Suggested Solutions

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H1 CHEMISTRY 8873/02

Paper 2 Structured Questions

18 September 2025
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class 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.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Section A
Answer **all** questions.

Section B
Answer **one** question.

A Data Booklet is provided.

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	/10
5	/14
6	/5
Section B	
7 / 8	/20
Total	/80

This document consists of **23** printed pages.

Section A

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

1 (a) *Use of the Data Booklet is relevant to this question.*

Chlorine has 25 isotopes, ranging from ^{28}Cl to ^{52}Cl.

(i) Complete Table 1.1 to show the number of each sub-atomic particle present in an $^{39}Cl^{+}$ ion.

Table 1.1

	number of protons	number of electrons	number of neutrons
$^{39}Cl^{+}$	**17**	**16**	**22**

[1]

A sample of chlorine contains three isotopes. Data for two of the isotopes present in this sample is shown in Table 1.2.

Table 1.2

mass number	abundance
35	68.43%
37	21.70%

The sample of chlorine has a relative atomic mass, A_r, of 35.53.

(ii) Calculate the mass number of the third isotope.

[2]

Abundance of the third isotope
= 100% – 68.43% – 21.70%
= 9.87%

Let the mass number of the third isotope be x.

$$35.53 = \left(35 \times \frac{68.43}{100}\right) + \left(37 \times \frac{21.70}{100}\right) + \left(x \times \frac{9.87}{100}\right)$$

$$x = 35.97 \approx \mathbf{36}\ (nearest\ whole\ number)$$

A beam of $^{35}Cl^{+}$ ions is deflected in an electric field.

(iii) State one similarity and one difference in the expected behaviour of a beam of $^{35}Cl^{-}$ ions in the same electric field. Briefly explain your answer.

[2]

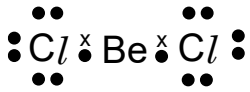
Similarity: The angle of deflection of both beams are of the same magnitude. This is because both ions have the same $\left|\frac{charge}{mass}\right|$ ratio.

Difference: The beams are deflected to opposite directions. The beam of $^{35}Cl^+$ cations is attracted to the negative plate while the beam of $^{35}Cl^-$ anions is attracted towards the positive plate.

(b) Beryllium chloride is a simple molecule with an electron–deficient central atom.

(i) Draw a 'dot–and–cross' diagram for the $BeCl_2$ molecule.

[1]



(ii) Name the shape of the $BeCl_2$ molecule.

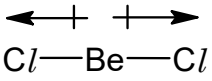
[1]

Linear

(iii) Deduce whether $BeCl_2$ is a polar molecule. Explain your answer.

[1]

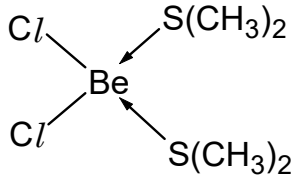
It is a non–polar molecule as the dipole moments cancel out.



$BeCl_2$ reacts with $S(CH_3)_2$ in a 1:2 ratio. Co-ordinate bonds are formed between Be and S atoms.

(iv) Draw a diagram to show the structure of the product. You should also show the co-ordinate bonds clearly.

[1]



(v) Suggest the bond angle around beryllium in the product. Explain your answer using Valence Shell Electron Pair Repulsion theory.

[2]

The bond angle is 109.5°. The 4 bond pairs are arranged as far apart as possible to minimise repulsion.

[Total: 11]

2 (a) Hydrogen peroxide can undergo both oxidation and reduction. On its own, it disproportionates to form water and oxygen gas.

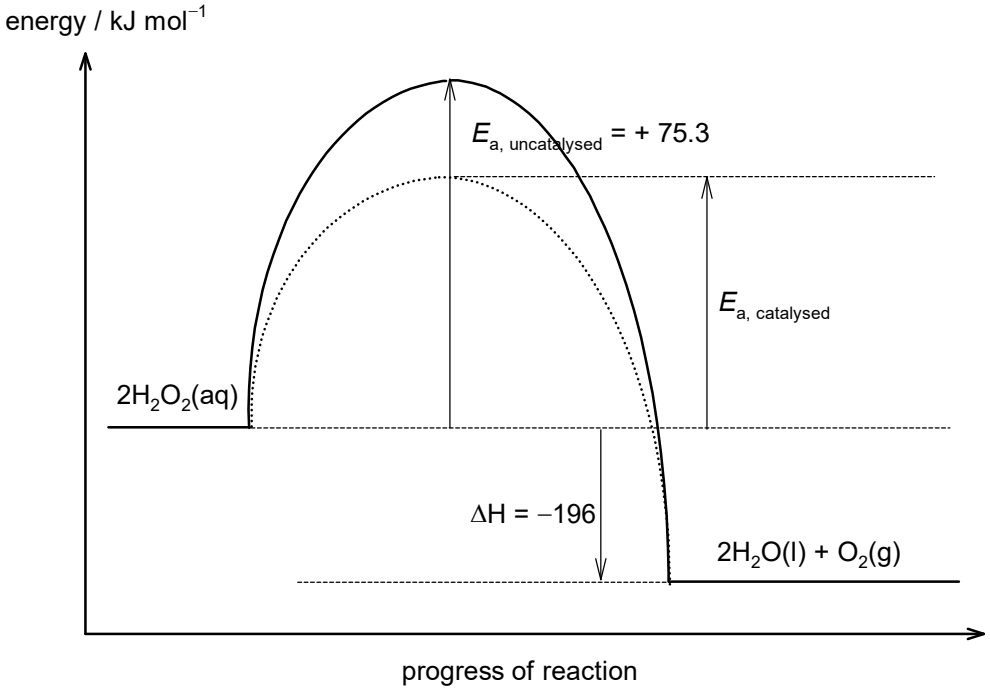
$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g) \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

(i) Sketch the energy profile diagram for the decomposition of $H_2O_2(aq)$ in Fig. 2.1.

