

RAFFLES INSTITUTION
2023 YEAR 6 PRELIMINARY EXAMINATION

Higher 2



CANDIDATE
NAME

CLASS

INDEX NUMBER

CHEMISTRY

9729/02

Paper 2 Structured Questions

13 September 2023

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write your name, class and index number in the spaces provided 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.

A Data Booklet is provided. Do not write anything in it.

You are reminded of the need for good English and clear presentation in your answers.

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
1	/ 10
2	/ 13
3	/ 15
4	/ 11
5	/ 14
6	/ 12
Total	/ 75

This document consists of **23** printed pages and **1** blank page.

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

- 1 (a) Chlorine is an element in Group 17 of the Periodic Table.

Describe and explain how the volatilities of the halogens vary from chlorine to iodine.

.....

.....

.....

..... [2]

- (b) **X** has the formula PCl_3^+ and contains ^{31}P , ^{35}Cl and ^{37}Cl .
X is unstable and breaks down into two fragments, **Y** and **Z**.

- (i) Complete Table 1.1 to describe the characteristics of these particles.

Table 1.1

	X	Y	Z
nucleon number	140		37
charge	+1	+1	

[1]

X and **Y** were fired with equal velocity into an electric field.

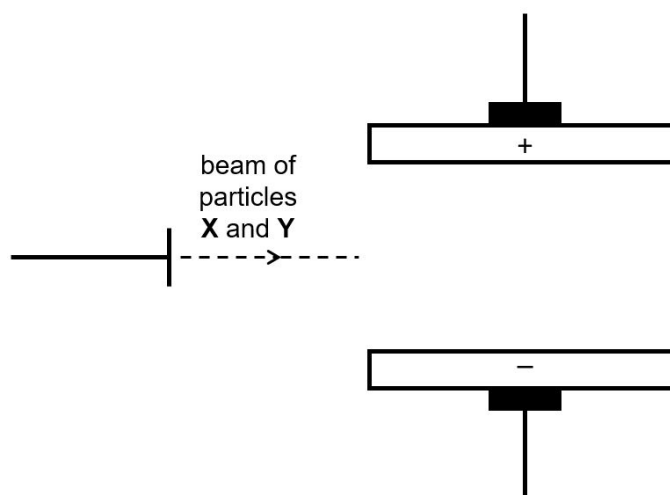


Fig. 1.1

- (ii) On Fig. 1.1, draw the paths taken by particles **X** and **Y** as they pass through the electric field. Label your drawing clearly. [1]

- (iii) Deduce the number of ^{35}Cl atoms in a particle of **Y** and give the shape of **Y**.

number of ^{35}Cl atoms in **Y**

shape of **Y** [2]

Electron affinity is a measure of the electrostatic attraction between an incoming electron and the nucleus – the stronger the attraction, the more energy is released.

The first electron affinity of an element is the energy change when one mole of gaseous atoms acquires one mole of electrons to form one mole of singly negatively charged gaseous ions.

Fig. 1.2 shows the trend in the first electron affinities of the elements aluminium to chlorine.

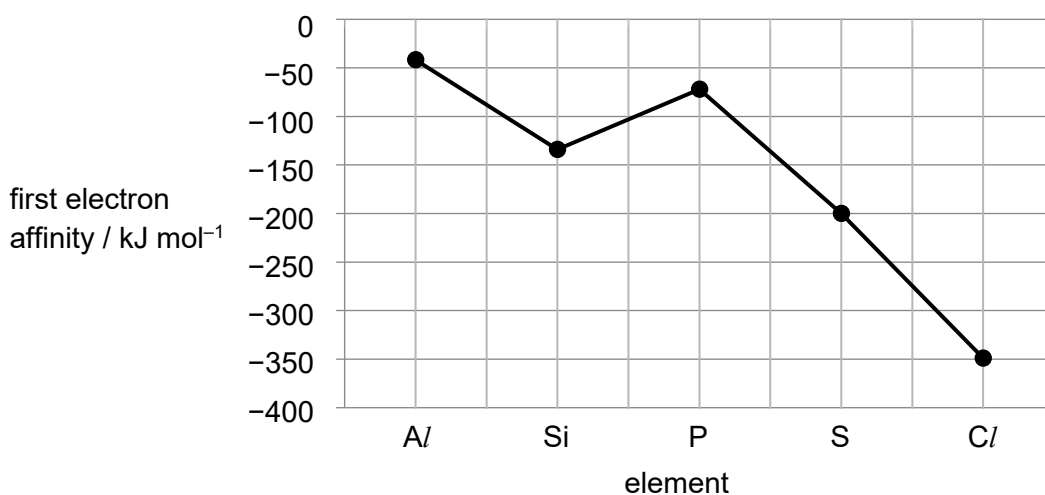
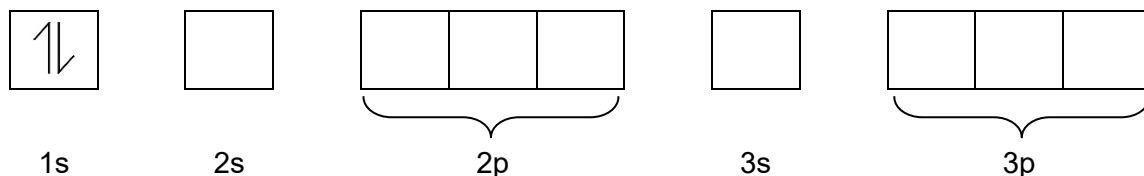


