EDEXCEL A-LEVEL CHEMISTRY

CHEMISTRY



EXAM QUESTION PACK

UNIT 5 OLD SPECIFICATION PAPERS

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Write your name here

Surname	Other names

Pearson 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 19 June 2017 – Morning
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet
Scientific calculator

Total Marks

Instructions

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

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- 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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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 Which species contains an element with the same oxidation number as vanadium has in NH_4VO_3?

☒ **A** $[AlH_4]^-$

☒ **B** K_2MnO_4

☒ **C** $NaClO_3$

☒ **D** $[Fe(CN)_6]^{4-}$

(Total for Question 1 = 1 mark)

2 Which of the following is **not** a disproportionation reaction?

☒ **A** $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

☒ **B** $6KOH + 3I_2 \rightarrow KIO_3 + 5KI + 3H_2O$

☒ **C** $2H_2O_2 \rightarrow 2H_2O + O_2$

☒ **D** $2CuI \rightarrow CuI_2 + Cu$

(Total for Question 2 = 1 mark)

3 The half-equation of a standard half-cell containing $Zn^{2+}(aq)\,|\,Zn(s)$ is

$$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s) \qquad E^{\ominus} = -0.76\,V$$

This is connected to a standard hydrogen electrode in a circuit and a current flows.
At the zinc electrode

☒ **A** zinc atoms are reduced.

☒ **B** zinc ions are reduced.

☒ **C** zinc atoms are oxidized.

☒ **D** zinc ions are oxidized.

(Total for Question 3 = 1 mark)

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4 Use the data provided to deduce the species which reacts with $V^{3+}(aq)$ to form $VO^{2+}(aq)$.

Electrode reaction	Standard electrode potential/ V
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.44
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80

☒ **A** $Fe^{2+}(aq)$

☒ **B** $Fe(s)$

☒ **C** $Ag^+(aq)$

☒ **D** $Ag(s)$

(Total for Question 4 = 1 mark)

5 In a fuel cell breathalyser, the following reaction occurs at one electrode.

$$C_2H_5OH(g) + H_2O(l) \rightarrow CH_3COOH(aq) + 4H^+(aq) + 4e^-$$

The reaction occurring at the other electrode is

☒ **A** $4H^+(aq) + O_2(g) + 4e^- \rightarrow 2H_2O(l)$

☒ **B** $2H_2(g) + 2O_2(g) + 4e^- \rightarrow 4OH^-(aq)$

☒ **C** $4OH^-(aq) \rightarrow 2H_2(g) + 2O_2(g) + 4e^-$

☒ **D** $2H_2O(l) \rightarrow 4H^+(aq) + O_2(g) + 4e^-$

(Total for Question 5 = 1 mark)

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6 Dilute aqueous sodium hydroxide and dilute aqueous ammonia are added to separate samples of aqueous nickel(II) chloride. In each case a green precipitate forms. What would be observed when excess alkali is added to the green precipitate?

		Addition of excess NaOH(aq)	Addition of excess NH_3(aq)
☒	**A**	Precipitate remains	Precipitate remains
☒	**B**	Precipitate remains	Precipitate dissolves to form a blue solution
☒	**C**	Precipitate dissolves to form a green solution	Precipitate remains
☒	**D**	Precipitate dissolves to form a green solution	Precipitate dissolves to form a blue solution

(Total for Question 6 = 1 mark)

7 In the reaction of sodium thiosulfate solution with iodine, the half-equation for the reaction of the thiosulfate ions is

☒ **A** $S_2O_3^{2-} + 3H_2O \rightarrow 2SO_3^{2-} + 6H^+ + 4e^-$

☒ **B** $S_2O_3^{2-} + 3H_2O + 4e^- \rightarrow 2SO_3^{2-} + 6H^+$

☒ **C** $2S_2O_3^{2-} + 2e^- \rightarrow S_4O_6^{2-}$

☒ **D** $2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$

(Total for Question 7 = 1 mark)

8 In the titration of sodium thiosulfate solution with iodine, starch indicator is added near the end-point. This is because

☒ **A** there is no warning of the end-point if starch is added at the start.

☒ **B** high concentrations of iodine decompose the starch.

☒ **C** the blue-black colour showing the presence of iodine would not be seen.

☒ **D** an insoluble complex forms between starch and high concentrations of iodine.

(Total for Question 8 = 1 mark)

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9 Evidence that the carbon-carbon bonds in benzene are all the same length is provided by

☒ **A** X-ray diffraction.

☒ **B** infrared spectroscopy.

☒ **C** a comparison of the enthalpy changes for the addition of hydrogen to benzene and the theoretical compound cyclohexa-1,3,5-triene.

☒ **D** a comparison of the rates of reaction of benzene and alkenes with bromine.

(Total for Question 9 = 1 mark)

10 The product of the reaction of benzene with sulfur trioxide dissolved in concentrated sulfuric acid is

☒ **A** $C_6H_5SO_3$

☒ **B** $C_6H_5SO_3H$

☒ **C** $C_6H_5SO_4$

☒ **D** $C_6H_5HSO_4$

(Total for Question 10 = 1 mark)

11 Benzene reacts with ethanoyl chloride in the presence of aluminium chloride. The equation for the reaction of ethanoyl chloride with aluminium chloride is

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

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

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

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

(Total for Question 11 = 1 mark)

12 In the high resolution proton nmr spectrum of butanone, $C_2H_5COCH_3$, there will be

☒ **A** one doublet and two triplets.

☒ **B** one quartet and one sextet.

☒ **C** one singlet, one triplet and one quartet.

☒ **D** one singlet, one doublet and one triplet.

(Total for Question 12 = 1 mark)

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13 The compounds $C_2H_5COOCH_3$ and $CH_3COOC_2H_5$ are most easily differentiated by the

- ☒ **A** infrared spectra outside the fingerprint region.
- ☒ **B** fragmentation patterns in their mass spectra.
- ☒ **C** splitting patterns in their high resolution nmr spectra.
- ☒ **D** numbers of peaks in their low resolution nmr spectra.

(Total for Question 13 = 1 mark)

14 The infrared spectrum of an organic compound with molecular formula $C_8H_8O_2$ has a strong peak in the range 1700–1680 cm^{-1} and a broad peak above 3300 cm^{-1}.

The compound could be

- ☒ **A** $H_3CC_6H_4COOH$
- ☒ **B** $C_6H_5CH_2COOH$
- ☒ **C** $C_6H_5COOCH_3$
- ☒ **D** $HOC_6H_4COCH_3$

(Total for Question 14 = 1 mark)

15 An organic compound is very soluble in water forming an alkaline solution that reacts with copper(II) ions to give a coloured product.

The compound is most likely to be

- ☒ **A** $C_4H_9NH_2$
- ☒ **B** C_4H_9CN
- ☒ **C** $C_6H_5NH_2$
- ☒ **D** $C_6H_5NO_2$

(Total for Question 15 = 1 mark)

16 The polymer poly(ethenol), which has the formula $\text{-}[CH_2CH(OH)]\text{-}_n$ is used to make capsules for liquid detergents because

- ☒ **A** it is inert.
- ☒ **B** it is water-soluble.
- ☒ **C** London forces between its molecules are very strong.
- ☒ **D** it neutralises acids that could harm fabrics.

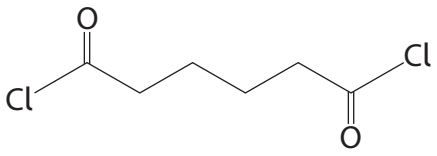
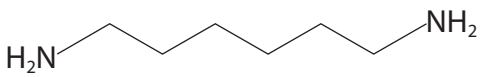
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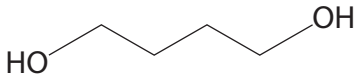
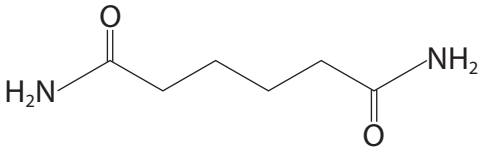
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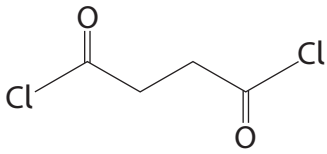
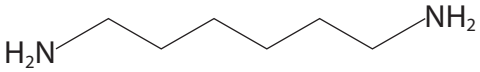
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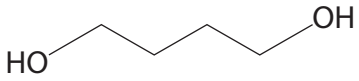
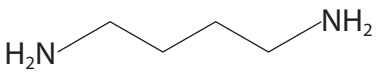
17 The formula of the repeat unit of a polymer is $-[OC(CH_2)_4CONH(CH_2)_6NH]-$.

The polymer is formed by the reaction of

☒ **A**  and 

☒ **B**  and 

☒ **C**  and 

☒ **D**  and 

(Total for Question 17 = 1 mark)

18 On combustion, 0.50 mol of a primary alcohol produced 45 g of water and 88 g of carbon dioxide.

The alcohol could be

☒ **A** ethanol

☒ **B** propan-1-ol

☒ **C** butan-1-ol

☒ **D** pentan-1-ol

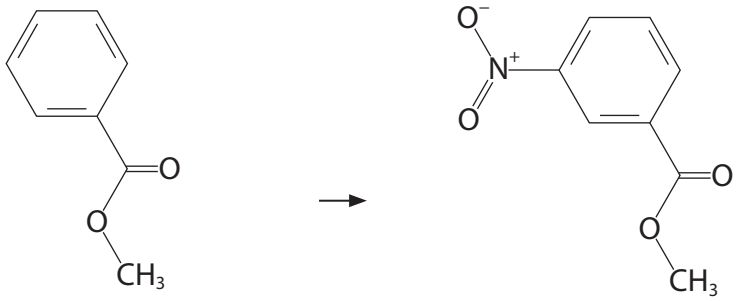
(Total for Question 18 = 1 mark)

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19 Crystals of methyl 3-nitrobenzoate can be prepared by nitration of methyl benzoate. The reaction is carried out in a flask surrounded by ice, and the product is purified by recrystallization from ethanol.



methyl benzoate
Molar mass = 136 g mol^{-1}

methyl 3-nitrobenzoate
Molar mass = 181 g mol^{-1}

(a) In this preparation, 2.00 g of methyl benzoate produced 1.50 g of methyl 3-nitrobenzoate. The percentage yield is

(1)

☒ **A** 82.9

☒ **B** 75.0

☒ **C** 56.4

☒ **D** 15.0

(b) In the recrystallization step, the highest yield will be obtained when

(1)

☒ **A** using excess ethanol to dissolve the crude solid.

☒ **B** heating the ethanol to 20 °C below its boiling temperature.

☒ **C** slowly filtering the hot mixture to remove insoluble impurities.

☒ **D** crystallizing the filtrate using an ice bath.

(Total for Question 19 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

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

20 Benzenediazonium chloride, $C_6H_5N_2^+Cl^-$, can be prepared from benzene in a series of steps.

$$C_6H_6 \xrightarrow{\text{Step 1}} C_6H_5NO_2 \xrightarrow{\text{Step 2}} \text{Compound } \mathbf{X} \xrightarrow{\text{Step 3}} C_6H_5N_2^+Cl^-$$

(a) (i) Identify the substances that are used to convert benzene into $C_6H_5NO_2$ in Step **1**.

(1)

.....

(ii) Give the mechanism of the reaction taking place in Step **1**, including one or more equations for the formation of the electrophile.

(4)

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(iii) Identify compound **X** and state the reagents needed to prepare it in Step **2**.

(2)

Compound **X** .....

Reagents .....

(iv) State the reagents and condition needed to convert compound **X** into benzenediazonium chloride in Step **3**.

(2)

Reagents .....

Condition .....

(b) Benzenediazonium chloride is used to prepare dyes.

Write an equation for a reaction of benzenediazonium chloride with a compound of your choice in which the product is a dye. Show the structure of the dye in your equation.

(2)

(c) Benzenediazonium chloride can be converted into benzoic acid, C_6H_5COOH, in two steps. The first step is a substitution reaction to produce the nitrile, C_6H_5CN. State the reagent needed for the second step.

(1)

.....

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(d) An aqueous solution of benzenediazonium chloride decomposes when it is warmed. The products of decomposition are a colourless unreactive gas, hydrochloric acid and an aryl (aromatic) compound. A white precipitate forms when bromine water is added to this aryl compound.

(i) Write a balanced equation showing the decomposition of an aqueous solution of benzenediazonium chloride. State symbols are not required.

(2)

(ii) Give the formula of the white precipitate.

(1)

(Total for Question 20 = 15 marks)

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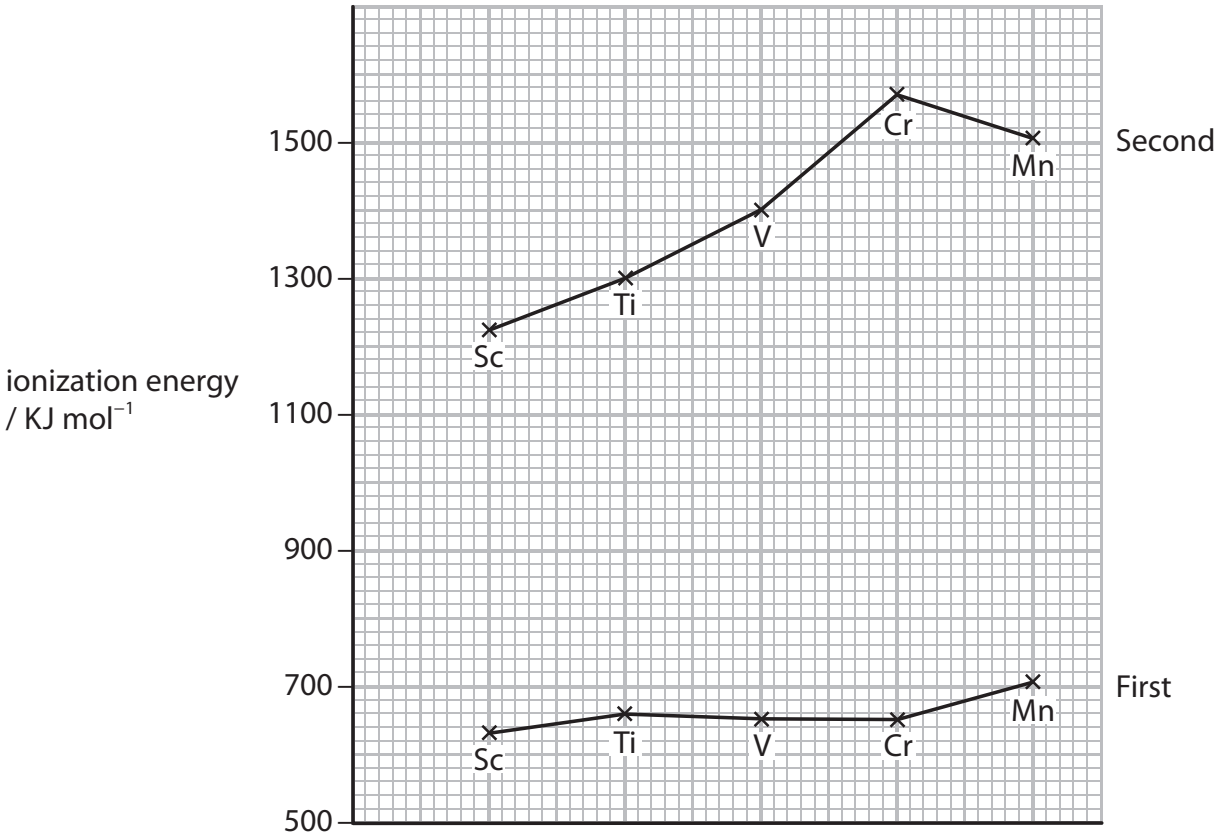
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21 This question is about the chemistry of chromium.

(a) The graph below shows the first and second ionization energies of the elements scandium to manganese.



(i) Explain why the values for the **first** ionization energies are very similar.

(2)

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*(ii) The electronic configuration of a chromium atom is [Ar] $3d^5 4s^1$

By considering the electronic configurations of the singly charged ions of vanadium, chromium and manganese, suggest why the second ionization energy of chromium is higher than the corresponding values for vanadium and manganese.

(3)

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(b) The table below shows the formulae of ions of chromium which exist in aqueous solution.

Ion	Oxidation number of chromium	Colour in aqueous solution
$Cr(H_2O)_6^{2+}$	+2	Blue
$Cr(H_2O)_6^{3+}$		
CrO_4^{2-}		
$Cr_2O_7^{2-}$		

(i) Complete the table above by adding the missing oxidation numbers and colours.

(3)

*(ii) Explain why the $Cr(H_2O)_6^{3+}$ ion is coloured.

(4)

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(iii) A solution containing aqueous Cr^{3+} ions reacts with zinc in suitable conditions to form Cr^{2+} ions and Zn^{2+} ions.

Draw a diagram of a cell that can be used to measure $E^{\ominus}_{cell}$ for the reaction. State the conditions which are necessary.

(3)

(iv) Use your Data booklet to calculate $E^{\ominus}_{cell}$.

(2)

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(c) A solution containing $Cr^{3+}(aq)$ ions is oxidized by hydrogen peroxide in the presence of hydroxide ions to form CrO_4^{2-} ions.

The half-equation for the reduction of hydrogen peroxide is

$$H_2O_2(aq) + 2e^- \rightarrow 2OH^-(aq)$$

(i) Write the half-equation for the oxidation of $Cr^{3+}(aq)$ in the presence of hydroxide ions to form CrO_4^{2-} ions.

(1)

(ii) Hence write the overall equation for this reaction.

(1)

(d) Write the equation for the reaction of chromate(VI) ions with hydrogen ions.

(1)

(Total for Question 21 = 20 marks)

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22 This question is about some naturally occurring amino acids, which have the formula $RCH(NH_2)COOH$.

(a) Amino acids can exist as zwitterions. What is meant by the term zwitterion?

(1)

.....

.....

.....

.....

(b) In the amino acid serine, the formula of the R group is $—CH_2OH$.

The structure of serine varies with pH. Draw its structure at pH 1.0 and at pH 10.0.

(2)

Structure at pH 1.0	Structure at pH 10.0

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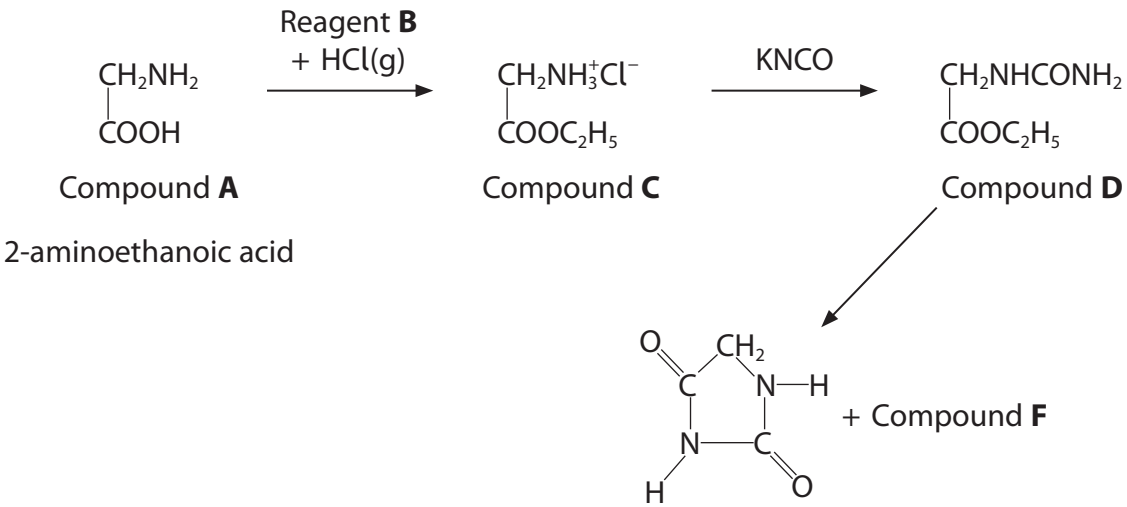
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(c) In the amino acid alanine, the formula of the R group is —CH_3. Alanine can polymerize forming a condensation polymer. Draw a section of this polymer showing **two** repeat units, displaying the link between them.

(2)

(d) Compound **A** is the amino acid 2-aminoethanoic acid. It can be converted in three steps into a cyclic compound, **E**, called hydantoin.



Compound **A**

2-aminoethanoic acid

Compound **C**

Compound **D**

Compound **E**

Hydantoin

(i) State a property shown by all naturally occurring amino acids **except** for 2-aminoethanoic acid.

(1)

.....

.....

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(ii) Name the **two** types of reaction which are occurring when 2-aminoethanoic acid is converted into compound **C**.

(2)

.....

.....

(iii) Suggest the identity of the other organic product, compound **F**, which forms when compound **D** is converted into compound **E**.

(1)

.....

(iv) When compound **E** reacts with hot dilute hydrochloric acid, 2-aminoethanoic acid is formed again, along with other products.

Suggest the type of reaction which is occurring.

(1)

.....

(v) Suggest the identity of the **two** products which also form in the reaction in (d)(iv).

(2)

.....

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(Total for Question 22 = 12 marks)

TOTAL FOR SECTION B = 47 MARKS

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SECTION C

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

23 This question is about complex ions.

Complex ions are ions in which a number of molecules or anions are bonded to a central metal cation.

Some of the first research on complex ions was carried out about 100 years ago, and demonstrated that there were two isomers with the molecular formula $Co(NH_3)_4Cl_3$.

In aqueous solution, many transition metal ions are surrounded by six water molecules forming ions such as $[Cu(H_2O)_6]^{2+}$. Complex ions, such as haem, are also found in biological systems. The haem groups are large organic molecules containing nitrogen atoms, which form complex ions with Fe^{2+}.

The shape of a complex ion depends on the number of bonds from the ligands to the central metal ion, and the different shapes can result in different types of stereoisomerism.

*(a) Explain why the formation of complex ions is a characteristic of transition metals, but Group 1 metals, such as sodium, do not show this property in general.

(2)

(b) (i) State all the types of bonding involving chloride ions in isomers of $Co(NH_3)_4Cl_3$

(1)

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(ii) The ion $[Co(NH_3)_4Cl_2]^+$ has stereoisomers. Name the type of stereoisomerism and explain how their structures differ.

The different structures may be shown on a diagram.

(2)

(c) Write the equation for the ligand exchange reaction of $[Cu(H_2O)_6]^{2+}$ with excess chloride ions from concentrated hydrochloric acid. State symbols are not required.

State the shape of the $[Cu(H_2O)_6]^{2+}$ ion, and suggest the shape of the copper complex ion produced.

(3)

Equation

Shape of $[Cu(H_2O)_6]^{2+}$ .....

Shape of complex ion produced .....

(d) (i) Explain the difference between monodentate and hexadentate ligands.

(2)

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*(ii) $EDTA^{4-}$ forms very stable complex ions. In solution, its reaction with copper ions can be represented as shown.

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

Explain why the equilibrium constant for this reaction is greater than that for the reaction of $[Cu(H_2O)_6]^{2+}$ with a monodentate ligand.

(2)

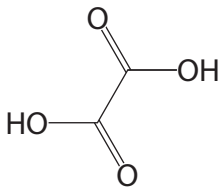
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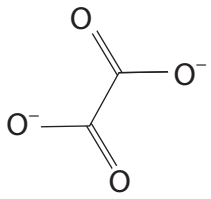
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(e) Crystals of a hydrated salt were prepared by reacting a solution containing iron(II) ions with a mixture of ethanedioic acid, $(COOH)_2$ and potassium ethanedioate, $K_2(COO)_2$ or $K_2C_2O_4$.



ethanedioic acid



ethanedioate ion

The resulting mixture was reacted with hydrogen peroxide, which oxidized the iron(II) ions and, after a suitable procedure was carried out, coloured crystals were produced.

The crystals contain a complex ion and the formula of the crystals can be written as $K_xFe_y(C_2O_4)_z(H_2O)_n$

The crystals were analysed.

(i) The percentage of water in 2.00 g of the crystals was measured by gentle heating until the mass was constant. The final mass was 1.78 g. Calculate the percentage by mass of water in the crystals.

(1)

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(ii) The percentage by mass of ethanedioate ions in the crystals was found by titrating an acidified solution containing 0.150 g of the crystals with a solution of 0.0100 mol dm^{-3} potassium manganate(VII). The titre was 36.60 cm^3.

The ethanedioate ions were oxidized by the manganate(VII) ions. The reactions which occur are

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

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

Use the titration results to calculate the percentage by mass of ethanedioate ions in the crystals.

(4)

(iii) To find the percentage by mass of iron in the crystals, they were first heated with concentrated sulfuric acid to decompose the ethanedioate ions, taking suitable safety precautions.

The iron ions in solution were then reduced to iron(II) ions with a suitable metal and these ions were then titrated with 0.0100 mol dm^{-3} potassium manganate(VII) solution. The iron(II) ions were oxidized to iron(III) ions in the titration.

Why must the ethanedioate ions be decomposed before determining the concentration of iron(II) ions?

(1)

.....

.....

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(iv) The percentage by mass of iron was found to be 11.4%.

Use this value, and the percentages of water and ethanedioate ions you have calculated, to deduce the percentage by mass of potassium in the crystals.

(1)

Species	Percentage by mass
water	
ethanedioate ions	
iron	11.4
potassium	

(v) The percentage by mass shows the **mass** of each species in 100 g.

Calculate the number of **moles** of each species in 100 g of the crystals and hence the ratio in moles.

(2)

Species	Number of moles in 100 g	Mole ratio
water		
ethanedioate ions		
iron		
potassium		

(vi) Suggest a formula, including the charge, for the complex ion present in the crystals.

(1)

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(vii) Draw a diagram showing how **one** ethanedioate ligand is bonded to the central metal ion.

(1)

(Total for Question 23 = 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

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Pearson

Mark Scheme (Results)

Summer 2017

Pearson Edexcel GCE
in Chemistry (6CH05) Paper 01
General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry

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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	Mark
1	**1. The only correct answer is C** ***A*** *is not correct because neither Al nor H has oxidation number +5* ***B*** *is not correct because neither K nor Mn has oxidation number +5* ***D*** *is not correct because neither Fe, C nor N has oxidation number +5*	**(1)**

Question Number	Correct Answer	Mark
2	**2. The only correct answer is A** ***B*** *is not correct because I disproportionates from 0 to +5 and -1* ***C*** *is not correct because O disproportionates from -1 to -2 and 0* ***D*** *is not correct because Cu disproportionates from +1 to +2 and 0*	**(1)**

Question Number	Correct Answer	Mark
3	**3. The only correct answer is C** ***A*** *is not correct because zinc atoms would be oxidised by hydrogen ions* ***B*** *is not correct because zinc is the negative electrode so does not gain electrons* ***D*** *is not correct because zinc atoms lose electrons to hydrogen ions*	**(1)**

Question Number	Correct Answer	Mark
4	**4. The only correct answer is C** ***A*** *is not correct because the electrode potential of the cell containing iron(II) ions is less positive than the one containing Vanadium (III) ions* ***B*** *is not correct because iron is a reducing agent* ***D*** *is not correct because silver is a reducing agent*	**(1)**

Question Number	Correct Answer	Mark
5	**5. The only correct answer is A** ***B*** *is not correct because there is no hydrogen gas present* ***C*** *is not correct because the reaction must supply electrons* ***D*** *is not correct because the reaction must supply electrons*	**(1)**

Question Number	Correct Answer	Mark
6	**6. The only correct answer is B** ***A*** *is not correct because nickel(II) ions form a soluble complex with ammonia* ***C*** *is not correct because nickel(II) ions form a soluble complex with ammonia* ***D*** *is not correct because nickel(II) hydroxide is not soluble in excess NaOH*	**(1)**

Question Number	Correct Answer	Mark
7	**7. The only correct answer is D** ***A*** *is not correct because the product is not* $S_4O_6^{2-}$ *ions* ***B*** *is not correct because the product is not* $S_4O_6^{2-}$ *ions* ***C*** *is not correct because the charges are not balanced*	**(1)**

Question Number	Correct Answer	Mark
8	**8. The only correct answer is D** ***A*** *is not correct because the end point could still be seen* ***B*** *is not correct because the starch is not decomposed* ***C*** *is not correct because the blue-black colour would be seen*	**(1)**

Question Number	Correct Answer	Mark
9	**9. The only correct answer is A** ***B*** *is not correct because infrared spectroscopy does not measure bond length* ***C*** *is not correct because the enthalpy changes do not measure bond length* ***D*** *is not correct because the rates of reaction do not measure bond length*	**(1)**

Question Number	Correct Answer	Mark
10	**10. The only correct answer is B** ***A*** *is not correct because* SO_3H *is substituted* ***C*** *is not correct because* SO_3H *is substituted* ***D*** *is not correct because* SO_3H *is substituted*	**(1)**

Question Number	Correct Answer	Mark
11	**11. The only correct answer is B** ***A*** *is not correct because the electrophile which forms is* CH_3CO^+ ***C*** *is not correct because the electrophile which forms is* CH_3CO^+ ***D*** *is not correct because the electrophile which forms is* CH_3CO^+	**(1)**

Question Number	Correct Answer	Mark
12	**12. The only correct answer is C** ***A*** *is not correct because there is no doublet in the spectrum* ***B*** *is not correct because there is no sextet on the spectrum* ***D*** *is not correct because there is no doublet in the spectrum*	**(1)**

Question Number	Correct Answer	Mark
13	**13. The only correct answer is B** ***A*** *is not correct because the bonds are too similar to be distinguished by infrared* ***C*** *is not correct because the splitting patterns will be the same* ***D*** *is not correct because the number of peaks in the low resolution spectra*	**(1)**

Question Number	Correct Answer	Mark
14	**14. The only correct answer is D** ***A*** *is not correct because there is no alcohol or phenol to give the peak at above 3300cm^{-1}* ***B*** *is not correct because there is no alcohol or phenol to give the peak at above 3300cm^{-1}* ***C*** *is not correct because there is no alcohol or phenol to give the peak at above 3300cm^{-1}*	**(1)**

Question Number	Correct Answer	Mark
15	**15. The only correct answer is A** ***B*** *is not correct because it does not form an alkaline solution* ***C*** *is not correct because it is not very soluble in water* ***D*** *is not correct because it does not form an alkaline solution*	**(1)**

Question Number	Correct Answer	Mark
16	**16. The only correct answer is B** ***A*** *is not correct because the property which is essential is that the capsule is water soluble to release the detergent* ***C*** *is not correct because the property which is essential is that the capsule is water soluble to release the detergent* ***D*** *is not correct because the property which is essential is that the capsule is water soluble to release the detergent*	**(1)**

Question Number	Correct Answer	Mark
17	**17. The only correct answer is A** ***B*** *is not correct because the OH and* $CONH_2$ *groups will not react to form a polymer* ***C*** *is not correct because the number of* (CH_2) *groups o in the polymer is incorrect* ***D*** *is not correct because the OH and* NH_2 *groups will not react to form a polymer*	**(1)**

Question Number	Correct Answer	Mark
18	**18. The only correct answer is C** ***A*** *is not correct because 1 mol alcohol gives 4 mol* CO_2 *so 4C are present* ***B*** *is not correct because 1 mol alcohol gives 4 mol* CO_2 *so 4C are present* ***D*** *is not correct because 1 mol alcohol gives 4 mol* CO_2 *so 4C are present*	**(1)**

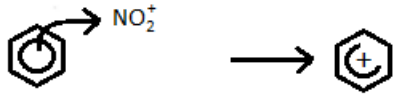
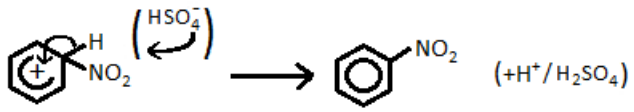
Question Number	Correct Answer	Mark
19(a)	**19(a). The only correct answer is C** ***A*** *is not correct because theoretical yield =* *(2 x 181/136) = 2.66g* *so % yield = (1.5/2.66) x 100* ***B*** *is not correct for the same reason* ***D*** *is not correct for the same reason*	**(1)**

Question Number	Correct Answer	Mark
19(b)	**19(b). The only correct answer is D** ***A*** *is not correct because some product would remain dissolved in excess ethanol* ***B*** *is not correct because the ethanol should be warmed until all the crude solid dissolves, which is not related to its boiling point* ***C*** *is not correct because slow filtration could cause crystallisation in the filter funnel*	**(1)**

Total for Section A = 20 MARKS

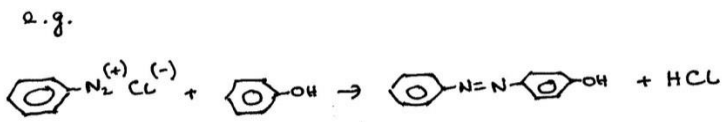
Section B

Question Number	Acceptable Answers	Reject	Mark
20(a)(i)	Concentrated nitric acid/ HNO_3 **and** concentrated sulfuric acid/H_2SO_4 ALLOW Concentrated nitric and sulfuric acid(s) IGNORE References to temperature	Nitric acid and concentrated sulfuric acid Nitrous acid HNO_2	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20(a)(ii)	$H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_2O + HSO_4^-$ OR $H_2SO_4 + HNO_3 \rightarrow H_2NO_3^+ + HSO_4^-$ **and** $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ OR $2H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ IGNORE state symbols even if incorrect **(1)**   Curly arrows from on or within the circle to N of NO_2^+ ALLOW Curly arrow from anywhere within the hexagon curly arrow to any part of the NO_2^+ including the + charge **(1)** Intermediate structure including charge with horseshoe covering at least 3 C atoms **and** facing the tetrahedral carbon **and** some part of the + charge must be within the horseshoe **(1)** Curly arrow **from C-H bond** to anywhere in the hexagon reforming the delocalised structure **(1)** Correct Kekule structures score full marks IGNORE Any involvement of HSO_4^- in the final step	Curly arrow on or outside the hexagon Dotted bonds to H and NO_2 unless clearly part of a 3D structure	**(4)**

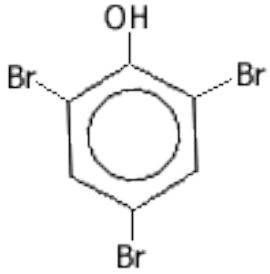
Question Number	Acceptable Answers	Reject	Mark
20(a)(iii)	**X** = $C_6H_5NH_2$ /phenylamine / aniline/ aminobenzene/ $C_6H_5NH_3^+$ Cl^- /phenylammonium chloride/ aniline hydrochloride **(1)** Reagents: Sn/ tin **and** (concentrated) hydrochloric acid/ HCl (followed by NaOH) ALLOW Iron/Fe for Sn **(1)** IGNORE Mention of catalyst Second mark is **independent** of first	Dilute HCl	**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(a)(iv)	Reagents: Sodium nitrite/ potassium nitrite/ $NaNO_2$/ KNO_2 **and** hydrochloric acid/ HCl ALLOW Nitrous acid / HNO_2 **and** hydrochloric acid /HCl **(1)** IGNORE concentration of acid Condition: temperature between 0(^oC) and 10(^oC)/ less than 10(^oC) **(1)**	Just H^+ for an acid	**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(b)	Equation using phenol, phenylamine or other compound with **activated** benzene ring and HCl as one product e.g.  Structure of dye including azo link / -N=N- **(1)** Rest of equation ALLOW TE on incorrect reagent provided -N=N- linking two benzene rings Use of NaOH (as solvent for phenol) giving NaCl Any position of substitution on ring **(1)**	Use of chloro-benzene/ nitro-benzene	**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(c)	Hydrochloric acid / HCl / any strong acid/ $H^+(aq)$ OR NaOH **followed by** hydrochloric acid / HCl IGNORE concentration , addition of water	HCN "NaOH **with** HCl"	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20(d)(i)	$C_6H_5N_2Cl + H_2O \rightarrow N_2 + HCl + C_6H_5OH$ N_2 as a product **(1)** Rest of the equation **(1)** IGNORE state symbols even if incorrect.	O_2 as a reagent	**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(d)(ii)	 ALLOW Kekule / $C_6H_2(OH)Br_3$ /$C_6H_2OHBr_3$ **(1)**	monobromophenol	**(1)**

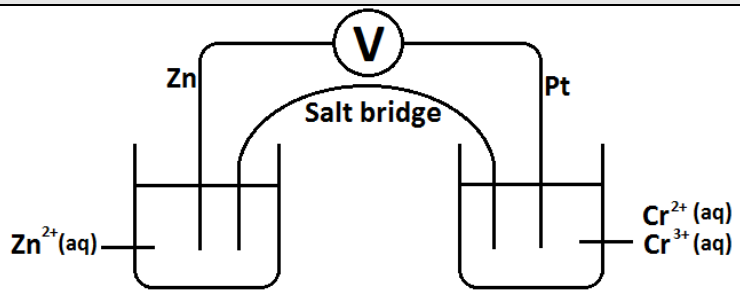
(Total for Question 20 = 15 marks)

Question Number	Acceptable Answers	Reject	Mark
21(a)(i)	Electrons are removed from 4s (orbital) in each element **(1)** Shielding (by 3d electrons) is the same in each element OR Increase in nuclear charge/ proton number is balanced by increase in number of shielding/3d electrons **(1)**		**(2)**

Question Number	Acceptable Answers	Reject	Mark
***21(a)(ii)**	**MP1** In Cr^+ the (second) electron is lost from the 3d subshell **and** in V^+ and Mn^+ it is lost from the 4s subshell **(1)** **MP2 and MP3** Any **TWO** of 3d is closer to nucleus than 4s, harder to remove **(1)** OR 3d is not as well shielded as 4s, harder to remove **(1)** OR 3d is half full so relatively stable, harder to remove **(1)**		**(3)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>21(b)(i)</td><td>
<table>
<tr><td>Ion</td><td>Oxidation number of chromium</td><td>Colour in aqueous solution</td></tr>
<tr><td>$Cr(H_2O)_6^{2+}$</td><td>+2</td><td>Blue</td></tr>
<tr><td>$Cr(H_2O)_6^{3+}$</td><td>+3</td><td>Green
ALLOW
violet</td></tr>
<tr><td>CrO_4^{2-}</td><td>+6</td><td>Yellow</td></tr>
<tr><td>$Cr_2O_7^{2-}$</td><td>+6</td><td>Orange</td></tr>
</table>
Oxidation number and colour for $Cr(H_2O)_6^{3+}$ (1)
Oxidation number and colour for CrO_4^{2-} (1)
Oxidation number and colour for $Cr_2O_7^{2-}$ (1)
ALLOW
1 mark for any two correct responses
2 marks for any four correct responses
2+ for +2 etc.
Dark/ light along with colour
</td><td>purple</td><td>(3)</td></tr>
</table>

Question Number	Acceptable Answers	Reject	Mark
***21(b)(ii)**	**MP1** (3)d orbital**s** are split/ (3)d subshells are split (by the attached ligands) **(1)** **MP2** Electrons are promoted (from lower to higher energy d orbital(s)/ levels OR Electrons are moved from lower to higher energy (d (orbital(s) / levels) ALLOW d-d transitions occur/ electrons are excited **(1)** **MP3** absorbing energy/ photons of a certain frequency (in the visible region) ALLOW Absorbing light **(1)** **MP4** Transmitted/ remaining/ reflected light is coloured/ is in the visible region ALLOW Complementary colour seen (The frequency of) transmitted/ remaining /reflected light/ is seen **(1)** Penalise omission of (3)d once only. Ignore reference to electrons relaxing/dropping to the ground state	Emitted light	**(4)**

Question Number	Acceptable Answers	Reject	Mark
21(b)(iii)	 **MP1** Beaker with Zn electrode in $Zn^{2+}(aq)$ **and** salt bridge **and** voltmeter **(1)** **MP2** beaker with Pt electrode in mixture of Cr^{2+}, Cr^{3+} **(1)** **MP3** All solutions 1 mol dm^{-3} (with respect to the ions) **and** T = 298 K ALLOW Concentrations given for one beaker only 1M for1 mol dm^{-3} **(1)** ALLOW diagram with Zn electrode on right. IGNORE References to pressure	Salt bridge not dipping into solution 1 mol	**(3)**

Question Number	Acceptable Answers	Reject	Mark
21(b)(iv)	$Zn^{2+}(aq)\|Zn(s)$ $E^{\ominus} = -0.76$ (V) **and** $Cr^{3+}(aq)\,)\|Cr^{2+}(aq)$ $E^{\ominus} = -0.41$ (V) **(1)** $E^{\ominus}_{cell}$ = (-0.41-(-0.76)) = (+)0.35 (V) **(1)** Correct answer including sign **+**0.35 with no working scores two Value of 0.35 with no sign and no working scores 1 No TE on incorrect data		**(2)**

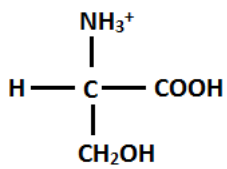
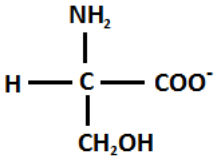
Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	$Cr^{3+}(aq)$ + **8**OH^- → CrO_4^{2-} + 4H_2O + 3e^- IGNORE State symbols	$Cr^{3+}(aq)$ + **4**OH^- → CrO_4^{2-} + 4H^+ + 3e^-	**(1)**

