YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME	**TEACHER'S COPY**		
CG		H1 GROUP	1 / 2

CHEMISTRY

8873/02

Paper 2 Structured and Free Response Questions

XX September 2025

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
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	**/ 11**	
2	**/ 9**	
3	**/ 11**	
4	**/ 12**	
5	**/ 5**	
6	**/ 12**	
Section B		
7 or 8	**/ 20**	
Penalty	**units**	**significant figures**
Total	**/ 80**	

This document consists of **16** printed pages and **1 blank page**.

Section A

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

1 (a) Elements **A**, **B** and **C** are three consecutive elements from Period 3 of the Periodic Table.

Element **B** has the successive ionisation energies as shown in Table 1.1.

Table 1.1

ionisation energies / kJ mol^{-1}							
1st	2nd	3rd	4th	5th	6th	7th	8th
577	1820	2740	11600	14800	18400	23300	27400

(i) Explain how the data shows that element **B** belongs to Group 13.

……

……

……[1]

Largest jump in ionization energy from removing 3rd electron to removing 4th electron. 4th electron is located in an inner principal quantum shell.

There are 3 valence electrons.

(ii) Hence, write the full electronic configuration of **B**.

$1s^2$……..[1]

$2s^2\ 2p^6\ 3s^2\ 3p^1$

(iii) Explain why the first ionisation energy of element **B** is lower than the first ionisation energy of elements **A** and **C**.

……

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……

……[3]

Element B (Group 13) and A (Group 2):
The outermost electron in A is in the 3s subshell, while the outermost electron in B is in the 3p subshell. As the average distance from the nucleus of a 3p orbital is slightly larger than that of a 3s orbital, less energy is required to remove the 3p electron in B.

Element B (Group 13) and C (Group 14):
The nuclear charge of B is lower than that of C, while their shielding effect is approximately the same since both have the same number of inner electronic shells.

As a result, B has a lower effective nuclear charge than C, and less energy is required to remove the outermost electron in B.

(b) Oxygen and chlorine react with phosphorus to form phosphorus(V) oxide and phosphorus(V) chloride respectively.

Describe the reactions when phosphorus(V) oxide and phosphorus(V) chloride are added separately to two separate beakers of water. In each case, give appropriate equations and state the likely pH of the resulting solution.

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.....[4]

P_4O_{10}, a covalent oxide, reacts vigorously and dissolves in water to form a strongly acidic solution with a pH of 1 / 2.

$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

PCl_5 undergoes complete hydrolysis to give strongly acidic solution with a pH of 1 / 2.

$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

(c) Group 1 elements are known as alkali metals because they are able to form alkaline solutions in water.

Table 1.2 shows how some Group 1 elements react with water.

Table 1.2

Group 1 element	description of the reaction with water
Li	fizzes steadily, gradually disappears
Na	fizzes rapidly, melts into a ball and disappears quickly
K	ignites with sparks and lilac flame, disappears very quickly

(i) Write an equation for the reaction between sodium and water.

.....[1]

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

(ii) Explain why the reaction of Group 1 metals and water becomes more vigorous down the group.

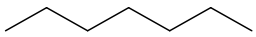
……

……[1]

Down the group, the ability to lose electrons / reducing power of the Group 1 metal increases.

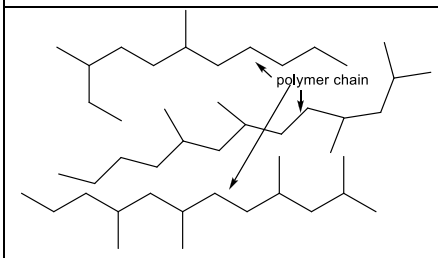
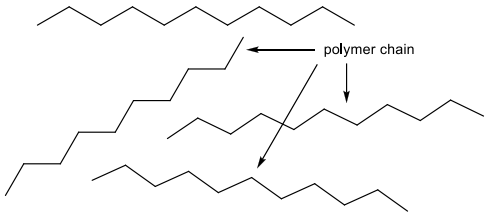
[Total: 11]

2 (a) In 1933, British chemists accidentally discovered that subjecting ethene to high pressure in the presence of trace amounts of oxygen resulted in the formation of a soft, white solid. This solid was identified as poly(ethene), marking the beginning of a major global polymer industry. Depending on the reaction conditions, the polymerisation of ethene can produce either low-density poly(ethene) (LDPE) or high-density poly(ethene) (HDPE), each with distinct structural and physical properties.

(i) Sketch the structures of LDPE and HDPE using  as a simplified representation of the polymer chain.

LDPE	HDPE

[2]

LDPE	HDPE
	

(ii) Poly(ethene) can be used to make squeezable bottles.

By considering the structure and properties of LDPE and HDPE, deduce which poly(ethene) is suitable as a material for squeezable bottles.

……

……

……

……[2]

LDPE.
In LDPE, due to branching, chains cannot be packed closely together, resulting in less extensive instantaneous dipole induced dipole interactions between polymer chains. LDPE is therefore soft/flexible and is used to make squeezable bottles.

(b) In recent years, there have been concerns worldwide about the environmental impact of catastrophic oil spills caused by oil tanker accidents at sea. Such oil spills can cause havoc to marine life and pose health hazards to the human population located in nearby coastal zones.

Conventional techniques such as use of sponges are not adequate to solve the problem of massive oil spills. Sponges have high reusability but low efficiency in clearing oil from sea water as it soaks up liquid mechanically.

