Pearson Edexcel International Advanced Level

Wednesday 14 January 2026

Morning (Time: 1 hour 45 minutes) | **Paper reference** **WCH15/01**

Chemistry
International Advanced Level
UNIT 5: Transition Metals and Organic Nitrogen Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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*.
- In the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

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

Turn over ▶

Pearson

SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A student wanted to measure the standard electrode potential of the half-cell for the reaction shown, using a standard hydrogen electrode.

$$V^{3+}(aq) \ + \ e^- \ \rightarrow \ V^{2+}(aq)$$
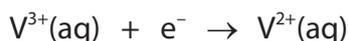
Which could **not** be used in making this measurement?

[Data: M_r VCl_2 = 121.9]

☒   **A**   an electrode of vanadium metal

☒   **B**   a pressure of 100 kPa of hydrogen gas

☒   **C**   a solution of vanadium(II) chloride of concentration 121.9 g dm^{-3}

☒   **D**   a temperature of 298 K

(Total for Question 1 = 1 mark)

2 An electrochemical cell was set up as shown.
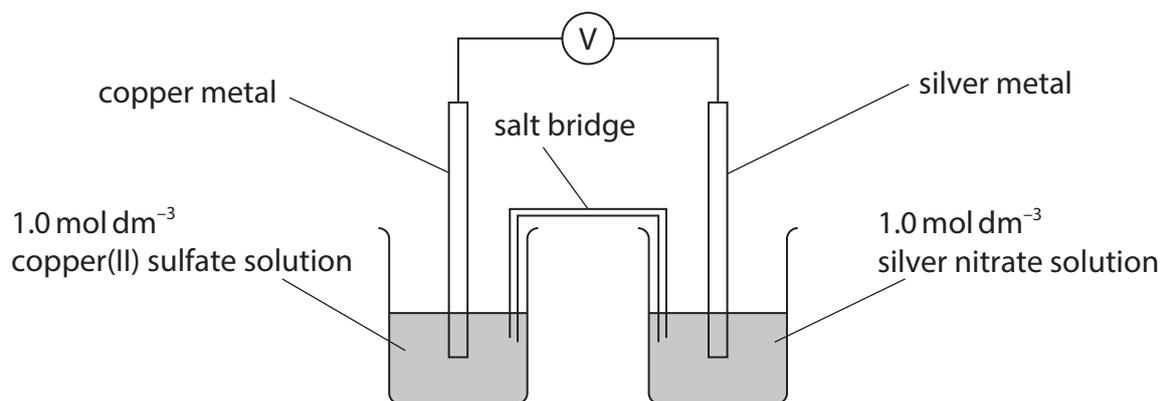
What is the emf of this cell at 298 K?
Use your Data Booklet.

☒   **A**   +1.14 V

☒   **B**   +0.46 V

☒   **C**   −0.46 V

☒   **D**   −1.14 V

(Total for Question 2 = 1 mark)

3 The concentration of an iodine solution was determined using a standard solution of sodium thiosulfate.

(a) 4.17 g of sodium thiosulfate was dissolved in deionised water, the solution made up to 250 cm^3 in a volumetric flask and mixed.
A 25.0 cm^3 portion was transferred to a conical flask using a pipette.

The measurement uncertainty of the volumetric flask was ±0.30 cm^3.

The measurement uncertainty of the pipette was ±0.03 cm^3.

The total measurement uncertainty of the balance weighing the mass of sodium thiosulfate was ±0.01 g.

Which is correct for the percentage uncertainties for this experiment?

(1)

☒ **A** the balance, pipette and volumetric flask have the same percentage uncertainties

☒ **B** the balance percentage uncertainty is the smallest

☒ **C** the pipette and volumetric flask have the same percentage uncertainties

☒ **D** the volumetric flask percentage uncertainty is ten times that of the pipette

(b) The 25.0 cm^3 of sodium thiosulfate solution in the conical flask was titrated with a solution containing iodine in the burette. No indicator was used.

What is the colour of the solution in the conical flask at the end-point?

(1)

☒ **A** blue-black

☒ **B** colourless

☒ **C** very pale yellow

☒ **D** red-brown

(Total for Question 3 = 2 marks)

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

4 What is the electronic structure of the metal ion in the double salt $(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$?

