WORKBOOK

AQA A-LEVEL YEAR 1

Chemistry

Organic, Inorganic and Physical Chemistry

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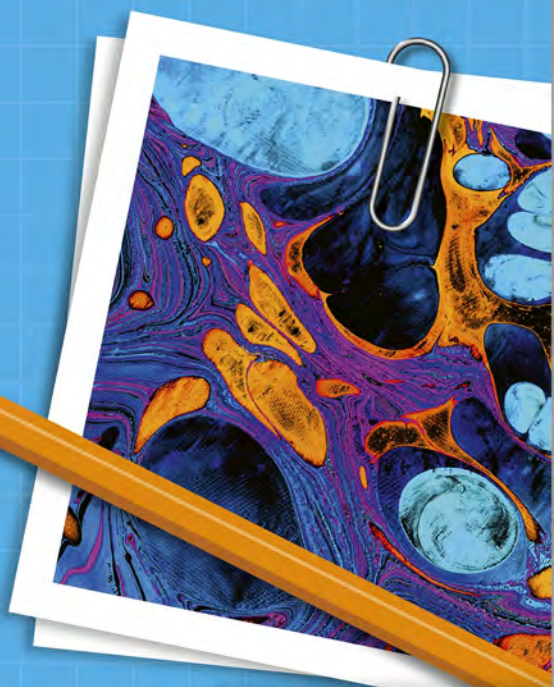
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WORKBOOK

Chemistry 1

Year 1 Topics

- Physical chemistry
- Inorganic chemistry
- Organic chemistry

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Contents

About this book

1 **This workbook** will help you to prepare for AQA A-level Chemistry Topics 3.1.1–3.1.7, 3.2.1–3.2.3 and 3.3.1–3.3.6.

2 **These topics** could be assessed in:
- A-level Paper 1, which lasts for 2 hours. Paper 1 is worth 35% of the A-level. There is a mixture of short- and long-answer questions, worth 105 marks.
- A-level Paper 2, which lasts for 2 hours. Paper 2 is worth 35% of the A-level. There is a mixture of short- and long-answer questions, worth 105 marks.
- A-level Paper 3, which lasts for 2 hours and covers any content and any practical skills. Paper 3 is worth 30% of the A-level. Questions on practical techniques and data analysis are worth 40 marks. There are 20 marks for questions testing across the specification and 30 marks for multiple-choice questions, a total of 90 marks.

3 **For each topic** in this workbook there are:
- stimulus materials, including key terms and concepts
- short-answer questions that build up to short- and long-answer questions and multiple-choice questions in exam-style
- spaces for you to write or plan your answers
- questions that test your mathematical skills

4 **Answering the questions** will help you to build your skills and meet the assessment objectives AO1 (knowledge and understanding), AO2 (application) and AO3 (analysis). Mathematical skills make up a minimum of 20% of the total marks across the A-level.

5 **Worked answers** are included for some practice questions to help you understand how to gain the most marks.

6 **Marks available** are indicated for all questions so that you can gauge the level of detail required in your answers.

7 **Timings** are given for the exam-style questions to make your practice as realistic as possible.

8 Icons next to a question will help you to identify:

where the practical elements of the course are covered

where your calculation skills are tested

where questions draw on synoptic knowledge, i.e. content from more than one topic

60 how long these questions should take you

9 **You still need** to read your textbook and refer to your revision guides and lesson notes.

10 **Answers** are available at: **www.hoddereducation.co.uk/workbookanswers.**

3.1.4 Energetics

Enthalpy change

The **enthalpy change** (ΔH) for an endothermic reaction has a positive value.

For an exothermic reaction, ΔH has a negative value.

Standard enthalpy changes are under standard conditions of 100 kPa at a stated temperature (298 K).

The **standard enthalpy change of combustion** ($\Delta_c H^\ominus$) is the enthalpy change when 1 mole of a substance is burned completely in oxygen under standard conditions.

The **standard enthalpy change of formation** ($\Delta_f H^\ominus$) is the enthalpy change when 1 mole of a compound is formed from its elements under standard conditions.

Practice questions ❓

1 Write equations to represent the standard enthalpy changes below.

   a enthalpy of combustion of methane   **1 mark**

   b enthalpy of formation of sodium chloride   **1 mark**

   c enthalpy of combustion of butan-1-ol, $CH_3CH_2CH_2CH_2OH(l)$ **1 mark**

   d enthalpy of combustion of potassium   **1 mark**

   e enthalpy of formation of magnesium nitrate   **1 mark**

2 Consider the equations for the reactions A to C below.

   A $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -394 \text{ kJ mol}^{-1}$

   B $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H = -286 \text{ kJ mol}^{-1}$

   C $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ $\Delta H = -1411 \text{ kJ mol}^{-1}$
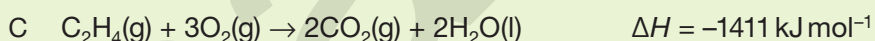
   a Write an equation to represent the enthalpy of formation of ethene, $C_2H_4(g)$.   **1 mark**

   b Explain why the information above indicates that all three reactions are exothermic.   **1 mark**

   c Calculate the enthalpy change for the following reactions.

     i $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$ **1 mark**

     ii $2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$ **1 mark**
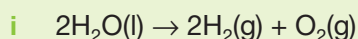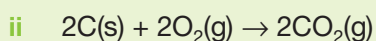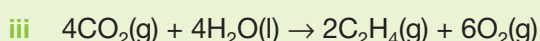
     iii $4CO_2(g) + 4H_2O(l) \rightarrow 2C_2H_4(g) + 6O_2(g)$ **1 mark**

