

Paper Reference(s) 9CH0/01

Pearson Edexcel Level 3 GCE

Chemistry

Advanced

**Paper 1: Advanced Inorganic and Physical
Chemistry**

Tuesday 4 June 2019 – Afternoon

**Time: 1 hour 45 minutes plus your additional
time allowance**

INSTRUCTIONS TO CANDIDATES

**Write your centre number, candidate number,
surname, other names and your signature in
the boxes below. Check that you have the
correct question paper.**

Centre No.					
Candidate No.					
Surname					
Other names					
Signature					
Paper Reference	9	C	H	0	/ 0 1

- **Use BLACK ink or BLACK ball-point pen.**
- **Answer ALL questions.**
- **Answer the questions in the spaces provided – there may be more space than you need.**

MATERIALS REQUIRED FOR EXAMINATION
Data Booklet, Scientific Calculator, Ruler

ITEMS INCLUDED WITH QUESTION PAPERS
Periodic Table

INFORMATION FOR CANDIDATES

- **The total mark for this paper is 90.**
- **The marks for EACH question are shown in brackets – use this as a guide as to how much time to spend on each question.**
- **For the question marked with an ASTERISK (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.**
- **A Periodic Table is provided.**

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(Turn over)

ADVICE TO CANDIDATES

- **Read each question carefully before you start to answer it.**
- **Show all your working in calculations and include units where appropriate.**
- **Check your answers if you have time at the end.**

Answer ALL questions.

Some questions must be answered with a cross in a box ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

1 This question is about atoms, molecules and ions.

(a) The numbers of subatomic particles in an ^{18}O atom are (1 mark)

☐ **A 8 protons, 10 neutrons and 8 electrons**

☐ **B 9 protons, 9 neutrons and 9 electrons**

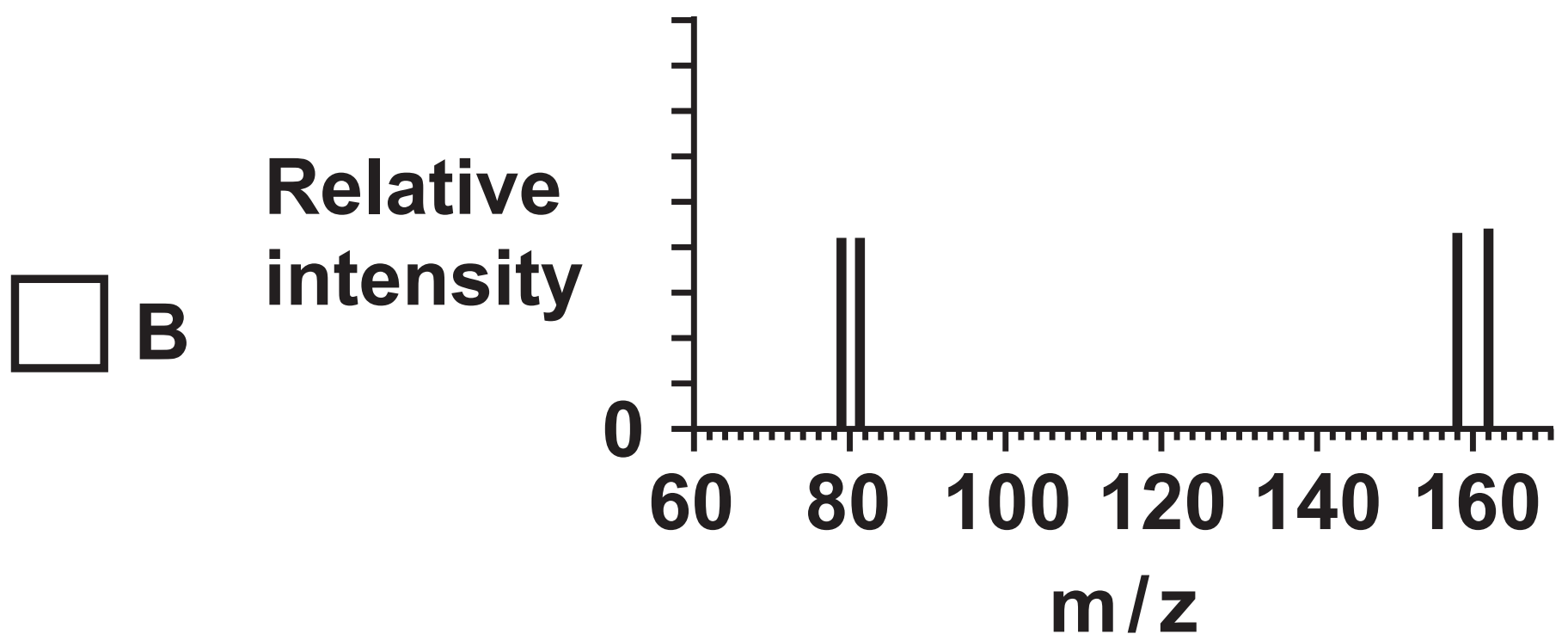
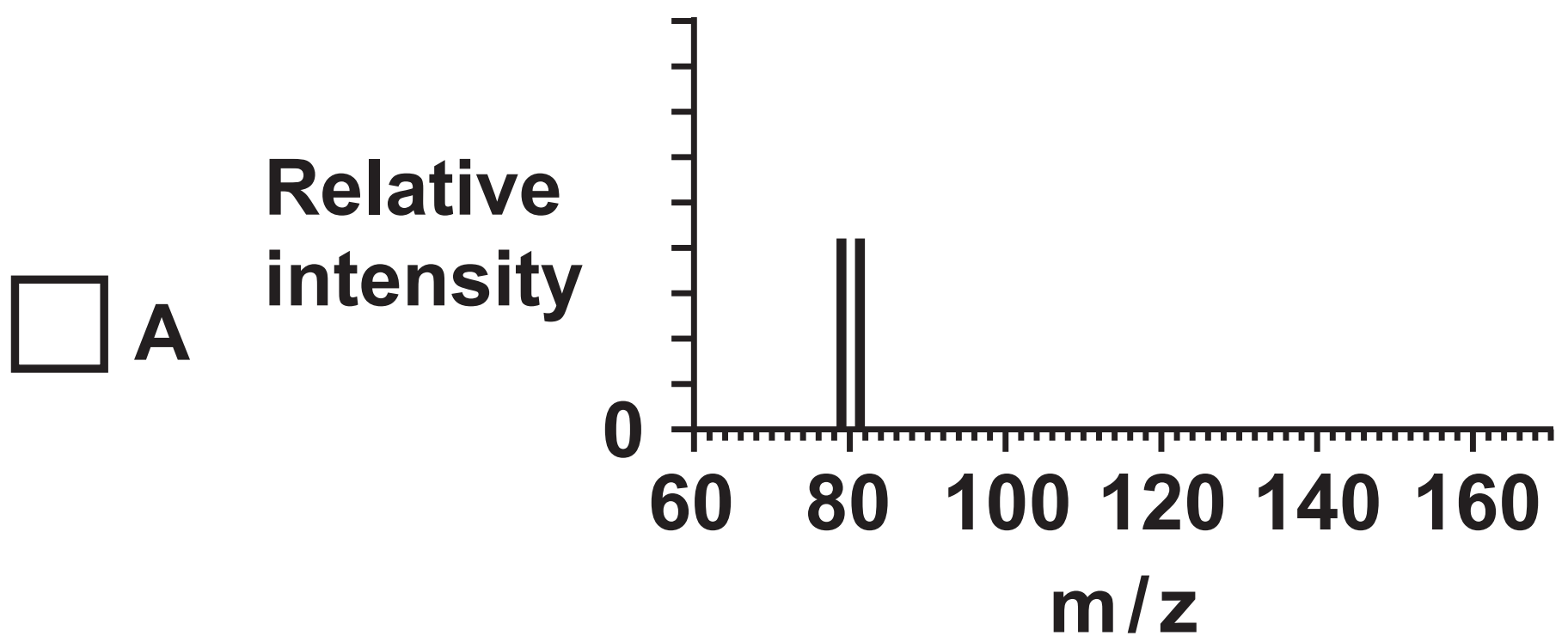
☐ **C 10 protons, 8 neutrons and 10 electrons**

