TASMANIAN ASSESSMENT, STANDARDS & CERTIFICATION

External Assessment 2025

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CHEMISTRY

CHM415115

Section A

Pages: 16
Questions: 6
Information Sheet: 1

Preparation time for this exam: 15 minutes

Suggested working time: 45 minutes

Instructions:

- Answer **all** questions and **all** items within each question.
- Write your answers in the spaces provided in this exam paper.
  - Spare diagrams have been provided at the end of this section. Indicate using the box provided if you have used the spare diagram.
- TASC approved scientific calculators can be used throughout the exam.
  - Show your workings in answers to numerical questions. No marks can be given for incorrect answers unless they are accompanied by details of the working.
- The exam is **three (3) hours** in length. The suggested working time for this section is **approximately 45 minutes**.
- The Chemistry Information Sheet can be used throughout the exam.
- All answers must be written in **English**.
- You **must** make sure your answers address the listed criterion.

Marker use	
C5	/ 45

Additional Instructions

Note: When you are asked to “show that”:

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- If you are unable to determine the required value, you should use the value given in the following items of the question.

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Section C	5	5	45 minutes	45 marks
Section D	6	6	45 minutes	45 marks
Totals	**22**	**22**	**180 minutes (3 hours)**	**180 marks**

Criterion

You **must** make sure your answers address:

- Criterion 5 identify and apply fundamental principles and theories of electrochemistry.

Question 1

Marker use

a) Acidified potassium permanganate ($H^+/KMnO_4$) readily reacts with sodium sulfite (Na_2SO_3) forming manganese(II) ions and sulfate ions in a redox reaction. Ignoring spectator ions:

i. Write the reduction half equation. /1

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ii. Write the oxidation half equation. /1

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iii. Combine the two half equations to form a balanced net ionic equation. /2

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b) Explain why a redox reaction will occur when zinc granules are added to a 1.0 mol L^{-1} solution of copper sulfate. Provide balanced half equations and state an observation noted during the reaction. /3

Explanation:.....

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Equations:.....

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Observation: .....

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Question 1 continues

Marker use

/2

c) 1.0 mol L^{-1} solutions of iron(III)chloride and tin(II)chloride are mixed.

Explain if a redox reaction will occur. If so provide relevant half equations.

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Total Q1

/9

Question 2

Marker use

Titanium is a strong, lightweight metal that is used in various metal alloys. Its most stable oxide, titanium dioxide, is the white pigment in paint.

a) Determine the oxidation state of titanium in the following substances:

/4

i. Titanium metal, $Ti_{(s)}$

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ii. Titanium tetrachloride, $TiCl_4$

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iii. Lithium hexafluorotitanate, Li_2TiF_6

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iv. Titanium hydride, TiH_2

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Titanium tetrachloride can be used to synthesise titanium hydride by reacting with magnesium hydride, as outlined in the equation below:

$$TiCl_4 + 2MgH_2 \rightarrow TiH_2 + 2MgCl_2 + H_2$$

b) Explain why $TiCl_4$ is acting as an oxidising agent in this reaction.

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Total Q2

/6

Question 3

Marker use

Lithium-ion batteries power many objects including mobile phones, buildings and cars. The chemistry of the lithium-ion battery is relatively simple. There are several basic types available.

The original and most common type, lithium metal oxide cell, is constructed with lithium metal absorbed in graphite ($Li + C_6$) and lithium ions absorbed in cobalt oxide ($Li^+ + CoO_2$).

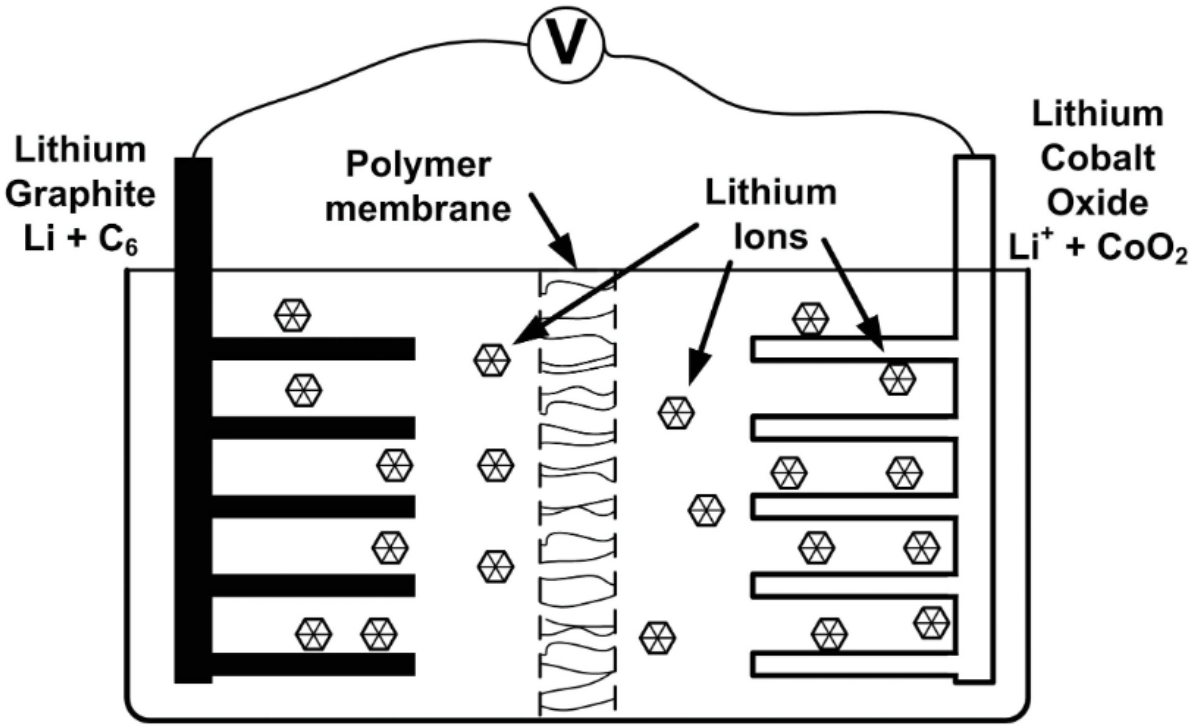

Figure 1

Spare diagram used (X) ☐

The redox equations within the electrochemical cell are:

$$Li + C_6 \rightarrow C_6 + Li^+ + e^-$$

$$Li^+ + CoO_2 + e^- \rightarrow LiCoO_2$$

a) Label Figure 1 to show:

i. The anode and cathode

ii. The polarity of the electrodes

iii. The direction of electron movement.

/3

Question 3 continues

Marker use

b) Write an overall balanced equation for the reaction occurring in the lithium metal oxide cell.

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c) The two half cells are separated by a porous polymer membrane. Outline the purpose of the polymer membrane.

/1

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d) If the emf of the lithium metal oxide cell is 3.6 V, calculate the E^o value for the half equation:

/1

$$Li^+ + CoO_2 + e^- \rightarrow LiCoO_2$$

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Total Q3

/6

Question 4

Marker use

An electrolytic cell consists of platinum electrodes immersed in a beaker containing 1.0 L of a 1.0 mol L^{-1} NaCl solution.

a) On Figure 2 below:

i. Circle the electrodes as either cathode or anode. /1

ii. Write the relevant half equations at the cathode and anode. /2

iii. State what would be observed at the cathode and anode. /2

Cathode or Anode

Half equation

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Observations

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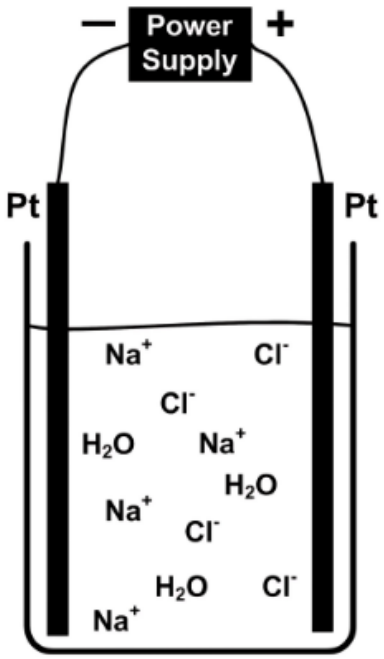

Cathode or Anode

Half equation

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Observations

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Figure 2

Spare diagram used (X) ☐

Question 4 continues

Marker use

b) A student decided to dissolve 1 mole of ferrous chloride ($FeCl_2$) into the 1.0 L NaCl solution. Explain what effect this would have on the products formed at the two electrodes.

