



CANDIDATE
NAME

CG

H1 GROUP

1 / 2 / 3

CHEMISTRY

8873/02

Paper 2 Structured and Free Response Questions

10 September 2024

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	/ 9	
2	/ 8	
3	/ 10	
4	/ 10	
5	/ 12	
6	/ 11	
Section B		
7 or 8	/ 20	
Penalty	units	significant figures
Total	/ 80	

Section A

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

- 1 (a) **A**, **B** and **C** are three consecutive period 3 elements in the periodic table. **D** is an isotope of one of the elements.

Table 1.1 shows information on the number of protons, neutrons and electrons in species of **A**, **B**, **C** and **D**.

Table 1.1

species	protons	neutrons	electrons
A	15	16	15
B²⁻	16	17	<i>q</i>
C	17	18	17
D⁻	17	17	18

- (i) Deduce the value of ***q***.

..... [1]

- (ii) Identify the element, **A**, **B** or **C**, that is isotopic to **D**.
Explain your answer.

.....

 [2]

- (b) Element **E** is a Period 3 element.

The first nine successive ionisation energies, in kJ mol^{-1} , of element **E** are given in Table 1.2.

Table 1.2

1st	2nd	3rd	4th	5th	6th	7th	8th	9th
1251	2298	3822	5159	6542	9362	11018	33604	38600

- (i) With reference to **E**, explain what is meant by *first ionisation energy* of **E**.

.....
 [1]

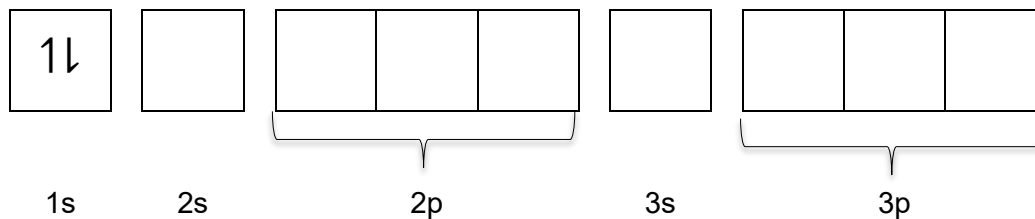
- (ii) Use the information given in Table 1.2 to deduce the identity of element **E**.
 Explain your answer.

.....

 [2]

(c) Sulfur is also an element found in the Period 3 of the Periodic Table.

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



[1]

(ii) State and explain the general trend in first ionisation energy across Period 3 elements. Explain why sulfur does not follow this general trend.

.....

.....

.....

.....

..... [2]

[Total: 9]

BLANK PAGE

- 2 (a) Magnesium exists as three principal isotopes, ^{24}Mg , ^{25}Mg and ^{26}Mg .

isotope	relative isotopic mass	natural abundance (%)
^{24}Mg	23.99	78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

Use the data to calculate the relative atomic mass of magnesium to **two** decimal places.

[1]

- (b) Gastric juice is a thin, acidic digestive fluid secreted by glands in the mucous membrane that lines the stomach. An average adult produces about 1 mole of gastric juice when pain is experienced. 1 mole of gastric juice contains 0.002 mole of hydrochloric acid.

An antacid is a substance which counteracts stomach acidity by raising the pH. One example is Brand F antacid which contains 20% magnesium carbonate, MgCO_3 . One tablet of antacid in Brand F has a mass of 325 mg.

- (i) Write a balanced equation for the reaction of Brand F antacid with hydrochloric acid.

..... [1]

- (ii) Calculate the amount of magnesium carbonate in one tablet of Brand F antacid.

[1]

- (iii) Calculate the number of tablets a person has to consume to remove the gastric juice.

[2]

- (c) Compound **G** contains carbon, hydrogen and oxygen only.
G contains 66.7% by mass of carbon, 11.1% by mass of hydrogen and 22.2% by mass of oxygen.
The relative molecular mass, M_r , of **G** is 72.

(i) Calculate the empirical formula and deduce the molecular formula of **G**.

[2]

- (ii) Compound **G** is a ketone.
Draw the displayed formula of **G**.

[1]

[Total: 8]

3 (a) Phosphorus reacts with fluorine to form phosphorus trifluoride, PF_3 , and phosphorus pentafluoride, PF_5 .

- (i) Draw the dot-and-cross diagram for one molecule of PF_3 . Show only the outer shell electrons.

[1]

- (ii) State the bond angle in a molecule of PF_3 and name the shape of the molecule.

Explain your answers using Valence Shell Electron Pair Repulsion Theory.

.....

.....

.....

.....

.....

.....

..... [3]

- (iii) Deduce whether PF_3 is a polar molecule.

Explain your answer.

.....

.....