☐ **D 18 protons, 18 neutrons and 18 electrons**

(Question continues on next page)

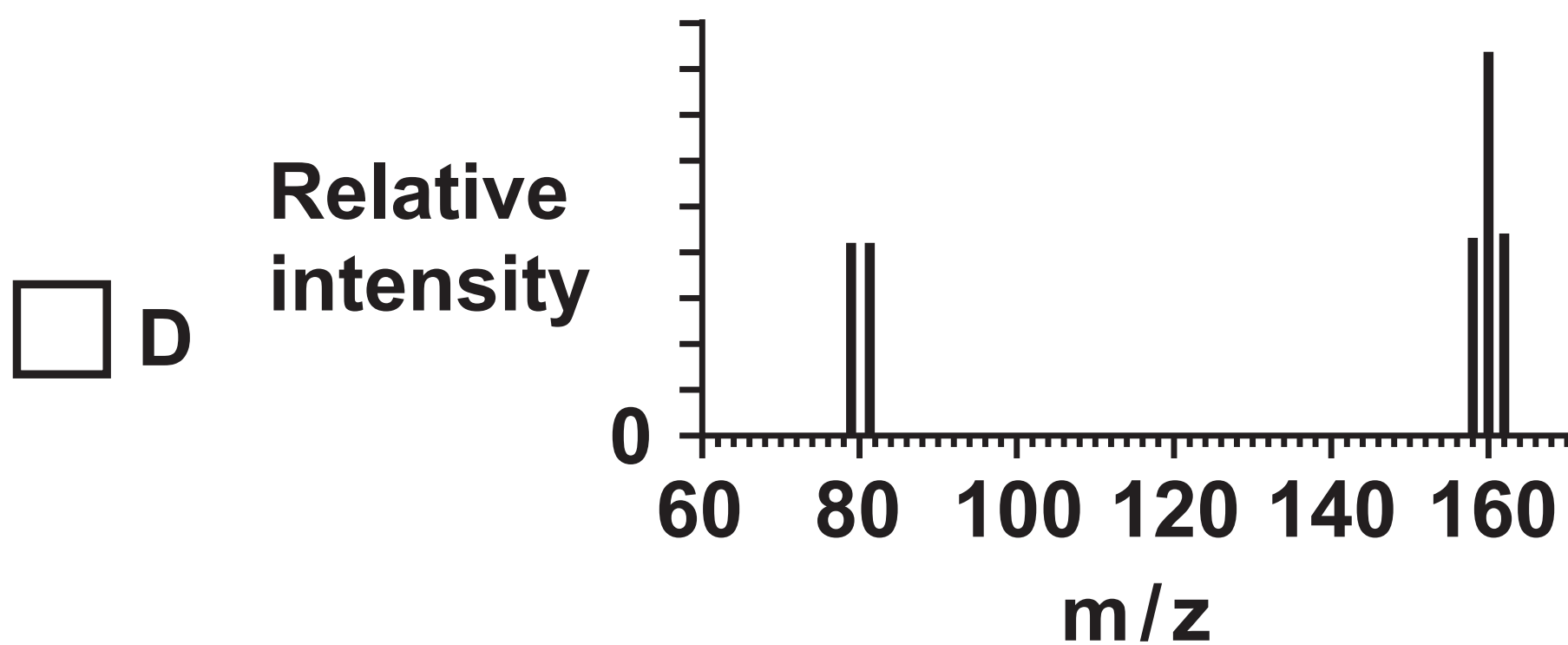
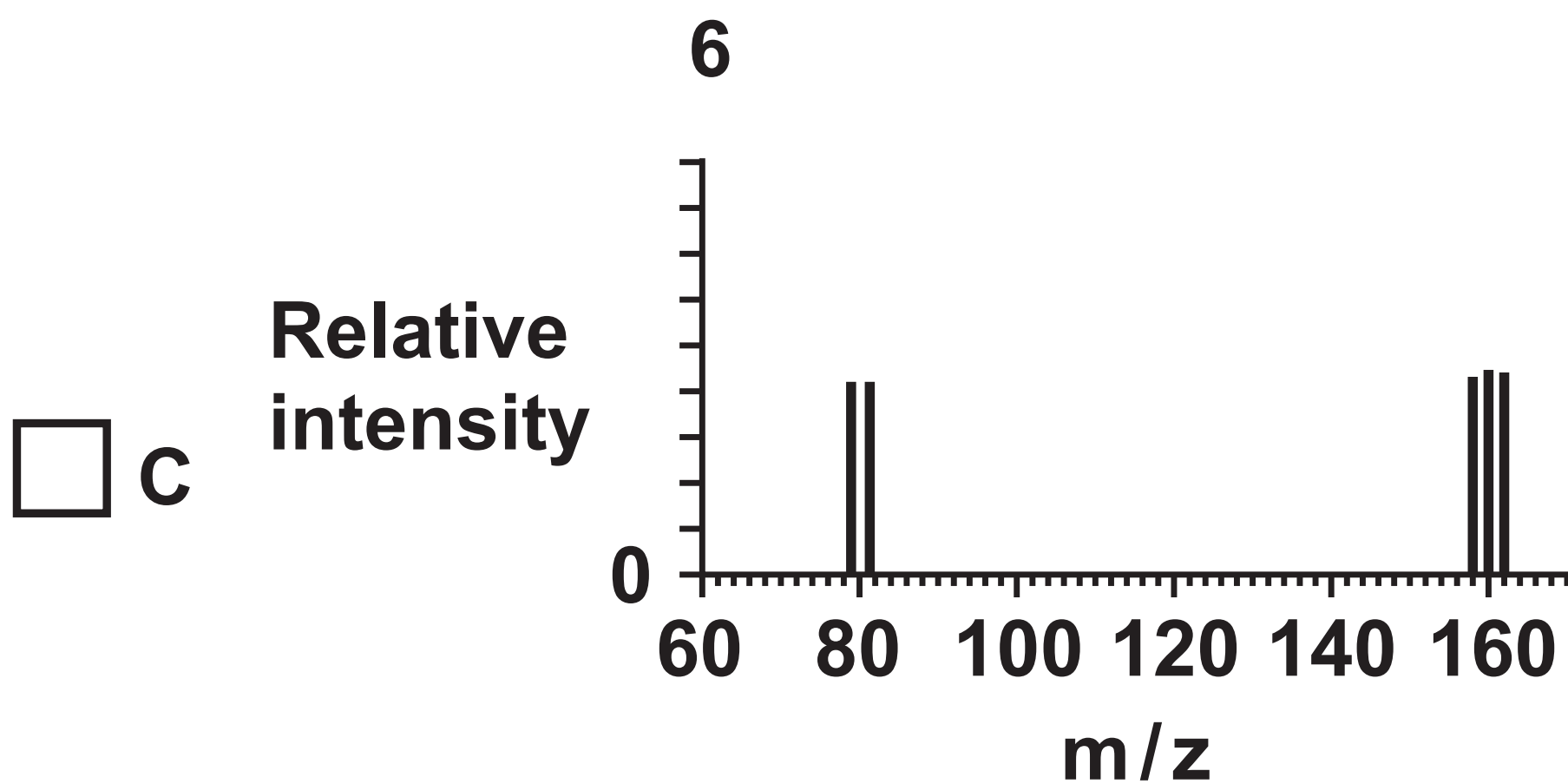
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(b) The mass spectrum of a sample of bromine MOLECULES with approximately equal proportions of the ^{79}Br and ^{81}Br isotopes is (1 mark)