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Total Q4

/7

Question 5

Marker use

An aqueous zinc sulfate solution was electrolysed using inert electrodes for 1.00 hour at a current of 50.5 amps. The cathode reaction is:

$$Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$$

a) Show that 61.6 g of zinc will theoretically form during electrolysis. /3

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b) Competing reactions in the electrolysis process reduced the yield of zinc to 83.0% of the theoretical amount. Calculate the time taken for the full 61.6 g of zinc to be produced using the 50.5 amps current given a yield of 83.0%. /1

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c) The yield reduction was due to the formation of a gas at the cathode. Explain the causes for this gas production. /2

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Total Q5 /6

Exam continues over the page

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Question 6

Marker use

A steel power pole was removed from a construction site.

As shown in Figure 3, the pole appeared to be in excellent condition above the ground, but when the soil was removed from its base, significant rusting of the pole and degradation of the concrete base could be seen.

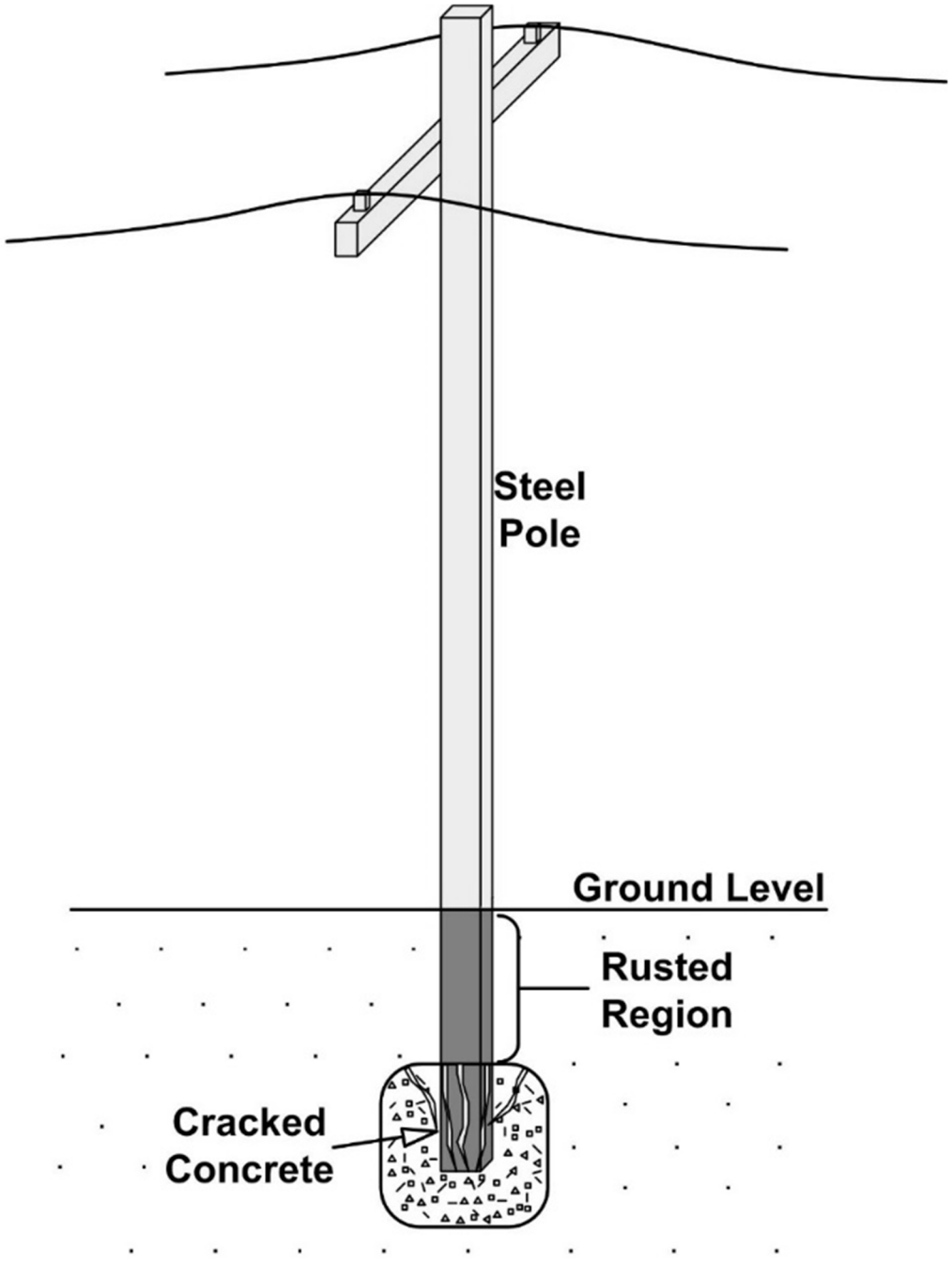

Figure 3

Question 6 continues

Marker use

a) By considering redox reactions and electron-ion movement, explain why the steel pole rusted below ground level, but there was no rust above ground. A diagram may assist your explanation.

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b) The concrete surrounding the base of the pole showed significant cracking and degradation. Explain why this occurred.

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Question 6 continues

Marker use

A new steel pole was installed close by. In an attempt to prevent corrosion, a tin post was placed in the ground near the pole and connected to it with a wire. See Figure 4.

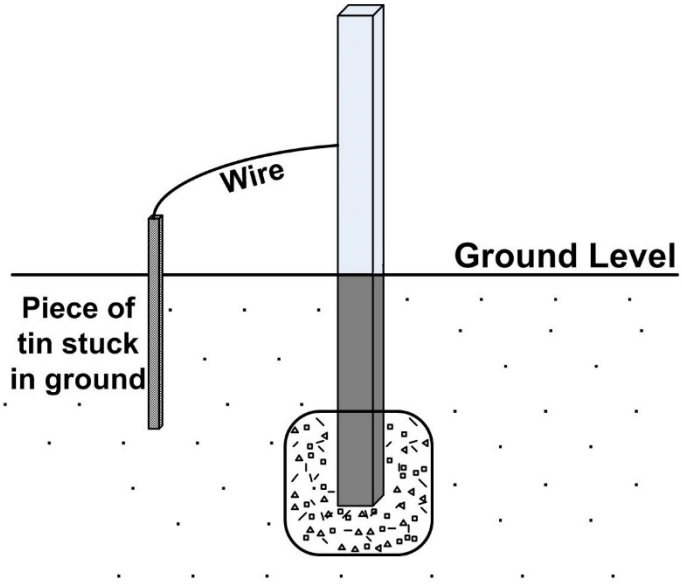

Figure 4

c) Explain why this method of corrosion prevention will fail and potentially lead to accelerated corrosion of the steel pole. /2

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d) Suggest an alternative method of corrosion protection for the pole. /1

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Total Q6 /11

Spare Diagrams

Question 3a)