Fig. 1.2

- (c) (i) Write an equation for the first electron affinity of phosphorus.

..... [1]

- (ii) Complete the diagram to show the arrangement of electrons in the orbitals of the anion formed in (c)(i).



[1]

(iii) The magnitude of the first electron affinity generally increases from aluminium to chlorine.

- ① In terms of nuclear charge and shielding effect, provide an explanation for this general trend.

.....
.....
..... [1]

- ② Suggest why phosphorus does not follow this trend.

.....
..... [1]

[Total: 10]

2 Gold is a transition element in Period 6.

- (a) Suggest why gold has a higher density than barium.

.....
..... [1]

In small-scale gold mining, mercury is often used to extract gold from its ore.

Mercury captures fine gold particles to form an amalgam, which is a soft, solid mixture of the two metals.

- (b) A gold-mercury amalgam formed typically contains between 40% and 80% of mercury by mass.

In a particular extraction, 250 g of amalgam was obtained from 20 kg of ore.

Calculate the maximum mass of gold present in the amalgam.

[1]

To recover the gold from the amalgam, the solid is heated to vaporise the mercury which escapes into the atmosphere.

- (c) Determine the concentration, in ppm, of mercury vapour in a 1 m^3 space if just 1 g of mercury is released into the atmosphere.

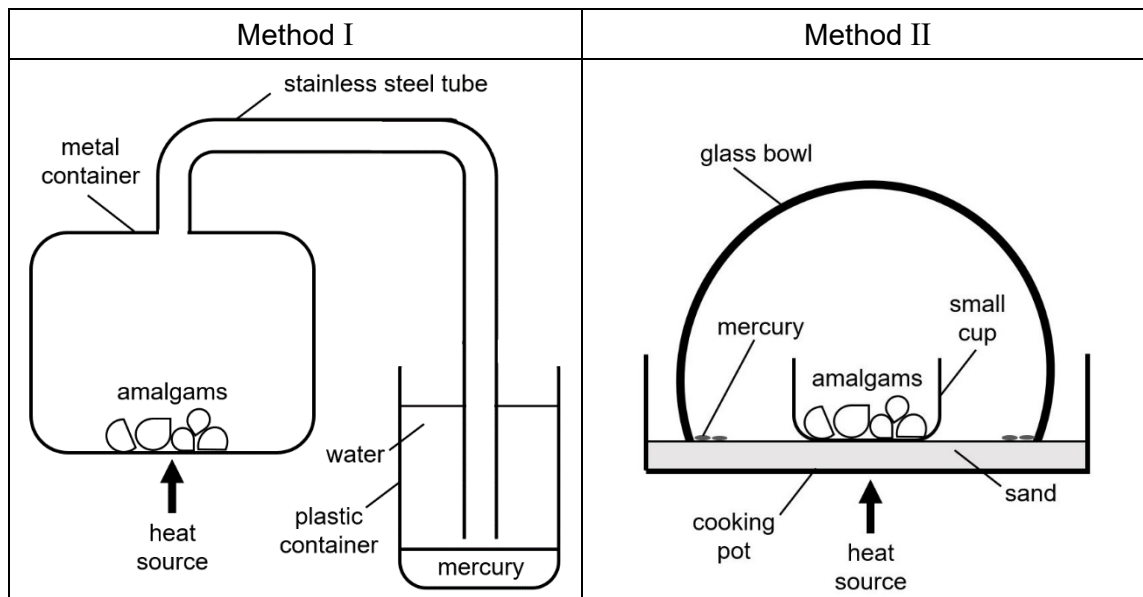
Density of air = 1.19 kg m^{-3}

(1 ppm of Hg = 1 g of Hg in 10^6 g of air)

[1]

Mercury is volatile and vapour concentrations above 0.001 ppm are considered hazardous to human health.

