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.

(Continues on next page)

## 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**

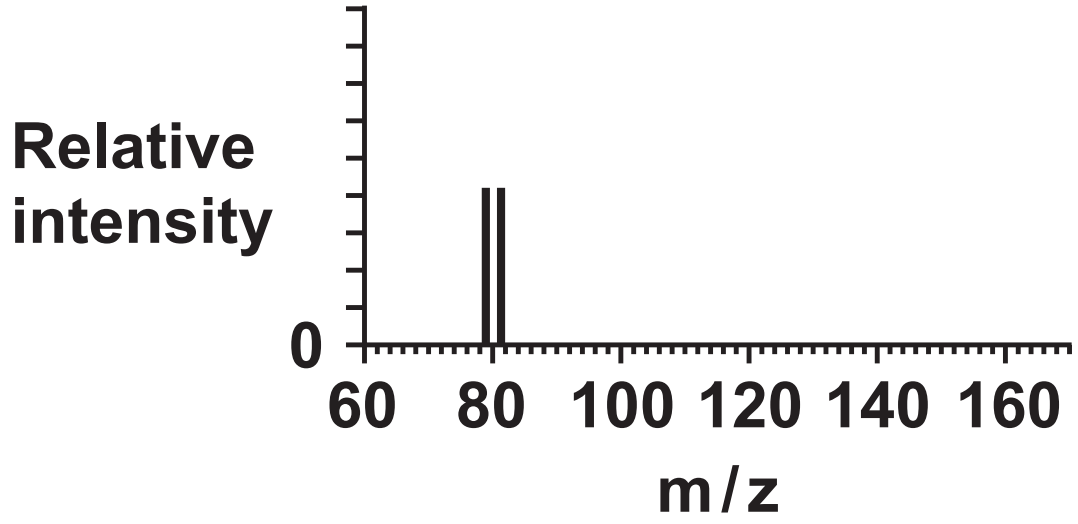
☐ **C 10 protons, 8 neutrons and 10 electrons**

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

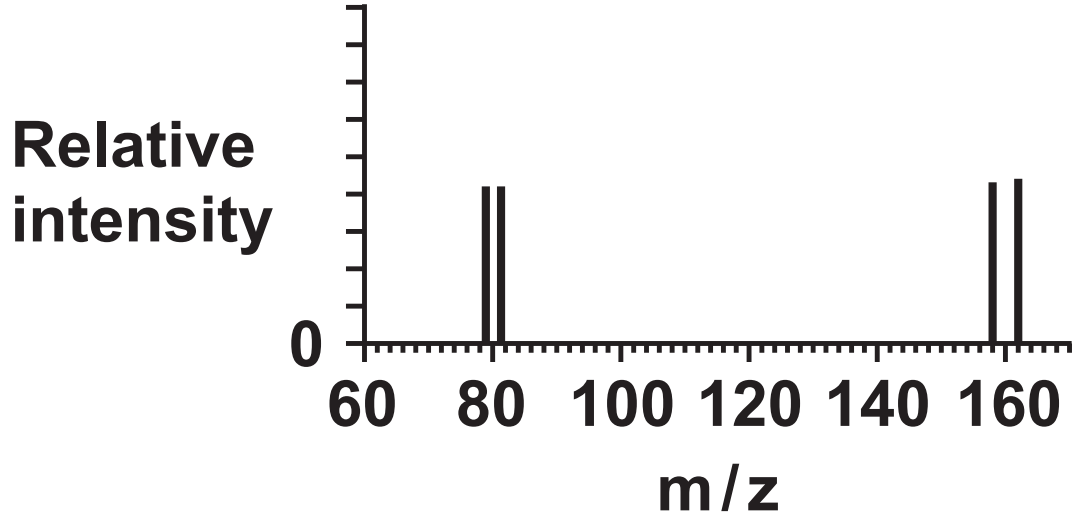
**(Question continues on next page)**

(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)