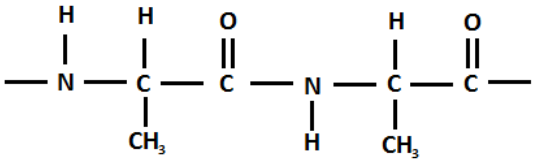
Question Number	Acceptable Answers	Reject	Mark
21(c)(ii)	**2**$Cr^{3+}(aq)$ + **10** OH^- +**3**H_2O_2 → **2**CrO_4^{2-} + **8**H_2O ALLOW TE on equation in (c)(i) using $4OH^-$: 2$Cr^{3+}(aq)$ + 2 OH^- +3H_2O_2 → 2CrO_4^{2-} + 8H^+		**(1)**

Question Number	Acceptable Answers	Reject	Mark
21(d)	2CrO_4^{2-} + 2H^+ → $Cr_2O_7^{2-}$ + H_2O		**(1)**

(Total for Question 21 = 20 marks)

Question Number	Acceptable Answers	Reject	Mark
22(a)	Both a negative and a positive charge are present (in a neutral molecule) OR Both COO^- and NH_3^+ are present ALLOW "Ion with extra H^+ on amine group and one less H^+ on carboxyl O" Formula showing the correct charges	Just "pole" or "region" for charge Just an ion that acts as an acid or a base	**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(b)	 pH 1.0  pH 10.0 Ion at pH 1.0: with NH_3^+ **(1)** Ion at pH 10.0 with COO^- **(1)**	Charge on – CH_2OH group	**(2)**

Question Number	Acceptable Answers	Reject	Mark
22(c)	 CONH displayed **(1)** Rest of molecule with extension bonds from C and N ALLOW 3 complete units Brackets round units and n following **(1)**	Ester link partial repeat units	**(2)**

Question Number	Acceptable Answers	Reject	Mark
22(d)(i)	They rotate (the plane of polarization) of (plane-)polarised light OR They are optically active OR they have a chiral centre/ they are chiral/they have a chiral carbon/ they have optical isomers / they form enantiomers		**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(d)(ii)	Esterification **(1)** IGNORE condensation Neutralization/ salt formation /acid-base / protonation **(1)**	Trans-esterification	**(2)**

Question Number	Acceptable Answers	Reject	Mark
22(d)(iii)	Ethanol/ C_2H_5OH If name **and** formula are given **both** must be correct		**(1)**

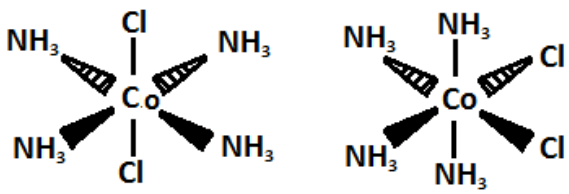
Question Number	Acceptable Answers	Reject	Mark
22(d)(iv)	Hydrolysis Acid hydrolysis	Extra answers	**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(d)(v)	Carbon dioxide/ CO_2 ALLOW H_2CO_3 **(1)** ammonium chloride/ NH_4Cl ALLOW Ammonia/ NH_3 **(1)** ALLOW Aminomethanoic acid / H_2NCOOH (max 1)		**(2)**

(Total for Question 22 = 12 marks)

Question Number	Acceptable Answers	Reject	Mark
***23(a)**	Transition metals have empty /partially filled d-orbitals (of suitable energy level) OR Group 1 metals such as Na do not have empty / partially filled d-orbitals (of suitable energy level) **(1)** Which can accept pairs of electrons (from ligands) OR Ligands can form dative covalent bonds into these (d) orbitals (into these empty orbitals) **(1)**		**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(b)(i)	Ionic **and** dative covalent / co-ordinate ALLOW Ionic and dative	London forces	**(1)**

Question Number	Acceptable Answers	Reject	Mark
23(b)(ii)	Geometric ALLOW cis-trans (isomers) / *E-Z* (isomers) **(1)** The 2 Cl ligands may be beside each other or opposite each other / The Cl-Co-Cl bond angle may be 90 or 180°. ALLOW diagrams **(1)**  IGNORE Lack of charge Second mark is independent of first	Diagrams not looking at all 3D	**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(c)	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$ **(1)** Ignore state symbols even if incorrect. $[Cu(H_2O)_6]^{2+}$ Octahedral ALLOW Bi-pyramidal if accompanied by a diagram **(1)** $CuCl_4^{2-}$ Tetrahedral ALLOW Square planar **(1)**	planar	**(3)**

Question Number	Acceptable Answers	Reject	Mark
23(d)(i)	Monodentate ligands use one lone pair in bonding OR Donate one pair of electrons (to the central ion) OR Form one dative covalent bond **(1)** Hexadentate ligands donate six lone pairs of electrons from (six different atoms in) the same molecule/ ion/ (to the central ion) OR Donate six pairs of electrons (to the central ion) OR Form six dative covalent bonds **(1)**	Just "have" one lone pair	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***23(d)(ii)**	2 moles of reactants go to 7 moles of products/ there is a **large** increase in the number of particles (going from left to right) **(1)** This means $\Delta S_{(system)}$ is larg**er**/ **more** positive / high**er** (so reaction more likely to have a positive ΔS_{total} and larger Kc) **(1)**		**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(i)	(0.22 x 100/ 2.00) = **11**(%) IGNORE sf except 1sf		**(1)**

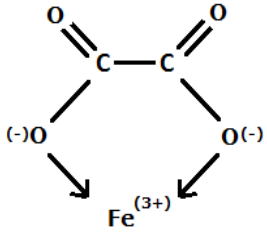
Question Number	Acceptable Answers	Reject	Mark
23(e)(ii)	Mol MnO_4^- = (36.60 x 0.0100/1000) = **3.66×10^{-4}** **(1)** Mol ethanedioate reacting = (3.66×10^{-4} x 5 /2) = **9.15×10^{-4}** **(1)** Mass ethanedioate = (9.15×10^{-4} x 88) = **0.0805 g** **(1)** % ethanedioate = (0.0805/ 0.150 x 100) = **53.68** **(1)** IGNORE sf except 1sf		**(4)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(iii)	Because ethanedioate reacts with manganate((VII)) ions		**(1)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(iv)	<table><tr><th>species</th><th>Percentage by mass</th></tr><tr><td>water</td><td>11</td></tr><tr><td>ethanedioate</td><td>53.68</td></tr><tr><td>iron</td><td>11.4</td></tr><tr><td>potassium</td><td>23.92</td></tr></table> TE on % for water and ethanedioate as long as some attempt made in (e)(ii) Ignore sf except 1 sf		**(1)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(v)	<table><tr><th>Species</th><th>Number of moles in 100 g</th><th>Mole ratio</th></tr><tr><td>water</td><td>0.611</td><td>3</td></tr><tr><td>ethanedioate ions</td><td>0.61</td><td>3</td></tr><tr><td>iron</td><td>0.204</td><td>1</td></tr><tr><td>potassium</td><td>0.61</td><td>3</td></tr></table> Number of moles and ratio for water and iron **(1)** Number of moles and ratio for ethanedioate and potassium **(1)** TE on (e)(iv) Ethanedioate = (e)(iv) value /88 Potassium = (e)(iv) value /39		**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(vi)	$[Fe(C_2O_4)_3]^{3-}$ ALLOW $[Fe(C_2O_4)_3(H_2O)_3]^{3-}$		**(1)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(vii)	 Two bonds shown, one from each COO^- ALLOW Lines instead of dative covalent arrows OR Delocalised structure shown with bonds from O at each end of the ion.		**(1)**

(Total for Question 23 = 23 marks)
Total for Section C = 70 MARKS

TOTAL FOR PAPER = 90 MARKS

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Chemistry

Advanced

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

Monday 15 June 2015 – 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 ▶

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6/6/6/6/1/2/

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PEARSON

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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 Which of the following is a redox reaction?

☒ **A** $Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$

☒ **B** $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

☒ **C** $4OH^- + 4MnO_4^- \rightarrow 4MnO_4^{2-} + 2H_2O + O_2$

☒ **D** $[Fe(H_2O)_6]^{3+} + 3OH^- \rightarrow [Fe(H_2O)_3(OH)_3] + 3H_2O$

(Total for Question 1 = 1 mark)

2 The oxidation state of nickel is **not** +2 in

☒ **A** $[Ni(CO)_4]$

☒ **B** $[Ni(H_2O)_4(OH)_2]$

☒ **C** $[Ni(NH_3)_6]^{2+}$

☒ **D** $[Ni(CN)_4]^{2-}$

(Total for Question 2 = 1 mark)

3 Which of the statements about a standard hydrogen electrode, for which $E^{\ominus} = 0$ V, is correct?

☒ **A** A suitable solution for use in the electrode is hydrochloric acid with a concentration of 0.1 mol dm^{-3}.

☒ **B** The pressure of the hydrogen has no effect on the value of $E^{\ominus}$.

☒ **C** The metal used in the electrode is platinum.

☒ **D** The temperature is 273 K.

(Total for Question 3 = 1 mark)

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

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4 The table below gives the standard electrode potentials of three half cells.

System	$E^{\ominus}$ / V
$H^+(aq) + e^- \rightleftharpoons \frac{1}{2}H_2(g)$	0.00
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Ag^{2+}(aq) + e^- \rightleftharpoons Ag^+(aq)$	+1.98

From these data it may be deduced that, under standard conditions,

☒ **A** Ag is a stronger reducing agent than H_2.

☒ **B** Ag^{2+} ions are stronger oxidizing agents than H^+ ions.

☒ **C** Ag^+ ions will disproportionate.

☒ **D** Ag^+ ions will react with H^+ ions.

(Total for Question 4 = 1 mark)

5 The value of E_{cell} indicates whether the cell reaction is thermodynamically feasible.
Which of the following is a correct statement about E_{cell}?

☒ **A** E_{cell} is directly proportional to the equilibrium constant.

☒ **B** E_{cell} is directly proportional to the entropy change of the system, ΔS_{system}.

☒ **C** E_{cell} is directly proportional to the total entropy change, ΔS_{total}.

☒ **D** The value of ln E_{cell} is directly proportional to the total entropy change, ΔS_{total}.

(Total for Question 5 = 1 mark)

6 In a methanol fuel cell, the following half-reaction occurs

$$CH_3OH(l) + H_2O(l) \rightarrow 6H^+(aq) + CO_2(g) + 6e^-$$

The half-reaction occurring in the other half of the fuel cell is

☒ **A** $H_2(g) + O_2(g) + 2e^- \rightarrow 2OH^-(aq)$

☒ **B** $2H^+(aq) + \frac{1}{2}O_2(g) + 2e^- \rightarrow H_2O(l)$

☒ **C** $2OH^-(aq) \rightarrow H_2(g) + O_2(g) + 2e^-$

☒ **D** $H_2O(l) \rightarrow 2H^+(aq) + \frac{1}{2}O_2(g) + 2e^-$

(Total for Question 6 = 1 mark)

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7 Which of the following statements about fuel cells is **not** true?

- ☒ **A** Reactants must constantly be fed into the cell when it is in use.
- ☒ **B** Fuel cells are 100% efficient.
- ☒ **C** Fuel cells convert chemical energy directly into electrical energy.
- ☒ **D** Fuel cells produce electricity more efficiently than a diesel generator.

(Total for Question 7 = 1 mark)

8 Copper(II) ions combine with three molecules of 1,2-diaminoethane, $NH_2CH_2CH_2NH_2$, to form a complex ion.

A bond angle, N — Cu — N, in this complex is

- ☒ **A** 120°
- ☒ **B** 109.5°
- ☒ **C** 107°
- ☒ **D** 90°

(Total for Question 8 = 1 mark)

9 Which of the following does **not** have a central metal ion having six bonds and an oxidation state of +2?

- ☒ **A** $[Cu(C_2O_4)_3]^{4-}$
- ☒ **B** $[Co(CN)_5(H_2O)]^{3-}$
- ☒ **C** $[Fe(CN)_6]^{3-}$
- ☒ **D** $[Zn(OH)_4(H_2O)_2]^{2-}$

(Total for Question 9 = 1 mark)

10 The reaction

$$[Fe(H_2O)_6]^{2+} + H_2O \rightarrow [Fe(H_2O)_5(OH)]^{+} + H_3O^{+}$$

is an example of

- ☒ **A** oxidation.
- ☒ **B** reduction.
- ☒ **C** ligand exchange.
- ☒ **D** acid-base behaviour.

(Total for Question 10 = 1 mark)

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11 Hydrated crystals of a compound have the formula $CrCl_3(H_2O)_6$.
A solution containing one mole of the compound reacts with two moles of silver nitrate to form two moles of silver chloride.
The complex chromium ion in the compound is most likely to be

☒ **A** $[Cr(H_2O)_3Cl_3]^{3+}$

☒ **B** $[Cr(H_2O)_4Cl_2]^{+}$

☒ **C** $[Cr(H_2O)_5Cl]^{2+}$

☒ **D** $[Cr(H_2O)_6]^{3+}$

(Total for Question 11 = 1 mark)

12 A **heterogeneous** catalyst is often preferred to a **homogenous** catalyst for an industrial process because

☒ **A** it is easily separated from the products.

☒ **B** it has empty d-orbitals.

☒ **C** it has more than one oxidation state.

☒ **D** it cannot be poisoned.

(Total for Question 12 = 1 mark)

13 In the reaction of benzene with chloromethane, aluminium chloride is added because it reacts with

☒ **A** benzene to produce an electrophile.

☒ **B** benzene to produce a nucleophile.

☒ **C** chloromethane to produce a nucleophile.

☒ **D** chloromethane to produce an electrophile.

(Total for Question 13 = 1 mark)

14 The reaction below can be catalysed by either Fe^{2+} ions or Fe^{3+} ions.

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

This is because

☒ **A** both reactants can react with Fe^{2+} ions.

☒ **B** both reactants can react with Fe^{3+} ions.

☒ **C** $S_2O_8^{2-}$ ions can be oxidized by Fe^{3+} ions and I^- ions can be reduced by Fe^{2+} ions.

☒ **D** $S_2O_8^{2-}$ ions can be reduced by Fe^{2+} ions and I^- ions can be oxidized by Fe^{3+} ions.

(Total for Question 14 = 1 mark)

15 The enthalpy changes of the reactions below are similar. The equilibrium constants for the two reactions are K_1 and K_2 respectively.

Reaction 1 $[Cu(H_2O)_6]^{2+}(aq) + EDTA^{4-}(aq) \rightleftharpoons [Cu(EDTA)]^{2-}(aq) + 6H_2O(l)$

Reaction 2 $[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CuCl_4]^{2-}(aq) + 6H_2O(l)$

The value of K_1 is greater than K_2 because

- ☒ **A** ΔS_{system} is much more positive in Reaction 1.
- ☒ **B** $\Delta S_{surroundings}$ is much more positive in Reaction 1.
- ☒ **C** the $EDTA^{4-}$ is more highly charged than Cl^-.
- ☒ **D** a lower concentration of $EDTA^{4-}$ is needed than Cl^-.

(Total for Question 15 = 1 mark)

16 Which of the following reacts with benzene under suitable conditions to form $C_6H_5COC_6H_5$?

- ☒ **A** C_6H_5CHO
- ☒ **B** C_6H_5COOH
- ☒ **C** $C_6H_5CH_2OH$
- ☒ **D** C_6H_5COCl

(Total for Question 16 = 1 mark)

17 Benzene is converted to benzenesulfonic acid, $C_6H_5SO_3H$, by reaction with

- ☒ **A** sulfuric(IV) acid, H_2SO_3.
- ☒ **B** sulfuric(VI) acid, H_2SO_4.
- ☒ **C** sulfur dioxide dissolved in sulfuric(IV) acid.
- ☒ **D** sulfur trioxide dissolved in sulfuric(VI) acid.

(Total for Question 17 = 1 mark)

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

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18 Benzene reacts with chlorine to produce 1,2,3,4,5,6-hexachlorocyclohexane, $C_6H_6Cl_6$, by

☒ **A** free radical addition.

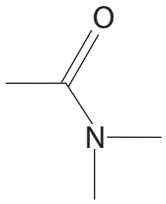
☒ **B** free radical substitution.

☒ **C** electrophilic addition.

☒ **D** electrophilic substitution.

(Total for Question 18 = 1 mark)

19 The skeletal formula of an organic compound is shown below.



This compound is

☒ **A** an amino acid.

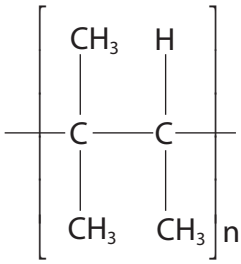
☒ **B** an amide.

☒ **C** a primary amine.

☒ **D** a secondary amine.

(Total for Question 19 = 1 mark)

20



Which is the IUPAC name for the monomer which reacts to make the polymer shown above?

☒ **A** 2-methylbut-1-ene

☒ **B** 2-methylbut-2-ene

☒ **C** 1,2-dimethylpropene

☒ **D** 1,1,2-trimethylethene

(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 (a) The table below shows the first and second ionization energies of nickel, copper and zinc.

Element	1st ionization energy / kJ mol^{-1}	2nd ionization energy / kJ mol^{-1}
Ni	737	1753
Cu	746	1958
Zn	906	1733

(i) Complete the electronic configurations for an atom of nickel and an atom of copper.

(2)

Ni: $1s^2\ 2s^2\ 2p^6$ .....

Cu: $1s^2\ 2s^2\ 2p^6$ .....

*(ii) The values for the first ionization energies of copper and nickel are similar, but the values of the second ionization energies are significantly different.

Explain how these data give evidence for the electronic configuration of a copper atom.

(2)

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(iii) Suggest why you might expect the **third** ionization energies of the three elements to increase from nickel to zinc.

(1)

.....

.....

.....

(b) (i) $Cu^+(aq)$ ions are not stable in solution and undergo a disproportionation reaction.

Suggest an equation for this reaction, including state symbols.

(1)

(ii) Suggest in what way the **appearance** of CuI is similar to that of ZnI_2.

Give a reason for this similarity.

(2)

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(c) Explain why zinc is **not** classified as a transition element.

(1)

.....

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.....

.....

(Total for Question 21 = 9 marks)

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22 This question is about vanadium and its ions.

(a) Consider the data below.

Electrode system	Standard electrode potential $E^{\ominus}$ / V
$V^{2+}(aq)\,\vert\,V(s)$	–1.18
$V^{3+}(aq), V^{2+}(aq)\,\vert\,Pt$	–0.26

(i) Draw a labelled diagram showing how to set up a cell, using the two electrode systems in the table above, in order to measure $E^{\ominus}_{cell}$.
Include standard conditions in your labelling.

(3)

(ii) Write an equation for the reaction in this cell. State symbols are not required.

(2)

(b) (i) Complete the table below with the missing standard electrode potentials.
Use the table starting on page 14 of your Data Booklet.

(1)

Electrode system	Standard electrode potential $E^{\ominus}$ / V
$[VO^{2+}(aq) + 2H^{+}(aq)], [V^{3+}(aq) + H_2O(l)]\,\vert\,Pt$	
$[VO_2^{+}(aq) + 2H^{+}(aq)], [VO^{2+}(aq) + H_2O(l)]\,\vert\,Pt$	
$I_2(aq), 2I^{-}(aq)\,\vert\,Pt$	+0.54
$[2H^{+}(aq) + O_2(g)], [H_2O_2(aq)]\,\vert\,Pt$	+0.68

P 4 5 0 7 3 R A 0 1 0 2 8
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(ii) The colours of the different oxidation states of vanadium are shown below.

Oxidation state	Colour
+5	yellow
+4	blue
+3	green
+2	violet

For each of the following experiments, **A** and **B**, calculate the $E^{\ominus}$ value for the proposed reaction. Use your answers to predict whether or not a reaction occurs in each case.

Give the formula of the vanadium product formed where a reaction occurs and give **one** observation you would make in each experiment.

(6)

Experiment A: Hydrogen peroxide is added to an aqueous solution containing VO_2^+ ions.

Experiment B: An aqueous solution of potassium iodide is added to an aqueous solution containing VO^{2+} ions.

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(c) An experiment was carried out to determine the percentage purity of a sample of ammonium vanadate(V), NH_4VO_3.

An impure sample of ammonium vanadate(V) with mass 0.150 g was dissolved in dilute sulfuric acid. This produced a solution containing VO_2^+ ions. Excess zinc powder was added to the solution, and this reduced the VO_2^+ ions to V^{2+} ions.

The solution containing V^{2+} ions was titrated with potassium manganate(VII) of concentration 0.0200 mol dm^{-3}. The manganate(VII) ions oxidized the V^{2+} back to VO_2^+. The volume of potassium manganate(VII) required was 35.50 cm^3.

(i) The manganate(VII) ions react as shown:

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

Show, by writing the appropriate half equation or otherwise, that 5 mol V^{2+} react with 3 mol MnO_4^-.

(1)

(ii) Calculate the number of moles of manganate(VII) ions used in the titration.

(1)

P 4 5 0 7 3 R A 0 1 2 2 8
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(iii) Calculate the number of moles of VO_2^+ in the original solution, and hence the percentage purity of the sample of NH_4VO_3. Give your answer to **three** significant figures.

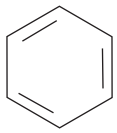
Molar mass of NH_4VO_3 = 116.9 g mol^{-1}.

(3)

(Total for Question 22 = 17 marks)

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23 Benzene is sometimes represented as Structure **X**, shown below, called a Kekulé structure after the chemist who suggested it.



Structure **X**

(a) What structural feature of benzene shows that Structure **X** is not an accurate representation?

(1)

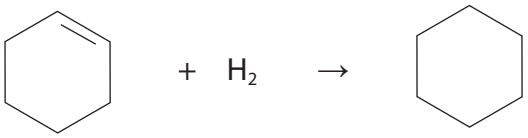
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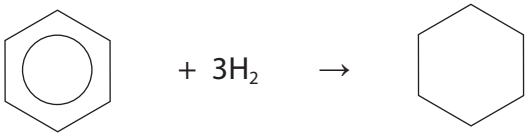
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(b) The enthalpy changes for the formation of cyclohexane from cyclohexene and from the actual structure of benzene are given below.



$+ \ H_2 \rightarrow$

$\Delta H = -118 \text{ kJ mol}^{-1}$



$+ \ 3H_2 \rightarrow$

$\Delta H = -205 \text{ kJ mol}^{-1}$

(i) Use the necessary data to estimate the enthalpy change for the theoretical conversion of Structure **X** to cyclohexane.

(1)

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(ii) On the enthalpy level diagram below, draw labelled horizontal lines to show the relative enthalpies of the actual structure of benzene, Structure **X** and cyclohexane. Add an arrow to show the enthalpy change from Structure **X** to benzene and calculate the value of this enthalpy change in kJ mol^{-1}. Write this value next to your arrow.

(2)



*(iii) Explain the difference in the arrangement of the electrons between benzene and Structure **X**.

(2)

.....

.....

.....

.....

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(c) Benzene reacts with bromine in the presence of a catalyst of iron(III) bromide.

Write a mechanism for the reaction of benzene with bromine to form bromobenzene. Include an equation to show the involvement of the catalyst.

(4)

P 4 5 0 7 3 R A 0 1 6 2 8
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(d) (i) State **two** observations which would be made when phenol reacts with bromine water.

(2)

(ii) Write the equation for this reaction showing the structure of the organic product.

(2)

*(iii) Explain why phenol can react with either bromine or with bromine water without a catalyst.

(2)

(Total for Question 23 = 16 marks)

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24 Benzene can be converted to phenylamine, $C_6H_5NH_2$, in two steps.

$$C_6H_6 \xrightarrow{\text{Step 1}} C_6H_5NO_2 \xrightarrow{\text{Step 2}} C_6H_5NH_2$$

(a) (i) Name the **two** reagents needed in Step 1.

(1)

.....

(ii) Suggest why the temperature should not be allowed to go above 55 °C in Step 1.

(1)

.....

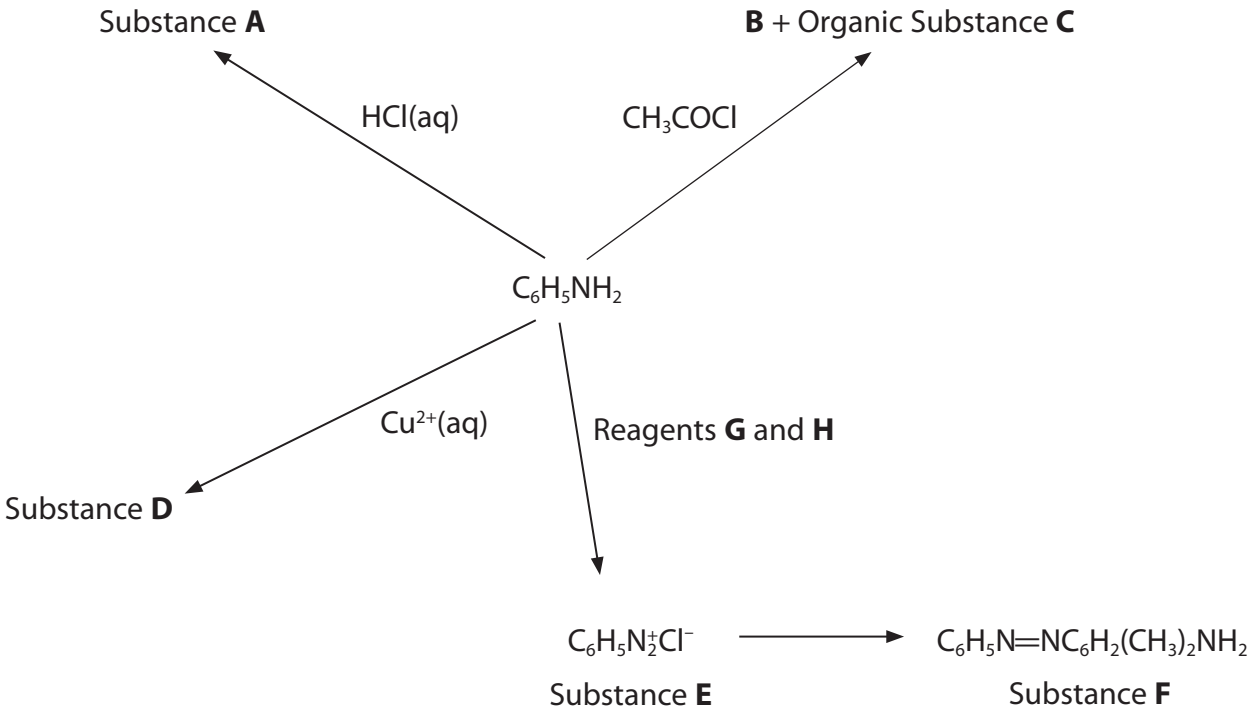
.....

(iii) Identify the **two** reagents used to carry out the reduction in Step 2.

(1)

.....

(b) Some reactions of phenylamine are shown below.



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(i) Give the formula of Substance **A**.

(1)

.....

(ii) Draw the displayed formula of the organic Substance **C**.

You need not display the benzene ring.

(1)

(iii) Substances **D** and **F** are both brightly coloured but for different reasons. Classify Substances **D** and **F**.

(2)

Substance **D** .....

Substance **F** .....

(iv) Name Substance **E**.

(1)

.....

(v) What **two** Substances, **G** and **H**, are required in the conversion of phenylamine to Substance **E**?

(1)

.....

(vi) Suggest the structural formula of the substance which reacts with Substance **E** to form Substance **F**.

(1)

(Total for Question 24 = 10 marks)

TOTAL FOR SECTION B = 52 MARKS

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SECTION C

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

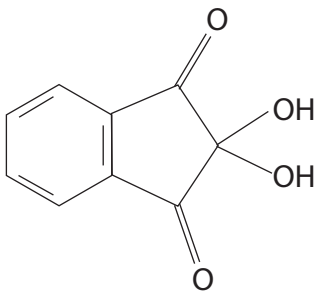
25 Read the passage below carefully and answer the questions which follow.

The general formula of most naturally occurring amino acids can be written $RCH(NH_2)COOH$, though in some amino acids, such as proline, the nitrogen atom is part of a five-membered ring. Amino acids are water soluble, though the extent of their solubility varies. All but one of the naturally occurring amino acids show optical activity.

The formula of the R group for some naturally occurring amino acids is shown below.

Amino acid	Formula of R group
serine	$-CH_2OH$
lysine	$-(CH_2)_4NH_2$
phenylalanine	$-CH_2C_6H_5$
leucine	$-CH_2CH(CH_3)_2$
iso-leucine	$-CH(CH_3)CH_2CH_3$
alanine	$-CH_3$

Mixtures of amino acids can be separated by electrophoresis. This method depends on amino acids moving different distances through paper or gel when an electric field is applied. They can also be separated by chromatography. Ninhydrin, shown below, is the chemical which is used to locate the position of the amino acids on chromatograms.



Ninhydrin detects ammonia and primary and secondary amines. When it reacts with primary amines, a deep blue or purple colour is produced in a complex series of reactions. With proline, a yellow compound forms.

Ninhydrin is widely used to detect fingerprints. Sweat secretions from ridges on the finger contain dipeptides and proteins. These are left on porous surfaces such as paper, and react with ninhydrin.

When ninhydrin reacts with amino acids, carbon dioxide is released from the carboxylic acid group. Archaeologists have used this reaction to release the carbon from proteins in ancient bones, and, by comparing the proportions of carbon and nitrogen in the remains, they have obtained evidence for the diets of these animals.

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(a) (i) At a pH of 5.68, serine exists as a zwitterion. Draw the formula of serine at this pH.

(1)

*(ii) At pH 5.68, serine and lysine can be separated by electrophoresis. By considering the structures of the amino acids at this pH, suggest why this separation occurs.

(2)

*(b) Serine is very soluble in water, whilst phenylalanine is much less soluble. Explain the difference, disregarding any effect of zwitterion formation.

(2)

(c) The naturally occurring amino acid which does not show optical activity is not shown in the table. Give the formula of the R group for this acid.

(1)

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(d) The optical activity of equimolar solutions of naturally occurring samples of leucine and iso-leucine can be measured in an experiment using plane-polarized light.

(i) What measurement is made to show the optical activity of amino acids?

(1)

.....

(ii) By considering the structures of iso-leucine and leucine, explain why iso-leucine has more stereoisomers than leucine.

Amino acid	Formula of R group
leucine	$-CH_2CH(CH_3)_2$
iso-leucine	$-CH(CH_3)CH_2CH_3$

(1)

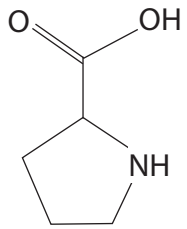
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(e) The amino acid proline, shown below, does not contain a primary amine group, but it can still form peptide bonds.

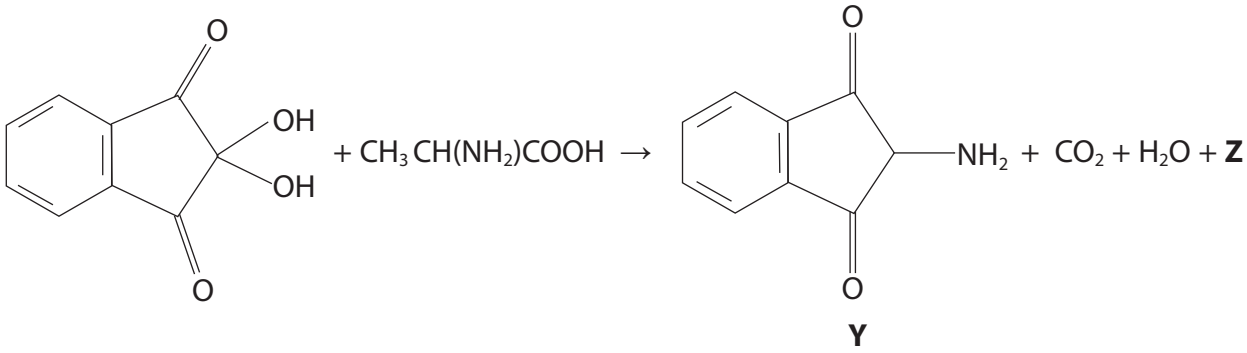


Draw the structure of the dipeptide formed when the carboxylic acid group of alanine reacts with proline. Circle the peptide group on your drawing.

(2)

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(f) The first steps of the reaction of ninhydrin with alanine can be summarised in the equation shown below.

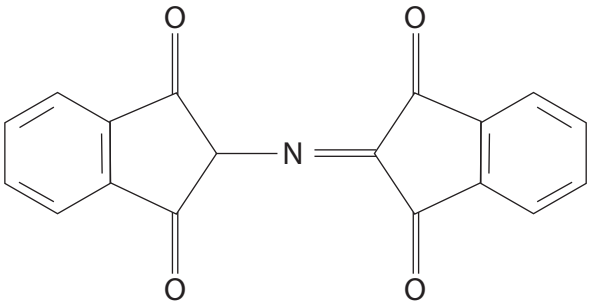


Y

(i) By balancing the equation, suggest the structural formula of the product **Z**.

(1)

(ii) In the final stage, **Y** reacts with another molecule of ninhydrin to form a dye, **Q**, shown below.



What is the molecular formula of **Q**?

(1)

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(iii) On combustion, 1.000 g of **Q** produces 2.614 g carbon dioxide, 0.2673 g water and 0.04620 g nitrogen.

Use these data to calculate the percentage composition by mass of **Q**, and hence its empirical formula. Show whether your answer is consistent with the molecular formula of **Q**.

(4)

(iv) Evidence for the structure of **Q** is obtained from data in its mass spectrum, and the number of peaks in its low resolution nmr spectrum.

Suggest **one** piece of evidence from **each** type of spectroscopy which would support the structure shown in (f)(ii). Give data where appropriate.

(2)

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(Total for Question 25 = 18 marks)

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

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

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

* Lanthanide series

* Actinide series

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Mark Scheme (Results)

Summer 2015

GCE Chemistry (6CH05/01)

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Summer 2015
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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

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	C		1

Question Number	Correct Answer	Reject	Mark
2	A		1

Question Number	Correct Answer	Reject	Mark
3	C		1

Question Number	Correct Answer	Reject	Mark
4	B		1

Question Number	Correct Answer	Reject	Mark
5	C		1

Question Number	Correct Answer	Reject	Mark
6	B		1

Question Number	Correct Answer	Reject	Mark
7	B		1

Question Number	Correct Answer	Reject	Mark
8	D		1

Question Number	Correct Answer	Reject	Mark
9	C		1

Question Number	Correct Answer	Reject	Mark
10	D		1

Question Number	Correct Answer	Reject	Mark
11	C		1

Question Number	Correct Answer	Reject	Mark
12	A		1

Question Number	Correct Answer	Reject	Mark
13	D		1

Question Number	Correct Answer	Reject	Mark
14	D		1

Question Number	Correct Answer	Reject	Mark
15	A		1

Question Number	Correct Answer	Reject	Mark
16	D		1

Question Number	Correct Answer	Reject	Mark
17	D		1

Question Number	Correct Answer	Reject	Mark
18	A		1

Question Number	Correct Answer	Reject	Mark
19	B		1

Question Number	Correct Answer	Reject	Mark
20	B		1

Section B

Question Number	Acceptable Answers	Reject	Mark
21a(i)	Ni: $(1s^2\ 2s^2 2p^6)\ 3s^2 3p^6\ 3d^8\ 4s^2$ (1) Cu: $(1s^2\ 2s^2 2p^6)\ 3s^2 3p^6\ 3d^{10} 4s^1$ (1) ALLOW capital letters, subscripts for superscripts ALLOW 4s before 3d Penalise omission of $3s^2 3p^6$ once only if rest is correct		2

Question Number	Acceptable Answers	Reject	Mark
21a*(ii)	First electron removed is from **4s** (in both atoms) (1) Second electron in Cu (is harder to remove so it is) EITHER closer to nucleus/in inner shell OR less shielded (1) IGNORE Comments about second electron being in full shell/ in a 3d shell/in a 3d orbital Reference to $3d^{10}$ stability		2

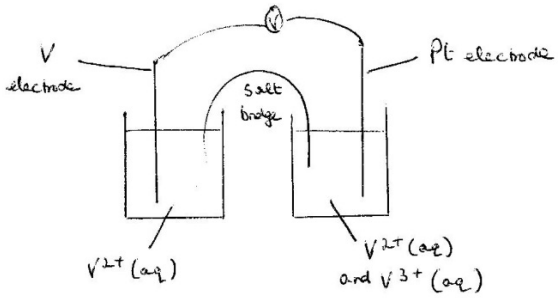
Question Number	Acceptable Answers	Reject	Mark
21a(iii)	(attraction on (3d) electrons increases due to) number of protons increasing / nuclear charge increasing IGNORE The charge density of the 2^+ ions increases Effective nuclear charge		1

Question Number	Acceptable Answers	Reject	Mark
21b(i)	$2Cu^{+}(aq) \rightarrow Cu(s) + Cu^{2+}(aq)$ IGNORE Eqm sign for $\rightarrow$	Reverse equation Any equation involving electrons	1

Question Number	Acceptable Answers	Reject	Mark
21b(ii)	Both white ALLOW (both) Colourless (1) COMMENT Ignore states eg solution/precipitate As have $3d^{10}$ / have a full 3d sub-shell /**ALL** 3d orbitals are full (1) IGNORE Does not have partially filled d orbitals They do not absorb light No d-d transitions occur		2

Question Number	Acceptable Answers	Reject	Mark
21c	(Zinc) does not form a (stable) **ion** with incompletely/partially filled d orbitals ALLOW d sub-shell for d orbitals The only (stable) **ion** formed by zinc has full d sub-shell It does not form a (stable) oxidation state with incompletely/partially filled d orbitals	Element has full d shells.	1

Total for Question 21 = 9 marks

Question Number	Acceptable Answers	Reject	Mark
22(a)(i)			3
	Beaker with V electrode in solution containing $V^{2+}(aq)$ AND beaker containing $V^{2+}(aq)$ and $V^{3+}(aq)$ with Pt electrode N.B. Both solution levels must be shown (1)		
	Labelled salt bridge AND connections to voltmeter ALLOW Suitable name or formula of salt for label	Salt bridge neither dipping into nor touching solution unless penalised in MP1	
	ALLOW Salts eg NaCl in salt bridge (1)	Salt bridge containing an alkali/acid	
	Ion concentrations = 1 mol dm^{-3} ALLOW M for mol dm^{-3} Concentrations given in one beaker only (1)	1 mole of V^{2+} and 1 mole of V^{3+}	
	Beaker positions may be reversed Ignore references to temperature and pressure		

Question Number	Acceptable Answers	Reject	Mark
22(a)(ii)	**First mark** $2V^{3+} + V \rightarrow 3V^{2+}$ Balanced equation, either direction ALLOW Eqm sign for $\rightarrow$ IGNORE State symbol even if incorrect (1) **Second mark** Correct direction ALLOW If balancing is incorrect or e^- included in equation (1)	e^- included	2

Question Number	Acceptable Answers		Reject	Mark
22b(i)	$([VO^{2+}(aq) + 2H^+(aq)], [V^{3+}(aq) + H_2O(l)] \mid Pt)$	+0.34		1
	$([VO_2^+(aq) + 2H^+(aq)], [VO^{2+}(aq) + H_2O(l)] \mid Pt)$	+1.00		
	Sign and value needed			

Question Number	Acceptable Answers	Reject	Mark
22(b)(ii)	**A:** (+)0.32 (V) (1) VO^{2+} (may be shown as a product in an overall equation) (1) EITHER Bubbles / effervescence (of colourless gas) OR Colour changes (from yellow) to blue TE on negative E_{cell} for 'stays yellow' ALLOW (from yellow) to green if justified by partial reduction (1) **B:** −0.2(0) (V) (1) no change / stays blue (1) If B=+0.2 or other positive value allow colour change from blue to green or brown. EITHER Consistent use of rule that reaction occurs when E_{cell} is positive OR Consistent use of rule that no reaction occurs when E_{cell} negative ALLOW If implied but not stated specifically (1)	Violet Stays violet	6

Question Number	Acceptable Answers	Reject	Mark
22c(i)	$V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ + 3e^-$ OR Ox number of V increases by 3, ox number of Mn decreases by 5 ALLOW Balanced full equation $5V^{2+} + 3MnO_4^- + 4H^+ \rightarrow$ $5VO_2^+ + 3Mn^{2+} + + 2H_2O$	Reverse equation unless used to deduce final correct equation.	1

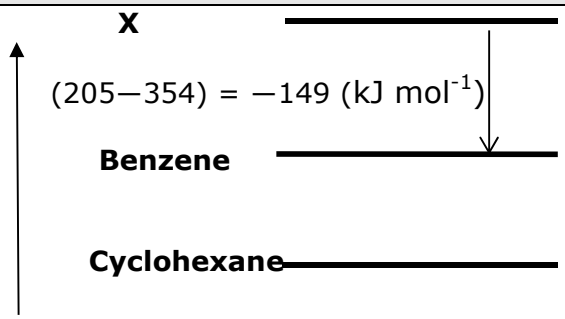
Question Number	Acceptable Answers	Reject	Mark
22(c)(ii)	(35.50 x 0.0200/1000) = $7.1(0) \times 10^{-4}$ / 0.00071		1

