OCR
Oxford Cambridge and RSA

Tuesday 14 May 2024 – Morning

AS Level Chemistry B (Salters)

H033/01 Foundations of chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry B

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name *StemUp Model Solution*

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

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SECTION A

You should spend a **maximum** of **25 minutes** on this section.

Write your answer to each question in the box provided.

1 On a Periodic Table the number 39.1 is shown for potassium, K.

What is this number?

A atomic number

B mass number

C relative atomic mass

D relative molecular mass

Your answer C **[1]**

2 SiO_2 has a covalent network structure.

What is correct for SiO_2?

A It consists of SiO_2 molecules joined by strong intermolecular bonds.

B It does not conduct electricity when molten.

C It has a low melting point.

D It is readily soluble in water.

Your answer B **[1]**

3 What is the missing product of the nuclear fusion reaction shown?

$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{1}_{0}n +$ .....

A a beryllium nucleus

B a helium nucleus

C a lithium nucleus

D a proton

Your answer B **[1]**

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4 Magnesium oxide reacts with dilute hydrochloric acid.

What is correct for this reaction?

A A gas is given off.

B A green solution of a salt is formed.

C It is a neutralisation.

D Magnesium hydrochloride is formed.

Your answer C **[1]**

5 This question is about the relationship between enthalpy changes and bonds broken and made.

Which row is correct?

	sign of ΔH	**description**	**bonds broken and made**
A	–	endothermic	more energy released in making bonds than used in breaking bonds
B	–	exothermic	less energy released in making bonds than used in breaking bonds
C	+	endothermic	less energy released in making bonds than used in breaking bonds
D	+	exothermic	more energy released in making bonds than used in breaking bonds

Your answer C **[1]**

6 What are possible products from cracking an alkane molecule?

A one alkane molecule and two alkene molecules

B two alkane molecules

C two alkane molecules and one alkene molecule

D two alkene molecules

Your answer A **[1]**

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7 What is a risk, rather than a benefit, of using chlorine solution?

A It can be toxic.

B It is a disinfectant.

C It kills bacteria.

D It sterilises water.

Your answer A **[1]**

8 An impure organic liquid is being purified after preparation.

The liquid is insoluble in water.

Why is a separating funnel used?

A To complete the distillation.

B To remove the sodium sulfate used for drying.

C To separate the impure liquid from aqueous washings.

D To separate the pure product from water.

Your answer C **[1]**

9 What is correct for all the halogens (Group 17)?

A Their atoms have electronic configurations ending p^5.

B They are gases.

C They are readily soluble in water.

D They have the highest first ionisation enthalpy in their period.

Your answer A **[1]**

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10 What occurs when aqueous chlorine reacts with aqueous iodide ions?

A $2Cl^- \rightarrow Cl_2 + 2e^-$

B Electrons are transferred from chlorine atoms.

C I^- is oxidised.

D The brown colour fades.

Your answer C **[1]**

11 Aluminium reacts with chlorine to form $AlCl_3$.

What is the maximum mass (in g) of $AlCl_3$ (M_r = 133.5) that could be made by reacting 5.4 g of aluminium with 10.7 g of chlorine?

A 13.4

B 16.1

C 27.0

D 40.0

Your answer A **[1]**

12 A reaction has a $K_c << 1 \times 10^{-10}$

What is correct for this reaction?

A Concentration of products = concentration of reactants.

B It forms an equilibrium with more products than reactants.

C It goes to completion.

D It hardly happens at all.

Your answer D **[1]**

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13 The table shows the tropospheric abundance and greenhouse factors for carbon dioxide and methane. The greenhouse factor measures the relative contribution to the greenhouse effect of one gram of each gas.

	tropospheric abundance by mass	**greenhouse factor**
CO_2	0.040%	1
CH_4	1.8 ppm	28

What is the approximate value of the fraction shown?

$$\frac{\text{contribution to the greenhouse effect of the methane in the troposphere}}{\text{contribution to the greenhouse effect of the carbon dioxide in the troposphere}}$$

A 1/80

B 1/8

C 45/1

D 80/1

Your answer B **[1]**

14 Iodobutane reacts with silver nitrate solution.

What is correct about this reaction?

A It gives a white precipitate.