☐ A




☐ B

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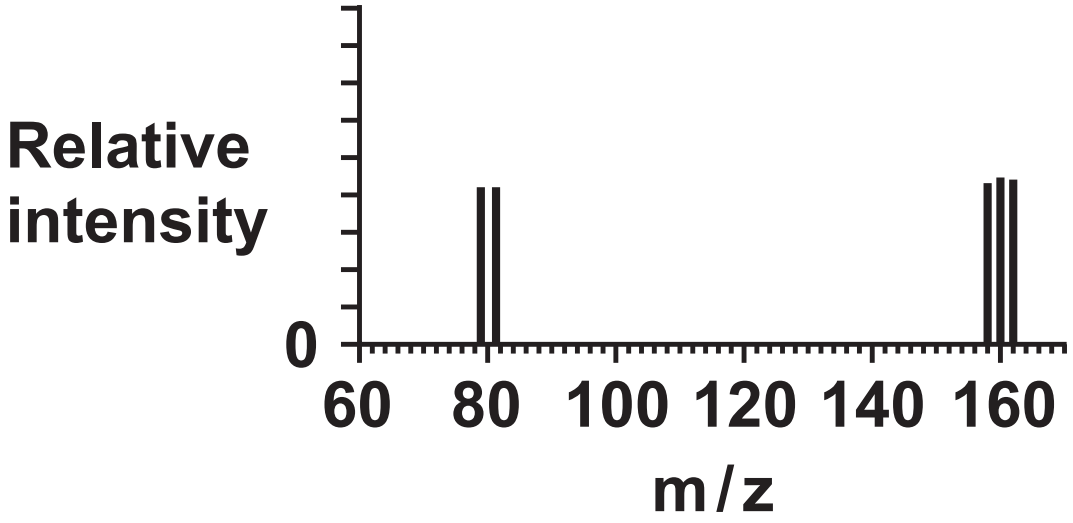
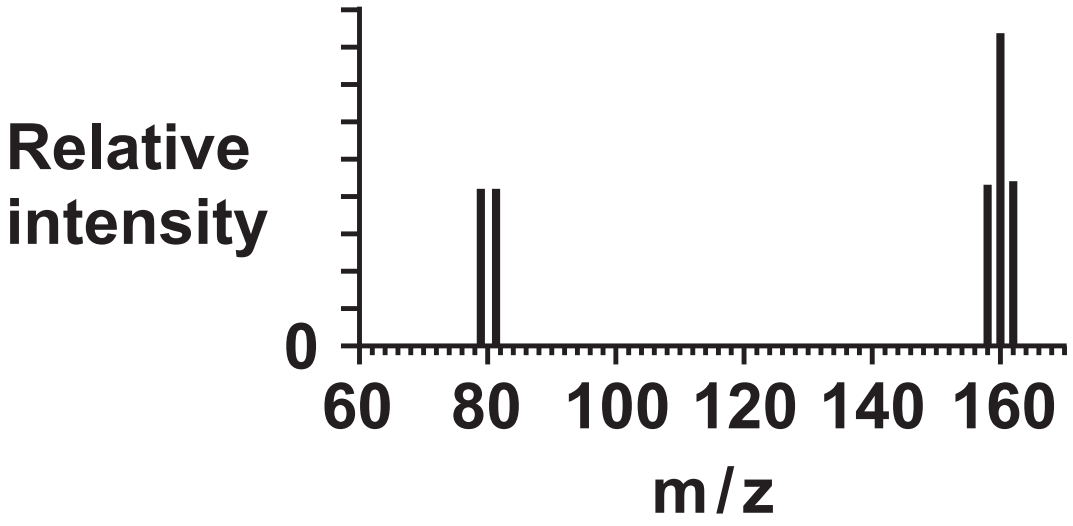
☐ C




☐ D




(Question continues on next page)

(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)

**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)**

(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)

(Question continues on next page)

(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 HOT aqueous sodium hydroxide solution.

(i) Complete the ionic equation for this reaction.

State symbols are not required. (1 mark)

_____ $Cl_2$ + _____ $OH^-$ $\longrightarrow$

_____ $Cl^-$ + _____ $ClO_3^-$ + _____ $H_2O$

(Question continues on next page)

(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)

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

$$CH_3CH_2COOH(aq) + NaOH(aq) \longrightarrow CH_3CH_2COO^-Na^+(aq) + H_2O(l)$$

$50{\cdot}0\,cm^3$ of sodium hydroxide solution, of concentration $1{\cdot}00\,mol\,dm^{-3}$, was placed in a polystyrene cup. The initial temperature was measured.

(Question continues on next page)

(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 |
|---|---|---|
| ☐ A | burette | ±0·05 $cm^3$ |
| ☐ B | 50 $cm^3$ measuring cylinder | ±1 $cm^3$ |
| ☐ C | 25 $cm^3$ pipette | ±0·06 $cm^3$ |
| ☐ D | 50 $cm^3$ pipette | ±0·08 $cm^3$ |

(Question continues on next page)

(ii) $50{\cdot}0\,cm^3$ of propanoic acid solution, of concentration $1{\cdot}00\,mol\,dm^{-3}$, 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 = $1{\cdot}00\,g\,cm^{-3}$, specific heat capacity of the mixture = $4{\cdot}18\,J\,g^{-1}\,°C^{-1}$] (3 marks)