Question Number	Acceptable Answers	Reject	Mark
22(c)(iii)	**In final answer** **92.2 scores 3 marks** **33.2 scores 2 marks** (ratio inverted) **55.3 scores 2 marks** (ratio 1:1) METHOD 1 Mol V^{2+} reacting = $7.10 \times 10^{-4} \times 5/3$ $=$**1.18333×10^{-3}** = mol VO_2^+ TE on answer to (c)(ii) (1) Mass NH_4VO_3 = $(1.183 \times 10^{-3} \times 116.9)$ = **0.1382927** g TE from 4.26×10^{-3} =0.497994 (1) % purity = (0.1382927x 100/ 0.150) = (92.19333) = **92.2%** TE from 0.497994 = 33.2% (1) METHOD 2 If 100% pure, moles of NH_4VO_3 $=0.150/116.9=1.283 \times 10^{-3}$ (1) Mol V^{2+} reacting = $7.10 \times 10^{-4} \times 5/3$ $=$**1.18333×10^{-3}** = mol VO_2^+ TE on answer to (c)(ii) (1) % purity = $=1.18333 \times 10^{-3} \times 100/1.283 \times 10^{-3}$ = **92.2%** (1) ALLOW TE at each step provided that each number used is to at least 2sf	x 3/5 = 4.26×10^{-4}	3

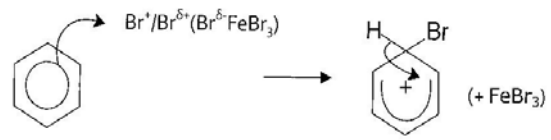
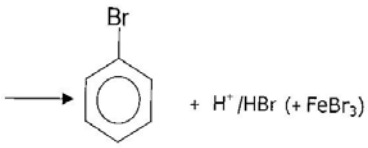
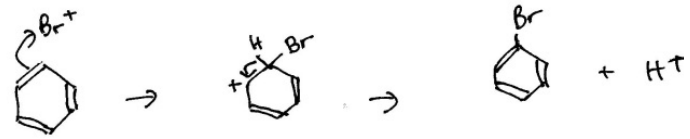
Total for Question 22 = 17 marks

Question Number	Acceptable Answers	Reject	Mark
23(a)	All carbon to carbon bonds same length/ longer C-C and shorter C=C not present IGNORE Just "benzene has a delocalised ring" Benzene does not have C=C double bonds Any references to shape/ bond angles		1

Question Number	Acceptable Answers	Reject	Mark
23(b)(i)	(3 x -118) = -354 (kJ mol^{-1})		1

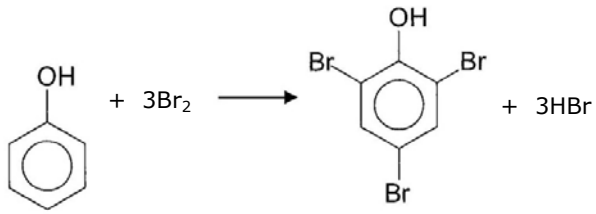
Question Number	Acceptable Answers	Reject	Mark
23(b)(ii)	 **First mark** Relative levels with names or formulae (1) **Second mark** Value —149 (kJ mol^{-1}) + arrow in correct direction ALLOW double-headed arrow (1) TE from value in (b)(ii) IGNORE $3H_2$ if shown / cyclohexene / other arrows/values	Diagram inverted scores 0 +149	2

Question Number	Acceptable Answers	Reject	Mark
23(b)*(iii)	The p/pi-/Π/6 electrons (of carbon) (1) are delocalised in benzene (but not in **X**) (1)		2

Question Number	Acceptable Answers	Reject	Mark
23(c)	**First mark:** $FeBr_3 + Br_2 \rightarrow FeBr_4^- + Br^+$ OR $Br\text{-}Br + FeBr_3 \rightarrow Br^{\delta+}\ldots.. Br^{\delta-}FeBr_3$ (1) Ignore state symbols even if wrong **Second, third and fourth marks:** **Either**   Arrow from benzene ring electrons (from **inside** the hexagon) to **Br^+ / $Br^{\delta+}$** (….. $Br^{\delta-}FeBr_3$) (1) Correctly drawn intermediate with delocalisation covering at least three carbon atoms, but not the carbon atom bonded to the bromine , with the positive charge shown inside the horseshoe The bonds to H and Br may be dotted (1) Arrow from / close to C-H **bond** to inside the hexagon **and** H^+ / HBr as product (1) **OR**  Use of Kekulé structure for benzene and intermediate with arrow from C=C double bond to **Br^+ / $Br^{\delta+}$** (….. $Br^{\delta-}FeBr_3$) (1) Correctly drawn intermediate with + charge on the C atom next to the C bonded to H and Br	Gap in wrong place	4

	The bonds to H and Br may be dotted (1) Arrow from / close to C-H **bond** to bond beside + charged C **and** H^+ / HBr as product (1) Each marking point is independent		

Question Number	Acceptable Answers	Reject	Mark
23(d)(i)	Bromine goes colourless OR It/the mixture goes from brown to colourless ALLOW Red-brown/ Orange/ yellow/ combinations of these colours Bromine is decolorised (1) White precipitate/solid forms / Steamy fumes (1) IGNORE Antiseptic smell Gets hot	Goes clear Red to colourless Bromine is discoloured Effervescence	2

Question Number	Acceptable Answers	Reject	Mark
23(d)(ii)	 Organic product with structure shown (1) Rest of equation correct ALLOW C_6H_5OH or Kekule for phenol (1) $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$ Scores MP2 only Substitution of 1Br or 2Br in any position in balanced equation scores MP2 only.		2

Question Number	Acceptable Answers	Reject	Mark
***23(d)(iii)**	**Lone pair of electrons on oxygen** (may be shown on a diagram) **and** EITHER overlaps with pi cloud OR Feeds into / donates into / interacts with benzene ring (1) Activating benzene ring / increasing electron density of ring / making attack by **electrophiles** easier (1) COMMENT 'Lone pair of electrons on oxygen increases electron density of ring' scores (2) ALLOW benzene becomes a better nucleophile for MP2	OH group overlaps Just 'making it more reactive'.	2

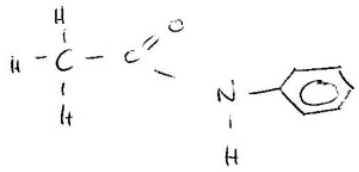
Total for Question 23 = 16 marks

Question Number	Acceptable Answers	Reject	Mark
24(a)(i)	Concentrated nitric acid AND concentrated sulfuric acid ALLOW 'concentrated nitric and sulfuric acids' Concentrated HNO_3 and concentrated H_2SO_4	Extra reagents	1

Question Number	Acceptable Answers	Reject	Mark
24(a)(ii)	To prevent multiple substitutions/ to stop di- or trinitrobenzene forming ALLOW To stop further substitution (of NO_2)/ further nitration IGNORE further reaction	Further **addition** of nitro groups	1

Question Number	Acceptable Answers	Reject	Mark
24(a)(iii)	Tin/ Sn AND **concentrated** HCl/ **concentrated** hydrochloric acid ALLOW Iron/Fe or Zn/Zinc for tin Conc for concentrated	Dilute HCl	1

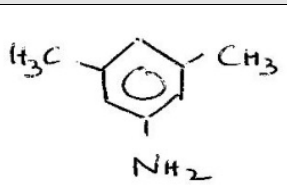
Question Number	Acceptable Answers	Reject	Mark
24(b)(i)	$C_6H_5NH_3^+Cl^-$ ALLOW $C_6H_5NH_3Cl$		1

Question Number	Acceptable Answers	Reject	Mark
24(b)(ii)	 ALLOW C_6H_5 for benzene Undisplayed CH_3	Skeletal formula Structural formula	1

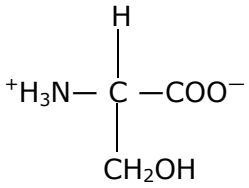
Question Number	Acceptable Answers	Reject	Mark
24(b)(iii)	**D** (transition metal) complex ion ALLOW Transition metal complex / copper complex IGNORE Formulae of ions (1) **F** (azo) dye / azo compound / diazo compound ALLOW diazonium compound molecule for compound (1)		2

Question Number	Acceptable Answers	Reject	Mark
24b(iv)	Benzenediazonium chloride ALLOW Phenyldiazonium chloride	Benzadiazonium chloride Diazonium salt	1

Question Number	Acceptable Answers	Reject	Mark
24b(v)	$HCl + NaNO_2$ OR Hydrochloric acid + Sodium nitrite / nitrate(III) OR alternative cation to Na^+ IGNORE HNO_2 Concentration of HCl	$HCl + HNO_2$	1

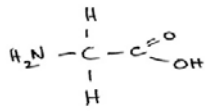
Question Number	Acceptable Answers	Reject	Mark
24b(vi)	 ALLOW any substitution positions $C_6H_3(CH_3)_2NH_2$ H- $C_6H_2(CH_3)_2NH_2$ Kekule structure	$C_6H_2(CH_3)_2NH_2$	1

Total for Question 24 = 10 marks

Question Number	Acceptable Answers	Reject	Mark
25(a)(i)	 OR $HOCH_2CH(NH_3^+)CO_2^-$ ALLOW Charge on NH_3 shown on N atom		1

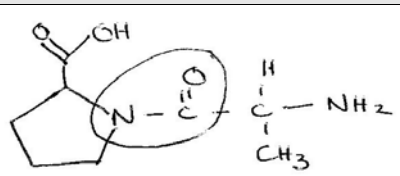
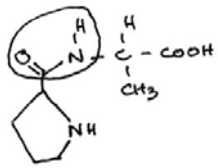
Question Number	Acceptable Answers	Reject	Mark
***25(a)(ii)**	**EITHER** At pH 5.68 both NH_2 groups on lysine will be NH_3^+ / lysine has an overall positive charge while serine has no overall charge (1) So only lysine will move to negative terminal / in an electric field (1) **OR** lysine has a greater positive charge (than serine) (1) Lysine will move faster / further in an electric field (1) ALLOW They have different charges so will move different distances/ at different speeds 1 mark max IGNORE Answers based on molecular mass		2

Question Number	Acceptable Answers	Reject	Mark
***25(b)**	**COMMENT** Ignore references to H bonds from amino and carboxyl groups and assume that "phenylalanine cannot form H bonds" refers to R group in the compound. Serine has an OH (alcoholic) group which can form H bonds with water (1) Benzene ring in phenylalanine is bulky /is large and non-polar / is hydrophobic / London forces between phenylalanine molecules are significant ALLOW van der Waals etc for London ALLOW If MP1 is not scored, 'phenylalanine cannot form H bonds with water' can score MP2 (1)	VdW / id-id	2

Question Number	Acceptable Answers	Reject	Mark
25(c)	H, -H, H- ALLOW $NH_2CH_2CO_2H$ / NH_2CH_2COOH 		1

Question Number	Acceptable Answers	Reject	Mark
25(d)(i)	(Measure) the amount of / angle of / degree of /extent of rotation (of plane of polarization/ plane polarized light) IGNORE direction they rotate the light	Just "polarimetry"	1

Question Number	Acceptable Answers	Reject	Mark
25(d)(ii)	(Leu has 1 chiral C but) Ile has 2 chiral C / 2 asymmetric C atoms OR The R group in Ile contains a chiral C (Leu has 2 optical isomers but Ile has 4 optical isomers) ALLOW Ile has (1) more chiral C (than leu) Chiral centres shown on formulae	Leu has no chiral C	1

Question Number	Acceptable Answers	Reject	Mark
25(e)	 CON circled with N as part of ring (1) Fully correct structure (1) ALLOW -CH(CH_3)NH_2 shown skeletally **OR** Dipeptide using NH_2 from alanine and COOH from proline, with correct structure and CONH circled **This scores max (1)** 	Just N-C circled	2

Question Number	Acceptable Answers	Reject	Mark
25(f)(i)	CH_3CHO / CH_2CHOH ALLOW Displayed or semi-displayed formula C_2H_4O	CH_3COH (unless with correct structure)	1

Question Number	Acceptable Answers	Reject	Mark
25(f)(ii)	$C_{18}H_9NO_4$		1

Question Number	Acceptable Answers	Reject	Mark
25(f)(iii)	**Several methods are possible.** **Amount of O should have been calculated and final answer should be consistent with masses/mols in calculation. There should be evidence of working at each stage for 4 marks** **MP1** 2.614 g CO_2 contain 0.7129 g C 0.2673 g H_2O contain 0.0297 g H OR 2.614 g CO_2 contain 0.059409 mol CO_2 0.2673 g H_2O contain 0.01485 mol H_2O (1) **MP2** Mass O in Q = (1.00 – 0.7129- 0.0297 -0.04620) = **0.2112** g (1) % mol/100g ratio C 71.29 5.94 18 H 2.97 2.97 9 N 4.62 0.33 1 O 21.12 1.32 4 **MP3** Number of moles of each element OR Number of mol in 100g Allow TE for incorrect mol of H – see calculation below (1) **MP4** Ratio stated must follow from numbers in calculation (so empirical formula is consistent with the molecular formula of **Q**) (1) **OR** **Calculation following error in H scores max (3)** If mass H is wrongly calculated as 0.01485 g, then mass O will be 0.22605 (TE for MP2) (1) % mol/100g ratio C 71.29 5.94 18 H 1.48 1.48 4.5 N 4.62 0.33 1 O 22.60 1.41 4.27		4

	Number of moles of each element (TE for MP3) (1) Ratio stated and empirical formula said not to be consistent (TE for MP4) (1)		

Question Number	Acceptable Answers	Reject	Mark
25(f)(iv)	Mass of molecular ion in mass spectrum = 303 / any sensible fragment with mass eg 302 / 158 / 145 or smaller fragment (1) ALLOW Molecular ion based on formula in f(i) Number of peaks in nmr = 2 / 3 ALLOW 5 (1)	4	2

Total for Question 25 = 18 marks

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Surname	Other names

Pearson Edexcel GCE

Centre Number	Candidate Number

Chemistry

Advanced

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

Tuesday 17 June 2014 – 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 ▶

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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 which of the following ions does the metal have an oxidation number of +3?

☒ **A** MnO_4^{2-}

☒ **B** VO^{2+}

☒ **C** $[Fe(CN)_6]^{4-}$

☒ **D** $[CrCl_2(H_2O)_4]^{+}$

(Total for Question 1 = 1 mark)

2 Copper metal is oxidized to Cu^{2+} by nitrate(V) ions which are reduced to nitrogen monoxide, NO.
By considering the changes to the oxidation numbers of copper and nitrogen, it can be deduced that in this reaction

☒ **A** 2 mol of copper reacts with 3 mol of nitrate(V) ions.

☒ **B** 2 mol of copper reacts with 5 mol of nitrate(V) ions.

☒ **C** 3 mol of copper reacts with 2 mol of nitrate(V) ions.

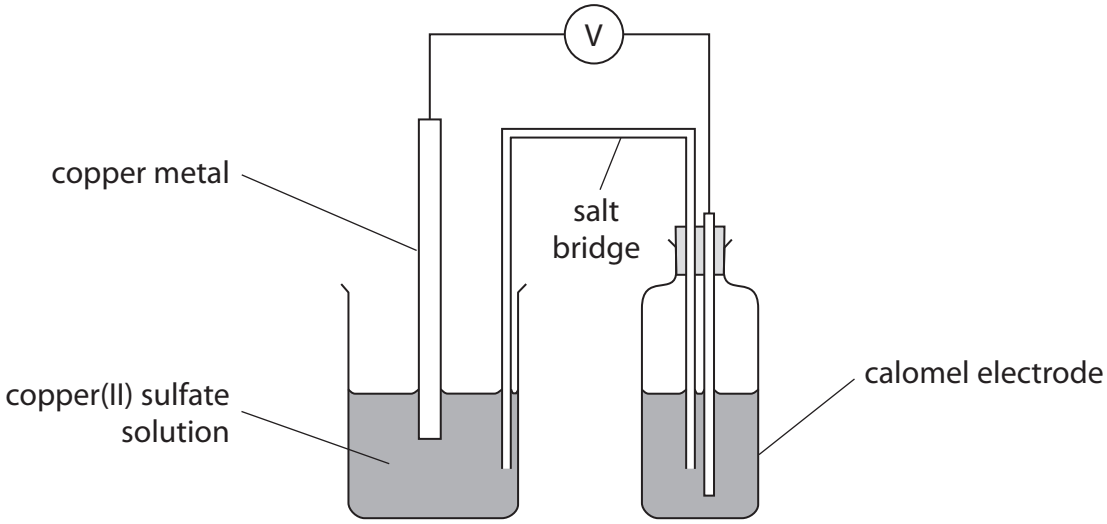
☒ **D** 5 mol of copper reacts with 2 mol of nitrate(V) ions.

(Total for Question 2 = 1 mark)

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

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3 The diagram below shows a cell set up between a copper metal / copper(II) ion electrode and a reference electrode, known as a calomel electrode.



Under standard conditions, the emf of this cell was −0.07 V. The standard electrode potential of the copper metal / copper(II) ion electrode is +0.34 V. Hence the standard electrode potential of the calomel electrode is

☒ **A** −0.41 V

☒ **B** −0.27 V

☒ **C** +0.27 V

☒ **D** +0.41 V

(Total for Question 3 = 1 mark)

4 For the reaction

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

at 450 K the total entropy change, ΔS_{total}, is negative. Hence the equilibrium constant, K_p, for this reaction at 450 K is

☒ **A** zero.

☒ **B** positive and greater than 1.

☒ **C** positive and less than 1.

☒ **D** negative.

(Total for Question 4 = 1 mark)

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5 The standard electrode potentials of two half reactions are shown below.

$$\tfrac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^- \qquad E^{\ominus} = +1.36\ V$$

$$Co^{3+} + e^- \rightleftharpoons Co^{2+} \qquad E^{\ominus} = +1.82\ V$$

Which of the following processes is thermodynamically favourable? The reaction of

- ☒ **A** Co^{2+} with Cl_2 to form Cl^-
- ☒ **B** Co^{2+} with Cl^- to form Cl_2
- ☒ **C** Co^{3+} with Cl_2 to form Cl^-
- ☒ **D** Co^{3+} with Cl^- to form Cl_2

(Total for Question 5 = 1 mark)

---

6 A solution of potassium manganate(VII) was used to determine the concentration of iron(II) ions in solution by titration in the presence of excess dilute sulfuric acid.

(a) With the potassium manganate(VII) in the burette, the end-point of the reaction is when the solution in the conical flask turns

(1)

- ☒ **A** colourless.
- ☒ **B** pink.
- ☒ **C** green.
- ☒ **D** orange.

(b) If insufficient acid is added, the titre value is

(1)

- ☒ **A** low and a brown precipitate forms.
- ☒ **B** low and a green precipitate forms.
- ☒ **C** high and a brown precipitate forms.
- ☒ **D** high and a green precipitate forms.

(Total for Question 6 = 2 marks)

---

7 What is the electronic configuration of the stable scandium ion?

- ☒ **A** [Ar] $3d^0\ 4s^2$
- ☒ **B** [Ar] $3d^1\ 4s^1$
- ☒ **C** [Ar] $3d^0\ 4s^1$
- ☒ **D** [Ar] $3d^0\ 4s^0$

(Total for Question 7 = 1 mark)

P 4 2 9 7 3 A 0 4 2 8
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8 The shapes of the complexes $[CrCl_4]^-$ and $[Pt(NH_3)_2Cl_2]$ are

	$[CrCl_4]^-$	$[Pt(NH_3)_2Cl_2]$
☒ **A**	square planar	square planar
☒ **B**	tetrahedral	tetrahedral
☒ **C**	square planar	tetrahedral
☒ **D**	tetrahedral	square planar

(Total for Question 8 = 1 mark)

9 The compound 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$, is a bidentate ligand; in formulae, it is usually abbreviated to 'en'.

When 1,2-diaminoethane is added to $[Co(NH_3)_6]^{2+}$ in aqueous solution, $[Co(en)_3]^{2+}$ is formed. What is the **best** explanation for this?

☒ **A** There are much stronger bonds between the ligands and the cobalt(II) ion in $[Co(en)_3]^{2+}$ than in $[Co(NH_3)_6]^{2+}$.

☒ **B** When $[Co(en)_3]^{2+}$ is formed from $[Co(NH_3)_6]^{2+}$ the reaction is exothermic.

☒ **C** When $[Co(en)_3]^{2+}$ is formed from $[Co(NH_3)_6]^{2+}$ the total entropy change is positive.

☒ **D** When $[Co(en)_3]^{2+}$ is formed from $[Co(NH_3)_6]^{2+}$ the reaction has a low activation energy.

(Total for Question 9 = 1 mark)

10 When aqueous sodium hydroxide is added to an aqueous solution of a transition metal compound, a green precipitate is formed which dissolves in excess sodium hydroxide forming a green solution. The transition metal ion present in the original solution is

☒ **A** Cr^{3+}

☒ **B** Fe^{3+}

☒ **C** Fe^{2+}

☒ **D** Ni^{2+}

(Total for Question 10 = 1 mark)

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11 Benzene reacts with a nitrating mixture of concentrated nitric and sulfuric acids. Which species is **least** likely to be present in the nitrating mixture?

- ☒ **A** NO_3^-
- ☒ **B** H_3O^+
- ☒ **C** HSO_4^-
- ☒ **D** NO_2^+

(Total for Question 11 = 1 mark)

12 Benzene (T_b = 80.1 °C) has a higher boiling temperature than ethanol (T_b = 78.5 °C). This is because the

- ☒ **A** benzene ring is stabilised.
- ☒ **B** London forces between benzene molecules are stronger than the hydrogen bonds between ethanol molecules.
- ☒ **C** hydrogen bonds between benzene molecules are stronger than the hydrogen bonds between ethanol molecules.
- ☒ **D** C–H bonds in benzene are stronger than the C–H bonds in ethanol.

(Total for Question 12 = 1 mark)

13 Separate 0.1 mol dm^{-3} aqueous solutions of ammonia, methylamine and phenylamine were prepared. Which of the following sequences shows the solutions in order of **increasing** pH?

- ☒ **A** phenylamine, methylamine, ammonia
- ☒ **B** phenylamine, ammonia, methylamine
- ☒ **C** methylamine, ammonia, phenylamine
- ☒ **D** methylamine, phenylamine, ammonia

(Total for Question 13 = 1 mark)

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

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14 The benzenediazonium ion, $C_6H_5N_2^+$, is an intermediate in the preparation of azo dyes.

(a) In the formation of an azo dye, the benzenediazonium ion is

(1)

☒ **A** an electrophile.

☒ **B** a nucleophile.

☒ **C** a carbocation.

☒ **D** a substituent.

(b) The temperature of the aqueous reaction mixture must be kept below 10 °C to prevent the benzenediazonium ion being converted into

(1)

☒ **A** benzene.

☒ **B** nitrobenzene.

☒ **C** phenylamine.

☒ **D** phenol.

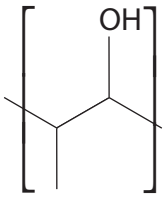
(Total for Question 14 = 2 marks)

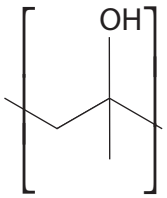
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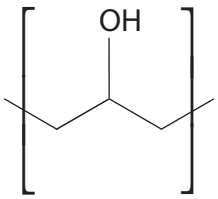
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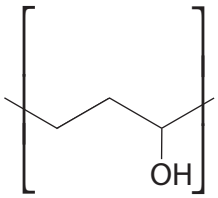
15 The monomer of the addition polymer poly(propenol) may be represented as $CH_3–CH=CHOH$.

The repeat unit of the addition polymer is

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 15 = 1 mark)

16 Chromatography may be used to separate mixtures of amino acids. This is best explained by the fact that different amino acids have different interactions with

☒ **A** the mobile phase only.

☒ **B** the stationary phase only.

☒ **C** the mobile phase **and** the stationary phase.

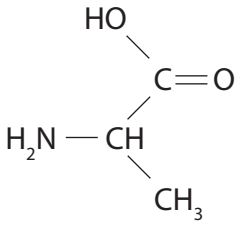
☒ **D** ninhydrin.

(Total for Question 16 = 1 mark)

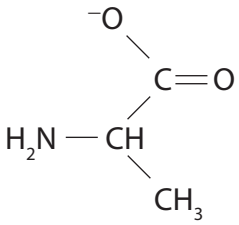
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17 In an aqueous solution with a pH of 7, the amino acid alanine exists mainly as

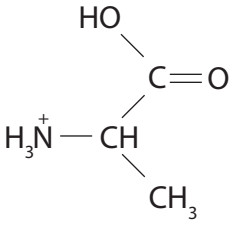
☒ **A**



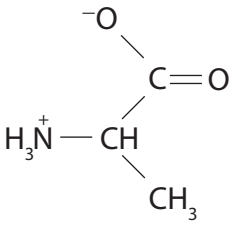
☒ **B**



☒ **C**



☒ **D**



(Total for Question 17 = 1 mark)

18 When a solid is purified by recrystallization, the procedure involves the removal of impurities by filtration of the hot mixture followed by filtration of the cold mixture. Which impurities are removed by these two filtrations?

	Hot filtration	Cold filtration
☒ **A**	insoluble impurities	insoluble impurities
☒ **B**	insoluble impurities	soluble impurities
☒ **C**	soluble impurities	insoluble impurities
☒ **D**	soluble impurities	soluble impurities

(Total for Question 18 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

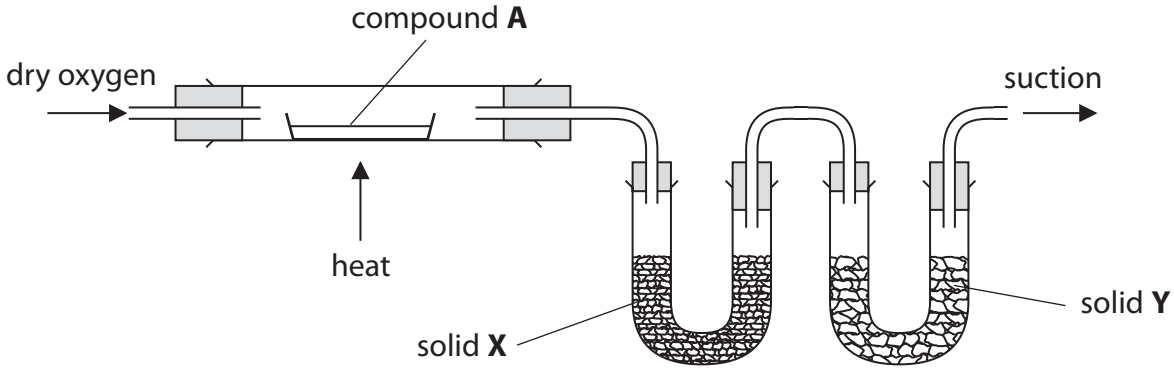
P 4 2 9 7 3 A 0 9 2 8
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SECTION B

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

19 A compound **A**, known to contain only the elements carbon, hydrogen and oxygen, was subjected to detailed analysis.

(a) A sample of **A** was burned completely in the apparatus shown below. Solid **X** absorbed the water formed in the combustion and solid **Y** absorbed the carbon dioxide.



(i) Explain why the oxygen must be dry.

(1)

(ii) Suggest a suitable substance to use as solid **X**.

(1)

(iii) Suggest a suitable substance to use as solid **Y**.

(1)

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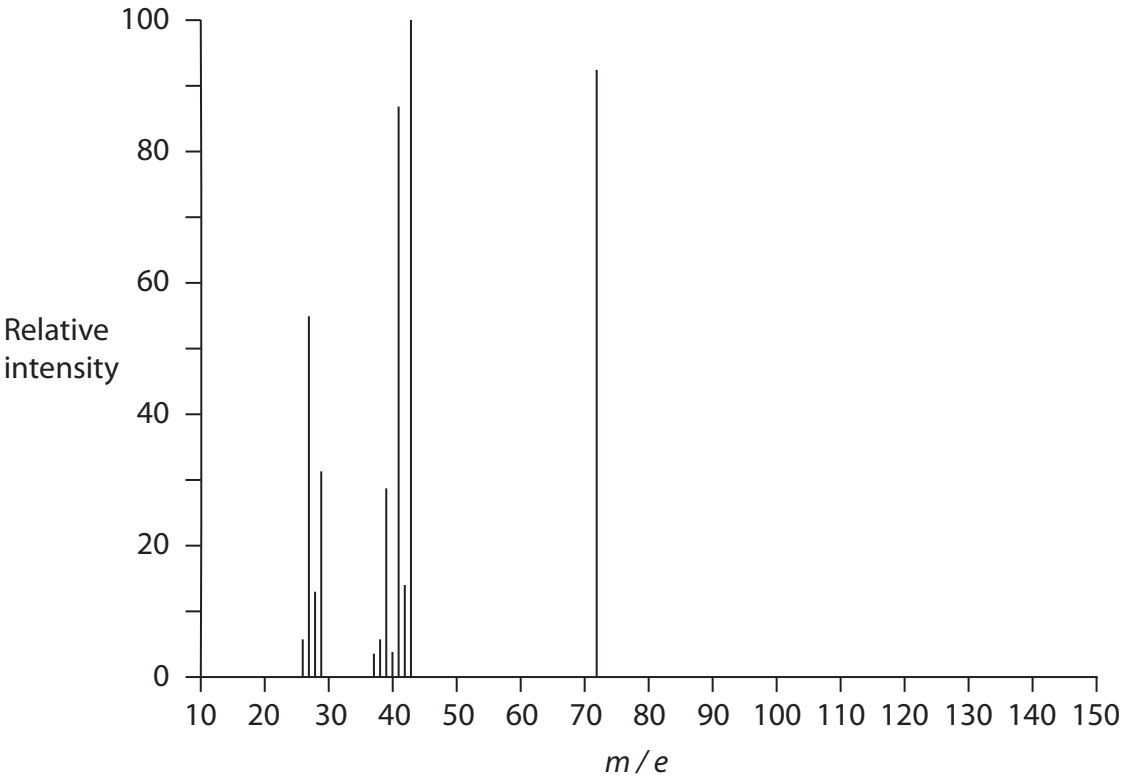
(iv) 3.60 g of compound **A** was burned completely. The mass of solid **X** increased by 3.60 g and the mass of solid **Y** increased by 8.80 g.

Use these data to calculate the empirical formula of compound **A**.
You **must** show your working.

(5)

P 4 2 8 7 3 A 0 1 1 2 8
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(b) The mass spectrum of **A** is shown below.



(i) Identify the molecular ion peak and hence deduce the molecular formula of **A**.

(2)

.....

.....

P 4 2 9 7 3 A 0 1 2 2 8
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(ii) Given that **A** does **not** have a ring structure, suggest the **structural** formulae of three of the species that might cause the peak at *m/e* = 43 in the mass spectrum of **A**.

(3)

*(c) The low resolution nmr spectrum of **A** has three peaks in the ratio 6:1:1. Draw the structure of **A** and show how your structure is consistent with the nmr data.

(3)

.....

.....

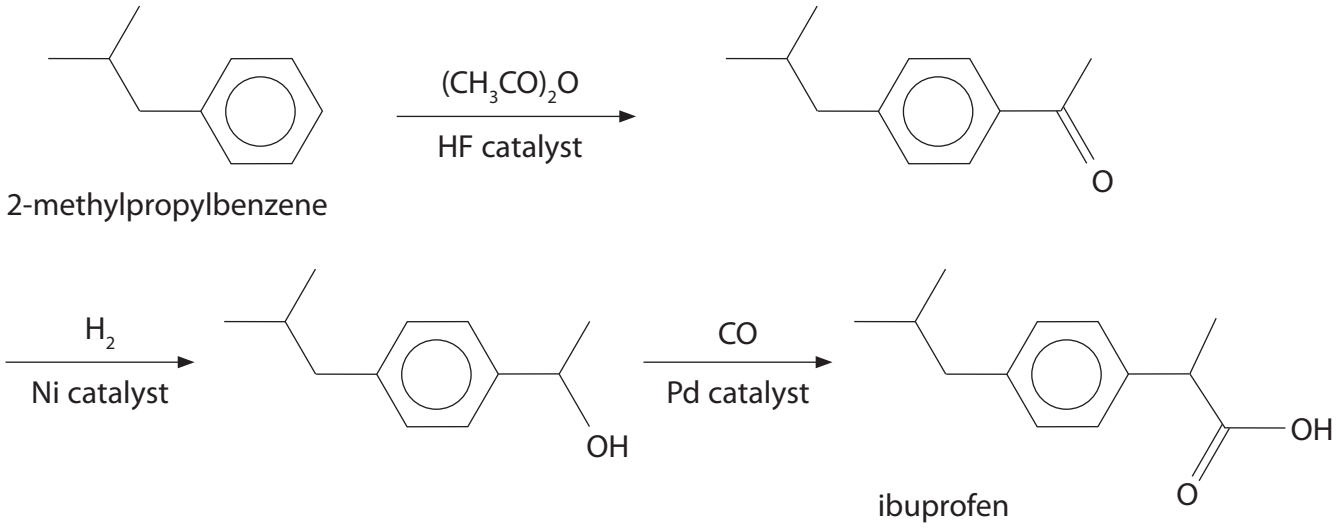
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(Total for Question 19 = 16 marks)

P 4 2 8 7 3 A 0 1 3 2 8
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20 Ibuprofen is a nonsteroidal anti-inflammatory drug (NSAID) widely used as an analgesic (pain reliever). It was discovered in the 1960s by the Boots Group which developed a six step synthesis from 2-methylpropylbenzene. The synthesis shown below was introduced in the 1990s by the BHC Company and received a Presidential Green Chemistry Challenge award in 1997. The citation noted that the synthesis has just three steps, all of which are catalytic, and an effective atom economy of 99%. Both syntheses are carried out in solution.



(a) (i) Suggest why a three step synthesis is likely to be 'greener' than a six step process.

(1)

.....

.....

(ii) Why does the use of catalysts make processes 'greener' (as well as faster)?

(1)

.....

.....

P 4 2 9 7 3 A 0 1 4 2 8
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(b) The first step of the synthesis is an electrophilic substitution which is usually carried out in a school laboratory using ethanoyl chloride and an aluminium chloride catalyst.

(i) Write an equation showing the formation of the electrophile in the **school** experiment.

(1)

(ii) Give the mechanism for the electrophilic substitution of 2-methylpropylbenzene by ethanoyl chloride, using the electrophile you have given in (b)(i).

(3)

(iii) Suggest **one** environmental benefit of using $(CH_3CO)_2O$, rather than ethanoyl chloride, in the manufacture of ibuprofen.

(1)

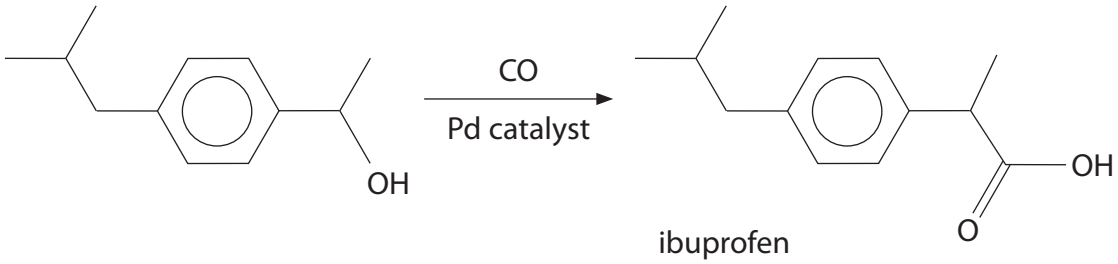
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P 4 2 8 7 3 A 0 1 5 2 8
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(c) The final stage of the modern synthesis for ibuprofen is shown below.



ibuprofen

(i) Suggest a benefit of using a **solid** catalyst in this reaction.

(1)

.....

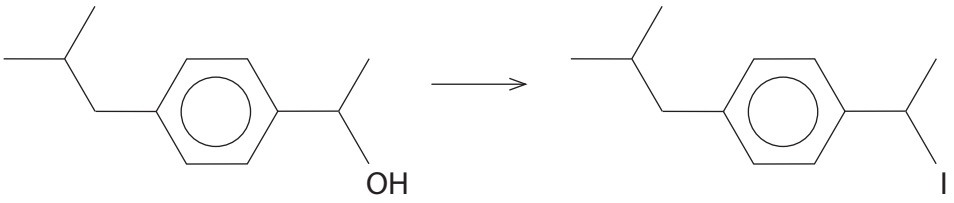
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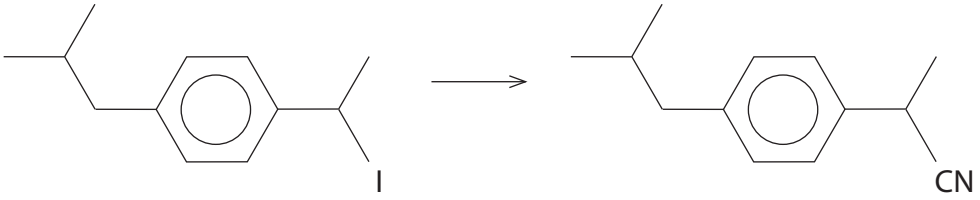
(ii) The preparation in part (c) can be carried out in a laboratory in three reactions.

(3)

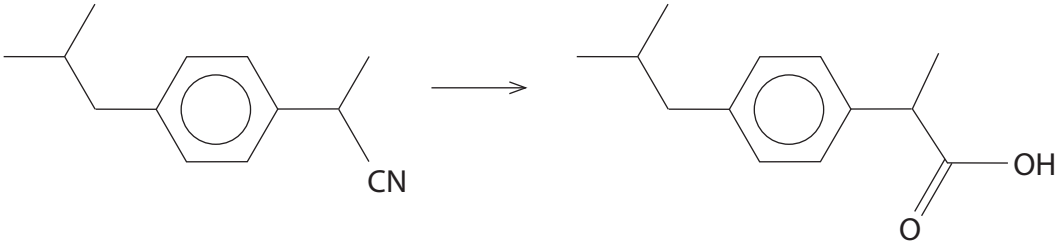
Reaction 1



Reaction 2



Reaction 3



Give:

The reagents for **Reaction 1**

.....

.....

The reagents and conditions for **Reaction 3**

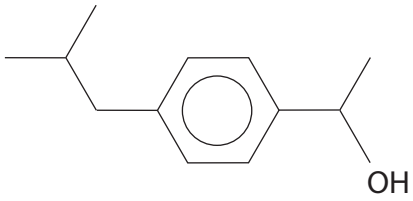
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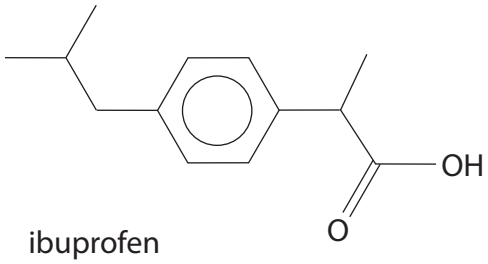
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(iii) Using your Data Booklet, explain how infrared spectroscopy can be used to distinguish between the two structures shown below.

(2)





ibuprofen

.....

.....

.....

.....

(d) Ibuprofen is a chiral molecule and only one of its enantiomers is biologically active. However, although the synthesis produces a racemic mixture, an isomerase enzyme in the body converts the inactive enantiomer into the active enantiomer.

(i) Explain the term 'chiral molecule'.

(1)

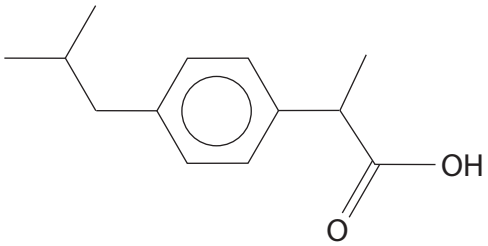
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(ii) Mark with an asterisk (*) the chiral centre on the structure of ibuprofen below.

(1)



P 4 2 9 7 3 A 0 1 8 2 8
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(iii) Explain the term 'racemic mixture'.

(1)

(iv) Suggest **two** benefits that arise from the isomerization of the inactive enantiomer of ibuprofen.

(2)

(Total for Question 20 = 18 marks)

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21 (a) The following method was used to estimate the concentration of ethanol in an aqueous solution, **Q**, prepared by the fermentation of sucrose.

25 cm^3 of **Q** was measured using a pipette and transferred to a 250 cm^3 volumetric flask; the flask was made up to the mark with distilled water and mixed thoroughly, forming a diluted solution, **R**.

25 cm^3 samples of **R** were mixed with an equal volume of a 0.200 mol dm^{-3} potassium dichromate(VI) solution and excess dilute sulfuric acid.

The mixture was allowed to stand for several hours and then the amount of unreacted potassium dichromate(VI) was determined by titration against a 0.255 mol dm^{-3} iron(II) ammonium sulfate solution. The mean titre was 23.85 cm^3.

(i) Use the ionic half-equations below to write the full ionic equation for the reaction between potassium dichromate(VI) and iron(II) ammonium sulfate.

State symbols are not required.

(1)

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

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

(ii) Calculate the number of moles of potassium dichromate(VI) that remained **unreacted** after standing for several hours with solution **R**.

(2)

P 4 2 9 7 3 A 0 2 0 2 8
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(iii) Calculate the number of moles of potassium dichromate(VI) that reacted with the ethanol while standing for several hours with solution **R**.

(2)

(iv) Write an ionic half-equation for the oxidation of ethanol to ethanoic acid.