To reduce mercury emission from the heating process, as well as to recover the mercury, two possible methods have been recommended to help the gold miners, who are often from poverty-stricken communities.



(The above diagrams are not drawn to scale.)

- (d) (i) For Method I, besides cooling down the stainless steel tube, explain why water is needed.

..... [1]

- (ii) Suggest how Method II allows mercury to be recovered from the amalgams.

.....
 [1]

- (iii) State one advantage and one disadvantage of Method II as compared to Method I.

advantage

.....

disadvantage

.....

[2]

In the presence of oxygen, gold dissolves in an aqueous solution of KCN to form complex anion **D** and hydroxide ions.

- (e) (i) Give the half-equation for the reduction of O_2 in the above reaction.

..... [1]

- (ii) In the reaction, 1 mol of O_2 oxidises 4 mol of Au.

Determine the oxidation state of Au in the complex anion **D**.

oxidation state of Au [1]

- (iii) **D** is a linear anion, with a single gold ion in its structure.
It does not contain any oxygen or hydrogen atoms.

State the formula of **D**.

..... [1]

- (f) (i) State what is meant by the term *metallic bond*.

.....

..... [1]

- (ii) The electronic configuration of mercury is $[Xe] 4f^{14} 5d^{10} 6s^2$.
Its inner electrons provide poor shielding for its outermost electrons.
It has one of the highest first ionisation energy among metals.

By considering the information given and your answer in (f)(i), suggest why mercury is a liquid, and not a solid at room temperature.

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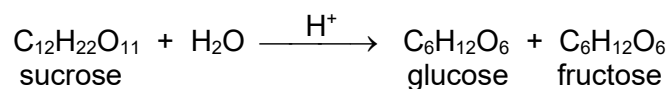
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..... [2]

[Total: 13]

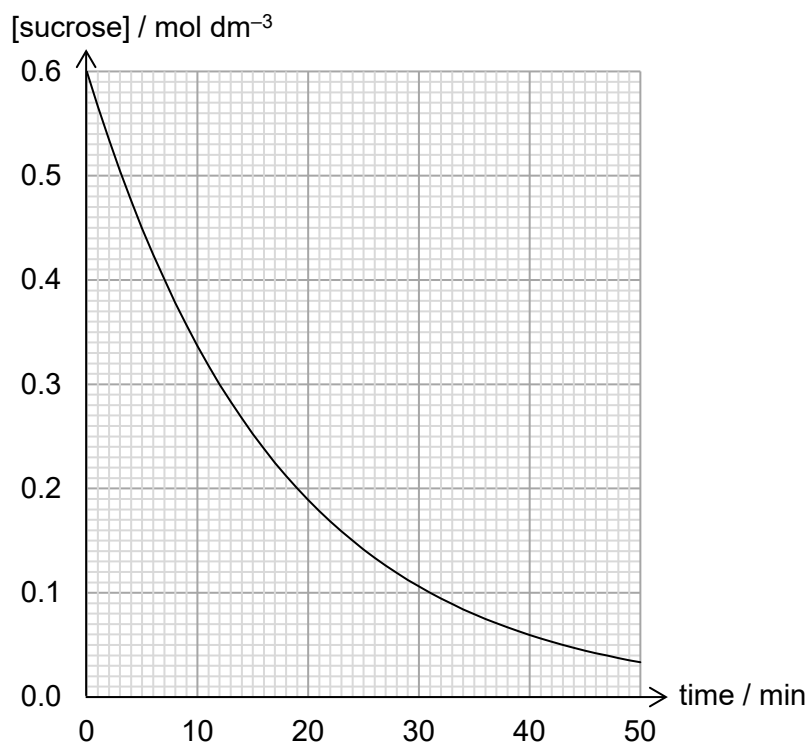
- 3 The rate of hydrolysis of sucrose can be determined experimentally using the continuous experimental method.



The hydrolysis of sucrose is catalysed by acid. The rate equation of this reaction can be written as follows.

$$\text{rate} = k[\text{sucrose}]^x[\text{H}^+]^y$$

- (a) Experiment 1 was conducted using 0.60 mol dm^{-3} sucrose with 6.0 mol dm^{-3} hydrochloric acid. The data collected from the experiment was used to plot a graph of concentration of sucrose against time.