☒ **A** $[Ar]3d^44s^2$

☒ **B** $[Ar]3d^5$

☒ **C** $[Ar]3d^6$

☒ **D** $[Ar]3d^64s^2$

(Total for Question 4 = 1 mark)

5 Vanadium forms many different ions when combining with oxygen.

In which ion does vanadium have a different oxidation number from the others?

☒ **A** VO^{2+}

☒ **B** VO_2^+

☒ **C** VO_4^{3-}

☒ **D** $V_4O_{12}^{4-}$

(Total for Question 5 = 1 mark)

6 The stability of complex ions increases as the basicity of the ligands increases. Multidentate ligands form more stable complexes than monodentate ligands.

Which is the order of relative stability of these four complexes?

☒ **A** $[Ni(H_2O)_6]^{2+} > [Ni(NH_3)_6]^{2+} > [Ni(CH_3NH_2)_6]^{2+} > [Ni(H_2NCH_2CH_2NH_2)_3]^{2+}$

☒ **B** $[Ni(H_2NCH_2CH_2NH_2)_3]^{2+} > [Ni(CH_3NH_2)_6]^{2+} > [Ni(NH_3)_6]^{2+} > [Ni(H_2O)_6]^{2+}$

☒ **C** $[Ni(H_2O)_6]^{2+} > [Ni(CH_3NH_2)_6]^{2+} > [Ni(NH_3)_6]^{2+} > [Ni(H_2NCH_2CH_2NH_2)_3]^{2+}$

☒ **D** $[Ni(H_2NCH_2CH_2NH_2)_3]^{2+} > [Ni(NH_3)_6]^{2+} > [Ni(CH_3NH_2)_6]^{2+} > [Ni(H_2O)_6]^{2+}$

(Total for Question 6 = 1 mark)

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

P 7 9 2 2 2 A 0 4 2 8

7 Which statement about the structure of $[Pt(NH_3)_2Cl_2]$ is correct?

☒ **A** a square planar complex with only one structure

☒ **B** a square planar complex with two isomeric forms

☒ **C** a tetrahedral complex with only one structure

☒ **D** a tetrahedral complex with two isomeric forms

(Total for Question 7 = 1 mark)

8 A student made three statements about the reaction scheme shown.

$$\text{Silver(I) chromate(VI)} \xleftarrow{\text{Ag}^+(\text{aq})} CrO_4^{2-} \xrightarrow{\text{H}^+(\text{aq})} Cr_2O_7^{2-} \xrightarrow[\text{H}^+(\text{aq})]{\text{Fe}^{2+}(\text{aq})} Cr^{3+} \xrightarrow[\text{H}^+(\text{aq})]{\text{Zn(s)}} Cr^{2+}$$
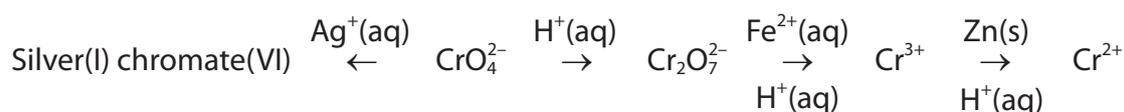
Statement **1**   The formula of silver(I) chromate(VI) is Ag_2CrO_4

Statement **2**   The conversion of CrO_4^{2-} to $Cr_2O_7^{2-}$ is not a redox reaction

Statement **3**   The minimum mass of zinc required to reduce
0.1 mol of Cr^{3+} to Cr^{2+} is 3.27 g

Of these three statements

☒ **A** only statement **1** is correct

☒ **B** only statements **1** and **2** are correct

☒ **C** only statements **2** and **3** are correct

☒ **D** statements **1**, **2** and **3** are correct

(Total for Question 8 = 1 mark)

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

9 The reaction between manganate(VII) ions and ethanedioate ions is autocatalytic, with the manganese(II) ions produced acting as the catalyst.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$
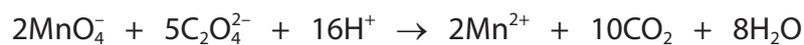
Rate of reaction is plotted against time for this reaction.