B It is faster than the reaction of chlorobutane with silver nitrate solution.

C It is slower than the reaction of bromobutane with silver nitrate solution.

D The rate is determined by the polarity of the C–I bond.

Your answer B **[1]**

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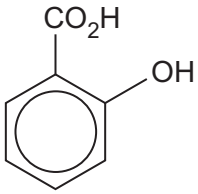
15 What is a property of the compound shown?



A It can be oxidised to a carbonyl compound.

B It gives a purple colour with neutral $FeCl_3$.

C It is neutral in solution.

D It reacts with alkalis but not carbonates.

Your answer B **[1]**

16 An impure solid is purified by recrystallisation.

What is correct?

A Insoluble impurities are removed by filtration at the end of the process.

B Soluble impurities remain in solution at the end of the process.

C The final mass of solid is greater than the mass before recrystallisation.

D The solid must be soluble in the chosen solvent at low temperatures.

Your answer B **[1]**

17 The thermal stability of Group 2 carbonates increases down the group.

What is a reason for this?

A The anion charge gets smaller down the group.

B The anion is more distorted down the group.

C The cation charge gets larger down the group.

D The cations get larger down the group.

Your answer D **[1]**

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18 A hydrocarbon molecule has 9 σ bonds and 2 π bonds.

What is the hydrocarbon?

A $CH_2CHCHCHCH_3$

B $CH_2CHCH_2CH_3$

C $CH_2CHCHCH_2$

D CH_2CHCH_3

Your answer C **[1]**

19 The reaction shown is sometimes used during the manufacture of bromine from sea water.

$Br_2(aq) + SO_2(g) + ... \rightarrow 2HBr(aq) + H_2SO_4(aq)$

What is correct about this reaction?

A '$H_2O(l)$' should be written on the dotted line.

B The colour darkens during the reaction.

C The pH falls during the reaction.

D The sulfur is oxidised from +2 to +6.

Your answer C **[1]**

20 An aqueous solution of calcium nitrate is electrolysed.

What is the product at the anode?

A calcium

B hydrogen

C nitrogen

D oxygen

Your answer D **[1]**

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SECTION B

21 Sodium bicarbonate, $NaHCO_3$, is used in baking cakes.
It decomposes when heated, giving carbon dioxide that causes the cakes to 'rise'.

$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$ **Equation 21.1**

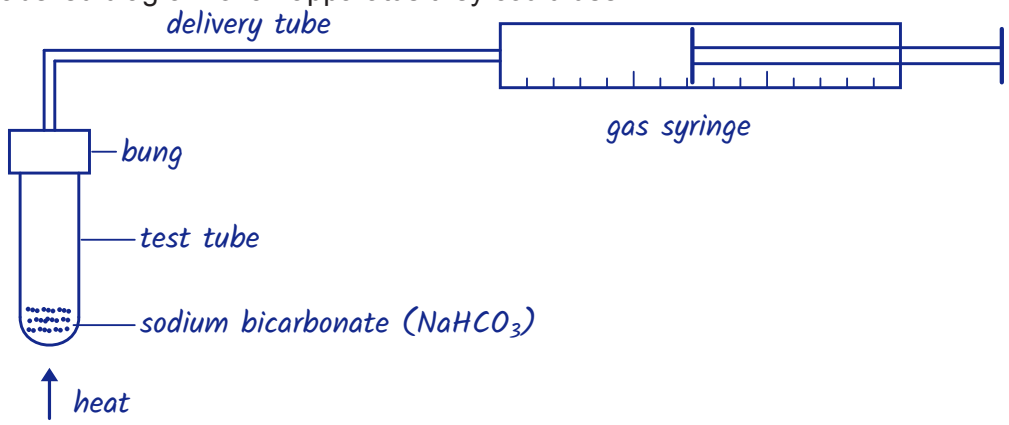
(a) Give the systematic name of $NaHCO_3$.

..sodium..hydrogen..carbonate..... **[1]**

(b) A pair of students want to check **Equation 21.1**.

They heat a sample of sodium bicarbonate, collect the carbon dioxide produced and measure its volume.

(i) Draw a labelled diagram of an apparatus they could use.



[2]

(ii) Calculate the volume of gas (in cm^3, measured at RTP) that they would expect to collect if they heated 0.10 g of sodium bicarbonate.

