

Name: _____

Class: _____



JURONG PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION 2024

CHEMISTRY
Higher 1

8873/02
2024

Paper 2

2 hours

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use a HB pencil for any diagrams, graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A (60 marks)

Answer **all** the questions.

Section B (20 marks)

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use		
Section A	1	6
	2	17
	3	6
	4	9
	5	12
	6	5
	7	5
Section B	8	20
	9	20
Penalty (delete accordingly)		
Missing/wrong units in final answer		-1 / NA
Total		80

This document consists of **24** printed pages and **4** blank pages.

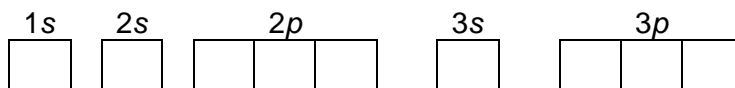
Section A

Answer **all** the questions in this section, in the spaces provided.

For
Examiner's
Use

- 1 The oxygen family is also called the chalcogens. It consists of the elements found in Group 16 of the periodic table, oxygen, sulfur, selenium, tellurium and polonium. Chalcogen can be found in nature in both free and combined states.

- (a) Complete the diagram to show the arrangement of electrons in the orbitals of a sulfur atom.



[1]

- (b) State and explain the general trend in the first ionisation energy across Period 3 elements.

Explain why sulfur does not follow this general trend.

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[2]

- (c) Selenium burns in air with a blue flame to form white solid SeO_2 . When SeO_2 reacts with water it forms $\text{H}_2\text{SeO}_3(\text{aq})$ which has a pH of less than 7.

- (i) Choose two oxides, each containing a different Period 3 element, which behave in a similar way to SeO_2 when they are added to water.

Write equation for the reaction of each oxides with water.

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[2]

- (ii) Suggest one other reagent that will react with separate samples of these oxides and with SeO_2 .

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[1]

[Total: 6]

2 Nitrogen and phosphorus are elements of Group 15 in the Periodic Table.

- (a) Nitrogen exists naturally as gaseous diatomic $\text{N}\equiv\text{N}$ molecules whereas phosphorus is a solid and exists as P_4 molecules comprising of P-P single bonds.

Account for the difference in their physical states in terms of structure and bonding.

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[2]

- (b) Nitrogen exhibits a range of oxidation numbers in its compounds.

- (i) Complete the table below which refers to the various oxidation numbers of nitrogen in its compounds.

Compound	Oxidation Number of Nitrogen
NO_2	
NO_3^-	
N_2O	
NH_2OH	

Table 2.1

[2]

Hydroxylamine, NH_2OH is oxidised by $\text{Fe}^{3+}(\text{aq})$, which is itself reduced to $\text{Fe}^{2+}(\text{aq})$. In an experiment, 0.0825 g of NH_2OH required 20.00 cm^3 of 0.250 mol dm^{-3} Fe^{3+} for complete reaction.

- (ii) How many moles of Fe^{3+} react with one mole of NH_2OH ?

[2]

- (iii) What change in oxidation number does the nitrogen in NH_2OH undergo during the reaction with Fe^{3+} ?

Explain your answer.

.....

[1]

- (iv) Which formula from Table 2.1 corresponds to the nitrogen-containing product of this reaction?

.....

[1]

- (v) Construct the half equations and hence the overall balanced equation for the reaction of NH_2OH with Fe^{3+} (in acidic solution).

[2]

- (c) Nitrate, NO_3^- , and phosphate, PO_4^{3-} , are oxoanions of nitrogen and phosphorus respectively.

Phosphoric acid, H_3PO_4 , is used in the production of Coca-Cola and other soft drinks. It serves as an acidulant, providing a tangy flavor and acting as a preservative to maintain the drink's freshness and shelf life.

Draw a dot-and-cross diagram to show the bonding PO_4^{3-} .

[1]

- (d) Phosphoryl chloride is a colourless liquid with the formula POCl_3 .

Table 2.2 shows the electronegativity values of the atoms in POCl_3 .

atom	electronegativity / pauling units
phosphorus	2.2
chlorine	3.0
oxygen	3.5

Table 2.2

- (i) Explain the term *electronegativity*.

