YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME	**SUGGESTED ANSWERS**
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**

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) **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
$\mathbf{B}^{2-}$	16	17	***q***
C	17	18	17
$\mathbf{D}^{-}$	17	17	18

(i) Deduce the value of ***q***. [1]

18

(ii) Identify the element, **A**, **B** or **C**, that is isotopic to **D**.
Explain your answer. [2]

C.
They have the same number of protons but different number of neutrons.

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

The first nine successive ionisation energies, in $kJmol^{-1}$, 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]

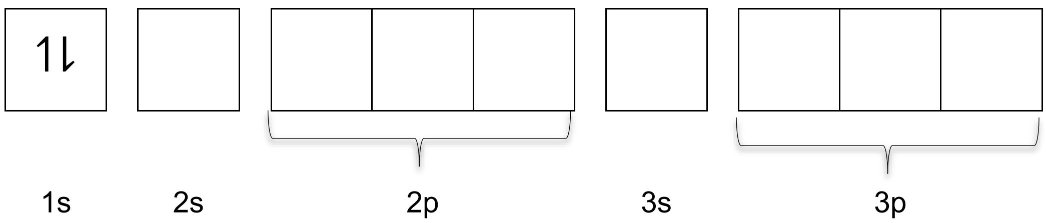
First ionisation energy of **E** is the **energy required** to remove **one mole of the outermost electrons** from **one mole of gaseous E atom** to form **one mole of gaseous E^+ cations**.

(ii) Use the information given in Table 1.2 to deduce the identity of element **E.**
Explain your answer. [2]

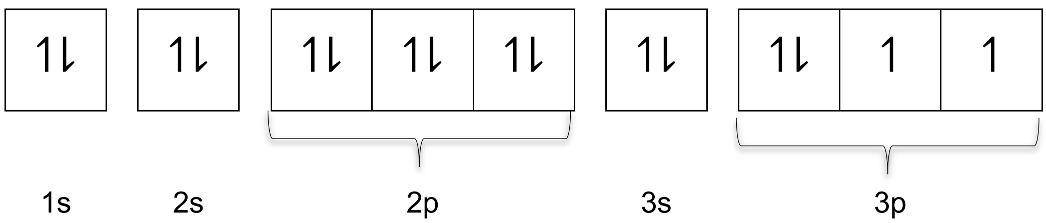
Element E is **chlorine**.
There is a **large increase between the 7th and 8th ionisation energy** suggesting that there are **7 valence electrons** in element E.

(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]

The first ionisation energy generally **increases** across Period 3.
Across Period 3, **nuclear charge increases, shielding effect is relatively constant**.
Hence, **effective nuclear charge increases** (or the attraction between the nucleus and the valence electrons becomes stronger), and **more energy is required** to remove the valence electrons from the atom.

Sulfur does not follow this general trend as the outermost **electron to be removed from sulfur in the 3p orbital is paired** and there is **inter-electronic repulsion**. Hence, less energy is required to remove the valence electron from S.

[Total: 9]

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]

$$\text{relative atomic mass} = \frac{(78.99 \times 23.99) + (10.00 \times 24.99) + (11.01 \times 25.98)}{100} = 24.31$$

(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]

$MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$

(ii) Calculate the amount of magnesium carbonate in one tablet of Brand F antacid. [1]

Amount of $MgCO_3$ = $(0.2 \times 0.325) \div 84.3 = 7.71 \times 10^{-4}$ mol

(iii) Calculate the number of tablets a person has to consume to remove the gastric juice. [2]

Amount of HCl present in 1 mole of gastric juice = $1 \times 0.002 = 0.002$ mol
Amount of $MgCO_3$ required = $0.002 \div 2 = 0.001$ mol
Number of tablets needed = $0.001 \div (7.71 \times 10^{-4}) = 1.29 = 2$

(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.

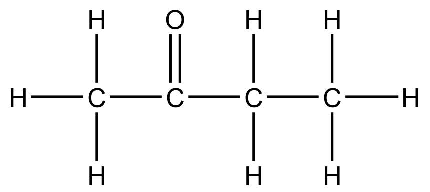
(i) Calculate the empirical formula and deduce the molecular formula of **G**. [2]

	C	H	O
moles	66.7 ÷ 12.0 = 5.558	11.1 ÷ 1.0 = 11.1	22.2 ÷ 16 = 1.387
ratio	4	8	1

empirical formula of **G** = C_4H_8O

Let $(C_4H_8O)_n$ be the molecular formula of **G**.
n × [(4 × 12.0) + (8 × 1.0) + (1 × 16.0)
n = 1
molecular formula of **G** = C_4H_8O

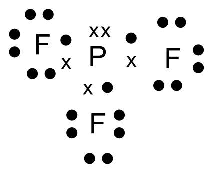
(ii) Compound **G** is a ketone.
Draw the displayed formula of **G**. [1]



[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]

Shape: trigonal pyramidal
Bond angle: 107°
Explanation:
The 4 electrons pairs around the P atom orientate themselves as far apart to minimise repulsion thus it has a basic shape of a tetrahedral. Of the 4 electron pairs, 3 are bond pairs and 1 is a lone pair. As the lone pair-bond pair repulsion is greater than the bond pair-bond pair repulsion, it adopts a trigonal pyramidal shape with a bond angle of 107°.

(iii) Deduce whether PF_3 is a polar molecule.
Explain your answer. [2]

PF_3 is a polar molecule.
The P–F bond is polar (since there is a difference in the electronegativity between P and F) and the dipole moments do not cancel out so there is a net dipole moment.

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

Explain why PF_5 exists whereas NF_5 does not exist. [1]

P is a period 3 element which has **energetically accessible vacant 3d orbitals** for **expansion of octet/ to accommodate more than 8 electrons** whereas N is a period 2 element which does not have energetically accessible (3d) orbitals.