..... [2]

- (iv) Nitrogen reacts with fluorine to form NF_3 only.

Explain why PF_5 exists whereas NF_5 does not exist.

.....

.....

..... [1]

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

Predict the colours of the final solution when

- KI(aq) is added to $\text{Cl}_2(\text{aq})$,
- KCl(aq) is added to $\text{Br}_2(\text{aq})$,
- KBr(aq) is added to $\text{I}_2(\text{aq})$.

Write equations for any reactions that occur. State clearly if no reaction occurs.

[3]

[Total: 10]

- 4 (a) Air is a mixture of mainly nitrogen and oxygen that does not react at room temperature. Gas molecules move about in the container in which they are enclosed with different amount of energy.

- (i) Sketch a graph to show the energy distribution of gas molecules at room temperature. Label this curve T.

[1]

- (ii) On the same axes sketch the energy distribution of the same gas molecules at a temperature of 150°C. Clearly label this curve 150°C.

[1]

At higher temperatures nitrogen and oxygen do react.

- (iii) Indicate an activation energy, E_a , on your graph.

[1]

- (iv) Use the sketches that you have drawn and collision theory to explain why an increase in temperature causes an increase in the rate constant and rate of a reaction.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[2]

- (b) A catalytic converter is an exhaust emission control device which converts toxic gases and pollutants in exhaust gas from an internal combustion engine into less-toxic pollutants.

For diesel engines the catalytic converter may also include a particle filter to remove solid particles of carbon. Fig. 4.1 shows one design of diesel particle filter.

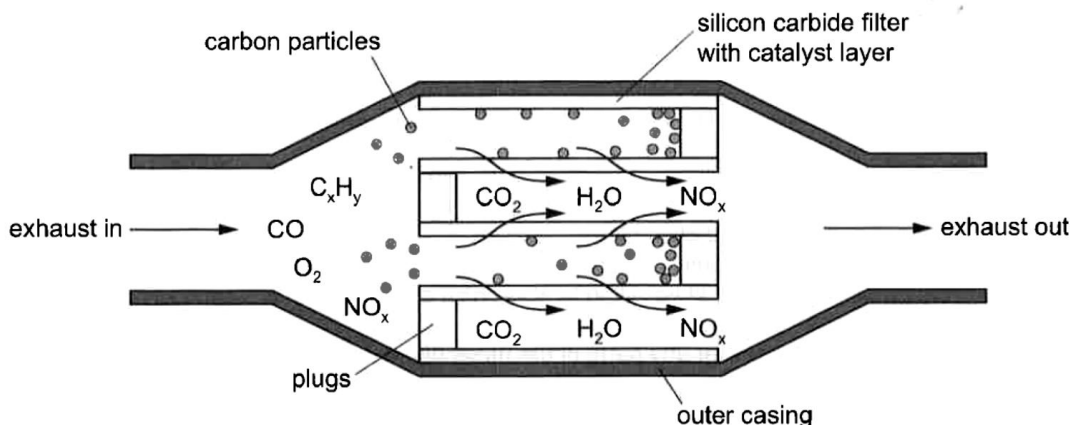
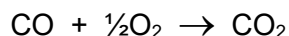


Fig. 4.1

The catalyst helps to remove other pollutants from the exhaust. For example,



- (i) Use information from the diagram to deduce another possible equation for a reaction occurring on the catalyst surface.

..... [1]

- (ii) State the **type** of catalyst involved in this reaction.
Outline the mode of action by this type of catalyst in the removal of pollutants from the exhaust.

.....

 [4]

[Total: 10]

- 5 (a) Separate samples of compound **J** are added to an excess of three different reagents as shown in Fig. 5.1.