Nanomaterials have emerged as a potential source of novel solution to this problem. One nanomaterial that offers huge promise is nanostructured organoclays. Each particle of nanostructured organoclay has a diameter of about 300 nm and is known to have low polarity.

(i) Explain why nanostructured organoclay cannot be considered a *nanoparticle*.

……

……[1]

It does not have all three dimensions less than 100 nm / one dimension is more than 100nm.

(ii) Give two reasons why nanostructured organoclay shows huge promise in solving the problem of oil spills.

……

……

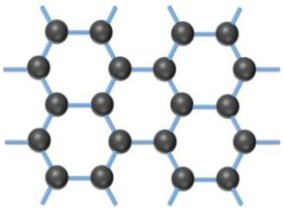
……[2]

The surface area to volume ratio is high, allowing a greater amount of oil to be absorbed.

Furthermore, it has low polarity, allowing it to absorb oil and not water, therefore allowing separation between the two.

(iii) Another material that can be used to remove oil spills is carbon nanotubes, which are formed when layers of graphene roll up. Draw the structure of graphene.

[1]



(iv) Carbon nanotubes can also be used in electronics, to make electrical wires and cables. Explain the property of carbon nanotubes that enables it to be used for such purposes.

……

……[1]

There are delocalised electrons that can act as mobile charge carriers. Hence it has high electrical conductivity.

[Total: 9]

3 The combustion of sulfur-containing fossil fuels such as coal results in the formation of acidic oxides sulfur dioxide (SO_2) and sulfur trioxide (SO_3), which are significant atmospheric pollutants.

To determine the sulfur content in a given coal sample, the following analytical procedure was carried out:

- **step 1**: A 4.0 kg sample of coal was subjected to complete combustion in a controlled environment. The combustion products were processed to isolate and collect the SO_2 and SO_3 from the exhaust gases.
- **step 2:** The collected gas mixture containing SO_2 and SO_3 was divided into two equal portions for separate analysis.
- **step 3:** The first portion of the SO_2 and SO_3 gas mixture was reacted with a solution of acidified potassium manganate(VII), $KMnO_4$. It was found that 0.0480 mol of acidified $KMnO_4$ was required for complete reaction.
- **step 4a:** The second portion of the SO_2 and SO_3 gas mixture was bubbled into 1.00 dm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.
- **step 4b:** A 25.0 cm^3 aliquot of the resulting alkaline solution was titrated with 0.250 mol dm^{-3} hydrochloric acid. The volume of hydrochloric acid required to reach the equivalence point was 22.40 cm^3.

(a) In step 3, a redox reaction took place. SO_2 is oxidised by $KMnO_4$ to form SO_4^{2-}. SO_3 does not react with $KMnO_4$.

The reduction of MnO_4^- in acidic medium is represented by the following half equation:

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

(i) Given that SO_2 is oxidised to SO_4^{2-}, write the half equation for this oxidation.

……[1]

$SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$

(ii) Construct a balanced equation for the reaction between MnO_4^- and SO_2.

……

……[1]

$2MnO_4^{2-} + 5SO_2 + 2H_2O \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 4H^+$

(iii) Calculate the amount of SO_2 present in the first portion of gas mixture.

[1]

Amount of $SO_2 = \frac{5}{2} \times 0.0480 = 0.120$ mol

(b) Steps 4a and 4b describe a back titration process.

In step 4a, both SO_2 and SO_3 undergo neutralisation with an excess amount of NaOH, according to the following equations.

$$SO_2 + 2OH^- \rightarrow SO_3^{2-} + H_2O$$

$$SO_3 + 2OH^- \rightarrow SO_4^{2-} + H_2O$$

(i) Calculate the amount of NaOH that reacted with HC*l* in step 4b.

[1]

NaOH + HC*l* → NaC*l* + H_2O

Amount of NaOH reacted in step 5

= Amount of HC*l* reacted

= $\frac{22.40}{1000} \times 0.250 = 0.005600$ mol

(ii) Calculate the amount of NaOH that reacted with both SO_2 and SO_3 in step 4a.

[3]

Initial amount of NaOH $= 1.00 \times 0.500 = 0.5000$ mol

Amount of NaOH (in 1 dm^3 solution) after step 4

$= \frac{1000}{25} \times 0.005600 = 0.2240$ mol

Amount of NaOH reacted with SO_2 and SO_3

= 0.5000 – 0.2240

= 0.276 mol

(c) **(i)** Using your answers to **(a)(iii)** and **(b)(ii)**, calculate the amount of SO_3 in each portion of the gas mixture. If you were unable to calculate a value in **a(iii)** or in **b(ii)**, you should use the values 0.105 mol and 0.250 mol respectively. These are **not** the correct answers.

[2]

Amount of OH^- reacted with SO_2 = 0.12 x 2 = 0.24 mol

Amount of OH^- reacted with SO_3 = 0.276 – 0.24 = 0.036 mol

Amount of $SO_3 = \frac{0.036}{2} = 0.018$ mol

(ii) Hence, calculate the total mass of sulfur in each portion of the gas mixture.

[1]

Mass of sulfur from SO_2 = 0.12 x 32.1 = 3.852 g

Mass of sulfur from SO_3 = 0.018 x 32.1 = 0.5778 g

Total mass of sulfur in each portion = 3.852 + 0.5778

= 4.4298 g

= 4.43 g

(iii) Using your answer in **(c)(ii)**, determine the percentage by mass of sulfur in the 4.0 kg coal sample.