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

Predict the colours of the final solution when

- KI(aq) is added to Cl_2(aq),
- KC*l*(aq) is added to Br_2(aq),
- KBr(aq) is added to I_2(aq).

Write equations for any reactions that occur. State clearly if no reaction occurs. [3]

- KI(aq) is added to Cl_2(aq),
  The colour of the final solution will be brown due to formation of I_2.
  $2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$

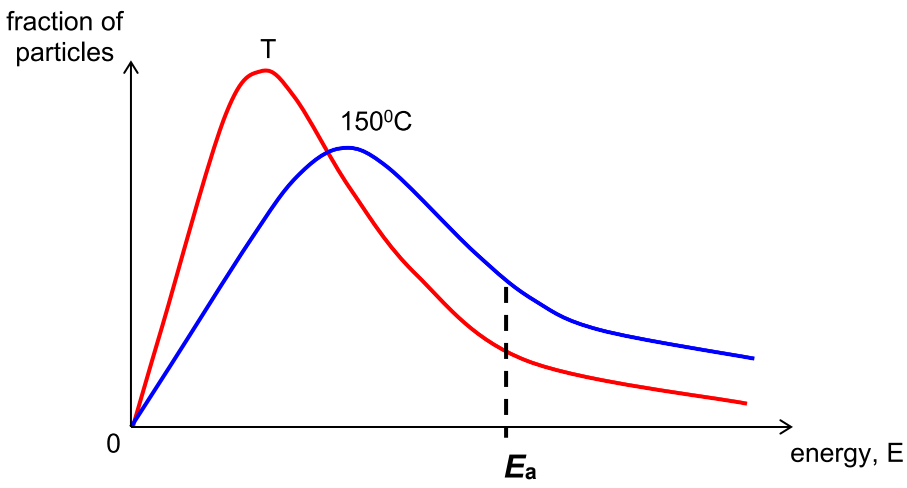
- KC*l*(aq) is added to Br_2(aq),
  No reaction
  The colour of the final solution will be orange due to Br_2.

- KBr(aq) is added to I_2(aq).
  No reaction
  The colour of the final solution will be brown due to I_2.

[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]

See (i).

At higher temperatures nitrogen and oxygen do react.

(iii) Indicate an activation energy, E_a, on your graph. [1]

See (i).

(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]

When the temperature is increased from T to 150^0C,

- 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 result in an **increase in the frequency of effective collisions** [√], hence the rate of reaction increases, with **an increase in rate constant k** [√].

(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.

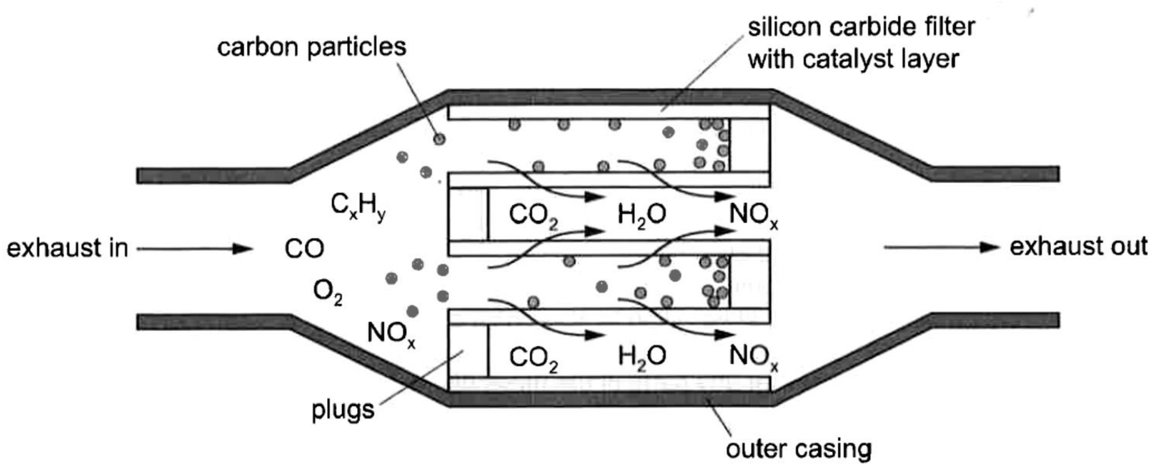


Fig. 4.1

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

$$CO + \frac{1}{2}O_2 \rightarrow CO_2$$

(i) Use information from the diagram to deduce another possible equation for a reaction occurring on the catalyst surface. [1]

$C_xH_y + (x + y/4)O_2 \rightarrow xCO_2 + y/2H_2O$

(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]

Type of catalyst: heterogeneous

- The **reactant molecules are adsorbed onto the active sites of the catalyst surface**.
- This adsorption of the reactant molecules at the catalyst surface speeds up the reaction as the **covalent bonds in the reactants molecules are weakened** [√]**, hence reducing activation energy for the reaction.** Reactant molecules are also **brought closer together with proper orientation for the reaction** .
- The products formed then **desorb and diffuse away from the catalyst surface** and the vacant active sites are available for adsorbing other reactant molecules.