- (i) Using the half-life method, deduce the order of reaction with respect to sucrose. Include any construction lines in your working.

- (ii) Using the graph, determine the initial rate of experiment 1.

[1]

- (iii) In experiment 2, the same concentration of sucrose solution was used, but with 2.0 mol dm^{-3} hydrochloric acid. The initial rate of experiment 2 was found to be $0.0125 \text{ mol dm}^{-3} \text{ min}^{-1}$.

Using your answer in (a)(ii), deduce the order of reaction with respect to H^+ . Show your working.

[1]

- (iv) Using the information above and data from experiment 2, calculate the value of k .

[1]

- (b) Explain, with the aid of a labelled Boltzmann distribution diagram, the effect of the presence of a catalyst on the rate of reaction.

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..... [3]

- (c) The rate constants of the following compounds undergoing the S_N2 mechanism are investigated and the results are shown in Table 3.1.

Table 3.1

reaction	rate constant / $\text{mol}^a \text{dm}^b \text{min}^{-1}$
compound A	0.614
compound B	0.0210
compound C	0.00310

- (i) The units for the rate constant in Table 3.1 is $\text{mol}^a \text{dm}^b \text{min}^{-1}$.

State the values of a and b .

a b [1]

- (ii) Describe the S_N2 mechanism between compound **A** and the ethoxide ion, $\text{CH}_3\text{CH}_2\text{O}^-$. Show all relevant charges, lone pairs and movement of electron pairs by using curly arrows.

[2]

- (iii) Explain why the reaction involving compound **C** has a significantly smaller rate constant than that of compound **A**.

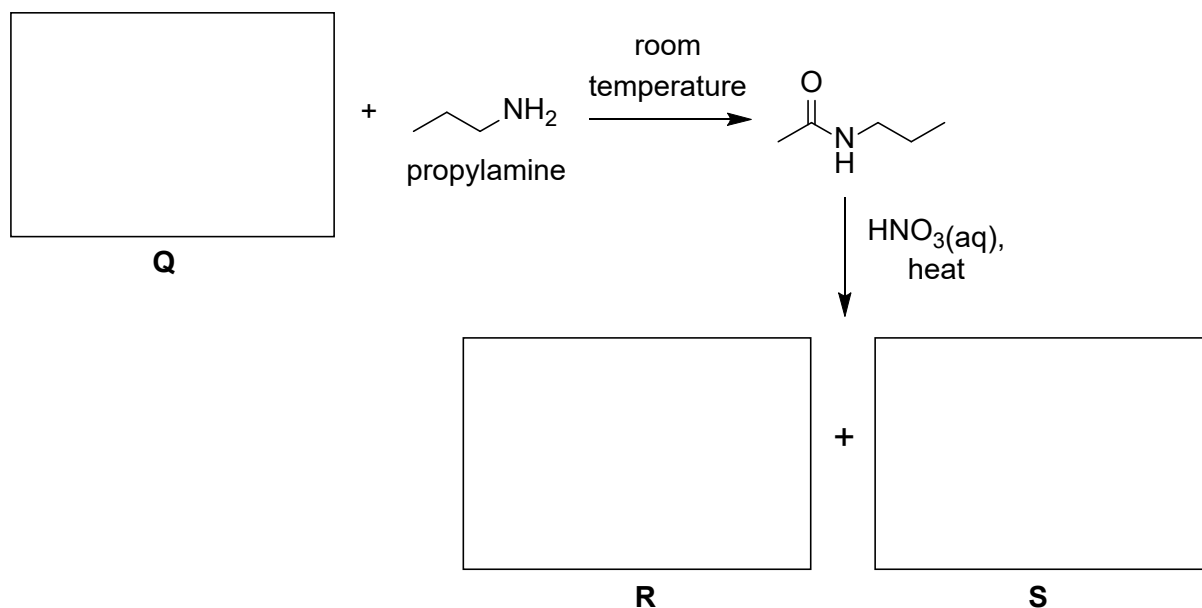
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..... [2]

- (iv) Using the concepts of electronic and steric effects, explain why compound **B** undergoes the S_N1 mechanism more readily than the S_N2 mechanism.

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.....
.....
..... [2]

[Total: 15]

- 4 (a) Draw the structures of the compounds, **Q**, **R** and **S**.



