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DUNMAN HIGH SCHOOL

Preliminary Examination

Year 6

H1 CHEMISTRY

Paper 2 Structured Questions

8873/02

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 **27** printed pages and **1** blank page.

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 $^{39}\text{Cl}^+$ ion.

Table 1.1

	number of protons	number of electrons	number of neutrons
$^{39}\text{Cl}^+$			

[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]

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

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

similarity

.....

.....

difference

.....

..... [2]

- (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]

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

.....

.....

..... [1]

BeCl_2 reacts with $\text{S}(\text{CH}_3)_2$ 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]

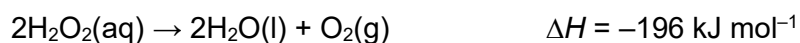
- (v) Suggest the bond angle around beryllium in the product. Explain your answer using Valence Shell Electron Pair Repulsion theory.

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

[Total: 11]

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



- (i) Sketch the energy profile diagram for the decomposition of $\text{H}_2\text{O}_2(\text{aq})$ in Fig. 2.1.

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

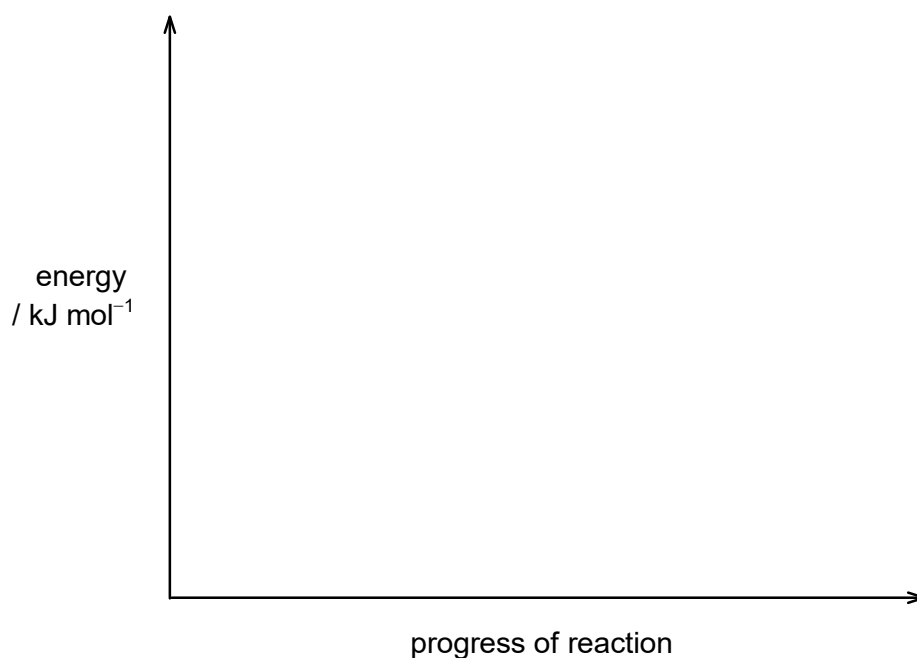


Fig. 2.1

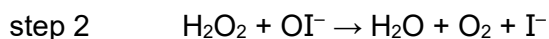
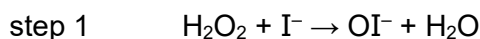
[2]

The uncatalysed reaction has an activation energy of $+75.3 \text{ kJ mol}^{-1}$ 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]

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



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

.....
 [1]

(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]

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

.....
 [1]

(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]

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

..... [1]

[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, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$, 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.