Label the activation energy E_a and the enthalpy change of reaction ΔH.

Fig. 2.1

[2]



The uncatalysed reaction has an activation energy of +75.3 kJ mol^{-1} and occurs slowly at room temperature. Presence of iodide catalyst changes the activation energy of the decomposition reaction by 18.8 kJ mol^{-1}.

(ii) On Fig. 2.1, add the energy profile diagram for the catalysed reaction.

[1]

(iii) Determine the activation energy of the reverse reaction in the presence of iodide catalyst.

[1]

E_a of catalysed (forward) reaction = 75.3 – 18.8 = 56.5 kJ mol^{-1}

E_a of reverse reaction with catalyst
= 196 + 56.5 = 252.5 kJ mol^{-1}

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The iodide-catalysed decomposition of H_2O_2 occurs in two steps:

step 1 $H_2O_2 + I^- \rightarrow OI^- + H_2O$

step 2 $H_2O_2 + OI^- \rightarrow H_2O + O_2 + I^-$

(iv) Explain, in terms of oxidation state, what happens to H_2O_2 in step 1.

[1]

H_2O_2 is reduced as the oxidation state of oxygen is decreased from –1 in H_2O_2 to –2 in H_2O or OI^-.

(b) Under acidic conditions, H_2O_2 oxidises I^- to I_2.

(i) Write a balanced equation for the reaction between I^- and H_2O_2 under acidic conditions.

[1]

[O] $2I^- \rightarrow I_2 + 2e^-$
[R] $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$
Overall: $\mathbf{H_2O_2 + 2H^+ + 2I^- \rightarrow 2H_2O + I_2}$

(ii) Describe the expected colour change as the reaction proceeds.

[1]

The mixture turns from colourless to brown.

(c) In the presence of an acid, 0.100 mol of H_2O_2 reacts with 0.100 mol of hypobromous acid HOBr to form oxygen gas and a bromine–containing product.

(i) State the change in oxidation state of bromine in this reaction.

[1]

Half-equation for oxidation of H_2O_2
$H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$

Since H_2O_2 and HOBr reacts in a 1:1 ratio, each mole of HOBr gains 2 moles of electrons. The oxidation state of bromine is decreases by 2 OR from +1 to –1.

(ii) Hence suggest a possible identity of the bromine–containing product.

[1]

Br^- or HBr

[Total: 9]

3 (a) Fig. 3.1 shows the setup to carry out an experiment to determine the standard enthalpy change of combustion of propan-2-ol, $CH_3CH(OH)CH_3$, an ingredient commonly used in alcohol wipes and hand sanitisers. It is a versatile reagent that can be used in the synthesis of many products.

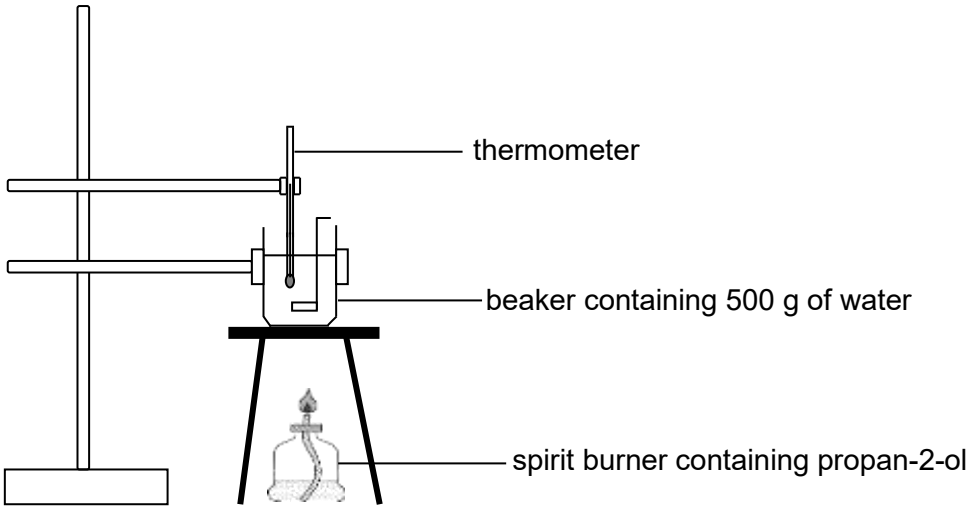


Fig. 3.1

Table 3.1 shows the experimental data obtained from the experiment.

Table 3.1

initial mass of spirit burner and propan-2-ol	44.83 g
final mass of spirit burner and propan-2-ol	41.98 g
mass of water heated	500 g
temperature rise	60.0 °C

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

[1]

Standard enthalpy change of combustion ($\Delta H_c^{\ominus}$) of a substance is the energy released when one mole of the substance is completely burnt in excess oxygen under standard conditions.

(ii) Write an equation which describes the standard enthalpy change of combustion, $\Delta H_c^{\ominus}$, of liquid propan-2-ol.

[1]

$CH_3CH(OH)CH_3(l) + \frac{9}{2}O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$

(iii) Use the data in Table 3.1 to calculate the standard enthalpy change of combustion of liquid propan-2-ol.

[Assume the specific heat capacity of water = 4.2 J g^{-1} K^{-1}]

[3]

heat absorbed by water = mcΔT
= (500) × 4.2 × 60.0
= 1.26 × 10^5 J

mass of propan-2-ol burnt = 44.83 – 41.98 = 2.85 g
n(propan-2-ol) burnt = 2.85 ÷ [3(12.0) + 8(1.0) + 16.0] = 4.75 x 10^{-2} mol

Since temperature rises, the reaction is exothermic (*i.e.* $\Delta H < 0$).