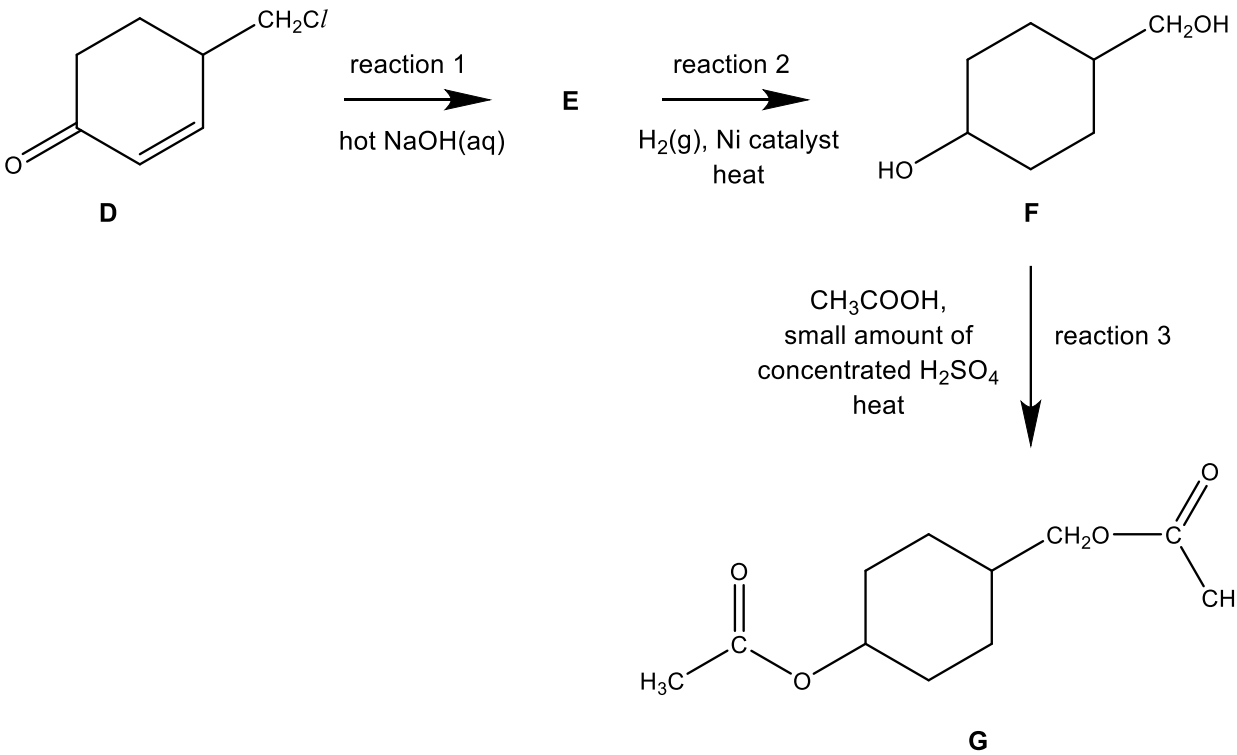
[1]

Total mass of sulfur in 4.0kg sample = 4.4298 x 2 = 8.8596 g

% by mass of sulfur $= \frac{8.8596 \times 100}{4000} = 0.221\%$

[Total: 11]

4 Compound **G** can be synthesised from compound **D** as shown in the three-step reaction scheme below.



(a) Name three functional groups present in compound **D**.

……..[1]

Alkene, ketone, chloroalkane or halogenoalkane

(b) Describe, in terms of orbital overlap, the bonding between the two carbon atoms of the C=C bond in compound **D**.

……

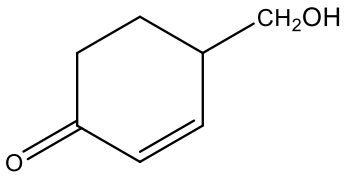
……

……[2]

Valence orbitals from each carbon atom overlap head-on to give a sigma bond.
The p orbital from each carbon atom overlap sideways to give π bond.

(c) Draw the structure of compound **E**.

[1]



(d) State the type of reaction for reactions 1, 2 and 3.

reaction 1 ……

reaction 2 ……

reaction 3 ……

[3]

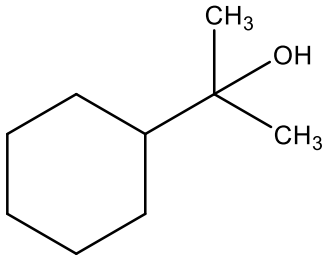
Reaction 1: Substitution
Reaction 2: Reduction
Reaction 3: Condensation

(e) Compound **F** can also be obtained from compound **G**. Suggest how this can be performed in a college laboratory.

……..[1]

Add dilute H_2SO_4, heat. / dilute NaOH, heat

(f) An alcohol, **H**, has the following structure:



H

Describe a simple chemical test to distinguish **F** and **H**.

……

……

……[2]

To each test tube containing R and T, add $K_2Cr_2O_7$, dilute H_2SO_4, then heat

For R, orange $K_2Cr_2O_7$ turns green.
For T, orange $K_2Cr_2O_7$ remains.

OR

To each test tube containing R and T, add $KMnO_4$, dilute H_2SO_4, then heat

For R, purple $KMnO_4$ decolourises.
For T, purple $KMnO_4$ remains.

(g) Explain why **F** is likely to have a higher boiling point than **D**.

……

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……[2]

The stronger hydrogen bonding between molecules of **F** require more energy to overcome compared to the permanent dipole-permanent dipole interactions between molecules of **D**.