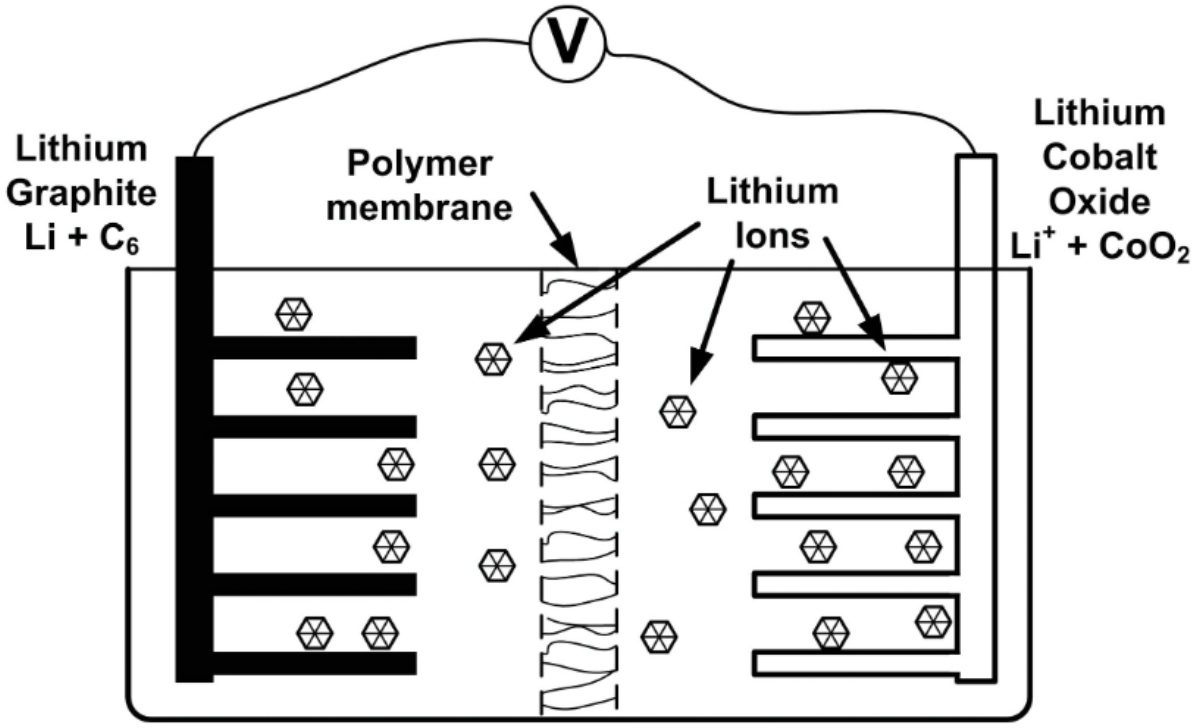

Figure 1

Question 4

Cathode or Anode

Half equation

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Observations

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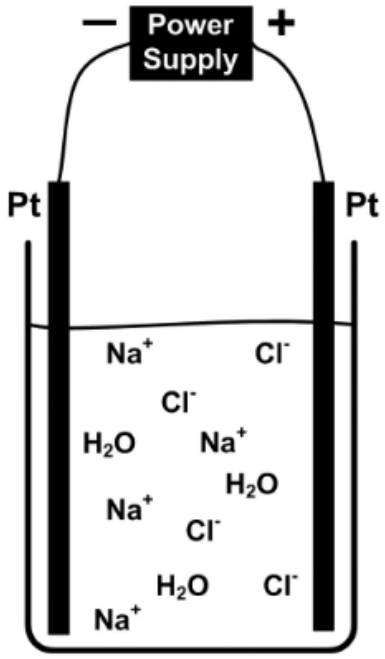

Cathode or Anode

Half equation

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Observations

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Figure 2

End of Section A

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CHEMISTRY

CHM415115

Section B

Pages: 16
Questions: 5
Information Sheet: 1

Suggested working time: 45 minutes

Instructions:

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Marker use	
C6	/ 45

Additional Instructions

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Criterion

You **must** make sure your answers address:

- Criterion 6 identify and apply principles and theories of thermochemistry, kinetics and equilibrium.

Question 7

Marker use

Increased concentration of carbon dioxide in the Earth's atmosphere is expected to affect ocean acidity and calcium carbonate availability.

This complex equilibrium is explained in four interlinked equilibrium equations displayed in Table 1.

Equation 1	$CO_{2(aq)} + H_2O_{(l)} \leftrightharpoons H_2CO_{3(aq)}$
Equation 2	$H_2CO_{3(aq)} \leftrightharpoons H^+_{(aq)} + HCO_3^-{}_{(aq)}$
Equation 3	$HCO_3^-{}_{(aq)} \leftrightharpoons H^+_{(aq)} + CO_3^{2-}{}_{(aq)}$
Equation 4	$CaCO_{3(s)} + H^+_{(aq)} \leftrightharpoons HCO_3^-{}_{(aq)} + Ca^{2+}_{(aq)}$

Table 1

a) With reference to equilibrium principles and Equations 1–3 in Table 1, explain why increased atmospheric concentrations of carbon dioxide gas will decrease ocean pH. /4

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b) By including Equation 4 from Table 1, explain the effect of increased atmospheric carbon dioxide levels on calcium carbonate present in shellfish and plankton. /2

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Total Q7 /6

Question 8

Marker use

Methyl salicylate, or wintergreen, is prepared by warming salicylic acid and methanol in the presence of a catalyst. The reaction can be represented by the following equation:

$C_6H_4(OH)COOH_{(l)} + CH_3OH_{(l)} \leftrightharpoons C_6H_4(OH)COOCH_{3(l)} + H_2O_{(l)}$; $\Delta H = -5.6$ kJ mol^{-1}

salicyclic acid — methyl salicylate

a) On the axes in Figure 5, sketch a potential energy curve of the reaction between salicylic acid and methanol. Clearly label:

/4

- Specific reactants and products
- ΔH of the reaction
- Activation Energy.

Figure 5

Spare diagram used (X) ☐

Question 8 continues

Marker use

b) In terms of reaction **kinetics** (not equilibrium), explain the most advantageous conditions for the preparation of methyl salicylate.

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c) In terms of reaction **equilibrium** (not kinetics), outline and justify the most advantageous conditions for the preparation of methyl salicylate.

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Total Q8

/10

Question 9

Marker use

A reaction to display factors that affect equilibrium is the cobalt(II)chloride in HCl equilibrium reaction.

$$CoCl_4^{2-}{}_{(aq)} + 6H_2O_{(l)} \rightleftharpoons Co(H_2O)_6^{2+}{}_{(aq)} + 4Cl^-{}_{(aq)} \quad ; \quad \Delta H = -ve$$

Blue **Pink**

When the equilibrium is moved to the left the solution is blue. When moved to the right it is pink.

a) Write an expression for the equilibrium constant for this reaction. /2

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b) When the solution was first prepared it was pink. After remaining on the laboratory bench for some time the solution remained pink. In this situation compare the rate of the forward reaction to the rate of the reverse reaction. /1

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c) When a small amount of concentrated HCl was added to the solution, the solution turned blue. The temperature remained constant.

i. Explain why the equilibrium shifted to the left. /2

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ii. State the effect on the value of the equilibrium constant when the HCl is added. /1

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Question 9 continues

Marker use

d) State the effect on the colour of the solution when the concentration of the mixture is reduced by adding a small quantity of water.

/1

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e) Explain the effect on the colour of the solution when a few drops of $AgNO_3$ solution are added.

/2

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Total Q9

/9

Question 10

Marker use

Bushfires in Tasmania can be catastrophic to native habitats. The fires this year in the west of Tasmania were started by lightning strikes.

a) Explain why wood will not burn without a spark, but burns rapidly once started.

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Question 10 continues

Marker use

Figure 6 shows the setup of a large bomb calorimeter used to measure the energy released from burning wood.