Use your equation, and the half-equation for the reduction of dichromate(VI) ions, to show that 3 mol of ethanol are oxidized by 2 mol of potassium dichromate(VI).

(2)

.....

.....

(v) Calculate the concentration of ethanol (in mol dm^{-3}) in solution **Q**.

(3)

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*(b) The indicator used in this titration was barium diphenylamine sulfonate, which turns from deep purple to colourless at the end-point.

Identify the ion responsible for turning the indicator from deep purple to colourless at the end-point.

By considering the type of reaction involved when this ion reacts with barium diphenylamine sulfonate, suggest how barium diphenylamine sulfonate acts as an indicator in this titration. Note that complex formation does **not** occur. The detailed reactions of this particular indicator are **not** required.

(3)

*(c) This method of determining ethanol concentration does not give very reliable results, although the titration is very accurate.

Suggest **one** reason why this might be the case, explaining how the measured concentration would differ from the actual concentration of the ethanol.

(3)

(Total for Question 21 = 16 marks)

TOTAL FOR SECTION B = 50 MARKS

P 4 2 9 7 3 A 0 2 2 2 8
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SECTION C

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

22

Metal Complexes

Complexes involve ligands forming dative covalent bonds with a central cation; the number of dative covalent bonds is the coordination number of the cation in the complex. Complexes may be positive, negative or neutral. The ligands may be neutral or negatively charged, but are never positively charged. The ligands must have a lone pair of electrons. In some complexes the central atom is neutral, as is the case with nickel carbonyl which is used in the Mond process for the purification of nickel:

$$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$$

The formation of complexes is typical of transition metals but other elements also form complexes. Zinc, which is a d block element but not a transition metal, and aluminium, which is a Group 3 element, both form complexes. Transition metal complexes are usually coloured, but if the interaction between the ligand and the central ion is very strong, then the resulting complex may well be colourless. This is the case with the complex $[FeF_6]^{3-}$.

The ligand in a complex affects its redox properties and this is apparent from considering the relevant standard electrode potentials. For example, with copper(II) species:

$$[Cu(H_2O)_6]^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) + 6H_2O(l) \qquad E^{\ominus} = +0.34\ V$$

$$[Cu(H_2O)_2(NH_3)_4]^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) + 2H_2O(l) + 4NH_3(aq) \qquad E^{\ominus} = -0.05\ V$$

Complexes are industrially important, for example in the purification of nickel mentioned above and in the extraction of gold which involves the complex $[Au(CN)_2]^-$.

Complex formation is used in estimating the concentrations of metal ions in solution. Examples of this are the use of EDTA in titration and dimethylglyoxime in gravimetric analysis. Complexes are also used in qualitative analysis, for example, in Tollens' reagent. This reagent is usually prepared by the addition of sodium hydroxide solution to an aqueous solution of silver nitrate followed by aqueous ammonia. The resulting solution contains diamminesilver(I) ions.

(a) The hydrated copper(II) ion is classed as a complex but the hydrated sodium ion is not. By considering the interaction between the water molecules and the sodium ion, explain why the hydrated sodium ion is **not** considered to be a complex.

(2)

(b) Suggest how the aluminium ion is able to form dative covalent bonds in its complexes such as $[AlF_6]^{3-}$.

(1)

*(c) (i) Transition metal complexes are usually coloured. Explain how the colours occur.

(4)

(ii) Why are zinc complexes such as $[Zn(NH_3)_4]^{2+}$ colourless?

(1)

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(iii) Suggest why the strong interactions between the F^- ligands and Fe^{3+} ion result in the complex $[FeF_6]^{3-}$ being colourless.

(2)

(d) Use the standard electrode potentials given in the passage to predict whether it is feasible for thiosulfate ions, $S_2O_3^{2-}$, to reduce copper(II) ions to copper. Consider the case when the copper(II) ions are dissolved in water, and when they are dissolved in aqueous ammonia. Give chemical equations to support your answer.

(3)

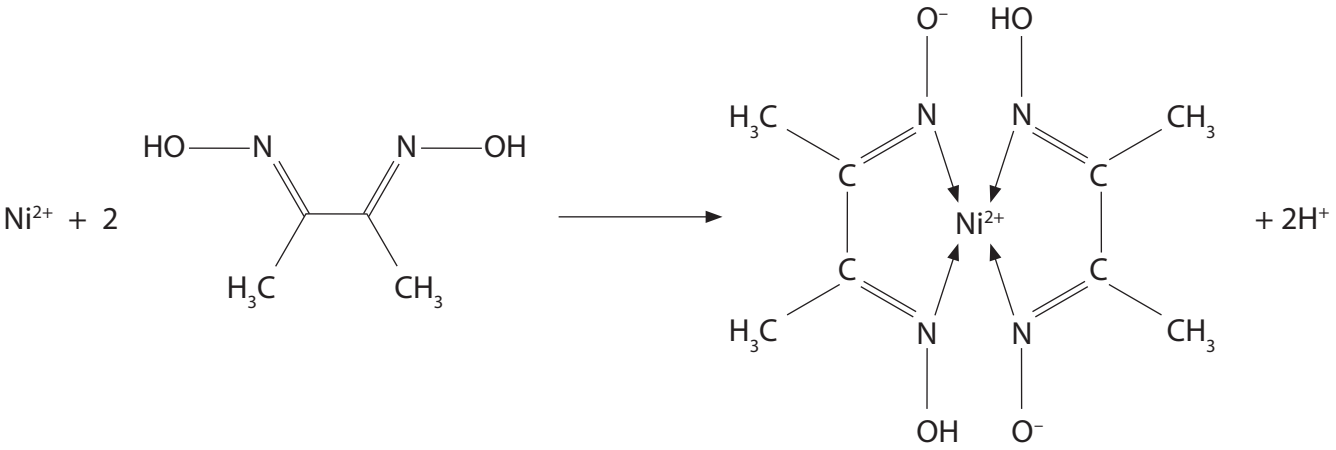
The relevant redox reaction for thiosulfate ions is

$$S_4O_6^{2-}(aq) + 2e^- \rightleftharpoons 2S_2O_3^{2-}(aq) \qquad E^{\ominus} = +0.09\ V$$

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(e) The proportion of nickel in nisil, an alloy of nickel and silicon used in thermocouples, may be determined by the following gravimetric analysis.

Finely ground nisil is dissolved in concentrated hydrochloric acid and, after neutralization, excess dimethylglyoxime dissolved in ethanol is added to the solution formed. The resulting red precipitate is filtered, washed, dried and weighed. The equation for the formation of the precipitate is



(i) State the coordination number of the nickel in the complex ion.

(1)

.....

(ii) In an experiment, 1.02 g of nisil formed 4.82 g of the complex. Calculate the percentage by mass of nickel in the alloy. The molar mass of the complex is 288.7 g mol^{-1}.

(2)

P 4 2 9 7 3 A 0 2 6 2 8
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(f) Suggest why the nickel carbonyl complex is used to purify nickel ores.

(1)

.....

.....

.....

.....

(g) Use the equilibria below to explain why ammonia is used to prepare Tollens' reagent, as described in the passage.

(3)

$2Ag^+(aq) + 2OH^-(aq) \rightleftharpoons Ag_2O(s) + H_2O(l)$ Equilibrium 1

$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq)$ Equilibrium 2

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(Total for Question 22 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

P 4 2 8 7 3 A 0 2 7 2 8
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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

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Mark Scheme (Results)

June 2014

GCE Chemistry 6CH05/01

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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

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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.

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Section A (multiple choice)

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

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

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

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

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

Question Number	Correct Answer	Reject	Mark
6 (a)	B		**1**
6 (b)	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	C		**1**

Question Number	Correct Answer	Reject	Mark
10	A		**1**

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

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

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

Question Number	Correct Answer	Reject	Mark
14 (a)	A		**1**
14 (b)	D		**1**

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

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

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

Question Number	Correct Answer	Reject	Mark
18	B		**1**

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Section B

Question Number	Acceptable Answers	Reject	Mark
19 (a)(i)	So that only the water formed in the combustion is absorbed by X / measured. ALLOW 'reacts with X' for 'absorbed by X' OR Otherwise the mass / amount of the water measured will be too high	Reacts with A References to Y	**1**

Question Number	Acceptable Answers	Reject	Mark
19 (a)(ii)	(Anhydrous) Calcium chloride / $CaCl_2$ / Magnesium sulphate / $MgSO_4$ / silica gel / sodium sulphate / Na_2SO_4 ALLOW Phosphorus(V) oxide / phosphorus pentoxide / P_4O_{10} / P_2O_5 / Silica beads	Sulfuric acid Calcium oxide Silica / SiO_2 anhydrous copper(II) sulfate	**1**

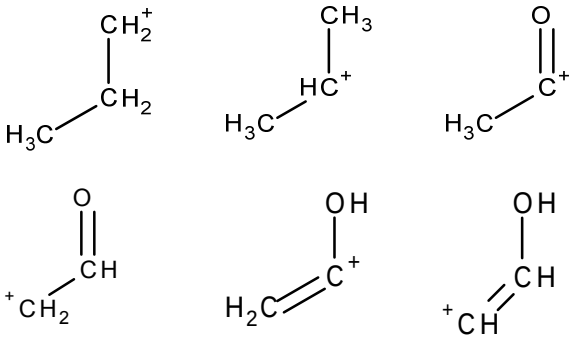
Question Number	Acceptable Answers	Reject	Mark
19 (a)(iii)	Soda lime OR calcium hydroxide / $Ca(OH)_2$ **and** sodium hydroxide / NaOH ALLOW sodium hydroxide / NaOH / potassium hydroxide / KOH / Calcium oxide / CaO	Limewater	**1**

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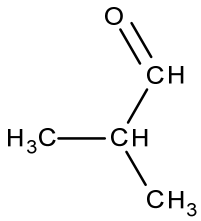
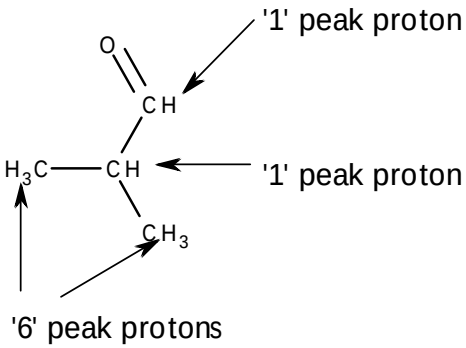
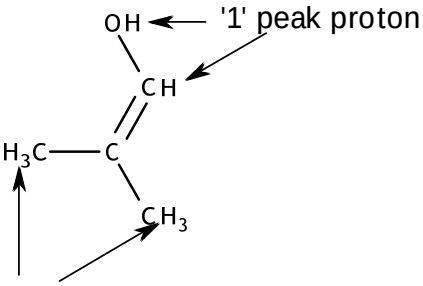
Question Number	Acceptable Answers	Reject	Mark
19 (a)(iv)	The methods below illustrate the allocation of marks. But the first four marks may be scored by any correct method. **Method 1** mol CO_2 = 8.8/44 = 0.2 (= mol C) **(1)** mol H_2O = 3.6/18 = 0.2 mol H = 2 x mol H_2O = 0.4 **(1)** mass O = 3.6 – (12 x 0.2 + 1 x 0.4) = 0.8 (g) **(1)** mol O = 0.8/16 = 0.05 **(1)** **Method 2** Mass H = 3.60 x 2/18 = 0.40 (g) = 0.40 / 1 = 0.40 (mol) **(1)** Mass C = 8.80 x 12/44 = 2.4 (g) = 2.4 / 12 = 0.20 (mol) **(1)** Mass O = 3.60 – (0.40 + 2.4) = 0.80(g) **(1)** = 0.80 / 16 = 0.05 (mol) **(1)** Empirical formula = C_4H_8O **(1)** TE on incorrect moles but the ratio **must** be whole number IGNORE use of O_2 for O in the 'words' Correct empirical formula with some working at each stage scores full marks **but** Correct empirical formula with **no** working or **unclear and non-scoring** working scores final mark only		**5**

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Question Number	Acceptable Answers	Reject	Mark
19 (b)(i)	(Molecular ion is m/e =) 72 (= M_r of **A**)**(1)** Molecular formula = C_4H_8O **(1)** No TE on incorrect molecular ion	 Structural Or Displayed Or Molecular ion	**2**

Question Number	Acceptable Answers	Reject	Mark
19 (b)(ii)	Any three of (1 mark for each structure)  ALLOW structural formulae (eg CH_3CO^+) IGNORE Position of positive charge Penalise omission of charge or negative charge once $C_3H_7^+$ and /or $C_2H_3O^+$ scores 1 if no scoring structure		**3**

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Question Number	Acceptable Answers		Reject	Mark
***19 (c)**	Structure of **A** (1)  Three (proton/H) environments (1) **Identify** the 6 protons in one environment and 1 each in the other two (1) No TE on incorrect structures except propan-2-ol : scores MP3 only	OR diagram (1)  6 proton label (1) **both** 1 proton labels (1) ALLOW enol structure  6 proton label (1) **both** 1 proton labels (1)		**3**

Total for Question 19 = 16 marks

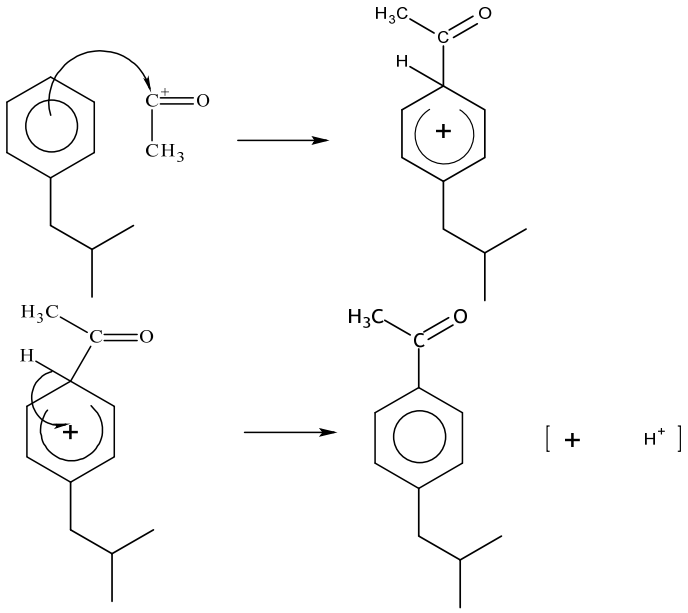
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Question Number	Acceptable Answers	Reject	Mark
20 (a)(i)	Overall **yield** higher OR Reduces use of solvents (ALLOW chemicals / reactants) OR Less loss of chemicals OR Less waste products IGNORE References to Energy / fuel / CO_2 References to atom economy More efficient conversion Fewer side products		**1**

Question Number	Acceptable Answers	Reject	Mark
20 (a)(ii)	Lowers (operating) temperature / energy (requirements) OR Less fuel needed IGNORE References to catalyst properties such as 'lowers E_a', 'can be re-used' Atom economy		**1**

Question Number	Acceptable Answers	Reject	Mark
20 (b)(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$ Structural formulae not required Positive charge may be anywhere on the electrophile. IGNORE Curly arrows even if incorrect		**1**

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Question Number	Acceptable Answers	Reject	Mark
20 (b)(ii)	 TE on incorrect electrophile in (b)(i) If benzene used instead of substituted benzene OR If final product is not 1,4 only MP 1 and 2 can be scored Curly arrow from on or within the circle to positively charged carbon ALLOW Curly arrow from anywhere within the hexagon Arrow to **any** part of the electrophile including to the + charge (which can be anywhere on the electrophile) **(1)** Intermediate structure including charge with horseshoe covering at least 3 carbon atoms, **and** facing the tetrahedral carbon **and** with some part of the positive charge within the horseshoe ALLOW dotted horseshoe **(1)** Curly arrow from C—H bond to anywhere in the benzene ring reforming delocalized structure of a stable molecule **(1)** Correct Kekulé structures score full marks Ignore any involvement of $AlCl_4^-$ in the final step	Curly arrow on or outside the hexagon Partial bonds to H and CH_3 unless part of a 3D with a wedge bond	**3**

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Question Number	Acceptable Answers	Reject	Mark
20 (b)(iii)	No HCl formed (as a by-product) OR Ethanoic acid easier to recover ALLOW Reverse arguments IGNORE Chlorine containing product References to ozone layer, acid rain, global warming Atom economy	Chlorine	**1**

Question Number	Acceptable Answers	Reject	Mark
20 (c)(i)	Catalyst (more) easily recovered / separated OR can be filtered OR Facilitates the use of flow (rather than batch) systems IGNORE references to properties of catalysts		**1**

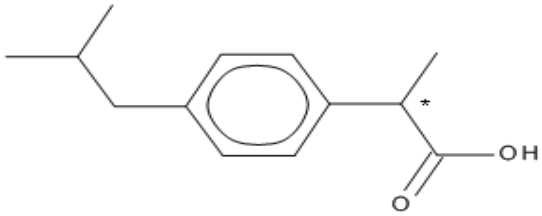
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Question Number	Acceptable Answers	Reject	Mark
20 (c)(ii)	**Reaction 1** (red) phosphorus / P / P_4 and iodine / I_2 ALLOW PI_3 / HI **(1)** **Reaction 3** Hydrochloric acid / HCl(aq) or sulfuric acid / H_2SO_4 (aq) **(1)** **and** reflux / heat **(1)** Award second mark for Acid / H^+ / H_3O^+ **and** reflux OR NaOH(aq) / KOH(aq) **(1)** (reflux) **then** acidify with HCl(aq) or H_2SO_4 (aq) **(1)** IGNORE Omission of states throughout	NaI + H_2SO_4 PI_5 Just H^+ / H_3O^+ reflux / heat without acid or with warm or <50°C	

Question Number	Acceptable Answers	Reject	Mark
20 (c)(iii)	C=O / carbonyl group (only) in carboxylic acid / ibuprofen **(1)** Absorption / peak at 1725 - 1700 (cm^{-1}) **(1)** If no other mark has been awarded, then ALLOW (for 1 mark) OH in both but in alcohol 3750 - 3200 (cm^{-1}) but in carboxylic acids 3300 to 2500 (cm^{-1})	ketone 1700 - 1680 (cm^{-1}) Single values rather than ranges	**2**

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Question Number	Acceptable Answers	Reject	Mark
20 (d)(i)	(A chiral molecule is) non-superimposable on its mirror image. ALLOW Asymmetric (tetrahedral) carbon atom / has a carbon atom bonded to **four** different groups / atoms IGNORE Has two enantiomers Functional (as in functional groups) Reference to rotation of plane polarized light	molecules / species (for groups)	**1**

Question Number	Acceptable Answers	Reject	Mark
20 (d)(ii)	 ALLOW any clear indication of chiral carbon		**1**

Question Number	Acceptable Answers	Reject	Mark
20 (d)(iii)	(A racemic mixture is) an equimolar mixture of the two enantiomers / (optical) isomers ALLOW (for equimolar mixture) equal amounts / concentrations / volumes / proportions OR 50:50 mixture	Just 'no effect on plane polarised light'	**1**

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Question Number	Acceptable Answers	Reject	Mark
20 (d)(iv)	Any two of 1. All the ibuprofen is useful (rather than half) 2. No need for separation of isomers / enantiomers 3. No need for a more complex synthesis forming just one enantiomer 4. Sometimes one enantiomer has negative effects 5. Smaller dosage may be used ALLOW (For point 4 above) Dose / inactive isomer is less likely to be harmful IGNORE Reference to cost / yield / atom economy / side effects		**2**

Total for Question 20 = 18 marks

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Question Number	Acceptable Answers	Reject	Mark
21 (a)(i)	$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$ Ignore state symbols even if incorrect	Any answers with electrons even if balanced	**1**

Question Number	Acceptable Answers	Reject	Mark
21 (a)(ii)	Ignore SF except 1 SF – penalise this and/or rounding errors once only in (a)(ii) – (v) Moles of Fe^{2+} reacting in titration $= 23.85 \times 10^{-3} \times 0.255$ $= 6.08175 \times 10^{-3}$ mol * **(1)** Moles of $Cr_2O_7^{2-}$ that reacted in titration = answer * ÷ 6 $= 6.08175 \times 10^{-3} \div 6$ $= 1.013625 \times 10^{-3}$ mol **(1)** Correct answer with no working scores 2		**2**

Question Number	Acceptable Answers	Reject	Mark
21 (a)(iii)	Moles of $Cr_2O_7^{2-}$ at start $= 25 \times 10^{-3} \times 0.200$ $= 5 \times 10^{-3}$ mol** **(1)** Moles of $Cr_2O_7^{2-}$ that reacted with ethanol = answer ** – answer 21(a)(ii) $= 5 \times 10^{-3} - 1.013625 \times 10^{-3}$ $= 3.986375 \times 10^{-3}$ mol **(1)** Correct answer with no working scores 2		**2**

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Question Number	Acceptable Answers	Reject	Mark
21 (a)(iv)	$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$ **(1)** 3 mol of ethanol needs 12 mol electrons supplied by 2 mol potassium dichromate(VI) ALLOW Use of oxidation numbers of C and Cr OR Use of ratio of electrons lost and gained OR Balanced equation: $3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$ **(1)** IGNORE Uncancelled species including the 12 electrons in the last equation	Use of [O] **Just** 3 mol of ethanol reacts with 2 mol $Cr_2O_7^{2-}$	**2**

Question Number	Acceptable Answers	Reject	Mark
21 (a)(v)	Moles of ethanol that reacted with potassium dichromate(VI) = ans. 21(a)(iii) x 3 ÷ 2 = 5.9795625 x 10^{-3} mol **(1)** Concentration in **Q** = previous answer x 10 x 40 = 2.391825 mol dm^{-3} **(2)** (1 mark for x 10 or x 40 and 1 mark for completion of calculation Correct answer with no working scores 3		**3**

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Question Number	Acceptable Answers	Reject	Mark
***21(b)**	Fe^{2+} / iron(II) **(1)** And any TWO of: Barium diphenylamine sulfonate is a **redox** indicator ALLOW reaction is **redox** **(1)** Barium diphenylamine sulfonate / indicator is reduced by iron(II) OR Iron(II) is oxidized by barium diphenylamine sulfonate / indicator OR Barium diphenylamine sulfonate / indicator oxidized by potassium dichromate(VI) OR Potassium dichromate(VI) is reduced by Barium diphenylamine sulfonate / indicator **(1)** The oxidized form / oxidation product of barium diphenylamine sulfonate is purple OR the reduced form is colourless ALLOW Oxidised and reduced form of the indicator have different colours **(1)**		**3**

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Question Number	Acceptable Answers	Reject	Mark
***21(c)**	**EITHER** **MP1** Difficult to know when reaction is complete OR Difficult to know when all the ethanol has been oxidized (to ethanoic acid) OR Some ethanol only oxidized to ethanal ALLOW Some ethanol is oxidized by air **(1)** **MP2** (depends on MP1 correct or 'ethanol evaporates') So less potassium dichromate(VI) will be used up **(1)** **MP3** (depends on MP1 or MP2 or 'ethanol evaporates') Ethanol concentration will appear low **(1)** **OR** Other compounds in the fermented solution (e.g. aldehydes) are oxidized also. **(1)** So more potassium dichromate(VI) will be used up **(1)** Ethanol concentration will appear high **(1)**	Ethanol evaporates Transfer losses / spillages Not all sugar fermented	**3**

Total for Question 21 = 16 marks
Total for Section B = 50 marks

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Section C

Question Number	Acceptable Answers	Reject	Mark
22 (a)	Oxygen atoms in water molecules have δ− charge. **(1)** Which form electrostatic / ion-dipole attractions with sodium (ion). **(1)** ALLOW for one mark copper(II) ions form dative covalent bonds but sodium ions do not (**both** needed)	 Ionic bonds / attractions Intermolecular forces Hydrogen bonds	**2**

Question Number	Acceptable Answers	Reject	Mark
22 (b)	Additional (dative covalent bond) lone pairs are accommodated in vacant (3)d orbitals / (3)d sub-shell ALLOW Vacant **higher** energy orbitals / sub-shells IGNORE 3s/3p	'Partially filled' for 'vacant'	**1**

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Question Number	Acceptable Answers	Reject	Mark
***22 (c)(i)**	(3)d orbitals / (3)d subshell split (by the attached ligands) **(1)** Electrons are promoted (from lower to higher energy d orbital(s) / levels) OR Electrons move from lower to higher energy (d orbital(s) / levels) ALLOW d—d transitions occur /electrons are excited **(1)** Absorbing energy /photons of a certain frequency (in the visible region) ALLOW Absorbing light **(1)** Reflected / transmitted / remaining light is coloured / in the visible region ALLOW Complementary colour seen Reflected / transmitted / remaining light / frequency is seen **(1)** Penalise omission of (3)d once only. Ignore reference to electrons relaxing / dropping to the ground state	Orbital / shell is split Emitted	**4**

Question Number	Acceptable Answers	Reject	Mark
22 (c)(ii)	Zn (3)d orbitals are / (3)d subshell is **full / complete** (so d−d transitions are not possible) / Zinc is $3d^{10}$	Zn does not have partially filled d subshell	**1**

Question Number	Acceptable Answers	Reject	Mark
22 (c)(iii)	(d−d) energy gap is large **(1)** the energy absorbed is outside the visible region / in the UV region **(1)** Stand alone marks		**2**

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Question Number	Acceptable Answers	Reject	Mark
22 (d)	**<u>Method 1: cell emfs</u>** For the reaction $Cu(H_2O)_6^{2+}(aq) + 2S_2O_3^{2-}(aq)$ $\rightarrow Cu(s) + 6H_2O(l) + S_4O_6^{2-}(aq)$ * $E^{\ominus}_{cell} = +0.34 - 0.09 = (+)0.25$ (V) **and** (Positive so) reaction is feasible **(1)** For the reaction $Cu(H_2O)_2(NH_3)_4^{2+}(aq) + 2S_2O_3^{2-}(aq)$ $\rightarrow Cu(s) + 2H_2O(l) + 4NH_3(aq) + S_4O_6^{2-}(aq)$ ** $E^{o}_{cell} = -0.05 - 0.09 = -0.14$ (V) **and** (Negative so) reaction is not feasible **(1)** If both values correct but feasibility omitted or incorrect award 1 mark **Both** equations (* & **) correct IGNORE Omission of H_2O and states from the equations **(1)** **<u>Method 2: anticlockwise rule</u>** Place the reactions in order of increasing (more positive) $E^{\ominus}$ values and check which reaction occurs in the anticlockwise direction. **(1)** $S_4O_6^{2-}(aq) + 2e^- \rightarrow 2S_2O_3^{2-}(aq)$ $E^o = +0.09$ V $Cu(H_2O)_6^{2+}(aq) + 2e^- \rightarrow Cu(s) + 6H_2O(l)$ $E^{\ominus} = 0.34$ V Reaction is feasible (desired reaction proceeds in anticlockwise direction) **(1)** $Cu(H_2O)_2(NH_3)_4^{2+}(aq) + 2e^-$ $\rightarrow Cu(s) + 2H_2O(l) + 4NH_3(aq)$ $E^o = -0.05$ V $S_4O_6^{2-}(aq) + 2e^- \rightarrow 2S_2O_3^{2-}(aq)$ $E^o = +0.09$ V Reaction is not feasible (proceeds in the opposite direction). **(1)**	electrons in equations	**3**

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Question Number	Acceptable Answers	Reject	Mark
22 (e)(i)	(coordination number =) 4 / four		**1**

Question Number	Acceptable Answers	Reject	Mark
22 (e)(ii)	Amount of complex = 4.82 / 288.7 (= 0.0166955 mol) Mass of nickel = 58.7 x 4.82 / 288.7 = 0.98003 g **(1)** % Nickel in alloy = 100 x 0.98 / 1.02 = 96.08 % **(1)** Correct answer with no working scores 2 Ignore SF except 1 ALLOW TE unless %>100 Use of A_r(Ni) = 59 (gives 96.57%)		**2**

Question Number	Acceptable Answers	Reject	Mark
22 (f)	Nickel carbonyl is a gas (so can be easily separated from impurities).		**1**

Question Number	Acceptable Answers	Reject	Mark
22 (g)	Silver(I) oxide is precipitated in alkaline solution OR Silver(I) ions need to be in solution OR (Ammonia) prevents precipitation of silver(I) oxide **(1)** Formation of diamminesilver(I) lowers concentration of $Ag^+(aq)$ OR Equilibrium 2 shifts to the right by addition of ammonia **(1)** (lower $[Ag^+]$) causes equilibrium 1 to shift to the left **(1)** IGNORE Omission of oxidation state of silver		**3**

Total for Question 22 = 20 marks

Total for Section C = 20 marks

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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)

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 ▶

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PEARSON

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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 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.

P 4 1 6 5 1 A 0 2 3 2
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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.

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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.

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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)

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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

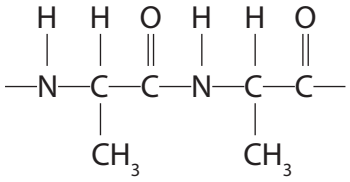
☒ **D** 5

(Total for Question 12 = 1 mark)

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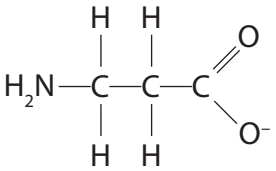
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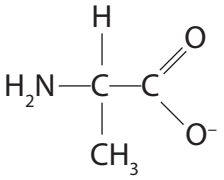
13 A section of the polypeptide made from a single amino acid is shown below.

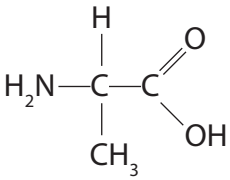


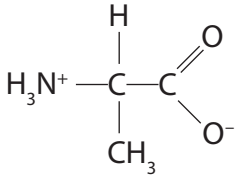
The polypeptide was heated with excess dilute sodium hydroxide solution until no further change took place.

Which of the following products is formed?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

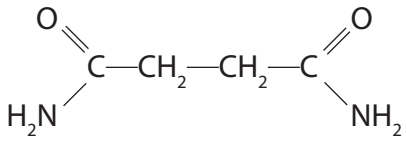
(Total for Question 13 = 1 mark)

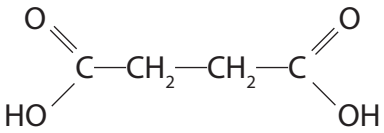
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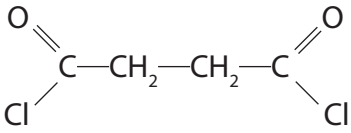
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14 Which of the following pairs of compounds could form a polyamide?

☒ **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)

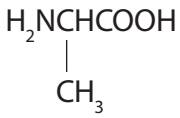
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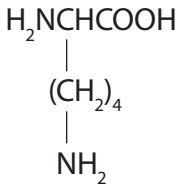
15 Which of the following amino acids is optically active and produces an approximately neutral solution when dissolved in water?

☒ **A** H_2NCH_2COOH

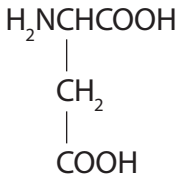
☒ **B**



☒ **C**



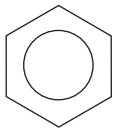
☒ **D**



(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.

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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

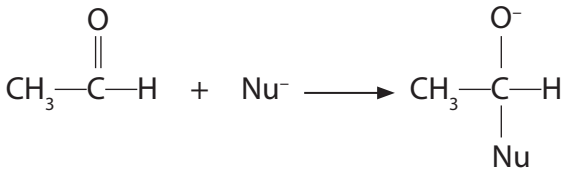
☒ **B** C_3H_8

☒ **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.

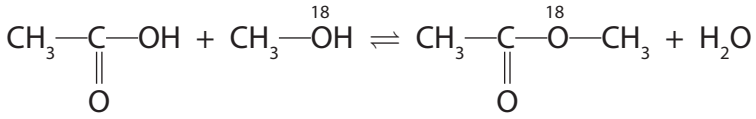
☒ **D** C═O bond is weak.

(Total for Question 18 = 1 mark)

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P 4 1 6 5 1 A 0 1 1 0 3 2
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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.

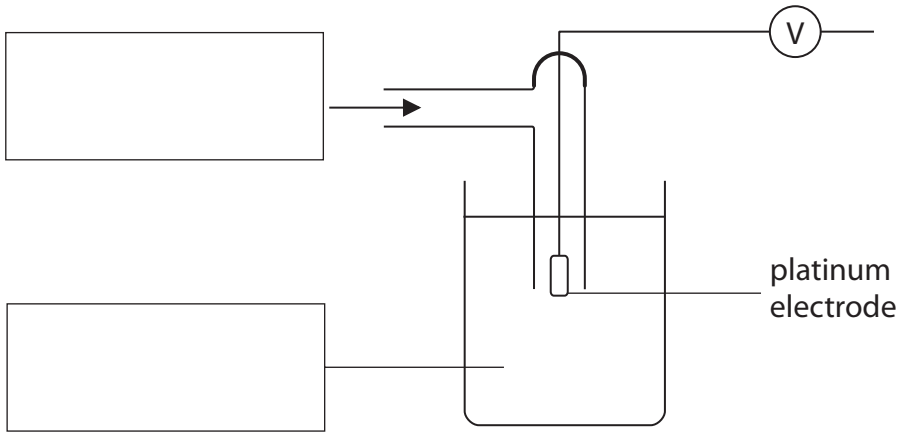
(2)

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

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(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)

P 4 1 6 5 1 A 0 1 4 3 2
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(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)

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.....

(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)

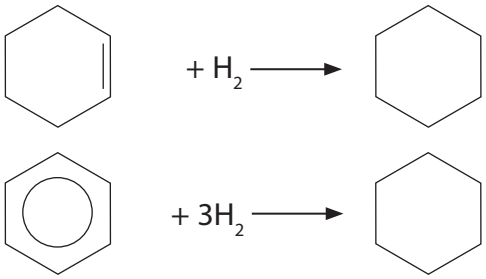
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(Total for Question 21 = 12 marks)

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



$\Delta H = -120$ kJ mol^{-1}

$\Delta H = -208$ kJ mol^{-1}

(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)

.....

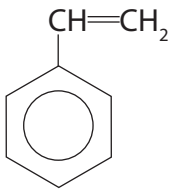
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(iii) Complete the following equation for the total hydrogenation of phenylethene. Suggest a value for the enthalpy change of this reaction.

(3)

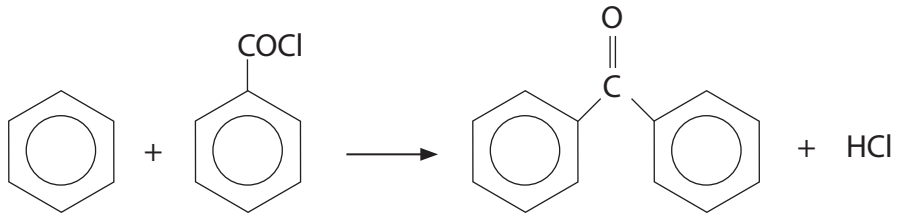


+ ..... H_2 →

ΔH = ... kJ mol^{-1}

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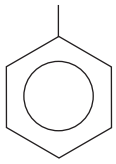
(b) The compound benzophenone is used as a sunscreen. It can be prepared from benzene, in the presence of aluminium chloride by the following reaction.



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 .....

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(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)

.....

.....

P 4 1 6 5 1 A 0 1 8 3 2
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(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)

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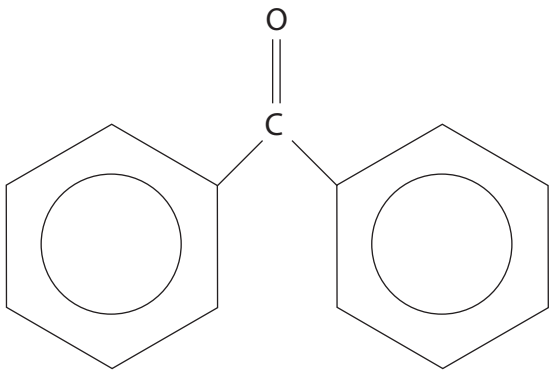
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(ii) In benzophenone there are three different hydrogen environments, X, Y and Z, that produce signals in the ratio 2:2:1 respectively in the proton nmr spectrum.

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)

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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)

.....

.....

P 4 1 6 5 1 A 0 2 0 3 2
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(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:

.....

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(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

.....

.....

.....

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(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

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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)

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(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)

.....

.....

.....

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*(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)

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*(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)

$$H_2O_2 + 2H^+ + \text{.....} \rightarrow \text{.....}$$

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*(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

P 4 1 6 5 1 A 0 3 2 3 2
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Mark Scheme (Results)

Summer 2013

GCE Chemistry 6CH05/01R
General Principles of Chemistry II

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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

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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.

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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**

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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

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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**

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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

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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**

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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**

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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**

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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

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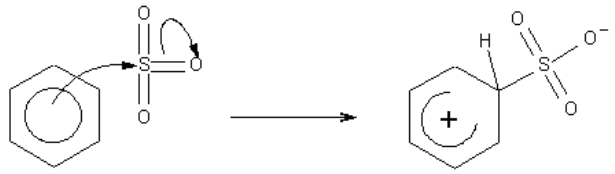
Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	**Fuming** sulfuric acid / **fuming** H_2SO_4 / oleum / $H_2S_2O_7$	Conc. (for fuming) Fuming dilute sulfuric acid **Just** sulfuric acid **Just** H_2SO_4	**1**

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**

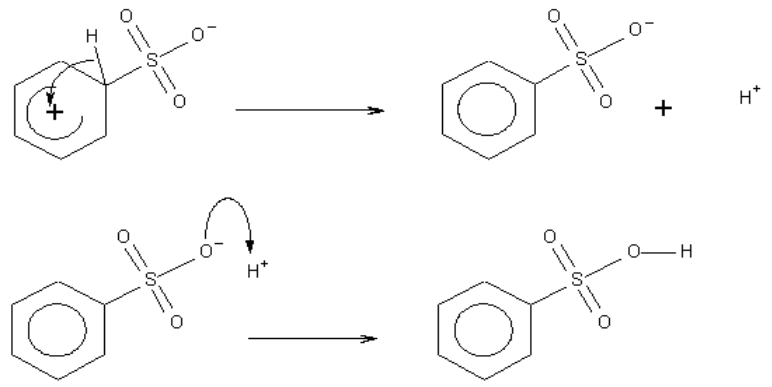
Question Number	Acceptable Answers	Reject	Mark
22 (a)(iii)	The sulfur trioxide can accept a pair of electrons OR (Three oxygen atoms so) sulfur has a large δ or partial / slight positive charge OR π bonds allow S—O bonds to be polarized more easily ALLOW Electron-deficient sulfur	An electron	**1**

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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**

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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**

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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

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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**

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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**

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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

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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**

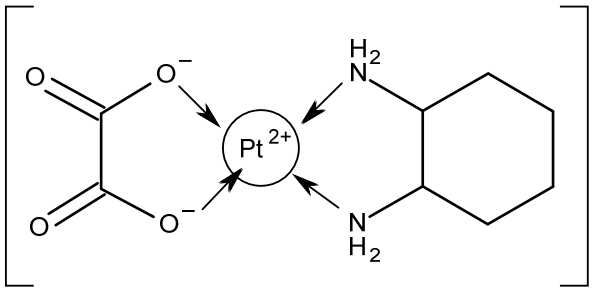
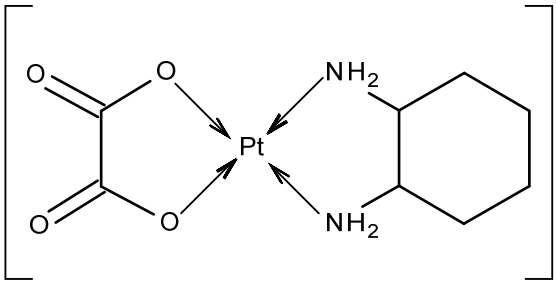
Question Number	Acceptable Answers	Reject	Mark
24(b)(i)	Colourless to (pale) pink ALLOW purple for pink	Clear for colourless	**1**

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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**

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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

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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**

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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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Chemistry

Advanced

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

Tuesday 22 January 2013 – 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 ▶

P41215A

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7/6/5/4/3/5/

P 4 1 2 1 5 A 0 1 2 4

PEARSON

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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 The reaction between iron and nickel(II) sulfate may be represented by the ionic equation

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

(a) This reaction is classified as a redox reaction because

(1)

☒ **A** the nickel(II) ions are oxidized and iron acts as an oxidizing agent.

☒ **B** the nickel(II) ions are oxidized and iron acts as a reducing agent.

☒ **C** the nickel(II) ions are reduced and iron acts as a reducing agent.

☒ **D** the nickel(II) ions are reduced and iron acts as an oxidizing agent.

(b) This reaction proceeds spontaneously, therefore

(1)

☒ **A** E_{cell} and ΔS_{total} for this reaction must both be positive.

☒ **B** E_{cell} and ΔS_{total} for this reaction must both be negative.

☒ **C** E_{cell} for this reaction must be positive and ΔS_{total} negative.