[Total: 12]

5 The reaction between peroxodisulfate ions ($S_2O_8^{2-}$) and iodide ions, I^-, is first order with respect to each reactant.

The reaction is represented by the equation shown.

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

A student conducted three experiments to find out how the initial rate is affected by the temperature and initial concentration of $S_2O_8^{2-}$.

experiment	temperature / °C	volume of $S_2O_8^{2-}$ / cm^3	volume of I^- / cm^3	volume of water / cm^3
1	50	25.0	25.0	0.0
2	50	12.5	25.0	12.5
3	70	25.0	25.0	0.0

(a) Explain, in terms of collision theory, how the initial rate of experiment 1 would compare with that of experiment 2.

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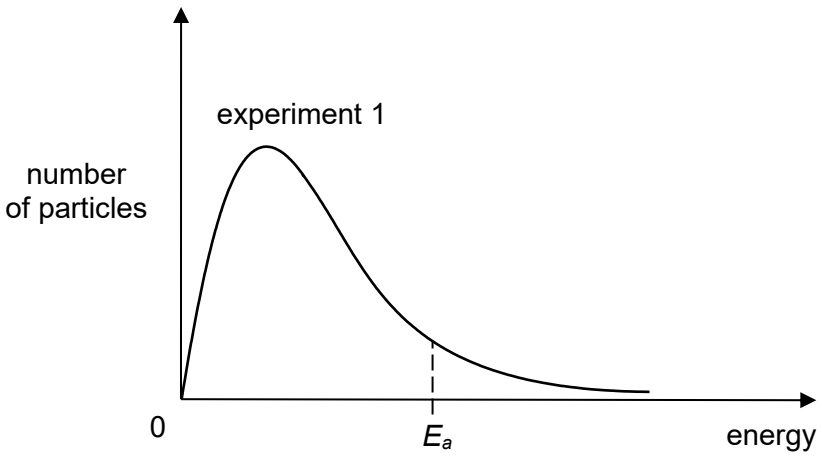
……[2]

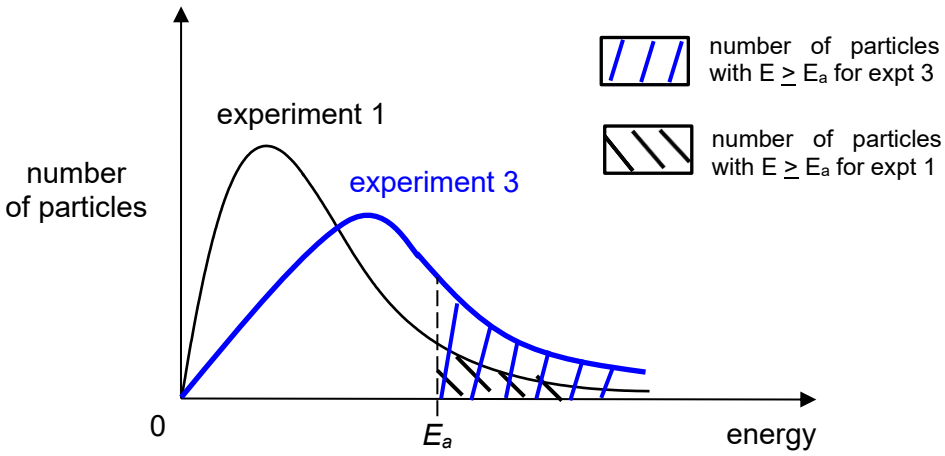
In experiment 1, the concentration of $S_2O_8^{2-}$ is higher, and the number of $S_2O_8^{2-}$ ions per unit volume is higher. The frequency of collisions increases.

Hence the frequency of effective collisions also increases. Initial rate of experiment 1 is faster than that of experiment 2.

(b) (i) The following curve shows the Boltzmann distribution for the molecular energies of the reaction mixture of experiment 1. The activation energy is labelled E_a.



On the same axes, draw a second Boltzmann distribution curve for the molecular energies of the reaction mixture of experiment 3. [1]



(ii) Using the original curve and the curve you have drawn in **(b)(i)**, explain the difference between the rate of reaction of experiments 1 and 3.

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……[2]

When the temperature is increased,

- The average kinetic energy of the particles increases.
- There is an increase in the fraction of particles with energy equal to or greater than the activation energy, E_a / this is as shown by the larger shaded area at a higher temperature in the above diagram.
- This result in an increase in the frequency of effective collisions
- A higher temperature also results in a larger rate constant k and hence an increase in reaction rate for reaction 3.

[Total: 5]

6 (a) Ethanoic acid and ethanol react in the presence of hot concentrated sulfuric acid, H_2SO_4, to form an ester, ethyl ethanoate, as shown in the equilibrium below.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

(i) Write an expression for the equilibrium constant, K_c, for the above reaction.

[1]

$$K_c = \frac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3CH_2OH][CH_3COOH]}$$

(ii) A mixture is prepared in which the initial concentrations of $CH_3COOH(l)$ and $CH_3CH_2OH(l)$ are both 0.5 mol dm^{-3}. After equilibrium is established, the concentration of $CH_3COOCH_2CH_3(l)$ is 0.34 mol dm^{-3}.

Use the information given to complete Table 6.1. You may assume there is no change in volume.