[3]

- (b) DIBAL produces the hydride ion, H^- , which acts as a nucleophile. It reacts with amides to form an aldehyde and an amine.

The first two steps of the mechanism are described below:

- In the first step, :H^- reacts with the C=O group of the amide to form an alkoxide anion intermediate.
- In the second step, the O^- in the intermediate reforms the π -bond and the C-N bond breaks.

Complete the mechanism in Fig. 4.1 for this reaction. Show the structure of the intermediate, all relevant charges, dipoles, lone pairs and curly arrows.

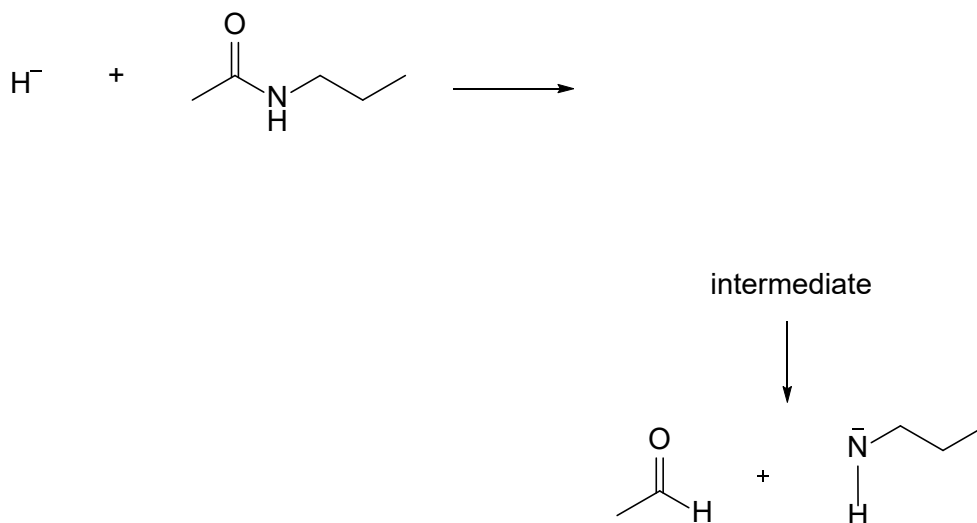


Fig. 4.1

[2]

- (c) A 25.0 cm^3 solution of 1.30 mol dm^{-3} propylamine ($K_b = 4.7 \times 10^{-4} \text{ mol dm}^{-3}$) was titrated with 0.80 mol dm^{-3} hydrochloric acid. The titration curve is illustrated in Fig. 4.2 below.

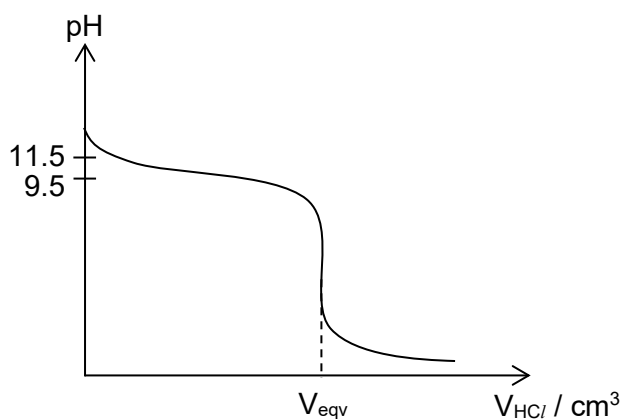


Fig. 4.2

- (i) Write an equation to show how propylamine, $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$, behaves as a weak base in water.

..... [1]

- (ii) Calculate the initial pH of the propylamine solution.

[2]

- (iii) During the titration, when $V \text{ cm}^3$ of the hydrochloric acid was added, a buffer with maximum buffering capacity was obtained.

Calculate the value of V and determine the pH of this buffer.

[2]

- (iv) The pH of the solution at the region between pH 9.5–11.5 remains approximately constant even though HCl was being added.

Using your answer in (c)(i), explain why.