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(Turn over)



(Question continues on next page)

(Turn over)

(c) The total number of electrons in ALL the occupied p orbitals in a chloride ion, Cl^- , is (1 mark)

☐ **A 5**

☐ **B 6**

☐ **C 12**

☐ **D 18**

(d) Which of these isoelectronic ions has the largest ionic radius? (1 mark)

☐ **A N^{3-}**

☐ **B O^{2-}**

☐ **C Na^+**

☐ **D Al^{3+}**

(TOTAL FOR QUESTION 1 = 4 MARKS)

(Questions continue on next page)

(Turn over)

2 This question is about some redox reactions of chlorine, bromine and iodine.

(a) An EXCESS of aqueous potassium bromide was added to chlorine water and the solution turned orange.

(i) Write an equation for this reaction. State symbols are not required. (1 mark)

(Question continues on next page)

(Turn over)

- (ii) Silver nitrate solution was added to the mixture in (a) and excess dilute ammonia solution was then added to the precipitate formed. Only some of the precipitate dissolved.

Deduce why only **SOME** of the precipitate dissolved. (3 marks)

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(Turn over)

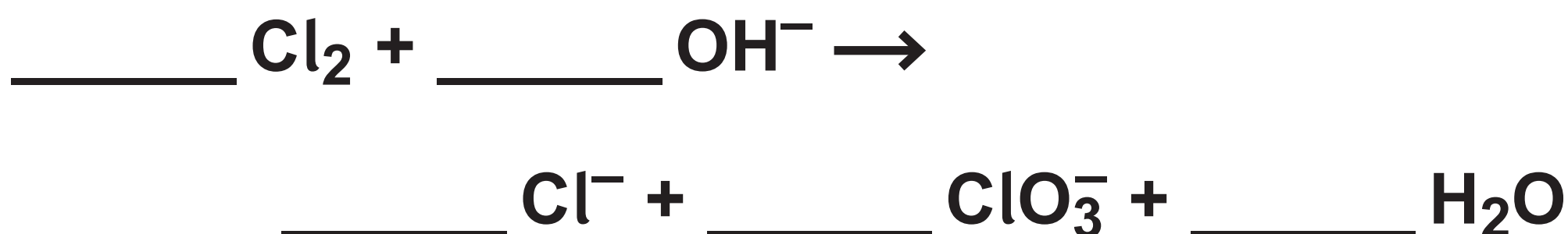
(iii) Aqueous potassium bromide was added to aqueous iodine, instead of chlorine water. There was no reaction.

Give a reason why no reaction occurred. (1 mark)

(b) Chlorine undergoes disproportionation when it reacts with H₂O aqueous sodium hydroxide solution.

(i) Complete the ionic equation for this reaction.

State symbols are not required.
(1 mark)



(Question continues on next page)

(Turn over)

- (ii) Explain, in terms of oxidation numbers, why this is a disproportionation reaction.
(2 marks)

(TOTAL FOR QUESTION 2 = 8 MARKS)

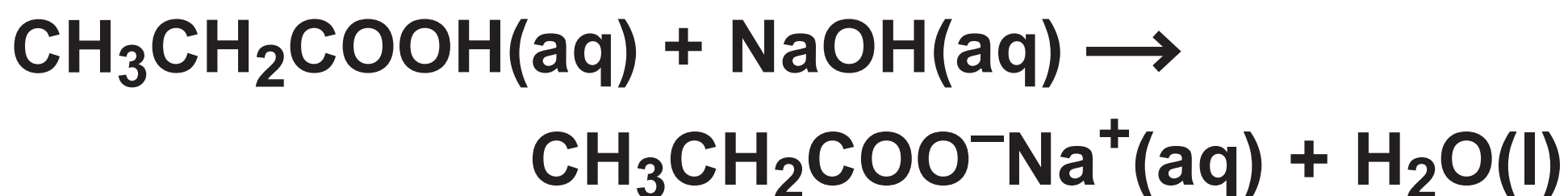
(Questions continue on next page)

(Turn over)

3 The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

(a) An experiment was carried out to determine the enthalpy change of neutralisation for the reaction between propanoic acid and sodium hydroxide.

The equation for this reaction is



50.0 cm³ of sodium hydroxide solution, of concentration 1.00 mol dm⁻³, was placed in a polystyrene cup. The initial temperature was measured.

(Question continues on next page)

(Turn over)

- (i) Which piece of equipment has the **SMALLEST** measurement uncertainty for the measurement of 50.0 cm^3 of sodium hydroxide solution? (1 mark)

	Equipment	Measurement uncertainty for EACH reading
<input type="checkbox"/> A	burette	$\pm 0.05\text{ cm}^3$
<input type="checkbox"/> B	50 cm^3 measuring cylinder	$\pm 1\text{ cm}^3$
<input type="checkbox"/> C	25 cm^3 pipette	$\pm 0.06\text{ cm}^3$
<input type="checkbox"/> D	50 cm^3 pipette	$\pm 0.08\text{ cm}^3$

(Question continues on next page)

(Turn over)

- (ii) 50.0 cm^3 of propanoic acid solution, of concentration 1.00 mol dm^{-3} , was added and thoroughly mixed with the sodium hydroxide solution in the polystyrene cup.

The maximum temperature rise was 6.5°C .

Calculate the enthalpy change of neutralisation for propanoic acid, in kJ mol^{-1} , giving your answer to the NEAREST WHOLE NUMBER.

[Assume density of the mixture = 1.00 g cm^{-3} , specific heat capacity of the mixture = $4.18 \text{ J g}^{-1}^\circ\text{C}^{-1}$] (3 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

(b) Another experiment was carried out with a solution of ethanoic acid and sodium hydroxide solution of the same concentration.

(i) Which graph A, B, C or D on pages 17–20 shows the correct way that the maximum temperature rise should be determined? (1 mark)