[Total: 10]

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

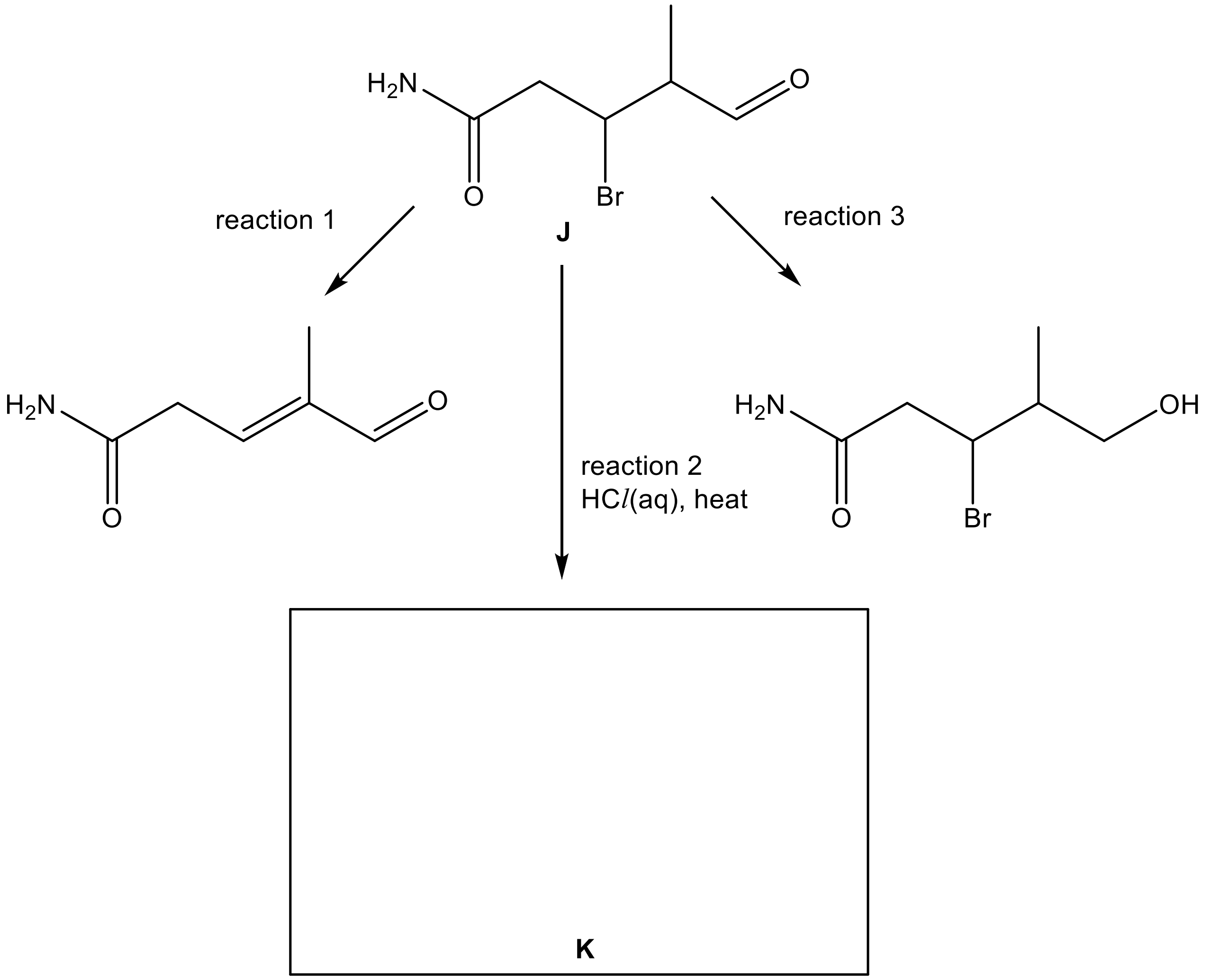
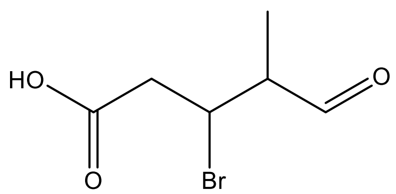


Fig. 5.1

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

ethanolic NaOH, heat

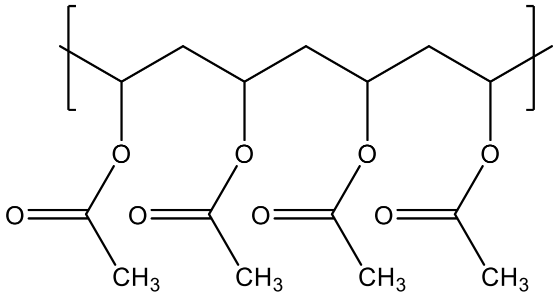
(ii) Draw the structure of compound **K** in the box in Fig. 5.1. [1]



(iii) State the *type of reaction* that occurred in reaction 3. [1]

Reduction

(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.



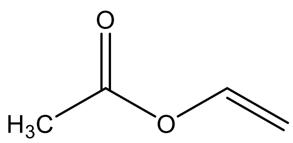
PVAc

Fig. 5.2

(i) State the type of polymerisation that produces PVAc. [1]

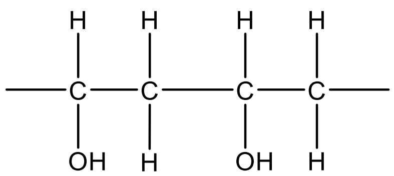
addition polymerisation

(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]



Reagent and conditions: H_2SO_4(aq) *or* NaOH(aq), heat

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

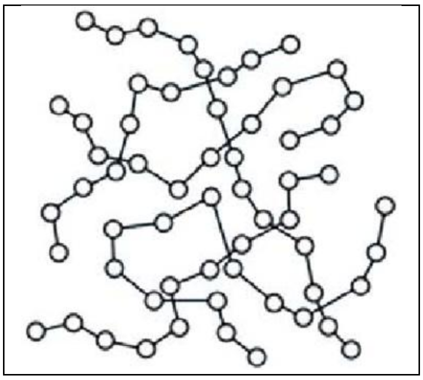


Diagram **M**

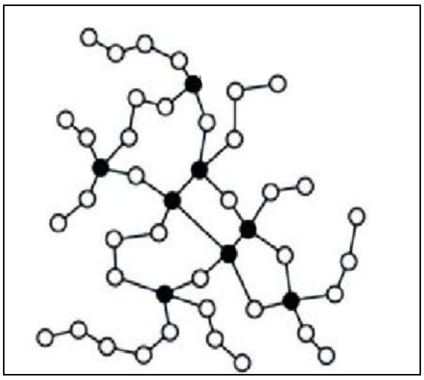


Diagram **N**

Fig. 5.3

(i) State which diagram, **M** or **N**, could be the representation for thermosets. Explain your answer. [1]

Diagram **N**.
There is extensive cross-linking present between the polymer chains.