Table 6.1

	$CH_3COOH(l)$ + $CH_3CH_2OH(l)$ ⇌ $CH_3COOCH_2CH_3(l)$ + $H_2O(l)$			
initial concentration / mol dm^{-3}	0.5	0.5	0	0
change in concentration / mol dm^{-3}				
equilibrium concentration / mol dm^{-3}			0.34	

[2]

	$CH_3COOH(l)$ + $CH_3CH_2OH(l)$ ⇌ $CH_3COOCH_2CH_3(l)$ + $H_2O(l)$			
initial concentration / mol dm^{-3}	0.5	0.5	0	0
change in concentration / mol dm^{-3}	- 0.34	- 0.34	+0.34	+0.34
equilibrium concentration / mol dm^{-3}	0.16	0.16	0.34	0.34

(iii) Hence, determine the value of K_c for this reaction.

[1]

$$K_c = \frac{(0.34)(0.34)}{(0.16)(0.16)} = 4.52$$

(iv) State and explain the immediate effect on the equilibrium of adding a few drops of aqueous sodium hydroxide to the mixture.

……

……

……[2]

NaOH reacts with CH_3COOH, causing $[CH_3COOH]$ to decrease.
Equilibrium position shifts left to increase the $[CH_3COOH]$.

(b) 25.0 cm^3 of 0.100 mol dm^{-3} ethanoic acid, CH_3COOH, is added to 25 cm^3 of 0.100 mol dm^{-3} of barium hydroxide, $Ba(OH)_2$, which is a strong base.

(i) Given that 1 mole of CH_3COOH reacts with 0.5 moles of $Ba(OH)_2$, show that $Ba(OH)_2$ is in excess.

[1]

Amount of CH_3COOH = 0.0025 mol

Amount of $Ba(OH)_2$ = 0.0025 mol

Amount of $Ba(OH)_2$ required to react with 0.0025 mol CH_3COOH = 0.0025 ÷ 2 = 0.00125 mol, which is less than the amount of $Ba(OH)_2$ available, so $Ba(OH)_2$ is in excess.

(ii) Determine the concentration of $Ba(OH)_2$ remaining in the resultant solution.

[1]

Amount of unreacted $Ba(OH)_2$ = 0.0025 – 0.00125 = 0.00125 mol
$[Ba(OH)_2]$ remaining = $0.00125 \div \frac{50}{1000}$ = 0.0250 mol dm^{-3}

(iii) Using your answer in **(b)(ii)**, calculate the pH of the resultant solution.

[1]

$[OH^-] = 2 \times 0.025 = 0.0500\ moldm^{-3}$

$pOH = -\log 0.0500 = 1.30$

$pH = 14 - 1.3 = 12.7$

(c) A buffer solution **J** can be made from ethanoic acid, CH_3COOH, and sodium ethanoate, CH_3COONa.

(i) Explain what is meant by the term *buffer solution*.

……

……

……[1]

A buffer solution is a solution whose pH does not change significantly on the addition of a small amount acid or base.

(ii) Write two equations to show how **J** behaves as a buffer when small amounts of $OH^-(aq)$ and $H_3O^+(aq)$ are separately added to portions of **J**.

……

……[2]

$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

$CH_3COO^- + H_3O^+ \rightarrow CH_3COOH + H_2O$

[Total: 12]

Section B

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

7 (a) Magnesium nitride is used in high-temperature industrial processes, such as the production of ceramics and metal alloys. In contrast, another magnesium compound, magnesium chloride, is commonly used as a de-icing agent during winter in colder climates.

Table 7.1 shows the melting points of magnesium nitride and magnesium chloride.

Table 7.1

compound	Mg_3N_2	$MgCl_2$
melting point / °C	1500	714

Explain, in terms of structure and bonding, the difference in their melting points.

……

……

……

……

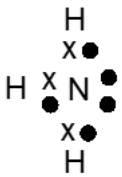
……[2]

Both have giant ionic lattice structures with strong electrostatic forces of attraction between oppositely charged ions. N^{3-} has a higher charge and smaller ionic radius than Cl^-. Hence more energy is required to overcome the stronger ionic bonds between Mg^{2+} and N^{3-}.

(b) (i) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

Draw a 'dot-and-cross' diagram to show the bonding in ammonia, NH_3.

[1]



(ii) State the shape and bond angle in a molecule of ammonia.

……

……..……...[1]

trigonal pyramidal
107°

(c) Ammonia reacts with a proton to form the ammonium ion.

State the type of bond that forms between ammonia and a proton.

……[1]
Dative bond

(d) While ethene and ammonia do not react together under normal conditions, they can react together under specific conditions, such as under high pressure and temperature with a catalyst, but this is not a typical reaction.

In a series of experiments, the reaction was carried out with different concentrations of ammonia and ethene.

The initial concentration and rate data obtained for each experiment is given in Table 7.2.

Table 7.2

experiment	$[CH_2CH_2]$ / mol dm^{-3}	$[NH_3]$ / mol dm^{-3}	relative initiate rate / mol dm^{-3} min^{-1}
1	5.00×10^{-4}	5.00×10^{-4}	1.00
2	1.00×10^{-3}	5.00×10^{-4}	2.00
3	8.00×10^{-4}	1.00×10^{-3}	3.20

(i) Use these data to deduce the order of reaction with respect to each of the two reactants.

Show how you arrived at your answers.

[3]

Comparing experiment 1 and 2,
When $[CH_2CH_2]$ doubles, keeping $[NH_3]$ constant, rate doubles.
Order of reaction with respect to CH_2CH_2 = 1

rate = $k[CH_2CH_2][NH_3]^b$

Comparing experiment 1 and 3,

$$\frac{rate_1}{rate_3} = \frac{k(5 \times 10^{-4})(5 \times 10^{-4})^b}{k(8 \times 10^{-4})(1 \times 10^{-3})^b} = \frac{1}{3.2}$$

$$\frac{5}{8}\left(\frac{1}{2}\right)^b = \frac{5}{16}$$

$$\left(\frac{1}{2}\right)^b = \frac{1}{2}$$

b = 1

order of reaction with respect to NH_3 = 1

(ii) Hence, write a rate equation for the reaction.