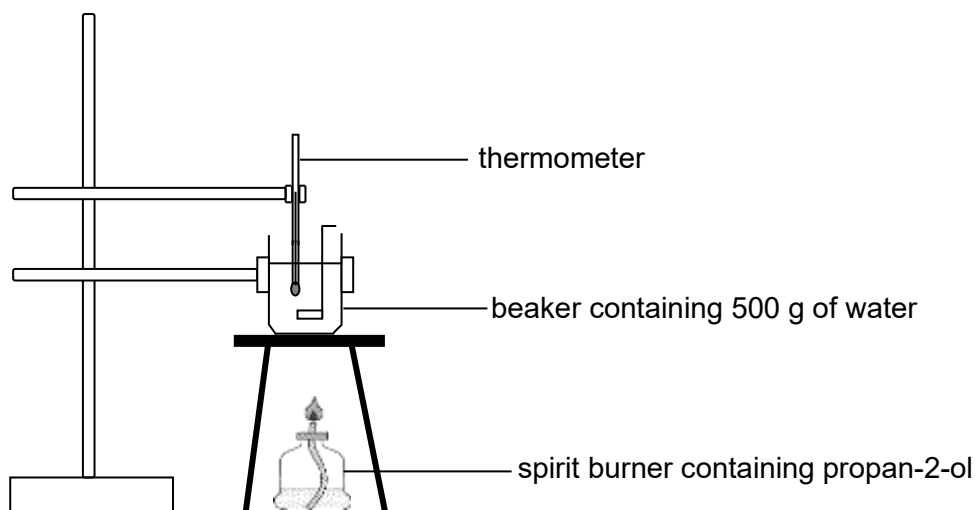


Fig. 3.1

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]

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

.....
 [1]

- (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 = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$]

[3]

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

State the type of reaction.

..... [1]

- (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.

X **Y** **Z**

.....

 [3]

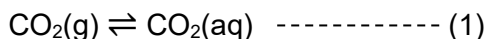
- (ii) **X** and **Z** are mixed in the same beaker. State the type of reaction that will occur and write an equation, including state symbols, for the reaction.

.....
 [2]

[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 .



The resultant carbonic acid formed, $\text{H}_2\text{CO}_3(\text{aq})$, then dissociates into hydrogencarbonate ions, HCO_3^- and hydrogen ions, H^+ , in the following equilibrium.



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 $\text{CO}_2(\text{aq})$ which results in an increase in breathing.

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

.....

 [1]

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

..... [1]

- (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]

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

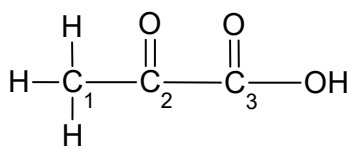


Fig. 4.1

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

..... [1]

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

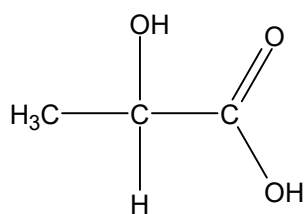
.....

..... [1]

(iii) Draw one constitutional isomer of pyruvic acid, $\text{CH}_3\text{COCO}_2\text{H}$.

[1]

- (c) Lactic acid, $\text{C}_3\text{H}_6\text{O}_3$, undergoes an elimination reaction to form compound **T** with molecular formula, $\text{C}_3\text{H}_4\text{O}_2$.



lactic acid

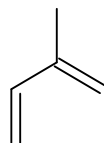
Draw the displayed formula of **T** and explain whether **T** can give rise to cis-trans isomers.

.....

 [2]

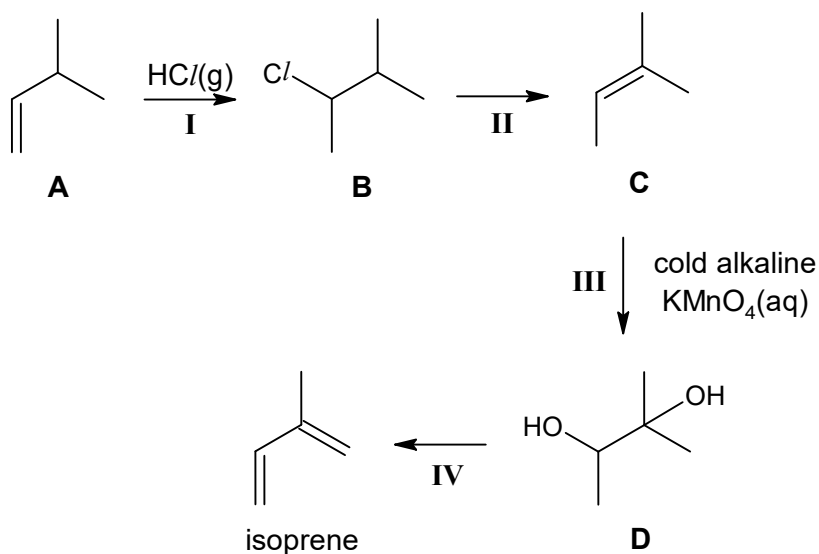
[Total: 10]

- 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]
- (ii) State the reagents and conditions used in steps **II** and **IV**.
 Step **II**
 Step **IV** [2]
- (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**.