$\Delta H_c^{\ominus}$ of liquid propan-2-ol $= -\left(\frac{\text{heat change, q}}{n_{\text{substance burnt}}}\right)$

$= -\frac{126000}{\mathbf{0.0475}} = -2652632$ J mol^{-1}

$= -2650$ kJ mol^{-1}

(b) When propan-2-ol is heated with aluminium oxide, Al_2O_3, propene is formed.

State the type of reaction.

[1]

Elimination

(c) Compounds **X**, **Y** and **Z** could be Al_2O_3, Na_2O or SO_3, but not necessarily in the same order.

Table 3.2 gives some information about **X**, **Y** and **Z**.

Table 3.2

compound	observations
X	**X** is a solid that dissolves completely in water to form a dark blue solution in the presence of universal indicator.
Y	**Y** is a solid that reacts with both NaOH(aq) and HCl(aq).
Z	**Z** is a colourless liquid that turns blue litmus paper red.

(i) Using the data given, identify the compounds **X**, **Y** and **Z** and write two chemical equations to show how **X** and **Y** react with hydrochloric acid.

[3]

X is Na_2O; **Y** is Al_2O_3 and **Z** is SO_3

$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l)$

$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

(ii) **X** and **Z** are mixed in the same beaker. State the type of reaction that will occur and write an equation, including state symbols, for the reaction.

[2]

Acid-base

$Na_2O(s) + SO_3(l) \rightarrow Na_2SO_4(s)$

[Total: 11]

4 **(a)** Blood plasma is a biological fluid that plays a crucial role in maintaining pH in the body. At body temperature, the pH of arterial blood plasma is maintained at 7.40.

Carbon dioxide inhaled is dissolved in blood plasma to form carbonic acid, H_2CO_3.

$$CO_2(g) \rightleftharpoons CO_2(aq) \quad \text{----------} \ (1)$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \quad \text{----------} (2)$$

The resultant carbonic acid formed, $H_2CO_3(aq)$, then dissociates into hydrogencarbonate ions, HCO_3^- and hydrogen ions, H^+, in the following equilibrium.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \quad \text{----------} \ (3)$$

During heavy exercise, pyruvic acid synthesised in muscles is broken down into lactic acid, which is then released into the blood and buffered by the blood plasma. This eventually leads to an increase in the concentration of $CO_2(aq)$ which results in an increase in breathing.

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

[1]

It is a solution which is capable of maintaining a fairly constant pH when small amounts of acids or base are added to it.

(ii) Write an equation to show how blood plasma can buffer the pH change when lactic acid is released into the blood.

[1]

$HCO_3^- + H^+ \rightarrow H_2CO_3$

(iii) By applying *Le Chatelier's* principle, explain why an increase in concentration of lactic acid results in an increase in breathing during heavy exercise.

[3]

As lactic acid is produced during heavy exercise, there is an increase in the concentration of hydrogen ions released into the blood. By *Le Chatelier's* principle, this causes the position of equilibrium (3) to shift to the left hence increasing concentration of H_2CO_3. As a result, position of equilibrium (2) shifts to the left to counter the increase in the $[H_2CO_3]$. The increase in $[CO_2(aq)]$

causes the position of equilibrium (1) to shift to the left, producing more $CO_2(g)$ that is expelled out of the body through heavy breathing.

(b) The structural formula of pyruvic acid is shown in Fig. 4.1.

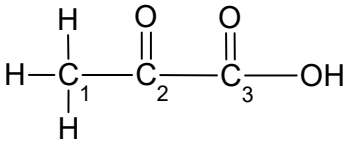


Fig. 4.1

(i) State the functional groups present in pyruvic acid.

[1]

Ketone and carboxylic acid

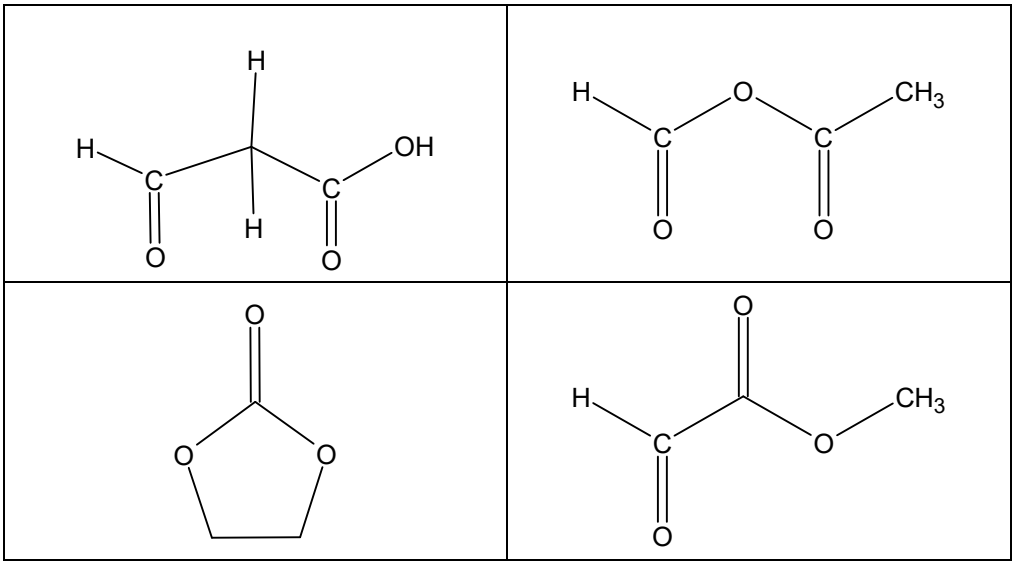
(ii) Which two carbon atoms in pyruvic acid adopt the same shape? State the bond angle around these carbon atoms.