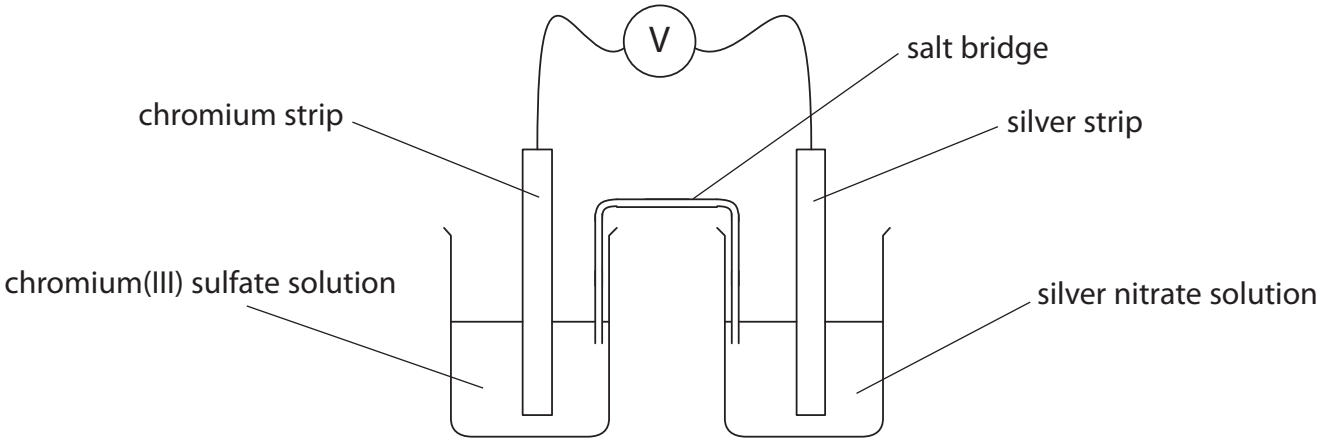
☒ **D** E_{cell} for this reaction must be negative and ΔS_{total} positive.

(Total for Question 1 = 2 marks)

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

P 4 1 2 4 5 A 0 2 2 4
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2 The diagram below shows an electrochemical cell.



(a) The salt bridge in this cell is **best** prepared by soaking filter paper in a

(1)

☒ **A** 1 mol dm^{-3} solution of potassium bromide.

☒ **B** 1 mol dm^{-3} solution of potassium chloride.

☒ **C** saturated solution of potassium nitrate.

☒ **D** saturated solution of potassium iodide.

(b) The relevant standard electrode potentials for this cell are shown below.

$$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s) \quad E^{\ominus} = -0.74\ V$$

$$Ag^{+}(aq) + e^- \rightleftharpoons Ag(s) \quad E^{\ominus} = +0.80\ V$$

The emf of the cell shown in the diagram is

(1)

☒ **A** +1.54 V

☒ **B** −1.54 V

☒ **C** +0.06 V

☒ **D** −0.06 V

(c) The mass of 1 mol of chromium(III) sulfate ($Cr_2(SO_4)_3$) is 392 g. Hence, for the cell in the diagram to measure the **standard** electrode potential, 1 dm^3 of the chromium(III) sulfate solution used must contain

(1)

☒ **A** 104 g of chromium(III) sulfate.

☒ **B** 196 g of chromium(III) sulfate.

☒ **C** 392 g of chromium(III) sulfate.

☒ **D** 784 g of chromium(III) sulfate.

(Total for Question 2 = 3 marks)

P 4 1 5 2 4 3 2 4 SZEMUS.CA.UK

3 Vanadium is classified as a transition metal. This is because vanadium

- ☒ **A** is a d-block element.
- ☒ **B** has incompletely filled d orbitals.
- ☒ **C** forms stable ions with incompletely filled d orbitals.
- ☒ **D** forms stable ions in which it has different oxidation states.

(Total for Question 3 = 1 mark)

4 Copper(II) sulfate solution is blue. This is because

- ☒ **A** excited electrons emit light in the blue region of the spectrum as they drop back to the ground state.
- ☒ **B** excited electrons emit light in the red region of the spectrum as they drop back to the ground state.
- ☒ **C** electrons absorb light in the red region of the spectrum and the residual frequencies are observed.
- ☒ **D** electrons absorb light in the blue region of the spectrum and the residual frequencies are observed.

(Total for Question 4 = 1 mark)

5 One method of manufacturing hydrazine (N_2H_4) involves the action of sodium chlorate(I) on excess ammonia at 443 K and 50 atm. The yield is normally around 80% but, if just 1 part per million of copper(II) ions is present, the yield drops to 30%.

The most likely explanation for this is the ability of copper(II) ions to

- ☒ **A** form complex ions with ammonia.
- ☒ **B** catalyse reactions producing other nitrogen compounds.
- ☒ **C** reduce the hydrazine as it is formed.
- ☒ **D** reduce the sodium chlorate(I).

(Total for Question 5 = 1 mark)

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

P 4 1 2 1 5 A 0 4 2 4
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6 Platinum forms a complex with the formula $Pt(NH_3)_2Cl_2$ and chromium forms a complex ion with the formula $CrCl_4^-$.

(a) Considering the shapes of these complexes,

(1)

☒ **A** both complexes are square planar.

☒ **B** both complexes are tetrahedral.

☒ **C** $Pt(NH_3)_2Cl_2$ is tetrahedral and $CrCl_4^-$ is square planar.

☒ **D** $Pt(NH_3)_2Cl_2$ is square planar and $CrCl_4^-$ is tetrahedral.

(b) Considering the structures of these complexes,

(1)

☒ **A** both complexes form stereoisomers.

☒ **B** neither complex forms a stereoisomer.

☒ **C** $Pt(NH_3)_2Cl_2$ forms a stereoisomer but $CrCl_4^-$ does not.

☒ **D** $CrCl_4^-$ forms a stereoisomer but $Pt(NH_3)_2Cl_2$ does not.

(c) Considering the bonding between the central atom and the ligands in these complexes,

(1)

☒ **A** the bonding in both complexes is dative covalent.

☒ **B** the bonding in both complexes is ionic.

☒ **C** the bonding in $Pt(NH_3)_2Cl_2$ is dative covalent and in $CrCl_4^-$ is ionic.

☒ **D** the bonding in $Pt(NH_3)_2Cl_2$ is ionic and in $CrCl_4^-$ is dative covalent.

(Total for Question 6 = 3 marks)

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

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7 When concentrated ammonia solution is added to a green solution of chromium(III) sulfate, a green precipitate is formed which slowly dissolves in excess of the concentrated ammonia solution.

The chromium-containing species formed in these reactions are

	Green precipitate	Resulting solution
☒ **A**	$Cr(OH)_3$	$[Cr(OH)_6]^{3-}$
☒ **B**	$Cr(OH)_3$	$[Cr(NH_3)_6]^{3+}$
☒ **C**	$(NH_4)_2CrO_4$	$[Cr(OH)_6]^{3-}$
☒ **D**	$(NH_4)_2CrO_4$	$[Cr(NH_3)_6]^{3+}$

(Total for Question 7 = 1 mark)

8 Bromine reacts much faster with phenylamine than with benzene. This is because

☒ **A** N—H bonds are weaker than C—H bonds.

☒ **B** nitrogen is very electronegative.

☒ **C** the benzene ring has greater electron density in phenylamine than in benzene.

☒ **D** phenylamine reacts by addition whereas benzene reacts by substitution.

(Total for Question 8 = 1 mark)

9 X-ray diffraction provides evidence that benzene molecules have

☒ **A** delocalized π electrons.

☒ **B** carbon–carbon bonds that are all the same length.

☒ **C** lower thermodynamic stability than molecules of 1,3,5-cyclohexatriene.

☒ **D** greater thermodynamic stability than molecules of 1,3,5-cyclohexatriene.

(Total for Question 9 = 1 mark)

P 4 1 2 4 5 A 0 6 2 4
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10 Benzene is nitrated using a mixture of concentrated nitric and sulfuric acids. The sulfuric acid

☒ **A** acts as a solvent for the benzene and the nitric acid.

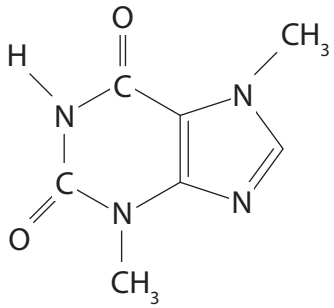
☒ **B** protonates the benzene to speed up the reaction.

☒ **C** protonates the nitric acid which acts as a base.

☒ **D** reacts with the benzene to form a benzenesulfonic acid intermediate.

(Total for Question 10 = 1 mark)

11 The compound shown below is found in cocoa beans and in chocolate. Which of the groups listed is **not** present in its structure?



☒ **A** Alkyl

☒ **B** Amide

☒ **C** Amine

☒ **D** Ketone

(Total for Question 11 = 1 mark)

12 The **distinguishing** characteristic of combinatorial chemistry is that it involves the

☒ **A** simultaneous synthesis of many products.

☒ **B** interaction of starting materials to form a unique product.

☒ **C** use of catalysts.

☒ **D** use of polymer supports.

(Total for Question 12 = 1 mark)

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

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13 Phenylamine (aniline), $C_6H_5NH_2$, may be prepared from nitrobenzene, $C_6H_5NO_2$.

(a) The reagent normally used for this reaction is

(1)

☒ **A** lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in ether.

☒ **B** concentrated ammonia in ethanol.

☒ **C** potassium dichromate(VI) in sulfuric acid.

☒ **D** tin in concentrated hydrochloric acid.

(b) The phenylamine is separated from the reaction mixture by

(1)

☒ **A** paper chromatography.

☒ **B** steam distillation.

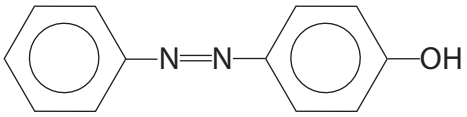
☒ **C** filtration.

☒ **D** recrystallization.

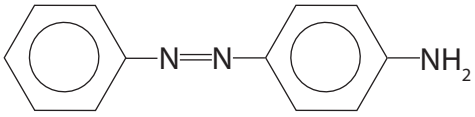
(c) One test for phenylamine is to convert it into a diazonium ion which is then reacted with phenol to form an azo dye. The structure of this dye is

(1)

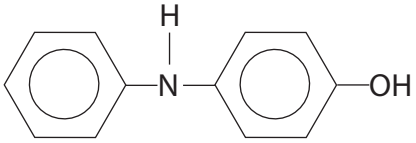
☒ **A**



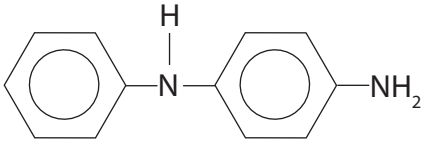
☒ **B**



☒ **C**



☒ **D**



(Total for Question 13 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

P 4 1 2 4 5 A 0 8 2 4
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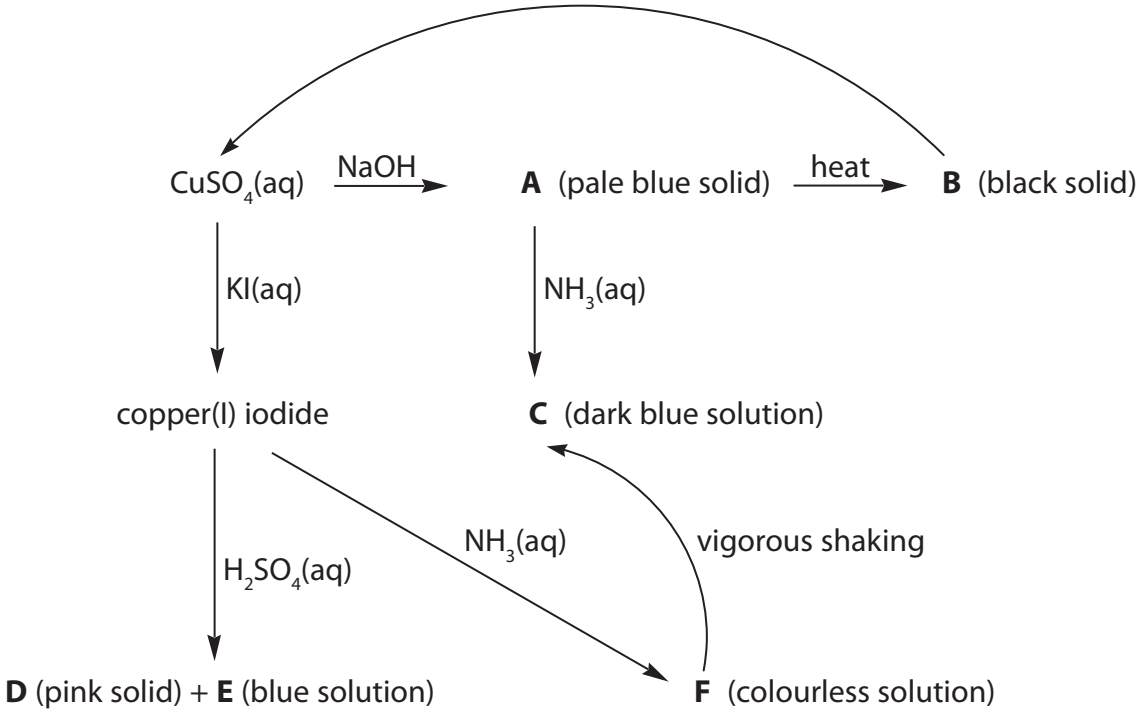
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P 4 1 5 2 4 9 2 4
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SECTION B

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

14 This question concerns the chemistry of copper. In the sequence below, **A**, **B**, **C**, **D**, **E** and **F** all contain copper in various oxidation states.



(a) Identify, by name (including the oxidation state where appropriate) or formula, the copper-containing species in the sequence.

(6)

A .....

B .....

C .....

D .....

E .....

F .....

P 4 1 2 3 5 A 0 1 0 2 4
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(b) Identify, by name or formula, the reagent that would be used to convert **B** into $CuSO_4(aq)$.

(1)

(c) (i) **C** and **F** are the same type of chemical species. Name this type.

(1)

(ii) Explain why **C** is coloured but **F** is colourless.

(3)

*(iii) Explain why **F** changes into **C** on shaking.

(2)

(d) The reaction of copper(I) iodide to form **D** and **E** is a disproportionation.

(i) Explain the term disproportionation.

(2)

.....

.....

.....

.....

(ii) Write an ionic equation for this reaction. State symbols are **not** required.

(1)

(iii) Use the relevant standard reduction (electrode) potentials, from the table on page 17 of your data booklet, to calculate the $E^{\ominus}_{cell}$ value for this reaction, giving your answer with the appropriate sign.

(2)

P 4 1 2 3 5 A 0 1 2 2 4
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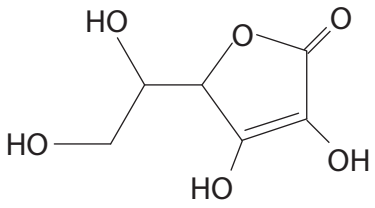
*(iv) If copper(I) iodide is treated with nitric acid, rather than sulfuric acid, a blue solution is still formed but no pink solid. Use the standard electrode potentials on page 15 of your data booklet to explain this. Quote any data that you use.

(4)

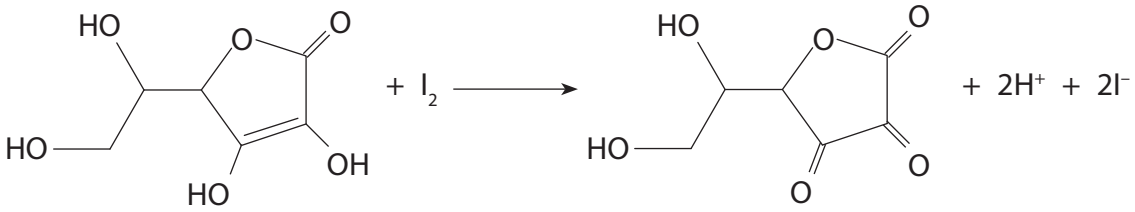
(Total for Question 14 = 22 marks)

P 4 1 2 3 5 A 0 1 3 2 4
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15 Vitamin C (L-ascorbic acid) is present in fresh fruit and vegetables although prolonged cooking destroys it. The structure of ascorbic acid, $C_6H_8O_6$, is shown below.



(a) The amount of ascorbic acid present in a sample is determined by reacting it with a known amount of iodine. The excess iodine is then measured by titration with a solution of sodium thiosulfate, using a starch indicator. The equations for the reactions are given below.



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

Four 500 mg vitamin C tablets were dissolved in distilled water and the solution made up to 250 cm^3 in a volumetric flask. A 25.0 cm^3 portion of this solution was added to an iodine solution containing 2.00×10^{-3} moles of iodine. The resulting mixture was titrated with sodium thiosulfate solution of concentration 0.0631 mol dm^{-3}. The titration was repeated and the mean (average) titre was 27.85 cm^3.

(i) State the type of chemical change undergone by ascorbic acid when it reacts with iodine.

(1)

.....

P 4 1 2 3 5 A 0 1 4 2 4
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(ii) State the colour of the solution in the flask just before the starch is added to the titration mixture and state the colour change at the end-point of the titration.

(2)

.....

.....

.....

(iii) Calculate the percentage by mass of ascorbic acid in the tablets. The molar mass of ascorbic acid is 176 g mol^{-1}.

(5)

P 4 1 2 5 2 4 A 0 1 5 2 4
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(iv) Explain why using four tablets in 250 cm^3 of solution gives a more accurate result than two tablets in 250 cm^3.

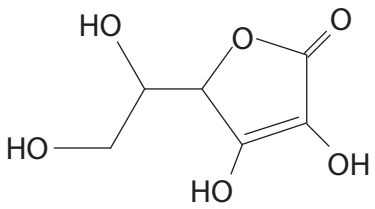
(1)

.....

.....

.....

(b) The structure of ascorbic acid is shown again below. Vitamin C is one of the optical isomers of this structure.



(i) Mark on this diagram the two chiral centres of this molecule.

(2)

(ii) How might you show that vitamin C is a single optical isomer and not a racemic mixture of the optical isomers of ascorbic acid?

(2)

.....

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.....

.....

(iii) Despite its name, ascorbic acid is not a carboxylic acid but it does contain an ester group. Suggest what happens to destroy vitamin C on prolonged cooking.

(1)

.....

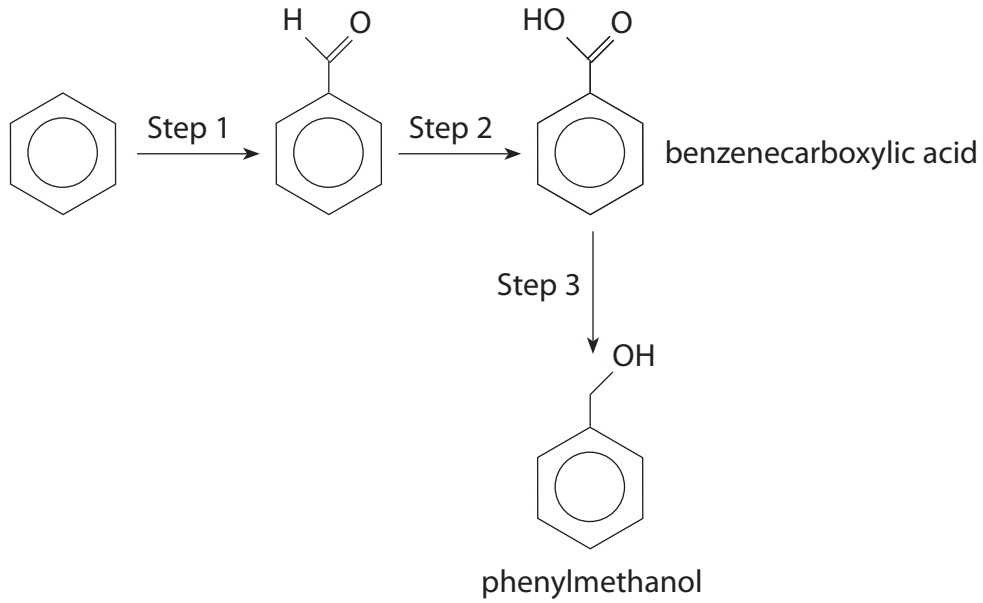
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(Total for Question 15 = 14 marks)

P 4 1 2 3 5 A 0 1 6 2 4
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16 Benzenecarboxylic acid (benzoic acid) and phenylmethanol (benzyl alcohol) are compounds which occur naturally and have a wide range of uses. For example, benzenecarboxylic acid is used as a food preservative and phenylmethanol is used as a solvent.

A laboratory sequence for the preparation of these two compounds is shown below.



(a) In the first step of the synthesis, benzene reacts with hydrogen chloride and carbon monoxide in the presence of aluminium chloride in an electrophilic substitution called the Gattermann-Koch reaction. The hydrogen chloride and carbon monoxide together behave as if they form the unstable species methanoyl chloride (HCOCl).

(i) Explain why benzene undergoes substitution rather than addition reactions. A detailed description of the bonding in benzene is **not** required.

(2)

.....

.....

.....

.....

(ii) Give the mechanism for step 1, including the formation of the electrophile.

(4)

(iii) Identify the reagents and essential conditions used in the remaining steps of the sequence. You may assume that the correct reaction temperatures are being used.

(4)

Step 2 .....

.....

.....

Step 3 .....

.....

.....

P 4 1 2 3 5 A 0 1 8 2 4
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*(b) Phenol reacts faster than phenylmethanol in electrophilic substitution reactions. Suggest why this is so.

(4)

(Total for Question 16 =14 marks)

TOTAL FOR SECTION B = 50 MARKS

P 4 1 2 3 5 A 0 1 9 2 4
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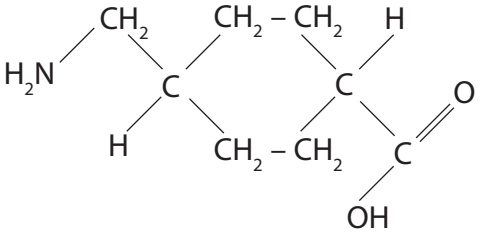
SECTION C

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

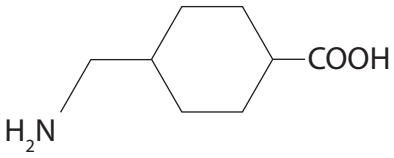
17

Tranexamic acid

Tranexamic acid is an amino acid. It is a white crystalline solid which melts at 300 °C. It is used to reduce bleeding during surgery and dental procedures and is especially useful where patients suffer from deficiencies in blood-clotting factors. The structure of tranexamic acid can be drawn as shown below.



or



As the name suggests, tranexamic acid is the *trans* form of a compound that forms geometric (or *cis-trans* or *E-Z*) isomers.

(a) (i) Explain why some molecules which contain a C═C double bond show geometric isomerism.

(2)

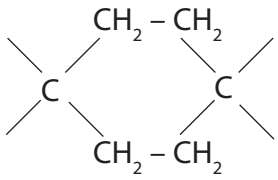
(ii) Suggest how tranexamic acid can form geometric isomers although it does not have a C═C double bond.

(1)

P 4 1 2 3 5 A 0 2 0 2 4
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(iii) Complete the diagram to show the structure of the *cis* isomer.

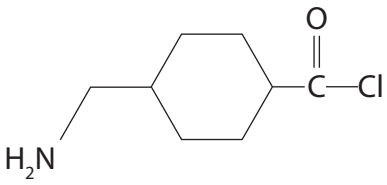
(1)



(iv) Explain why tranexamic acid melts at 300 °C while the alkane, undecane ($C_{11}H_{24}$) which has almost the same number of electrons, melts at −26 °C. A detailed description of the forces involved is **no**t required.

(3)

(b) The diagram below shows a compound, **K**, which is a derivative of tranexamic acid.



(i) Identify by name or formula a compound that might react with tranexamic acid to form **K**.

(1)

(ii) Under suitable conditions, molecules of **K** react together forming a polymer, **L**. Draw the structure of **L**, showing two repeat units.

(2)

(iii) Name the type of polymerization that results in the formation of **L**.

.....

(1)

(iv) State the type of naturally occurring substance which contains the same type of linkage as in the polymer **L**.

(1)

.....

P 4 1 2 3 5 A 0 2 2 4
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(c) If the sequence of reactions, that produces polymer **L** from tranexamic acid, is carried out starting with the *cis* isomer of tranexamic acid, an organic compound, **M**, is formed.

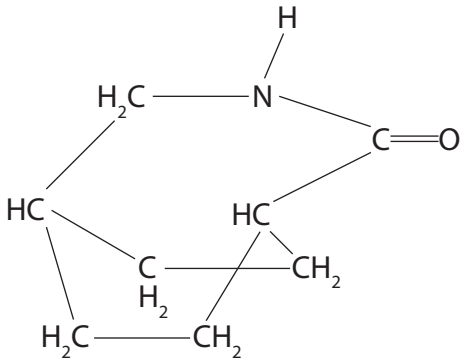
The low resolution nuclear magnetic resonance (nmr) spectrum of **M** has six peaks with relative heights 4:4:2:1:1:1.

The infrared (IR) spectrum of **M** has peaks in the region 1700–1630 cm^{-1} and 3500–3140 cm^{-1}.

(i) The structure of **M** is shown below.

The nmr spectrum shows that the molecule, **M**, has six different hydrogen environments. Use the letters **a** to **f** to label the H atoms of **M** showing the six hydrogen environments. All thirteen hydrogen atoms should be labelled.

(4)



(ii) Explain how the IR data are consistent with the structure of **M**.

(2)

.....

.....

.....

(iii) Suggest why **M** is formed from the *cis* isomer but not from the *trans* isomer.

(2)

.....

.....

.....

(Total for Question 17 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

P 4 1 2 3 5 A 0 1 2 3 2 4
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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

P 4 1 2 8 T 4 M 5 P . A C O U N 2 4 2 4

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Mark Scheme (Results)

January 2013

GCE Chemistry (6CH05) Paper 01

General Principles of Chemistry II
Transition Metals and Organic Chemistry

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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(a)	C		**1**
(b)	A		**1**

Question Number	Correct Answer	Reject	Mark
2(a)	C		**1**
(b)	A		**1**
(c)	B		**1**

Question Number	Acceptable Answers	Reject	Mark
3	C		**1**

Question Number	Acceptable Answers	Reject	Mark
4	C		**1**

Question Number	Acceptable Answers	Reject	Mark
5	B		**1**

Question Number	Correct Answer	Reject	Mark
6(a)	D		**1**
(b)	C		**1**
(c)	A		**1**

Question Number	Correct Answer	Reject	Mark
7	B		**1**

Question Number	Acceptable Answers	Reject	Mark
8	C		**1**

Question Number	Acceptable Answers	Reject	Mark
9	B		**1**

Question Number	Acceptable Answers	Reject	Mark
10	C		**1**

Question Number	Acceptable Answers	Reject	Mark
11	D		**1**

Question Number	Acceptable Answers	Reject	Mark
12	A		**1**

Question Number	Acceptable Answers	Reject	Mark
13(a)	D		**1**
(b)	B		**1**
(c)	A		**1**

TOTAL FOR SECTION = 20 MARKS

Section B

Question Number	Acceptable Answers	Reject	Mark
14 (a)	**A** = copper(II) hydroxide / $Cu(OH)_2$ / $Cu(OH)_2(H_2O)_4$ **(1)** **B** = copper(II) oxide / CuO **(1)** **C** = tetraamminecopper(II) / $Cu(NH_3)_4^{2+}$ / $Cu(NH_3)_4(H_2O)_2^{2+}$ ALLOW $Cu(NH_3)_6^{2+}$ / hexaamminecopper(II) **(1)** **D** = copper / Cu / copper(0) / Cu(0) **(1)** **E** = copper(II) sulfate / $CuSO_4$ / Cu^{2+} / $Cu(H_2O)_6^{2+}$ **(1)** **F** = diamminecopper(I) / $Cu(NH_3)_2^+$ **(1)** ALLOW coordination numbers 1-6 in **F** Oxidation number separate from name IGNORE state symbols even if incorrect names without oxidation numbers except for **D**	Formulae with incomplete or unbalanced charges Incorrect oxidation states even with correct formulae	**6**

Question Number	Acceptable Answers	Reject	Mark
14 (b)	(Dilute) sulfuric acid / H_2SO_4 / $H_2SO_4(aq)$ ALLOW concentrated		**1**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(i)	(transition metal / d-block element) complex(es) /complex ion(s) IGNORE ammines	Complex molecules amines, ions, ligands	**1**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(ii)	Copper ion in **C** has partially filled **d** orbital(s) / subshell / $3d^9$ ALLOW unpaired d electron d shell **(1)** Copper ion in **F** has (completely) filled **d** orbitals / subshell / $3d^{10}$ **(1)** Reference to complete / incomplete d orbitals **max 1** EITHER Electronic **transitions** between partially filled (d) orbitals (of different energy) are possible OR Electronic **transitions** between (completely) filled (d) orbitals (of different energy) are not possible **(1)** ALLOW Equivalent words for transition e.g. promotion / jump / movement Penalise use of just 'shell' once IGNORE references to electrons returning to lower energy levels and emission of light	d orbitals empty no unpaired electrons (in F) orbital (singular) Splitting impossible because d orbitals full	**3**

Question Number	Acceptable Answers	Reject	Mark
14 (c)(iii)	Copper(I) is **oxidized** (to copper(II)) ALLOW **F** / it is **oxidized** **(1)** By oxygen / air **(1)** Second mark depends on first IGNORE 'shaking'		**2**

Question Number	Acceptable Answers	Reject	Mark
14 (d)(i)	(simultaneous) oxidation and reduction **(1)** OR Simultaneous increase or decrease in oxidation number of an element **(1)** ALLOW 'Species' 'atoms of the same type' for 'element' Explanation in terms of copper(I) IGNORE Atom / ion / compound / substance / reactant	molecule	**2**

Question Number	Acceptable Answers	Reject	Mark
14 (d)(ii)	$2Cu^+ \rightarrow Cu + Cu^{2+}$ OR $2CuI + 2H^+ \rightarrow Cu + Cu^{2+} + 2HI$ OR $2CuI \rightarrow Cu + Cu^{2+} + 2I^-$ IGNORE state symbols even if incorrect	Non-ionic equations	**1**

Question Number	Acceptable Answers	Reject	Mark
14 (d)(iii)	ALLOW The use of cell notation (as in the Data Booklet SEP table) in place of equations e.g. $Cu^+(aq) \mid Cu(s)$ $E^\ominus = +0.52$ (V) (from the data book the equations are) $Cu^+(aq) + e^- \rightarrow Cu(s)$ $E^\ominus = +0.52$ (V) $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$ $E^\ominus = +0.15$ (V) **(1)** So $E^\ominus_{cell} = 0.52 - 0.15 =$ **+**0.37 (V) **(1)** Correct answer including sign with no working scores full marks TE for second mark for use of Cu^{2+}|Cu +0.34 (V) which gives +0.19(V)/+0.18(V) No TE on incorrect equation in (d)(ii)	**Answer** without + sign	**2**

Question Number	Acceptable Answers	Reject	Mark
14 (d)(iv)	ALLOW In both schemes the use of cell notation (as in the Data Booklet SEP table) in place of equations e.g. $Cu^{2+}(aq) \mid Cu(s)$ $E^{\ominus} = +0.34$ (V) Penalise omission of electrons from equations and vertical lines from cell diagrams and reversal of equation without reversing sign. once only IGNORE omission of + sign for all $E^{\ominus}$ values **Scheme 1 (oxidation of copper)** Copper (formed (by disproportionation)) is oxidized (by nitric acid) must be stated in words stand alone mark **(1)** Relevant half equations are $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $E^{\ominus} = +0.34$ (V) **(1)** $2NO_3^-(aq) + 4H^+(aq) + 2e^- \rightarrow N_2O_4(g) + 2H_2O(l)$ $E^{\ominus} = +0.80$ (V) OR $NO_3^-(aq) + 3H^+(aq) + 2e^- \rightarrow HNO_2(aq) + H_2O(l)$ $E^{\ominus} = +0.94$ (V) **(1)** Correct overall equation scores both marks: $Cu + 2\ NO_3^- + 4H^+ \rightarrow Cu^{2+} + N_2O_4 + 2H_2O$ OR $Cu + NO_3^- + 3H^+ \rightarrow Cu^{2+} + HNO_2 + H_2O$ So $E^{\ominus}_{cell}$ is +0.46 (V) (or +0.60 (V) or just 'positive') **(1)** **Scheme 2 (oxidation of copper(I)** Copper(I) iodide / Cu^+ is oxidized (by nitric acid) must be stated in words **(1)** stand alone mark $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$ $E^{\ominus} = +0.15$ (V) **(1)** $2NO_3^-(aq) + 4H^+(aq) + 2e^- \rightarrow N_2O_4(g) + 2H_2O(l)$ $E^{\ominus} = +0.80$ (V) OR $NO_3^-(aq) + 3H^+(aq) + 2e^- \rightarrow HNO_2(aq) + H_2O(l)$ $E^{\ominus} = +0.94$ (V) **(1)** Correct overall equation scores both marks:		**4**

	$2Cu^+ + 2NO_3^- + 4H^+ \rightarrow 2Cu^{2+} + N_2O_4 + 2H_2O$ $2Cu^+ + NO_3^- + 3H^+ \rightarrow 2Cu^{2+} + HNO_2 + H_2O$ So $E^{\ominus}_{cell}$ is +0.65 (V) (or +0.79 (V) or just 'positive') **(1)** IGNORE (omission of) state symbols even if incorrect		

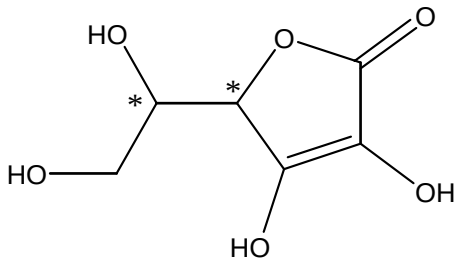
Total for Q14 = 22 Marks

Question Number	Acceptable Answers	Reject	Mark
15 (a)(i)	(vitamin C / ascorbic acid) oxidation / oxidized / oxidised ALLOW oxidisation	Redox / oxidation-reduction / reduction-oxidation	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (a)(ii)	(very) pale yellow / straw coloured **(1)** IGNORE 'just before the end-point' blue-black to colourless (both needed) **(1)** Accept (dark) blue or black ALLOW pale yellow / straw coloured to colourless for 1/2	Just 'yellow' Clear	**2**

Question Number	Acceptable Answers	Reject	Mark
15 (a)(iii)	Moles $S_2O_3^{2-}$ = 27.85 x 10^{-3} x 0.0631 **(1)** (= 1.757335 x 10^{-3}) moles of I_2 remaining = Moles $S_2O_3^{2-}$ ÷ 2 = 27.85 x 10^{-3} x 0.0631 ÷ 2 = 8.786675 x 10^{-4} = 8.79 x 10^{-4} **(1)** Moles ascorbic acid = moles I_2 at start − moles I_2 remaining = 2.00 x 10^{-3} − 8.786675 x 10^{-4} = 1.1213325 x 10^{-3} = 1.12 x 10^{-3} **(1)** M_r (ascorbic acid) = 176 Mass ascorbic acid in 250 cm^3 = 10 x M_r x moles ascorbic acid = 10 x 176 x 1.1213325 x 10^{-3} **(1)** (= 1.97355) Percentage ascorbic acid in tablet 100 x mass ascorbic acid in 250 cm^3 ÷ 2 = 100 x 10 x 176 x 1.1213325 x 10^{-3} ÷ 2 = 98.67726 = 98.7% **(1)** IGNORE SF except 1 SF Premature rounding gives 98.5% (5) Correct answer with no working scores full marks TE at each stage of the calculation.	Answers greater than 100%	**5**

Question Number	Acceptable Answers	Reject	Mark
15(a)(iv)	EITHER Using larger **mass** reduces the percentage error / uncertainty (in weighing) OR Using larger amount reduces the percentage error / uncertainty in **weighing** OR Reverse discussion of two tablets ALLOW using four tablets gives a more representative sample	Just 'reduces the percentage error' Titration value will be larger (with four tablets) so reduces the percentage error (in volume measurement)	**1**

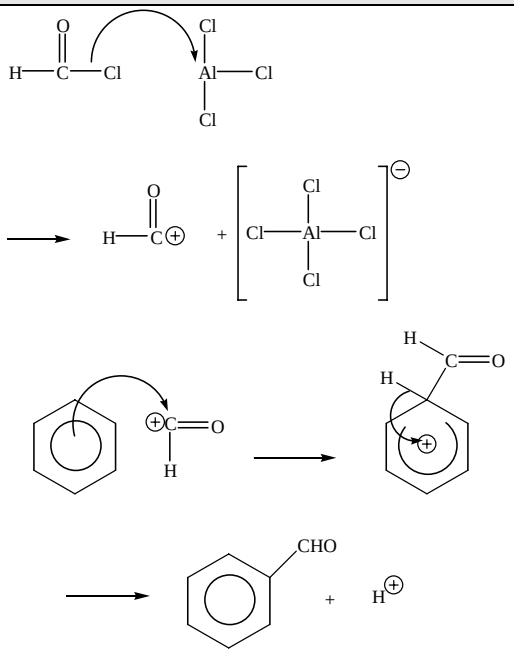
Question Number	Acceptable Answers	Reject	Mark
15 (b)(i)	 **(2)** Mark independently ALLOW any clear indication of chiral centres		**2**

Question Number	Acceptable Answers	Reject	Mark
15 (b)(ii)	**First mark** Use of (plane-)polarized light (mentioned somewhere) **(1)** ALLOW Use a polarimeter **Second mark** Pure optical isomer / enantiomer) **rotates** the **plane** of (plane-) polarized light OR racemic mixture has no effect on the **plane** of (plane-) polarized light **(1)** IGNORE optically active / inactive ALLOW rotates plane-polarized light scores 2		**2**

Question Number	Acceptable Answers	Reject	Mark
15(b)(iii)	(Ester group / vitamin C / it) is hydrolysed ALLOW Vitamin C is oxidized Ester / vitamin C is broken down to form carboxylic acid **and** alcohol (groups) IGNORE Just 'breaks down'	C=O is broken Just 'oxidation'	1

Total for Q15 =14 Marks

Question Number	Acceptable Answers	Reject	Mark
16(a)(i)	The delocalization of the (π) electrons of the ring make benzene more stable (than 1,3,5-cyclohexatriene) **(1)** IGNORE bonding in benzene is strong Substitution retains this (stable) arrangement OR Addition removes this (stable) arrangement **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
16(a)(ii)	 Formation of electrophile (curly arrow, structural formulae not required). Positive charge may be anywhere on the electrophile ALLOW HCl + CO for HCOCl ALLOW Non-displayed electrophile **(1)** Curly arrow from benzene ring to electrophile **(1)** Wheland structure with gap opposite tetrahedral carbon **(1)** Curly arrow from C—H bond into ring and formation of **correct** organic product OR Kekulé structures **(1)** IGNORE Use of $AlCl_4^-$ to pick off proton Proton product First curly arrow may come from any part of the delocalisation circle Second curly arrow may come from any part of the C–H bond Positive charge on the Wheland structure may be in any part of the horseshoe	-COH /-HCO Positive charge on the tetrahedral carbon	**4**

Question Number	Acceptable Answers	Reject	Mark
16(a)(iii)	In each step the second mark is dependent on the first **Step 2** Potassium dichromate((VI)) / $K_2Cr_2O_7$ / sodium dichromate((VI)) / $Na_2Cr_2O_7$ ALLOW Potassium manganate ((VII)) / $KMnO_4$ Sodium manganate ((VII)) / $NaMnO_4$ **(1)** Stand alone mark Sulfuric acid / H_2SO_4 (ALLOW nitric acid) **(1)** Ignore 'concentrated' ALLOW Acidified potassium (/ sodium) dichromate((VI)) OR Acid and potassium (/ sodium) dichromate((VI)) **(2)** $Cr_2O_7^{2-}$ and H^+ OR acidified dichromate((VI)) **(1)** **Step 3** Lithium tetrahydridoaluminate((III)) / $LiAlH_4$ OR Lithium aluminium hydride **(1)** Stand alone mark (Dry) ether / ethoxyethane / (di)ethyl ether **(1)** Sodium borohydride / $NaBH_4$ in ethanol, alkali or water scores 1/2 **(1)**	Incorrect oxidation number Hydrochloric acid Hydrogen and catalyst / Tin and HCl	**4**

Question Number	Acceptable Answers	Reject	Mark
16(b)	**Marking Point 1** Electron density of the ring increased **(1)** Stand alone mark **Marking Point 2** Due to donation of oxygen / OH group lone pair to the ring **(1)** **Marking Point 3 and 4** Any two from in phenol oxygen / OH group attached directly to ring Oxygen / OH group in phenylmethanol too far away / not attached directly to ring (In phenol) lone pair overlaps with the π electrons / delocalised electrons (of the ring) ALLOW p orbital for lone pair for this mark **(2)**		**4**

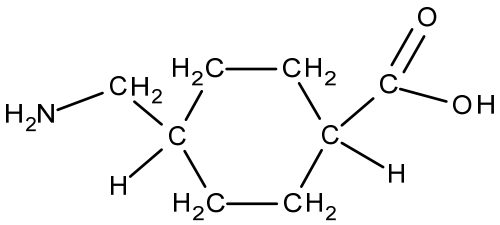
Total for Q16 = 14 Marks

TOTAL FOR SECTION B = 50

Section C

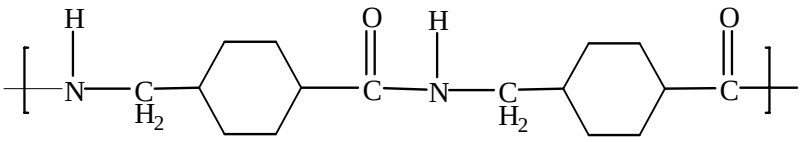
Question Number	Acceptable Answers	Reject	Mark
17(a)(i)	There is a barrier to rotation about a (C=C) bond **(1)** ALLOW restricted / limited / no rotation Each carbon atom (in the C=C double bond) has (two) different atoms / groups attached **(1)** IGNORE reference to priority groups	Just 'molecule cannot rotate'	**2**

Question Number	Acceptable Answers	Reject	Mark
17(a)(ii)	There is a barrier to / restricted rotation about the ring OR The ring behaves like a double bond	Reference to benzene ring Just 'molecule cannot rotate'	**1**

Question Number	Acceptable Answers	Reject	Mark
17(a)(iii)	 Any diagram of the correct molecule showing the groups (attached to the ring) on same side of the ring OR zwitterion ALLOW Amine group in skeletal form	Omission of amine CH_2	**1**

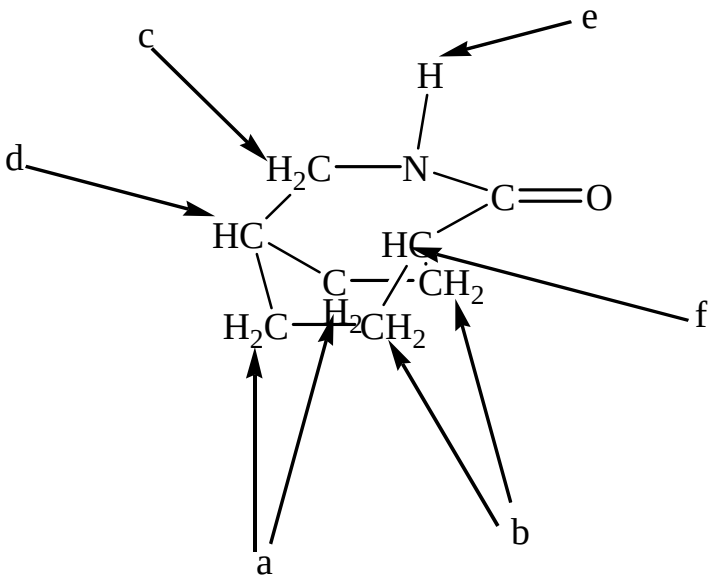
Question Number	Acceptable Answers	Reject	Mark
17(a)(iv)	Tranexamic acid exists as a zwitterion OR Diagram of zwitterion OR Description of zwitterion formation **(1)** So the (strongest) intermolecular forces are ionic (strong) ALLOW electrostatic for ionic **(1)** IGNORE H bonding in tranexamic acid if **either** of the first two marks scored. Otherwise... Hydrogen bonding in tranexamic acid scores 1/2 max Undecane has (only) (much weaker) London / dispersion / van der Waals / temporary induced dipole (-induced dipole) forces / interactions **(1)**		**3**

Question Number	Acceptable Answers	Reject	Mark
17(b)(i)	Phosphorus(v) chloride / PCl_5 ALLOW phosphorus pentachloride / phosphorus(III) chloride / PCl_3 / phosphorus trichloride Thionyl chloride (sulfur dichloride oxide) / $SOCl_2$	HCl	**1**

Question Number	Acceptable Answers	Reject	Mark
17(b)(ii)	 **First mark** amide linkage ALLOW CONH for amide linkage **(1)** **Second mark** Completion of structure (brackets not required) with displayed or skeletal formula **(1)** Second mark dependent on first Dimer scores amide linkage mark only		**2**

Question Number	Acceptable Answers	Reject	Mark
17(b)(iii)	Condensation / addition-elimination (polymerization)	Addition (polymerization) Elimination (polymerization) Polyamide formation	**1**

Question Number	Acceptable Answers	Reject	Mark
17(b)(iv)	Protein / proteins / polypeptide / polypeptides / peptide / peptides ALLOW Enzyme / Enzymes	Nylon Polyamide amino acids	1

Question Number	Acceptable Answers	Reject	Mark
17(c)(i)	Check sequence of letters. Candidates may have labelled the groups of hydrogen atoms with different letters, which is fine. **First mark** Unique N**H** (at e) **(1)** **Second mark** **(1)** Unique C**H**$_2$ (at c) **Third mark** **(1)** C**H** (at d) and C**H** (at f) with different unique labels **Fourth mark** **(1)** 2C**H**$_2$ (at a) and 2C**H**$_2$ (at b) with different new labels 		4

Question Number	Acceptable Answers	Reject	Mark
17(c)(ii)	C═O amide (stretching vibrations are in the region) 1700-1630 cm^{-1} **(1)** N—H amide (stretching vibrations are in the region) 3500-3140 cm^{-1} **(1)** Amide only needs to be mentioned once but... These answers without mention of **amide** max 1 Amides have peaks in these regions max 1	Ketone Amine (for amide)	2

Question Number	Acceptable Answers	Reject	Mark
17(c)(iii)	**Any two from** In the trans isomer the (amine and acid chloride) groups are too far apart to react intramolecularly / to form **M** OR Because the groups are on opposite sides of the (plane of the) **ring** OR More likely to polymerize / react with adjacent molecules. **(2)** Marks may also be scored by a reverse argument: In the cis isomer the (amine and acid chloride) groups are on the same side of the (plane of the) **ring** **(1)** So close enough to react intramolecularly / to form **M (1)**	bond	2

Total for Q17 = 20 Marks

TOTAL FOR SECTION C = 20 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 ▶

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7/7/5/5/3/

P 3 9 3 0 9 A 0 1 2 0

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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 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)

P 3 9 3 0 9 A 0 2 2 0
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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.