……[1]

rate = $k[CH_2CH_2][NH_3]$

(iii) Using your answer to **d(ii)** and data from Table 7.2, determine the rate constant, *k*.

State the units for *k*.

[2]

rate = $k[CH_2CH_2][NH_3]$
$1.00 = k(5.00 \times 10^{-4})(5.00 \times 10^{-4})$
$k = 4.00 \times 10^6$ mol^{-1} dm^3 min^{-1}

(e) Alkenes can be oxidised to carboxylic acids. When pent-1-ene is oxidised, butanoic acid is one possible product formed. Two possible constitutional isomers of butanoic acid are shown in Table 7.3.

Table 7.3

isomer 1	isomer 2
$(CH_3)_2CHCOOH$	$HCOOCH_2CH_2CH_3$

Name these two isomers.

isomer 1 ……..…….

isomer 2 ……

[2]

Isomer 1: methylpropanoic acid
Isomer 2: propyl methanoate

(f) Define the term *standard enthalpy change of neutralisation*.

……

……..……..…….[1]

Heat change when an acid and a base react to form one mole of water at 298 K and 1 bar.

(g) To determine the maximum change in temperature when sodium hydroxide is added to hydrochloric acid, the following experiment was carried out.

1. 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid is transferred to a polystyrene cup.
2. The initial temperature of the hydrochloric acid before sodium hydroxide is added is measured and recorded.
3. 5.0 cm^3 portions of aqueous sodium hydroxide are added to the polystyrene cup. The temperature of the solution in the cup is measured after each addition. The maximum temperature occurs when complete neutralisation has been achieved.

The results are shown in Fig. 7.1.

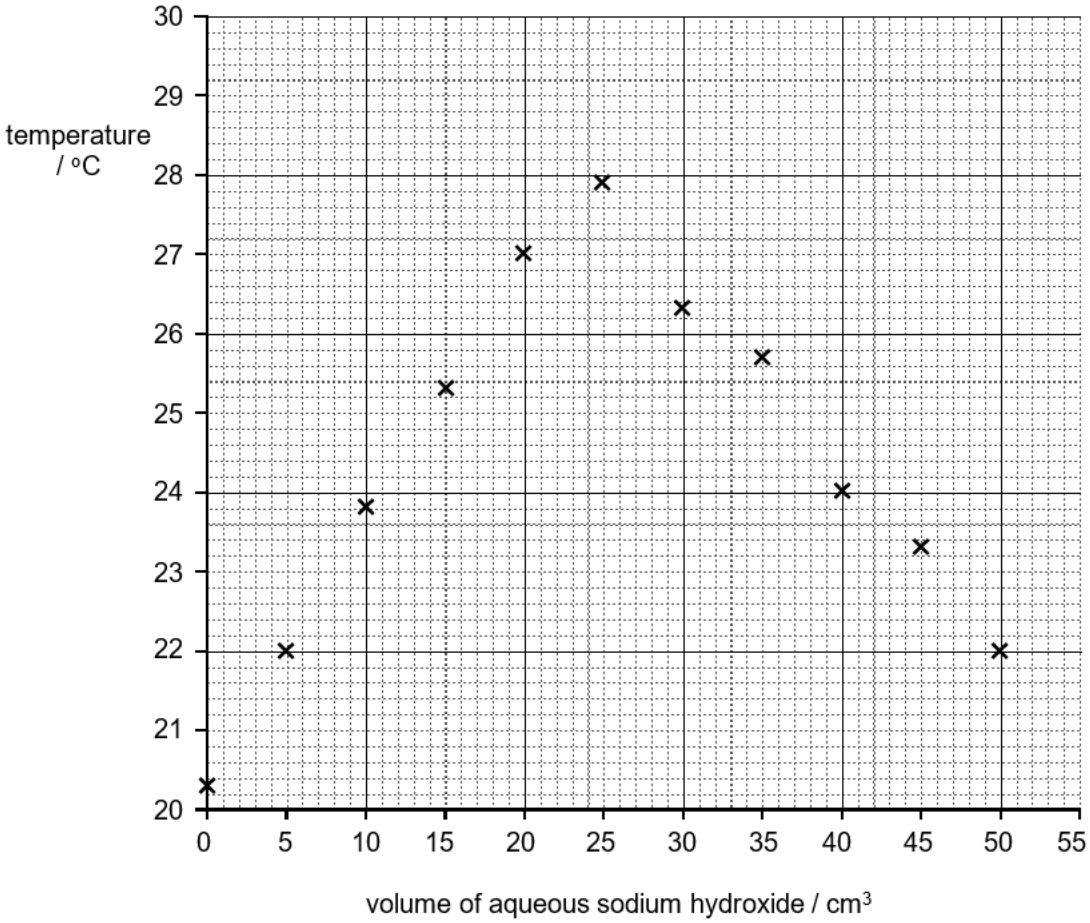


Fig. 7.1

(i) Draw two separate straight lines of best fit in Fig. 7.1.

The first line should take into account the increasing temperatures.

The second line should take into account the decreasing temperatures.