(ii) State one difference in physical properties between thermoplastics and thermosets. [1]

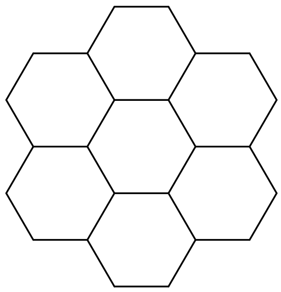
Thermoplastics **soften on heating** (and harden on cooling) / **low tensile strength** / **more flexible and soft** whereas thermosets **cannot be soften on heating** / **high tensile strength** / **much more rigid and stiffer**.

(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]

Nanomaterials are materials with at least one dimension on the scale of 1-100 nm.
Nanoparticles are particles with all dimensions on the scale of 1-100 nm.

(ii) Draw a diagram to illustrate the structure of graphene. [1]



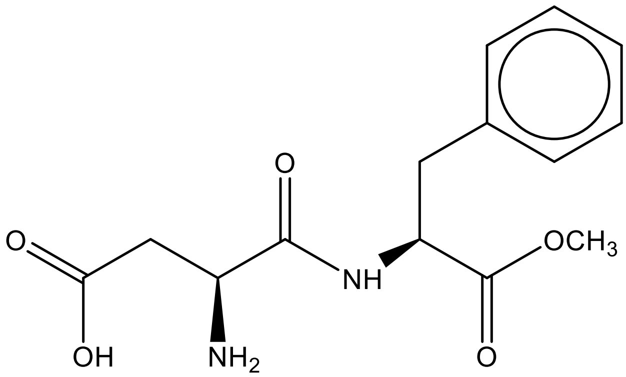
(iii) Explain why graphene is a good electrical conductor. [1]

One p electron per carbon atom is delocalised over the graphene layer and is able to act as a mobile charge carrier. Hence it has high electrical conductivity.

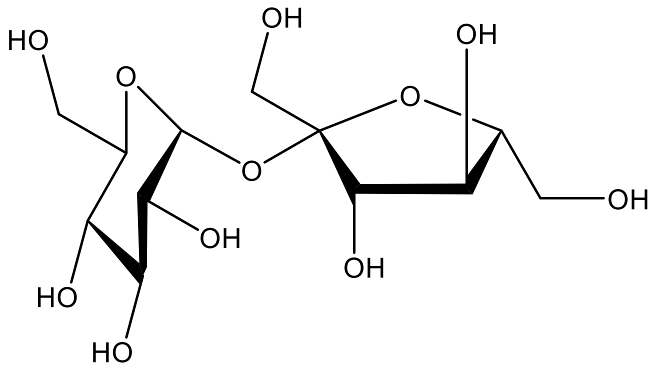
[Total: 12]

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 110g 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 $330cm^3$ cans.



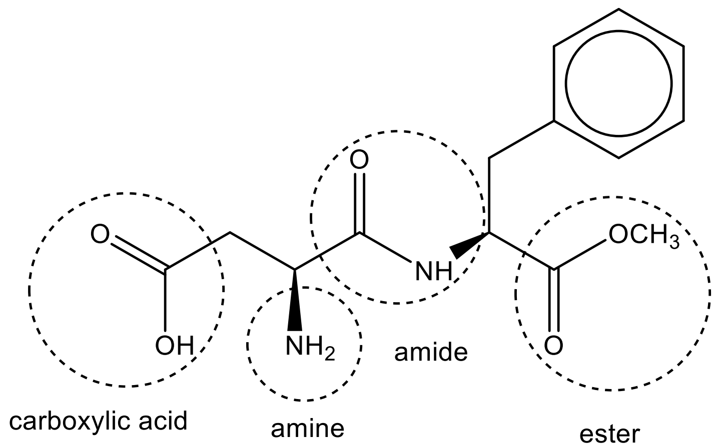
aspartame



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]

M_r of aspartame = 14 × 12.0 + 18 × 1.0 + 2 × 14.0 + 5 × 16.0 = 294.0
M_r of sucrose = 12 × 12.0 + 22 × 1.0 + 11 × 16.0 = 342.0

(ii) Calculate how many grams of sucrose would be present in a typical can of 'regular non-diet' carbonated soft drink. [1]

Mass of sucrose = (110/1000) × 330 = 36.3g

(iii) Calculate how many moles of sucrose there are in your answer to **(b)(ii)**. [1]

Number of moles = 36.3 ÷ 342.0 = 0.106mol

(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]

Aspartame is 180 times sweeter per gram than sucrose.

Mass of aspartame = 36.3 ÷ 180 = 0.202g

(v) Suggest why a 330cm^3 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]

Since **only 0.202 g of aspartame is present in 330 cm^3 carbonated drink, compared to 36.3 g of sucrose**, the overall **mass of the 'diet' drink will be lighter**. Hence, it will float in water.

(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 – 1310cm^{-1}.

Suggest the bond which absorbs in this range. [1]

C-O bond in ether

[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.