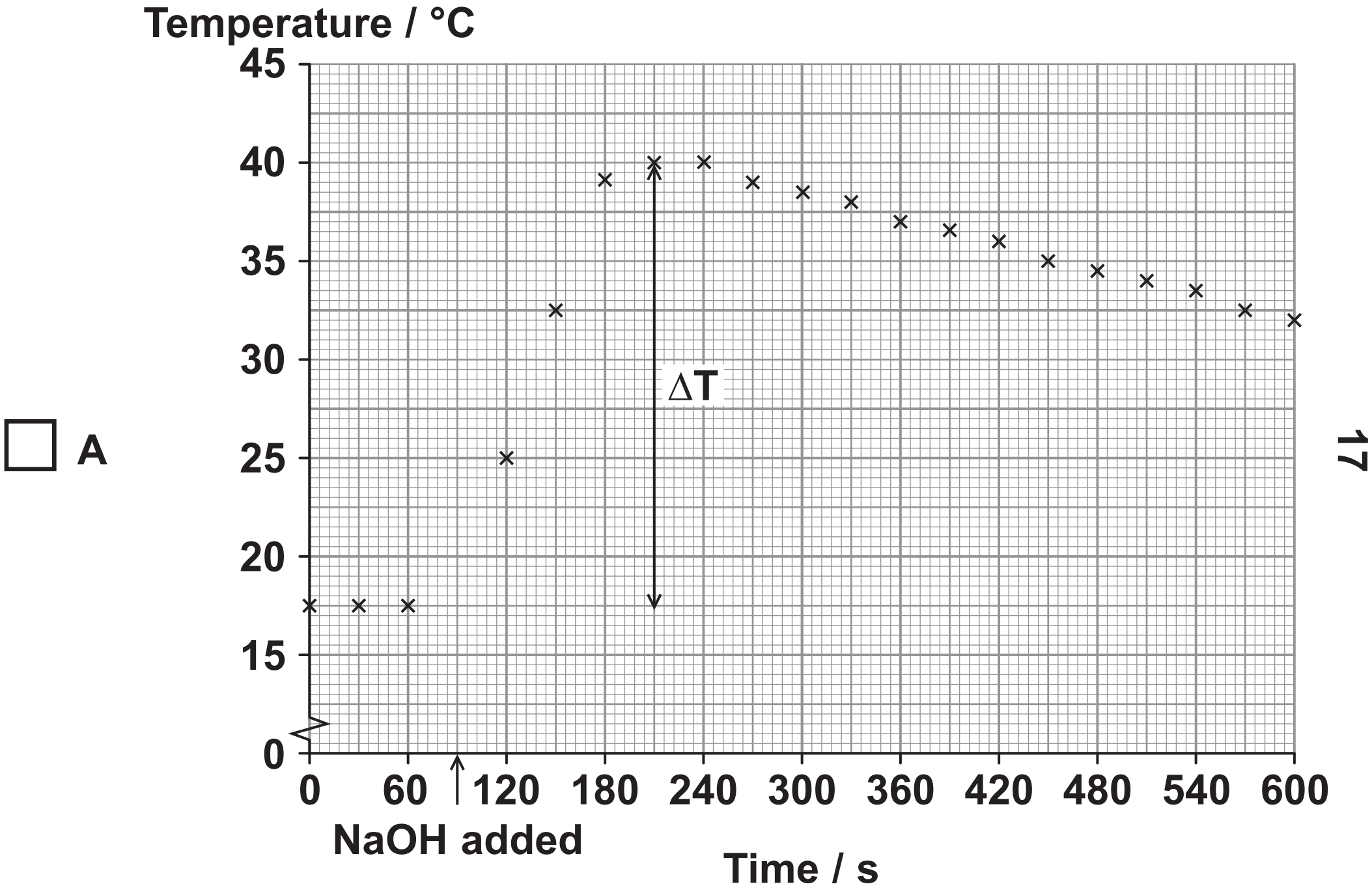
(Continue your answer on next page)

(Question continues on next page)

(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)

(Question continues on next page)

