

External Assessment 2021

CHEMISTRY

CHM415115

Part **1**

Pages	16
Questions	5
Information Sheet	1

Reading time: 15 minutes – you may begin writing during this time

Suggested working time: 45 minutes

Instructions

- Attempt **all** questions and **all** parts within each question.
- Write your answers in the spaces provided in this exam paper.
 - Spare diagrams have been provided at the end of the exam booklet.
 - Indicate in the box provided if you have used the spare diagrams.
- A TASC approved scientific calculator 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 appropriate units must be included.
- All answers must be written in **English**.
- You **must** make sure your answers address:
 - Criterion 5 identify and apply fundamental principles and theories of electrochemistry.

Marker use	
C5	40

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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 part(s) of the question.
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Guide to Exam Structure

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Part 1	5	5	45 minutes	40
Part 2	5	5	45 minutes	40
Part 3	7	7	45 minutes	40
Part 4	7	7	45 minutes	40
Total	24	24	180 minutes (3 hours)	160

Question 1

Marker use

a) Acidified VO_2^+ (aq) ions form vanadium(II) ions: V^{2+} (aq) when they react with zinc metal, forming zinc ions.

i. Use half equations to represent the oxidation and the reduction reactions occurring, identifying the oxidiser as part of your answer.

Oxidation half equation:

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Reduction half equation:

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Oxidiser:

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ii. Use oxidation numbers to verify that VO_2^+ (aq) is the strongest oxidiser of the following vanadium-containing ions: VO_2^+ (aq), VOCl_2 (s) and V^{2+} (aq).

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Question 1 continues

Question 1 continued

Marker use

b) Aluminium–air cells using aqueous electrolytes are one type of battery being investigated for powering vehicles.

i. Explain, in terms of electron structure, why aluminium is a reducer.

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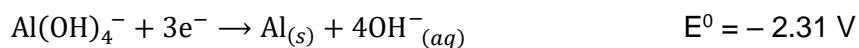
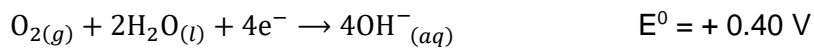
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ii. Use the information provided below to write the overall net cell equation for the aluminium–oxygen cell.



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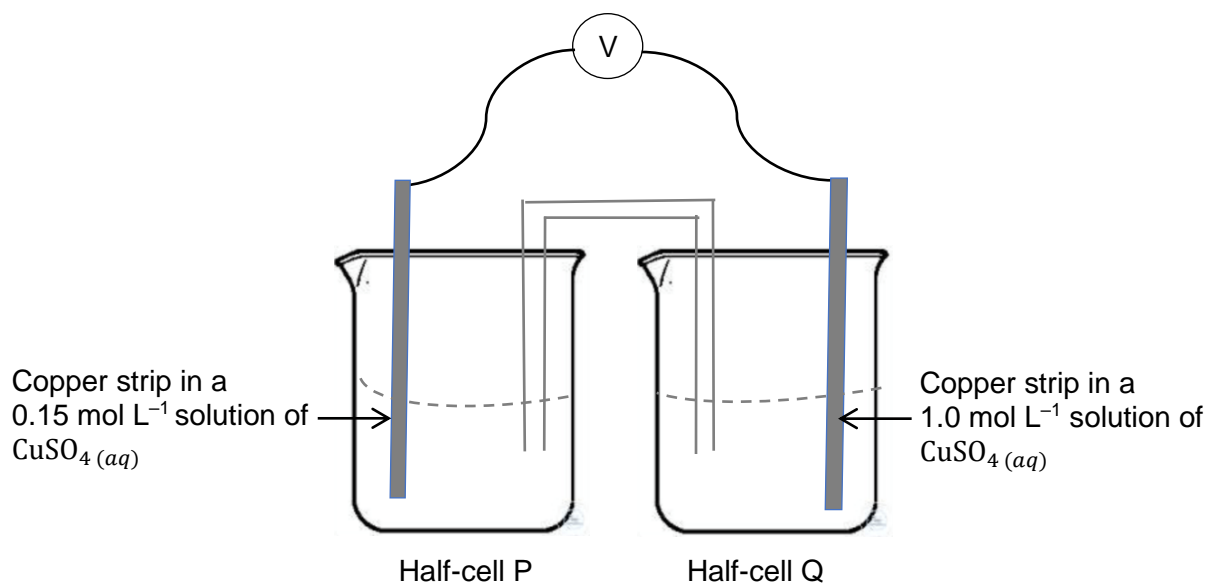
Total Q1

9

Question 2

Marker use

A student set up the electrochemical cell at 25°C as shown below:



The student recorded the **initial voltage** of the cell as **+0.16 V** at 25°C.

When the voltmeter was replaced with a light bulb, **the solution in half-cell P became darker blue around the copper strip.**

- a) Write a half-equation to represent the reaction occurring in half-cell P and state the polarity of the electrode in this half-cell.

Half-equation:

Polarity of electrode:

2

- b) Calculate the reduction potential of the half-cell P.

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- c) State why the electrode in half-cell P does not have an electrode potential of +0.34 V.

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Question 2 continues

Question 2 continued

Marker use

d) Over time the EMF of the cell dropped to 0 V. Give a reason for this observation.

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e) Which **two (2)** of the following aqueous solutions are **unsuitable** to use when making the salt bridge for this cell? Justify your answer.

- sodium chloride, $\text{NaCl}_{(aq)}$
- barium chloride, $\text{BaCl}_{2(aq)}$
- ethanol, $\text{C}_2\text{H}_5\text{OH}_{(aq)}$

Solution 1:

Reason:

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Solution 2:

Reason:

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/ 2

f) Explain the effect, if any, on the electrochemical cell if the copper electrode in half-cell P is replaced with a silver electrode.

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/ 2

Total Q2

/ 10

Question 3

Marker use

Refer to the Standard Reduction Potentials table (on page 8 of the Information Sheet) to help you answer the following questions.

- a) Only one pair of the chemicals listed below can exist together in an aqueous solution. Identify the pair of chemicals, explaining your choice.

Either $\text{Sn}^{2+}_{(aq)}$ and $\text{Br}^{-}_{(aq)}$

Or $\text{Sn}^{2+}_{(aq)}$ and $\text{Fe}^{3+}_{(aq)}$

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- b) Three different metals labelled A, B and C undergo a series of experiments to determine their relative strength as reducers.