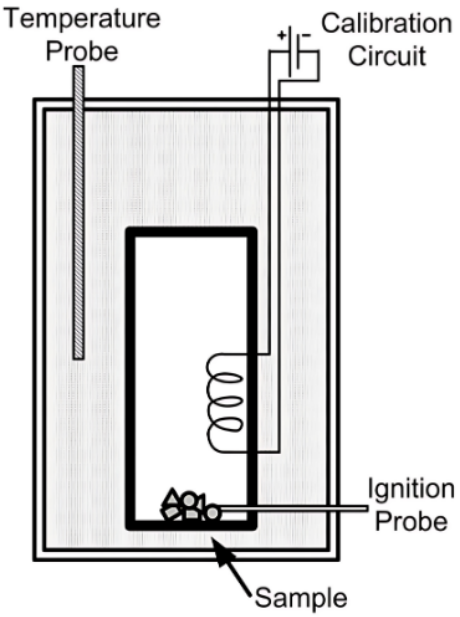

Figure 6

Initially the calorimeter needed to be calibrated. To do this a current of 11.0 A at 55.0 V was passed through the calibration circuit for 5.00 minutes. The temperature increased by 17.0 °C.

b) Show that the calibration factor of the calorimeter is about 11 kJ K^{-1}. /2

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c) A 3.10 g wood sample was placed in the calorimeter and pressurised with excess pure oxygen. When ignited, the calorimeter temperature rose by 12.5 °C. Calculate the heat of combustion of wood. /2

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Question 10 continues

Question 10 continued

If a CO_2 probe is connected to the bomb calorimeter, the rate of wood combustion can be investigated.

After one experiment, graphical data on CO_2 volume was produced. This is displayed in Figure 8.

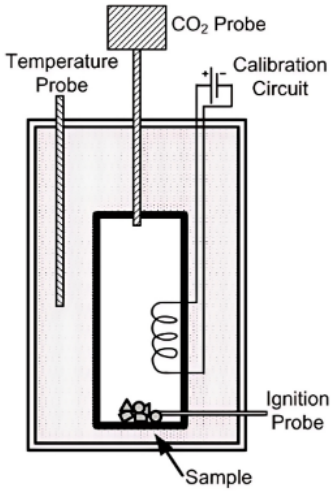

Figure 7

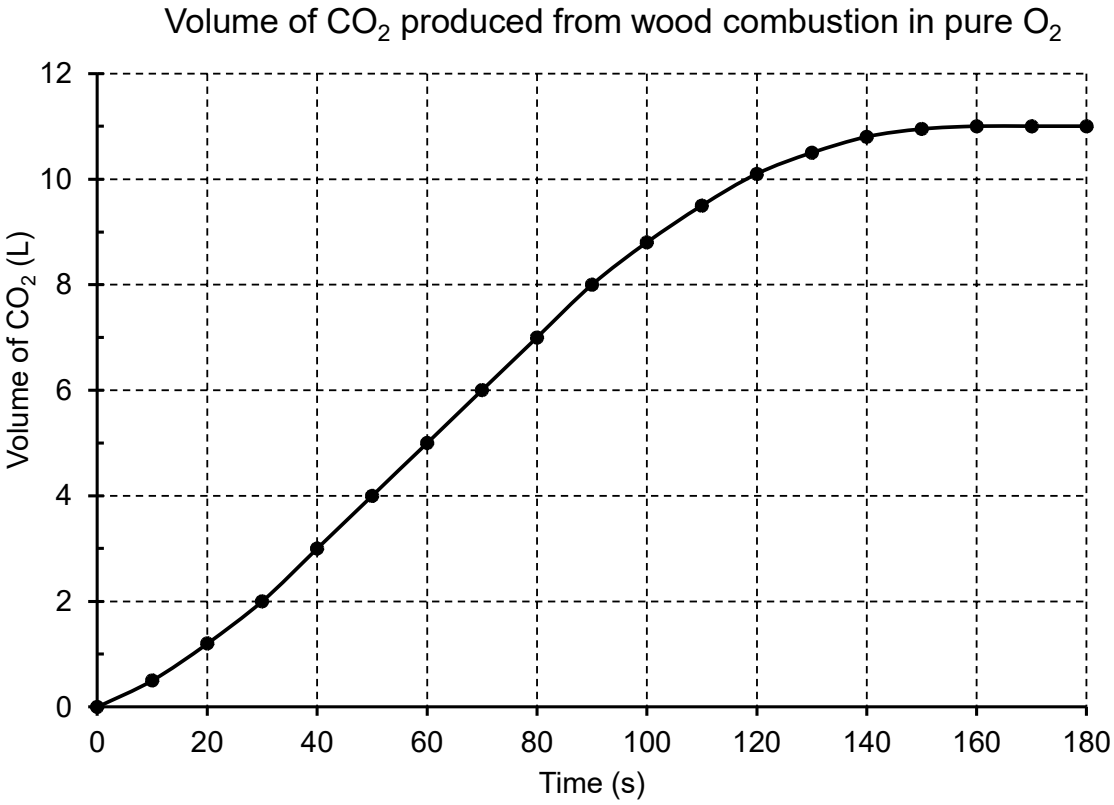

Figure 8

Spare diagram used (X) ☐

d) From Figure 8, calculate the average rate of reaction during the first minute.

/1

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Question 10 continues

Marker use

e) Explain the effect on the reaction rate if the wood in the calorimeter was broken up into smaller pieces.

/2

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f) Sketch a line on Figure 8 that represents burning **half the amount** of wood that was broken into **smaller pieces**.

/2

Total Q10

/13

Question 11

Marker use

Evaporation of water is an example of an endothermic equilibrium reaction. The equation is displayed below:

$$H_2O_{(l)} \rightleftharpoons H_2O_{(g)} \quad ; \quad \Delta H > 0$$

a) The equilibrium expression for this reaction is $K_c = [H_2O_{(g)}]$. State why $H_2O_{(l)}$ is excluded from the K_c expression. /1

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b) Explain why the value of K_c increases as temperatures increases. /2

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c) The vapour pressure of water is 23.8 mm Hg at SLC. Show that the value of K_c for the water evaporation reaction is 1.28×10^{-3} mol L^{-1}, by finding the concentration of water vapour at SLC. /2

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Question 11 continues

Marker use

/2

d) One drop of liquid water (0.050 g) is added to an empty dry 2.0 L flask at 25 ^{o}C, sealed and allowed to reach equilibrium. By using the K_c value from part c), calculate the mass of water remaining once equilibrium is reached.

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Total Q11

/7

Spare Diagrams

Question 8a)