.....

[1]

- (ii) Draw the shape of POCl_3 .

Indicate clearly the polarity of each bond it contains, and its overall net polarity.

[2]

- (iii) Predict **all** possible intermolecular forces which could exist between POCl_3 molecules.

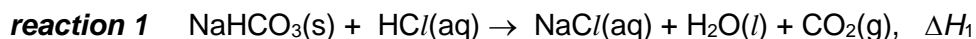
Explain how these forces arise.

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[3]

[Total: 17]

- 3 An experiment was conducted to determine the molar enthalpy change of a reaction, ΔH_1 .



In this experiment, 5.00 g of sodium hydrogen carbonate was added 50.0 cm³ of hydrochloric acid in a polystyrene cup at time, $t = 3.0$ min. The temperature of hydrochloric acid was measured at regular time intervals, before and after sodium hydrogencarbonate is added.

A graph of temperature, T , against time, t , was obtained as shown in Fig 3.1.

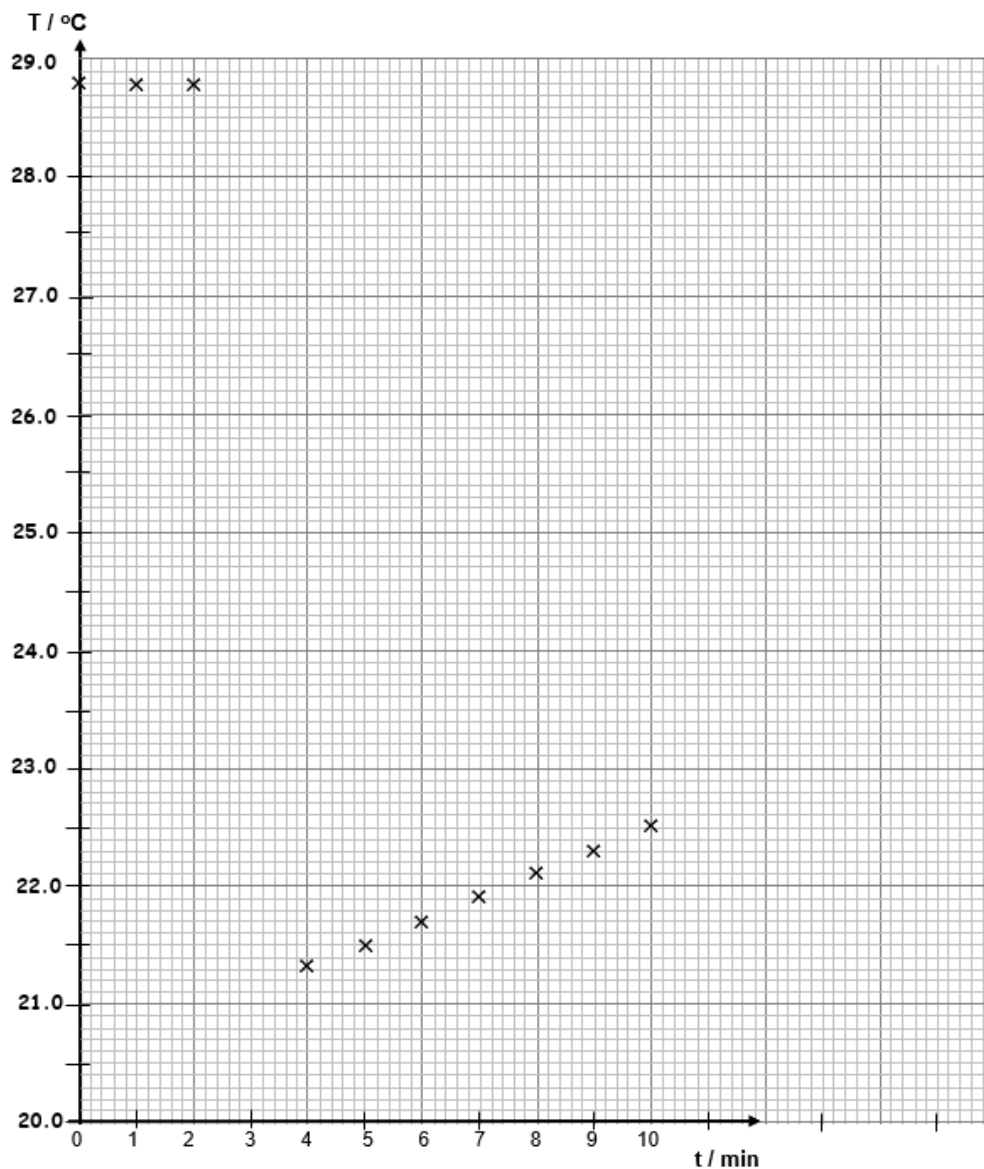


Fig. 3.1

- (a) Draw a best-fit straight line taking into account all of the points before $t = 3.0$ min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to rise steadily.

Extrapolate (extend) both lines to $t = 3.0$ min.

From the graph, read the minimum temperature, T_{\min} , and the maximum temperature, T_{\max} , at $t = 3.0$ min.

Deduce the temperature change, ΔT , at $t = 3.0$ min.

$T_{\min} = \dots\dots\dots$

$T_{\max} = \dots\dots\dots$