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..... [1]

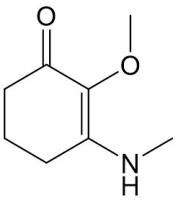
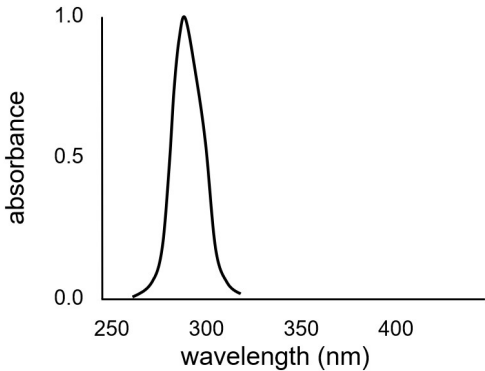
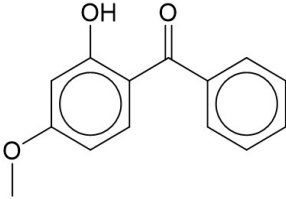
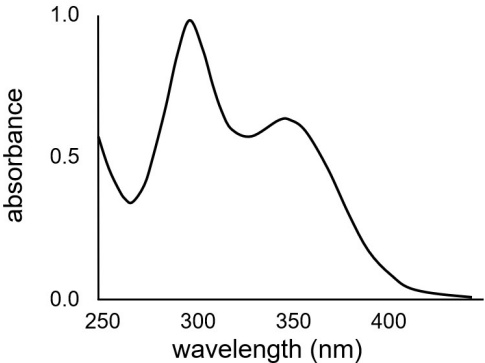
[Total: 11]

- 5 Sunscreen protects our skin from the harmful effects of ultraviolet (UV) radiation. It contains organic molecules which absorb and convert the radiation to heat energy.

There are two types of UV radiation that reach the Earth's surface, UVB and UVA. The wavelength range of UVB is 280–320 nm while that of UVA is 320–400 nm.

Table 5.1 shows the absorption spectrum for compound **U** and oxybenzone. A higher peak indicates stronger absorption at that wavelength of radiation.

Table 5.1

	structure	absorption spectrum
compound U		
oxybenzone		

- (a) A compound that has a greater extent of delocalisation of π electrons absorbs radiation over a larger range of wavelengths.

By comparing the structures of the compounds, explain the difference in the absorption spectra in Table 5.1. Hence, explain which compound is a better choice for use in sunscreen.

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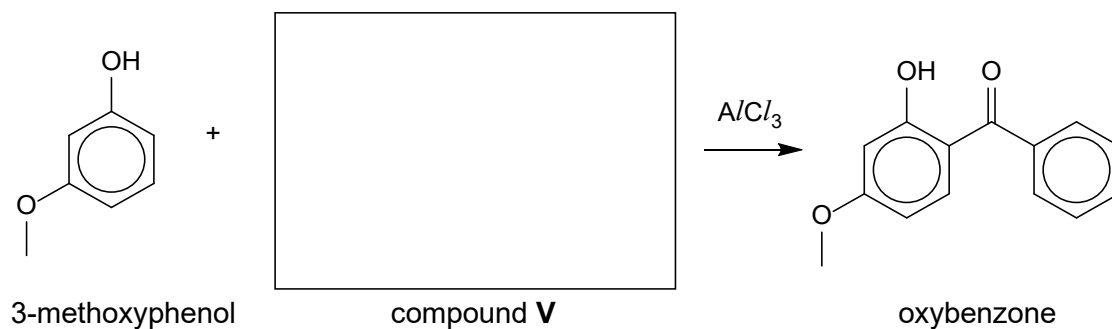
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.....[3]

- (b) Oxybenzone is produced by a substitution reaction of 3-methoxyphenol with compound **V**.



- (i) Draw the structure of compound **V** in the space provided. [1]

- (ii) Suggest a simple chemical test to distinguish between 3-methoxyphenol and oxybenzone.

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..... [2]

- (c) Oxybenzone is soluble in water.

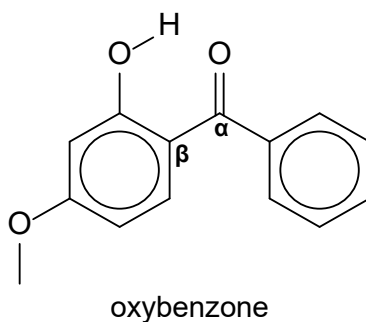


Fig. 5.1

- (i) On Fig. 5.1, draw a labelled diagram to illustrate how oxybenzone interacts with one molecule of water. [1]

At low temperatures, there is restricted rotation about the bond between the α -carbon and β -carbon in oxybenzone. However, at high temperatures, there is free rotation about this bond.