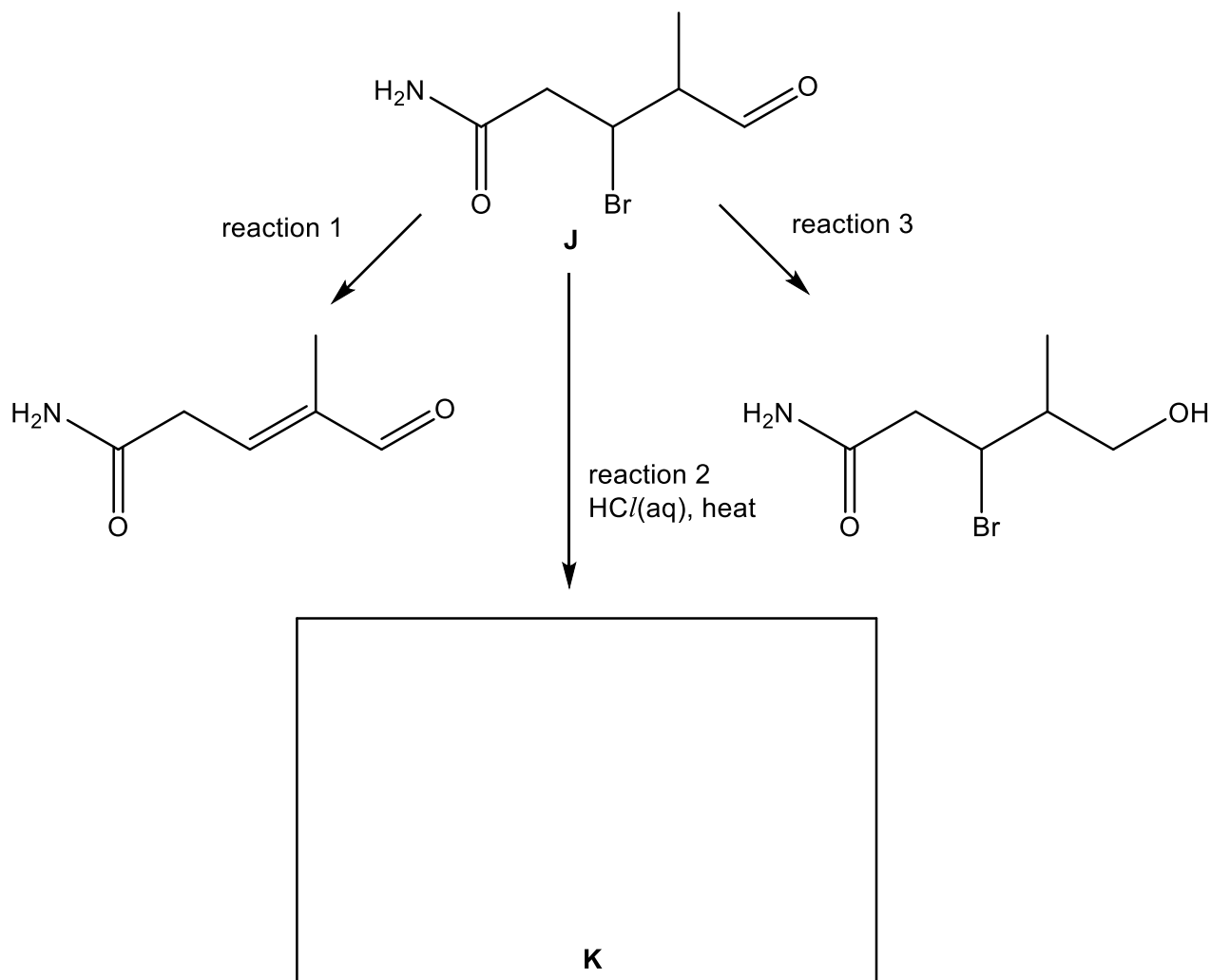


Fig. 5.1

- (i) Suggest the reagents and conditions for reaction 1.

..... [1]

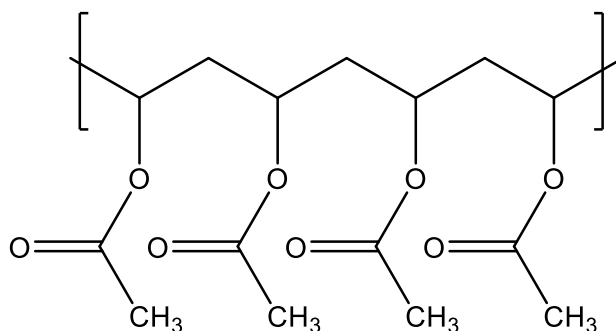
- (ii) Draw the structure of compound **K** in the box in Fig. 5.1.

..... [1]

- (iii) State the *type of reaction* that occurred in reaction 3.

..... [1]

- (b) Polyvinyl acetate, PVAc, is a useful adhesive for gluing together articles made from wood, paper or cardboard. Fig. 5.2 shows a section (not a repeat unit) of PVAc.



PVAc

Fig. 5.2

- (i) State the type of polymerisation that produces PVAc.

..... [1]

- (ii) PVAc is made from monomer **L**. Draw the structure of **L**.

[1]

- (iii) PVAc can be converted to polyvinyl alcohol, PVA.

Draw a section of PVA containing **2** repeat units.

Suggest the reagents and conditions needed to make PVA from PVAc in the laboratory.

..... [2]

- (c) Fig. 5.3 shows the molecular representation of two types of plastics – thermoplastics and thermosets.