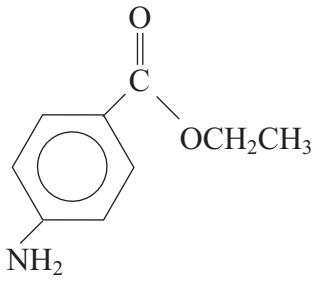
☒ **C** it does not produce emissions which damage the ozone layer.

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

(Total for Question 5 = 3 marks)

P 3 9 3 0 9 A 0 4 2 0
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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.

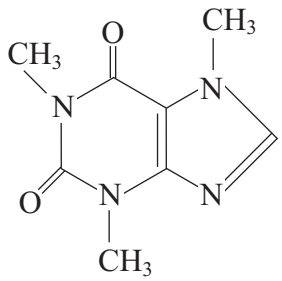
☒ **C** A dichromate(VI) breath analyser and an infrared breath analyser.

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

(Total for Question 8 = 1 mark)

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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

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(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

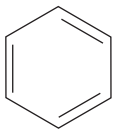
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SECTION B

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}.

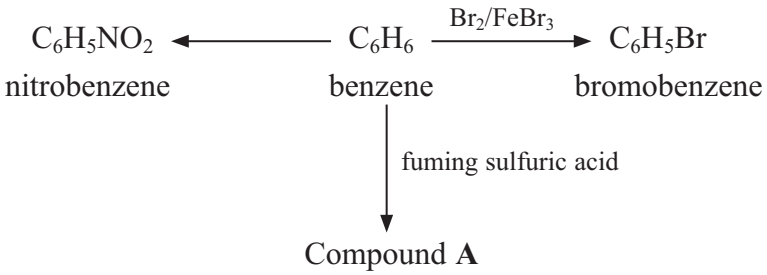
Use this information and your answer to (i), to calculate the difference in stability of benzene and the Kekulé structure.

What does this tell us about the bonding in benzene?

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

(4)

(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)

P 3 9 3 7 0 9 A 0 1 6 0 2 0
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(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)

P 3 9 3 7 0 9 A 0 1 2 0
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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)

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.....

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.....

(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)

.....

.....

P 3 9 3 T O M U P . A C O U K 2 2 0

(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)

P 3 9 3 2 0 A 0 0 U K 3 2 0
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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)

P 3 9 3 7 0 9 A 0 1 4 2 0
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(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)

.....

.....

.....

.....

.....

.....

(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, $Mn(CN)_6^{5-}$.

P 3 9 3 7 0 9 A 0 1 6 2 0
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(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)

P 3 9 3 7 9 A 0 1 2 0

(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)

P 3 9 3 T O M U P . A C O U K 8 2 0

(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

P 3 9 3 9 9 A 0 0 U K 9 2 0
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The Periodic Table of Elements

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

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

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

* Lanthanide series

* 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
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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**

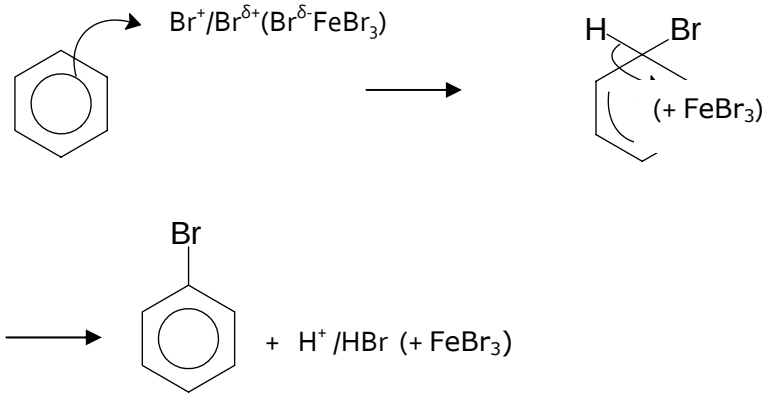
Section B

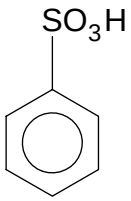
Question Number	Acceptable Answers	Reject	Mark
12(a)(i)	(3 x -120) = -360 (kJ mol^{-1}) IGNORE ΔH, and case of letters in units e.g allow Kj	No sign or + sign in answer, ie 360/+360 Any other wrong units ΔE	**1**

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**

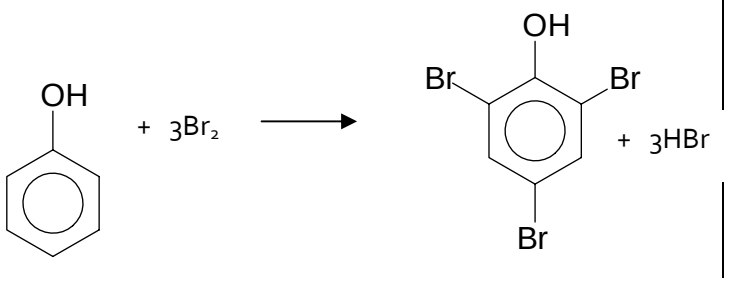
Question Number	Acceptable Answers	Reject	Mark
12(b)(i)	Concentrated nitric acid/HNO_3 **(1)** Concentrated sulfuric acid/H_2SO_4 **(1)** Allow conc or c. in place of 'concentrated' ALLOW Concentrated nitric acid and sulfuric acid OR Concentrated HNO_3 and H_2SO_4 **(2)** Second mark depends on nitric 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 **$Br^+/Br^{\delta+}$**($\ldots.Br^{\delta-}FeBr_3$) **(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**

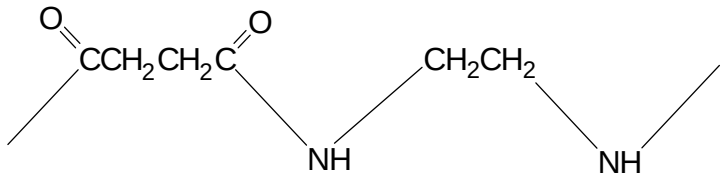
Question Number	Acceptable Answers	Reject	Mark
12(d)	(Chloromethyl)benzene/chloromethylbenzene/ chlorophenylmethane/ benzyl chloride OR dichloromethane **(1)** ALLOW phenylchloromethane Aluminium chloride **(1)** ACCEPT formulae eg C_7H_7Cl, $C_6H_5CH_2Cl$, CH_2Cl_2, $AlCl_3$ ACCEPT other halogen carriers 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**

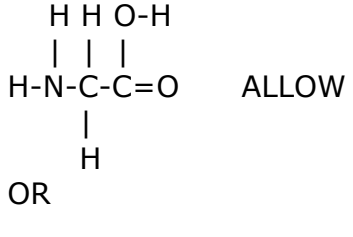
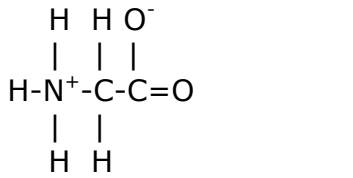
Question Number	Acceptable Answers	Reject	Mark
14(a)	**Route 1 by mol of H, C and N** $\frac{0.072}{18}$ = 0.004 mol water OR 0.008 mol H(atoms) **And** $\frac{0.176}{44}$ = 0.004 mol carbon (dioxide) **(1)** $\frac{24.0}{24000}$ = 0.001 mol nitrogen N_2 OR 0.002 mol N(atoms) **(1)** Mass of H + mass 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**

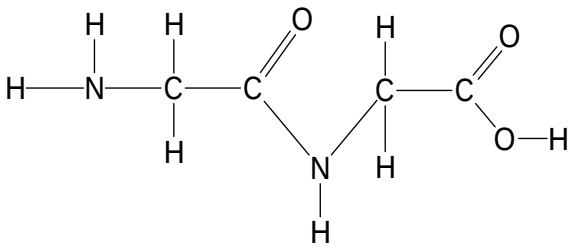
	moles of C = 0.004 moles of N = 0.002 empirical formula is $C_4H_8O_3N_2$ **(1)** **Route 3 Percentage by mass of each element in 0.132 g** First three marks by either method above. Then percentages are: H – 6.06 C – 36.36 N – 21.21 So O is 100 – (6.06 + 36.36 + 21.21) = 100 – 63.63 = 36.37 Mole ratios 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 ⇌ 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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Centre Number	Candidate Number

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

Wednesday 1 February 2012 – 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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7/7/5/5/3/

P 3 5 3 0 2 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 An electrochemical cell consists of a standard hydrogen electrode and a $Cu^{2+}(aq)|Cu(s)$ electrode which uses copper(II) sulfate solution. Which one of the following does **not** affect the e.m.f. of the cell?

☒ **A** The volume of the copper(II) sulfate solution.

☒ **B** The temperature.

☒ **C** The pressure of the hydrogen.

☒ **D** The concentration of the copper(II) sulfate solution.

(Total for Question 1 = 1 mark)

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2 Which answer corresponds to the correct value of $E^{\ominus}_{cell}$ for the oxidation of hydrogen peroxide by manganate(VII) ions? The half-reactions are

$$2H^+ + O_2 + 2e^- \rightleftharpoons H_2O_2 \qquad E^{\ominus} = +0.68\ V$$

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O \qquad E^{\ominus} = +1.51\ V$$

The overall equation is

$$2MnO_4^- + 6H^+ + 5H_2O_2 \rightleftharpoons 2Mn^{2+} + 8H_2O + 5O_2$$

☒ **A** $E^{\ominus}_{cell} = +2.19\ V$

☒ **B** $E^{\ominus}_{cell} = -0.83\ V$

☒ **C** $E^{\ominus}_{cell} = -0.38\ V$

☒ **D** $E^{\ominus}_{cell} = +0.83\ V$

(Total for Question 2 = 1 mark)

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

P 3 5 3 0 2 A 0 2 2 8
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3 The transition metal complex $Pt(NH_3)_2Cl_2$ exists as two geometric isomers. This is because the complex

☒ **A** is square-planar.

☒ **B** is tetrahedral.

☒ **C** contains a double bond.

☒ **D** is octahedral.

(Total for Question 3 = 1 mark)

4 Hydrogen peroxide, H_2O_2, can be analysed by titration. The hydrogen peroxide solution is treated with acidified potassium iodide solution, and the liberated iodine is titrated with a standard solution of sodium thiosulfate, $Na_2S_2O_3$. The products are iodide ions and tetrathionate ions, $S_4O_6^{2-}$.

Which of the following applies to this reaction?

		Action of H_2O_2	Action of $S_2O_3^{2-}$
☒	**A**	oxidizing agent	oxidizing agent
☒	**B**	oxidizing agent	reducing agent
☒	**C**	reducing agent	oxidizing agent
☒	**D**	reducing agent	reducing agent

(Total for Question 4 = 1 mark)

5 A hydrated transition metal ion is colourless. Which of the following could be the electronic configuration of this ion?

☒ **A** [Ar] $3d^5 4s^2$

☒ **B** [Ar] $3d^8$

☒ **C** [Ar] $3d^{10} 4s^2$

☒ **D** [Ar] $3d^{10}$

(Total for Question 5 = 1 mark)

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6 Which of the following reagents would enable you to separate iron(III) hydroxide from a mixture of iron(III) hydroxide and copper(II) hydroxide?

☒ **A** Dilute hydrochloric acid

☒ **B** Aqueous ammonia

☒ **C** Dilute nitric acid

☒ **D** Sodium hydroxide solution

(Total for Question 6 = 1 mark)

7 When a solution containing 0.10 mol of chromium(III) chloride, $CrCl_3.6H_2O$, is treated with excess silver nitrate solution, 0.20 mol of silver chloride, AgCl, is immediately precipitated. The formula of the complex ion in the solution is

☒ **A** $[Cr(OH)_6]^{3-}$

☒ **B** $[Cr(H_2O)_6]^{3+}$

☒ **C** $[CrCl(H_2O)_5]^{2+}$

☒ **D** $[CrCl_2(H_2O)_4]^{+}$

(Total for Question 7 = 1 mark)

8 Which of the following species is **not** able to act as a ligand in the formation of transition metal complexes?

☒ **A** $C_6H_5NH_2$

☒ **B** NH_3

☒ **C** $NH_2CH_2CH_2CH_2NH_2$

☒ **D** NH_4^+

(Total for Question 8 = 1 mark)

9 The element zinc, with electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$, is **not** regarded as a transition element because

☒ **A** the oxide of zinc is amphoteric.

☒ **B** none of its ions has an unpaired electron in the *d*-subshell.

☒ **C** it does not readily form complex ions.

☒ **D** it has a boiling temperature low enough for it to be easily distilled.

(Total for Question 9 = 1 mark)

P 3 5 3 0 2 A 0 4 2 8
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10 The compounds below were heated with aqueous sodium hydroxide solution. Which one of them did **not** give sodium ethanoate, CH_3COONa, as one of the products?

☒ **A** CH_3COOCH_3

☒ **B** CH_3COCH_3

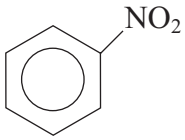
☒ **C** CH_3COOH

☒ **D** CH_3COCl

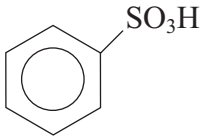
(Total for Question 10 = 1 mark)

11 Which of the following products is formed when phenylamine (aniline) is reacted with **dilute** sulfuric acid?

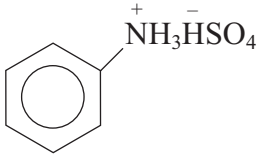
☒ **A**



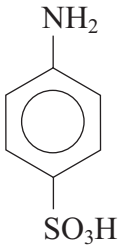
☒ **B**



☒ **C**



☒ **D**



(Total for Question 11 = 1 mark)

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

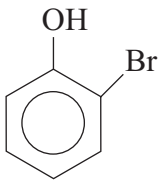
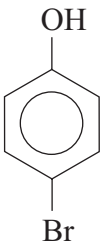
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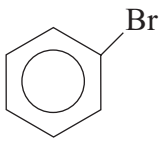
12 For the nitration of phenol, which is the most suitable set of conditions and the reason for its use?

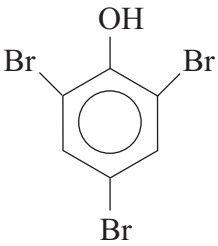
		Conditions	Reactivity of phenol to electrophiles compared with benzene
☒	**A**	dilute nitric acid at room temperature	more reactive
☒	**B**	concentrated nitric and sulfuric acid at room temperature	more reactive
☒	**C**	concentrated nitric and sulfuric acid at 55 °C	the same
☒	**D**	dilute nitric acid and dilute sulfuric acid at room temperature	less reactive

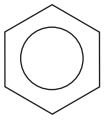
(Total for Question 12 = 1 mark)

13 Phenol reacts with excess bromine water to give as the organic product(s)

☒ **A**  and 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 13 = 1 mark)

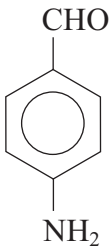
P 3 5 3 0 2 A 0 6 2 8
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14 An organic compound, **X**, shows the following properties:

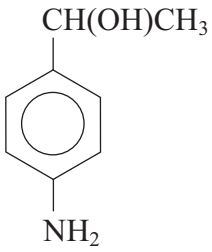
- Oxidation of compound **X** produces a substance that reacts with 2,4-dinitrophenylhydrazine to give a yellow precipitate but does **not** react with Fehling's or Benedict's solution.
- Compound **X** reacts with ice-cold nitrous acid to form a compound that gives a yellow precipitate with an alkaline solution of phenol.

What is the formula of compound **X**?

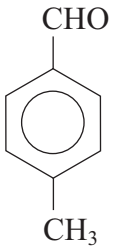
☒ **A**



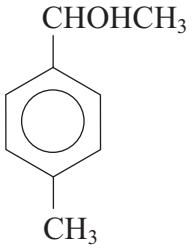
☒ **B**



☒ **C**



☒ **D**



(Total for Question 14 = 1 mark)

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15 Which sequence shows the bases in order of decreasing strength?

☒ **A** $C_6H_5NH_2 > CH_3NH_2 > NH_3$

☒ **B** $NH_3 > CH_3NH_2 > C_6H_5NH_2$

☒ **C** $CH_3NH_2 > NH_3 > C_6H_5NH_2$

☒ **D** $NH_3 > C_6H_5NH_2 > CH_3NH_2$

(Total for Question 15 = 1 mark)

16 Bromoethane can be made by heating ethanol under reflux with 50% sulfuric acid and sodium bromide. When the mixture is distilled, the products include sulfur dioxide, bromine, hydrogen bromide and water as well as bromoethane.

The product mixture is shaken with sodium carbonate solution and later with anhydrous sodium sulfate before being re-distilled. Which of the following shows the correct list of impurities removed at each step?

		Aqueous sodium carbonate wash	Addition of sodium sulfate
☒	**A**	HBr	SO_2, Br_2, water
☒	**B**	SO_2, Br_2	HBr, water
☒	**C**	SO_2, HBr	Br_2, water
☒	**D**	SO_2, Br_2, HBr	water

(Total for Question 16 = 1 mark)

17 A compound is known to have either the structure $H_2NCH_2CH_2NH_2$ or H_2NCH_2COOH. Which of the following tests would best distinguish between the two compounds?

☒ **A** Reaction with concentrated aqueous sodium hydroxide.

☒ **B** Reaction with nitrous acid.

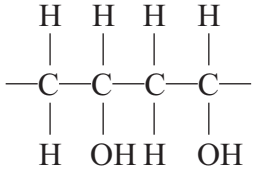
☒ **C** Reaction with aqueous sodium hydrogencarbonate.

☒ **D** Reaction with ethanoyl chloride.

(Total for Question 17 = 1 mark)

P 3 5 3 0 2 A 0 8 2 8
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18 Poly(ethenol) is a water-soluble polymer. A section of the chain has the structure shown below.



The polymer is used for making hospital laundry bags so that laundry can be loaded directly into washing machines without it having to be handled.

Poly(ethenol) is water soluble because the polymer

☒ **A** is broken down by the water into monomers.

☒ **B** is broken down by the washing detergent.

☒ **C** breaks into monomers at the temperature of the wash.

☒ **D** forms many strong hydrogen bonds with the water.

(Total for Question 18 = 1 mark)

19 Which of the following substances is capable of damaging the ozone layer?

☒ **A** NaCl

☒ **B** CO_2

☒ **C** C_2HF_5

☒ **D** $C_2F_3Cl_3$

(Total for Question 19 = 1 mark)

20 Analysis suggests that a particular organic synthesis produces a medicine that contains trace impurities that may be hazardous. What is the best way for this discovery to be reported and evaluated?

☒ **A** In a scientific journal which subjects its articles to peer review.

☒ **B** On the Internet in an article on a website.

☒ **C** In a newspaper article in several broadsheet newspapers.

☒ **D** In a widely circulated magazine.

(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 (a) Chromium is a typical transition metal, although its electronic configuration does **not** fit the general trend found in the first transition series.

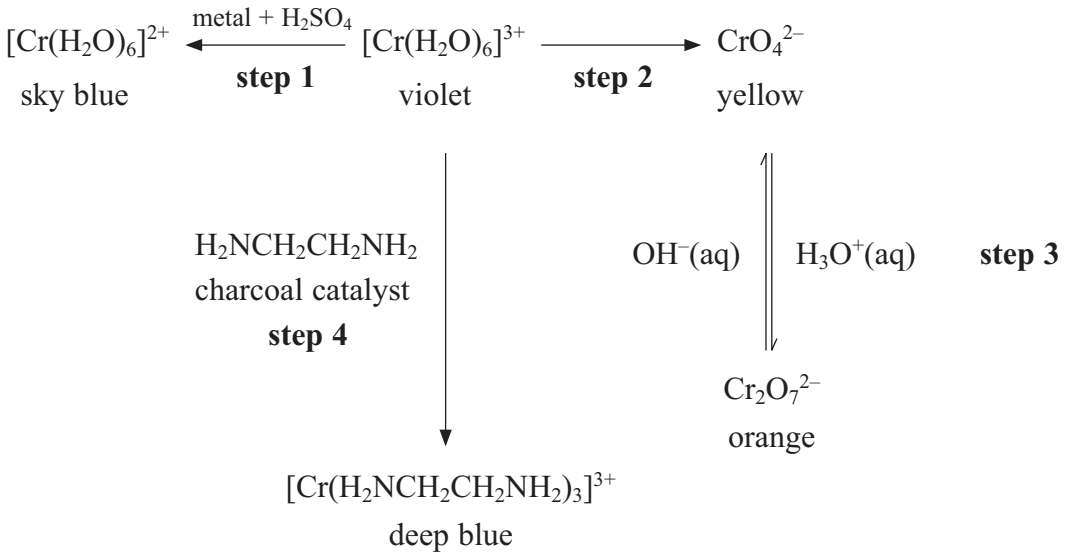
Complete the electronic configurations in *s,p,d* notation for vanadium and chromium.

(1)

Vanadium: [Ar] .....

Chromium: [Ar] .....

(b) Some interconversions found in the chemistry of chromium are shown below. Use this information to answer the questions that follow.



(i) State **two** typical properties of transition metals, other than the formation of coloured ions, which are shown in the diagram above.

(2)

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P 3 5 3 0 2 A 0 2 8
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(ii) Use $E^{\ominus}$ values from your data booklet to suggest a metal that could be used for **step 1**. Justify your answer by calculating $E^{\ominus}$ for your cell.

(2)

(iii) Explain, using oxidation numbers, whether or not the conversion in **step 3** is a redox reaction.

(2)

(iv) The organic compound $H_2NCH_2CH_2NH_2$ that is used in **step 4** is 1,2-diaminoethane, often called ethylenediamine.
It is a **bidentate ligand**. Explain the meaning of this term.

(1)

(v) Explain, in terms of its structure, how $H_2NCH_2CH_2NH_2$ can act as a bidentate ligand whereas H_2NNH_2 cannot.

(2)

P 3 5 3 0 2 A 0 1 1 2 8
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(c) The half-equations relating the interconversion of the species $Cr^{2+}(aq)$, $Cr^{3+}(aq)$ and $Cr_2O_7^{2-}(aq)$ are given below.

Half-equation I: $Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$

Half-equation II: $Cr_2O_7^{2-}(aq) + 6e^- + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

(i) Use your data booklet to find $E^{\ominus}$ for each of the above half-equations.

(1)

Half-equation I ..... Volts

Half-equation II ..... Volts

*(ii) Write the overall equation for the disproportionation of Cr^{3+} into Cr^{2+} and $Cr_2O_7^{2-}$.

Use the $E^{\ominus}$ values you have obtained in (c)(i) to show whether or not this disproportionation is feasible under standard conditions.

(4)

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(Total for Question 21 = 15 marks)

P 3 5 3 8 2 A 0 1 2 8
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22 (a) Tiglic acid is a compound that is used as a defensive agent by some beetles.

(i) Tiglic acid contains, by mass, 60% carbon, 8% hydrogen, with the remainder being oxygen. Show that these data are consistent with the formula $C_5H_8O_2$.

(1)

(ii) Tiglic acid contains a carbon-carbon double bond and a carboxylic acid group.

Suggest **one** test for each of these groups in tiglic acid. State what you would do and what you would see as a positive result for the tests.

(4)

Test for C═C .....

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Test for —COOH .....

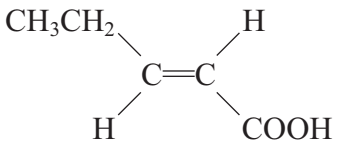
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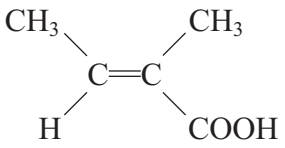
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STEMUP.CO.UK

(b) It is suggested that the structure of tiglic acid is either that of **A** or **B**.



A



B

(i) State, with a reason, whether **B** is the *E*- or *Z*- isomer.

(2)

.....

.....

.....

(ii) The mass spectrum of tiglic acid shows two prominent peaks at mass/charge ratios 45 and 55. Write the formulae of the fragments giving rise to each of these peaks.

(2)

45 .....

55 .....

(iii) Does this data from the mass spectrum **alone** enable you to decide which of **A** or **B** is the structure of tiglic acid? Explain your answer.

(1)

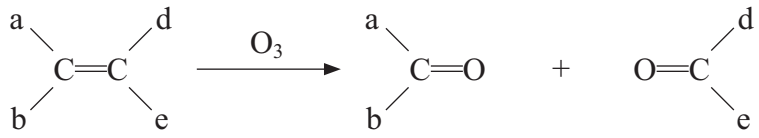
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P 3 5 3 8 2 A 0 4 2 8
STUDYUP.CO.UK

(c) The position of a C═C double bond in a molecule can be determined by ozonolysis. The compound is reacted with ozone and then dilute acid, two carbonyl compounds being produced as shown below.



Ozonolysis of tiglic acid gives two carbonyl compounds, **C** and **D**.

Compound **C** gives a silver mirror with Tollens' reagent and gives iodoform with iodine in alkali.

Compound **D** does **not** give a silver mirror with Tollens' reagent, but does give iodoform with iodine in alkali.

*(i) From the results of the experiments, deduce the functional groups present in **C** and **D**. By considering the two possible structures for tiglic acid, give the structural formulae of **C** and **D**.

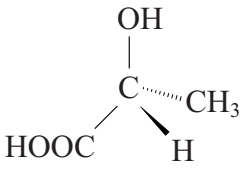
From the structures you have drawn, state which of the structures **A** or **B** could represent tiglic acid.

(6)

(ii) Explain whether or not these tests show definitely that your answer to (c)(i) represents tiglic acid.

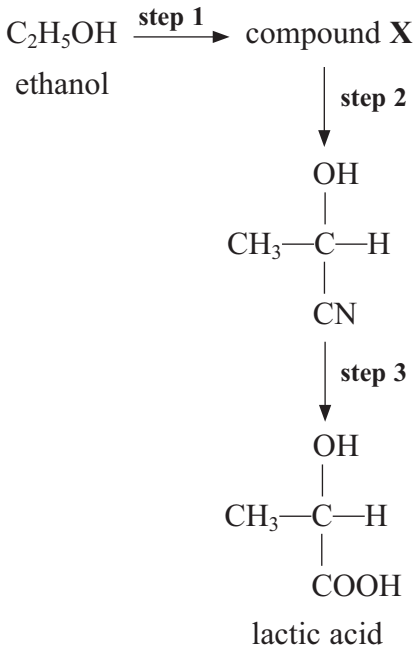
(1)

(d) Lactic acid is a chiral molecule that is found in sweat as the (–) isomer only. Its structural formula is



(–) - lactic acid

(i) Lactic acid can be made from ethanol in three steps.



lactic acid

Give the structural formula of the intermediate **X** and the reagents and conditions required for **steps 1** and **2**.

(4)

Step 1 .....

.....

Step 2 .....

.....

P 3 5 3 6 2 A 0 1 6 2 8
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(ii) Classify the type and mechanism of the reaction that occurs in **step 2**.

(1)

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*(iii) By considering the stereochemistry of the mechanism in **step 2**, explain why this synthesis would **not** give a single optical isomer of lactic acid.

(2)

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(iv) Suggest why synthetic pathways for the manufacture of pharmaceuticals may require reactions that are highly stereospecific.

(1)

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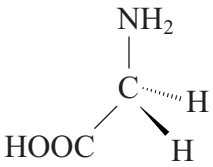
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(Total for Question 22 = 25 marks)

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23 Proteins are polymers of α-amino acids, the simplest of which is glycine.



(a) (i) Draw the **structural** formula for the zwitterion of glycine in the solid state.

(1)

(ii) Explain, on the basis of your answer to (a)(i), why glycine has a relatively high melting temperature for such a small molecule.

(2)

(iii) Draw the structure of the protein chain that would be formed if glycine alone were to be polymerized. Show part of the chain containing two glycine residues.

(2)

P 3 5 3 8 2 0 1 3 0 8 2 8
STUDYUP.CO.UK

*(b) A solution of hydrolysed protein contains the individual amino acids that make up the protein. Briefly state how you would use chromatography, together with known samples of amino acids, to show which amino acids the protein contained. Do **not** give detailed experimental instructions.

(5)

(Total for Question 23 = 10 marks)

TOTAL FOR SECTION B = 50 MARKS

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SECTION C

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

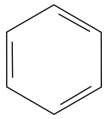
24 Read the passage below carefully and answer the questions which follow.

Molecular structure and colour chemistry

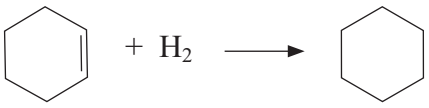
The sight of tubes of paint or of coloured pencils in an artists' supply shop is something that most people enjoy; we love colour.

The ability to synthesise brightly-coloured compounds coincides with the rapid growth of the organic chemicals industry. Synthetic organic dyes started to appear in the mid-19th century when William Perkin synthesised Mauve in 1856 at the age of 18. He was trying to synthesise quinine even though he did not know the structure of the molecule.

In the 19th century many chemists did not believe that molecules existed. The work of Butlerov, Couper, and notably Kekulé showed that molecules not only exist but have specific structures. In 1865 Kekulé suggested a ring structure for the aromatic compound benzene which he represented as



Kekulé knew that benzene does not react with bromine water. Later work showed that the enthalpy change of hydrogenation of the compound is $-205\ kJ\ mol^{-1}$, rather than the value of $-360\ kJ\ mol^{-1}$ that would be expected if the structure was exactly as shown above, given that the enthalpy change of hydrogenation for cyclohexene to cyclohexane



is $-120\ kJ\ mol^{-1}$.

When Greiss in 1856 discovered diazotisation and the azo dyes, he used a reaction characteristic of aromatic amines. Witt, in 1876, found the functional groups in the dye molecule that make it water-soluble and enable it to attach to the cloth fibres. Graebe, Liebermann and Perkin in 1869 patented the synthesis of alizarin, found in madder root grown in Holland and Von Baeyer synthesised indigo in 1880, until then grown in India. Synthetic dyes were made available in large quantities and were cheaper than the sources from plants.

Now the organic chemical industry produces a vast range of pigments and dyestuffs for use in paints and for fabrics, inks and other materials, making our world the most colourful that it has ever been.

P 3 5 3 0 2 2 A 0 0 2 0 2 8
STEMUP.COUK

(a) (i) Explain why Perkin's attempted synthesis of quinine was almost certain to fail.

(1)

(ii) Suggest the effect that the growth of the organic chemicals industry in the late 19th century had on Holland and India in particular.

(2)

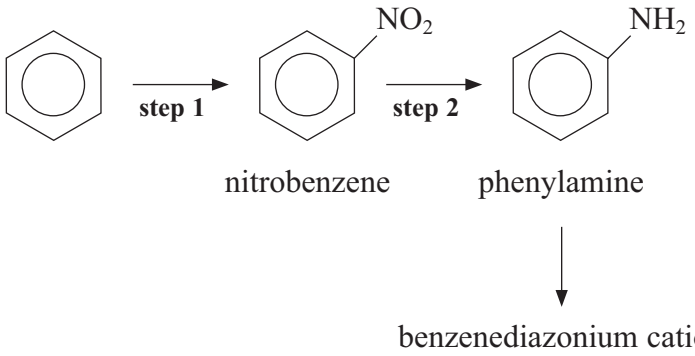
(b) (i) What observation did Kekulé make to show that benzene does **not** react with bromine water? Explain the significance of this with reference to his representation of the molecule.

(2)

(ii) Explain, in terms of the bonding in the benzene ring, why the enthalpy of hydrogenation is less exothermic than would be expected from a molecule with three double bonds.

(3)

(c) The first steps in the preparation of an azo dye from benzene are shown below.



Give the mechanism for the reaction in **step 1**, including the equation for the formation of the electrophile.

(4)

Equation for formation of electrophile

Mechanism

P 3 5 3 0 2 A 0 0 2 2 2 8
STUDMUP.ACOUK

(d) (i) Phenylamine is converted into the benzenediazonium cation using sodium nitrite and hydrochloric acid at a temperature between 0 °C and 10 °C.

Explain why the temperature must **not** be lower or higher than these limits if a good yield is to be obtained.

(2)

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(ii) Draw the structural formula of the benzenediazonium cation showing all the bonds and the charge.

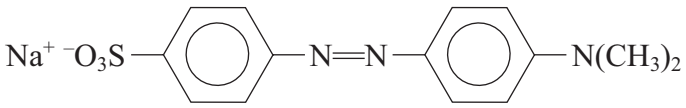
(1)

(iii) Suggest how you could convert a sample of the benzenediazonium cation into an azo dye. Give the name of the other compound you would use and the skeletal formula of the azo dye you would obtain.

(3)

P 3 5 3 0 2 A 0 2 3 2 8
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(e) The structural formula of methyl orange is given below.



Suggest the main features of methyl orange which make it water-soluble, giving your reasons.

(2)

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(Total for Question 24 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

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STEMUP.COUK

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P 3 5 3 0 2 A 0 2 7 2 8
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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

P 3 5 3 T E M 2 P . A 0 0 U N 2 8 2 8

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Mark Scheme (Results)
January 2012

GCE Chemistry (6CH05) Paper 01
General Principles of Chemistry II
Transition Metals and Organic Nitrogen Chemistry
(including synoptic assessment)

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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.

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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.