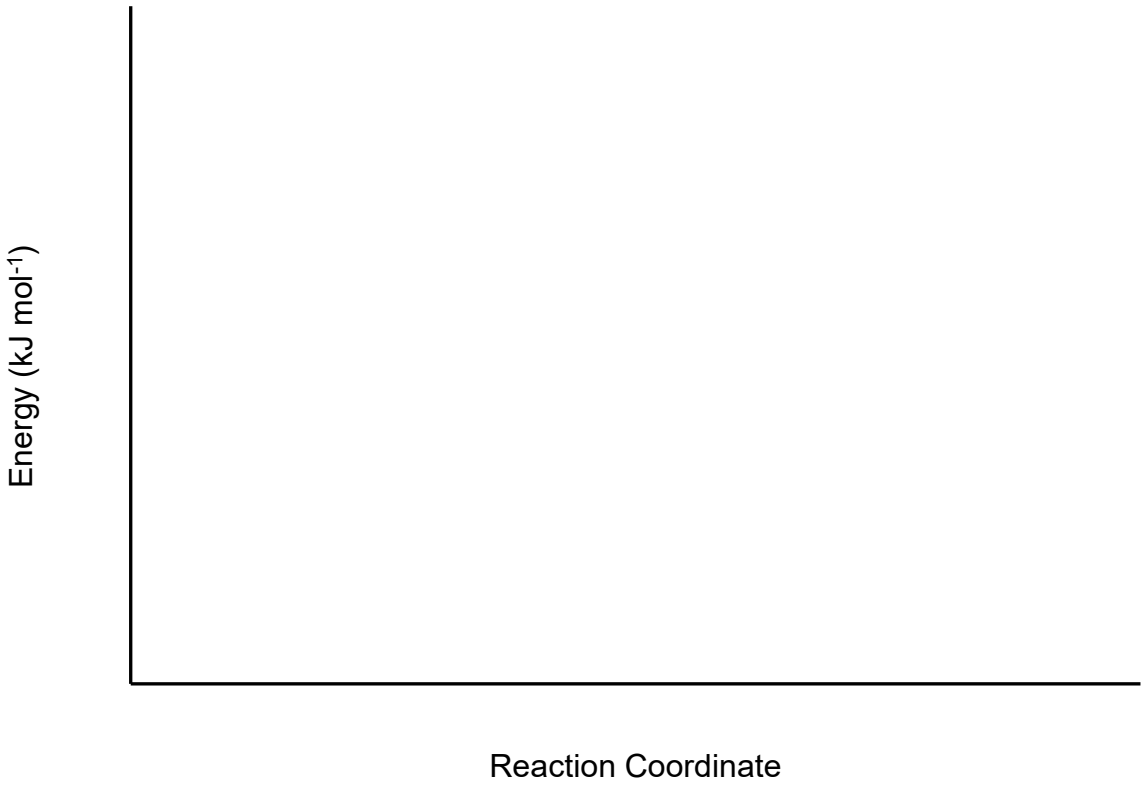

Figure 5

Question 10d)

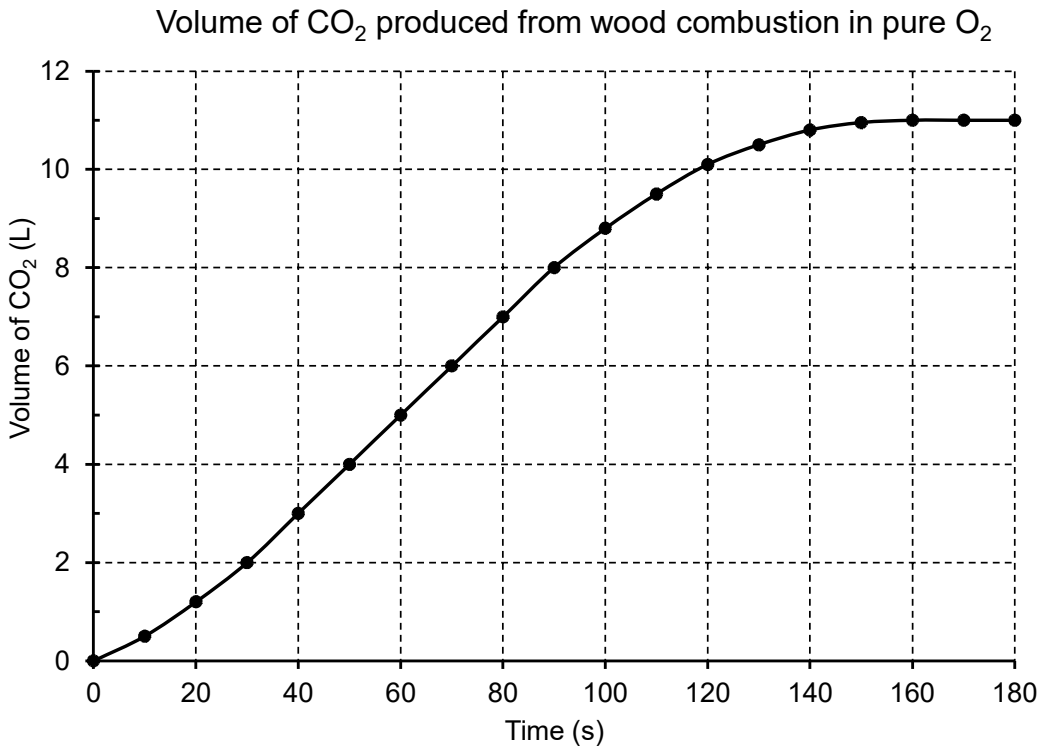

Figure 8

End of Section B

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CHEMISTRY

CHM415115

Section C

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Questions: 5
Information Sheet: 1

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Marker use	
C7	/ 45

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Criterion

You **must** make sure your answers address:

- Criterion 7 demonstrate knowledge and understanding of properties and reactions of organic and inorganic matter.

Question 12

Marker use

Figure 9 displays the organic molecule acetylsalicyclic acid, or Aspirin.

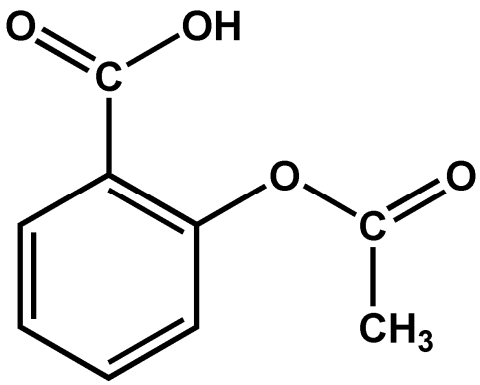

Figure 9

a) Excluding the benzene ring, name **two (2)** other functional groups present in Aspirin. /2

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Aspirin's structure displayed in Figure 9 includes an aromatic or benzene ring that is drawn with alternating single and double bonds (Kekule arrangement).

b) Draw a more acceptable diagram of benzene and explain its structure. /3

i. Diagram

ii. Explanation

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Question 12 continues

Marker use

c) Aspirin is known to have low solubility in water.

i. Explain this low solubility in terms of intermolecular forces. /2

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ii. State if the solubility increases, decreases or stays the same in a less polar solvent such as ethanol. /1

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Total Q12 /8

Question 13

Marker use

/3

a) Complete Table 2 for the organic molecules provided.

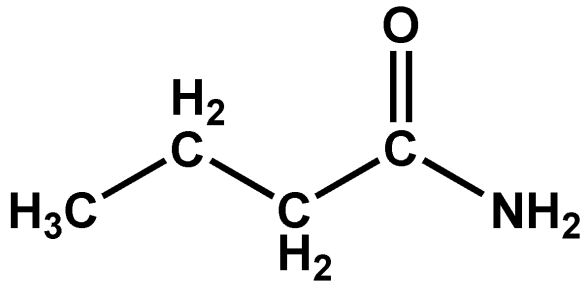
	Name	Structural formula
i.	2,3-dichlorohexanal	
ii.		
iii.	pentyl propanoate	

Table 2

Spare diagram used (X) ☐

Question 13 continues

Marker use

Two (2) other structures are displayed in Table 3. They are the amino acid alanine, and the hydroxy carboxylic acid lactic acid. Both are found in biological systems.

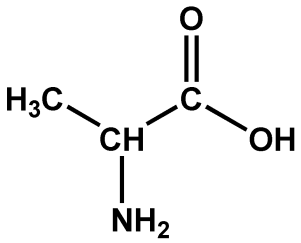
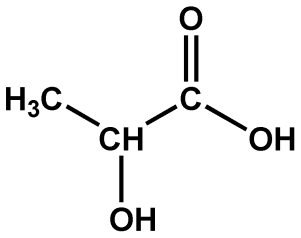
	
Alanine $C_3H_7NO_2$ MP = 297 ˚C (decomposes)	Lactic Acid $C_3H_6O_3$ MP = 18 ˚C

Table 3

b) Explain why alanine has a relatively high melting point. /2

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c) State the features of alanine's structure that make it an amino acid. /1

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d) Lactic acid can be polymerised via condensation polymerisation forming a compostable flexible plastic. Draw **three (3)** repeat units of the polymer formed. /2

Total Q13 /8

Question 14

Marker use

Alcohols can be used to synthesise a large range of products. Figure 10 is a schematic diagram for some of the reactions using propan-1-ol as the starting point.

a) Fill in the missing structures for the organic products **A to G** and formulas for the non-organic products **H and I.**