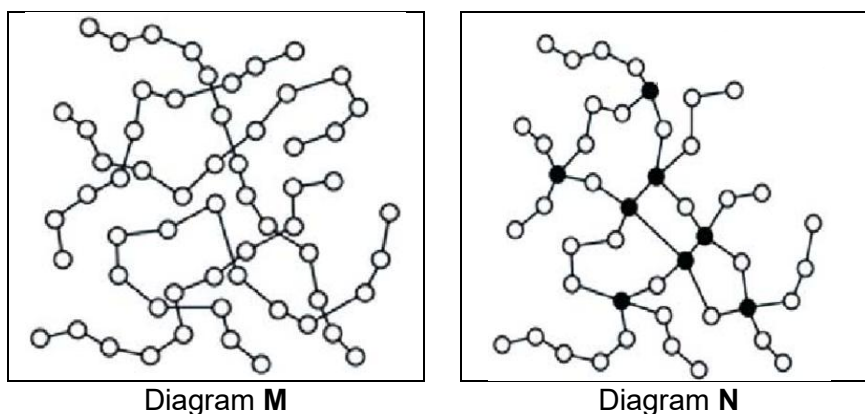


Fig. 5.3

- (i) State which diagram, **M** or **N**, could be the representation for thermosets. Explain your answer.

.....
 [1]

- (ii) State one difference in physical properties between thermoplastics and thermosets.

.....
 [1]

(d) Graphene nanomaterials have been considered as a novel class of nanomaterials that show exceptional structural, optical, thermal, electrical, and mechanical properties.

(i) Explain the difference between a nanoparticle and a nanomaterial.

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

(ii) Draw a diagram to illustrate the structure of graphene.

[1]

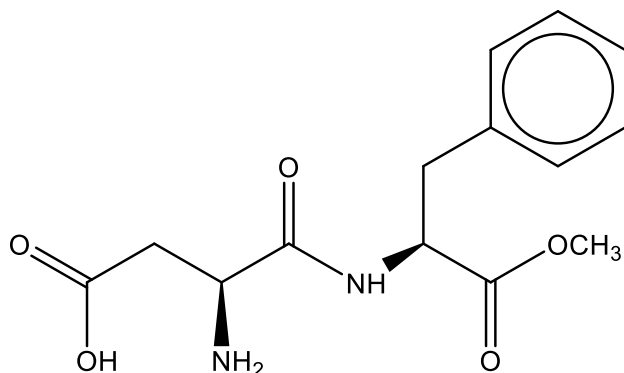
(iii) Explain why graphene is a good electrical conductor.

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

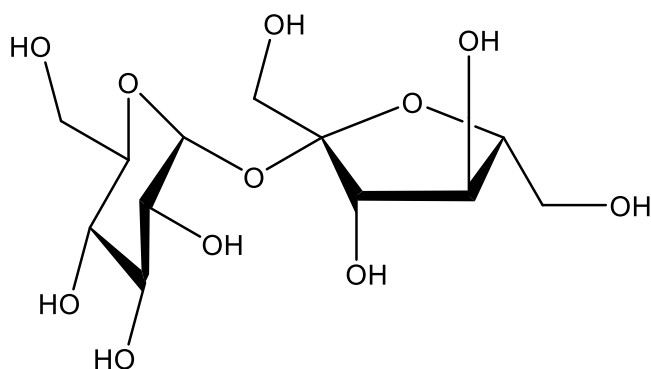
[Total: 12]

- 6 Sugar is composed of sucrose, $C_{12}H_{22}O_{11}$. It is used as a sweetener in many foods and drinks. Typical 'regular non-diet' carbonated soft drinks contain about 110 g of sucrose per dm^3 . 'Sugar-free' or 'diet' or 'light' drinks often replace this sucrose with an artificial sweetener. Aspartame, $C_{14}H_{18}N_2O_5$, is 180 times sweeter per gram than sucrose and is used as an artificial sweetener.

Carbonated drinks are often sold in 330 cm^3 cans.



aspartame



sucrose

- (a) Circle **and** name **four** different functional groups that are present within the aspartame molecule shown above.

Do not include benzene or an alkyl group.

[4]

- (b) (i) Calculate the relative molecular mass of aspartame and of sucrose.

M_r aspartame =

M_r sucrose = [1]

- (ii) Calculate how many grams of sucrose would be present in a typical can of 'regular non-diet' carbonated soft drink.

[1]

- (iii) Calculate how many moles of sucrose there are in your answer to (b)(ii).

[1]

- (iv) Calculate the mass of aspartame that would need to be present in a can of carbonated soft drink in order to have the same sweetness of taste as a can of 'regular non-diet' carbonated soft drink.

[2]

- (v) Suggest why a 330 cm³ can of carbonated soft drink marketed as a 'diet' drink will float in water whereas a 'regular non-diet' can of the same drink in an identical can does not.

.....

.....

.....

..... [1]

- (c) *Use of the Data Booklet is relevant to this question.*

Infra-red absorptions are useful in identifying functional groups present in molecules.