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Section A (multiple choice)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

TOTAL FOR SECTION A = 20 MARKS

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Section B

Question Number	Acceptable Answers	Reject	Mark
21(a)	$3d^3 4s^2$ OR $4s^2 3d^3$ $3d^5 4s^1$ OR $4s^1 3d^5$ both must be correct. ALLOW Electron numbers could be on the line or as subscripts IGNORE case of letters		**1**

Question Number	Acceptable Answers	Reject	Mark
21(b)(i)	Variable/varying/different/several/ more than one **oxidation state /number** **(1)** Complex (ion formation) **(1)** Treat Physical properties (if correct) including catalytic activity as neutral	Each metal has a different oxidation number Ligand exchange	**2**

Question Number	Acceptable Answers	Reject	Mark
21(b)(ii)	The following metals scores (2) marks with correct E value: Mg 1.96, Ce 1.92, U 1.39, Al 1.25, Mn 0.78, V 0.77, Zn 0.35 **NOTE:** Positive sign/unit not needed, but penalise negative value The following metals score (1) mark with correct E value: Li 2.62, Rb 2.52, K 2.51, Ca 2.46, Na 2.30, Cr 0.33, Fe 0.03 **NOTE:** Positive sign/unit not needed, but penalise negative value	All other metals 0/2	**2**

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Question Number	Acceptable Answers	Reject	Mark
21(b)(iii)	Not a redox process Chromate and dichromate **both** the same/no change in oxidation number **(1)** contain Cr(VI) 6/6+ **(1)** Mark independently OR Not redox and **both** contain Cr(VI) 6/6+ **(2)**		**2**

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Question Number	Acceptable Answers	Reject	Mark
21(b)(iv)	Forms two (dative/covalent) bonds/has two lone pairs (to the Transition Metal/ion) OR donates two pairs of electrons (to the Transition Metal/ion) **Check answer to (v) if mark not awarded here**	'…to the molecule'	**1**

Question Number	Acceptable Answers	Reject	Mark
21(b)(v)	**Any two from** Both have two nitrogen atoms with lone pairs or implied **(1)** or Far enough apart/longer chain in between in en (but not in hydrazine)/too close in hydrazine/hydrazine is too short/not as long **(1)** or Dative bonds/lone pairs too close/repel in hydrazine **(1)** OR for two marks Forms 5-membered ring (with en with no angle strain/stable) **(2)** or Bond angles too acute/too much ring strain in hydrazine **(2)** **Mark for iv can be awarded here.**	N=N, or triple bond in hydrazine max 1 or if implies **only** en has lone pairs max 1	**2**

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Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	- 0.41 (V) +1.33 (V) **Both** answers needed, with number and sign, for 1 mark IGNORE additional words		**1**

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Question Number	Acceptable Answers	Reject	Mark
***21(c)(ii) QWC**	Combines the equations to obtain $8Cr^{3+} + 7H_2O \rightarrow 6Cr^{2+} + Cr_2O_7^{2-} + 14H^+$ ALLOW $6Cr^{3+} + 2Cr^{3+}$ instead of $8Cr^{3+}$ IGNORE state symbols even if wrong species **(1)**, balance **(1)** $E^{\ominus}_{reaction}$ = — 1.74V **(1)** So not feasible on condition of negative value **(1)** OR $6Cr^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 8Cr^{3+} + 7H_2O$ If fully correct **(1)** $E^{\ominus}_{reaction}$ = + 1.74V **(1)** **Disproportionation** not feasible on condition of positive value but reject 'reaction is spontaneous' **(1)** **Other wrong equations** **IF** $Cr_2O_7^{2-}$ or Cr^{2+} on left Then + 1.74 V **(1)** **If** Cr^{3+} alone on the left Then -1.74 V **(1)** and reaction not feasible **(1)**	1 max for the equation if electrons are shown balanced or unbalanced	**4**

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Question Number	Acceptable Answers	Reject	Mark
22(a)(i)	C 60/12 = 5 H 8/1 = 8 O 32/16 = 2 ALLOW 1 mol = 100 g So 60 %C = C_5, etc		**1**

Question Number	Acceptable Answers	Reject	Mark
22(a)(ii)	**C=C** **Test** : add bromine water/Br_2(aq) **(1)** **Result**: From yellow/brown/red-brown/orange to colourless/decolorises **(1)** OR **Test** : add (acidified) potassium manganate((VII)) (solution) **(1)** **Result**: goes from pink/purple to colourless/brown **(1)** **Test** : add alkaline potassium manganate((VII)) (solution) **(1)** **Result**: goes green **(1)** **COOH:** **Test** : add $NaHCO_3$ /Na_2CO_3/sodium carbpnate (solution) **(1)** **Result**: Fizzes/bubbles/large volume neutralized **(1)**	Bromine/Br_2/Br_2(l) clear for colourless clear for colourless PCl_5 /$LiAlH_4$ as test NaOH/NaOH(aq) colourless gas evolved	**4**

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	ALLOW gas given off that turns limewater cloudy OR **Test** : with **blue** litmus **(1)** **Result**: turns red **(1)** The test can be with any other indicator, including universal indicator, with the correct initial and final colour ALLOW pH meter **(1)** pH 4-6 **(1)** OR **Test** : add ethanol with conc H_2SO_4 (and warm) **(1)** **Result**: gives pleasant/fruity smell of ester **(1)** OR **Test:** add magnesium **(1)** **Result:** fizzing/bubbles etc (of hydrogen) **(1)** ALLOW gas given off that burns with a squeaky pop	Add sodium colourless gas evolved	

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Question Number		Reject	Mark
22(b)(i)	Explanation of precedence/priority in terms of atomic numbers/masses of the attached groups OR Highest-precedent/priority groups on each carbon are on opposite sides of the molecule **(1)** *E*-/entgegen **(1)** Mark independently	Both CH_3/methyl groups on the same side so Z (0/2)	**2**

Question Number	Acceptable Answers	Reject	Mark
22(b)(ii)	45 $COOH^+$ /CO_2H^+ **(1)** 55 $C_4H_7^+$ OR $C_3OH_3^+$ **(1)** ALLOW Structural/displayed formulae of ions Absence of + charge (1 max)		**2**

Question Number	Acceptable Answers	Reject	Mark
22(b)(iii)	If they say yes **(0)** (No) (Cleavage of the C—COOH bond in) both compounds gives fragment(s) of the same mass OR Both give the same peak(s)/fragment(s) Both give CO_2H^+/ $C_4H_7^+$ fragments The mark can be scored by referring to just one of the fragments/peaks/masses.	'No' on its own	**1**

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Question Number	Acceptable Answers	Reject	Mark
***22(c)(i) QWC**	**C** is CH_3CHO (alone) **(2)** **D** is $CH_3COCOOH$ (alone) **(2)** so tiglic acid must be **B** **(1)** tiglic acid mark can only be awarded if correct structures of either **C** or **D** are given. **Any one of the following** **C** must be an aldehyde **(1)** **D** is a ketone **(1)** Mention that CH_3CO present in either/both compounds (because of formation of iodoform) **(1)** If one or both of the structures are incorrect any of the last 3 marks can be awarded max 5 If C and D are fully correct, but the wrong way round max 5	CH_3COH **1 max**	**6**

Question Number	Acceptable Answers	Reject	Mark
22(c)(ii)	Doesn't distinguish *E*- isomer from *Z*-isomer/geometric isomers (so no) OR Doesn't distinguish which sides of C=C functional groups are on	Just isomers/ stereoisomers/ enatiomers	**1**

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Question Number	Acceptable Answers	Reject	Mark
22(d)(i)	CH_3CHO **(1)** ACCEPT displayed or skeletal **Step 1** (heat)using acidified potassium dichromate/or $H^+/Cr_2O_7^{2-}$ **(1)** distil (product as formed) conditional on dichromate **(1)** **Step 2** HCN with KCN OR KCN with H^+/acid OR KCN with (cold) NaOH(aq)/alkali **(1)** ALLOW HCN with NaOH/alkali For step 2 Ignore conditions e.g. any references to heat	CH_3COH Manganate VII/$KMnO_4$ Reflux HCN alone	**4**

Question Number	Acceptable Answers	Reject	Mark
22(d)(ii)	**Nucleo**philic addition Any recognisable spelling of 'philic' and addition, either order **Both** words needed	**Nutro**philic addition Any other or additional words	**1**

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Question Number	Acceptable Answers	Reject	Mark
***22(d)(iii) QWC**	Ethanal is planar (at the reaction site) OR Ethanal is a planar molecule **(1)** Attack (from CN^- to give the cyanohydrin) is (equally likely) from either side/above or below/from both sides (of the molecule) (so a racemic mixture is formed) **(1)** Mark independently	Intermediate is planar Square planar Can attack carbocation from either side/any reference to SN1/SN2	**2**

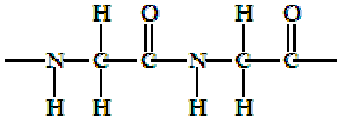
Question Number	Acceptable Answers	Reject	Mark
22(d)(iv)	Receptors for the compound in the body are often stereospecific so only one stereoisomer is pharmacologically active OR Body recognises one (stereo)isomer ALLOW Only one (stereo)isomer is active OR One/the other isomer may be toxic/dangerous/harmful OR One isomer destroys body cells OR (Different) isomers have different biological/pharmacological/biochemical properties		**1**

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Question Number	Acceptable Answers	Reject	Mark
23(a)(i)	Formula showing $-NH_3^+$ and $—COO^-$ /$—CO_2^-$ Charges can be anywhere on functional group Rest of the molecule must be correct ALLOW displayed/part displayed formula		**1**

Question Number	Acceptable Answers	Reject	Mark
23(a)(ii)	**Any two from** High energy needed (to overcome) **(1)** strong ionic/electrostatic forces OR strong forces between oppositely charged ions/between positive and negative **(1)** between **different** (zwitter)ions OR between $-NH_3^+$ and $—COO^-$ OR between one molecule and another OR Chains of zwitterions/molecules **(1)**	any reference to intermolecular forces eg (strongly) polar/bond polarity if they state the ionic bond is within the same molecule	**2**

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Question Number	Acceptable Answers	Reject	Mark
23(a)(iii)	 Correct peptide link **(1)** Minimum two residues and extension to the rest of the molecule **(1)** ALLOW $-NHCH_2CONHCH_2CO-$ **(2)** Drawn the other way round, i.e. starting with the carbonyl group Brackets around outside with 'n' ie ~~(~~.....~~)~~$_n$ Second mark depends on first		**2**

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Question Number	Acceptable Answer	Reject	Mark
***23(b) QWC**	**Key Points** **KP1** Spot (of hydrolysate) on paper/tlc/thin layer chromatogram **(1)** **KP2** Marker spots of known amino-acids/measure R_f **(1)** **KP3** Run in (suitable) solvent/discussion of comparative solubilities in phases **(1)** **KP4** (Spray with) ninhydrin (and heat) [Stand alone mark] **(1)** **KP 5** Marker spots and the unknown spots correspond ALLOW Compare R_f values of marker spots with hydrolysate spots **(1)** OR If 2-d chromatography used (2 different solvents run in two directions at right angles): **KP1** Spot (of hydrolysate) on paper/tlc/thin layer chromatogram **(1)** **KP2** Run in (suitable) solvent in one direction **(1)** **KP3** Develop in suitable/different solvent at right angles OR discussion of comparative solubilities in phases **(1)** **KP4** Spray with ninhydrin (andheat) **(1)** **KP5** Compare hydrolysate spots with same experiment for known amino acids **(1)** OR	Spot one amino acid/protein Water alone as solvent Spot one amino acid	**5**

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	if column/GLC/GC used **KP1** Put amino acid mixture (Hydrolysate) into column **(1)** **KP2** Separately known amino-acids into column **(1)** **KP3** Detect amino acids in effluent with Ninhydrin/mass spectrometry **(1)** **KP4** Measure retention times/ discussion of comparative solubilities in phases **(1)** **KP 5** Compare retention times **(1)**	Spot one amino acid	

TOTAL FOR SECTION B = 50 MARKS

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Section C

Question Number	Acceptable Answers	Reject	Mark
24(a)(i)	Not knowing the structure of the molecule (means that the reactions/reagents/reactants needed to make it are also unknown) ALLOW Structure not known		**1**

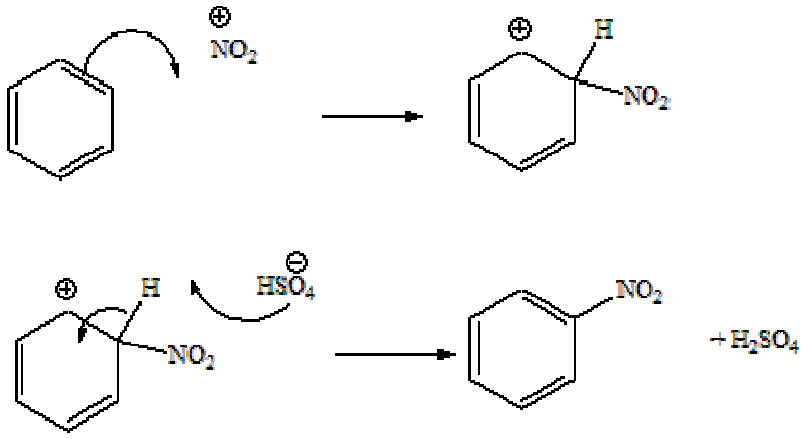
Question Number	Acceptable Answers	Reject	Mark
24(a)(ii)	Credit any reasonable arguments for example: **First mark** No longer any demand for madder/indigo OR Cheaper alternatives available **(1)** **Second mark** So the growing industries collapsed OR no market for crops OR farmers had to grow alternative crops OR decreased employment OR economic damage OR decreased GDP OR Loss of export **(1)**		**2**

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Question Number	Acceptable Answers	Reject	Mark
24(b)(i)	**First mark** Double bonds expected to react with bromine water turning it colourless OR Bromine water remained yellow/orange/red/brown **(1)** **Second mark** So benzene does not contain double bonds OR Double bonds not normal/not simply double bonds/any indication that double bonds are different OR His representation incorrect **(1)**		**2**

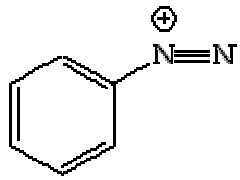
Question Number	Acceptable Answers	Reject	Mark
24(b)(ii)	The p/pi-/π/6 electrons (of carbon) OR π system **(1)** Electrons are delocalised around the ring **(1)** Which gives the molecule greater stability/need more energy to break the bonds in benzene (and hence a less exothermic hydrogenation enthalpy) Allow it is more stable **(1)**	Harder to break/disrupt [alone]	**3**

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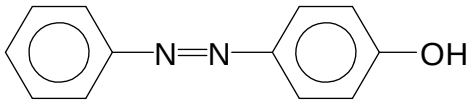
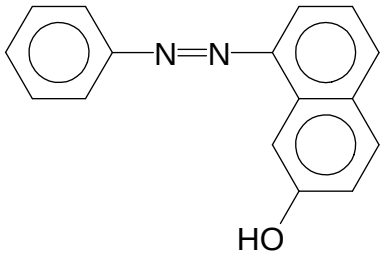
Question Number	Acceptable Answers	Reject	Mark
24(c)	$2H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ **(1)** OR $H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_2O + HSO_4^-$ OR $H_2SO_4 + HNO_3 \rightarrow H_2NO_3^+ + HSO_4^-$ **and** $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ **Charges are needed for first mark**  Attack on nitronium ion arrow must start on or in the benzene **(1)** Wheland intermediate Can be a part, but not complete circle, in correct place inside ring BUT part circle must cover minimum of 3 carbon atoms AND must not include where nitro group is attached and must positive charge somewhere **(1)** **Either but only one of first two marks can be lost if bond is clearly to oxygen** Arrow from H bond into the ring to produce either H^+ or H_2SO_4 and return to aromaticity **(1)**		**4**

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Question Number	Acceptable Answers	Reject	Mark
24(d)(i)	< 0° C/temperature too low: reaction too slow/insufficient energy to overcome activation energy **(1)** > 10° C/temperature too high: diazonium ion decomposes/produces phenol **(1)**	Will not take place	**2**

Question Number	Acceptable Answers	Reject	Mark
24(d)(ii)	 Positive charge can be on either N Cl^- may be given as well ALLOW circle in benzene ring and hydrogens/carbons displayed OR ---N=N $^+$ Is acceptable providing charge is on the end N	Positive charge on wrong N	**1**

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Question Number	Acceptable Answers	Reject	Mark
24 (d)(iii)	Adds phenol in sodium hydroxide/OH^-/alkali ALLOW 2-naphthol in sodium hydroxide/OH^- /alkali **(1)** Correct structure for the -N=N- bond between 2 benzene rings **(1)** Remainder of molecule **(1)** which is either:  ALLOW anionic form of —OH OR if 2-naphthol is used it is:  	Ignore position of –OH group on the ring	**3**

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Question Number	Acceptable Answers	Reject	Mark
24 (e)	**First mark** $-SO_3^-$ are solvated / hydrated Can be drawn with polar H of water OR Negative ion bonds with/attracted to water **(1)** **Second mark** **Nitrogen/oxygen** atoms **hydrogen-bonded** (to water) Can be drawn **(1)**	Just sodium ions attracted to water	**2**

TOTAL FOR SECTION C = 20 MARKS

TOTAL FOR PAPER = 90 MARKS

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Write your name here

Surname	Other names

Centre Number | Candidate Number

Edexcel GCE

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

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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)

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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.

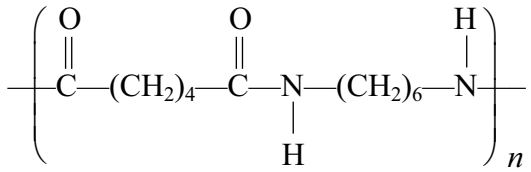
(Total for Question 3 = 1 mark)

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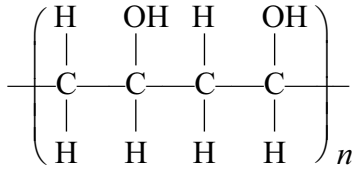
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4 Four polymers labelled **A to D** have the following formulae:

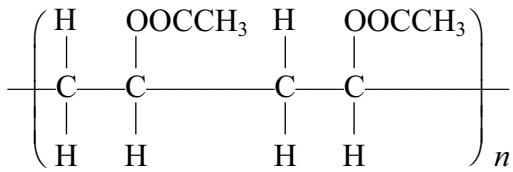
A



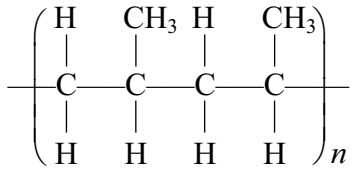
B



C



D



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

(1)

☒ **A**

☒ **B**

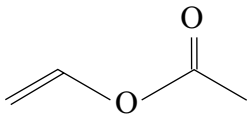
☒ **C**

☒ **D**

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(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**

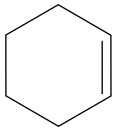
(Total for Question 4 = 3 marks)

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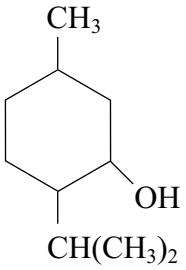
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5 The formulae of some organic compounds labelled **A to D** are shown below.

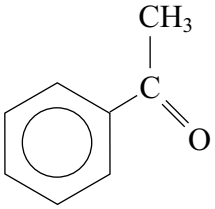
A



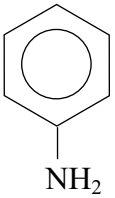
B



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)

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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)

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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)

P 3 8 4 8 0 A 0 8 2 4
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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.

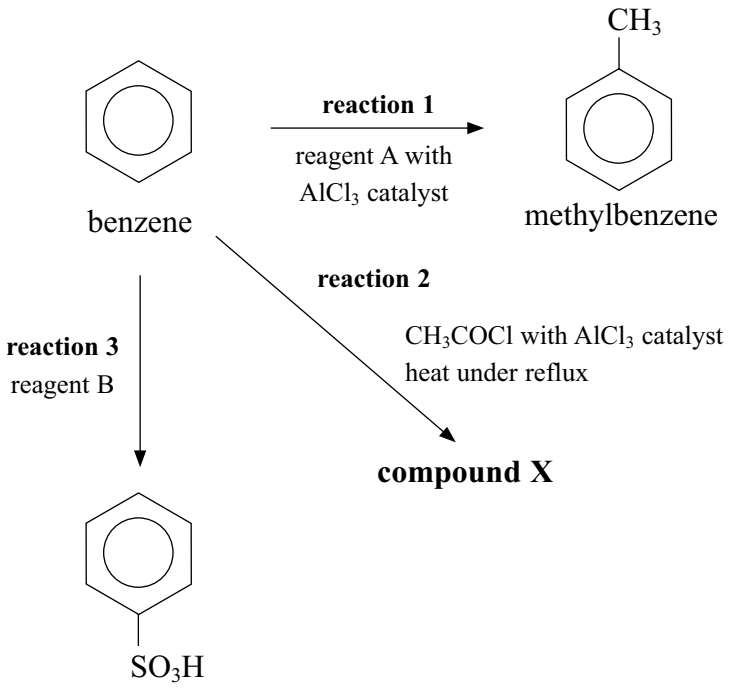
(Total for Question 12 = 1 mark)

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)

P 3 8 4 8 0 A 0 1 0 2 4
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(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)

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

(1)

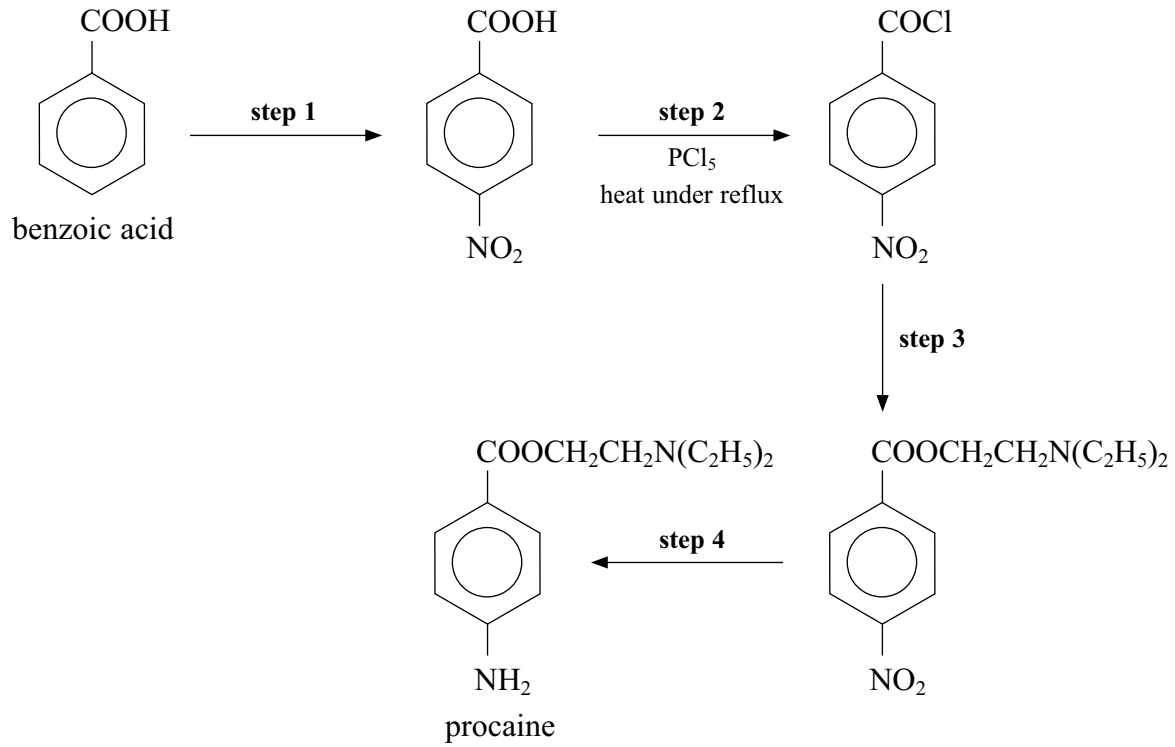
.....

(Total for Question 13 = 9 marks)

P 3 8 4 8 0 A 0 1 1 2 4
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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)

.....

.....

P 3 8 4 8 0 A 0 1 2 2 4
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(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)

.....

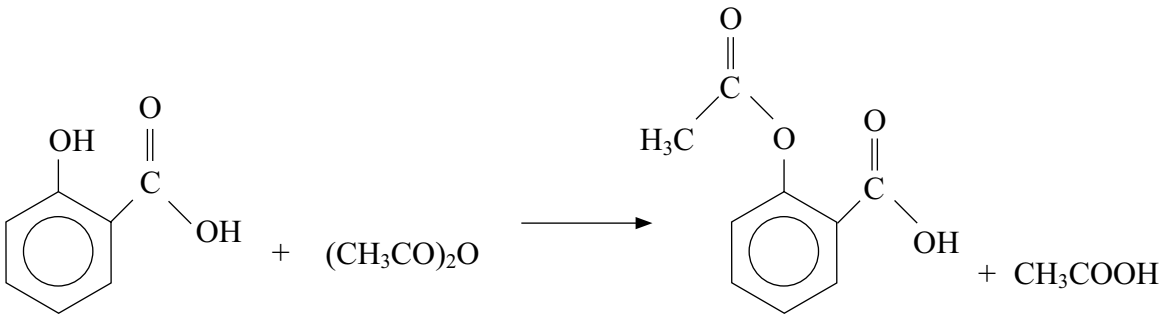
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(b) A student produced a sample of aspirin by the esterification of 9.40 g of 2-hydroxybenzoic acid with excess ethanoic anhydride.



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)

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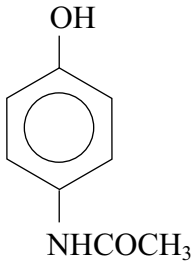
(iii) Explain what effect recrystallization has on the final yield.

(1)

.....

.....

(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)

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.....

(Total for Question 14 = 21 marks)

P 3 8 4 8 0 A 0 1 5 2 4
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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)

.....

.....

.....

.....

(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)

P 3 8 4 8 0 A 0 1 6 2 4
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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)

.....

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(Total for Question 16 = 12 marks)

TOTAL FOR SECTION B = 48 MARKS

P 3 8 4 8 0 A 0 1 8 2 4
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SECTION C

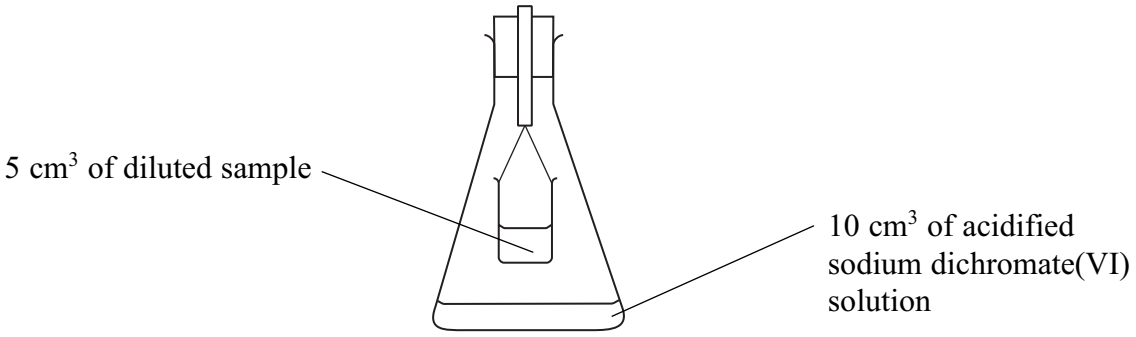
Answer ALL the questions. Write your answers in the spaces provided.

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)

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

$$CH_3CH_2OH \rightarrow CH_3COOH$$

P 3 8 4 8 0 A 0 1 9 2 4
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(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)

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

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

P 3 8 4 8 0 A 0 2 0 2 4
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(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)

.....

.....

.....

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(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

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

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

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

* Lanthanide series

* Actinide series

P 3 8 4 8 0 P.&C O U K 2 4 2 4

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Mark Scheme (Results)

June 2011

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

ALWAYS LEARNING

PEARSON

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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**

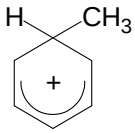
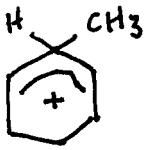
Question Number	Correct Answer	Mark
12	C	**1**

TOTAL FOR SECTION A = 20 MARKS

Section B

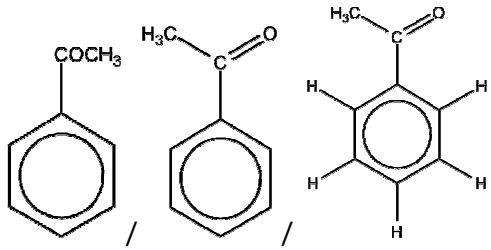
Question Number	Acceptable Answers	Reject	Mark
13 (a)(i)	CH_3Cl / CH_3Br / CH_3I Ignore name and state symbols Allow displayed formula	Name alone	**1**

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 *Mr* 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 = 8.6×10^{-4} (mol) **(1)** So moles I_2 = 4.3×10^{-4} (mol) **(1)** So moles of dichromate unreacted = $4.3 \times 10^{-4} / 3$ = 1.433×10^{-4} (mol) **(1)** So moles of dichromate reacted with ethanol = $8 \times 10^{-4} - 1.43 \times 10^{-4} = 6.567 \times 10^{-4}$ (mol) **(1)** So moles of ethanol = $6.567 \times 10^{-4} \times 3/2$ mol = 9.85×10^{-4} (mol) **(1)** Concentration = $9.85 \times 10^{-4} / 0.005$ = 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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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 31 January 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 ▶

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7/7/5/5/2/

N 3 7 9 5 4 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 What type of bonding occurs between the metal ion and ligand in the complex ion $[Cu(H_2O)_6]^{2+}$?

☒ **A** Metallic

☒ **B** Ionic

☒ **C** Hydrogen

☒ **D** Dative covalent

(Total for Question 1 = 1 mark)

---

2 Which of these four amino acids could **not** rotate the plane of plane-polarised light?

☒ **A** $H_2NCH(CH_3)COOH$

☒ **B** $H_2NCH(CH_2COOH)COOH$

☒ **C** H_2NCH_2COOH

☒ **D** $H_2NCH(CH_2SH)COOH$

(Total for Question 2 = 1 mark)

---

3 In the solid state, the amino acid serine exists in the form

☒ **A** $H_3N^+CH(CH_2OH)COOH$

☒ **B** $H_3N^+CH(CH_2OH)CO_2^-$

☒ **C** $H_2NCH(CH_2OH)COOH$

☒ **D** $H_2NCH(CH_2OH)CO_2^-$

(Total for Question 3 = 1 mark)

---

4 The best method for separating a mixture of amino acids in solution is

☒ **A** distillation.

☒ **B** solvent extraction.

☒ **C** chromatography.

☒ **D** recrystallization.

(Total for Question 4 = 1 mark)

N 3 7 9 5 4 A 0 2 2 4
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5 How many different peaks due to hydrogen atoms would you expect to see in a **low resolution** proton nmr spectrum of propanoic acid, CH_3CH_2COOH?

- ☒ **A** Two
- ☒ **B** Three
- ☒ **C** Five
- ☒ **D** Six

(Total for Question 5 = 1 mark)

---

6 In a **high resolution** proton nmr spectrum of ethanoic acid, CH_3COOH, the peak due to the hydrogen atoms in the methyl group would be a

- ☒ **A** singlet.
- ☒ **B** doublet.
- ☒ **C** triplet.
- ☒ **D** quartet.

(Total for Question 6 = 1 mark)

---

7 Which of these compounds will **not** form an amide in a reaction with ethanoyl chloride?

- ☒ **A** NH_3
- ☒ **B** $CH_3CH_2NH_2$
- ☒ **C** $CH_3CH_2NH(CH_3)$
- ☒ **D** $CH_3CH_2N(CH_3)_2$

(Total for Question 7 = 1 mark)

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

N 3 7 9 5 4 A 0 3 2 4
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8 This question concerns the following organic compounds.

A CH_3COCl

B CH_3COOH

C $CH_3COOCH_2CH_3$

D C_6H_5OH

Which compound is most likely to

(a) form the solution with the lowest pH when mixed with water?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) burn with a smoky flame?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) have a fruity smell?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) have an absorption in its IR spectrum at about 1795 cm^{-1}?

(1)

☒ **A**

☒ **B**

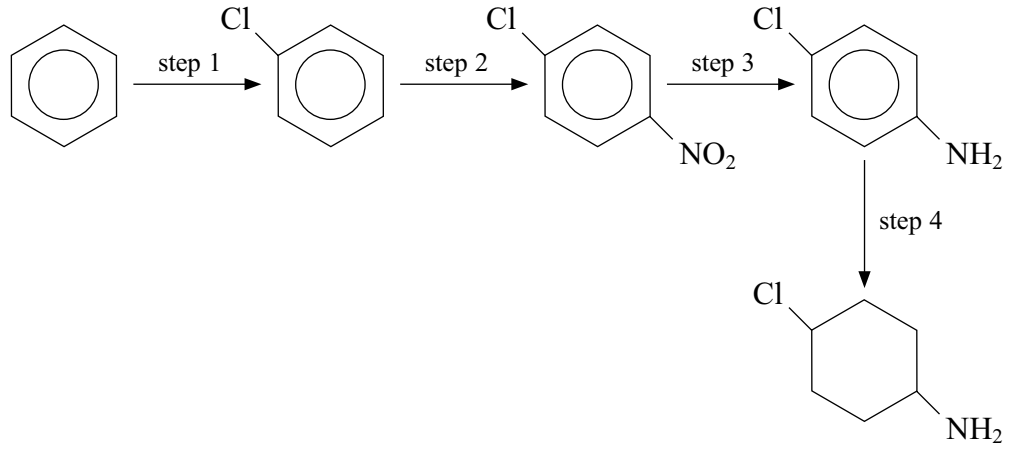
☒ **C**

☒ **D**

(Total for Question 8 = 4 marks)

N 3 7 9 5 4 A 0 4 2 4
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9 This question is about the reaction scheme below.



Which step is most likely to need

(a) tin and concentrated hydrochloric acid?

(1)

- ☒ **A** Step 1
- ☒ **B** Step 2
- ☒ **C** Step 3
- ☒ **D** Step 4

(b) a catalyst of iron(III) chloride?

(1)

- ☒ **A** Step 1
- ☒ **B** Step 2
- ☒ **C** Step 3
- ☒ **D** Step 4

(c) a nickel catalyst?

(1)

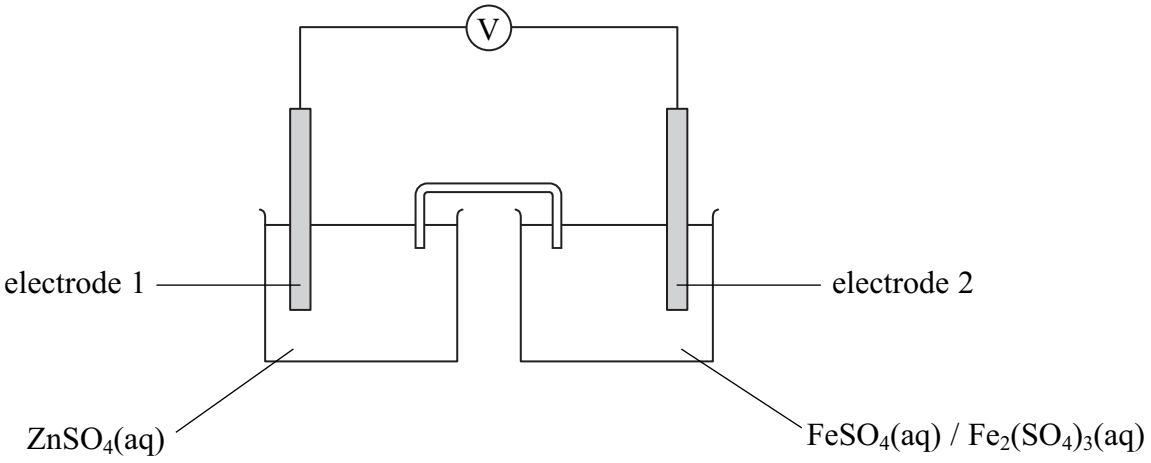
- ☒ **A** Step 1
- ☒ **B** Step 2
- ☒ **C** Step 3
- ☒ **D** Step 4

(Total for Question 9 = 3 marks)

N 3 7 9 5 4 A 0 5 2 4
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10 The apparatus below can be used to measure the value of E_{cell} for the reaction

$$2Fe^{3+}(aq) + Zn(s) \rightarrow 2Fe^{2+}(aq) + Zn^{2+}(aq)$$



The electrodes are:

		electrode 1	electrode 2
☒	**A**	zinc	iron
☒	**B**	iron	zinc
☒	**C**	zinc	platinum
☒	**D**	platinum	platinum

(Total for Question 10 = 1 mark)

11 Copper reacts with silver ions according to the reaction below.

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

$E^{\ominus}_{cell}$ for this reaction is

☒ **A** +0.46 V

☒ **B** +1.14 V

☒ **C** +1.26 V

☒ **D** +1.94 V

(Total for Question 11 = 1 mark)

N 3 7 9 5 4 A 0 6 2 4
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12 $E^{\ominus}_{cell}$ for four reactions are shown in the table below.

	$E^{\ominus}_{cell}$ / V
Reaction 1	+1.10
Reaction 2	+0.65
Reaction 3	+0.10
Reaction 4	–1.30

Which reaction

(a) is thermodynamically not feasible?

(1)

☒ **A** Reaction 1

☒ **B** Reaction 2

☒ **C** Reaction 3

☒ **D** Reaction 4

(b) has the largest value for ln K?

(1)

☒ **A** Reaction 1

☒ **B** Reaction 2

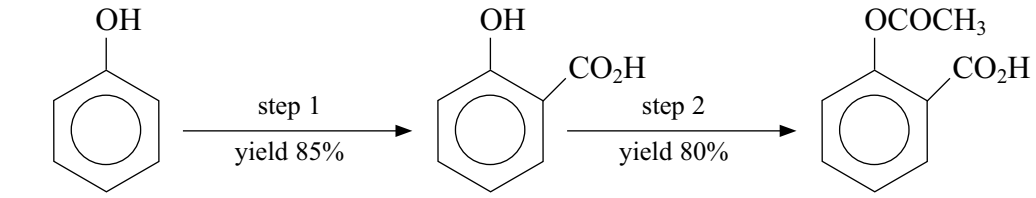
☒ **C** Reaction 3

☒ **D** Reaction 4

(Total for Question 12 = 2 marks)

N 3 7 9 5 4 A 0 7 2 4
SYEMUP.CO.UK

13 Consider the reaction scheme below and calculate the mass of aspirin you would expect to form if you started with 47 g of phenol.



phenol, $M_r = 94$ aspirin, $M_r = 180$

☒ **A** 31.96 g

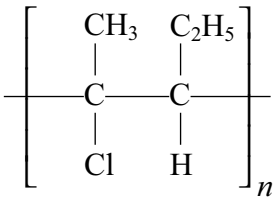
☒ **B** 61.20 g

☒ **C** 74.25 g

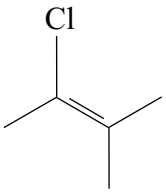
☒ **D** 90.00 g

(Total for Question 13 = 1 mark)

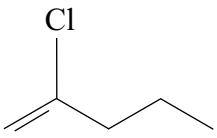
14 Which of the monomers **A to D** would form the polymer below?



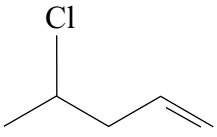
☒ **A**



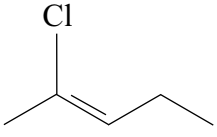
☒ **B**



☒ **C**



☒ **D**



(Total for Question 14 = 1 mark)

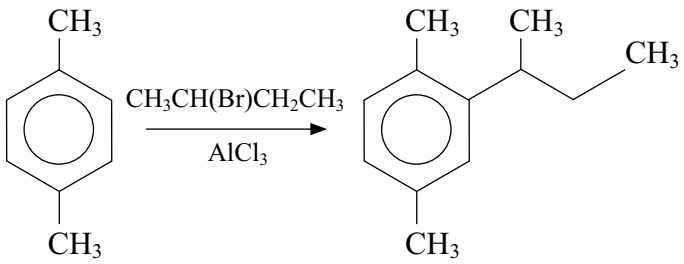
TOTAL FOR SECTION A = 20 MARKS

N 3 7 9 5 4 A 0 8 2 4
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SECTION B

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

15 In the reaction shown below, the aromatic compound 1,4-dimethylbenzene reacts with 2-bromobutane. The reaction is catalysed by aluminium chloride, $AlCl_3$, which dissolves in the reaction mixture.



1,4-dimethylbenzene

(a) (i) Name the type of reaction and the mechanism.

(1)

.....

(ii) Write the equation to show how the attacking species forms and give the mechanism for the reaction.

(4)

Equation

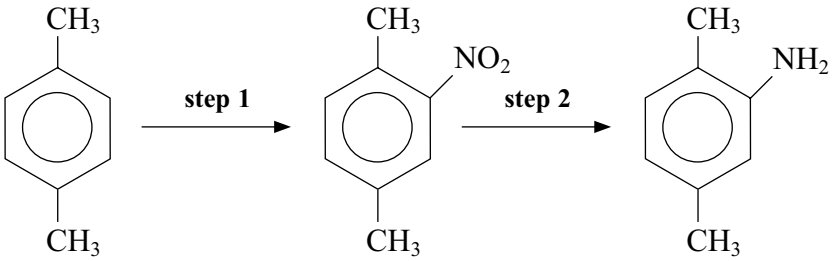
Mechanism

N 3 7 9 5 4 A 0 9 2 4
SYEMUP.CO.UK

(b) The same reaction can also be carried out using a heterogeneous graphite catalyst under similar conditions. Assuming both reactions have a similar rate and yield, suggest one advantage of using the solid graphite catalyst instead of aluminium chloride. Justify your answer.

(2)

(c) A student proposed to synthesise the compound 2,5-dimethylphenylamine, used in the manufacture of dyes, following the scheme below.



1,4-dimethylbenzene 2,5-dimethylphenylamine

(i) What two reagents are needed for **step 1**?

(2)

(ii) Suggest why 1,4-dimethylbenzene is more reactive than benzene in reactions such as **step 1**.

(2)

N 3 7 9 5 4 A 0 1 0 2 4
STEMUP.CO.UK

(iii) What type of reaction occurs in **step 2**?

(1)

.....

*(iv) 2,5-dimethylphenylamine can be used to make azo-dyes. State the reagents and conditions needed to make an azo-dye from 2,5-dimethylphenylamine and phenol. Include equations for the organic reactions.

(5)

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(Total for Question 15 = 17 marks)

N 3 7 9 5 4 A 0 1 1 2 4
STUDYMUP.CO.UK

16 The leaves of the rhubarb plant contain ethanedioic acid, $(COOH)_2$, a toxic white soluble solid. The acid is readily oxidized by potassium manganate(VII) under acidic conditions. A sample of 250 g of rhubarb leaves was finely chopped then soaked in warm water to release any ethanedioic acid present. The mixture was then filtered and made up to a volume of 500 cm^3 using distilled water. 10.0 cm^3 of the solution was then titrated with 0.0100 mol dm^{-3} acidified potassium manganate(VII) solution from a burette, requiring 11.30 cm^3 to completely oxidize the sample.