[1]

Carbon atoms 2 and 3. 120°

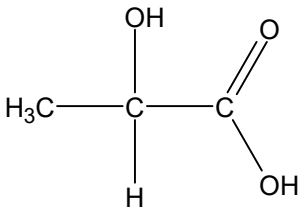
(iii) Draw one constitutional isomer of pyruvic acid, CH_3COCO_2H.

[1]



any possible structure

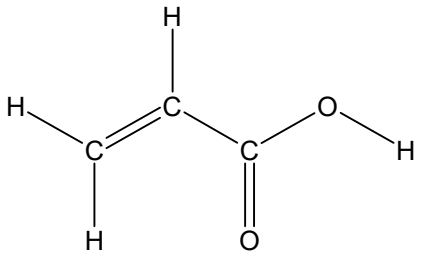
(c) Lactic acid, $C_3H_6O_3$, undergoes an elimination reaction to form compound **T** with molecular formula, $C_3H_4O_2$.



lactic acid

Draw the displayed formula of **T** and explain whether **T** can give rise to cis-trans isomers.

[2]

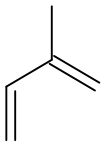


Compound **T**

T is not able to exhibit cis-trans isomers as one carbon of the carbon-carbon double bond is bonded to two identical H atoms.

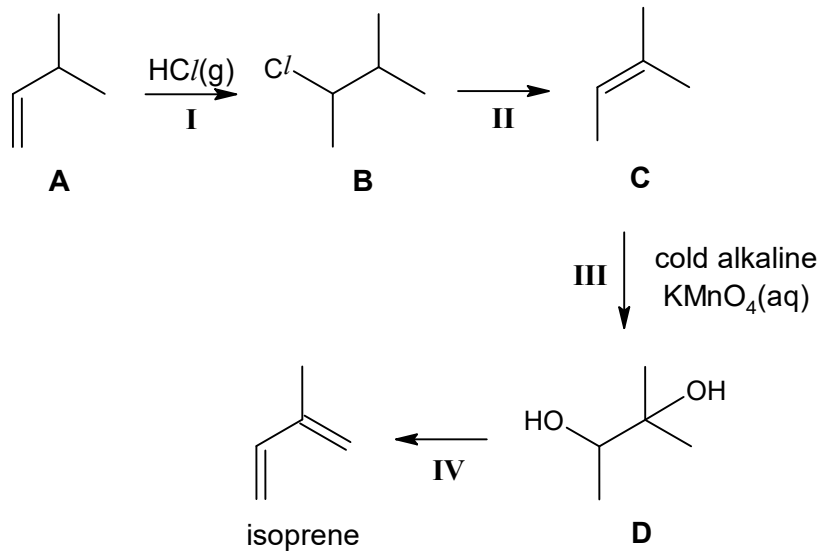
[Total: 10]

5 British and French chemists in the 19th century showed that natural rubber was a polymer of isoprene (C_5H_8). During the First World War, driven by fears that natural sources would not meet the increasing demand, a synthetic version of isoprene was produced in Germany in 1909.



isoprene

Isoprene can be synthesised from compound **A** in a 4–step process as shown.



(a) **(i)** Give the IUPAC name of compound **A**.

[1]

3-methylbut-1-ene

(ii) State the reagents and conditions used in steps **II** and **IV**.

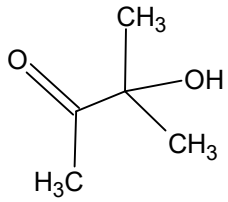
[2]

Step **II**: ethanolic NaOH, heat (under reflux)

Step **IV**: (excess) concentrated H_2SO_4, heat

(iii) Draw the structure of the product formed when compound **D** is warmed with acidified $K_2Cr_2O_7$.

[1]



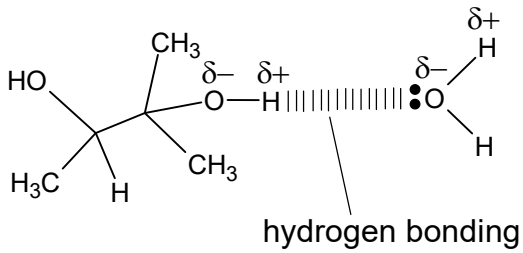
(iv) Explain, in terms of structure and bonding, why compound **B** has a higher boiling point than compound **C**.

[2]

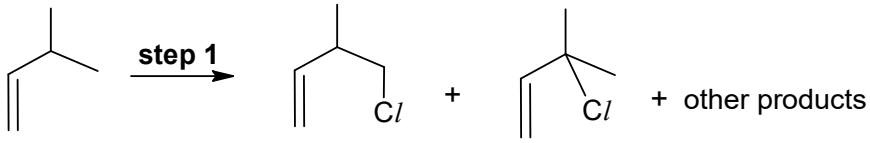
Both compound B and C have simple molecular structure. More energy is required to overcome the stronger permanent dipole – permanent dipole interactions between molecules of compound B than the instantaneous dipole-induced dipole interactions between molecules of compound C.

(v) Compound **D** is soluble in water. Draw a labelled diagram to show the interaction between **D** and a water molecule.

[1]



(b) The following reaction shows an alternative route to form an intermediate for the synthesis of isoprene.



A **F** **G**

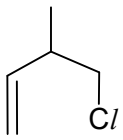
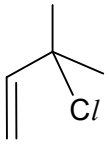
(i) State the reagents and conditions of **step 1**, which will result in formation of compounds **F** and **G**.

[1]

Cl_2(g), uv light

(ii) Predict the ratio of **F** to **G** formed in Table 5.1.