Which graph would be obtained?
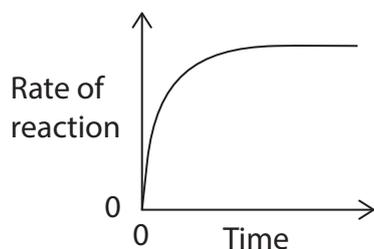
Graph 1
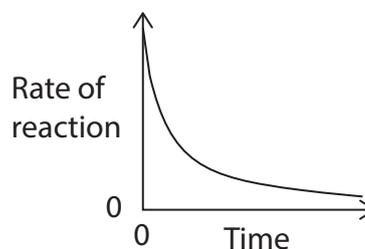
Graph 2
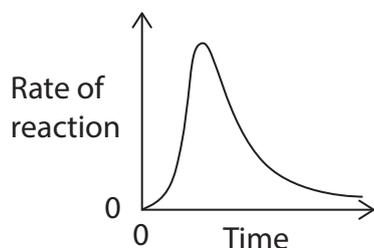
Graph 3
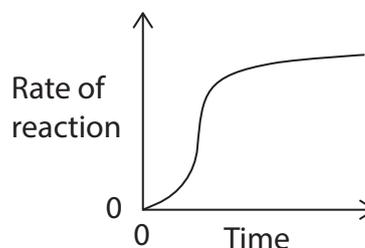
Graph 4

- ☒ **A** Graph 1
- ☒ **B** Graph 2
- ☒ **C** Graph 3
- ☒ **D** Graph 4

(Total for Question 9 = 1 mark)

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

10 This question is about the compound shown.

What types of reactions can this compound undergo?

- ☒ **A** electrophilic addition and electrophilic substitution

- ☒ **B** electrophilic addition and nucleophilic addition

- ☒ **C** electrophilic substitution and nucleophilic substitution

- ☒ **D** nucleophilic addition and nucleophilic substitution

(Total for Question 10 = 1 mark)

11 How many isomeric compounds with the molecular formula $C_6H_4Br_2$ contain a benzene ring?

- ☒ **A** 2

- ☒ **B** 3

- ☒ **C** 4

- ☒ **D** 5

(Total for Question 11 = 1 mark)

12 What are the intermolecular forces in triethylamine, $(C_2H_5)_3N$?

- ☒ **A** hydrogen bonds only

- ☒ **B** hydrogen bonds, London forces and permanent dipole-permanent dipole interactions

- ☒ **C** London forces only

- ☒ **D** London forces and permanent dipole-permanent dipole interactions only

(Total for Question 12 = 1 mark)

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

13 The diagram shows the repeat unit of a polypeptide made from only one amino acid.
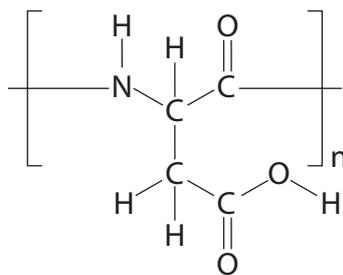
The polypeptide is hydrolysed by excess aqueous alkali.

Which is the structure of the organic species formed in this reaction?

☒ **A**

☒ **B**

☒ **C**

☒ **D**
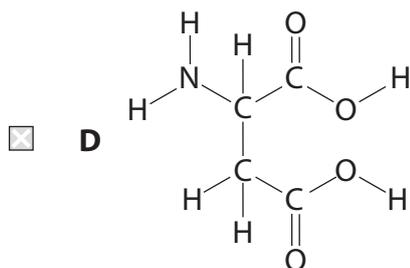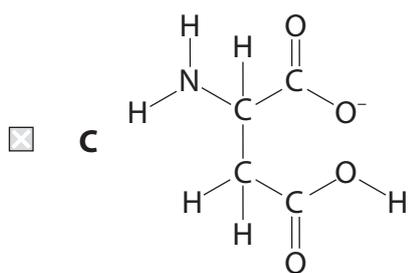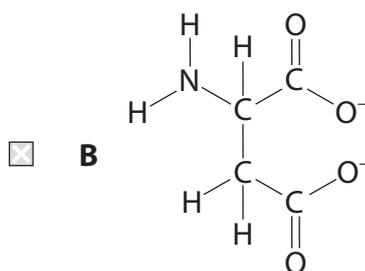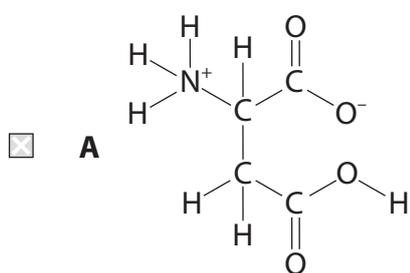
(Total for Question 13 = 1 mark)