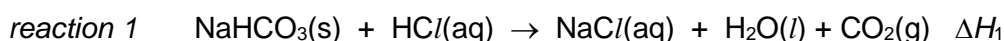
$\Delta T = \dots\dots\dots$ [2]

- (b) Calculate the heat change, q , for your experiment using the value you deduced in (a).

Assume that the specific heat capacity of the solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ and that the density of the solution is 1.00 g cm^{-3} .

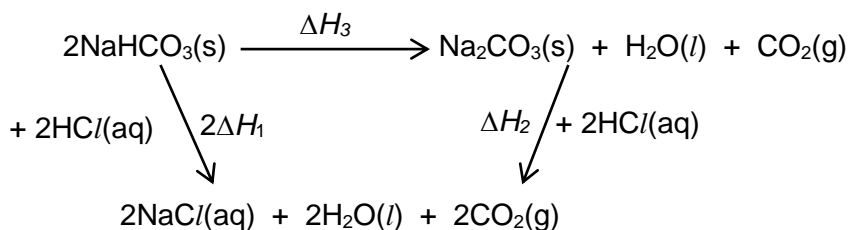
[1]

- (c) Determine the molar enthalpy change, ΔH_1 , for **reaction 1**. The hydrochloric acid is in excess.



[1]

- (d) An energy cycle is shown in the diagram below.



- (i) Write an equation to show the relationship between ΔH_1 , ΔH_2 and ΔH_3 .

$\dots\dots\dots$ [1]

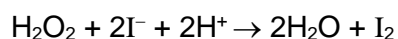
- (ii) Use your answers in (c) and (d)(i), calculate a value, in kJ mol^{-1} , for ΔH_3 .

Given that $\Delta H_2 = -31.6 \text{ kJ mol}^{-1}$

[1]

[Total: 6]

- 4 In the late 19th century, the two pioneers of the study of reaction kinetics, Vernon Harcourt and William Esson, studied the rate of the reaction between hydrogen peroxide and iodide ions in acidic solution.



A student carried out a study on the kinetics of the above reaction. In Experiment 1, both $[\text{H}_2\text{O}_2]$ and $[\text{H}^+]$ were kept constant at 0.05 mol dm^{-3} and $[\text{I}^-]$ was plotted against time. The following curve in Fig. 4.1 was obtained.