Table 5.1

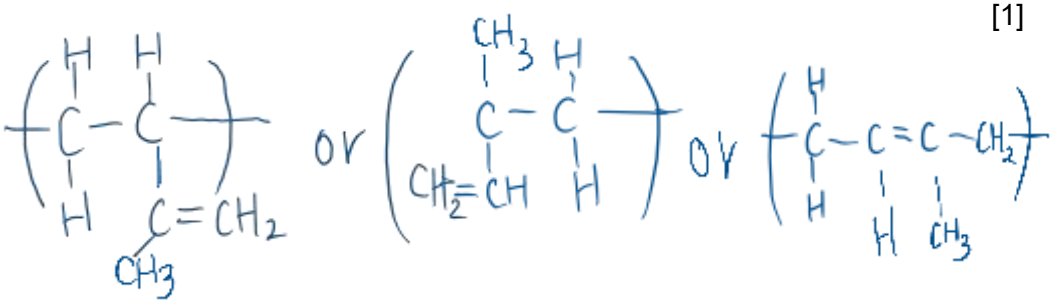
structure	 **F**	 **G**
ratio	6	1

[1]

(c) In principle, the polymerisation of isoprene can result in different types of isomeric polymers.

(i) Draw the repeating unit of one possible polymer formed from isoprene.

[1]



(ii) Many thermoplastic polymers can be converted into thermosets by heating.

Suggest how the conversion of poly(isoprene) from thermoplastic into thermoset could have taken place.

[2]

Poly(isoprene) is unsaturated as it contains C=C bonds. When heated, the pi bonds are broken, and covalent cross-links are formed between different strands of the poly(isoprene) to form a thermoset.

(d) Compound **D** can undergo polymerisation with ethanedioic acid to form the polymer as shown in Fig. 5.1.

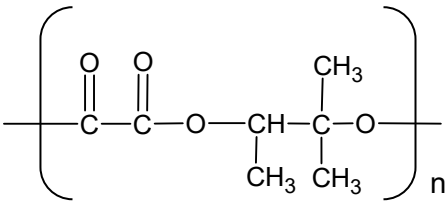


Fig. 5.1

(i) State the type of polymerisation to form the polymer in Fig. 5.1.

[1]

Condensation polymerisation

(ii) Explain why the polymer formed in Fig. 5.1 is not suitable to be used to make container to store alkaline cleaning detergents.

[1]

The alkaline solution will cause hydrolysis of the ester linkages in the polymer.

[Total: 14]

6 Nanomaterials are chemical substances or materials that are manufactured and used at a very small scale. Nanomaterials are developed to exhibit novel characteristics compared to the same material without nanoscale features, such as increased strength, chemical reactivity or conductivity.

A fullerene is an allotrope of carbon whose molecule consists of carbon atoms connected by single and double bonds so as to form a closed or partially closed mesh, with fused rings of five and six atoms. The molecule may be a hollow sphere, ellipsoid, tube, or many other shapes and sizes.

(a) Suggest what is meant by the term *allotropes*.

[1]

Same element but different structure

(b) Fig. 6.1 shows the arrangement of carbon atoms in fullerene. Use the diagram to explain how this arrangement gives fullerene the properties of high strength and high electrical conductivity.

Fig. 6.1

[2]

- One p electron per C atom delocalised, therefore exhibit high electrical conductivity.
- Each C attached to 3 other C by a network of strong covalent bonds, therefore exhibit high strength.

(c) Sunscreens block harmful ultraviolet light from the sun reaching the skin. Zinc oxide is commonly used in sunscreens as it blocks ultraviolet light. Bulk zinc oxide is white, but nanoparticulate zinc oxide is invisible on the skin.

(i) One disadvantage of nanoparticulate sunscreens is that they tend to clump together, making them difficult to apply.

Suggest another disadvantage of using these nanoparticulate sunscreens.

[1]

It may be more difficult to tell where sunscreen has been applied if is invisible on the skin.

(ii) Predict how nanoparticulate zinc oxide could present a risk to human health.

[1]

Small enough to go through the pores AND can get into the blood and affect organs.

[Total: 5]

Section B

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

7 **(a)** Group 1 metals can react with protic solvents such as water and ethanol.

For example, ethanol, CH_3CH_2OH, can react with lithium to form lithium ethoxide, $CH_3CH_2O^-Li^+$. Hydrogen gas is also produced in the reaction.

(i) Write the equation for the reaction between ethanol and lithium.

[1]

$2CH_3CH_2OH + 2Li \rightarrow 2CH_3CH_2O^-Li^+ + H_2$

(ii) Suggest an explanation, in terms of atomic structure, how you would expect the reactivity of Group 1 metals with ethanol to change down the group from lithium to rubidium.

[3]

The reactivity of Group 1 metals with ethanol will increase down the group.

Down the group, number of electron shells increases, hence there is an increase in shielding effect and the distance between the nucleus and valence electron increases.

Despite the increasing nuclear charge, electrostatic attraction between its nucleus and valence electron decreases. Hence, it becomes easier for Group 1 metals to lose their valence electron during the reaction.

(b) Both hydrogen bromide and hydrogen iodide decompose on heating to form their constituent elements.

Describe and explain the difference in the thermal stabilities of hydrogen bromide and hydrogen iodide.

[2]

HBr decomposes on strong heating while HI decomposes readily in the presence of a hot rod.

HBr is more thermally stable than HI as H—Br bond is stronger than H—I bond. Hence, more energy is required to decompose HBr.

(c) The mechanism of a reaction can be studied using kinetic studies.
Nitrogen dioxide, NO_2, reacts with fluorine gas, F_2, to form nitryl fluoride, NO_2F.

$$2NO_2(g) + F_2(g) \rightarrow 2NO_2F(g) \qquad \Delta H < 0$$

Experiment 1 was conducted using 0.0200 mol dm^{-3} of $NO_2(g)$ and 0.240 mol dm^{-3} of $F_2(g)$ at 60 °C. The results are shown in Table 7.1.