14 Which structure of the amino acid lysine is a zwitterion?

☒ **A**

H_2N — backbone with H, $C=O$, O^-, side chain ending in NH_3^+

☒ **B**

H_3N^+ — backbone with H, $C=O$, OH, side chain ending in NH_3^+

☒ **C**

H_3N^+ — backbone with H, $C=O$, OH, side chain ending in NH_2

☒ **D**

H_2N — backbone with H, $C=O$, O^-, side chain ending in NH_2
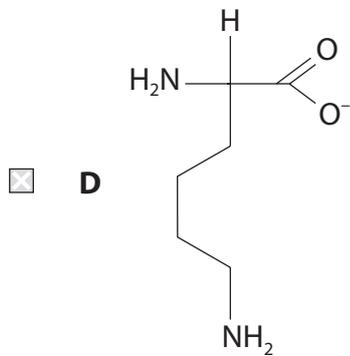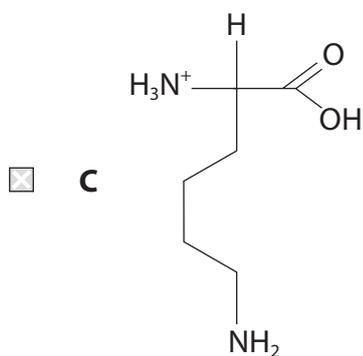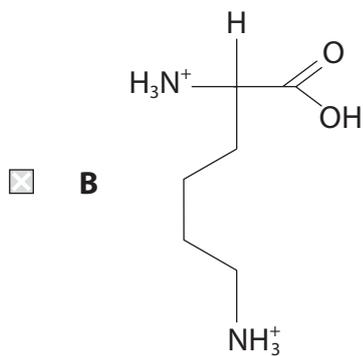
(Total for Question 14 = 1 mark)

15 This question is about the reaction scheme shown.
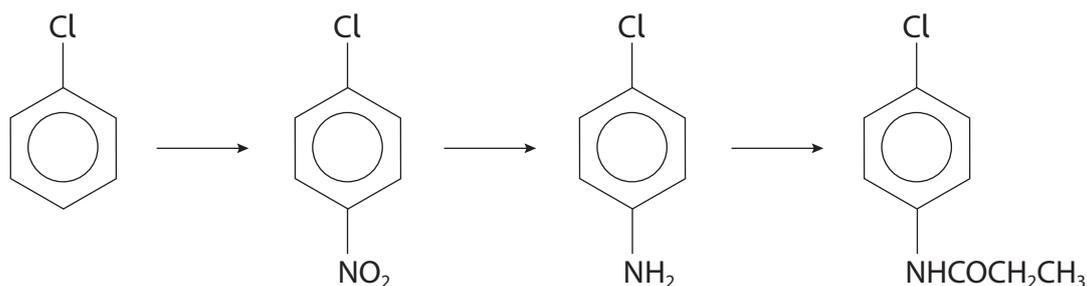
In the first step of this scheme the yield is relatively low, due to the formation of side products, one of which is 1-chloro-2-nitrobenzene.

(a) How many peaks are present in the ^{13}C NMR spectra of 1-chloro-4-nitrobenzene and 1-chloro-2-nitrobenzene?

(1)

		Number of peaks	Number of peaks
☒	**A**	3	3
☒	**B**	3	4
☒	**C**	4	4
☒	**D**	4	6

(b) Which acid is **not** used as one of the reagents in this reaction scheme?

(1)

☒ **A** ethanoic acid

☒ **B** hydrochloric acid

☒ **C** nitric acid

☒ **D** sulfuric acid

(Total for Question 15 = 2 marks)

16 Complete combustion of a hydrocarbon produced 1.32 g of carbon dioxide and 0.45 g of water.

Which **empirical** formula is consistent with these data?

☒ **A** CH_2

☒ **B** CH_4

☒ **C** C_3H_5

☒ **D** C_6H_{10}

(Total for Question 16 = 1 mark)

17 The reaction to produce a solid organic compound results in the formation of an aqueous solution of the compound.

(a) Solvent extraction is used to separate the organic compound.