$M_r(NaHCO_3) = 23.0 + 1.0 + 12.0 + 3(16.0) = 84.0$

$n(NaHCO_3) = 0.10 / 84.0 = 1.19 \times 10^{-3}$ mol

$n(CO_2) = 1.19 \times 10^{-3} / 2 = 5.95 \times 10^{-4}$ mol

$V = 5.95 \times 10^{-4} \times 24\,000 = 14$ cm^3

volume = ...14..... cm^3 **[2]**

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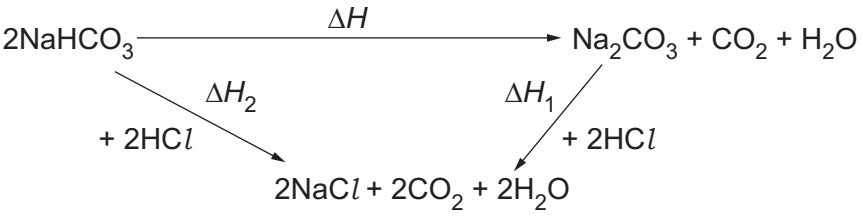
(c) The students wish to measure the ΔH for the reaction in **Equation 21.1**.

They react $NaHCO_3$ and Na_2CO_3 separately with hydrochloric acid in glass beakers. They measure the temperature changes in each experiment.

They then use the Hess cycle in **Fig 21.1** to measure ΔH.

Fig. 21.1



The students' results for measuring ΔH_1 are:

Mass of Na_2CO_3 / g	2.0
Volume of 2.0 mol dm^{-3} HC*l* (excess) / cm^3	25.0
Initial temperature of solution / °C	19.3
Final temperature of solution / °C	25.1

(i) Calculate the value of ΔH_1 (in kJ mol^{-1}).
(Assume there are 27.0 g of solution with the same specific heat capacity as water.)

energy = $mc\Delta T$ = 27.0 × 4.18 × (25.1 − 19.3) = 654.6 J

$n(Na_2CO_3)$ = 2.0 / 106.0 = 1.89 × 10^{-2} mol

ΔH_1 = −0.6546 kJ / 1.89 × 10^{-2} mol = −34.7 = −35

ΔH_1 = ...−35..... kJ mol^{-1} **[3]**

(ii) The greatest measurement uncertainty is 0.05 g in the mass.

What percentage is 0.05 of 2.0?

0.05 / 2.0 × 100 = 2.5 %

answer = ...2.5..... % **[1]**

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(iii) As well as measurement uncertainties, there are also errors caused by experimental limitations. One such error is 'heat loss' during the measurement of ΔH_1.

The students could reduce heat loss by changing one piece of apparatus.

Describe this change and explain how it will reduce heat loss.

Replace the glass beaker with a polystyrene cup (with a lid).

Polystyrene is a better (thermal) insulator than glass, so less heat is lost to the surroundings. **[2]**

(iv) The students do another experiment and calculate that $\Delta H_2 = +22\,\text{kJ mol}^{-1}$.

Calculate ΔH in kJ mol^{-1}, using your answer from **(i)** and the cycle in **Fig. 21.1**.

$\Delta H = \Delta H_2 - \Delta H_1$

$\Delta H = +22 - (-35) = +57\ \text{kJ mol}^{-1}$

ΔH = +57 kJ mol^{-1} **[2]**

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22 Knowledge of the structure of atoms developed gradually over time.
By the year 1914 the arrangement of the electrons was still being worked out.
A scientist called Neils Bohr studied atomic spectra and devised the idea of electrons being in energy levels.

(a) Atomic spectra can be either absorption spectra or emission spectra.

Describe the appearance of an atomic **absorption** spectrum and explain how it is formed.
Give **one** similarity between the atomic absorption and emission spectra of the same element.

Appearance: a continuous (rainbow) spectrum of colours crossed by a series of dark (black) lines.

White light is passed through the gaseous atoms. Electrons absorb energy and are excited, moving up from a lower energy level to a higher energy level.

Only light of a definite frequency is absorbed, because the energy of the photon must equal the gap between the levels, $\Delta E = h\nu$.

Each absorbed frequency is missing from the light, so it shows as a dark line in the spectrum.