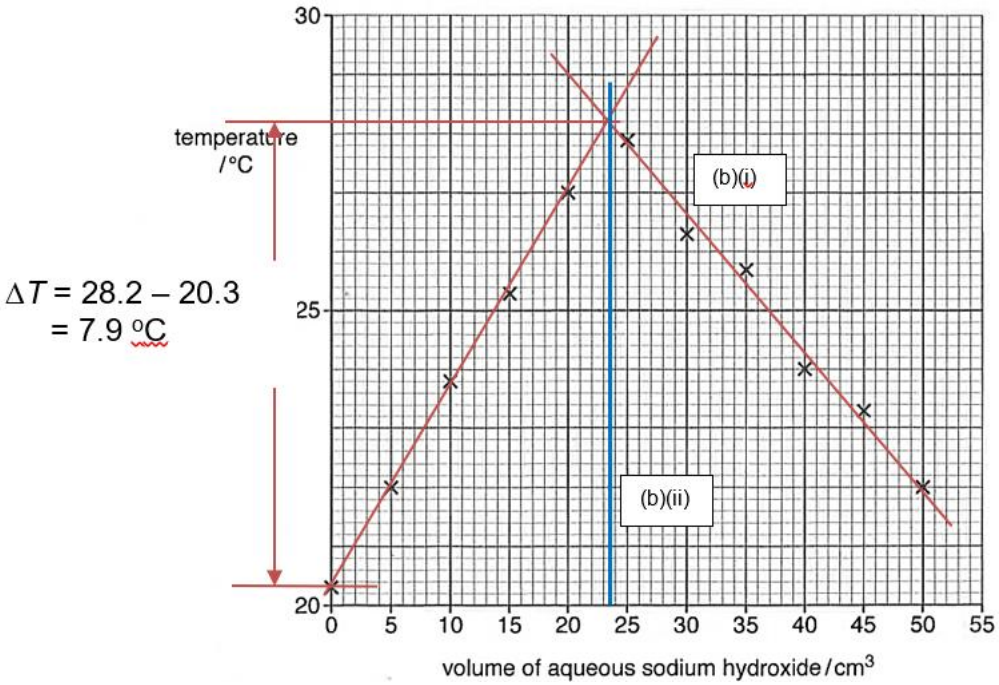
Extend these lines until they intersect (cross).

Use your graph to determine the maximum temperature rise, ΔT_{max}, of the experiment.

Show your working.

ΔT_{max} = ……..…… °C

[2]



ΔT_{max} = 28.2 – 20.3 = 7.9 °C

(ii) Use your graph to determine the volume of sodium hydroxide, V_{NaOH}, required to neutralise the acid.

Show on your graph how you determined this value.

V_{NaOH} = ... cm^3

[1]

23.5 cm^3

(iii) Using your answers to **(g)(i)** and **(g)(ii),** calculate the energy, in kJ, evolved during the reaction.

You should assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and the density of each solution is 1.00 g cm^{-3}.

[1]

heat evolved = (25.0 + 23.5) × 4.18 × 7.9 = 1601.57 J = 1.60 kJ

(iv) Using your answer to **(g)(iii),** calculate a value for the enthalpy change of neutralisation, in kJ mol^{-1}, for the reaction between hydrochloric acid and sodium hydroxide.

[2]

amount of water formed = amount of HCl = 0.025 mol

$\Delta H_n^{\ominus}$ = - 1.60157 ÷ 0.025
= - 64.1 kJ mol^{-1}

[Total: 20]

8 (a) The Group 17 elements, chlorine, bromine and iodine, are non-metals that show trends in their physical and chemical properties.

(i) Name the bond present in a molecule of chlorine.

……[1]

Covalent bond

(ii) Give the definition of the bond present in a molecule of chlorine.

……

……[1]

It is the electrostatic forces of attraction between two positively charged chlorine nuclei and the shared pair of electrons.

(iii) When KI(aq) is added to Br_2(aq), the colour of the final solution is brown.

Explain this observation using the relative oxidising power of the Group 17 elements.

Write an equation to illustrate your answer.