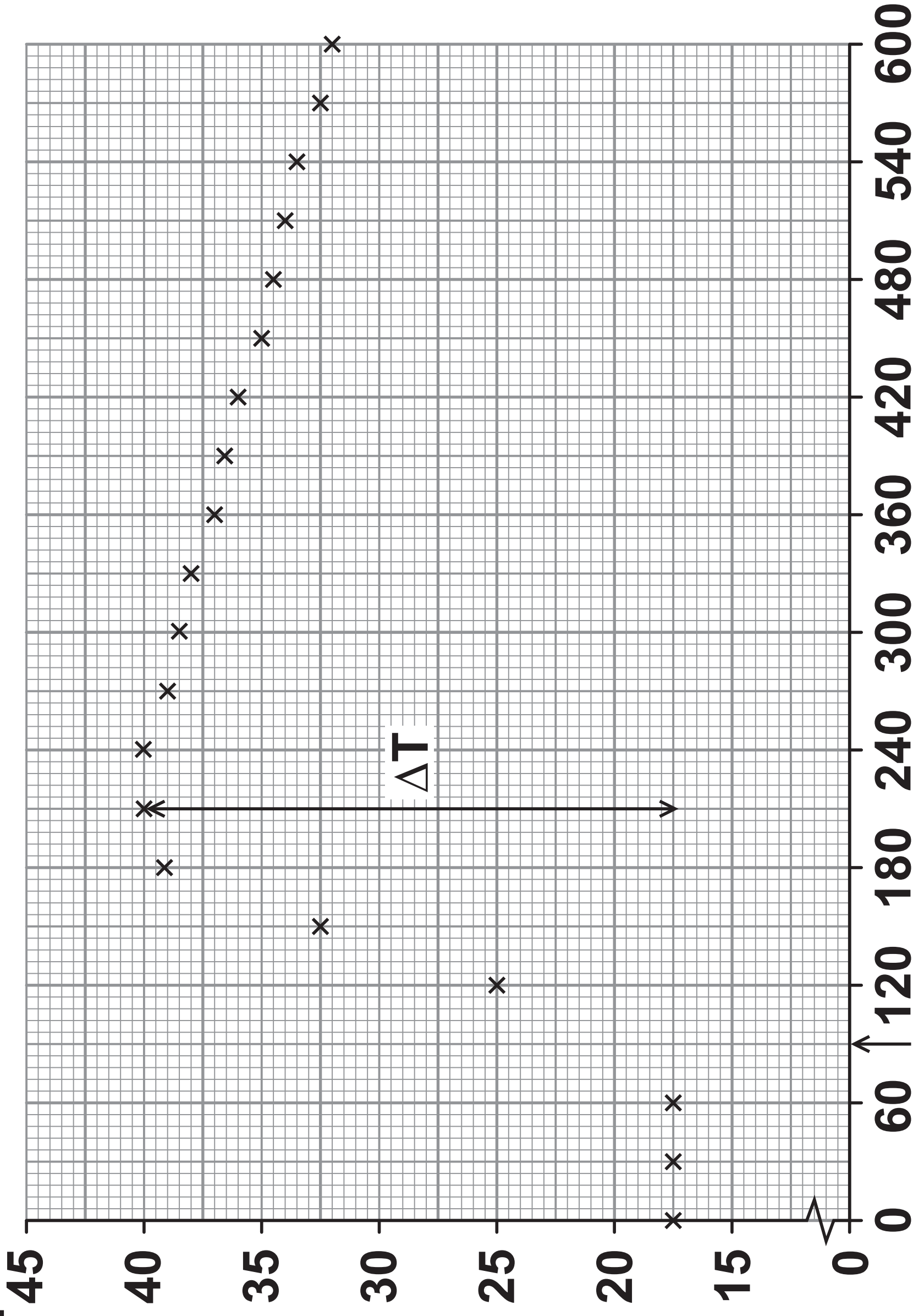
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A

Temperature / °C



NaOH added

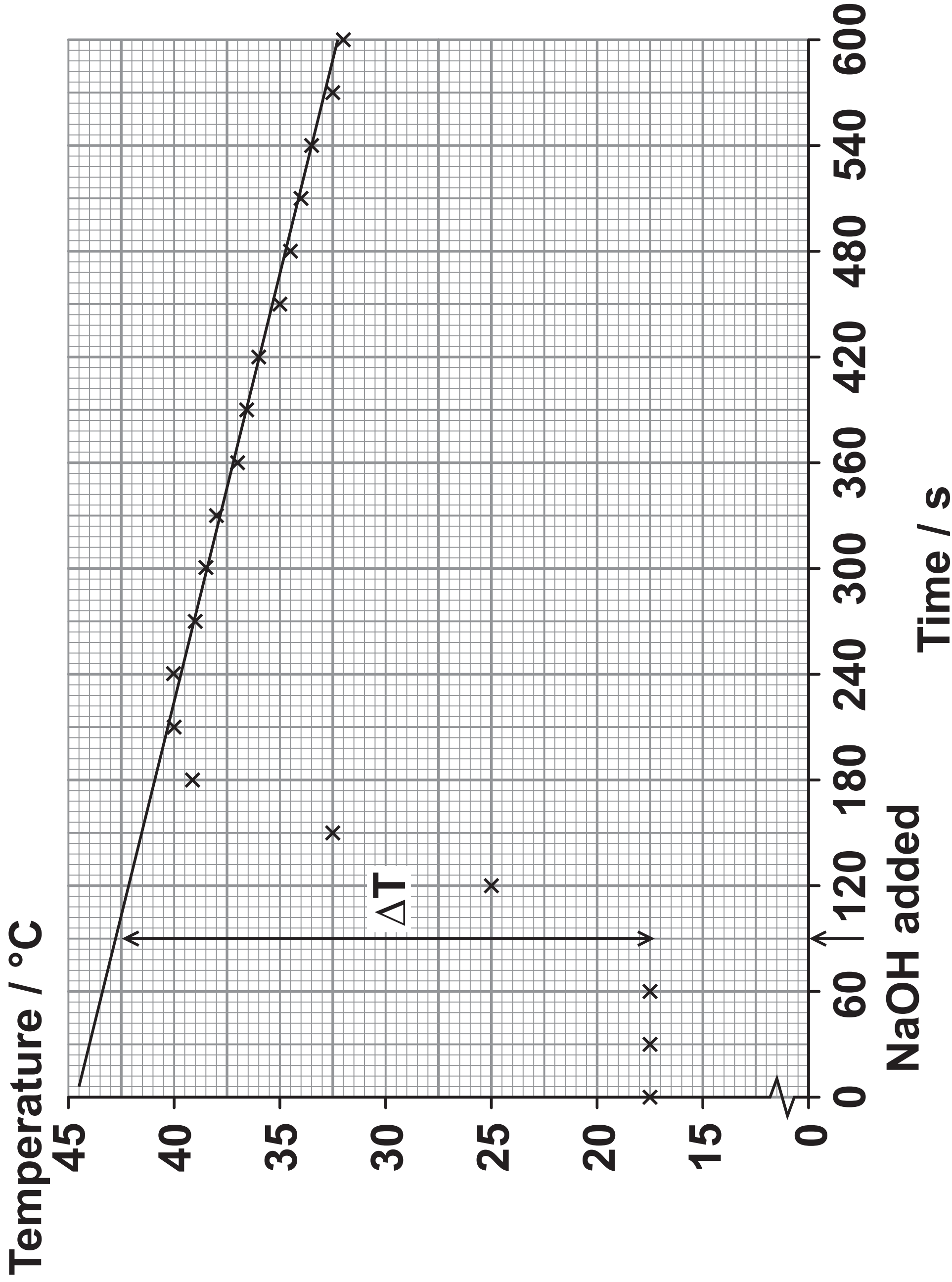
Time / s

(Question continues on next page)

(Turn over)