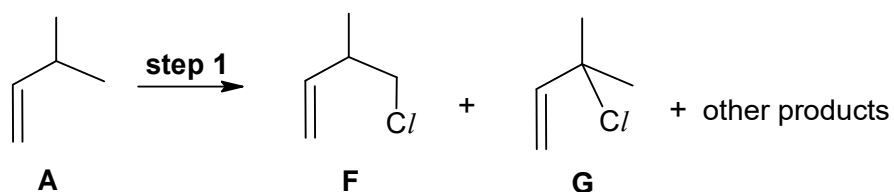
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 [2]

- (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.

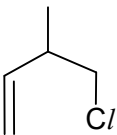
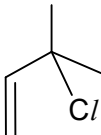


- (i) State the reagents and conditions of **step 1**, which will result in formation of compounds **F** and **G**.

..... [1]

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

Table 5.1

structure	 F	 G
ratio		

[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]

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

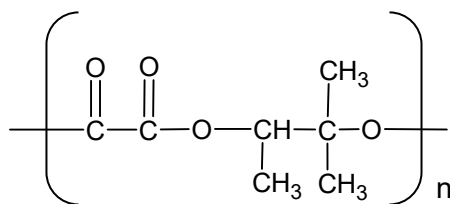


Fig. 5.1

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

..... [1]

(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]

[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]

- (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]

(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]

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

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

[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, $\text{CH}_3\text{CH}_2\text{OH}$, can react with lithium to form lithium ethoxide, $\text{CH}_3\text{CH}_2\text{O}^-\text{Li}^+$. Hydrogen gas is also produced in the reaction.

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

..... [1]

- (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.

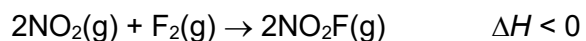
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.....
..... [3]

- (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.

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

- (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 .



Experiment 1 was conducted using $0.0200 \text{ mol dm}^{-3}$ of $\text{NO}_2(\text{g})$ and $0.240 \text{ mol dm}^{-3}$ of $\text{F}_2(\text{g})$ at 60°C . The results are shown in Table 7.1.

Table 7.1

time / min	$[\text{NO}_2] / \text{mol dm}^{-3}$
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 $[\text{NO}_2]$ against time on the grid provided in Fig. 7.1. [2]

