}$ = 5.71 x 10^{-4} x $\frac{5}{2}$ **(1)** = 1.4275 x 10^{-3} (mol) Amount of $C_2O_4^{2-}$ in 250 cm^3 / rhubarb leaves = 1.4275 x 10^{-3} x 10 = 1.4275 x 10^{-2} (mol) **(1)** Mass $H_2C_2O_4$ in 250 cm^3 = 1.4275 x 10^{-2} x 90 **(1)** = 1.28475 g % $H_2C_2O_4$ in rhubarb = $\frac{1.28475}{250}$ x 100 = 0.5139 % **(1)** IGNORE SF except 1 SF Correct answer with no working scores 5 TE on all parts of calculation If M_r = 88 used then final answer is 0.50248%		**5**

Question Number	Acceptable Answers	Reject	Mark
24(c)(i)	(Ligand that) Has two lone pairs that can bond (separately) (to the central ion / atom) OR Occupies two coordination positions (around a central ion / atom) OR Two points of attachment (to the central ion / atom) OR Forms two **dative** bonds (to the central ion / atom) OR Two atoms of the same ion / molecule that bond with central metal ion / atom	Two ligands **Just** two lone pairs	**1**

Question Number	Acceptable Answers	Reject	Mark
24(c)(ii)	 Or  Square planar shape around Pt drawn as above and zero net charge NOTE The structure of each ligand must be totally correct **(1)** Both nitrogen atoms attached **and** both C-O oxygen atoms attached from separate COO^- groups **(1)** **Dative** covalent bonds **(1)** **Mark each point separately**	Different oxygen atoms from the same carboxyl group attached to different coordination positions. If O attached from a C=O oxygen	3

Question Number	Acceptable Answers	Reject	Mark
24(d)(i)	(Alkaline or neutral or acidified) potassium manganate(VII) / $KMnO_4$ / MnO_4^- **(1)** Forms ethane-1,2-diol (name or structural / skeletal / displayed formula) **(1)** NOTE It does not matter how the ethane-1,2-diol has been formed (Oxidized by) (refluxing with) acidified potassium dichromate(VI) / $Cr_2O_7^{2-}$ and H^+ OR Acidified/alkaline potassium manganate(VII) / MnO_4^- with either H^+ or OH^- OR (Oxidized by) nitric acid (c.f. passage) **(1)** **Mark each point separately** Max 2 for a three step synthesis e.g. bromine followed by NaOH then oxidation ALLOW correct formulae instead of names	Molecular formula $C_2H_6O_2$ Air catalyzed by V_2O_5	**3**

Question Number	Acceptable Answers	Reject	Mark
24(d)(ii)	Carbohydrates and / or glucose are obtained from renewable / sustainable resources (whereas ethene is obtained from crude oil) ALLOW Reverse argument for ethene		**1**

Question Number	Acceptable Answers	Reject	Mark
24(d)(iii)	**Ethanedioic acid** Will have one (singlet) peak / hydrogen environment (due to the COOH protons) **(1)** **Propanoic acid** Will have three peaks / three hydrogen environments **(1)** Triplet, quartet / quadruplet & singlet in any order OR Split(ting) pattern 3,4,1 in any order **(1)** NOTE If first mark for **propanoic acid** hasn't been awarded "triplet, quartet / quadruplet & singlet" **scores 2** Intensity in ratio 3:2:1 in any order **(1)** ALLOW labelled and annotated diagrams Max. 3 if not clear that hydrogens/protons give rise to the peaks		**4**

Total for Section C = 21 Marks

Total for Paper = 90 Marks

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