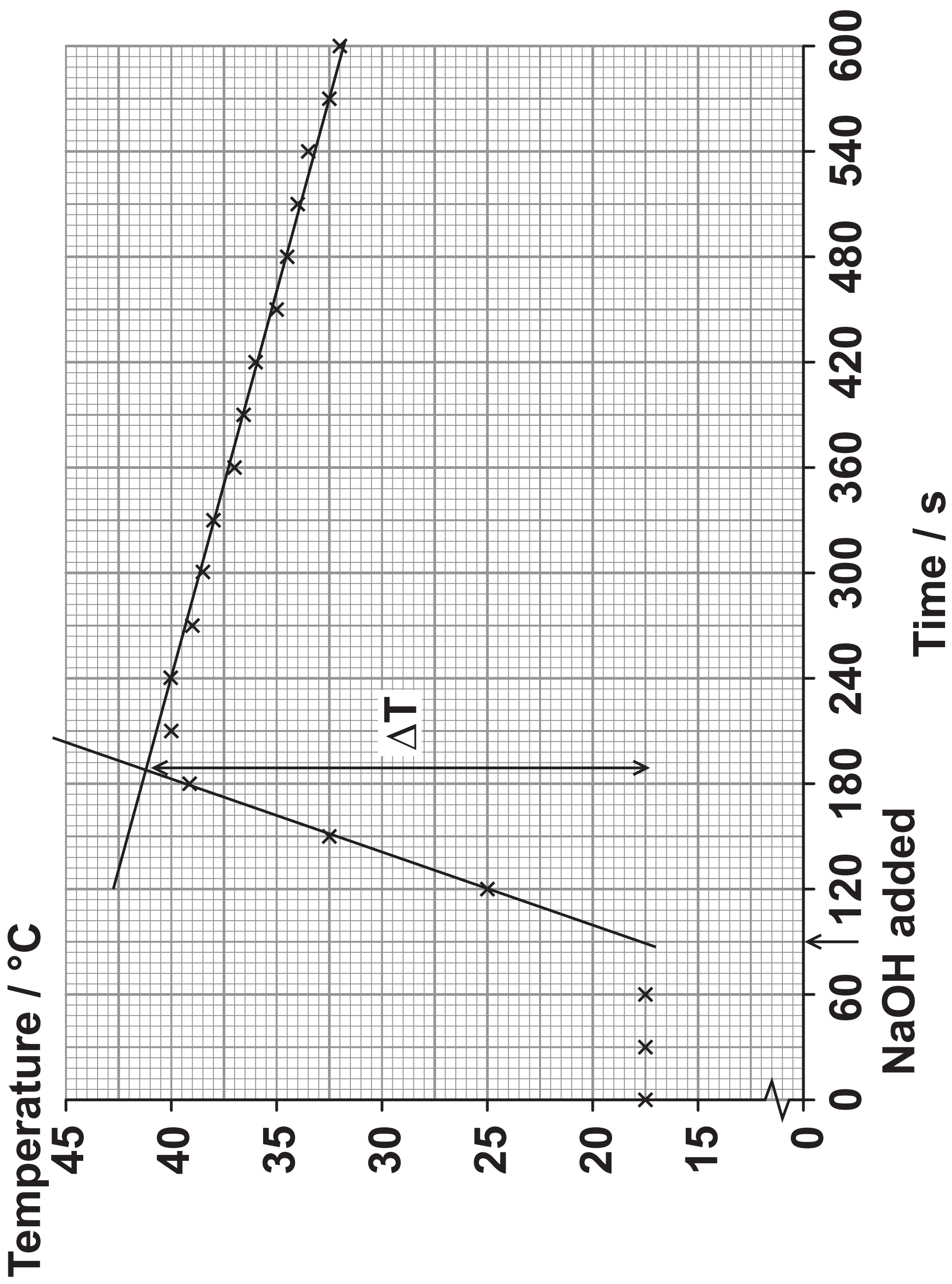
B



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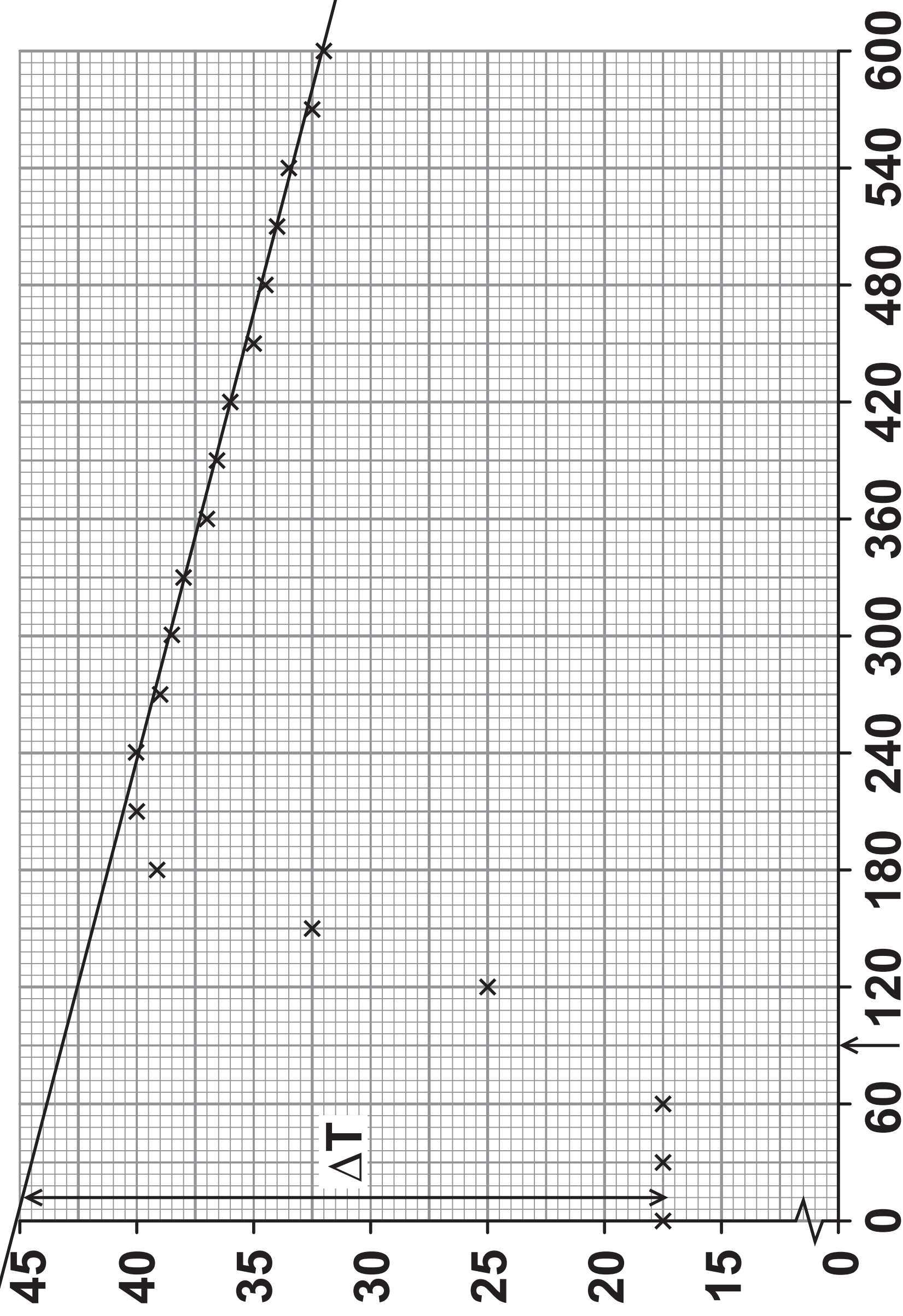
□ C



(Question continues on next page)

(Turn over)

Temperature / °C



D

NaOH added

Time / s

(Question continues on next page)

(Turn over)

- (ii) Explain why the data book value for the standard enthalpy change of neutralisation of ethanoic acid with sodium hydroxide is $-55.2 \text{ kJ mol}^{-1}$ but the value for hydrochloric acid is $-57.1 \text{ kJ mol}^{-1}$. (2 marks)