Similarity: the lines in the absorption and emission spectra of the same element are in the same place (at the same frequencies). **[5]**

(b) Later work led to the ideas of electron orbitals.

Give the shape of an s-orbital.

spherical (a sphere) **[1]**

(c) Electron configurations help to explain the similarities and trends in the Periodic Table.

(i) Complete the electron configuration of a calcium atom.

$1s^2$ *$2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$* **[1]**

(ii) Magnesium has similar reactions to calcium.

Explain why, in terms of electron configurations.

Both have two electrons in their outer s sub-shell (Mg $3s^2$, Ca $4s^2$), so the same outer electron configuration. **[1]**

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(iii) An element **A** has the following properties:

- It is a silvery metal with a melting point of 29 °C.
- Its atoms contain d electrons.
- It forms an oxide of formula $\mathbf{A}_2O_3$ with M_r less than 200.

Identify **A**, giving at least **three** reasons based on its properties.

A is ...gallium, Ga.....

Reasons: A forms A_2O_3, so it has a +3 oxidation state (3 outer shell electrons);
it is in Group 13 (3).
Its atoms contain d electrons, so it is in Period 4 or below (after calcium, it has 3d electrons).
Its melting point is very low (29 °C), so it is not a transition metal.
$M_r(A_2O_3) < 200$, so $A_r < 76$; $M_r(Ga_2O_3) = 2(69.7) + 3(16.0) = 187.4$.

..... **[4]**

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23 Ethanoic acid, CH_3COOH, is widely used for making other substances, such as polymers.

Most ethanoic acid is now made from methanol by the Cativa process.

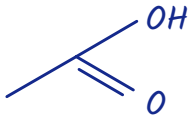
The Cativa process has three stages, shown below.

Stage 1: $CH_3OH + HI \rightarrow CH_3I + H_2O$

Stage 2: $CH_3I + CO \rightarrow CH_3COI$

Stage 3: $CH_3COI + H_2O \rightarrow CH_3COOH + HI$

(a)
(i) Draw the **skeletal** formula of ethanoic acid.



[1]

(ii) Name CH_3I, the product of **Stage 1**.

iodomethane ..... **[1]**

(b) What is the atom economy of the Cativa process for producing ethanoic acid?

Overall: $CH_3OH + CO \rightarrow CH_3COOH$, the only product
(HI is regenerated), so all atoms end up in the product.

atom economy = ...100..... % **[1]**

(c) Calculate the minimum mass of CO needed to make 15 g of ethanoic acid by the Cativa process.

Give your answer to an **appropriate** number of significant figures.

Overall: $CH_3OH + CO \rightarrow CH_3COOH$, so 1 mol CO gives 1 mol acid

$M_r(CH_3COOH) = 60.0$, so $n = 15 / 60.0 = 0.25$ mol

$n(CO) = 0.25$ mol

mass of CO $= 0.25 \times 28.0 = 7.0$ g (2 s.f.)

mass = ...7.0..... g **[3]**

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(d) **Stage 1** is a nucleophilic substitution.

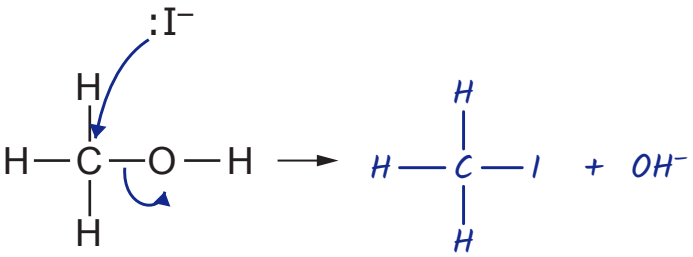
(i) What is a **nucleophile**?

A species (molecule or negative ion) that donates a lone pair of electrons to form a (dative) covalent bond. **[1]**

(ii) In **Stage 1**, I^- ions from the HI displace OH^- ions from methanol, CH_3OH.

Complete the mechanism for this process.

Use curly arrows and show the products.



[2]

(e) The Cativa process uses an iridium catalyst in **Stage 2**.
An alternative process, called the Monsanto process, uses a rhodium catalyst. The Monsanto process makes more propanoic acid as a by-product than the Cativa process.