Table 7.1

time / min	$[NO_2]$ / mol dm^{-3}
0	0.0200
80	0.0158
160	0.0124
240	0.0098
320	0.0076
400	0.0060
480	0.0048

(i) Use the data in Table 7.1 to plot a graph of $[NO_2]$ against time on the grid provided in Fig. 7.1.

[2]

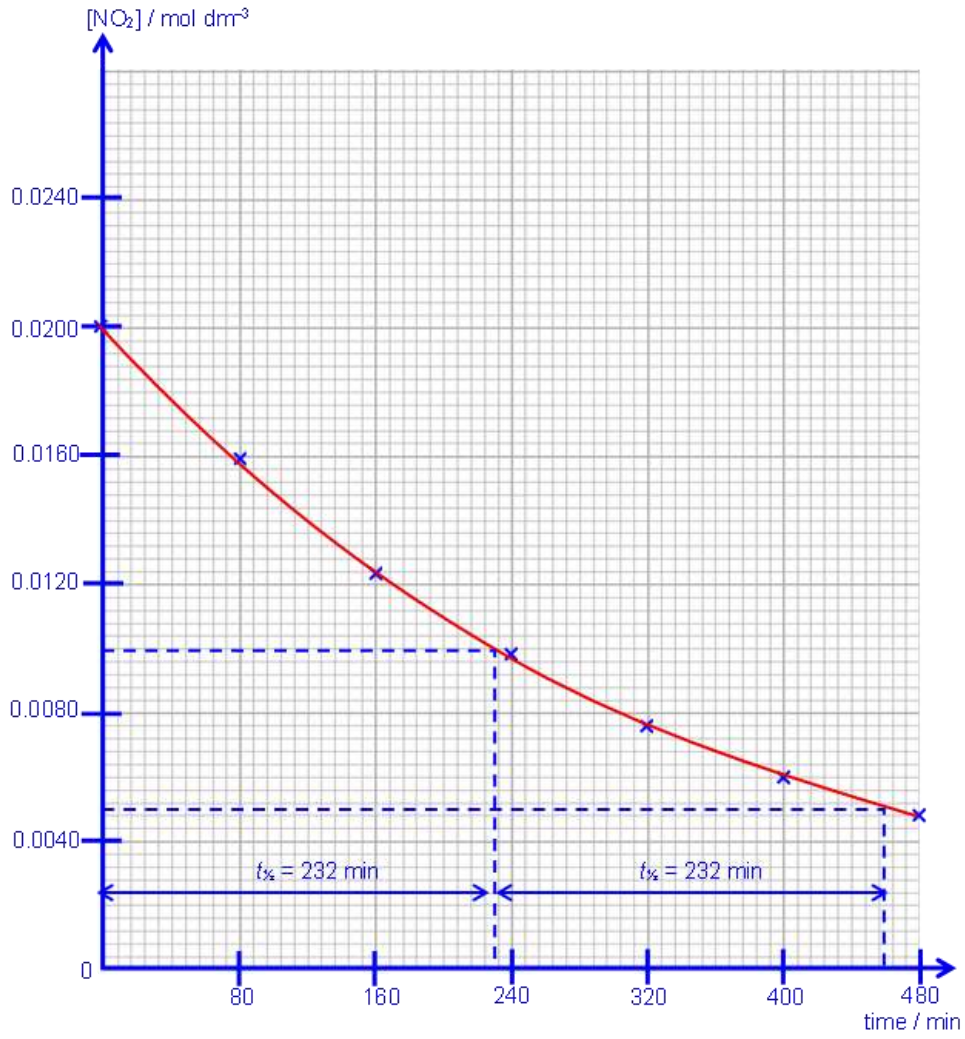


Fig. 7.1

(ii) Use your graph in Fig. 7.1 to show that the reaction is first order with respect to NO_2. Explain your reasoning.

[2]

Since $t_{½}$ is constant at 232 min, order of reaction with respect to NO_2 is 1.

(iii) Another experiment was conducted with 0.0200 mol dm^{-3} of $NO_2(g)$ and 0.480 mol dm^{-3} of $F_2(g)$ at the same temperature. The time taken for $[NO_2]$ to decrease from 0.0200 mol dm^{-3} to 0.0100 mol dm^{-3} is half that of experiment 1.

Deduce the order of reaction with respect to F_2. Explain your reasoning.

[2]

When $[NO_2]$ is kept constant and $[F_2]$ is doubled, the rate is doubled.
Hence the reaction is 1st order with respect to F_2.

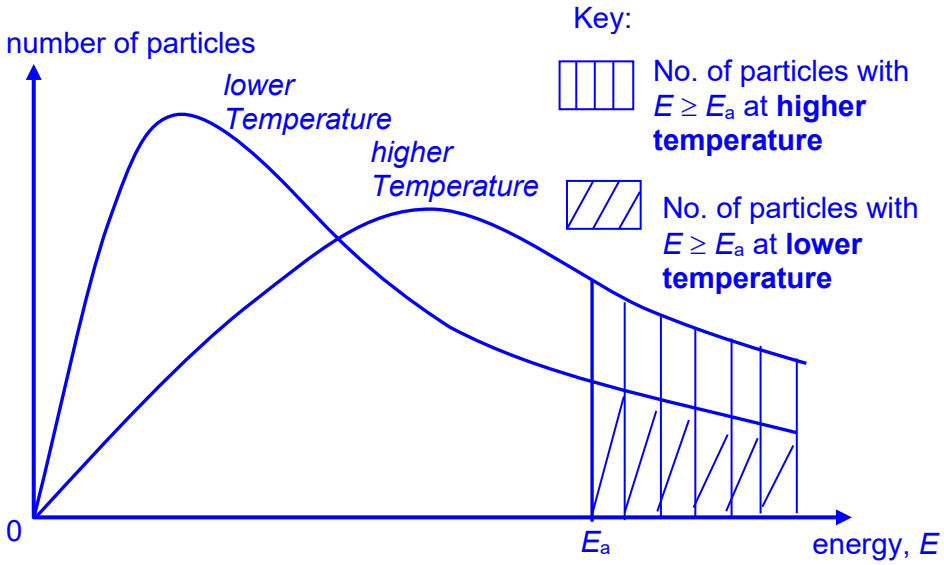
(iv) Write the rate equation for the reaction.