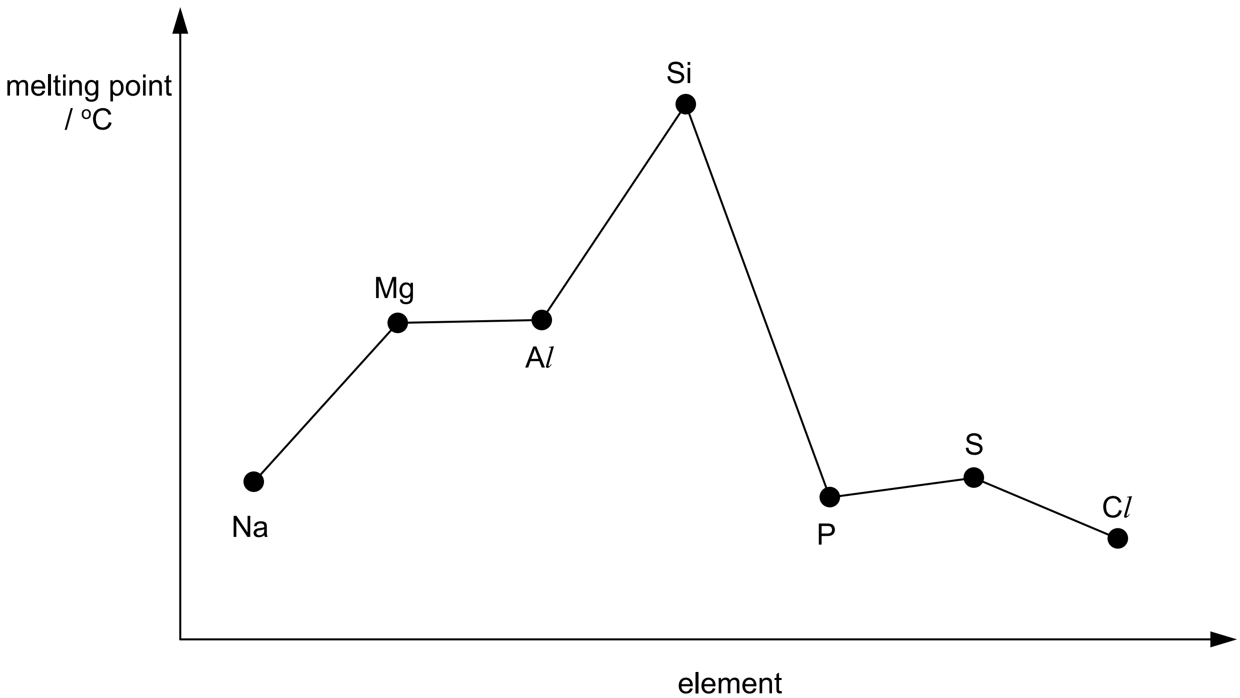


Fig. 7.1

Explain this variation in terms of the structures and bonding of the elements. [6]

- Sodium, magnesium and aluminium have high melting points as
  - they have **giant metallic lattice structures** and
  - a large amount of energy is required to break the **strong electrostatic forces of attraction between the sea of delocalized electrons and the metal cations**.
- Their melting point increases from sodium to aluminium as the strength of the metallic bond increases
  - as the **charge density of the metal cation increases from Na^+ to Al^{3+} as well as the number of delocalized electrons increases**.
  - more energy is required to overcome the strong metallic bonds from sodium to aluminium.

- Silicon has a very high melting point as
  - it has a **giant molecular structure** and
  - a large amount of energy is required to break the **numerous strong electrostatic forces of attractions between the nuclei of the Si atoms and the shared pair of electrons**.
  - The **covalent bonds in the Si are stronger than the metallic bonds** in Na, Mg and Al. Hence Si has a much higher melting than the three metals.

- Phosphorus, sulfur, chlorine and argon have lower melting points as
  - they have **simple molecular structure** and are non-polar with **weak instantaneous-dipole induced-dipole between the molecules**,
  - least amount of energy is required to overcome these weak intermolecular forces of attractions.

- The variation in melting point from phosphorus to argon is in the same order as the size of the electron cloud of the molecules ($S_8 > P_4 > Cl_2$). As **the electron cloud increases in size, it is more easily polarized and hence the strength of instantaneous-dipole induced-dipole increases**.

- The **metallic bond in Na is marginally stronger than the instantaneous dipole – induced dipole between the P_4** and **much stronger than the instantaneous dipole – induced dipole between Cl_2 molecules**.
  However, the **metallic bond in Na is slightly weaker than the instantaneous dipole – induced dipole between the S_8 molecules**. Hence the melting point of Na is in between that of P_4 and S_8 and much higher than Cl_2.

(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 250cm^3 with deionised water.

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

$$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$$

(i) Explain in terms of the change in oxidation number which species has been reduced. [1]

Cr has been reduced.
The oxidation number of Cr decreases from + 6 in $Cr_2O_7^{2-}$ to + 3 in Cr^{3+}.

(ii) Calculate the mass of iron(II) sulfate which is present in one tablet. [4]

Amount of $Cr_2O_7^{2-}$ used = 0.00150 × (23.50 ÷ 1000) = 3.525 × 10^{-5} mol
Amount of Fe^{2+} present in 25.0 cm^3 = 6 × (3.525 × 10^{-5}) = 2.115 × 10^{-4} mol
Amount of Fe^{2+} present in 250 cm^3 = 10 × (2.115 × 10^{-4}) = 2.115 × 10^{-3} mol
Mass of $FeSO_4$ in 5 tablets = (2.115 × 10^{-3}) × (55.8 + 32.1 + 4 × 16.0) = 0.32126 g
Mass of $FeSO_4$ in 1 tablet = 0.32126 ÷ 5 = 0.0643 g

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

$$2C_2H_5OH(l) + CH_3CHO(l) \rightleftharpoons CH_3CH(OC_2H_5)_2(l) + H_2O(l)$$

(i) Explain what is meant by the term *dynamic equilibrium*. [1]

Dynamic equilibrium refers to a **reversible reaction** in which the **forward and reverse reactions are continuing at the same rate** and **concentrations of both reactants and products are constant**.

(ii) Predict and explain how an increase in concentration of ethanal will affect the position of equilibrium of this reaction. [1]

When the concentration of the ethanal is increased, the **position of the equilibrium will shift to the right** to **reduce the additional ethanal**.