- (ii) By considering the information above, explain why the solubility of oxybenzone in water increases with increasing temperature. [2]

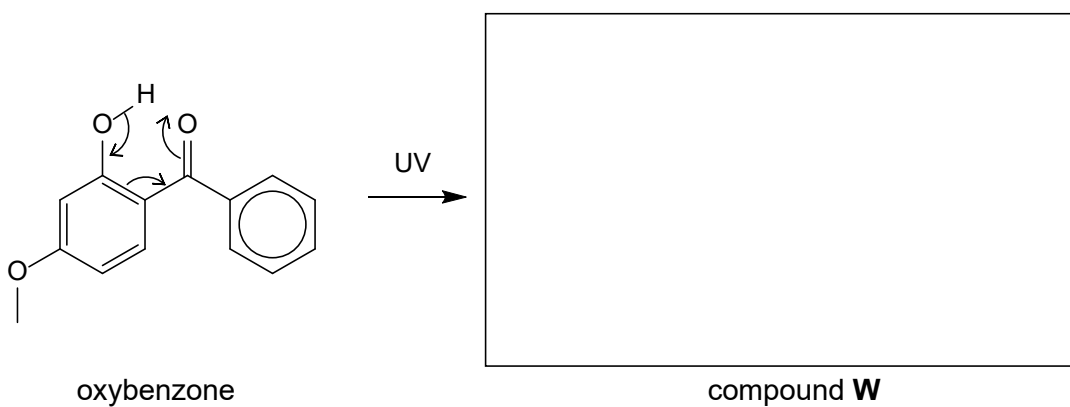
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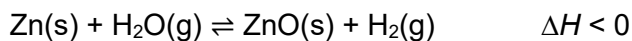
..... [2]

- (d) When oxybenzone absorbs UV radiation, it undergoes the following mechanism.



- (i) Draw the structure of compound **W**. [1]

- (e) Zinc oxide is commonly found in sunscreen. It can be produced from zinc and steam according to the following equation.



2.60 mol of zinc and 2.60 mol of steam are placed in a sealed vessel and heated. At equilibrium, 2.58 mol of zinc oxide is produced. The total pressure at equilibrium is 10 atm.

- (i) Calculate the partial pressure of H_2 at equilibrium.

[1]

- (ii) Write the expression for the equilibrium constant, K_p , of this reaction. Use your expression to calculate the value of K_p .

[2]

- (iii) Explain how a decrease in temperature affects the yield of zinc oxide.

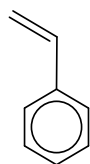
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 [1]

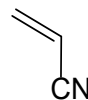
[Total: 14]

- 6 Polymers are large molecules made from small building blocks called monomers.

Two such monomers are shown below.



styrene



acrylonitrile

- (a) State the number of π electrons in each molecule of styrene and acrylonitrile.

number of π electrons in styrene

number of π electrons in acrylonitrile [2]

Fig. 6.1 shows the propagation step during the addition polymerisation of styrene through a radical mechanism.

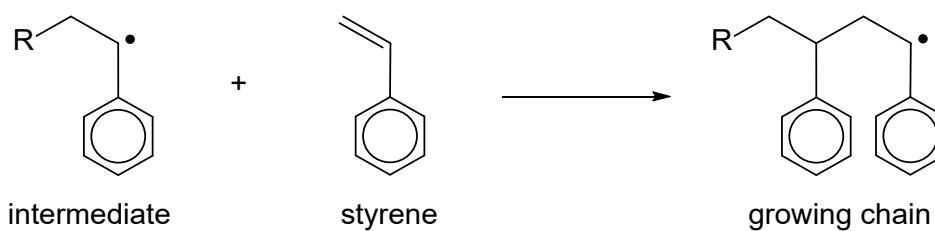


Fig. 6.1

- (b) (i) Using relevant information from the *Data Booklet*, calculate the enthalpy change for the propagation step as shown in Fig. 6.1.

[1]

- (ii) Define the term *entropy*.

.....
..... [1]

- (iii) The entropy change for the propagation step shown in Fig. 6.1 has a negative value. Explain why.

.....
..... [1]

- (iv) The propagation step in the polymerisation of styrene is exothermic.

Explain why the propagation step is not spontaneous at high temperatures.

.....
.....
..... [1]

Addition polymerisation can also proceed through an anionic or cationic mechanism.

Fig. 6.2 shows the propagation steps during polymerisation of styrene via the anionic and cationic mechanisms.