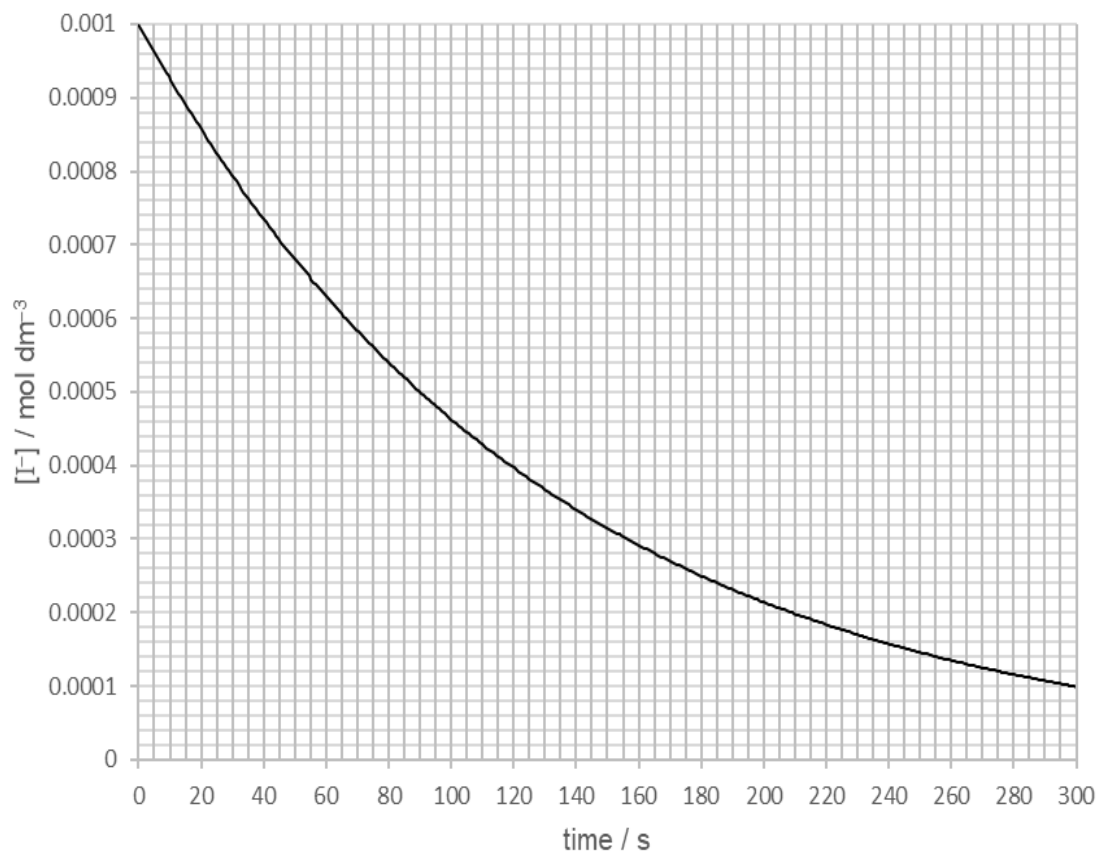


Fig. 4.1

- (a) Use the graph to determine the order of reaction with respect to $[\text{I}^-]$. Show all your workings, and draw relevant construction lines on the Fig. 4.1.

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[2]

- (b) The study was repeated with the same initial $[I^-]$ but varying $[H_2O_2]$ and $[H^+]$.

Experiment no.	$[H_2O_2] / \text{mol dm}^{-3}$	$[H^+] / \text{mol dm}^{-3}$	relative rate
1	0.050	0.05	0.476
2	0.025	0.05	0.238
3	0.100	0.10	0.952

- (i) Use the above data to deduce the orders with respect to $[H_2O_2]$ and $[H^+]$, explaining your reasoning.

[2]

- (ii) Write the rate equation and the units for rate constant for the reaction between hydrogen peroxide and iodide ions in acidic solution.

[2]

- (c) Explain, with the aid of a labelled Boltzmann distribution diagram, the effect of temperature on the rate of reaction.

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[3]

[Total: 9]

5 (a) Compound **H** has the structural formula $\text{CH}_2=\text{CHCH}(\text{NH}_2)\text{COOH}$.

(i) Name all the functional groups in **H**.

.....

.....

[2]

(ii) Draw a labelled diagram to illustrate the types of orbital overlap in the $\text{C}=\text{C}$ double bonds in **H**.

(iii) Compound **H** reacts with Br_2 in inert organic solvent.

[2]

Draw the structure of the product formed.

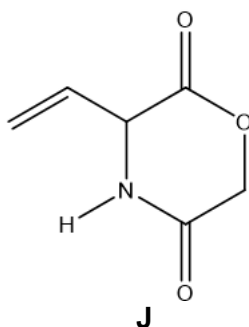
(iv) Give the reagents and conditions required for **H** to be converted to $\text{CH}_2=\text{CHCH}(\text{NH}_2)\text{CH}_2\text{OH}$.