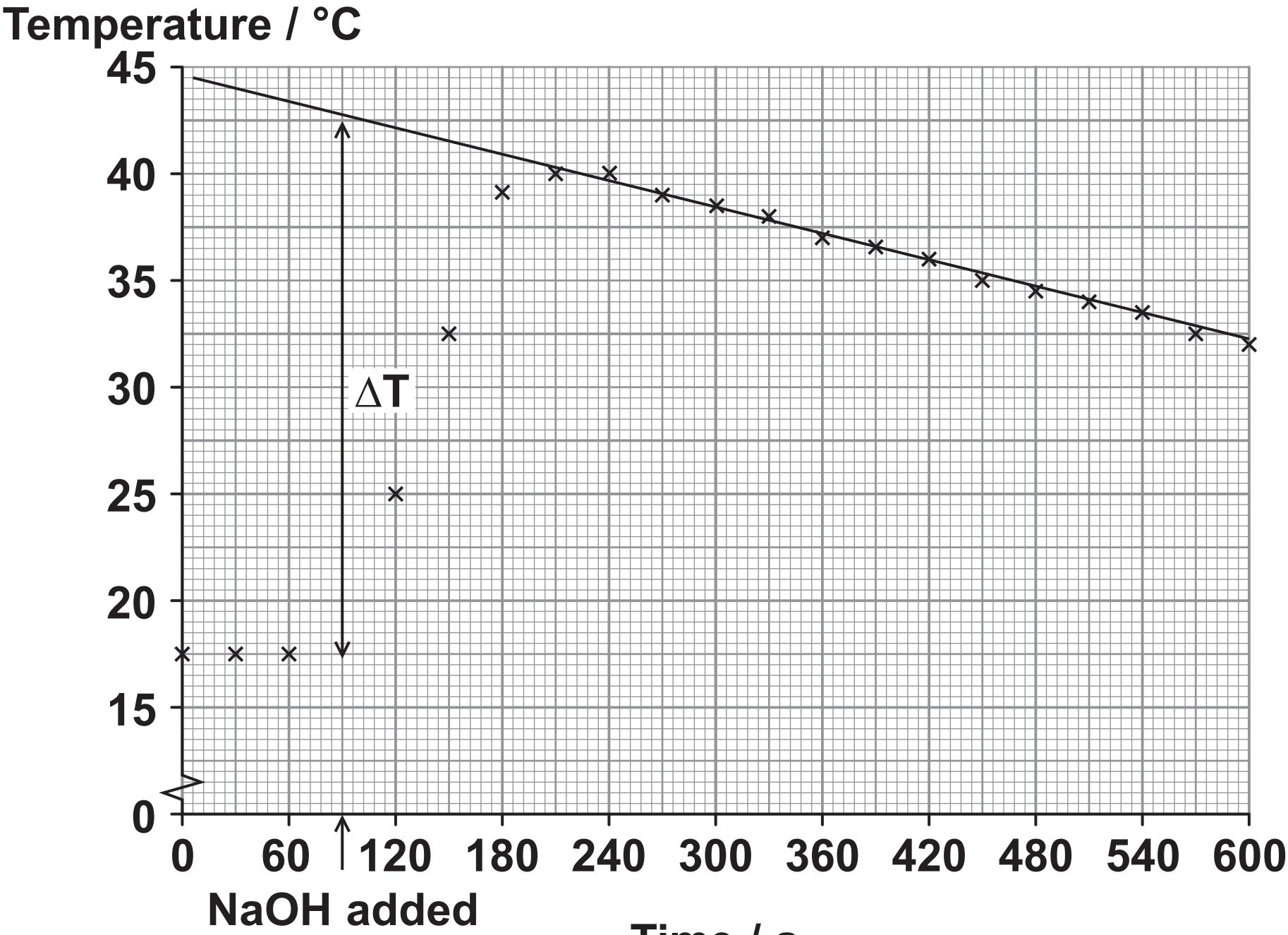



A

17

(Question continues on next page)

(Turn over)




B

18

(Question continues on next page)