One of the bonds sucrose absorbs in the range 1000 – 1310 cm⁻¹.

Suggest the bond which absorbs in this range.

bond [1]

[Total: 11]

Section B

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

- 7 (a) The variation in the melting points for the elements sodium to chlorine are shown in Fig. 7.1.

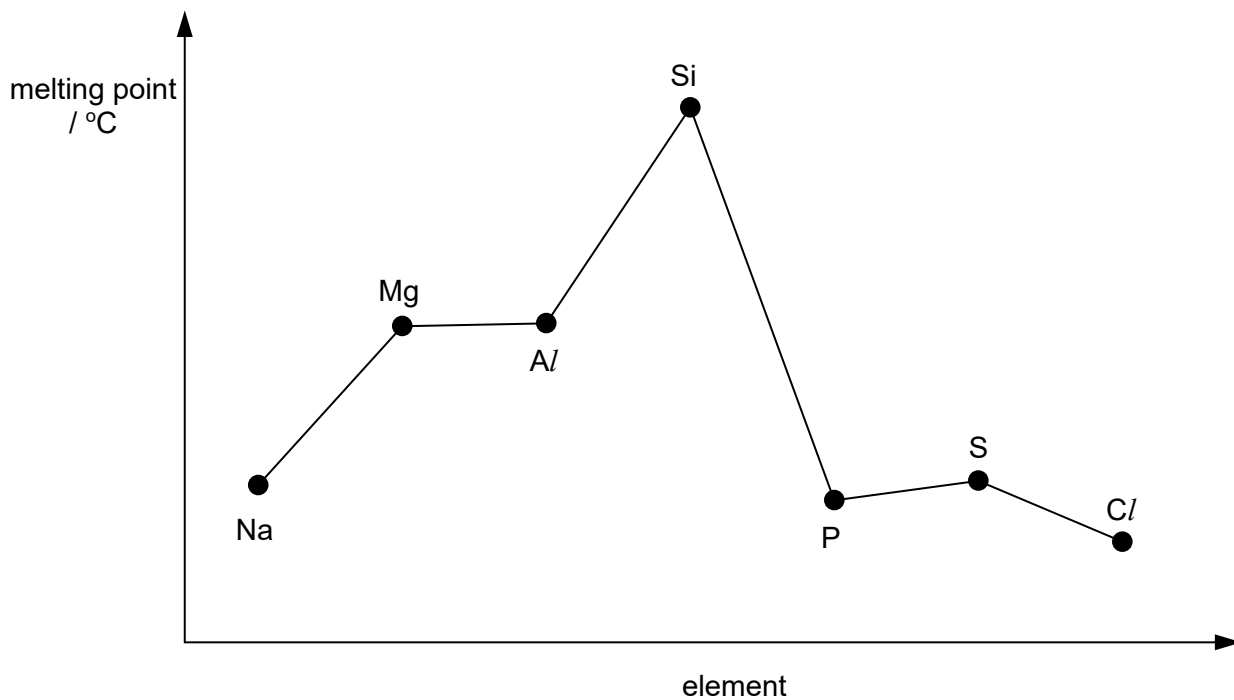


Fig. 7.1

Explain this variation in terms of the structures and bonding of the elements.

[6]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

- (b) Iron tablets containing iron(II) sulfate, FeSO_4 , are used by many people as a dietary supplement.

A solution is prepared by dissolving five powdered iron tablets in dilute sulfuric acid. This solution is made up to 250 cm^3 with deionised water.

25.0 cm^3 of the prepared solution requires 23.50 cm^3 of $0.00150 \text{ mol dm}^{-3}$ aqueous potassium dichromate(VI) for complete reaction. The equation for the reaction is as follows.



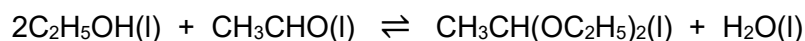
- (i) Explain in terms of the change in oxidation number which species has been reduced.

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

- (ii) Calculate the mass of iron(II) sulfate which is present in one tablet.

[4]

- (c) The reaction between ethanol and ethanal can be described as being in dynamic equilibrium.



- (i) Explain what is meant by the term *dynamic equilibrium*.

.....

 [1]

- (ii) Predict and explain how an increase in concentration of ethanal will affect the position of equilibrium of this reaction.

.....

 [1]

- (iii) Write an expression for the equilibrium constant, K_c , for the reaction between ethanol and ethanal shown above.

[1]

- (iv) The reaction mixture is allowed to reach equilibrium at constant temperature.