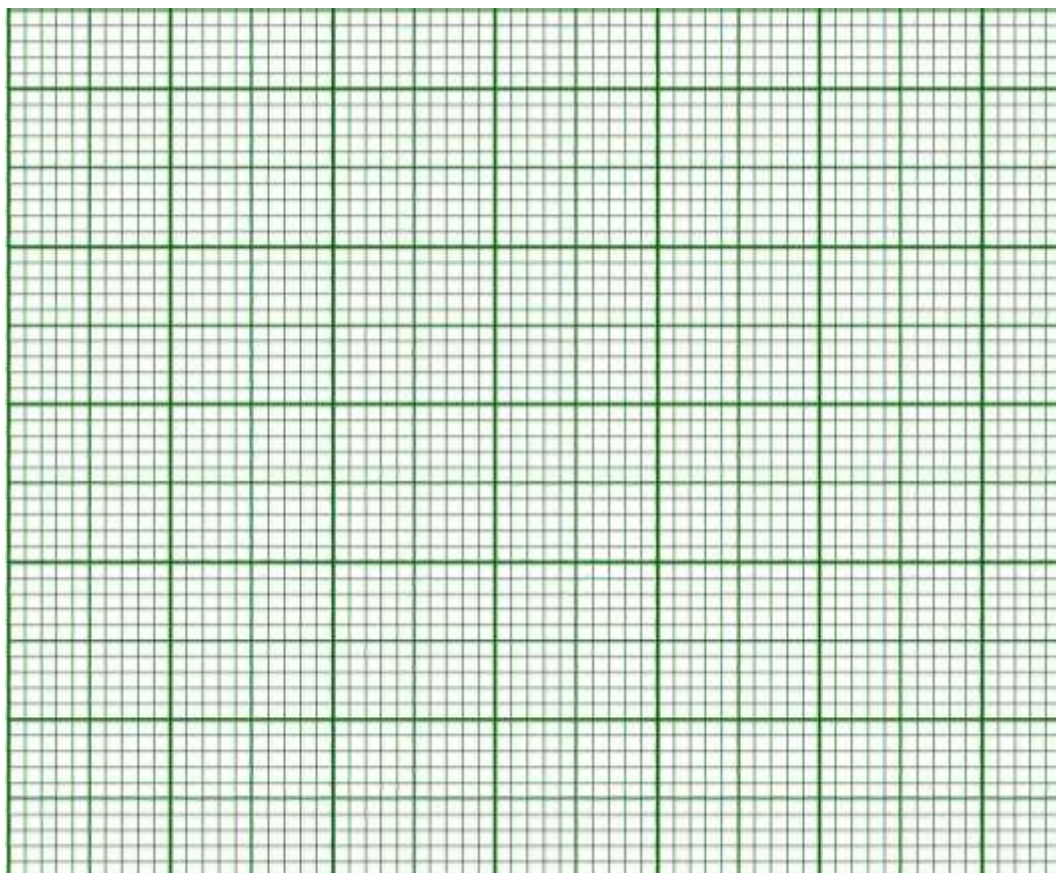


Fig. 7.1

- (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]

- (iii) Another experiment was conducted with $0.0200 \text{ mol dm}^{-3}$ of $\text{NO}_2(\text{g})$ and $0.480 \text{ mol dm}^{-3}$ of $\text{F}_2(\text{g})$ at the same temperature. The time taken for $[\text{NO}_2]$ to decrease from $0.0200 \text{ mol dm}^{-3}$ to $0.0100 \text{ mol dm}^{-3}$ is half that of experiment 1.

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

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

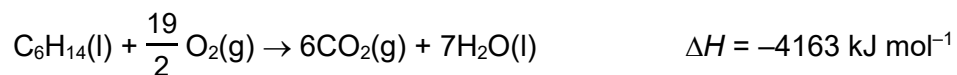
- (iv) Write the rate equation for the reaction.

..... [1]

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

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.....
.....
..... [3]

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



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]

- (e) Use the following energy cycle and Table 7.2 to calculate the standard enthalpy change of formation of benzene, $\Delta H_f^\ominus (\text{C}_6\text{H}_6(\text{l}))$.

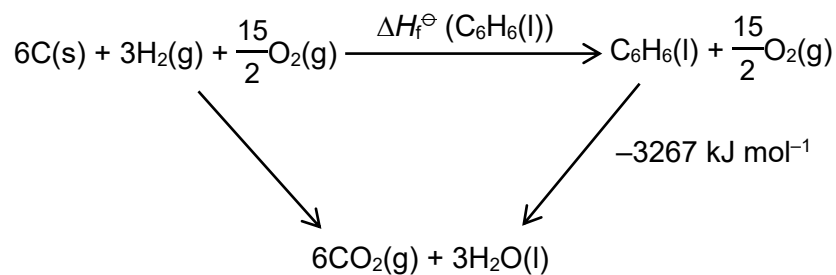


Table 7.2

standard enthalpy change of formation of $\text{H}_2\text{O}(\text{l})$ / kJ mol^{-1}	-286
standard enthalpy change of formation of $\text{CO}_2(\text{g})$ / kJ mol^{-1}	-394

[2]

[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]

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

..... [1]

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

..... [1]

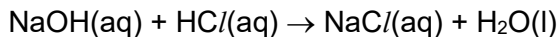
(iv) By showing relevant calculations, determine which of the following solutions at 25 °C has a higher concentration of OH^- .