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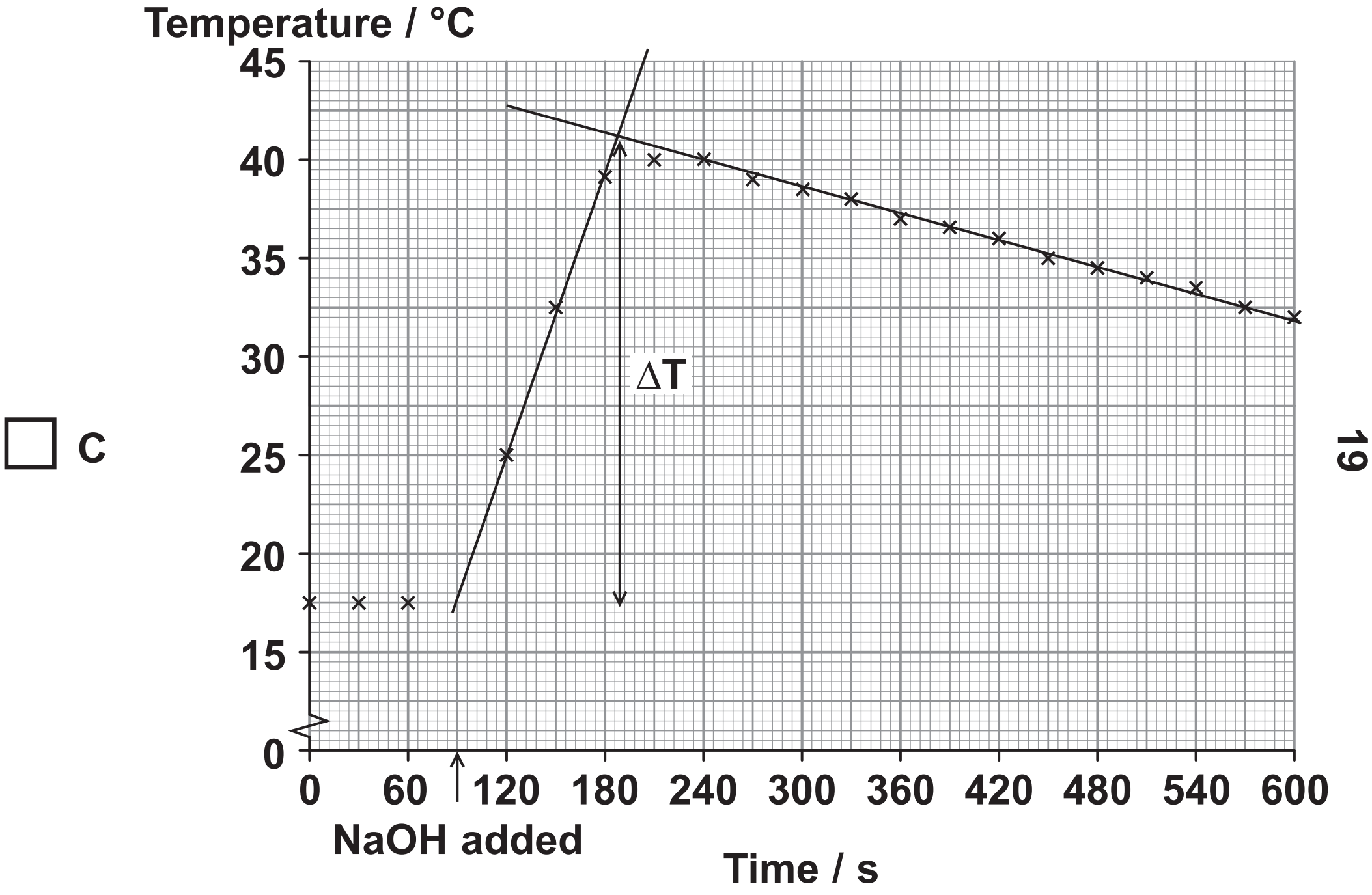
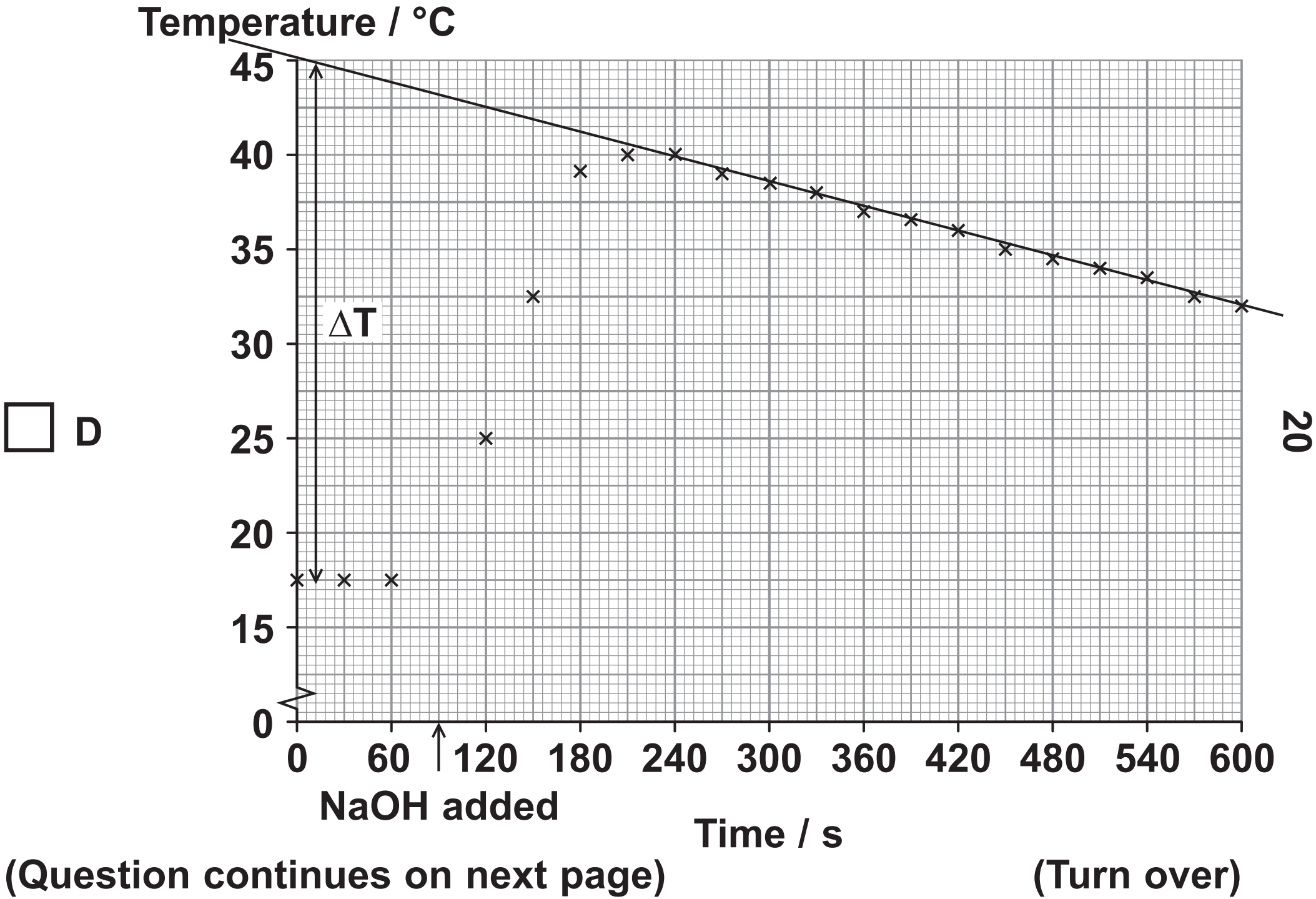