/9

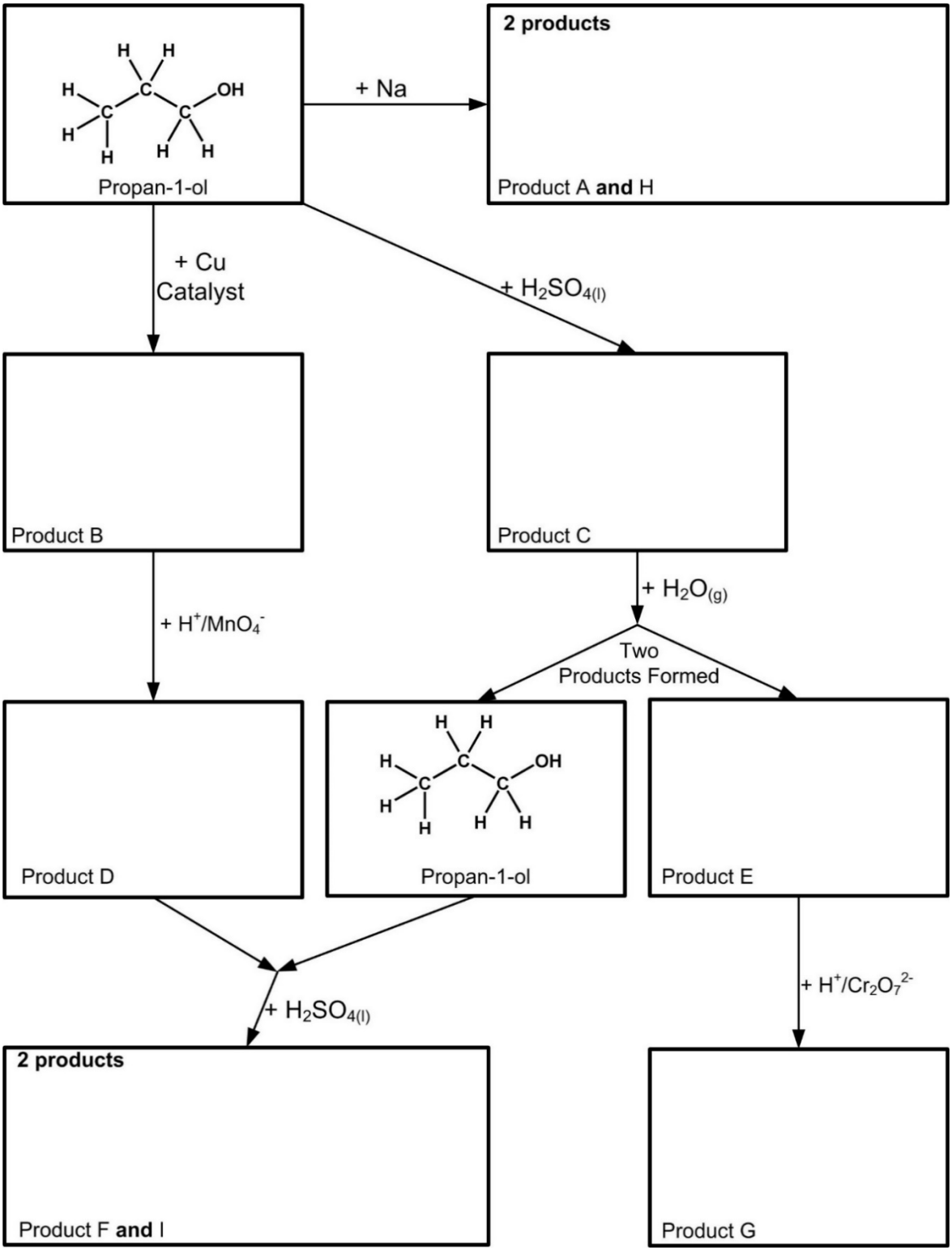

Figure 10

Spare diagram used (X) ☐

Question 14 continues

Marker use

A student was concerned that her starting material, propan-1-ol, had fermented to propanoic acid. To check its structure, she ran both an infrared and a mass spectrum of her sample of propan-1-ol.

The two spectra are displayed in Figure 11.

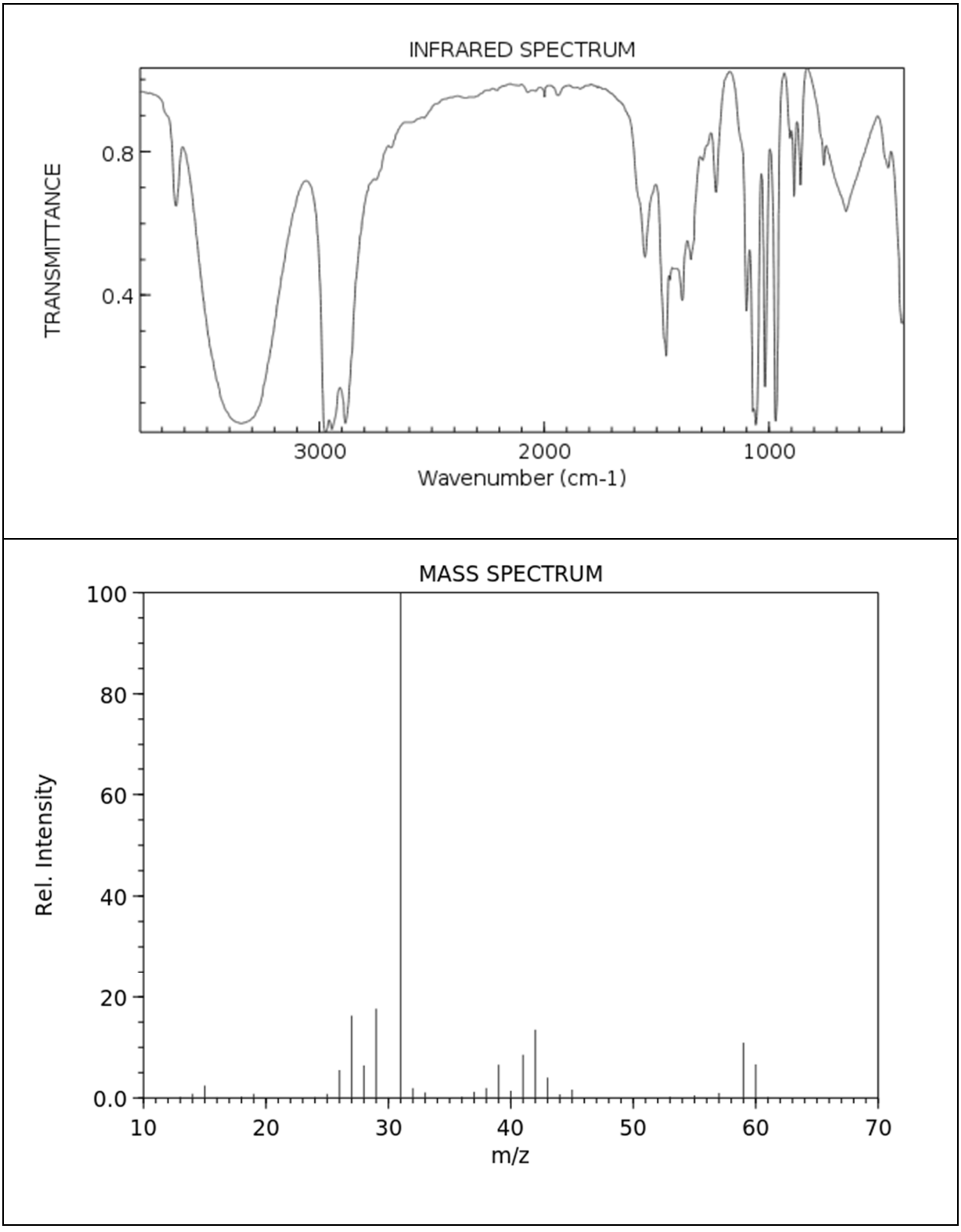

Figure 11

Question 14 continues

Marker use

/4

b) Explain what characteristics of **both** spectra indicate that propan-1-ol is the starting material.

i. Infrared spectrum .....