……

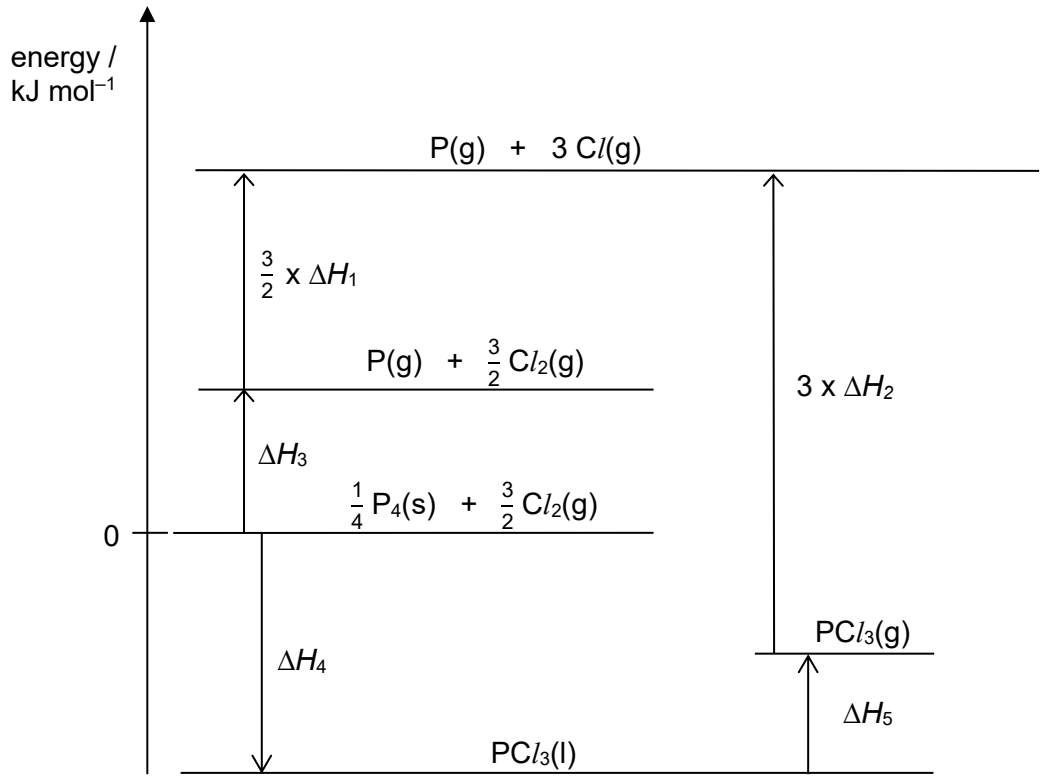
……

……[2]

Oxidising power of halogens decrease down the group. Bromine oxidises iodide to form iodine.

$Br_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Br^-(aq)$

(b) Liquid phosphorous trichloride can be prepared in the laboratory by the reaction of chlorine with red phosphorus. An energy level diagram which starts from $P_4(s)$ and $Cl_2(g)$ is shown below.



(i) Define the term *standard enthalpy change of formation*.

……

……[1]

Heat change when one mole of a compound is formed from its constituent elements in their standard physical states at 298 K and 1 bar.

(ii) State the enthalpy changes that are represented by ΔH_1 and ΔH_4.

ΔH_1 ……

ΔH_4 ……

[2]

- ΔH_1 : bond energy (Cl–Cl)
- ΔH_4 : ΔH^{θ}_f ($PCl_3(l)$)

(iii) Hence, use the information given below and relevant data from the *Data Booklet* to calculate the bond energy of the P–C*l* bond in PCl_3.

ΔH_3	+314.6 kJ mol^{-1}
ΔH_4	–319.7 kJ mol^{-1}
ΔH_5	+31.0 kJ mol^{-1}

[2]

By Hess law,
$\Delta H_4 = \Delta H_3 + 3/2 \times \Delta H_1 - 3 \times \Delta H_2 - \Delta H_5$
–319.7 = +314.6 + 3/2 (244) - 3 x BE (P-Cl) - 31.0
BE (P-Cl) = +323 kJ mol^{-1}

(c) Methanol is an important alcohol used in fuel blends and in the production of methyl esters. It can be oxidised to formaldehyde for the manufacture of urea–formaldehyde resin glues.

Methanol is manufactured industrially from carbon monoxide and hydrogen gas in an enclosed system. A dynamic equilibrium is established as shown.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -90 \text{ kJ mol}^{-1}$$

The reaction is typically subjected to the following industrial conditions.

pressure	50 MPa
temperature	250 °C
catalyst	copper-zinc oxide mixture

(i) Define the term *dynamic equilibrium*.

……

……

……[1]

A dynamic equilibrium refers to a reversible reaction where the forward and reverse reactions are continuing at the same rate and concentrations of both reactants and products are constant.

(ii) Explain the effect the high pressure and use of catalyst has on

- the position of equilibrium
- the rate of reaction

effect of high pressure

……

……

……

……

effect of catalyst

……

……

……

……
[3]

Pressure
By Le Chatelier's Principle, with a high pressure of 50 MPa, the equilibrium position will shift to the right so as to favour the production of less gaseous molecules to reduce the pressure.

At higher pressure, the reaction proceeds at a faster rate due to more effective collisions.

Catalyst:
There is no change to the equilibrium position, as the catalyst speeds up the rate of both forward and backward reaction to the same extent.

Rate of the reaction increases due to lowering of activation energy

(iii) The reaction is performed at a moderately high temperature of 250 ^{o}C.

Suggest why a low temperature is not used industrially instead.

……[1]

The reaction will be very slow if performed at low temperature.

(d) An alkene, $CH_2=CHCH(OH)CH_2CO_2H$, can be polymerised to form two different polymers.

Draw a repeat unit for each of the polymers. In each case, state the type of polymerisation involved.

repeat unit for polymer 1

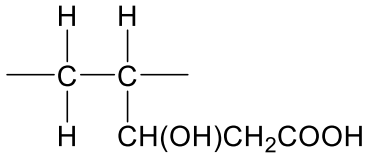
type of polymerisation: ……

repeat unit for polymer 2

type of polymerisation: ……

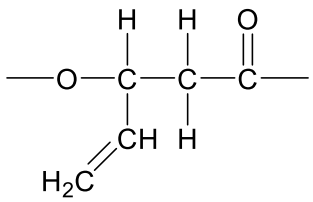
[4]

repeat unit for polymer 1



type of polymerisation: addition polymerisation

repeat unit for polymer 2



type of polymerisation: condensation polymerisation

(e) Copper(II) nitrate decomposes on heating.

$$2Cu(NO_3)_2 \rightarrow 2CuO + 4NO_2 + O_2$$

Explain why this is redox reaction, in terms of oxidation numbers.

……

……

……

……[2]

N is being reduced as the oxidation number of N decreases from +5 in $Cu(NO_3)_2$ to +4 in NO_2.

O is being oxidised as the oxidation number of O increases from -2 in $Cu(NO_3)_2$ to 0 in O_2.

[Total: 20]