[1]

rate = $k[NO_2][F_2]$

(v) With the aid of a Maxwell–Boltzmann diagram, explain how increasing the temperature of this gaseous reaction affects its rate.

[3]



At higher temperature, total number of reactant particles remain unchanged but average kinetic energy of the reactant particles increases.
The number of reactant particles with energy ≥ E_a increases.
Frequency of effective collisions in the reaction increases.
Since rate of reaction is proportional to the frequency of effective collisions, the rate of reaction increases.

(d) Hexane, C_6H_{14}, burns in excess oxygen according to the equation below.

$$C_6H_{14}(l) + \frac{19}{2} O_2(g) \rightarrow 6CO_2(g) + 7H_2O(l) \qquad \Delta H = -4163 \text{ kJ mol}^{-1}$$

Calculate the mass of hexane (M_r = 86.0) to be burnt to raise the temperature of 2.00 dm^3 of water from 30.5 °C to 68.5 °C.

[2]

heat to be released = $2000 \times 4.18 \times (68.5 - 30.5)$
= 317680 J
amount of hexane to be burnt = $[317680 \div (4163 \times 10^3)]$ = 0.07631 mol
mass of hexane = 0.07631×86.0
= 6.56 g

(e) Use the following energy cycle and Table 7.2 to calculate the standard enthalpy change of formation of benzene, $\Delta H_f^{\ominus}$ ($C_6H_6(l)$).

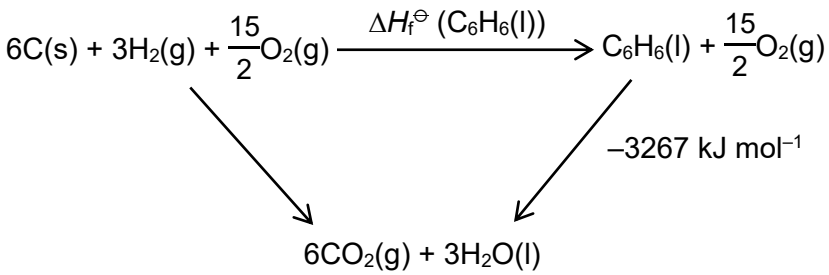


Table 7.2

standard enthalpy change of formation of $H_2O(l)$ / kJ mol^{-1}	–286
standard enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	–394

[2]

By Hess' law,
$\Delta H_f^{\ominus}(C_6H_6(l)) = [6(-394) + 3(-286)] - (-3267)$
$= +45.0$ kJ mol^{-1}

[Total: 20]

8 (a) Ammonia, NH_3, is a weak base while sodium hydroxide is a strong base.

(i) Explain the difference between a weak and a strong base.

[1]

A weak base partially dissociates in water while a strong base completely dissociates in water.

(ii) Write an equation for the reaction of ammonia with water to illustrate its behaviour as a weak base.

[1]

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

(iii) Write the expression for the base dissociation constant, K_b, for ammonia.

[1]

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$

(iv) By showing relevant calculations, determine which of the following solutions at 25 ºC has a higher concentration of OH^-.

- Solution **A**, 0.150 mol dm^{-3} aqueous sodium hydroxide
- Solution **B**, 0.200 mol dm^{-3} aqueous ammonia of pH 11.3

[2]

For solution A, $[OH^-] = [NaOH] = 0.150$ mol dm^{-3}

For solution B, pOH = 14 – pH = 14 – 11.3 = 2.7
$[OH^-] = 10^{-pOH} = 10^{-2.7} = 0.00200$ mol dm^{-3}

Since 0.150 > 0.00200, solution A has a higher concentration of OH^-.

(b) Solution **C** is a mixture of aqueous NH_3 and aqueous NaOH. A 25.0 cm^3 portion of solution **C** was transferred into a 250 cm^3 volumetric flask. The solution was made up to 250 cm^3 with deionised water.

A 25.0 cm^3 sample of the diluted solution **C** was titrated against 0.100 mol dm^{-3} aqueous hydrochloric acid. 20.40 cm^3 of aqueous hydrochloric acid was required to completely neutralise the NaOH present to reach the **first** endpoint.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Further addition of 5.40 cm^3 aqueous hydrochloric acid to the same sample of diluted solution **C** completely neutralised the NH_3 present to reach the **second** endpoint.

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$$

(i) Calculate the amount, in moles, of NH_3 present in the 25.0 cm^3 sample of diluted solution **C**.

[1]

amount of $HCl = 0.0054 \times 0.100 = 0.000540$ mol

$NH_3 \equiv HCl$
amount of NH_3 in 25.0 cm^3 diluted solution = 0.000540 mol

(ii) Calculate the concentration, in mol dm^{-3}, of NaOH present in the original solution **C**.