Desirable properties of the solvent include that it is

(1)

☒ **A** miscible with water and dissolves the compound fully

☒ **B** immiscible with water and dissolves the compound fully

☒ **C** miscible with water and partially dissolves the compound

☒ **D** immiscible with water and partially dissolves the compound

(b) The resulting impure compound is purified by recrystallisation.

When recrystallisation is used to purify a solid, which of the following statements is true?

(1)

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

☒ **B** all impurities must be soluble in the solvent used

☒ **C** insoluble impurities are removed by filtering a hot solution

☒ **D** soluble impurities are removed by filtering a hot solution

(Total for Question 17 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

18 A Friedel-Crafts acylation reaction was carried out using methoxybenzene and ethanoyl chloride, in the presence of aluminium chloride.

methoxybenzene
mass = 5.25 g
$M_r = 108$

ethanoyl chloride
mass = 4.50 g
$M_r = 78.5$

isomer **1**
mass = 3.20 g
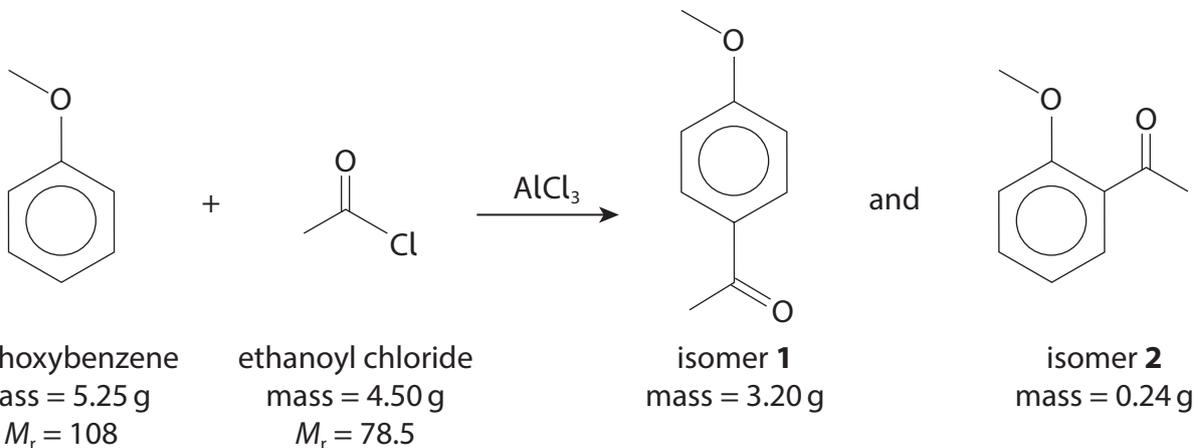
isomer **2**
mass = 0.24 g

(a) (i) Calculate which is the limiting reagent.

(2)

(ii) Calculate the percentage yield of isomer **1**.

(3)

(b) Draw the mechanism for the reaction producing isomer **1**, including the role of $AlCl_3$ in this reaction.

(5)

(c) Suggest a possible reason why isomer **1** has a significantly higher yield than isomer **2**.

(1)

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(Total for Question 18 = 11 marks)

19 This question is about molecules containing carbon-carbon double bonds.

Some values for the enthalpy changes of hydrogenation of different molecules to produce cyclohexane are shown.

	cyclohexene	cyclohexa-1,4-diene	cyclohexa-1,3-diene	benzene
Enthalpy change of hydrogenation / kJ mol^{-1}	−120	−240	−232	−208

Explain the differences in the enthalpy changes of hydrogenation for these four molecules.
Justify your answer in terms of structure and bonding, **and** the stability to hydrogenation.

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(Total for Question 19 = 4 marks)

20 Crystals of cobalt(II) chloride dissolve in water to form a pink solution containing complex ion **A**. Addition of a few drops of ammonia solution produces a blue precipitate, **B**, which redissolves as more ammonia is added.
The resulting solution contains a yellow complex ion **C**.
On standing in air, this complex ion **C** is oxidised to a brown solution containing complex ion **D**.

(a) (i) Write an equation for the reaction when **A** is converted into **B**.
State symbols are not required.

(2)

(ii) State the type of reaction and the role of ammonia when **B** is precipitated from the solution of **A**.