These are not the correct symbols for the metals, but use them when answering the questions.

All solutions have a concentration of 1 mol L^{-1} .

Experiment 1

- When metal C is placed in a solution containing $\text{B}^{+}_{(aq)}$ ions, $\text{C}^{2+}_{(aq)}$ ions and metal B are produced.

Experiment 2

- When an electrochemical cell is made using a strip of metal A placed in $\text{A}(\text{NO}_3)_2_{(aq)}$ and a strip of C placed in $\text{C}(\text{NO}_3)_2_{(aq)}$, metal A is the anode.

Experiment 3

- When metal C is placed in a solution of hydrochloric acid, hydrogen gas is given off, but no reaction is observed when metal B is placed in the hydrochloric acid solution.

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Question 3 continues

Question 3 continued

Marker use

- i. Write an equation to represent the reaction occurring in Experiment 1.

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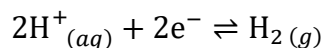
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- ii. Use chemical shorthand notation to represent the electrochemical cell made in Experiment 2.

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- iii. Use the information from the three experiments, and the format of the Standard Reduction Potentials table (on page 8 of the Information Sheet), to write the reduction half equation for each of the metal ions in their appropriate position. Use the reduction half equation for hydrogen ions as a reference:



[You do not have to indicate how the results from the experiment support your answer, but their inclusion may assist when answering the question.]

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Total Q3

/ 8

Question 4

Marker use

- a) In the 18th century the wooden hull of a ship was covered with a layer of copper plates to help prevent deterioration of the wood. The copper plates were attached with iron nails.

A few years later the copper had become detached from the hull in many places because the iron nails had been heavily corroded.

- i. Explain this observation, including appropriate half equations in your answer.

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Closer inspection revealed that some nails, which were less corroded, had a mixture of brown paper, hair and wool trapped between the nail head and the copper plates.

- ii. Explain this observation.

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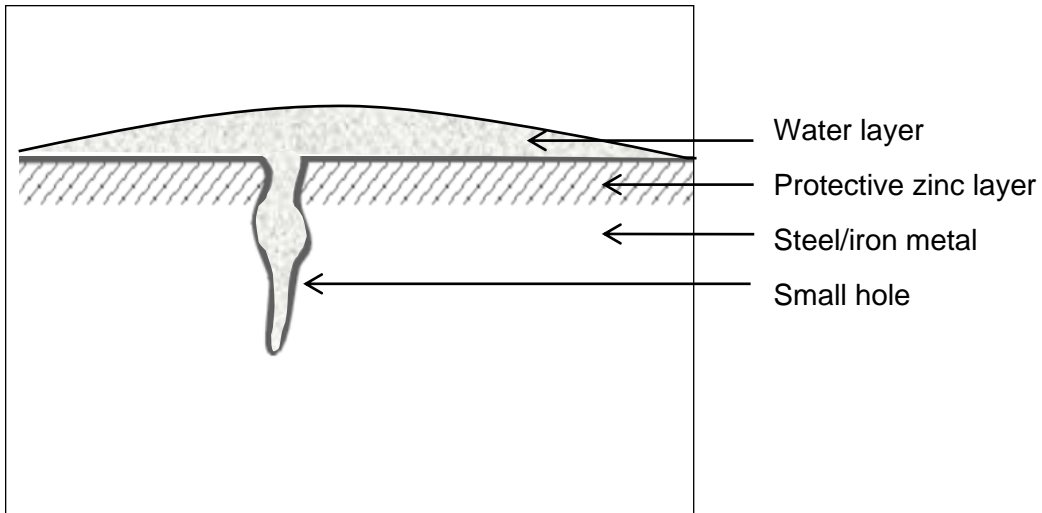
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Question 4 continues

Question 4 continued

Marker use

- b) "Pitting corrosion" can occur in a galvanised water tank when a small hole initially forms. Corrosion grows from this spot.



Spare diagram used (✓)

- i. Label the diagram with the anode area, cathode area, electron flow and the cation flow.

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- ii. Explain why the hole grows bigger. You do not need to include equations in your answer.

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Total Q4

8

Question 5

Marker use

Aluminium and zinc are commonly used metals. Electrolysis is used to produce both of these metals in Tasmania.

- a) Explain, writing chemical equations to support your answer, why zinc metal can be produced by the electrolysis of aqueous zinc sulfate, $\text{ZnSO}_4(aq)$, yet aluminium metal must be produced from molten aluminium oxide.

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- b) Only one of the electrodes used in the electrolysis process to produce zinc is made of aluminium. State which electrode is made of aluminium, explaining your choice.

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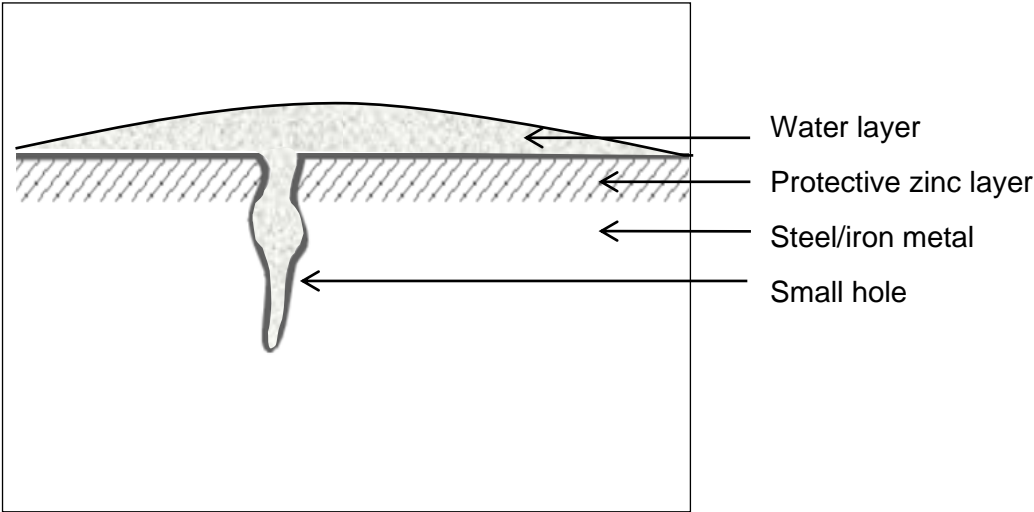
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Total Q5

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Spare Diagram

Question 4



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End of Part 1

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External Assessment 2021

CHEMISTRY

CHM415115

Part **2**

Pages	12
Questions	5
Information Sheet	1

Suggested working time: 45 minutes

Instructions

- Attempt **all** questions and **all** parts within each question.
- Write your answers in the spaces provided in this exam paper.
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 - The appropriate units must be included.
- All answers must be written in **English**.
- You **must** make sure your answers address:
 - Criterion 6 identify and apply fundamental principles and theories of thermochemistry, kinetics and equilibrium.