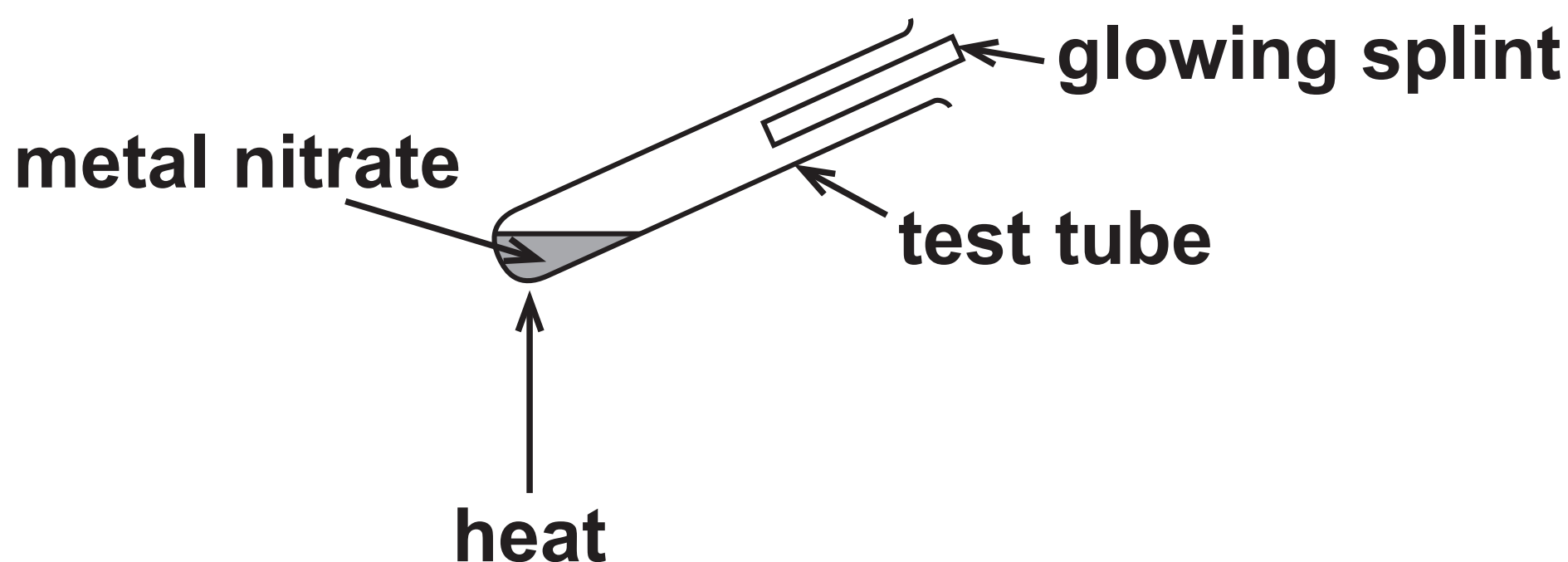
(TOTAL FOR QUESTION 3 = 7 MARKS)

(Questions continue on next page)

(Turn over)

4 Thermal decomposition is the breaking down of a substance by heat.

(a) An experiment was carried out to investigate the thermal decomposition of a metal nitrate using the apparatus shown.



(Question continues on next page)

(Turn over)

- (i) The glowing splint is used as a test for one of the gases given off in this experiment.

Identify this gas and the positive result of the test. (1 mark)

(Question continues on next page)

(Turn over)

- (ii) Give the name and appearance of the other gas given off in this experiment when a Group 2 nitrate is heated. (1 mark)**

(Question continues on next page)

(Turn over)

(iii) Write the equation for the decomposition of the Group 1 compound, sodium nitrate, used in this experiment. State symbols are not required. (1 mark)

**(Question continues on next page)
(Turn over)**

(iv) Describe the apparatus that would be used to compare the decomposition of metal carbonates. Include how the rate of decomposition would be compared. (2 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

(b) Explain why magnesium carbonate decomposes much more readily on heating than barium carbonate. (3 marks)

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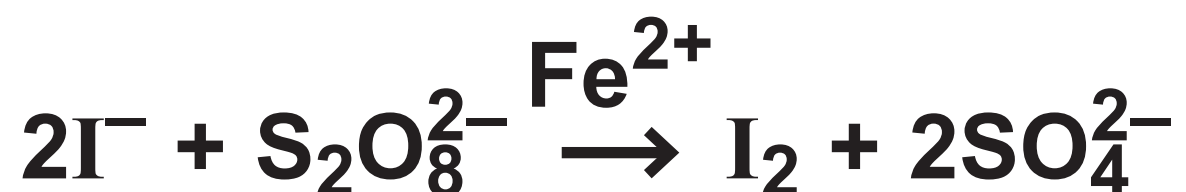
(TOTAL FOR QUESTION 4 = 8 MARKS)

(Questions continue on next page)

(Turn over)

5 This is a question about catalysis.

(a) The reaction between iodide ions and peroxodisulfate ions is catalysed by iron(II) ions.



**(i) Give a reason why the reaction between iodide ions and peroxodisulfate ions has a high activation energy and is therefore very slow without a catalyst.
(1 mark)**

(Question continues on next page)

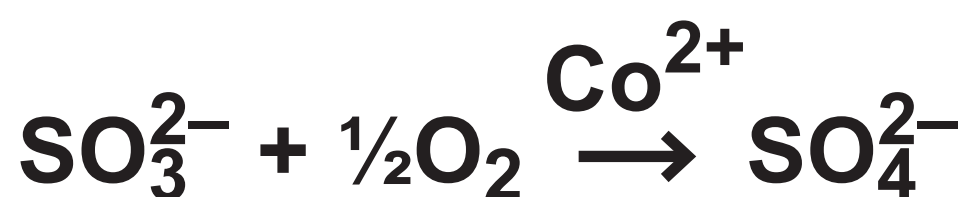
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- (ii) Explain, with the aid of two equations, how the iron(II) ions catalyse this reaction. State symbols are not required.
(3 marks)

(Question continues on next page)

(Turn over)

- (b) The oxidation of sulfate(IV) ions to sulfate(VI) ions is catalysed by cobalt(II) ions in ACIDIC solution. The role of cobalt(II) ions is similar to that of iron(II) ions in (a).**



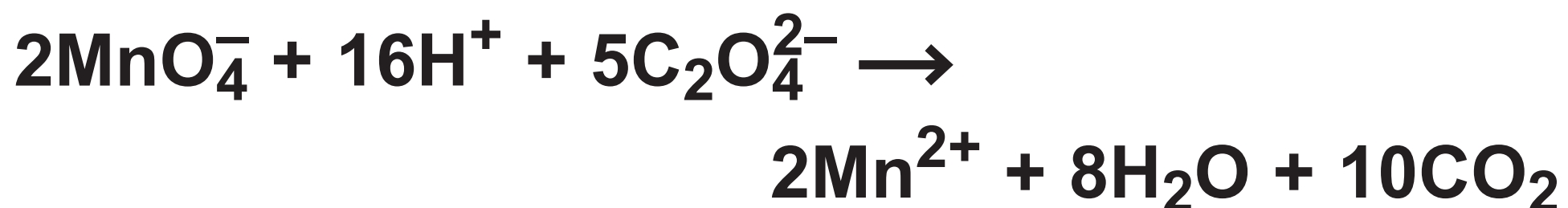
(Question continues on next page)

Deduce two ionic equations to show how cobalt(II) ions catalyse the reaction in ACIDIC solution. State symbols are not required. (2 marks)

(Question continues on next page)

(Turn over)

(c) The rate of oxidation of ethanedioate ions by manganate(VII) ions starts slowly and then rapidly increases.