(iii) Write an expression for the equilibrium constant, K_c, for the reaction between ethanol and ethanal shown above. [1]

$$K_c = \frac{[CH_3CH(OC_2H_5)_2][H_2O]}{[C_2H_5OH]^2[CH_3CHO]}$$

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

In this equilibrium mixture the concentrations are:

- $CH_3CHO(l)$, 0.1325moldm^{-3}
- $CH_3CH(OC_2H_5)_2(l)$, 1.311moldm^{-3}
- $H_2O(l)$, 1.311moldm^{-3}

The K_c value is 0.074.

Calculate the equilibrium concentration of ethanol. [1]

$$K_c = \frac{[CH_3CH(OC_2H_5)_2][H_2O]}{[C_2H_5OH]^2[CH_3CHO]}$$

$0.074 = [(1.311)(1.311)] \div [[C_2H_5OH]^2 \times 0.1325]$
$[C_2H_5OH]^2 = 175.29$
$[C_2H_5OH] = \sqrt{175.29} = 13.2$ mol dm^{-3}

(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.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

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

At exactly 2.5 minute, 4.070g 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.

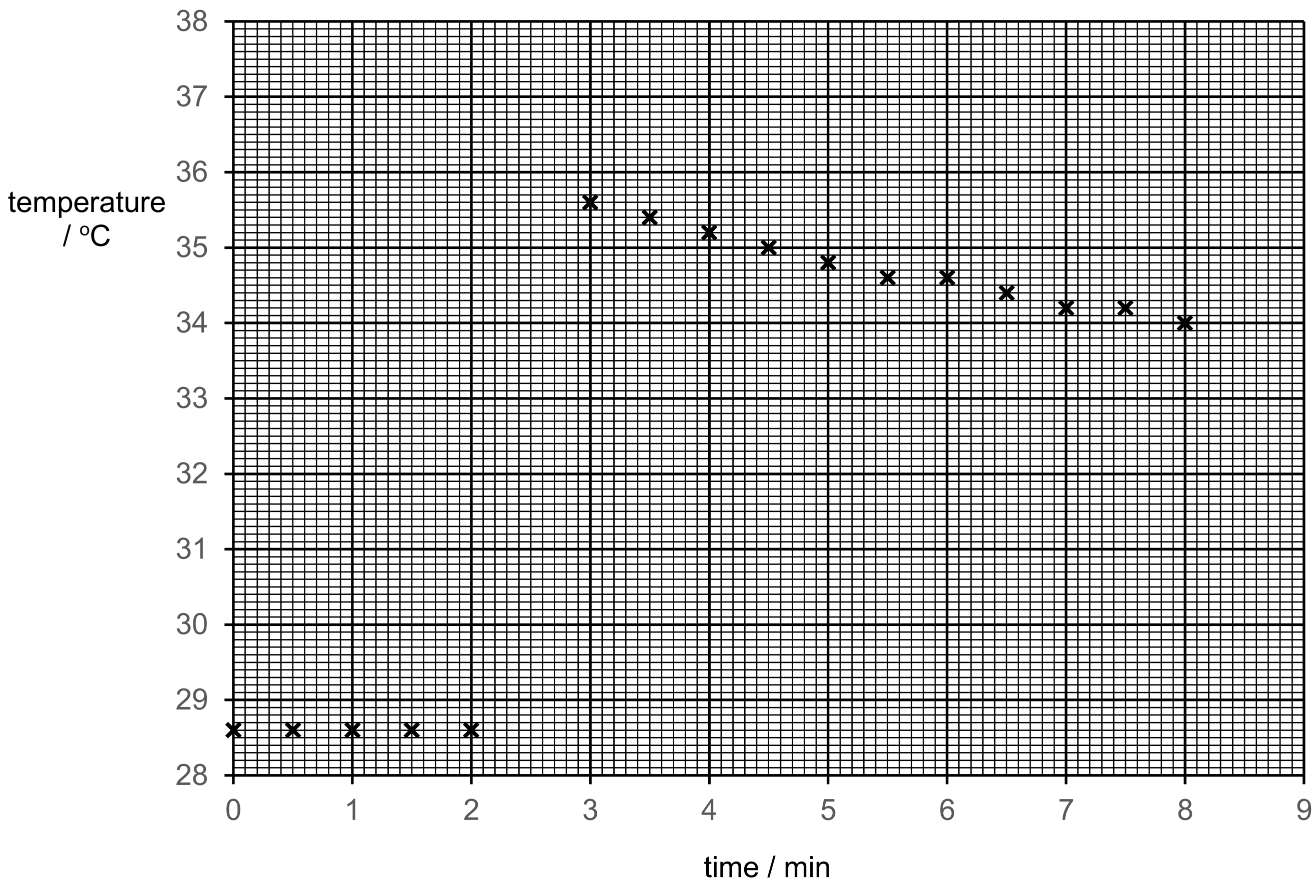


Fig. 7.2

(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, ΔT_{max}, of the experiment.

Show your working.

ΔT_{max} = ... °C [2]

ΔT_{max} = 35.8 – 28.6 = 7.2 °C

(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 reaction is 4.18$Jg^{-1}K^{-1}$ and the density of the solution is 1.00gcm^{-3}. [1]

heat evolved = 50 × 4.18 × 7.2 = 1504.8 J = 1.50 kJ

(iii) Using your answer to **(d)(ii),** calculate a value for the enthalpy change of reaction, in $kJmol^{-1}$, for the reaction between sodium carbonate and hydrochloric acid. The hydrochloric acid is in excess. [2]

amount of Na_2CO_3 = 4.070 ÷ 106.0 = 0.038396 mol

$\Delta H_n^\ominus$ = –1.5048 ÷ 0.038396 = –39.191 = –39.2 kJ mol^{-1}

[Total: 20]

8 **(a)** **(i)** Explain what is meant by the term *order of reaction*. [1]

The order of reaction with respect to a given reactant is the power to which the concentration of that reactant is raised to in an experimentally determined rate equation.
or
In an experimentally rate equation, rate = $k[A]^x$, x is the order of reaction with respect to [A].