Marker use	
C6	40

Additional Instructions

- Note: When you are asked to “**show that**”:
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Total	24	24	180 minutes (3 hours)	160

Question 6

Marker use

The following three statements are found on internet sites. In terms of chemistry these statements are not correct.

- a) Statement: The pH scale extends from 0 to 14.

Hydrochloric acid solution, $\text{HCl}_{(aq)}$ ($M_r = 36.46$), with a concentration of 320 g L^{-1} , is available at a local hardware shop. By determining the pH of this solution, show that the statement is **incorrect**.

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- b) Statement: The pH of pure water is 7.0.

What additional information needs to be included to make this statement **correct**?

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- c) Statement: UV light acts as a catalyst to speed up the decomposition of hydrogen peroxide into water and oxygen.

Justify that this statement is **incorrect**, referring to what is meant by a 'catalyst' in your answer.

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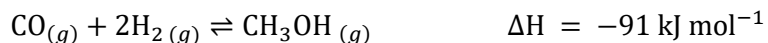
Total Q6

6

Question 7

Marker use

Methanol can be produced industrially by the reaction of carbon monoxide gas and hydrogen gas:



- a) This reaction is a compromise between the two naturally occurring forces, towards minimum enthalpy and maximum entropy. Identify the direction favoured in each case by circling the correct answer:

Minimum enthalpy favours: forward reaction back reaction

Maximum entropy favours: forward reaction back reaction

- b) Use Le Chatelier's Principle to explain the advantage of using a higher pressure on the equilibrium yield of methanol.

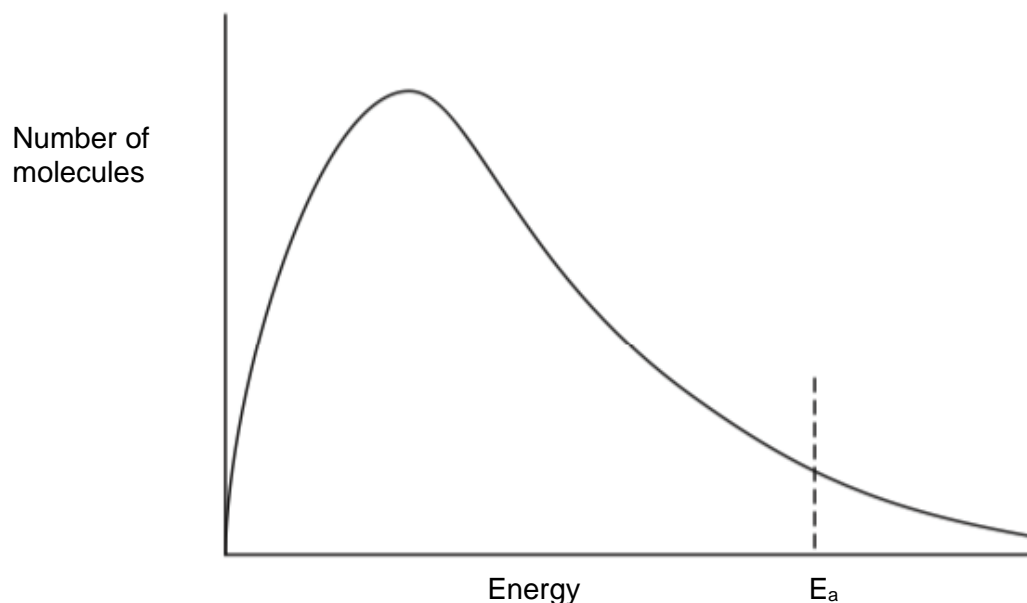
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The graph below shows the distribution of molecular energies of a mixture of carbon monoxide and hydrogen at 250°C.



Spare diagram used (✓)

- c) If the temperature is increased there is an increase in the rate of reaction.
- i. Sketch a curve on the graph above to show how the distribution of molecular energies changes when the temperature increases.

Question 7 continues

Question 7 continued

Marker use

ii. With reference to the graph on page 4, explain how a small increase in temperature causes a large increase in the rate of reaction.

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d) By considering the yield of methanol and rate of reaction, explain why there has to be a compromise on the temperature of the reaction used in the production of methanol.

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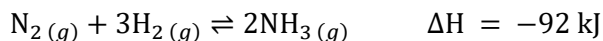
Total Q7

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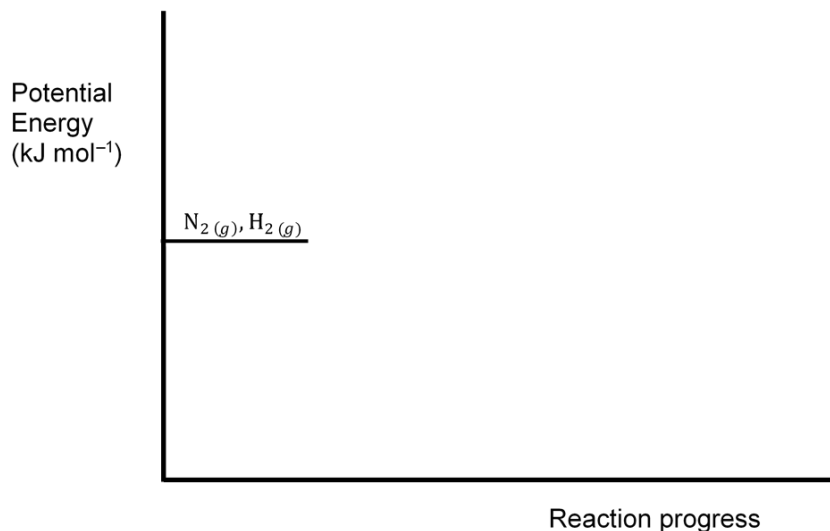
Question 8

Marker use

Consider the following catalysed reaction, with an **experimental** ΔH :



- a) The activation energy for the forward reaction is 50 kJ mol^{-1} . Complete a labelled potential energy diagram for the reaction between nitrogen and hydrogen.