(i) In which **block** of the Periodic Table are rhodium (Rh) and iridium (Ir) both found?

d-block **[1]**

(ii) Explain why the Cativa process is 'greener' than the Monsanto process.

The Cativa process makes less by-product (less propanoic acid), so less separation is needed and more of the reactants form ethanoic acid. **[1]**

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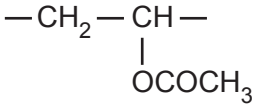
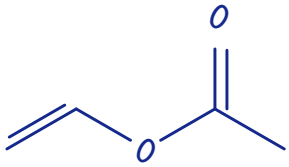
(f) Ethanoic acid can be converted to ‘vinyl acetate’.

Vinyl acetate is the monomer for PVAc, a polymer used in wood glue.



repeating unit of PVAc

Draw the **skeletal** formula of the monomer vinyl acetate.



[2]

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Turn over for the next question

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24 Some students investigate the rate of the reaction of sodium thiosulfate with acid.

$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow H_2O(l) + SO_2(g) + S(s)$ **Equation 24.1**

The students make a pencil mark on a piece of paper. They measure the time it takes for the precipitate of sulfur to block out their view of the mark.

The rate of reaction is given by: Rate $\propto$ 1/time

Mixtures of sodium thiosulfate solution and water are made up as shown in the table.
5 cm^3 of 2.0 mol dm^{-3} HC*l* is added to each one.
The time for the mark to be blocked out is noted.

The students get the following results at room temperature.

Volume of sodium thiosulfate / cm^3	Volume of water / cm^3	Time / s	Rate (1/time) / s^{-1}
10	40	100	0.010
20	30	44	0.023
30	20	35	.....0.029.....
40	10	26	0.038
50	0	20	0.050

(a)
(i) Fill in the missing value in the table. **[1]**

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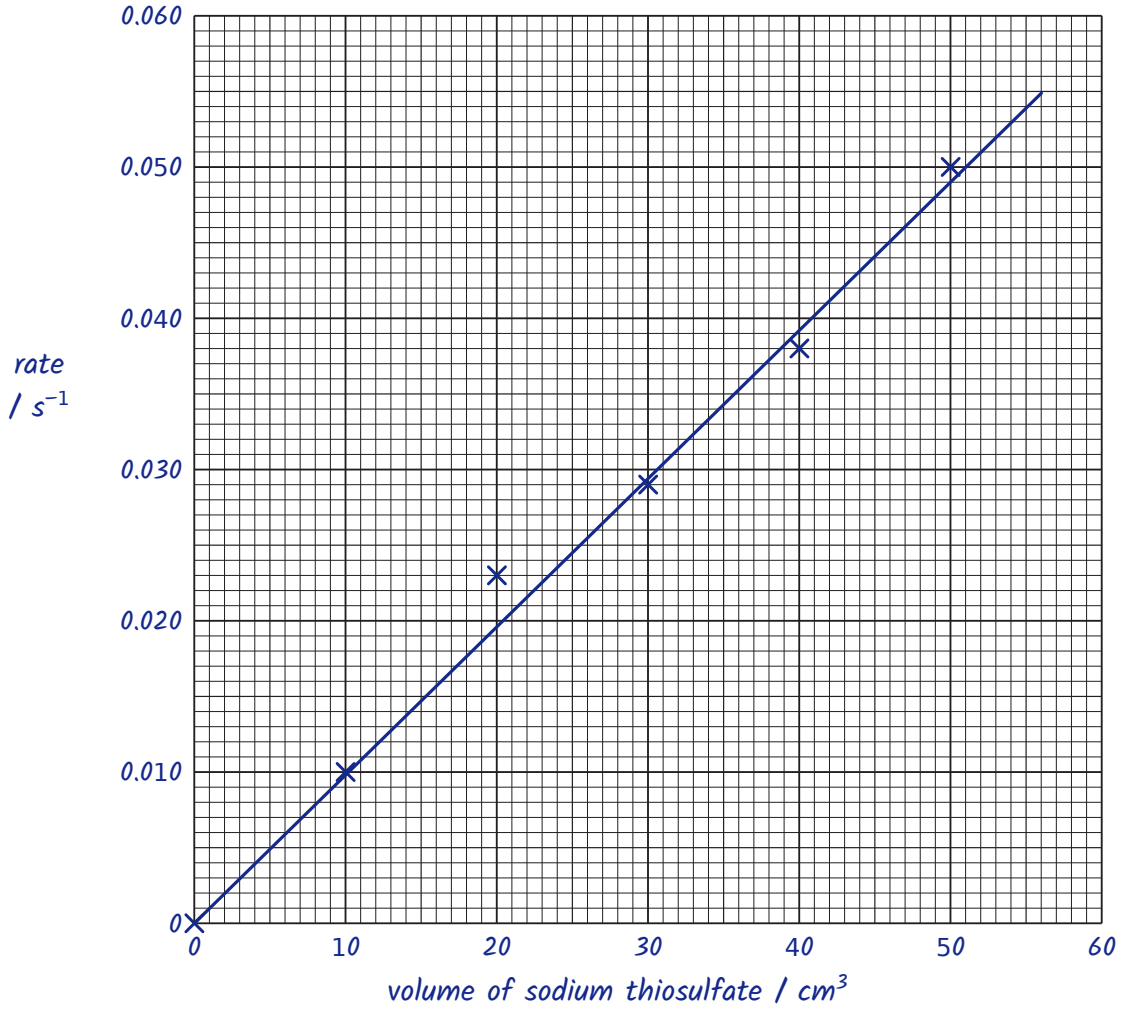
(ii) On the graph paper below, plot a graph of rate against volume of sodium thiosulfate, including the origin. Label the axes.