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

$$5Br^- + BrO_3^- + 6H^+ \rightarrow 3Br_2 + 3H_2O$$

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.

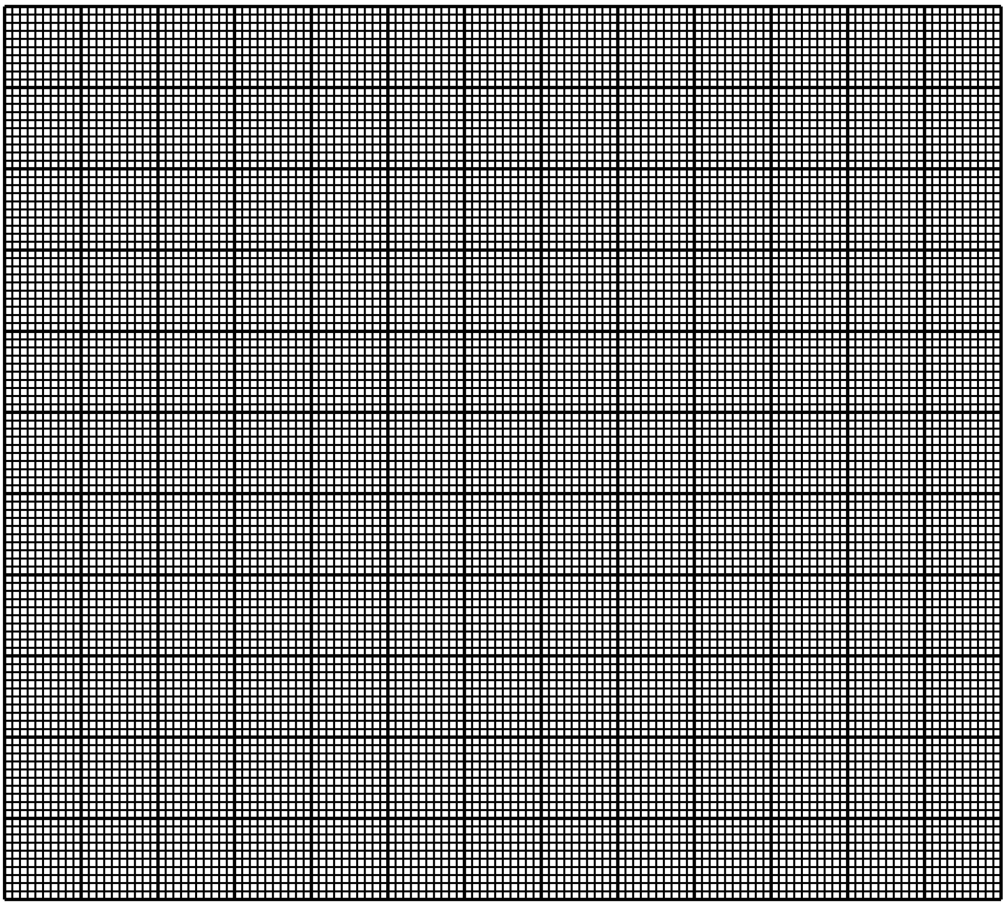
The results for two of the three experiments are shown in Table 8.1.

Table 8.1

	reaction 1	reaction 2
time/s	$[Br^-]$/moldm^{-3}	$[BrO_3^-]$/moldm^{-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

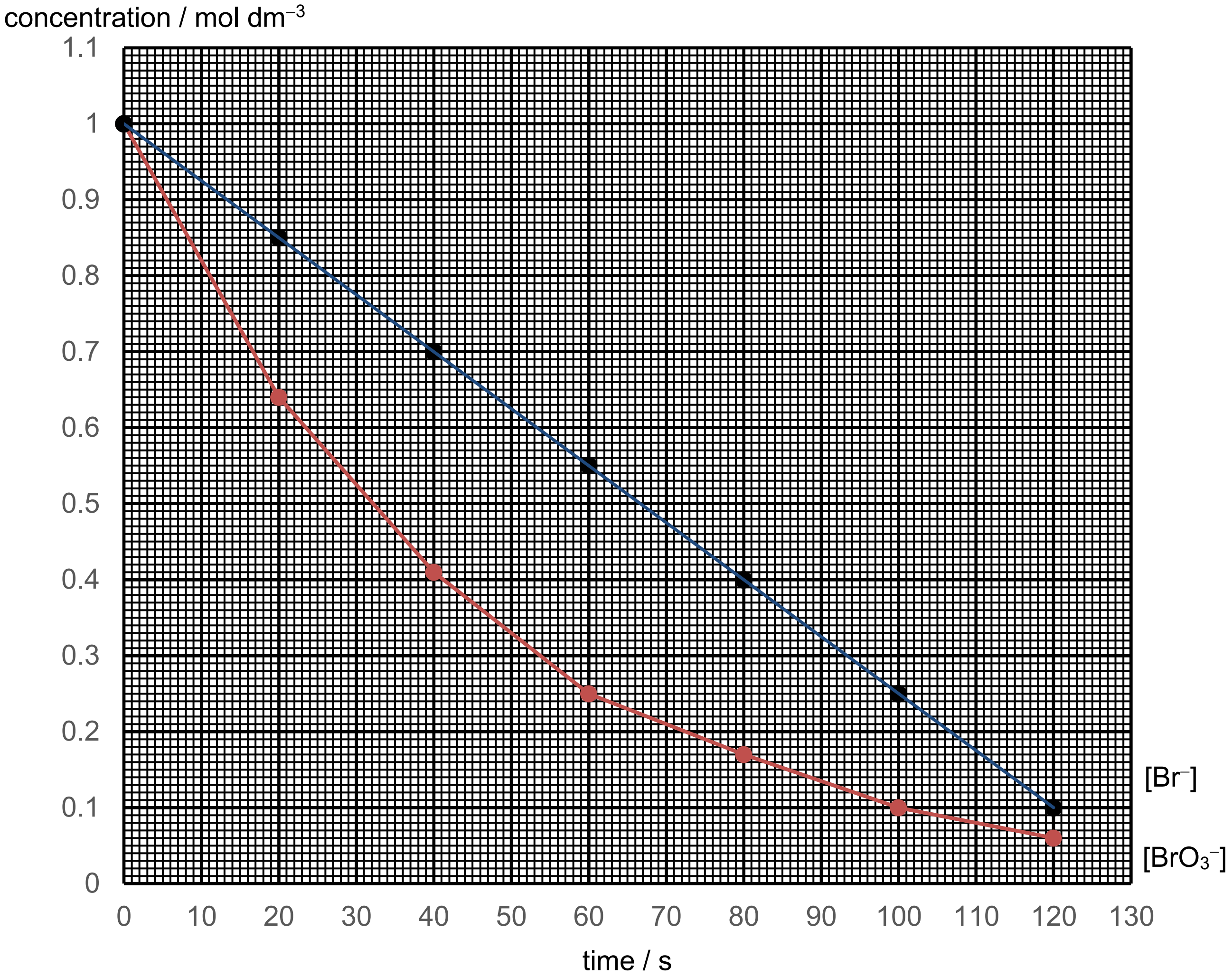
(ii) On the grid, plot a graph of $[Br^-]$ against time.
Label the line $[Br^-]$. [3]