C

19

(Question continues on next page)

(Turn over)




D

20

(Question continues on next page)

(Turn over)

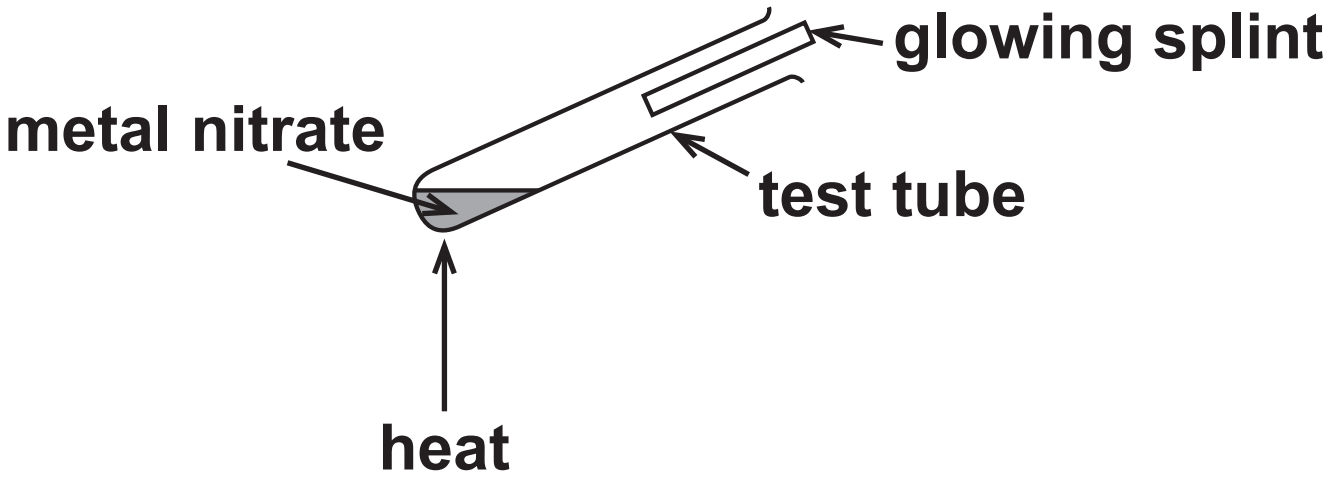
(ii) Explain why the data book value for the standard enthalpy change of neutralisation of ethanoic acid with sodium hydroxide is $-55{\cdot}2\,kJ\,mol^{-1}$ but the value for hydrochloric acid is $-57{\cdot}1\,kJ\,mol^{-1}$. (2 marks)

**(TOTAL FOR QUESTION 3 = 7 MARKS)**

(Questions continue on next page)

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)

(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)

(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)

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

(Question continues on next page)

(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)

(Question continues on next page)

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

**(TOTAL FOR QUESTION 4 = 8 MARKS)**

**(Questions continue on next page)**

5 This is a question about catalysis.

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

$$2I^- + S_2O_8^{2-} \xrightarrow{Fe^{2+}} I_2 + 2SO_4^{2-}$$

(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)

(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)

(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).

$$SO_3^{2-} + \tfrac{1}{2}O_2 \xrightarrow{Co^{2+}} SO_4^{2-}$$

(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)

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

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

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)

(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)**

**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)**

(Question continues on next page)

(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)

(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)

(Continue your answer on next page)

(Question continues on next page)

(d) An equation for the ionisation of water is

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The expression for the ionic product of water is

$$K_w = [H^+(aq)][OH^-(aq)]$$

The value of $K_w$ at 310 K is $2{\cdot}40 \times 10^{-14}\,mol^2\,dm^{-6}$

(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)

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

(Question continues on next page)

(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)

*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)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

(Continue your answer on next page)