What is the catalyst in this reaction?
(1 mark)

- ☐ A CO_2
- ☐ B H^+
- ☐ C Mn^{2+}
- ☐ D MnO_4^-

(Question continues on next page)

(Turn over)

(d) The trend in the strength of gaseous adsorption by three transition elements is

tungsten > platinum > silver

Silver is not suitable as a replacement for platinum in a catalytic converter because the adsorption of gases is too weak to allow significant chemical reaction.

(Question continues on next page)

Give a possible reason why tungsten would also NOT be a suitable replacement for platinum in a catalytic converter. Refer to the mechanism of heterogenous catalysis in your answer. (1 mark)

(TOTAL FOR QUESTION 5 = 8 MARKS)

(Questions continue on next page)

(Turn over)

6 This is a question about water.

(a) Water might be expected to have a lower boiling temperature than hydrogen sulfide but it actually has a higher boiling temperature.

Comment on this statement by referring to the intermolecular forces in both these substances.

A detailed description of how the intermolecular forces arise is not required. (4 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)
(Turn over)

(b) Explain why both water and carbon dioxide molecules have polar bonds but only water is a polar molecule. (4 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

- (c) Pure water ionises to form H_3O^+ and OH^- ions, although only to a very small extent. Draw the dot-and-cross diagrams of these ions. Use dots (●) for the hydrogen electrons and crosses (×) for the oxygen electrons. (2 marks)**

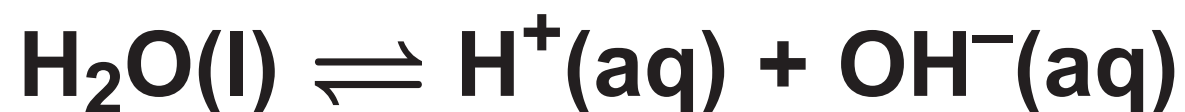
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(Turn over)

(Question continues on next page)

(Turn over)

(d) An equation for the ionisation of water is



The expression for the ionic product of water is

$$K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]$$

The value of K_w at 310 K is $2.40 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$

(Question continues on next page)

(i) Calculate the pH of water at 310 K.

Give your answer to TWO decimal places. (2 marks)

(Question continues on next page)

(Turn over)

- (ii) Predict, with a reason, whether water is acidic, alkaline or neutral at 310 K. (2 marks)**

(Question continues on next page)

(Turn over)

(iii) Predict, with a reason, the sign of the enthalpy change for the ionisation of water. (1 mark)

(TOTAL FOR QUESTION 6 = 15 MARKS)

(Questions continue on next page)

(Turn over)

***7 Colour is often used in chemistry to identify substances.**

Compare and contrast the origin of the colour of a copper(II) complex with the origin of the colour of the copper(II) ion in a flame test.

You do not need to state any specific colours. (6 marks)

(Continue your answer on next page)

(Turn over)

(Continue your answer on next page)

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(Continue your answer on next page)

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(Turn over)

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(Continue your answer on next page)

(Turn over)

(Turn over)

- 8 Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.**
- (a) In order to calculate the first electron affinity of hydrogen, a student was asked to draw a Born-Haber cycle for sodium hydride.**

The cycle had TWO errors but the numerical data were correct.

(Question continues on next page)

(Turn over)

$\text{Na}^+(\text{g}) + \text{e}^- + \text{H}(\text{g})$	
$+218 \text{ kJ mol}^{-1}$	↑ Half of the enthalpy change of atomisation of hydrogen $\text{Na}^+(\text{g}) + \text{e}^- + \frac{1}{2}\text{H}_2(\text{g})$ First ionisation energy of sodium $\text{Na}(\text{g}) + \frac{1}{2}\text{H}_2(\text{g})$ ↑ Enthalpy change of atomisation of sodium $\text{Na}(\text{s}) + \frac{1}{2}\text{H}_2(\text{g})$ ↑ Enthalpy change of formation of sodium hydride $\text{NaH}(\text{s})$
$+496 \text{ kJ mol}^{-1}$	First electron affinity of hydrogen $\text{Na}^+(\text{g}) + \text{H}^-(\text{g})$ Lattice energy of sodium hydride
$+107 \text{ kJ mol}^{-1}$	-804 kJ mol^{-1}
-56 kJ mol^{-1}	

(Question continues on next page)

(Turn over)

- (i) Identify and correct the TWO errors in this Born-Haber cycle.
(2 marks)

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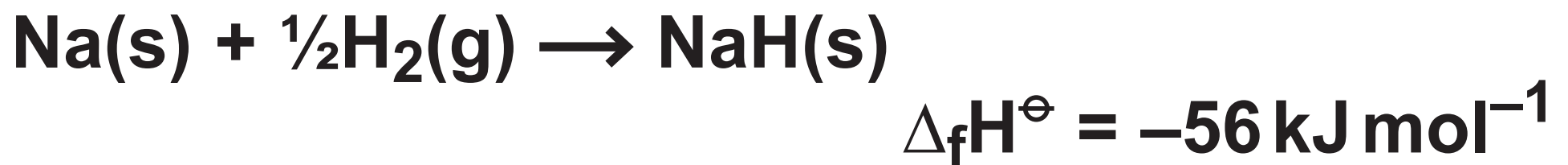
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- (ii) Calculate the first electron affinity, in kJ mol^{-1} , of hydrogen, using the values given in the cycle. (1 mark)**

(Question continues on next page)

(Turn over)

(b) The equation for the formation of sodium hydride is



The standard entropy change of the system, $\Delta S^{\ominus}_{\text{system}}$, for this reaction is $-76.5 \text{ J K}^{-1} \text{ mol}^{-1}$.

(Question continues on next page)

- (i) Deduce the feasibility of this reaction at 298 K by calculating the free energy change, ΔG . (2 marks)**

(Question continues on next page)

(Turn over)

(ii) Calculate the temperature at which $\Delta G = 0$. (1 mark)

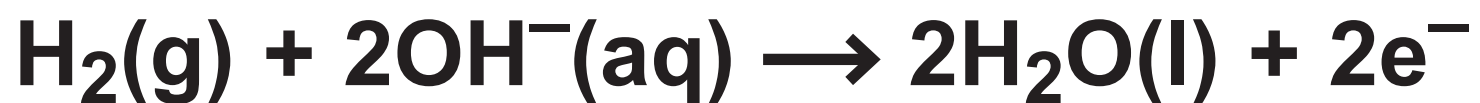
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- (c) The sodium hydride is crushed in the presence of water to release the hydrogen gas for a fuel cell.**

The overall equation for the reaction occurring in the fuel cell is



In an alkaline fuel cell the oxidation half-equation is



(Question continues on next page)

(Turn over)

Deduce the reduction half-equation for the alkaline fuel cell.

**State symbols are not required.
(1 mark)**

(Question continues on next page)

(Turn over)

(d) Lattice energies provide an indication of ionic bond strength.

Which are the lattice energies of the hydrides NaH, KH and MgH₂?
(1 mark)

Lattice energy / kJ mol ⁻¹			
	Sodium hydride, NaH	Potassium hydride, KH	Magnesium hydride, MgH ₂
<input type="checkbox"/> A	-804	-711	-1018
<input type="checkbox"/> B	-804	-711	-2718
<input type="checkbox"/> C	-804	-911	-1018
<input type="checkbox"/> D	-804	-911	-2718

(TOTAL FOR QUESTION 8 = 8 MARKS)

(Questions continue on next page)

(Turn over)

9 This is a question about buffer solutions.

(a) A buffer solution always (1 mark)

- ☐ **A keeps the pH less than 7.**
- ☐ **B contains equimolar amounts of acid and its conjugate base.**
- ☐ **C keeps the pH constant if small quantities of acid or base are added.**
- ☐ **D resists changes in pH if small quantities of acid or base are added.**

(Question continues on next page)

(Turn over)

(b) A buffer solution with a pH of 3.90 is required.