Spare diagram used (✓)

2

- b) Define the bond energy of nitrogen, $\text{N}_2(g)$.

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- c) Use data from the following table to determine the **theoretical** ΔH for the production of ammonia.

Bond	H – H	N – H	N ≡ N
Average energy (kJ mol^{-1})	436	391	941

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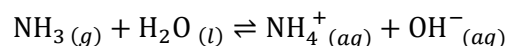
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Question 8 continues

Question 8 continued

Marker use

Ammonia is soluble in water. The following equilibrium is established in a sealed bottle:



- d) Which of the reactants, **either** $\text{NH}_3(g)$ **or** $\text{H}_2\text{O}(l)$, is a Brønsted-Lowry acid? Justify your answer.

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- e) The contents of the bottle are in dynamic equilibrium, but when the lid is removed, there is the distinctive smell of ammonia. Explain, in terms of equilibrium, what is occurring when the lid is on and when it is removed.



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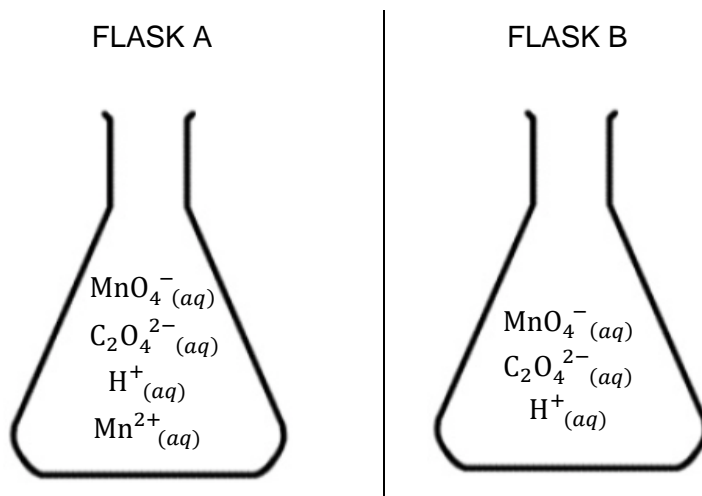
Total Q8

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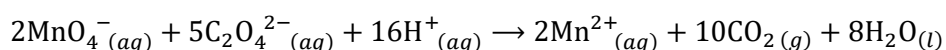
Question 9

Marker use

Identical quantities of potassium permanganate, colourless sodium oxalate and sulfuric acid solutions are added to separate flasks, labelled A and B. Manganese(II) chloride $\text{MnCl}_{2(aq)}$ is also added to flask A.



The following overall chemical reaction occurs in each flask:

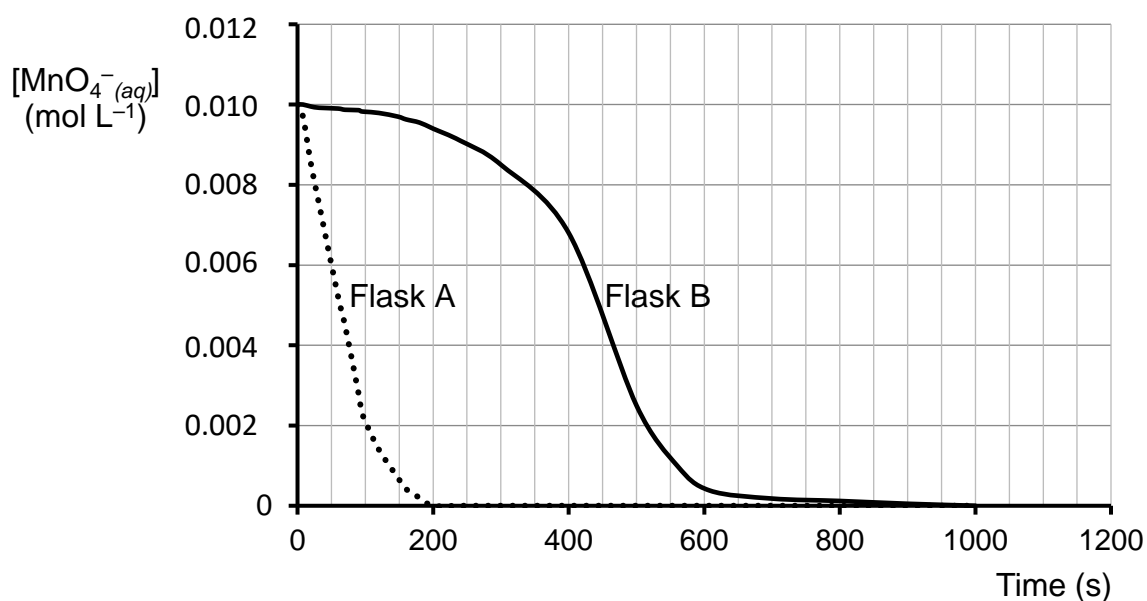


- a) Name **two (2)** properties of the reactants and/or products that would enable the rate of the reaction to be determined.

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The concentration of the permanganate ion, $[\text{MnO}_4^- (aq)]$, is measured in each flask as the reaction proceeds and the results graphed. The temperature of each flask is the same.



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Question 9 continues

Question 9 continued

Marker use

b) Determine the rate of reaction in Flask A at 50 seconds.

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c) State the role of the manganese(II) ion, $Mn^{2+}_{(aq)}$.

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d) Explain the shape of the graph representing the reaction in flask B.

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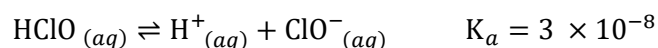
Total Q9

6

Question 10

Marker use

Hydrogen and chlorine, often with oxygen, form acids such as hydrochloric acid and hypochlorous acid. Consider a solution of hypochlorous acid:



- a) Define K_a for hypochlorous acid and use it to state which of the components of the equilibrium mixture of hypochlorous acid has the greatest concentration.

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- b) The K_a value for hydrochloric acid is not usually given in data tables. Account for this fact.

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Aqueous chlorine reacts with water to form an equilibrium mixture containing hydrochloric acid and hypochlorous acid solutions.

- c) Write a chemical equation to represent this equilibrium mixture.