[1]

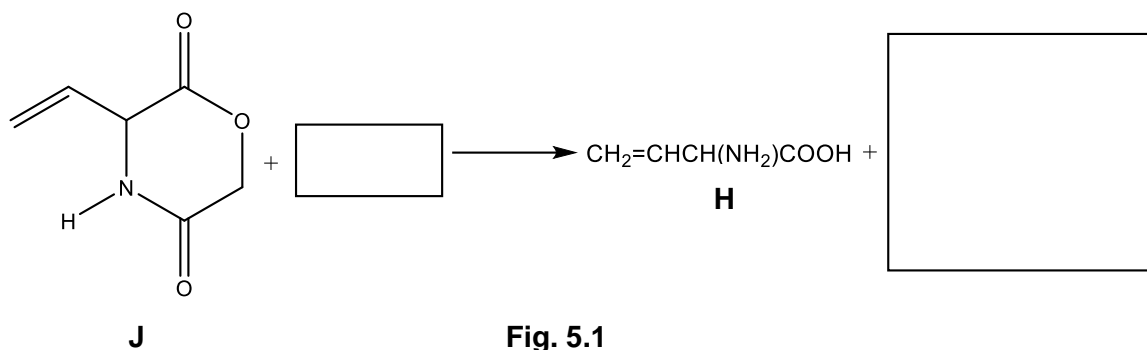
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[1]

(b) Compound **H** can be prepared from the reaction of **J** with an excess of hot aqueous acid.



- (i) Complete **Fig. 5.1** to show the equation for this reaction.



[1]

- (ii) Name the type of reaction in **(b)(i)**.

.....

[1]

- (c) Polymers consists of monomers joined together by undergoing either addition or condensation polymerisation.

Compound **H** can react to form either an addition polymer, **K**, or a condensation polymer, **L**, depending on the conditions.

- (i) Draw **one** repeat unit of addition polymer, **K**.

[1]

- (ii) Draw **two** repeat units of condensation polymer, **L**.

The new functional group formed should be displayed.

[2]

- (iii) Explain why condensation polymers can normally biodegrade more readily than addition polymers.

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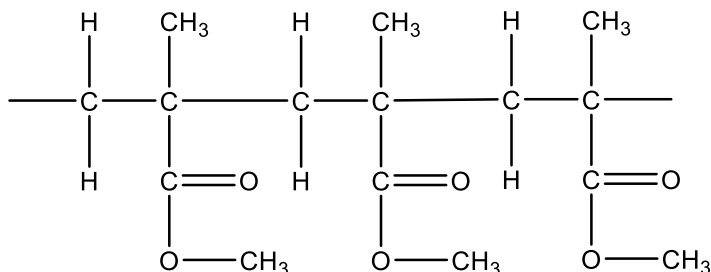
[1]

[Total: 12]

- 6 Polymethyl methacrylate, or PMMA, is a transparent organic polymer that is used as an alternative to glass. It has a melting point of 160°C . It is a rigid plastic that can find its application in a variety of industries.

Also referred to as plexiglass or acrylic glass, PMMA is used because it is easy to shape, tough and cost-effective. It has the ability to keep a light beam reflected within the surface and is also resistant to UV radiation.

Part of the polymer chain of PMMA is shown below.



- (a) Draw the monomer used to produce PMMA.

[1]

- (b) Predict whether PMMA is a thermoplastic or thermosetting polymer. Explain your answer using the information in the question **and** your knowledge of the structure and bonding in polymers.

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[2]

- (c) State one environmental advantage of recycling PMMA.

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[1]

- (d) PMMA polymer is also known as bone cement in the healthcare industry. It is used by orthopaedic surgeons for procedures like joint replacement or treating bone damages.

The formation of the bone cement is exothermic and involves polymerisation to form PMMA.

Explain why the formation of bone cement is exothermic, considering the bonds broken and formed.