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

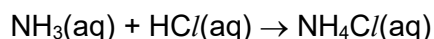
[2]

- (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 $0.100 \text{ mol dm}^{-3}$ aqueous hydrochloric acid. 20.40 cm^3 of aqueous hydrochloric acid was required to completely neutralise the NaOH present to reach the **first** endpoint.



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.



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

[1]

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

[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.

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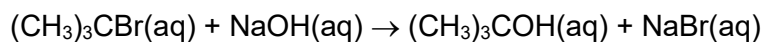
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..... [2]

(c) $(\text{CH}_3)_3\text{CBr}$ reacts with sodium hydroxide as shown below.



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

Table 8.2

experiment	initial $[(\text{CH}_3)_3\text{CBr}]$ / mol dm^{-3}	initial $[\text{NaOH}]$ / mol dm^{-3}	initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
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 $(\text{CH}_3)_3\text{CBr}$ and with respect to NaOH .

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.....

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..... [2]

- (ii) Hence write the rate equation for the reaction between $(\text{CH}_3)_3\text{CBr}$ and NaOH , stating the units of the rate constant.

.....

..... [1]

- (iii) On the axes provided in Fig. 8.1, sketch a graph of $(\text{CH}_3)_3\text{CBr}$ 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.

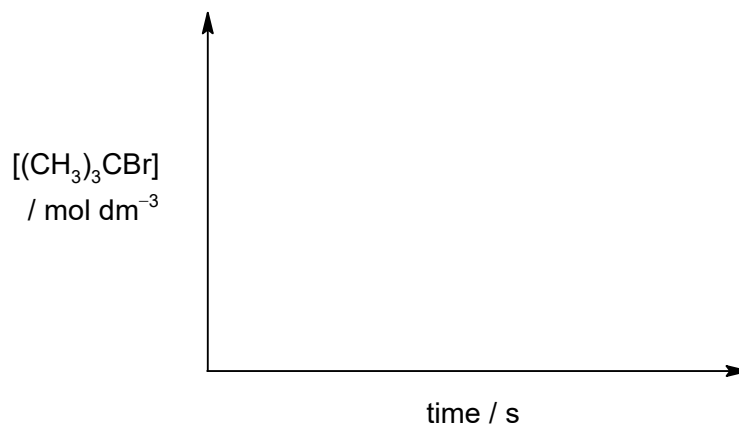


Fig. 8.1

.....
..... [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 .

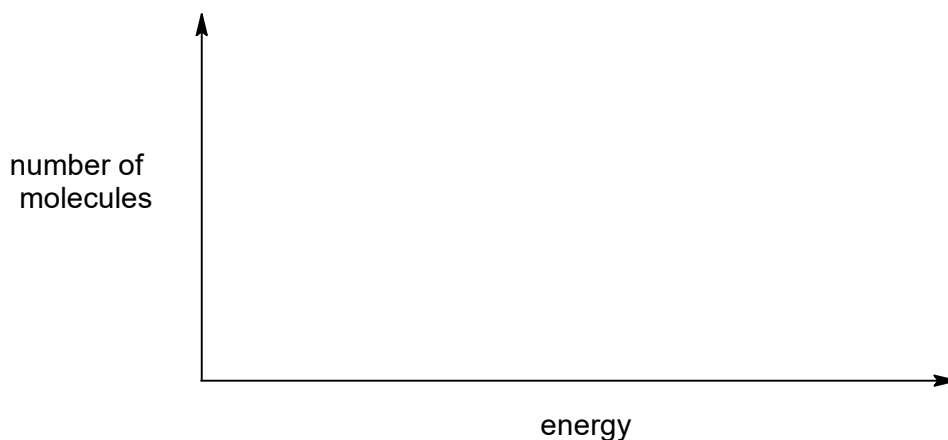


Fig. 8.2

[2]

- (ii) On the same axes provided in Fig. 8.2, label the new activation energy, $E_{a(\text{new})}$, 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.

.....

.....

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.....

..... [2]

[Total: 20]