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- d) Household bleach is an equilibrium mixture containing $\text{Cl}_2_{(aq)}$, $\text{HClO}_{(aq)}$ and $\text{ClO}^-_{(aq)}$, as well as other ions. The ratio of these three chemical species in the equilibrium mixture is pH dependent.

By considering the position of the equilibrium when the pH is below 2, predict which of the three chemical species is most abundant. Explain.

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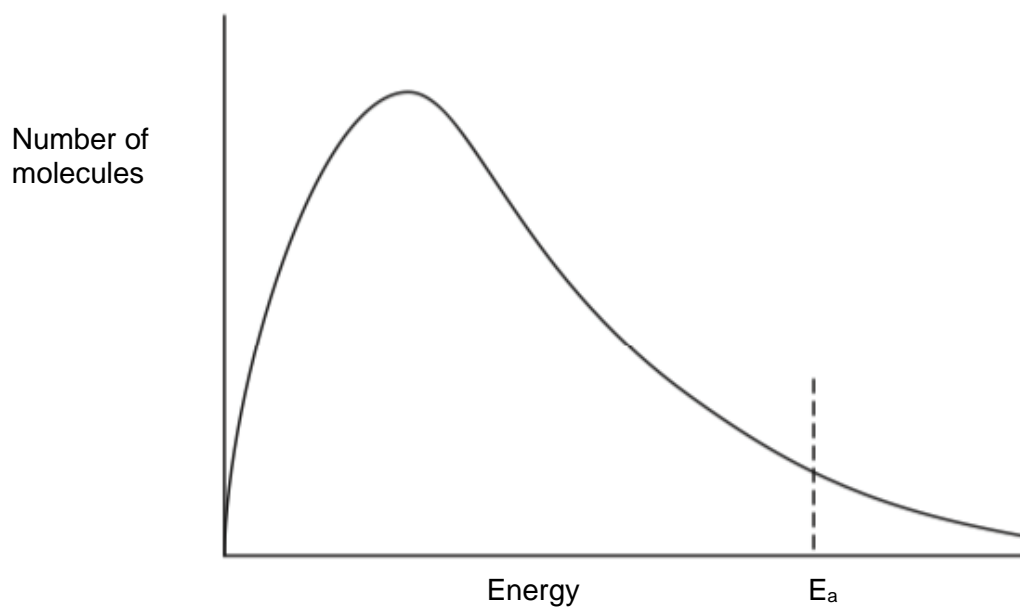
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Total Q10

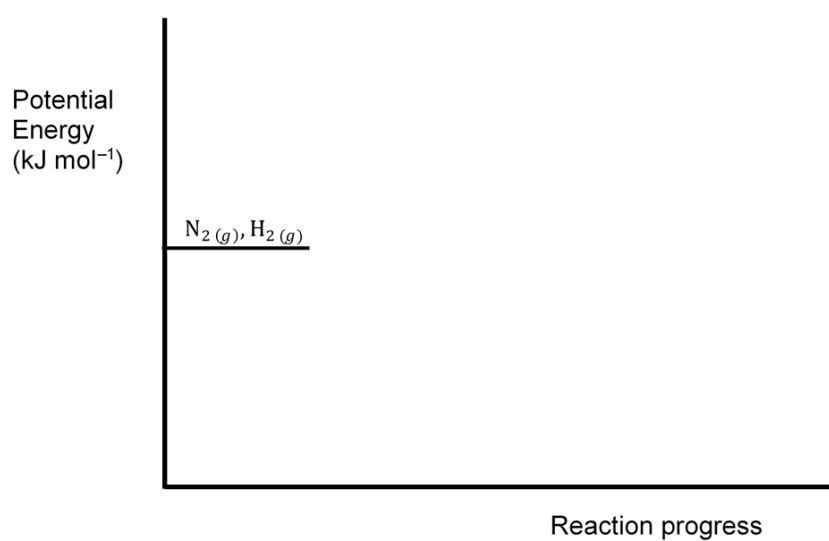
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Spare Diagrams

Question 7



Question 8



End of Part 2



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CHEMISTRY

CHM415115

Part **3**

Pages	16
Questions	7
Information Sheet	1

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- All answers must be written in **English**.
- You **must** make sure your answers address:
 - Criterion 7 demonstrate knowledge and understanding of properties and reactions of organic and inorganic matter.

Marker use	
C7	40

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Additional Instructions

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Total	24	24	180 minutes (3 hours)	160

Question 11

Marker use

This question relates to the preparation and properties of some organic compounds.

a) Propan-1-ol can be used to prepare propan-1-amine.

i. Using structural formulae for any organic compounds, write a chemical equation to represent this reaction.

/ 1

ii. Both of these organic compounds are very soluble in water. Explain how the presence of the functional groups contributes to this property.

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b) Pure ethanal is best made by converting ethanol to ethanal using a copper catalyst rather than using acidified potassium dichromate. Explain.

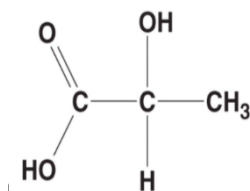
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c) Lactic acid can form a polymer called polylactic acid under suitable conditions.

/ 2

The structure of lactic acid is:



Name the type of polymer formed, justifying your choice.

[You are not required to draw the structure of the polymer when answering this question.]

Type of polymer:

Justification:

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Total Q11

/ 7

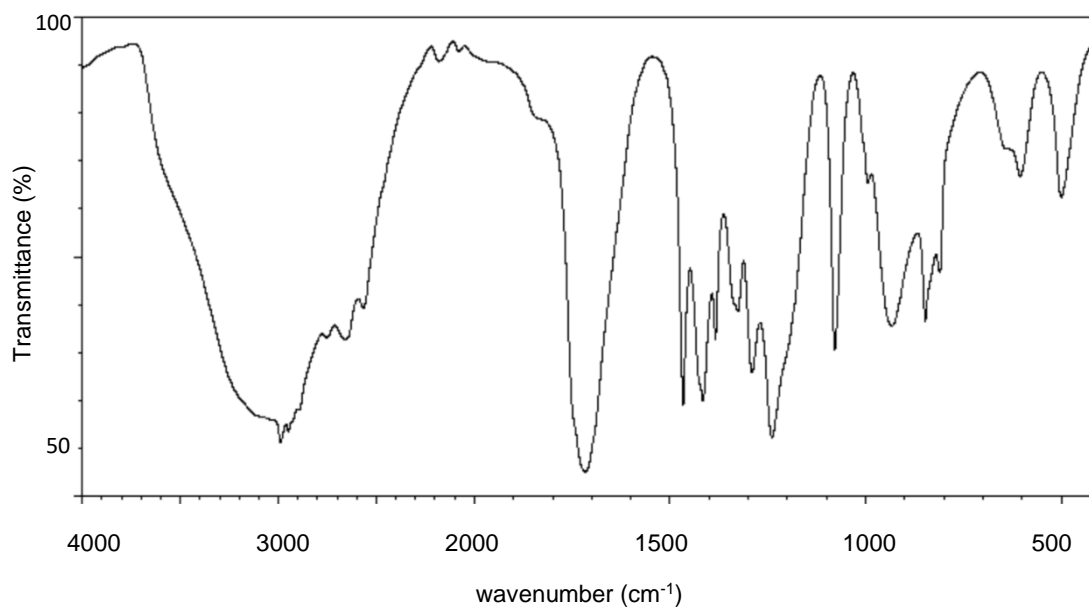
Question 12

Marker use

Use the following information to **name** the compounds X, Y and Z.

- Compound X has the molecular formula C_3H_7I .
- When heated with a solution of potassium hydroxide, compound Y, with molecular formula C_3H_8O , is formed.
- Reacting compound Y with a suitable oxidiser yields compound Z.
- The IR spectrum of compound Z is given below:

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Compound X:

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Compound Y:

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Compound Z:

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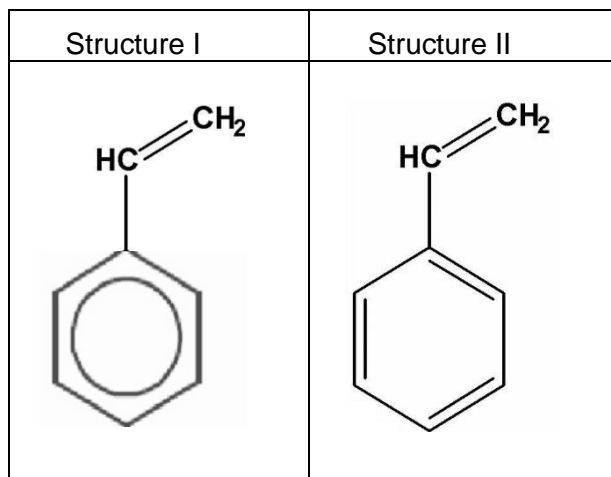
Total Q12

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Question 13

Marker use

The structure of styrene, $C_6H_5CHCH_2$, can be represented in either of the following ways:



- a) By considering the type of carbon to carbon bonds in styrene, explain why **Structure I** is the preferred presentation of styrene.

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- b) Styrene forms a polymer, polystyrene. Draw the structure showing how at least **two (2)** monomers form the polymer.

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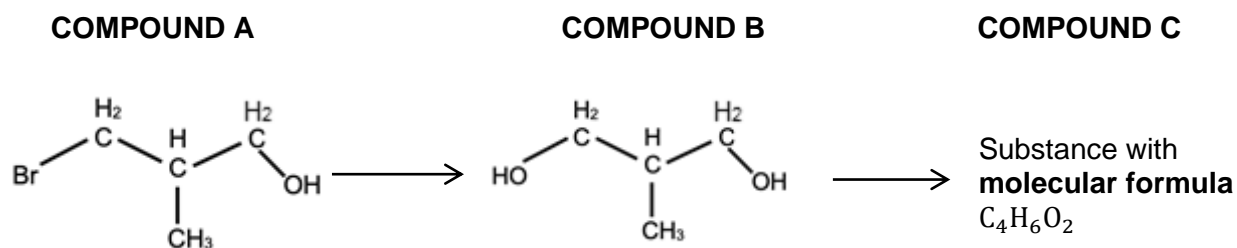
Total Q13

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Question 14

Marker use

Consider the following:

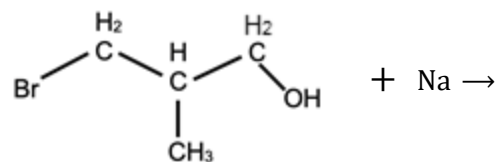


a) Name compound **A**.

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b) Complete the structural chemical equation to represent the reaction between compound **A** and sodium.



/ 1

c) Name the functional group(s) present in compound **C**.

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/ 1

d) Compound **A** can be dehydrated using concentrated sulfuric acid.

i. Draw the structure of the substance formed.

/ 1

ii. Draw the structure of an isomer of **A** that cannot be oxidised by acidified potassium permanganate.

/ 1

Total Q14

/ 5

Question 15

Marker use

Nitrogen gas instead of air is used to inflate tyres of an aircraft. Some car companies now offer car owners the option of filling their tyres with nitrogen rather than air, claiming that the tyres have a lower increase in pressure when the tyres heat.

a) Explain:

i. How a gas exerts pressure on the walls of a tyre.

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ii. Why the pressure of the tyre increases as the tyre heats.

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b) The tyres of a car experience a 40°C increase in temperature on a journey. If dry air is used to inflate a tyre instead of nitrogen, is the increase in pressure the same when the temperature increases? Explain.

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c) If a tyre has a volume of 8.5 L, how many of these car tyres can be inflated to a pressure of 220 kPa from one 50 L gas cylinder of nitrogen, initially at a pressure of 18 000 kPa? Assume the temperature remains constant.

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Question 15 continues

Question 15 continued

Marker use

One reason given for using nitrogen rather than air to inflate a tyre is that oxygen in the air can escape through the tyre wall more easily than nitrogen because its molecules are smaller than those of nitrogen.

- d) Explain why oxygen molecules are smaller than nitrogen molecules even though the oxygen molecules have a higher molecular mass.

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Total Q15

10

Question 16

Marker use

a) Write the electron configuration for a neon atom in the ground state using sub-shells.

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b) Deduce the formula of the compound that contains 2+ ions and 3- ions that are isoelectronic with neon.

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c) An element, such as neon, is able to be identified by its unique emission spectrum. State what is occurring within an atom when an emission spectrum is produced.