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[1]

[Total: 5]

- 7** Carbon nanotubes offer a promising approach in cancer treatment through their unique physical properties. They have been shown to be effective tumor killers in those with kidney or breast cancer.

For
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Mechanism of Action:

1. Injection of Multi-Walled Nanotubes (MWNTs): Multi-walled carbon nanotubes are introduced directly into the tumor.
2. Laser Treatment: A specialised laser that emits near-infrared radiation is used to target the tumor. The laser treatment typically lasts for about 30 seconds.
3. Vibration and Heat Generation: The carbon nanotubes vibrate in response to the near-infrared radiation, producing heat.
4. Tumor Cell Death: The generated heat raises the temperature of the tumor cells. Once the temperature reaches a certain threshold, the tumor cells begin to die, effectively shrinking the tumor.

- (a)** Explain why carbon nanotubes are considered as nanomaterials rather than nanoparticles.

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[2]

- (b)** Suggest one advantage of using carbon nanotubes in the treatment of cancer.

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[1]

- (c)** Carbon nanotubes can be used as biosensors implanted in the human body due to its high electrical conductivity, high durability, low density and absence of toxic metals.

Explain why a carbon nanotube is a good conductor of electricity.

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[1]

- (d)** Suggest why a single carbon nanotube would have high tensile strength.

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[1]

[Total: 5]

Section B

Answer **one** question from this section, in the spaces provided.

For
Examiner's
Use

- 8 (a) *Use of Data Booklet is relevant to this question.*

Chlorine has two naturally occurring isotopes, ^{35}Cl and ^{37}Cl .

- (i) State the number of protons, neutrons and electrons in an atom of ^{37}Cl .

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[1]

- (ii) The first electron affinity is defined as the amount of energy released when one mole of gaseous atoms gains one mole electrons to form one mole of singly charged gaseous anions.



Calculate the amount of energy released when one chlorine atom gained one electron to form chloride ion, Cl^- .

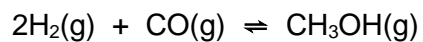
[1]

- (iii) State and explain the difference in size between the radius of the chloride ion, Cl^- and the radius of a chlorine atom.

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[2]

- (b) The gas-phase reaction of carbon monoxide with hydrogen forming methanol is an example of an equilibrium. The value of equilibrium constant, K_c , is 0.0311 at 500 K.



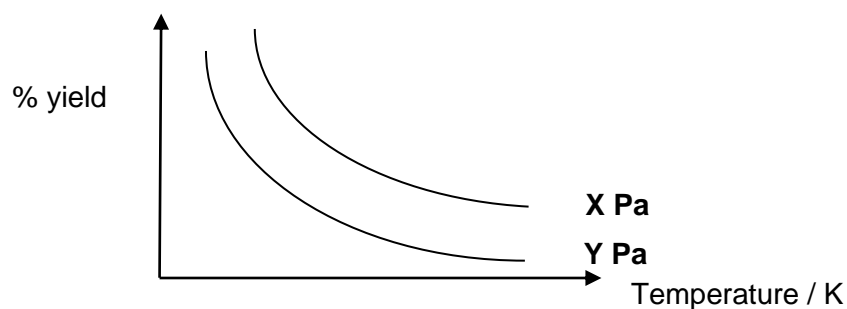
- (i) Write the expression for K_c for this reaction and give its units.

[2]

- (ii) Calculate the equilibrium concentration of methanol when the equilibrium concentrations of hydrogen and carbon monoxide are $0.151 \text{ mol dm}^{-3}$ and $0.0850 \text{ mol dm}^{-3}$ respectively.

[1]

- (iii) The effects on the equilibrium yield of methanol caused by changes in the pressure and in the temperature of the gaseous mixture are shown in the graph below.



- Deduce whether the forward reaction is exothermic or endothermic.

Explain your answer using references to the graph and to the equilibrium position.

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[2]

- Deduce whether **X** or **Y** is at a higher pressure.

Explain your answer using references to the graph and to the equilibrium position.

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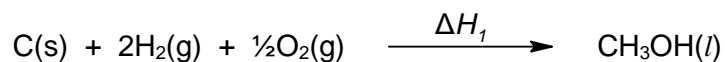
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[2]

- (c) An equation involving formation of methanol is shown below.