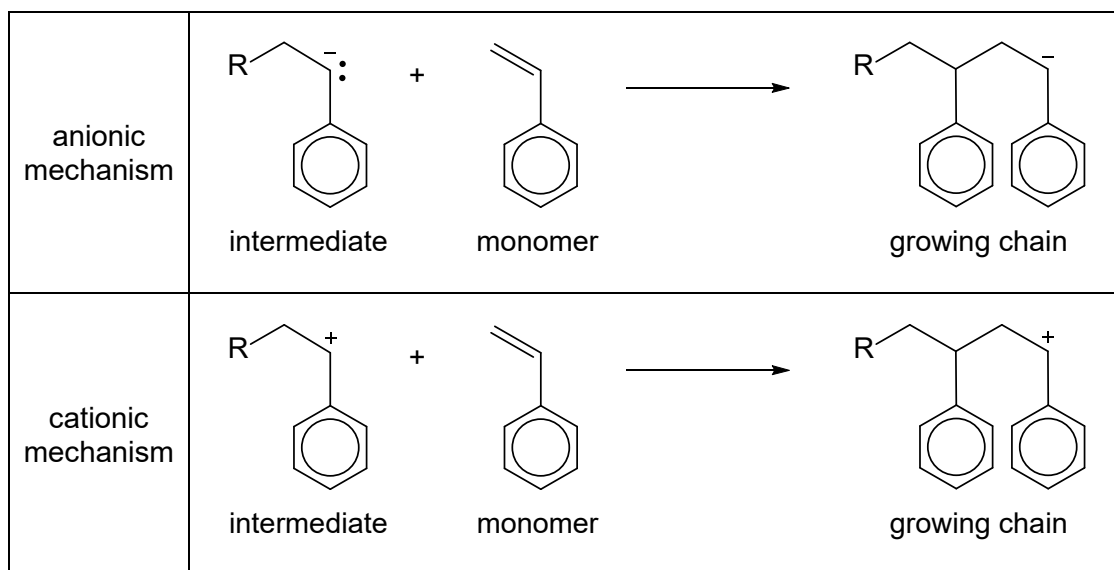
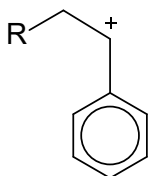
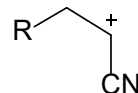


Fig. 6.2

- (c) (i) In Fig. 6.2, draw curly arrows to show the movement of electron pairs in the propagation step for the anionic mechanism. [1]
- (ii) The intermediates formed through the cationic mechanism for styrene and acrylonitrile are shown below.



intermediate from styrene



intermediate from acrylonitrile

Comment on the stability of the intermediates.

.....

.....

.....

.....

.....

..... [3]

- (d) A fixed amount of styrene was separately polymerised via the radical and anionic mechanisms.

Fig. 6.3 shows the distribution of the polymer chain lengths formed through each mechanism. The polymer chain length is measured by the number of repeating units in each polymer.

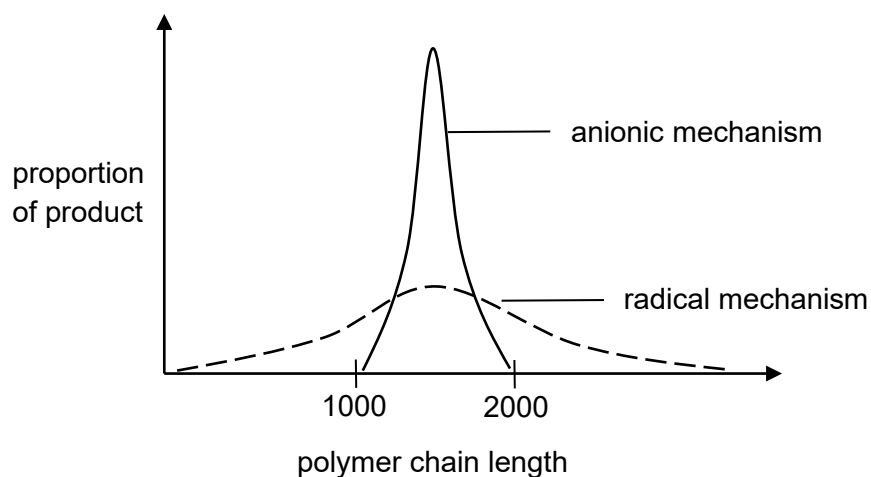


Fig. 6.3

The radical mechanism produces polymers with a wider distribution in chain lengths due to the termination step.

Suggest an explanation for this observation.

.....

.....

.....

..... [2]

[Total: 12]