[3]

amount of $HCl = 0.0204 \times 0.100 = 0.00204$ mol
$NaOH \equiv HCl$
amount of NaOH in 25.0 cm^3 diluted solution = 0.00204 mol

amount of NaOH in 250 cm^3 diluted solution
$= 0.00204 \times \frac{250}{25}$
= 0.0204 mol
= amount of NaOH in 25.0 cm^3 of original solution

[NaOH] in the original solution = 0.0204 / 0.025 = 0.816 mol dm^{-3}

(iii) Table 8.1 shows some data on three indicators.

Table 8.1

indicator	colour in acid	colour in alkali	pH range of colour change
methyl orange	red	yellow	3.2 – 4.4
bromothymol blue	yellow	blue	6.0 – 7.6
thymolphthalein	colourless	blue	8.8 – 10.5

State and explain which indicator is the **most** suitable for the **second** endpoint of the titration.

[2]

Methyl orange is the most suitable indicator.

The pH at second endpoint is less than 7 for a strong acid-weak base titration between HC*l* and NH_3. Moreover, endpoint pH lies closer to the pH range of colour change of methyl orange.

(c) $(CH_3)_3CBr$ reacts with sodium hydroxide as shown below.

$$(CH_3)_3CBr(aq) + NaOH(aq) \rightarrow (CH_3)_3COH(aq) + NaBr(aq)$$

Experiments are done using these reagents and the results are shown in Table 8.2.

Table 8.2

experiment	initial $[(CH_3)_3CBr]$ / mol dm^{-3}	initial [NaOH] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	1.00	2.00	0.0100
2	1.00	3.00	0.0100
3	3.00	1.00	0.0300

(i) Use Table 8.2 to determine the order of reaction with respect to $(CH_3)_3CBr$ and with respect to NaOH.

[2]

Comparing experiments 1 & 2,
When [NaOH] × 3/2 while $[(CH_3)_3CBr]$ is kept constant, initial rate remains unchanged. Hence rate of reaction is independent of [NaOH] and the reaction is zero order with respect to NaOH.

Comparing experiments 2 & 3,
When [NaOH] × 1/3, initial rate remains unchanged at 0.0100 mol dm^{-3} s^{-1} as reaction is zero order with respect to NaOH. Hence, rate × 3 when $[(CH_3)_3CBr]$ × 3 and the reaction is first order with respect to $(CH_3)_3CBr$.

(ii) Hence write the rate equation for the reaction between $(CH_3)_3CBr$ and NaOH, stating the units of the rate constant.

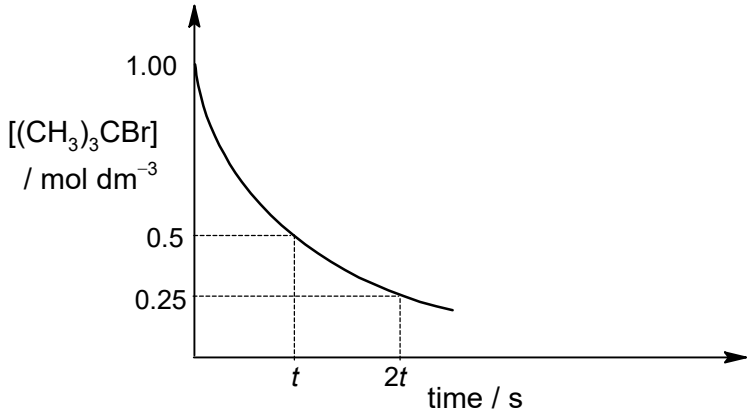
[1]

rate = $k[(CH_3)_3CBr]$
units of k = s^{-1}

(iii) On the axes provided in Fig. 8.1, sketch a graph of $(CH_3)_3CBr$ against time for experiment 1.

Explain how the shape of the graph is consistent with your answer in **(c)(i)**. You may find it useful to label key points on your graph.

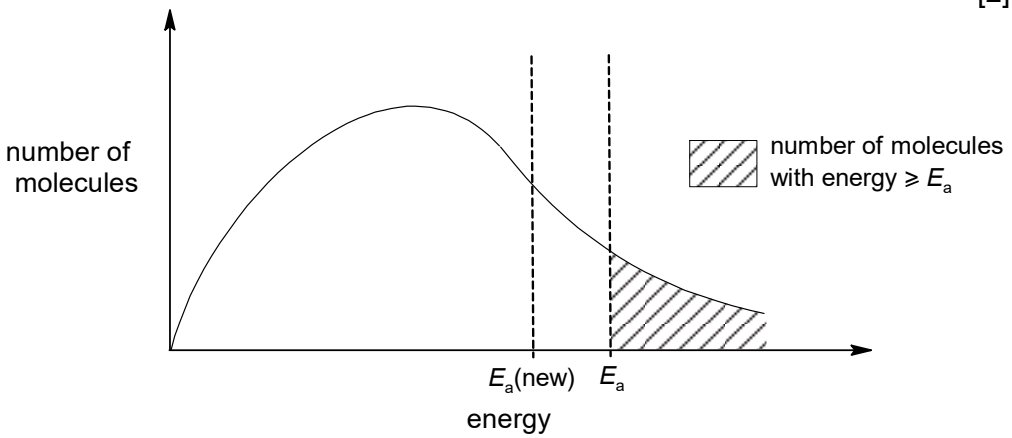
[2]



(d) **(i)** On the axes provided in Fig. 8.2, sketch a Maxwell–Boltzmann distribution for the molecular energies of a gaseous reaction mixture.

Label the activation energy, E_a.

[2]



(ii) On the same axes provided in Fig. 8.2, label the new activation energy, E_a(new), when a suitable catalyst is added to the same gaseous reaction mixture.

Hence, explain what happens to the rate of the reaction in the presence of the catalyst.

[2]

There are more molecules/particles with energy more than or equal to the lowered new activation energy.

Hence the frequency of effective collision between the molecules/particles increases and the rate of reaction increases.

[Total: 20]