**(TOTAL FOR QUESTION 7 = 6 MARKS)**

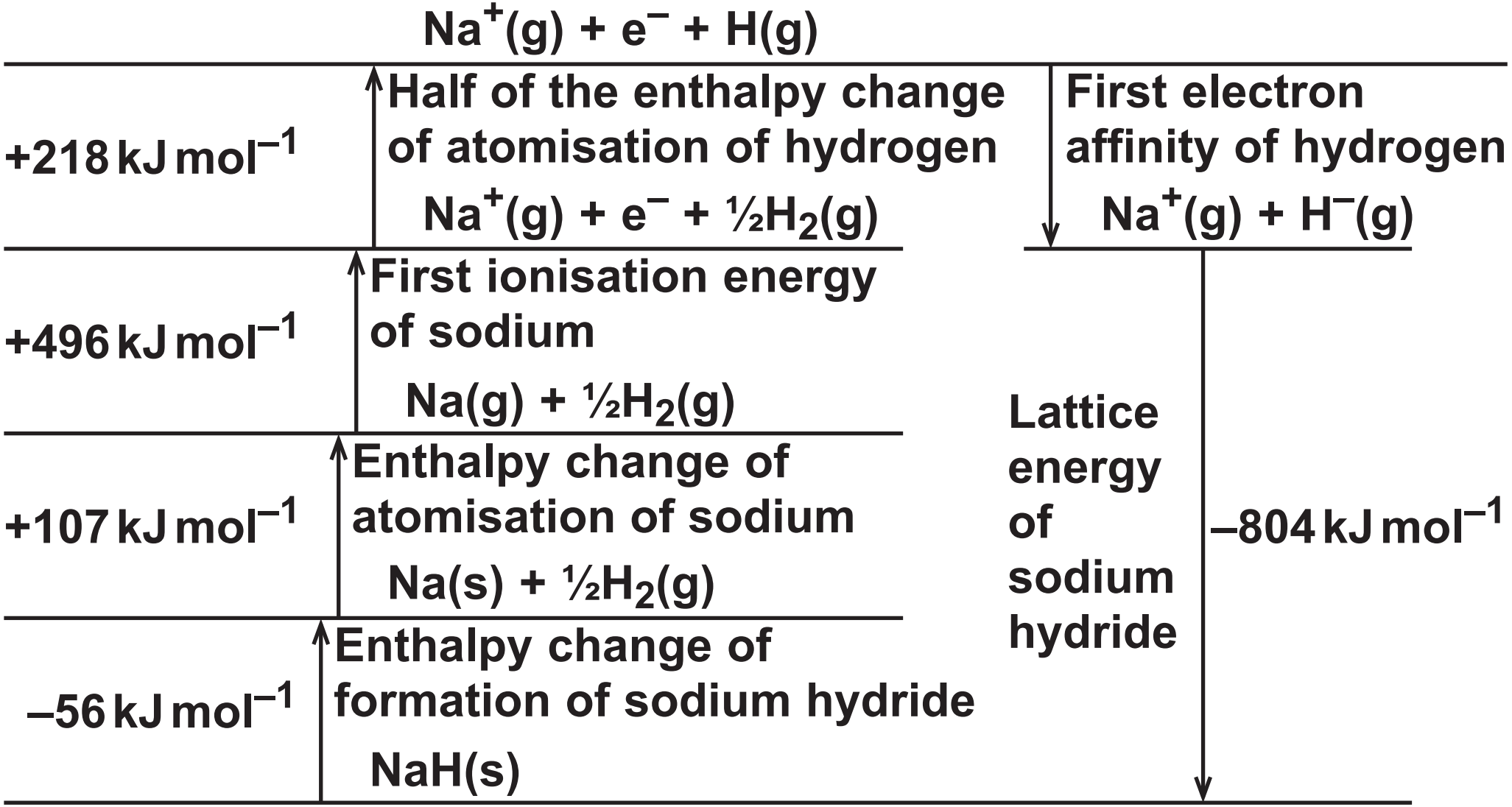
**(Questions continue on next page)**

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)






(Question continues on next page)

(Turn over)

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

(Question continues on next page)

(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)

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

$$Na(s) + \tfrac{1}{2}H_2(g) \longrightarrow NaH(s)$$

$$\Delta_f H^{\ominus} = -56\,kJ\,mol^{-1}$$

The standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for this reaction is $-76{\cdot}5\,J\,K^{-1}\,mol^{-1}$.

(Question continues on next page)

(i) Deduce the feasibility of this reaction at 298 K by calculating the free energy change, $\Delta G$. (2 marks)

(Question continues on next page)

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

(Question continues on next page)

(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

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l)$$

In an alkaline fuel cell the oxidation half-equation is

$$H_2(g) + 2OH^-(aq) \longrightarrow 2H_2O(l) + 2e^-$$

(Question continues on next page)

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

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

**(Question continues on next page)**

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

Which are the lattice energies of the hydrides NaH, KH and $MgH_2$? (1 mark)

| | Lattice energy / kJ mol$^{-1}$ | | |
|---|---|---|---|
| | Sodium hydride, NaH | Potassium hydride, KH | Magnesium hydride, $MgH_2$ |
| ☐ A | –804 | –711 | –1018 |
| ☐ B | –804 | –711 | –2718 |
| ☐ C | –804 | –911 | –1018 |
| ☐ D | –804 | –911 | –2718 |

**(TOTAL FOR QUESTION 8 = 8 MARKS)**

(Questions continue on next page)

**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)**

(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 $cm^3$ 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 = $1{\cdot}74 \times 10^{-5}\,mol\,dm^{-3}$] (5 marks)

(Continue your answer on next page)

(Question continues on next page)

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

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

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)