concentration
of reactant
/ $mol dm^{-3}$



time / s

(iii) On the same grid, plot a graph of $[BrO_3^-]$ against time.
Label the line $[BrO_3^-]$. [2]



(iv) Deduce the order of reaction with respect to Br^-.
Use your graph to explain your answer. [1]

Order of reaction with respect to $[Br^-]$ = 0
The line is a straight line indicating a constant rate with decreasing concentration.

(v) Deduce the order of reaction with respect to BrO_3^-.
Use your graph to explain your answer. [1]

Order of reaction with respect to $[BrO_3^-]$ = 1
The half-life is constant at about 30 s.

(v) The order of reaction with respect to $[H^+]$ is first order.

The rate of reaction is 8.80×10^{-6} $mol dm^{-3} s^{-1}$ when $[Br^-] = 0.10$ $mol dm^{-3}$, $[BrO_3^-] = 0.10$ $mol dm^{-3}$ and $[H^+] = 0.40$ $mol dm^{-3}$.

Calculate the rate constant for this reaction and state its units. [2]

rate = $k[BrO_3^-][H^+]$
$k = \text{rate} / [BrO_3^-][H^+] = (8.80 \times 10^{-6}) \div (0.10 \times 0.40) = 2.20 \times 10^{-4}$ mol^{-1} dm^3 s^{-1}

(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]

A *Brønsted-Lowry acid* is a proton donor and a *Brønsted-Lowry base* is a proton acceptor.

(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. [2]

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

HCl is the acid and its conjugate base is Cl^-.
H_2O is the base and its conjugate acid is H_3O^+.

(iii) Calculate the pH of 0.03 $mol dm^{-3}$ hydrochloric acid.
Give your answer to three significant figures. [1]

pH = –log (0.03) = 1.52

(c) Sugar is composed of sucrose, $C_{12}H_{22}O_{11}$. It is used as a sweetener in many foods and drinks.

(i) Define the standard enthalpy change of formation. [1]

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

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

$$12C(s) + 11H_2(g) + 5\tfrac{1}{2}O_2(g) \rightarrow C_{12}H_{22}O_{11}(s)$$

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

$\Delta H_c^{\ominus}$ (sucrose)/kJmol^{-1}	–5650
$\Delta H_f^{\ominus}$ (H_2O(l))/kJmol^{-1}	–286
$\Delta H_f^{\ominus}$ (CO_2(g))/kJmol^{-1}	–393.5

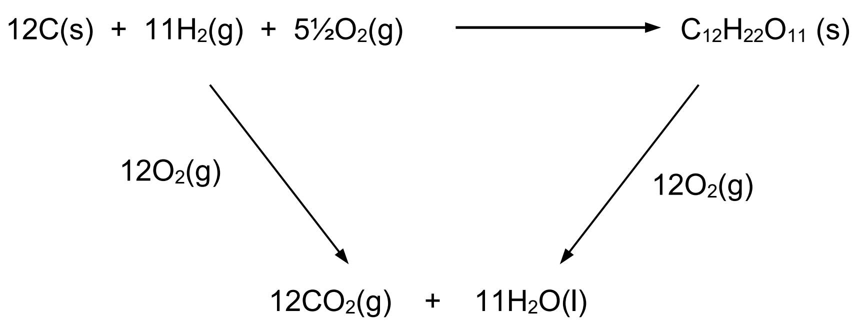


Fig. 8.1

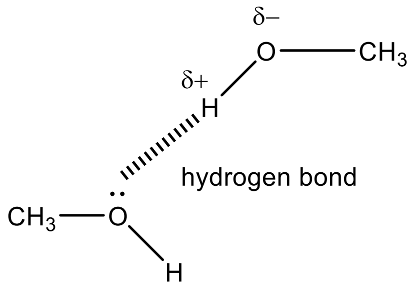
[3]

$\Delta H_f^{\ominus}$ (sucrose) + $\Delta H_c^{\ominus}$ (sucrose) = (11 × $\Delta H_f^{\ominus}$ (H_2O(l)) + (12 × $\Delta H_f^{\ominus}$ (CO_2(g))
$\Delta H_f^{\ominus}$ (sucrose) = (11 × –286) + (12 × –393.5) – (–5650) = –2218 = –2220 kJ mol^{-1}

(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]



[√] for showing dipole moment
[√] for showing lone pair on O atom
[√] for showing dashed line between protonic H atom and lone pair on O atom
[√] for labelling hydrogen bond

[Total: 20]