(2)

Type of reaction

....

Role of ammonia

....

(b) Give the formulae of the cobalt complex ions **C** and **D**.

(2)

C ....

D ....

*(c) Explain why solutions containing the ions **A**, **C** and **D** are coloured, and why the three solutions are different colours.

(6)

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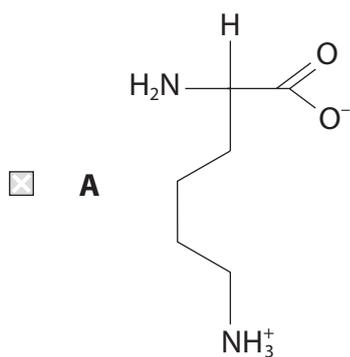
(Total for Question 20 = 12 marks)

P79222A01728

21 Cerium(IV) is readily reduced to cerium(III). Solutions of cerium(IV) can be used in titrations to determine the number of moles of a reducing agent.

(a) $250 \, cm^3$ of a solution contained $12.46 \, g$ of cerium(IV) sulfate, $Ce(SO_4)_2$.
This solution was titrated against $25.0 \, cm^3$ portions of a solution containing tin(II) ions of concentration $0.0552 \, mol \, dm^{-3}$.
The mean titre for the titration was $18.40 \, cm^3$.

Complete the equation for the titration reaction, including the final charge on the tin ion.
You **must** show all your working.

(6)

Final charge on the tin ion: ....

Equation: ....Ce^{4+}(aq) + ...Sn^{2+} $\rightarrow$ ....Ce^{3+} + ...Sn......

(b) Potassium manganate(VII) is frequently used in this type of titration.

Give **one** advantage and **one** disadvantage for the use of manganate(VII) solutions in titrations.

(2)

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(Total for Question 21 = 8 marks)

22 Peroxodisulfate ions, $S_2O_8^{2-}$, react with iodide ions, I^-, as shown.

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$
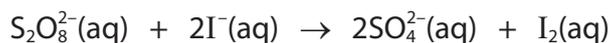
The standard cell potential, $E_{cell}^{\ominus}$, for this reaction is +1.47V.

(a) Write the cell diagram for measuring this cell potential using the conventional representation of half-cells.

(2)

(b) (i) Write the ionic half-equation for the reduction reaction.

(1)

(ii) Calculate the value for the reduction potential in this half-equation. Use your Data Booklet.

(1)

(iii) State the relationship between $E_{cell}^{\ominus}$ and total entropy change, and how the $E_{cell}^{\ominus}$ value demonstrates that this reaction is thermodynamically feasible.

(3)

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(iv) Explain why, despite being thermodynamically feasible, the reaction does not proceed in the absence of a catalyst.

(2)

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(c) The reaction can be catalysed by addition of either iron(II) or iron(III) ions.

(i) Explain, using suitable equations, why the addition of either of these two ions results in the reaction proceeding.
State symbols are not required.

(3)

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(ii) Justify your answer to (c)(i) using your answer to (b)(ii) and the $E^{\ominus}$ value for the reduction of Fe(III) to Fe(II) given in your Data Booklet.

(3)

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(Total for Question 22 = 15 marks)

TOTAL FOR SECTION B = 50 MARKS

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P79222A02228

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

23 Extending the carbon chain is an important process in organic synthesis.
A few procedures can be used to extend the carbon chain when starting with halogenoalkanes. For example, iodomethane can be converted into ethanoic acid either via a nitrile, or by using a Grignard reagent, or by the reaction with water and carbon monoxide with a transition metal catalyst.

(a) Iodomethane reacts to form ethanenitrile.

(i) State the reagent and condition for this reaction.

(2)

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(ii) Ethanenitrile is hydrolysed to ethanoic acid by reaction with hydrochloric acid.

Write the equation for this reaction.

(2)

(iii) Ethanenitrile can also be hydrolysed using aqueous alkali, but an acid then needs to be added to form ethanoic acid.

State why the acid is needed.

(1)

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(b) Iodomethane can be converted into ethanoic acid via a Grignard reagent.

(i) Write the equation for the formation of this Grignard reagent.
Include the conditions required.

(2)

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(ii) Give the name of the reagent that would react with the Grignard reagent to form ethanoic acid.