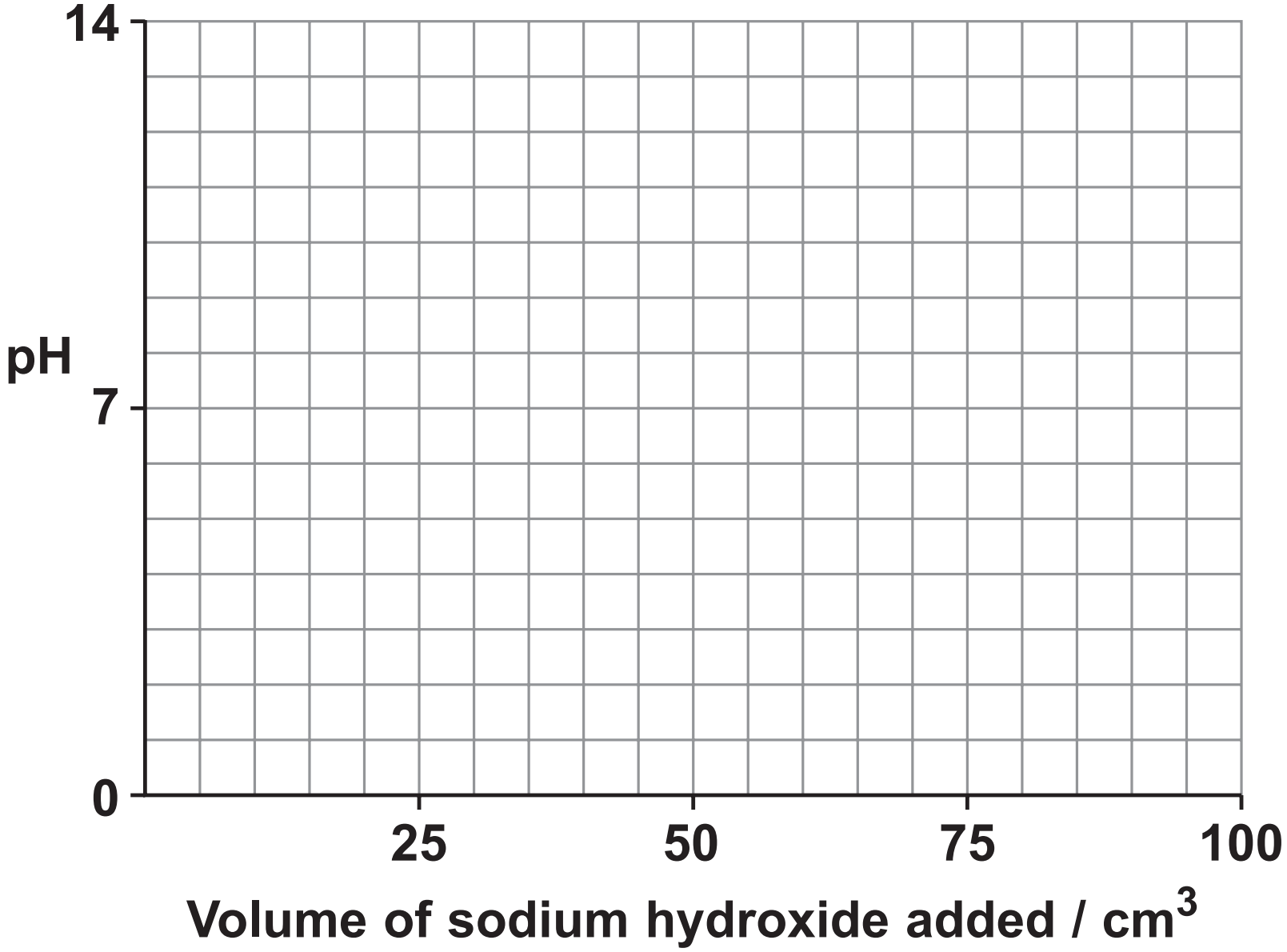
(Question continues on next page)

(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)




(Question continues on next page)

(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)

10 This question is about equilibrium systems.

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

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The composition of an equilibrium mixture at 698 K and a total pressure of 2·40 atm is shown in the table.

| Substance | $SO_2(g)$ | $O_2(g)$ | $SO_3(g)$ |
|---|---|---|---|
| Number of moles /mol | 0·0160 | 0·0120 | 0·772 |

(Question continues on next page)

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

Include units, if appropriate.
(5 marks)

(Continue your answer on next page)

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

(Question continues on next page)

(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)

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

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

(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)**

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

$$Fe_3O_4(s) + 4H_2(g) \rightleftharpoons 3Fe(s) + 4H_2O(g)$$

The $K_c$ expression for this equilibrium is (1 mark)

☐ A $K_c = \dfrac{[Fe] \times [H_2O]}{[Fe_3O_4] \times [H_2]}$

☐ B $K_c = \dfrac{[Fe]^3 \times [H_2O]^4}{[Fe_3O_4] \times [H_2]^4}$

☐ C $K_c = \dfrac{[H_2O]}{[H_2]}$

☐ D $K_c = \dfrac{[H_2O]^4}{[H_2]^4}$

**(TOTAL FOR QUESTION 10 = 11 MARKS)**

**TOTAL FOR PAPER = 90 MARKS**

**END**