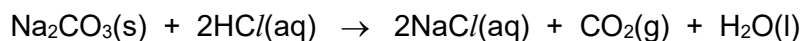
In this equilibrium mixture the concentrations are:

- $\text{CH}_3\text{CHO}(\text{l})$, $0.1325 \text{ mol dm}^{-3}$
- $\text{CH}_3\text{CH}(\text{OC}_2\text{H}_5)_2(\text{l})$, $1.311 \text{ mol dm}^{-3}$
- $\text{H}_2\text{O}(\text{l})$, $1.311 \text{ mol dm}^{-3}$

The K_c value is 0.074.

Calculate the equilibrium concentration of ethanol.

- (d) An experiment is performed to find the enthalpy change of reaction for the reaction between sodium carbonate, Na_2CO_3 , and aqueous hydrochloric acid.



The temperature of a 50 cm^3 solution of 2.0 mol dm^{-3} aqueous hydrochloric acid in a polystyrene cup is measured every 30 seconds for 2 minutes.

At exactly 2.5 minute, 4.070 g of solid Na_2CO_3 is poured into the aqueous hydrochloric acid. The temperature of the resulting mixture is then measured every 30 seconds until the 8th minute.

The results are shown in Fig. 7.2.

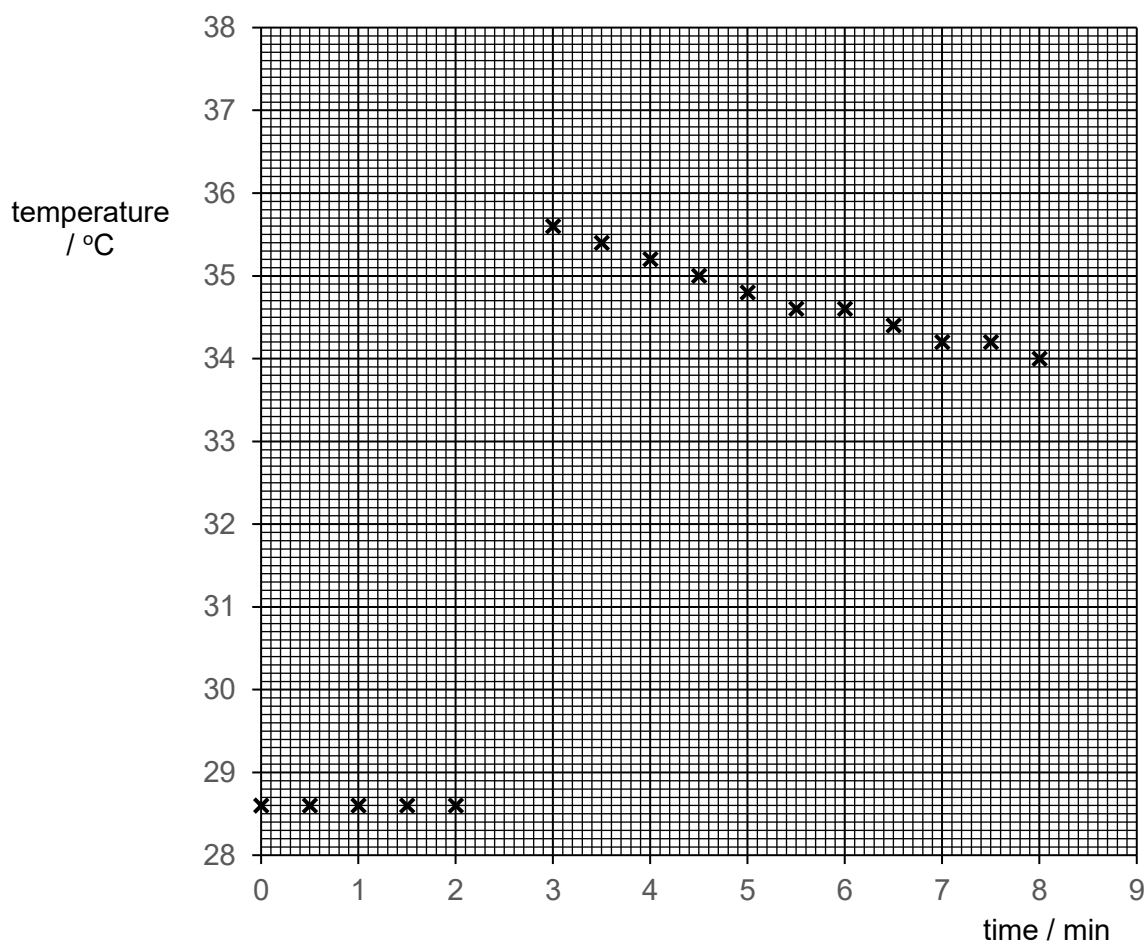


Fig. 7.2

- (i) Draw two separate straight lines of best fit.

The first line should take into account all of the points before $t = 2.5$ min.