(1)

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(c) The steps show how a rhodium complex ion is thought to catalyse the production of ethanoic acid from **excess** methanol via iodomethane.

Step **1** $\qquad$ $CH_3OH + HI \rightarrow CH_3I + H_2O$

Step **2** $\qquad$ $[Rh(CO)_2I_2]^- + CH_3I \rightarrow [Rh(CO)_2I_3CH_3]^-$

Step **3** $\qquad$ $[Rh(CO)_2I_3CH_3]^- \rightarrow [Rh(CO)I_3(COCH_3)]^-$

Step **4** $\qquad$ $[Rh(CO)I_3(COCH_3)]^- + CO \rightarrow [Rh(CO)_2I_3(COCH_3)]^-$

Step **5** $\qquad$ $[Rh(CO)_2I_3(COCH_3)]^- \rightarrow [Rh(CO)_2I_2]^- + CH_3COI$

Step **6** $\qquad$ $CH_3COI + H_2O \rightarrow CH_3COOH + HI$
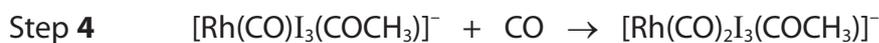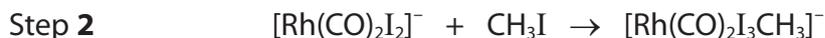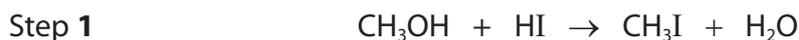
The rate equation for this reaction is shown.

$$rate = k[[Rh(CO)_2I_2]^-][HI]$$

The $[Rh(CO)_2I_2]^-$ ion used as the catalyst is the *cis*-isomer of a square planar complex.

(i) State how the series of steps demonstrates that $[Rh(CO)_2I_2]^-$ acts as a catalyst.

(1)

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(ii) Deduce the oxidation state of rhodium in $[Rh(CO)_2I_2]^-$.
Justify your answer.

(2)

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(iii) Complete the table with two diagrams and two coordination numbers.
Show the three-dimensional structure of the two rhodium complex ions.

(4)

Complex ion	Diagram	Coordination number
$[Rh(CO)_2I_2]^-$		
$[Rh(CO)_2I_3CH_3]^-$		6
$[Rh(CO)I_3(COCH_3)]^-$		

(iv) State the overall order of this reaction.

(1)

....

(v) The rate-determining step for this reaction is Step **2**.

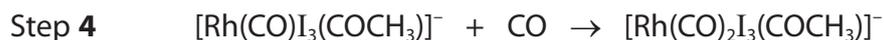Explain why the rate equation means that Step **2** could be the
rate-determining step.

(2)

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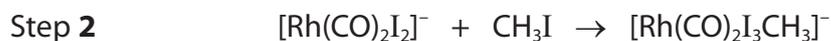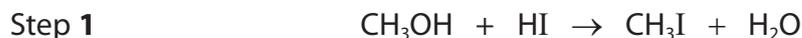
(vi) Explain how the proposed mechanism shows that the reaction is zero order with respect to carbon monoxide and methanol, using your answers to both (c)(iv) and (c)(v).

Steps **1** to **6** of the proposed mechanism have been replicated for your convenience.

Step **1** $\qquad$ $CH_3OH + HI \rightarrow CH_3I + H_2O$

Step **2** $\qquad$ $[Rh(CO)_2I_2]^- + CH_3I \rightarrow [Rh(CO)_2I_3CH_3]^-$

Step **3** $\qquad$ $[Rh(CO)_2I_3CH_3]^- \rightarrow [Rh(CO)I_3(COCH_3)]^-$

Step **4** $\qquad$ $[Rh(CO)I_3(COCH_3)]^- + CO \rightarrow [Rh(CO)_2I_3(COCH_3)]^-$

Step **5** $\qquad$ $[Rh(CO)_2I_3(COCH_3)]^- \rightarrow [Rh(CO)_2I_2]^- + CH_3COI$

Step **6** $\qquad$ $CH_3COI + H_2O \rightarrow CH_3COOH + HI$

(2)

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(Total for Question 23 = 20 marks)

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

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The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1.0
H
hydrogen
1

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

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

* Lanthanide series

140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71

* Actinide series

232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103