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ii. Mass spectrum .....

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Total Q14

/13

Question 15

Marker use

a) Write the electron configuration of the following elements or ions displayed in Table 4. /3

Al	
S^{2-}	
Co	

Table 4

Spare diagram used (X) ☐

b) Write the equation that represents the reaction occurring during the first ionisation energy of aluminium. /1

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c) The first five successive ionisation energies of aluminium are shown in Table 5. Explain why there is a large increase between the 3rd and 4th ionisation energies. /2

Ionisation level	1st	2nd	3rd	4th	5th
Ionisation energy (kJ mol^{-1})	577	1816	2744	11580	14840

Table 5

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Question 15 continues

Marker use

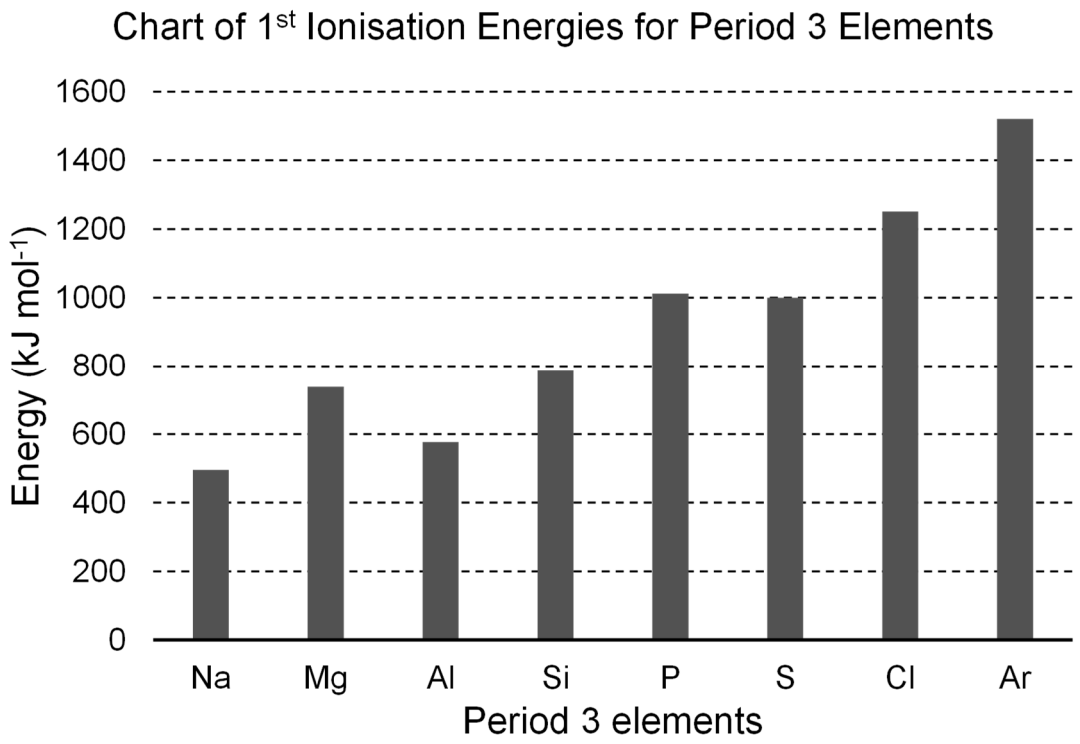

Figure 12

Aluminium is in period 3 of the periodic table. The first ionisation energy of period 3 elements generally increases from left to right across the periodic table, as shown in Figure 12.

d) Explain this generally increasing trend.

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e) Explain why the first ionisation energy of aluminium is lower than the first ionisation energy of magnesium.

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Total Q15

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Question 16

Marker use

a) Using the kinetic theory of gases, explain why a helium balloon expands when it is heated.

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b) Table 6 shows that the molar volume of sulfur dioxide gas at 0.0°C and 1.0 atm pressure is lower than that of helium. With reference to ideal gases, explain why sulfur dioxide has a lower molar volume than helium.

/3

Gas	Molar Volume at STP
$He_{(g)}$	22.4 L
$SO_{2(g)}$	21.9 L

Table 6

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Total Q16

/6

Spare Diagrams

Question 13 a)

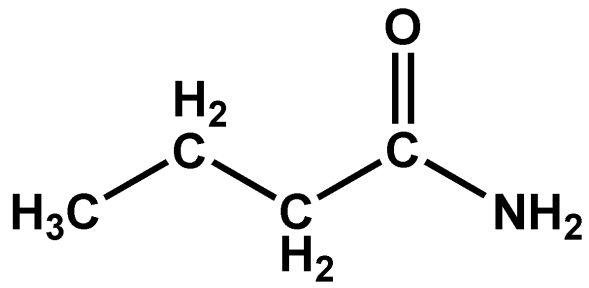
	Name	Structural formula
i.	2,3-dichlorohexanal	
ii.		
iii.	pentyl propanoate	

Table 2

Spare Diagrams

Question 14 a)

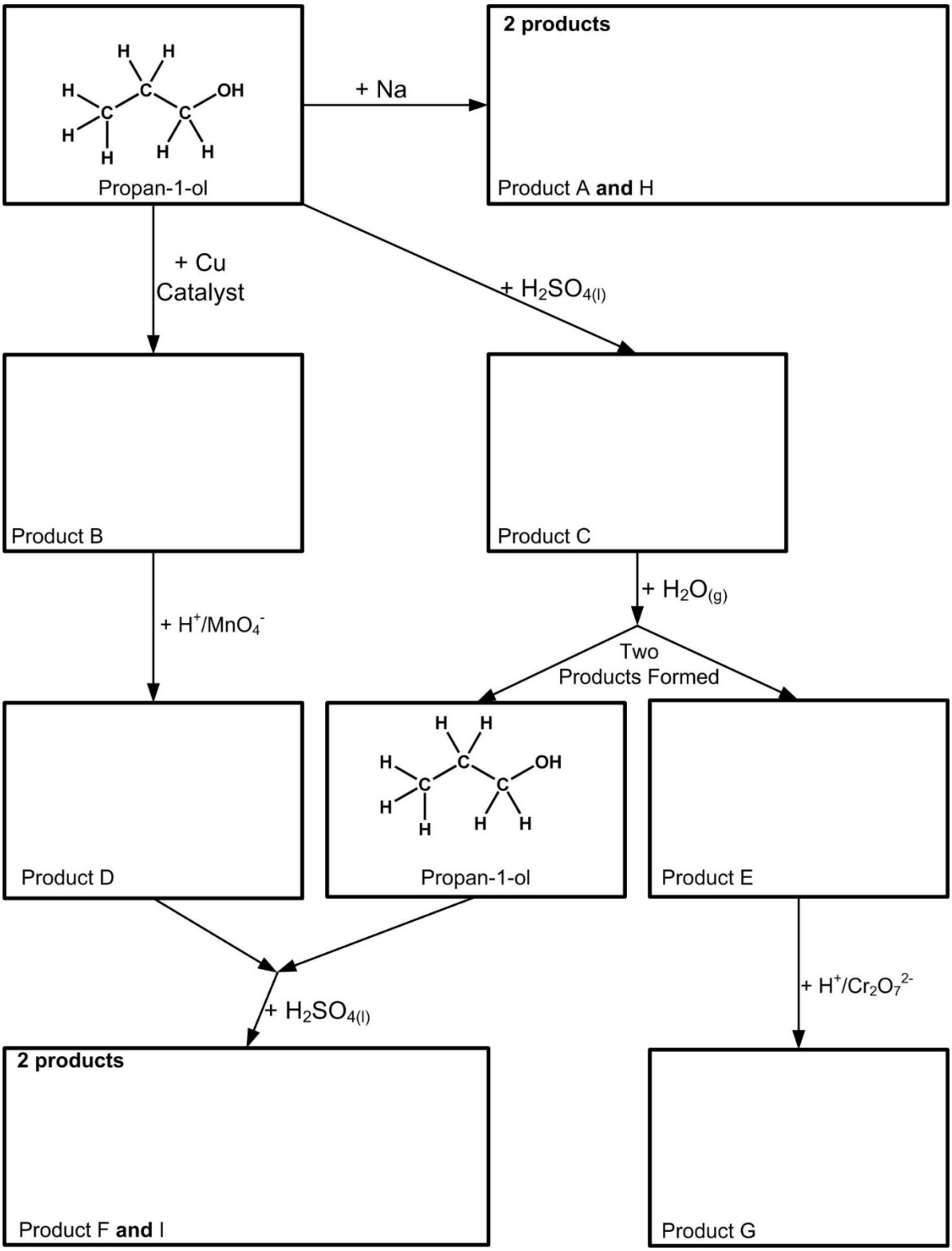


Figure 10

Spare Diagrams

Question 15 a)