Draw a line of best fit.



[3]

(iii) Explain why 'volume of sodium thiosulfate' is proportional to 'concentration of sodium thiosulfate'.

The total volume is kept constant (50 cm^3), so the amount of thiosulfate per unit volume is proportional to its volume. **[1]**

(iv) The graph shows the relationship between rate and thiosulfate concentration for the reaction in **Equation 24.1**.

Describe this relationship and explain it in terms of molecular collisions.

Rate is directly proportional to thiosulfate concentration (a straight line through the origin): doubling the concentration doubles the rate.

Doubling the concentration doubles the number of thiosulfate ions in the same volume, so the frequency of (successful) collisions doubles. **[2]**

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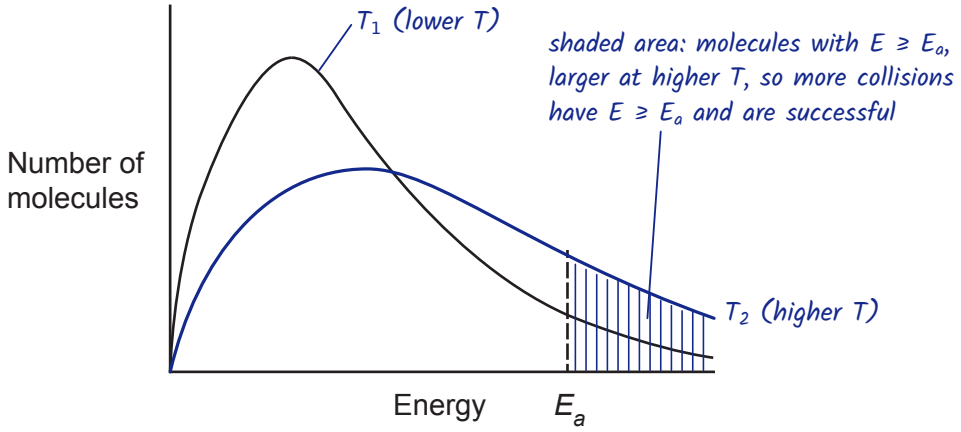
(b) The students repeat the experiment, varying the temperature. They find that the reaction gets faster as the temperature is increased.

Complete and label the diagram below to explain why reactions get faster as the temperature increases.



[2]

(c)
(i) Assign oxidation states to the sulfur atoms in the equation.

Write the oxidation states on the dotted lines below the atoms.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow H_2O(l) + SO_2(g) + S(s)$$

+2 +4 0

[2]

(ii) State what is being oxidised and what is being reduced in the reaction.

Sulfur (in $S_2O_3^{2-}$) is both oxidised (+2 to +4 in SO_2) and reduced (+2 to 0 in S). **[1]**

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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