The second line should take into account all of the points after the temperature of the mixture has started to fall steadily.

Extend both lines to $t = 2.5$ min.

Use your graph to determine the maximum temperature rise, $\Delta T_{\max}$, of the experiment.

Show your working.

$$\Delta T_{\max} = \dots\dots\dots^{\circ}\text{C}$$

[2]

- (ii) Using your answer to (d)(i), calculate the energy, in kJ, evolved during the reaction.

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

[1]

- (iii) Using your answer to (d)(ii), calculate a value for the enthalpy change of reaction, in kJ mol^{-1} , for the reaction between sodium carbonate and hydrochloric acid. The hydrochloric acid is in excess.

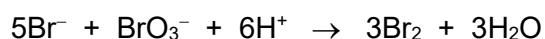
[2]

[Total: 20]

- 8 (a) (i) Explain what is meant by the term *order of reaction*.

..... [1]

The oxidation of bromide ions by bromate(V) ions, BrO_3^- , in acidic solution is represented by the equation below.



To investigate how the rate of reaction depends on the concentration of each of the three reactants, three experiments were carried out. In each experiment the concentrations of two reactants were in excess and kept constant, whilst the concentration of the third reactant was measured every 20 seconds for 120 seconds.

The results for two of the three experiments are shown in Table 8.1.