(a) (i) Write the half equation for the oxidation of ethanedioic acid to form carbon dioxide, and the half equation for the reduction of manganate(VII) ions, MnO_4^-, in acidic solution to form manganese(II) ions. State symbols are **not** required.

(2)

(ii) Use your answers to (a)(i) to write the overall equation for the reaction, showing that the ratio of ethanedioic acid to manganate(VII) ions in the full equation is 5 : 2. State symbols are **not** required.

(1)

N 3 7 9 5 4 A 0 1 2 2 4
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*(iii) Calculate the % by mass of the ethanedioic acid present in the leaves, giving your final answer to **two** decimal places.

(5)

(iv) What is the level of accuracy of a burette in each reading? Use your answer to calculate the percentage error in the titre volume of 11.30 cm^3.

(2)

N 3 7 9 5 4 A 0 1 3 2 4
STUDYUP.CO.UK

(v) Suggest **two** reasons, other than the accuracy of the equipment used for measurements, why the results obtained in this experiment may be considered unreliable.

(2)

(vi) A student risk assessment for this experiment suggested wearing gloves, but a supervisor said that this was unnecessary. Why do you think this precaution was suggested by the student and why was it rejected by the supervisor?

(2)

(vii) An aqueous solution of MnO_4^- ions contained a small amount of chloride ions, Cl^-, as an impurity. Use this fact, and items 70 and 85 from page 16 of the data booklet, to suggest why this solution went cloudy after a time.

(2)

N 3 7 9 5 4 A 0 1 4 2 4
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(b) An aqueous solution containing Mn^{2+} ions is pale pink in colour due to the presence of the complex ion $[Mn(H_2O)_6]^{2+}(aq)$.

(i) Complete the electronic configuration of the Mn^{2+} ion.

(1)

$1s^2$ .....

(ii) What shape would you expect this complex ion to be?

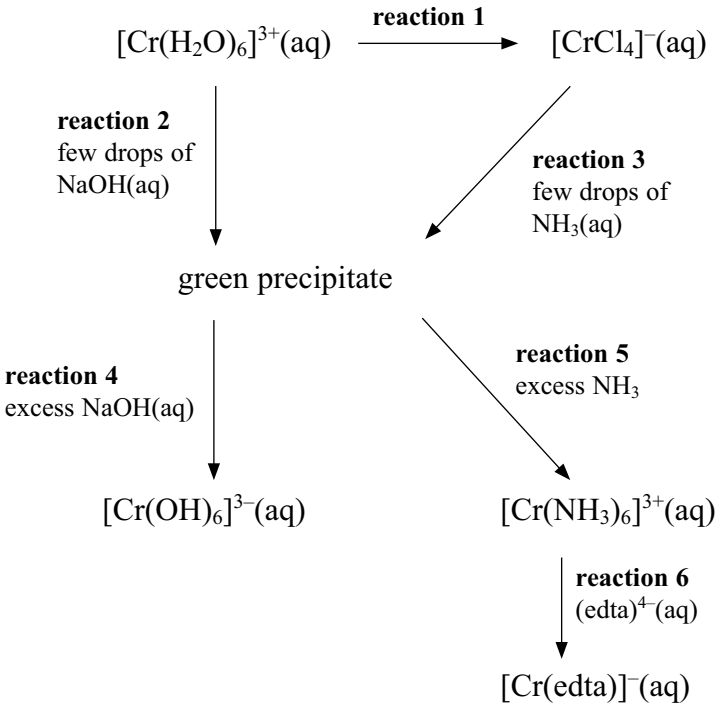
(1)

.....

(Total for Question 16 = 18 marks)

N 3 7 9 5 4 A 0 1 5 2 4
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17 The reaction scheme below summarises some of the reactions of chromium ions in aqueous solution. Look carefully at the scheme and answer the questions that follow.



(a) (i) Explain why the $[Cr(H_2O)_6]^{3+}$ ion is coloured.

(3)

(ii) Suggest what reagent is needed for **reaction 1** and identify the type of reaction.

(2)

N 3 7 9 5 4 A 0 1 6 2 4
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(b) (i) $[Cr(H_2O)_6]^{3+}$ ions react with water to form an acidic solution. Complete the equation for this reaction.

(2)

$[Cr(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons$ ..... + ...

(ii) The pH of an aqueous solution of $[Cu(H_2O)_6]^{2+}$ is higher than that of an aqueous solution of $[Cr(H_2O)_6]^{3+}$ of the same concentration. Suggest why this is so.

(2)

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.....

(c) Give the formula of the green precipitate formed in **reactions 2 and 3**.

(1)

.....

(d) By considering the nature of the reactants in **reaction 4**, explain why the green precipitate reacts as shown in the scheme. Suggest how you could reverse **reaction 4**.

(3)

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(e) Write the equation for **reaction 6** and use this to explain, in terms of the entropy change, why the complex $[Cr(edta)]^-$ is relatively more stable than $[Cr(NH_3)_6]^{3+}$.

(2)

Equation

.....

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.....

(Total for Question 17 = 15 marks)

TOTAL FOR SECTION B = 50 MARKS

N 3 7 9 5 4 A 0 1 7 2 4
STUDYUP.CO.UK

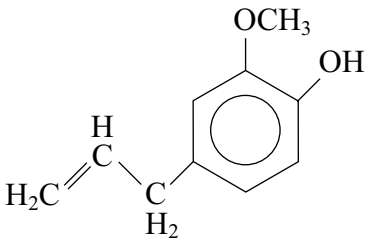
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N 3 7 9 5 4 A 0 1 8 2 4
STEMUP.CO.UK

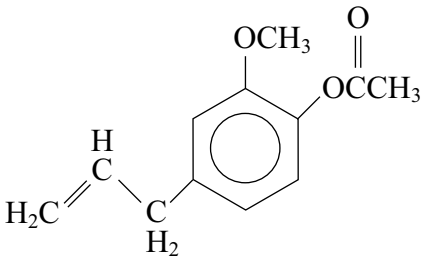
SECTION C

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

18 Eugenol, a pale yellow oil, and eugenol ethanoate are phenol-derived compounds found in the evergreen clove tree *Eugenia aromaticum*.



Eugenol



Eugenol ethanoate

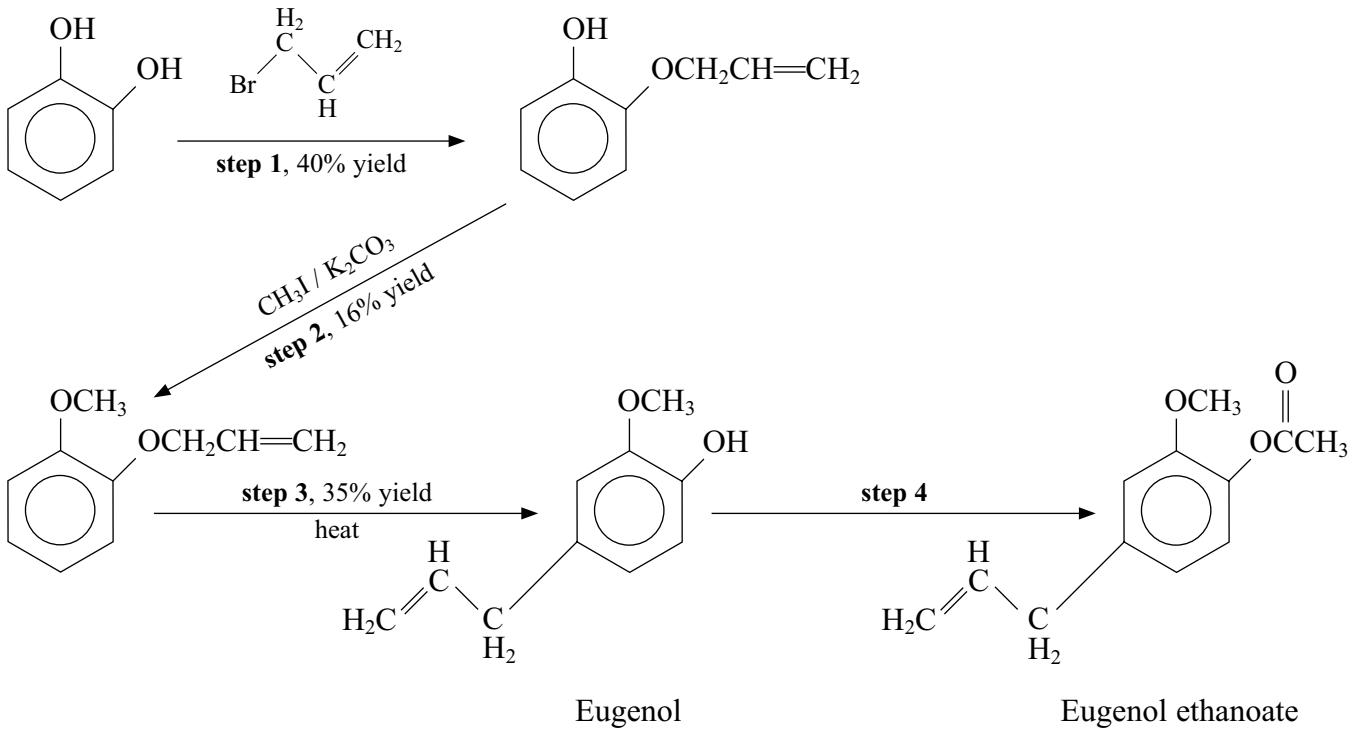
Eugenol is used in perfumes, the manufacture of food flavourings and as a local anaesthetic. Eugenol ethanoate is mainly used in perfumes and aftershaves. Although used for many years, both compounds are classified as harmful and have been tested to determine their toxicity by ingestion. However, humans would need to consume very large amounts to reach toxic levels.

The compounds are the main constituents of clove oil which can be extracted from the dried buds of *Eugenia aromaticum's* flowers. Traditionally the oil is extracted by steam distillation, though a greater yield of oil can be obtained using a Soxhlet extractor to pass a chlorinated solvent through the dried buds several times to dissolve the clove oil. An alternative technique uses carbon dioxide as a solvent. Above a temperature of 304 K and a high pressure of 73.8 atm, carbon dioxide behaves as a supercritical fluid and when passed through the clove buds, it dissolves the clove oil. Releasing the pressure causes the carbon dioxide to turn back into a gas, leaving the clove oil behind. A summary of the characteristics of the clove oil obtained by the three extraction techniques is shown in the table below.

Extraction method	Mass of oil per 100 g of dried buds / g	% eugenol and eugenol ethanoate in the oil produced	Extraction time / h	Colour and texture	Use of organic solvent
Supercritical carbon dioxide	19.6	78.4	2	pale yellow oil	no
Steam distillation	11.5	53.5	4–6	brown-yellow oil	yes
Soxhlet extraction	41.8	40.1	6	brown paste	yes

N 3 7 9 5 4 A 0 1 9 2 4
STEMUP.COUK

Both molecules can also be manufactured synthetically in the laboratory. A reaction scheme for synthesising both molecules is summarised below.



Eugenol

Eugenol ethanoate

(a) (i) 0.328 g of eugenol produced synthetically was burnt completely in excess oxygen, producing 0.880 g of carbon dioxide and 0.216 g of water. Use these data to show they are consistent with the molecular formula of eugenol.

(4)

N 3 7 9 5 4 A 0 2 0 2 4
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(ii) Describe a chemical test you could carry out to confirm the presence of a carbon-carbon double bond in the product of **step 1**. What would you expect to see?

(2)

.....

.....

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.....

(iii) What technique would you use to heat the reactants in **step 3** to minimise the loss of any volatile material?

(1)

.....

(iv) Suggest what reagent(s) could be used in **step 4**.

(1)

.....

.....

N 3 7 9 5 4 A 0 2 1 2 4
STUDYPAGE.COM

(b) (i) Draw and label the apparatus suitable for extracting clove oil from clove buds by steam distillation in the laboratory.

(3)

(ii) The distillate formed is a mixture of water and clove oil with a significant amount of oil dissolved in the water. Outline the steps that have to be taken to obtain the dry oil.

(3)

.....

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N 3 7 9 5 4 A 0 2 2 2 4
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(c) Toxicity data for substances such as eugenol are generally obtained by tests on animals such as rats and guinea pigs. In the case of eugenol, do you think such tests are reasonable? Briefly justify your answer.

(1)

*(d) Evaluate the three extraction methods for obtaining clove oil using information from the table. Give **one** reason why the synthetic route of obtaining eugenol, shown on page 20, is less preferable than extraction from clove buds.

(5)

(Total for Question 18 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

N 3 7 9 5 4 A 0 2 3 2 4
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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

N 3 7 9 5 4 STEM GP.CO.UK 2 4 2 4

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Mark Scheme (Results)
January 2011

GCE

GCE Chemistry (6CH05/01)

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January 2011

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Section A (multiple choice)

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

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

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

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

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

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

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

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

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

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

Question Number	Correct Answer	Mark
8 (d)	A	**1**

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

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

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

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

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

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

Question Number	Correct Answer	Mark
12 (b)	A	**1**

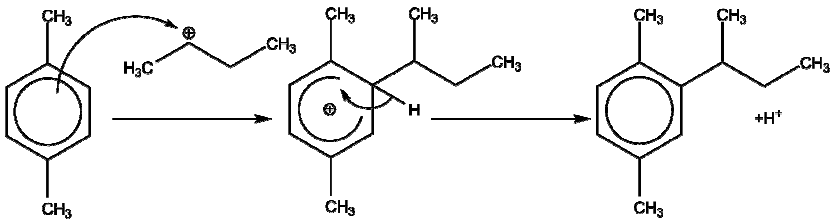
Question Number	Correct Answer	Mark
13	B	**1**

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

TOTAL FOR SECTION A = 20 MARKS

Section B

Question Number	Acceptable Answers	Reject	Mark
15 (a) (i)	Electrophilic substitution (any order)		**1**

Question Number	Acceptable Answers	Reject	Mark
15 (a) (ii)	$AlCl_3 + CH_3CH(Br)CH_2CH_3 \rightarrow AlCl_3Br^- + CH_3C^+HCH_2CH_3$ ALLOW $CH_3CH(Br)CH_2CH_3 \rightarrow Br^- + CH_3C^+HCH_2CH_3$ Ignore position of the + for this mark Ignore curly arrows in this equation **(1)**  Electron pair (curly arrow) from ring to positively charged **second** carbon of carbocation **(1)** Structure of intermediate must include positive sign **(1)** Electron pair from C-H bond reforms delocalized ring **(1)**	$AlCl_4^-$	**4**

Question Number	Acceptable Answers	Reject	Mark
15 (b)	**Advantage** Graphite catalyst easier to remove / separate / can be filtered off (from reaction mixture) / graphite can be re-used **(1)** **Justification** $AlCl_3$ is soluble or graphite is insoluble /different state / different phase **OR** Graphite can be re-used **(1)** **Mark independently**	Just graphite is a heterogeneous catalyst	**2**

Question Number	Acceptable Answers	Reject	Mark
15 (c) (i)	(Conc) nitric acid **(1)** (Conc) sulfuric acid **(1)** penalise dilute once only		**2**

Question Number	Acceptable Answers	Reject	Mark
15 (c) (ii)	Greater electron density **in ring** / ring is activated / more susceptible to electrophilic attack **(1)** Due to electron releasing / donating methyl groups **(1)**	Just more susceptible to attack	**2**

Question Number	Acceptable Answers	Reject	Mark
15 (c) (iii)	Reduction ALLOW redox	Hydrogenation	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (c) (iv)	$NaNO_2$ / sodium nitrite / sodium nitrate(III) & HCl (any strong acid) **(1)** Temp 0-10˚C / less than 10˚C / any quoted temperature between 0 -10˚C / in ice bath **(1)** $C_6H_3(CH_3)_2NH_2 + HNO_2 + HCl \rightarrow C_6H_3(CH_3)_2N_2^+Cl^- + 2H_2O$ **(1)** Add phenol dissolved in alkali **(1)** $(C_6H_3(CH_3)_2N_2^+Cl^- + C_6H_5OH) \rightarrow C_6H_3(CH_3)_2N_2C_6H_4OH + (HCl)$ **(1)** Mark given for correct organic product Allow correct organic product shown as $-O^-$ instead of -OH **Mark independently**	HNO_3	**5**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (i)	$(COOH)_2 \rightarrow 2CO_2 + 2H^+ + 2e^-$ **(1)** $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (ii)	$5(COOH)_2 + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$ ALLOW multiples ALLOW $5(COOH)_2 + 2MnO_4^- + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O + 10H^+$ Ignore state symbols even if incorrect	Equation with electrons left in	**1**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (iii)	Moles of MnO_4^- = 11.30/1000 x 0.010 = 1.13×10^{-4} (mol) **(1)** Moles of $(COOH)_2$ in 10 cm^3 = 1.13×10^{-4} x 5/2 = 2.825×10^{-4} (mol) **(1)** Moles of $(COOH)_2$ in whole sample = 2.825×10^{-4} x 50 = 0.01412(5) (mol) **(1)** Mass of acid = 0.01412(5)x 90 = 1.27 g **(1)** % in leaves = 1.27/250 x 100 = 0.51 (%) **(1)** If ratio 5 : 2 is not used, maximum **(4)** e.g. if ratio 2:5 is used then percentage in leaves = 0.08%	TE for 5th mark if % is greater than 100% Rounding errors once in first 4 marks Final answers not quoted to 2 dp	**5**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (iv)	± 0.05 cm^3 **(1)** [(0.05 x 2) / 11.3] x 100 = 0.88% **(1)** ALLOW ±0.025 cm^3 **(1)** [(0.025 x 2) / 11.3] x 100 = 0.44% **(1)** ALLOW TE for second mark		**2**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (v)	Any two from: Only one titration carried out **(1)** Leaves may contain other substances that MnO_4^- could oxidize/ react with **(1)** Not all ethanedioic acid extracted from leaves **(1)** ALLOW temperature too low / below 60˚C **(1)** Different amounts of acid from different leaves **(1)**	Errors in technique e.g. transfer errors	**2**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (vi)	(Wearing gloves suggested as) ethanedioic acid is toxic / harmful OR rhubarb **leaves** are toxic /harmful **(1)** (Unnecessary because) it is (very) dilute / present in small amounts **(1)** ALLOW because is not absorbed through the skin **Second mark is independent of the first**	References to weak acid Rhubarb is toxic	**2**

Question Number	Acceptable Answers	Reject	Mark
16 (a) (vii)	(Cloudiness due to) **MnO_2** (solid /precipitate) **(1)** Ignore colour of precipitate EITHER Suitable use of E^{θ} (+0.34V) **OR** MnO_4^- ions are a strong enough oxidizing agent to oxidize Cl^- ions **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
16 (b) (i)	$(1s^2)2s^22p^63s^23p^63d^5$ $(4s^0)$	$4s^2$ $3d^3$	**1**

Question Number	Acceptable Answers	Reject	Mark
16 (b) (ii)	Octahedral		**1**

Question Number	Acceptable Answers	Reject	Mark
17 (a) (i)	(Ligands cause) d orbitals / sub-shell / sub level to split **(1)** **Some** frequencies of light (energy) are absorbed **(1)** To promote electrons (within d level / d → d transitions) **(1)** ALLOW as alternative for second mark Remaining light is transmitted / reflected (resulting in the colour seen) **Mark independently**	Description of flame test	**3**

Question Number	Acceptable Answers	Reject	Mark
17 (a) (ii)	Concentrated HCl / HCl / HCl (aq) **(1)** **Ligand** exchange / replacement / substitution **(1)** **Mark independently**	Dilute HCl	**2**

Question Number	Acceptable Answers	Reject	Mark
17 (b) (i)	$[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_3O^+$ **(1) (1)** ALLOW $[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_2O + H^+$ **(1) (1)** ALLOW second mark for number of H_3O^+ ions related to incorrect complex e.g. $[Cr(H_2O)_4(OH)_2]^{2+} + 2H_3O^+$ scores second mark Ignore state symbols even if wrong		**2**

Question Number	Acceptable Answers	Reject	Mark
17 (b) (ii)	The concentration of oxonium / hydrogen ions is less in the $[Cu(H_2O)_6]^{2+}$ / fewer hydrogen ions produced or reverse argument based on Cr ion **(1)** ALLOW $[Cr(H_2O)_6]^{3+}$ / chromium ion deprotonates more easily if H_3O^+ shown in equation in (b) (i) Because copper ion is 2+ whilst the chromium ion is 3+ / charge on copper ion is less than charge on Cr ion / less charge density on 2+ ions / Cr (3+) draws more electron density from the O-H bond **(1)**	Just chromium complex more acidic The concentration of oxonium / hydrogen ions is greater in the $[Cu(H_2O)_6]^{2+}$ / more hydrogen ions produced Ligand exchange	**2**

Question Number	Acceptable Answers	Reject	Mark
17 (c)	$Cr(OH)_3$ / $Cr(H_2O)_3(OH)_3$		**1**

Question Number	Acceptable Answers	Reject	Mark
17 (d)	NaOH is a (strong) base / alkali **(1)** $Cr(H_2O)_3(OH)_3$ loses (three) protons / undergoes further deprotonation **OR** $Cr(OH)_3$ is amphoteric (so reacts with strong bases) **(1)** To reverse reaction 4 add (sulfuric) acid / H^+ / HCl **(1)**	Chromium is amphoteric	**3**

Question Number	Acceptable Answers	Reject	Mark
17 (e)	$[Cr(NH_3)_6]^{3+} + (edta)^{4-} \rightarrow [Cr(edta)]^- + 6NH_3$ **(1)** Ignore missing brackets Ignore state symbols even if wrong During the reaction number of particles increases (2 to 7) / more moles of product than reactants AND entropy (of system) increases **(1)**	Entropy increases because a gas is produced only Just more products than reactants	**2**

TOTAL FOR SECTION B = 50 MARKS

Section C

Question Number	Acceptable Answers	Reject	Mark
18 (a) (i)	Mass of C in CO_2 = 12/44 x 0.88 = 0.24 g Mass of H in H_2O = 2/18 x 0.216 = 0.024g **(1)** So mass of oxygen = 0.328 – (0.24 + 0.024) = 0.064 g **(1)** Moles of C = 0.24/12 = 0.02 Moles of H = 0.024/1 = 0.024 Moles of O = 0.064/16 = 0.004 **(1)** Ratio = simplest ratio = 5:6:1 so $C_{10}H_{12}O_2$ **(1)** **OR** Moles of CO_2 0.88/44 = 0.02 Moles of H_2O 0.216/18 = 0.012 **(1)** Moles of H = 0.024 therefore ratio of C:H is 5:6 **(1)** Can gain remaining two marks if they continue calculation as above **OR** $C_{10}H_{12}O_2$ = 164 **(1)** Percentage carbon is 120/164 = 73.2% Percentage hydrogen is 7.3% Percentage oxygen is 19.5% **(1)** Mass of carbon = 73.2 x 0.328/100 = 0.24 Mass of hydrogen = 7.3 x 0.328/100 = 0.024 Mass of oxygen = 19.5 x 0.328/100 = 0.064 **(1)** Mass of carbon in CO_2 is 12/44 x 0.88 = 0.24 Mass of hydrogen in H_2O is 1/9 x 0.216 = 0.024 **(1)** **OR** Mass of C in CO_2 = 12/44 x 0.88 = 0.24 g Mass of H in H_2O = 2/18 x 0.216 = 0.024g **(1)** So mass of oxygen = 0.328 – (0.24 + 0.024) = 0.064 g **(1)** Percentage of C = 0.24/0.328 = 73.2% Percentage of H = 0.024/0.328 = 7.3% Percentage of O = 0.064/0.328 =19.5% **(1)** $C_{10}H_{12}O_2$ = 164 Percentage carbon is 120/164 = 73.2% Percentage hydrogen is 12/164 = 7.3% Percentage oxygen is 32/164 = 19.5% **(1)**		**4**

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Question Number	Acceptable Answers	Reject	Mark
18 (a) (ii)	Add (small amount of) Br_2 / bromine **(1)** (Br_2 turns from orange / yellow / red-brown to) colourless / decolourised **(1)** **OR** Add (small amount of) **acidified** $KMnO_4(aq)$ **(1)** $KMnO_4(aq)$ turns from purple/pink to colourless / brown **(1)** **OR** Add (small amount of) **alkaline** $KMnO_4(aq)$ **(1)** $KMnO_4(aq)$ turns from purple/pink to green **(1)**	clear	**2**

Question Number	Acceptable Answers	Reject	Mark
18 (a) (iii)	(Heat under) reflux **OR** microwave (in sealed container)		**1**

Question Number	Acceptable Answers	Reject	Mark
18 (a) (iv)	CH_3COCl / $CH_3COO(COCH_3)$ / ethanoyl chloride / ethanoic anhydride ALLOW CH_3COOH / ethanoic acid **and** H_2SO_4 / sulfuric acid / HCl / hydrochloric acid	Correct answer plus $AlCl_3$ Acyl chloride	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (b) (i)	steam source and r.b /pear-shaped flask (and clove buds) **OR** r.b /pear-shaped flask being heated and containing **water** (and clove buds) **(1)** Condenser with water jacket, in correct position and direction of water flow **(1)** Collection vessel **(1)** -1 if apparatus does not work e.g. sealed -1 for no joints or leaky joint	Conical flask if being heated with the clove buds in	**3**

Question Number	Acceptable Answers	Reject	Mark
18 (b) (ii)	Mix organic solvent and oil-water mixture in a separating funnel then separate **(1)** Distil / rotary evaporate (to separate clove oil from organic solvent) **(1)** Add (anhydrous)$CaCl_2$ /(anhydrous) $MgSO_4$ /(anhydrous) Na_2SO_4 /silica gel / calcium oxide to clove oil, (then filter / decant) **(1)** ALLOW name or formula of drying agent (Second and third marks in either order) **OR** Add (saturated solution) of NaCl / sodium salt **(1)** Separate in a separating funnel **(1)** Add named drying agent to clove oil, (then filter / decant) **(1)**	(Anhydrous) $CuSO_4$ NaOH, sodium carbonate, sodium hydrogencarbonate , calcium carbonate	**3**

Question Number	Acceptable Answers	Reject	Mark
18 (c)	Choice with justification **(1)** e.g. 'yes it's reasonable as clove oil may be in use at harmful /toxic levels so we need to identify what that **level** is' 'no as clove oil has been in use for many years in many ways so tests on animals not necessary to confirm it's safe to use at current levels' / no, as humans would have to consume large amounts	Yes because it's toxic No, because of objections to animal testing in general	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (d)*	**4 clear justified comparisons – 1 mark each** **$ScCO_2$** oil obtained seems **purer** (as colour closely matches that of eugenol) requires no further purification, (others use solvent extraction) greater yield per hour yield 15.3g per 100g of buds no organic solvent (because it is chlorinated) **and** so environmental problems / harmful / damage ozone layer requires high pressure so likely to be expensive / requires specialist equipment **Steam distillation** steam distillation can be done using standard lab equipment /does not require high pressures yield only 6.1g / 6.2g per 100g of buds Steam gives the least yield per hour **Soxhlet** produces greater yield of oil but has a smaller percentage of eugenol /eugenol ethanoate yield 16.8g per 100g of buds (takes longer) but does not require high pressures uses organic solvent (because it is chlorinated) **and** so environmental problems / harmful / damage ozone layer Oil obtained seems least pure **(4)** **Synthetic route** has several steps, each with a low yield clove buds are renewable but materials in synthesis are not / materials in synthesis likely to be obtained from oil **(1)**	produces pale yellow oil Just no organic solvent Only two hours / shorter time than other methods Just higher percentage yield Just no organic solvent Higher yield than soxhlet Cost of chemicals Yield is 35 %	**5**

TOTAL FOR SECTION C = 20 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)

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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7/7/7/2/

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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)

N 3 6 5 0 7 A 0 2 2 8

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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)

N 3 6 5 0 7 A 0 3 2 8

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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)

N 3 6 5 0 7 A 0 4 2 8

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

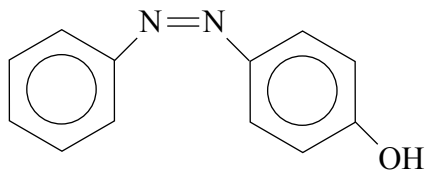
☒ **D** $CH_3COOCl + AlCl_3 \rightarrow [CH_3COO]^- + AlCl_4^+$

(Total for Question 14 = 1 mark)

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

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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)

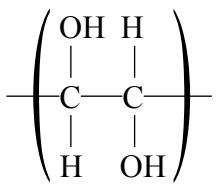
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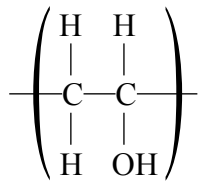
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17 The addition polymer poly(ethenol) is water-soluble. The repeating unit of poly(ethenol) is

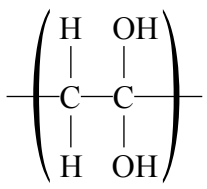
☒ **A**



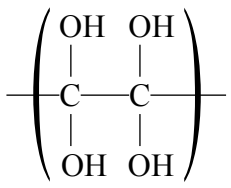
☒ **B**



☒ **C**



☒ **D**



(Total for Question 17 = 1 mark)

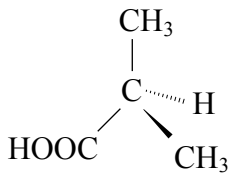
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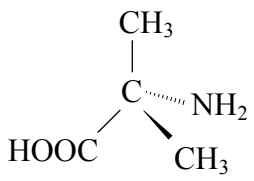
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18 A white organic compound, **X**, is optically active and reacts with ninhydrin to give a coloured product. The structural formula of **X** could be

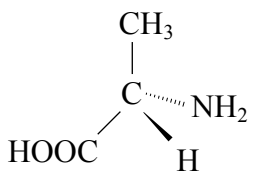
☒ **A**



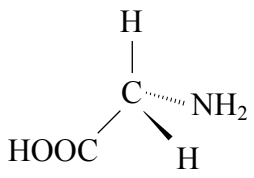
☒ **B**



☒ **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.

N 3 6 5 0 7 A 0 8 2 8

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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

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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)

N 3 6 5 0 7 A 0 1 0 2 8

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(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)

N 3 6 5 0 7 A 0 1 2 2 8

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(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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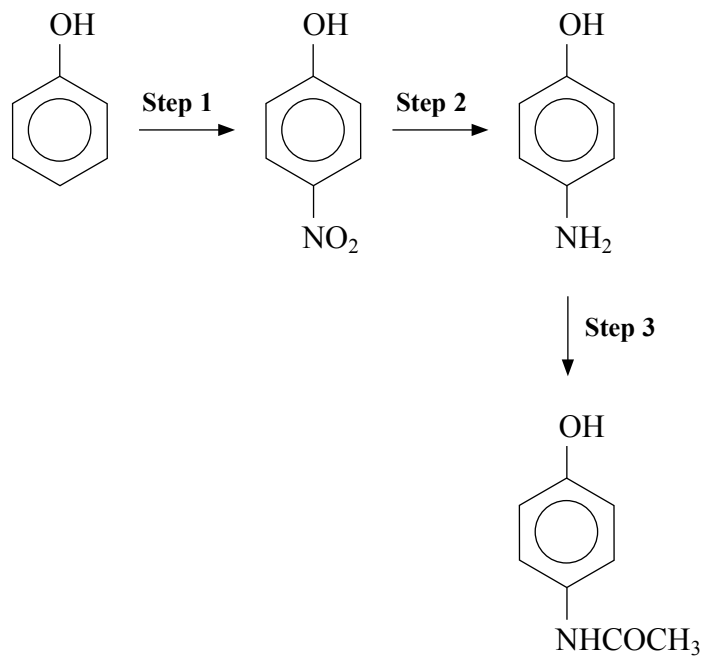
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(Total for Question 21 = 23 marks)

N 3 6 5 0 7 A 0 1 3 2 8

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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)

N 3 6 5 0 7 A 0 1 4 2 8

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

(2)

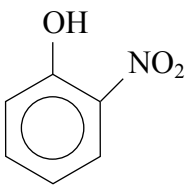
(iii) Suggest reagents that could be used for **step 2**.

(2)

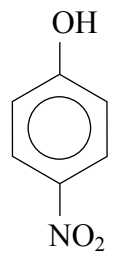
(iv) Suggest the name or formula of a reagent that could be used in **step 3**.

(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)

N 3 6 5 0 7 A 0 1 5 2 8

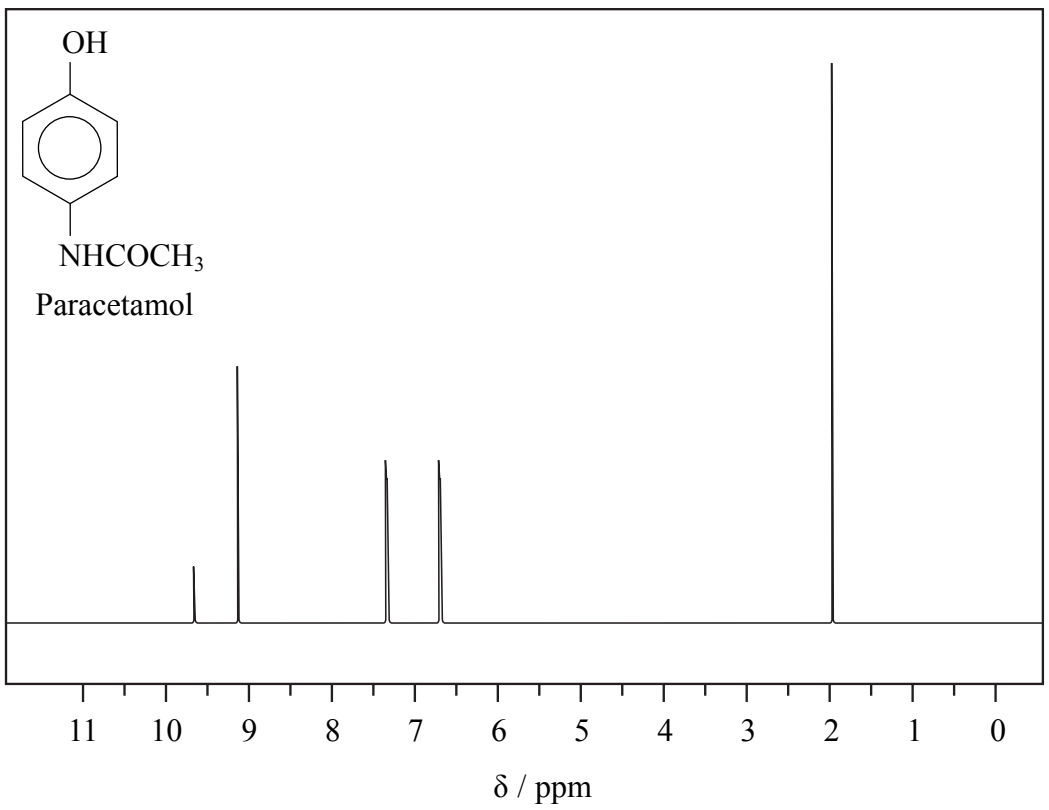
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(c) The nmr spectrum of paracetamol is given below. The peaks at 6.7 and 7.4 ppm are due to the protons on the benzene ring and are both doublets.

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)



.....

.....

.....

.....

.....

(Total for Question 22 = 14 marks)

N 3 6 5 0 7 A 0 1 6 2 8

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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)

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(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

N 3 6 5 0 7 A 0 1 8 2 8

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SECTION C

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

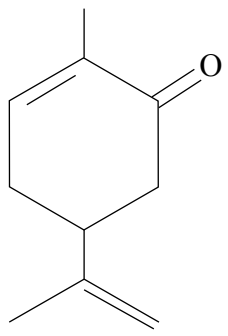
24

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)



N 3 6 5 0 7 A 0 1 9 2 8

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(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)

N 3 6 5 0 7 A 0 2 0 2 8

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(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)

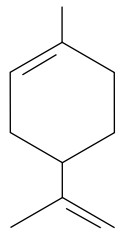
Working

Hence skeletal formula of reduction product.

N 3 6 5 0 7 A 0 2 1 2 8

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(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)

N 3 6 5 0 7 A 0 2 2 2 8

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(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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N 3 6 5 0 7 A 0 2 7 2 8

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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GCE

GCE Chemistry (6CH05/01)

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Summer 2010

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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**

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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**

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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**

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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**

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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**

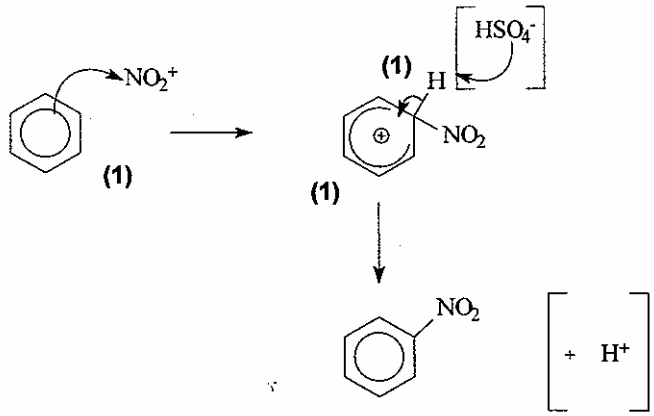
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Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ Ignore state symbols even if wrong.	Non-ionic equation.	**1**

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**

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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**

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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**

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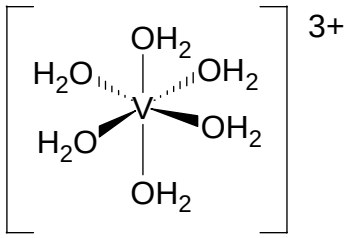
Question Number	Acceptable Answers	Reject	Mark
22(a)(iv)	ethanoyl chloride OR acetyl chloride OR CH_3COCl OR equivalent displayed formula OR ethanoic anhydride OR acetic anhydride OR $(CH_3CO)_2O$ OR equivalent displayed formula Right name but wrong formula does not score Ignore minor spelling errors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

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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**

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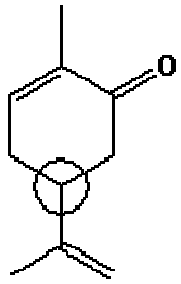
Question Number	Acceptable Answers	Reject	Mark
23(b)(i)	(+) 0.34 (V) OR (+) 0,34 V sign not needed		**1**

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**

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Section C

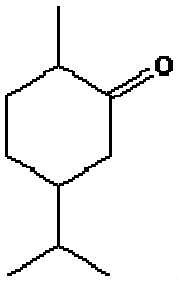
Question Number	Acceptable Answers	Reject	Mark
24(a)		Circles that encompass two atoms	**1**

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**

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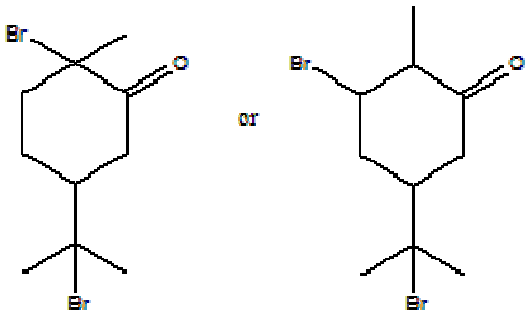
Question Number	Acceptable Answers	Reject	Mark
24(c)	(C=C): add bromine (water) **(1)** decolourises **(1)** OR $KMnO_4$ **(1)** purple → brown / colourless **(1)** (C=O): add 2,4-dnp / 2,4-dinitrophenylhydrazine/ Brady's reagent **(1)** orange or yellow or orange-red or red ppt **(1)** Ignore a negative 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**

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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**

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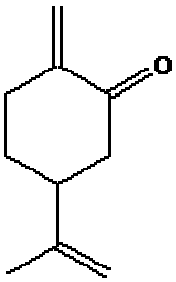
Question Number	Acceptable Answers	Reject	Mark
24(d)(ii)	(a ketone/C=O) absorption / peak / trough / within the range 1680 – 1700 (cm^{-1}) **(1)** Ignore units will be seen in carvone but not in limonene / the reduction product **(1)** omission of the value for the absorption loses first mark only	1720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

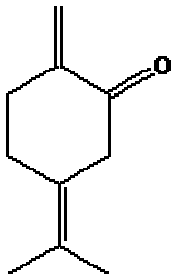
Question Number	Acceptable Answers	Reject	Mark
24(e)(i)	 for both double bonds having HBr added **(1)** ignore added hydrogens for correct orientation in **exocyclic** double bond **(1)** stand alone	Any structure retaining C=C bonds	**2**

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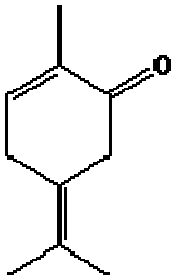
Question Number	Acceptable Answers	Reject	Mark
24(e)(ii)	HBr can be eliminated using a hydrogen from the carbon on either side of the bromine **(1)** which would then give a double bond in a different position from that in carvone **(1)** this second mark can be answered using a skeletal / structural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

From the left-hand structure above:

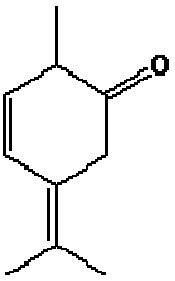


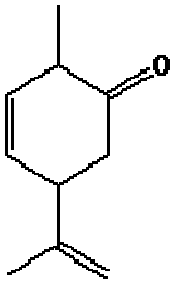


From either of the structures above:



From the right-hand structure above:





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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**

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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**

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