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Total Q16

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Exam continues over the page

Question 17

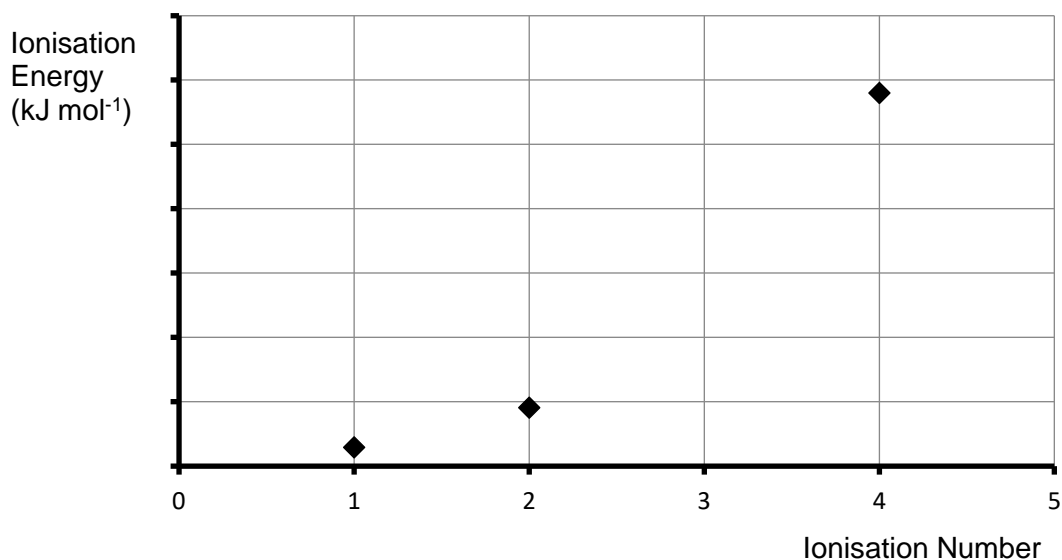
Marker use

- a) Write an equation to represent the first ionisation of aluminium.

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- b) The graph below shows the 1st, 2nd and 4th ionisation energies for aluminium. Represent the approximate value of the 3rd ionisation energy for aluminium on the graph.



Spare diagram used (✓)

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- c) Aluminium exists as an unstable 1+ cation (eg AlCl), the 2+ cation is not listed in common references, and the 3+ cation is the one normally found in compounds (eg AlCl₃).

Explain these facts, using subshell electron configurations to support your answer.

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Question 17 continues

Question 17 continued

Marker use

- d) Explain why aluminium is the least reactive of the period 3 metals and chlorine is the most electronegative.

Aluminium:

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Chlorine:

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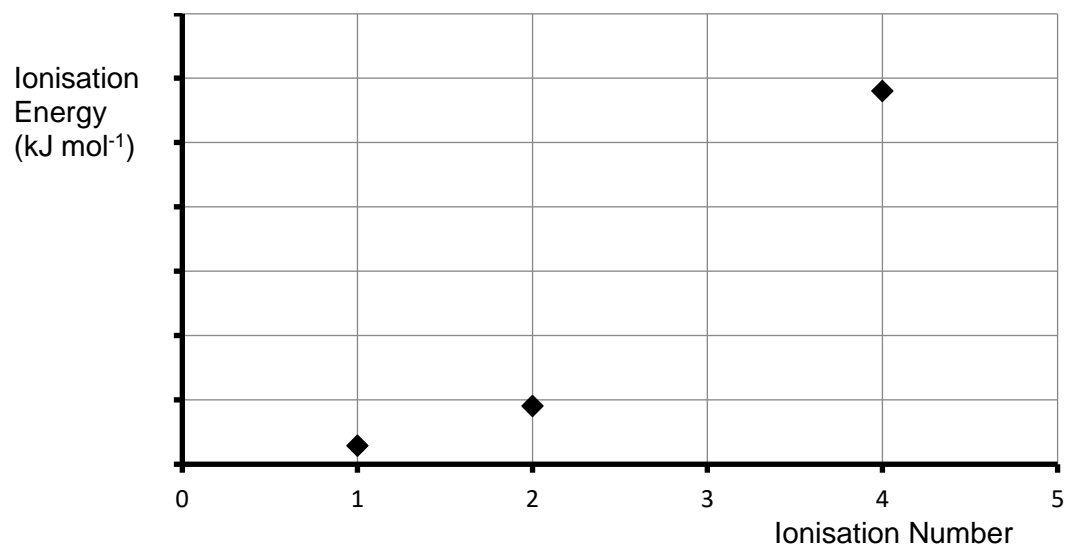
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Total Q17

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Spare Diagram

Question 17



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End of Part 3



OFFICE OF TASMANIAN
ASSESSMENT, STANDARDS
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External Assessment 2021

CHEMISTRY

CHM415115

Part **4**

Pages	16
Questions	7
Information Sheet	1

Suggested working time: 45 minutes

Instructions

- Attempt **all** questions and **all** parts within each question.
- Write your answers in the spaces provided in this exam paper.
 - Spare diagrams have been provided at the end of the exam booklet.
 - Indicate in the box provided if you have used the spare diagrams.
- A TASC approved scientific calculator 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 appropriate units must be included.
- All answers must be written in **English**.
- You **must** make sure your answers address:
 - Criterion 8 apply logical processes to solve quantitative chemical problems.

Marker use	
C8	40

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 part(s) of the question.
 - If you are unable to determine the required value, you should use the value given by the examiner in the following parts of the question.

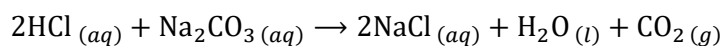
Guide to Exam Structure

	Questions available	How many questions to answer	Suggested working time	Marks available
Part 1	5	5	45 minutes	40
Part 2	5	5	45 minutes	40
Part 3	7	7	45 minutes	40
Part 4	7	7	45 minutes	40
Total	24	24	180 minutes (3 hours)	160

Question 18

Marker use

The concentration of an hydrochloric acid solution was determined by titration techniques. The following reaction occurs:



- 25.0 mL of hydrochloric acid solution was placed in a conical flask
- 23.35 mL of a sodium carbonate solution of concentration $0.0729 \text{ mol L}^{-1}$ was required for neutralisation.

a) Calculate the concentration of the hydrochloric acid used in the titration.

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b) This sodium carbonate solution was made by dissolving a known mass of sodium carbonate-10-water, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, in water to make up 250.0 mL of solution. Calculate the mass of solid used.