Al	
S^{2-}	
Co	

Table 4

End of Section C

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CHEMISTRY

CHM415115

Section D

Pages: 16
Questions: 6
Information Sheet: 1

Suggested working time: 45 minutes

Instructions:

- Answer **all** questions and **all** items within each question.
- Write your answers in the spaces provided in this exam paper.
- TASC approved scientific calculators can be used throughout the exam.
    - Show your workings in answers to numerical questions. No marks can be given for incorrect answers unless they are accompanied by details of the working.
- The exam is **three (3) hours** in length. The suggested working time for this section is **approximately 45 minutes**.
- The Chemistry Information Sheet can be used throughout the exam.
- All answers must be written in **English**.
- You **must** make sure your answers address the listed criterion.

Marker use	
C8	/ 45

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Additional Instructions

Note: When you are asked to “show that”:

- You should calculate your own answer to the appropriate number of significant figures and then use this value to answer the following item(s) of the question.
- If you are unable to determine the required value, you should use the value given in the following items of the question.

Guide to Exam Structure

	Questions available	Questions to answer	Suggested working time	Marks available
Section A	6	6	45 minutes	45 marks
Section B	5	5	45 minutes	45 marks
Section C	5	5	45 minutes	45 marks
Section D	6	6	45 minutes	45 marks
Totals	**22**	**22**	**180 minutes (3 hours)**	**180 marks**

Criterion

You **must** make sure your answers address:

- Criterion 8 apply logical processes to solve quantitative chemical problems.

Question 17

Marker use

Borax ($Na_2B_4O_7.10H_2O$) is often used as a household cleaner. In dilute solutions it is a surface cleaner and if mixed correctly with sodium carbonate it can make an effective laundry detergent.

A science student made a 200 mL borax solution by dissolving 47.5 g of borax in distilled water.

a) Show that the concentration of **borax** in the solution is about 0.6 mol L^{-1}.

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The student then made an ineffective laundry detergent by mixing:

- 50 mL of the borax solution above
- 120 mL of a 1.5 mol L^{-1} Na_2CO_3 solution.

b) The student believes the detergent was ineffective due to a high concentration of sodium ions (Na^+). By first calculating the moles of sodium ions in each component, determine the total sodium ion concentration in the final solution.

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Total Q17

/7

Question 18

Marker use

For the following reaction:

$$SO_{2(g)} + 2H_2S_{(g)} \rightarrow 3S_{(s)} + 2H_2O_{(l)}$$

And given the following data:

1. $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\Delta H = -297$ kJ
2. $H_{2(g)} + S_{(s)} \rightarrow H_2S_{(g)}$ $\Delta H = -20.0$ kJ
3. $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H = -286$ kJ

a) Show that the enthalpy of reaction (ΔH) is approximately -230 kJ.

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b) Calculate the amount of energy released in forming 40.0 g of $S_{(s)}$.

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Total Q18

/7

Question 19

Marker use

Ammonia (NH_3) and oxygen (O_2) combine to form nitrogen and water by the chemical reaction:

$$4NH_{3(g)} + 3O_{2(g)} \rightarrow 2N_{2(g)} + 6H_2O_{(g)}$$

Useful molecular masses
$M(NH_3) = 17.03 \text{ g mol}^{-1}$
$M(O_2) = 32.00 \text{ g mol}^{-1}$
$M(N_2) = 28.02 \text{ g mol}^{-1}$

100.0 g of ammonia is reacted with 100.0 g of oxygen.

a) Show that about 58 g of nitrogen is produced.

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b) Calculate the mass of the **excess reactant** remaining after the reaction has completed.

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Question 19 continues

Marker use

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c) In this reaction the oxygen gas was not weighed out. Instead, it was collected in a 1.00 litre pressure vessel. Calculate the pressure in the vessel after the collection of 100.0 g of oxygen gas at 25 ^{o}C.

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Total Q19

/9

Question 20

Marker use

Analysis of iron is best achieved by titration against a standardised potassium permanganate ($KMnO_4$) solution.

Potassium permanganate ($KMnO_4$) needs to be standardised against a primary standard such as sodium oxalate $Na_2C_2O_4$.

Useful molecular mass
$M(Fe) = 55.85 \text{ g mol}^{-1}$

a) List **two (2)** properties of a primary standard such as $Na_2C_2O_4$.

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During a standardisation, 23.8 mL of a $KMnO_4$ solution of unknown concentration reacted with exactly 25.0 mL of the 0.05227 mol L^{-1} acidified $Na_2C_2O_4$ solution. The equation for the standardisation reaction is:

$$2MnO_4^-{}_{(aq)} + 5C_2O_4^{2-}{}_{(aq)} + 16H^+{}_{(aq)} \rightarrow 2Mn^{2+}{}_{(aq)} + 10CO_{2(g)} + 4H_2O_{(l)}$$

b) Show that the concentration of the $KMnO_4$ solution is about 0.022 mol L^{-1}.

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Question 20 continues

Question 20 continued

Marker use

The standardised $KMnO_4$ solution is then used to find the amount of iron in a mineral sample. The following reaction is used:

$$MnO_4^-{}_{(aq)} + 5Fe^{2+}{}_{(aq)} + 8H^+{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 8H_2O_{(l)}$$

3.527 g of the mineral sample is dissolved in acid, filtered, and made up to 1000 mL with distilled water. All the iron is now in the Fe^{2+} state.

25.0 mL of this acidified Fe^{2+} solution is found to titrate with 7.10 mL of the standardised $KMnO_4$ solution.

c) Calculate the number of moles of $KMnO_4$ titrated.

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d) Calculate the concentration of iron in the acidified Fe^{2+} solution.

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e) Calculate the percentage by mass of iron in the mineral sample.

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/3

Total Q20

/10

Question 21

Marker use

Industrial production of sulfur trioxide uses the Contact Process. This involves the following equilibrium reaction:

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

a) In one reaction at a certain temperature, 1.3 moles of $O_{2(g)}$ and 2.1 moles of $SO_{2(g)}$ were placed in an 8.0 L container and allowed to reach equilibrium. At this point the amount of $SO_{3(g)}$ was 1.2 moles. /4

Show that the equilibrium constant K_c for the reaction is about 20 mol^{-1} L.

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b) When a similar mixture of the three gases at the same temperature is analysed, the following concentrations are determined: /2

$[O_{2(g)}]$ = 0.29 mol L^{-1}

$[SO_{2(g)}]$ = 3.9 mol L^{-1}

$[SO_{3(g)}]$ = 8.2 mol L^{-1}

By first calculating the value of the reaction quotient Q, determine whether the forward or reverse reaction is favoured.

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Total Q21 /6

Question 22

Marker use

Calculate the final pH of a solution produced by adding 50.00 mL of 0.00987 mol L^{-1} hydrochloric acid (HCl) solution to 38.00 mL of 0.0140 mol L^{-1} barium hydroxide ($Ba(OH)_2$) solution.

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Total Q22

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End of Section D

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