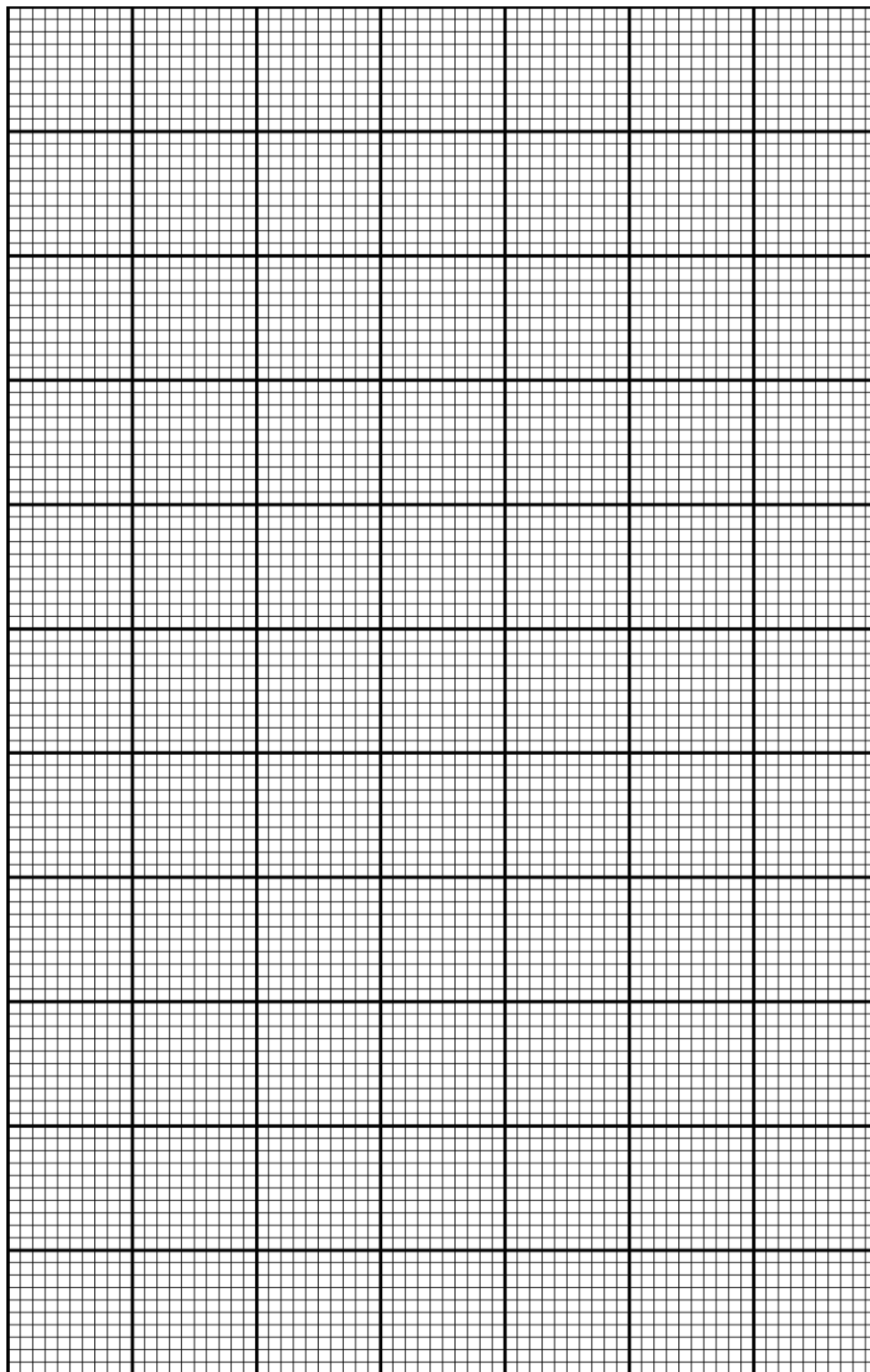
Table 8.1

	reaction 1	reaction 2
time/s	$[\text{Br}^-]/\text{mol dm}^{-3}$	$[\text{BrO}_3^-]/\text{mol dm}^{-3}$
0	1.00	1.00
20	0.85	0.64
40	0.70	0.41
60	0.55	0.25
80	0.40	0.17
100	0.25	0.10
120	0.10	0.06

- (ii) On the grid, plot a graph of $[\text{Br}^-]$ against time.
Label the line $[\text{Br}^-]$.

[3]

concentration
of reactant
/ mol dm^{-3}



time / s

- (iii) On the same grid, plot a graph of $[\text{BrO}_3^-]$ against time.
Label the line $[\text{BrO}_3^-]$.

[2]

- (iv) Deduce the order of reaction with respect to Br^- .
Use your graph to explain your answer.

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

- (v) Deduce the order of reaction with respect to BrO_3^- .
Use your graph to explain your answer.

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

- (vi) The order of reaction with respect to $[\text{H}^+]$ is first order.

The rate of reaction is $8.80 \times 10^{-6} \text{ mol dm}^{-3} \text{ s}^{-1}$ when
 $[\text{Br}^-] = 0.10 \text{ mol dm}^{-3}$, $[\text{BrO}_3^-] = 0.10 \text{ mol dm}^{-3}$ and $[\text{H}^+] = 0.40 \text{ mol dm}^{-3}$.

Calculate the rate constant for this reaction and state its units.

[2]

- (b) Johannes Brønsted and Martin Lowry independently came to similar conclusions about acid-base behaviour early in the 20th century.

(i) Define a *Brønsted-Lowry acid* and a *Brønsted-Lowry base*.

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

(ii) Write an equation for the reaction between hydrogen chloride, HCl , and water.
Indicate which species are the acid, the base and their conjugate pairs in the reaction.

.....

acid conjugate base

base conjugate acid [2]

(iii) Calculate the pH of 0.03 mol dm^{-3} hydrochloric acid.
Give your answer to three significant figures.

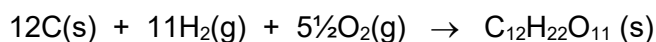
[1]

(c) Sugar is composed of sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. It is used as a sweetener in many foods and drinks.

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

[1]

(ii) A scientist made sucrose from carbon, hydrogen and oxygen.



The enthalpy change of formation of this reaction is difficult to measure directly.

Calculate the standard enthalpy change of formation of sucrose using the data in Table 8.2 and the energy cycle in Fig. 8.1.

Table 8.2

$\Delta H_{\text{c}}^{\ominus}$ (sucrose) / kJ mol^{-1}	-5650
$\Delta H_{\text{f}}^{\ominus}$ ($\text{H}_2\text{O(l)}$) / kJ mol^{-1}	-286
$\Delta H_{\text{f}}^{\ominus}$ ($\text{CO}_2\text{(g)}$) / kJ mol^{-1}	-393.5

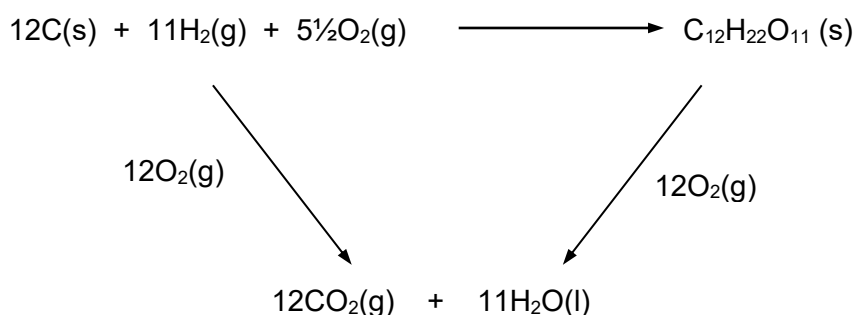


Fig. 8.1

[3]

- (d) The properties of methanol, CH_3OH , are affected by the strong intermolecular forces present between methanol molecules.

Draw a labelled diagram to name and show the strongest intermolecular forces present.

Your diagram should include two methanol molecules.

[2]

[Total: 20]

BLANK PAGE

BLANK PAGE

BLANK PAGE