- (i) The following enthalpy change of combustion can be used to calculate ΔH_1 .

$$\Delta H_c \text{ methanol} = -726 \text{ kJ mol}^{-1}$$

$$\Delta H_c \text{ carbon} = -393 \text{ kJ mol}^{-1}$$

$$\Delta H_c \text{ hydrogen} = -286 \text{ kJ mol}^{-1}$$

Define the term *standard enthalpy change of combustion*.

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[1]

- (ii) Use the data given (c)(i) to calculate ΔH_1 .

[2]

- (iii) Write an equation to represent the standard enthalpy change of combustion of methanol.

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[1]

- (iv) Use the bond energies given in the *Data Booklet* to calculate a value for the enthalpy change of combustion of methanol.

[2]

- (v) The value given for the standard enthalpy change of combustion of methanol in (c)(i) is different from the value calculated in (c)(iv).

One reason is the bond energy values are only average values.

State another reason why value given for the standard enthalpy change of combustion of methanol in (c)(i) is different from the value calculated in (c)(iv).

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[1]

- (vi) When 3.00 g of methanol was burned, it was found that 250 g of water was heated from 25 °C to 76 °C. Calculate the percentage efficiency of heat transfer for this experiment using relevant data from (c)(i).

Assume that the specific heat capacity of the solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ and that the density of the solution is 1.00 g cm^{-3} .

[2]

[Total: 20]

- 9 (a) Calcium carbonate is a dietary supplement used when the amount of calcium taken in the diet is not enough.

To meet the recommended dietary allowance of calcium, an adult would need to consume between 2.5 to 3.0 grams of calcium carbonate.

A chemist dissolve a sample of calcium carbonate tablets in 50.0 cm^3 of 1.20 mol dm^{-3} hydrochloric acid, in excess. After all the bubbles were driven off, the solution was diluted with water and make up to 250 cm^3 to solution.

25.0 cm^3 of the resultant solution was titrated with 23.50 cm^3 of $0.0200 \text{ mol dm}^{-3}$ of sodium hydroxide for complete reaction.

- (i) Write the equation for the reaction between calcium carbonate and hydrochloric acid.

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[1]

- (ii) Calculate the amount of hydrochloric acid remaining in 250 cm^3 of resultant solution.

[2]

- (iii) Calculate the amount of hydrochloric acid which reacted with calcium carbonate in 250 cm^3 of solution.

[1]

- (iv) Calculate the mass of calcium carbonate in the sample. Hence, determine if the sample of calcium carbonate tablets meets the typical recommended dietary allowance.

[2]

- (b) Bicarbonate, HCO_3^- , has a wide range of uses across various industries due to its chemical properties. One of which is the food industry which sodium bicarbonate is used as a buffering agent found in food additive.

- (i) Define what is meant by the terms *acid* and *base* using the Brønsted-Lowry theory of acids and bases.

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[1]

- (ii) A solution of $0.100 \text{ mol dm}^{-3}$ of a weak base, HCO_3^- at 25°C was found to have pH of 9.68.

Calculate the concentration of OH^- in the solution.

[1]

- (iii) Write equation to represent the ionisation of HCO_3^- in water.

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[1]

- (iv) Write an expression for the base dissociation constant, K_b , of HCO_3^-

[1]

- (v) Calculate the K_b value of HCO_3^- .

[1]

- (vi) Write two separate equations to show how bicarbonate, HCO_3^- , can act as a buffering agent when small amount of acid and base are added to it.

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[2]

- (c) (i) State the formulae of the chlorides of the elements Na to P where the element is in its highest oxidation states. Explain your reason of choice.

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[2]

- (ii) Magnesium and phosphorus react with chlorine to form magnesium chloride and phosphorus(V) chloride respectively.

Write equation to show what happens when solid samples of each of these chlorides are added separately to water.

In each case, state the likely pH of the resultant solution.

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[3]

- (iii) Both magnesium chloride and magnesium oxide exist as white solids with a melting point of 714°C and 2850°C respectively.

Explain the differences between the two melting points in terms of their structure and bonding.

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[2]

[Total: 20]

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