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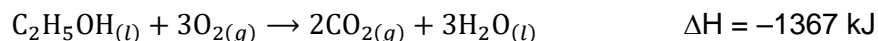
Total Q18

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Question 19

Marker use

The chemical reaction for the complete combustion of ethanol is given below:



- a) Calculate the theoretical amount of heat released when 20.0 mL of ethanol ($M_r = 46.07$) is burned to produce carbon dioxide and water. The density of ethanol is 0.789 g mL^{-1} .

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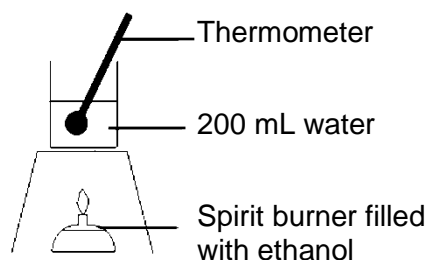
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- b) A year 12 student determined the experimental heat of combustion, ΔH , of ethanol using a spirit burner, as shown in the diagram opposite.

The following measurements were recorded:

- Volume of water heated = 200.0 mL
- Mass of ethanol burned = 1.75 g
- Initial temperature of water = 20.2°C
- Final temperature of water = 73.5°C



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Use these values to calculate the **experimental** heat of reaction.

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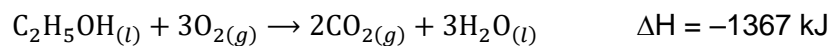
Question 19 continues

Question 19 continued

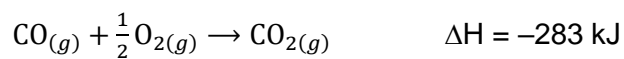
Marker use

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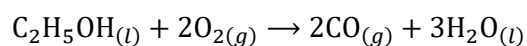
The chemical reaction for the complete combustion of ethanol is given below:



c) Use the following extra information:



to find the heat reaction of the **incomplete** combustion of ethanol represented below:



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Total Q19

/ 8

Question 20

Marker use

In some research the amount of hydrogen peroxide, H_2O_2 , in a solution is routinely analysed by titrating with acidified potassium permanganate solution. The balanced equation for this reaction indicates that 5 moles of the hydrogen peroxide reacts with 2 moles of the permanganate ion.

- a) Show that 1.00 mL of an acidified 0.020 mol L^{-1} potassium permanganate solution reacts completely with 1.7 mg of hydrogen peroxide.

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The hydrogen peroxide content in disinfectant is analysed using this technique.

- The weight of the disinfectant is 0.334 g.
 - The endpoint of the titration is 5.34 mL when a 0.020 mol L^{-1} acidified potassium permanganate solution is used.
- b) Determine the percentage by mass of hydrogen peroxide in the disinfectant. Give your answer to the correct number of significant figures.

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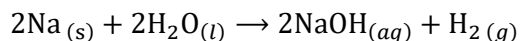
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Exam continues over the page

Question 21

Marker use

a) When 1.08×10^{-2} mol of sodium is placed in 500 mL of water the following reaction occurs:



Calculate the pH of the resulting solution at 25°C, assuming a negligible loss of water.

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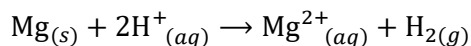
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b) Magnesium ribbon reacts with hydrochloric acid according to the following equation:



0.635 g of magnesium is added to 50.0 mL of hydrochloric acid solution of concentration 0.980 mol L⁻¹.

i. Show that magnesium is in excess.

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Question 21 continued

Marker use

ii. Calculate the concentration of the cation(s) in solution after the reaction is complete.

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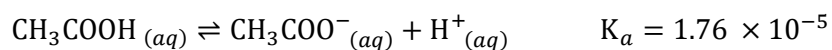
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Question 22

Marker use

a) Ethanoic acid is a weak acid:



An ethanoic acid solution contains the following concentrations:

$$[\text{CH}_3\text{COO}^-_{(aq)}] = 1.2 \times 10^{-3} \text{ mol L}^{-1}$$

$$[\text{H}^+_{(aq)}] = 8.3 \times 10^{-6} \text{ mol L}^{-1}$$

$$[\text{CH}_3\text{COOH}_{(aq)}] = 1.5 \times 10^{-3} \text{ mol L}^{-1}$$

Show that this solution is not at equilibrium.

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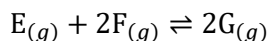
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Question 22 continues

Question 22 continued

Marker use

b) Consider the following equilibrium reaction:



- i. 2.0 mol of gas E was heated with 1.0 mol of gas F in a sealed container. When equilibrium was established there was 0.8 mol of gas G present. Calculate the amount, **in moles**, of E and F in this equilibrium mixture.

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- ii. At another temperature an equilibrium mixture of the gases in a 1.50 L sealed container has 2.50 mol of gas E, 1.20 mol of gas F and 0.85 mol of gas G.

Calculate the value of the equilibrium constant, K_c , at this temperature.

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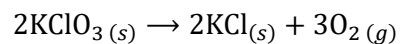
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Question 23

Marker use

These questions involve the production of gases in chemical reactions.

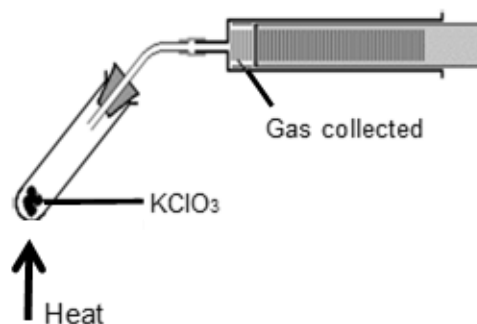
- a) Oxygen gas is produced when a sample of potassium chlorate, KClO_3 , is heated:



50.2 mL of gas is collected at 20.0°C and 98.2 kPa.

Calculate the mass of potassium chlorate used, assuming the reaction goes to completion.

($M_r(\text{KClO}_3) = 122.5$)



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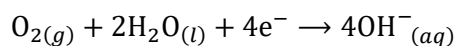
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Question 23 continues

Question 23 continued

Marker use

b) In a zinc–air battery the following half-equation represents the cathode reaction:



The article about the zinc–air battery on the Wikipedia website claims that the oxygen in 1 litre of air is required for one ampere-hour of capacity used.

Verify the accuracy of the claim, given the following information:

- Air contains 21% oxygen by volume.
- 1 ampere-hour is equivalent to 3600 C.
- Assume standard laboratory conditions.

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Total Q23

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