Calculate the MASS, in grams, of sodium ethanoate that should be added to 50.0 cm³ of an ethanoic acid solution of concentration 0.800 mol dm⁻³ to form this buffer solution.

Give your answer to an appropriate number of significant figures.

[K_a for ethanoic acid = 1.74 × 10⁻⁵ mol dm⁻³] (5 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

- (c) One of the systems controlling the pH of blood is the carbonic acid-hydrogencarbonate buffer system.



Explain how this buffer system helps to control the pH of blood when extra carbon dioxide is present due to strenuous exercise. (3 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

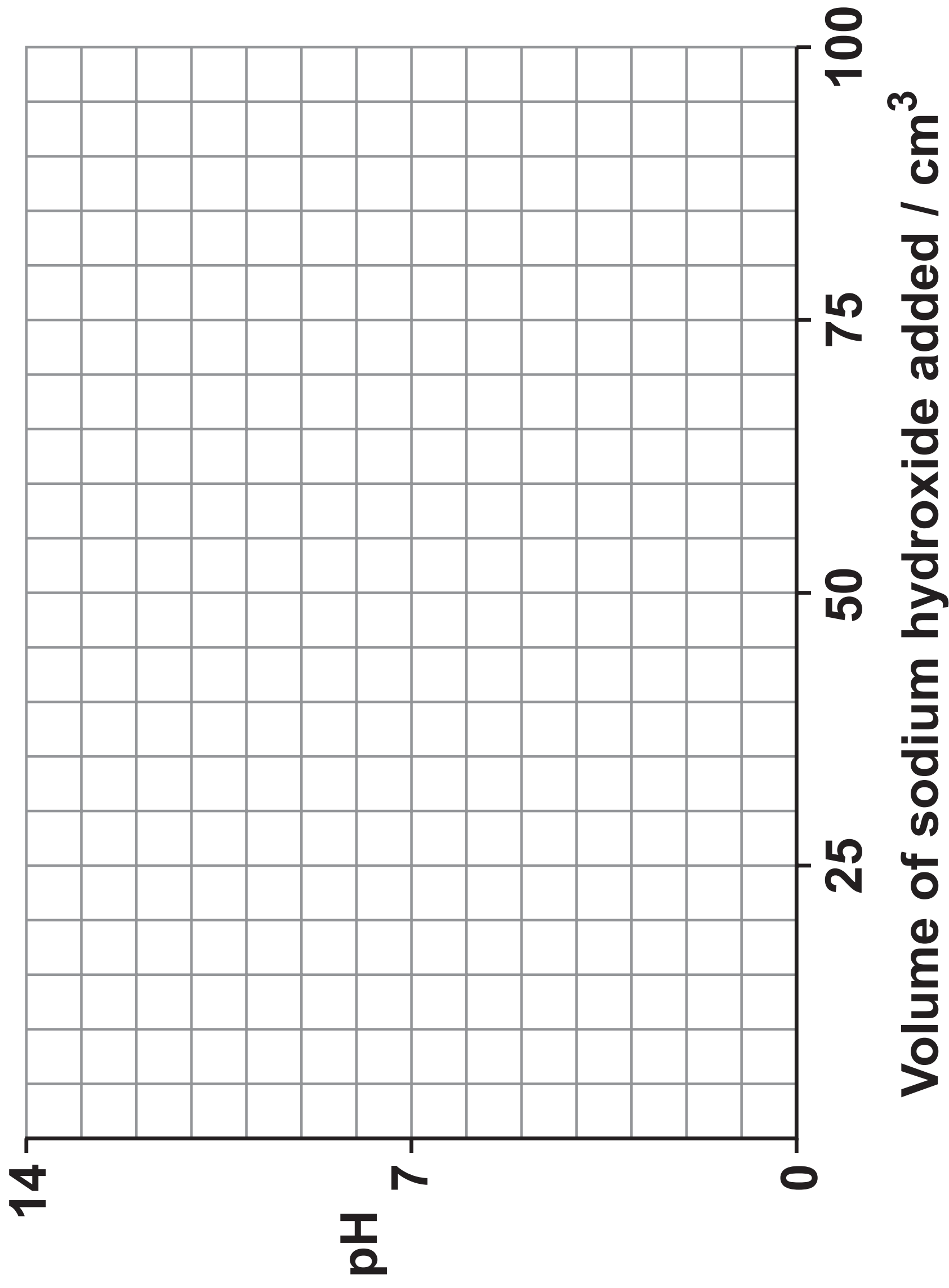
(d) A weak acid-strong base titration curve can be used to demonstrate buffer action.

(i) On page 69, draw a titration curve for the addition of 100 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} to 40.0 cm^3 of propanoic acid solution of concentration 0.100 mol dm^{-3} which has a pH of 3.0.

**Show the part of the curve that demonstrates buffer action.
(4 marks)**

(Question continues on next page)

(Turn over)



(Question continues on next page)

(Turn over)

- (ii) Describe, without calculation, how you would use your curve to determine the value of K_a for propanoic acid. (2 marks)

(TOTAL FOR QUESTION 9 = 15 MARKS)

(Questions continue on next page)

(Turn over)

10 This question is about equilibrium systems.

(a) Sulfur dioxide and oxygen form an equilibrium with sulfur trioxide.



The composition of an equilibrium mixture at 698 K and a total pressure of 2.40 atm is shown in the table.

Substance	SO₂(g)	O₂(g)	SO₃(g)
Number of moles /mol	0.0160	0.0120	0.772

(Question continues on next page)

(Turn over)

- (i) Calculate the value of K_p at this temperature.**

**Include units, if appropriate.
(5 marks)**

**(Continue your answer on next page)
(Turn over)**

- (ii) Calculate the number of sulfur dioxide molecules present in this equilibrium mixture. (1 mark)**

(Question continues on next page)

(Turn over)

(iii) Deduce, by referring to K_p , how the number of sulfur dioxide molecules will change if more oxygen is added to the equilibrium mixture. (2 marks)

(Question continues on next page)

(Turn over)

- (b) An equilibrium exists in aqueous solution between the chromate(VI) ions and the dichromate(VI) ions.**



(Question continues on next page)

**Explain any change in the position of equilibrium if a few drops of sodium hydroxide solution are added to this equilibrium system.
(2 marks)**

(Question continues on next page)

(Turn over)

(c) The equilibrium for the reaction between hydrogen gas and an oxide of iron is



The K_c expression for this equilibrium is (1 mark)

☐ A $K_c = \frac{[\text{Fe}] \times [\text{H}_2\text{O}]}{[\text{Fe}_3\text{O}_4] \times [\text{H}_2]}$

☐ B $K_c = \frac{[\text{Fe}]^3 \times [\text{H}_2\text{O}]^4}{[\text{Fe}_3\text{O}_4] \times [\text{H}_2]^4}$

☐ C $K_c = \frac{[\text{H}_2\text{O}]}{[\text{H}_2]}$

☐ D $K_c = \frac{[\text{H}_2\text{O}]^4}{[\text{H}_2]^4}$

(TOTAL FOR QUESTION 10 = 11 MARKS)

TOTAL FOR PAPER = 90 MARKS
END