3 a What is meant by the term *standard enthalpy of combustion*? **1 mark**

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b What are the standard conditions of enthalpy change? **1 mark**

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c Write an equation for the standard enthalpy of combustion of the following substances. Include state symbols.

i $Mg(s)$ **1 mark**

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ii $C_2H_6(g)$ **1 mark**

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iii $C_2H_4(OH)_2(l)$ **1 mark**

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Calorimetry

The heat change (*q*) in a reaction, measured in joules (J), is calculated using:

$q = mc\Delta T$

m is the mass of the substance undergoing the temperature change (in g).

c is its specific heat capacity (in $J\,K^{-1}\,g^{-1}$).

ΔT is the temperature change (in °C or K).

Practice questions ?

4 A sample of 0.0232 mol of propan-1-ol was burned in a spirit burner and the energy used to heat 200 g of water in a glass beaker. The standard enthalpy of combustion of propan-1-ol is –2021 kJ mol^{-1}. The specific heat capacity of water is 4.18 $J\,K^{-1}\,g^{-1}$.

a Calculate the theoretical temperature change that should be achieved. Give your answer to 3 significant figures. **3 marks**

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b The temperature change observed was 38.2°C. Suggest two reasons why the temperature change observed was less than the theoretical temperature change. **2 marks**

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5 In an experiment, 1.00 g of liquid propanone (CH₃COCH₃) were completely burned in air. The heat evolved raised the temperature of 150 g of water from 18.8°C to 64.3°C.

Calculate the enthalpy of combustion of propanone. The specific heat capacity of water is 4.18 J K⁻¹ g⁻¹.

5 marks

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6 This question relates to required practical 2.

In an experiment to determine the enthalpy of dissolution of potassium iodide, the temperature of 50.0 cm³ of water was recorded every minute for 3 minutes in a 100 cm³ beaker. At the fourth minute, 10.0 g of solid potassium iodide were added and the mixture stirred, but the temperature was not recorded. The temperature was recorded at 1-minute intervals for a further 6 minutes. The results are shown in the table below.

Time/min	0	1	2	3	4	5	6	7	8	9	10
Temperature/°C	20.4	20.4	20.4	20.4		16.8	16.3	16.5	16.7	16.9	17.1

a Plot a graph of temperature against time on the grid below. Use your graph to find the temperature rise, ΔT, at the fourth minute. Show your working on the graph by drawing suitable lines of best fit.

5 marks
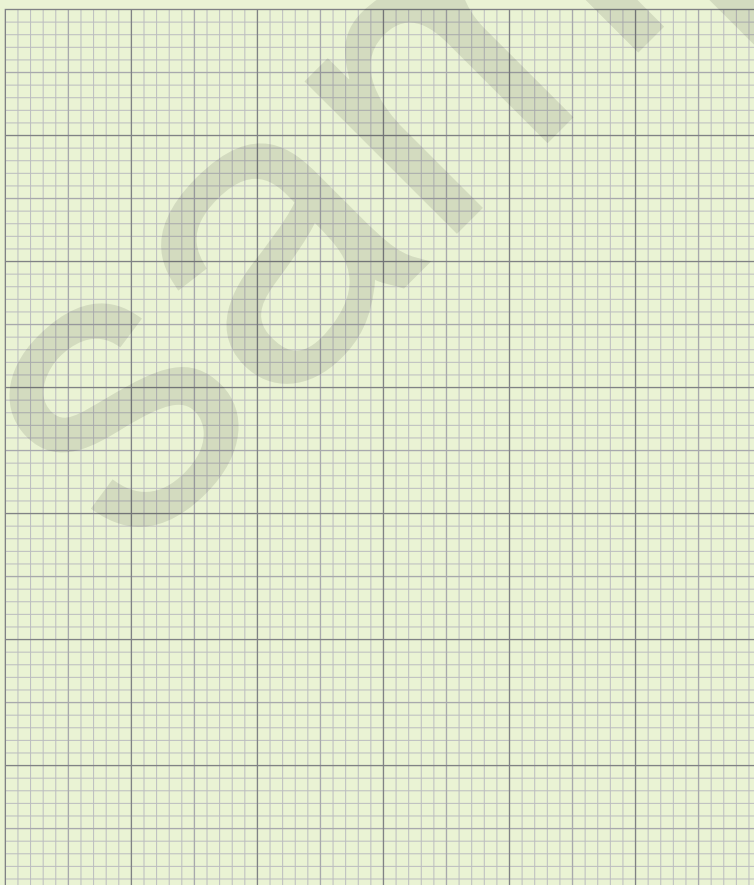
ΔT = ... °C

b Use the value of ΔT from your graph and the information provided to calculate the enthalpy of dissolution of potassium iodide. The density of the solution is $1.00\,g\,cm^{-3}$ and the specific heat capacity of the solution is $4.18\,J\,K^{-1}\,g^{-1}$. **4 marks**

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c The value for the enthalpy of dissolution of potassium iodide quoted in books is $+20.3\,kJ\,mol^{-1}$. Suggest why the value obtained in **b** is less than the quoted value. **1 mark**

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Applications of Hess's law

Hess's law states that the enthalpy change in a chemical reaction is independent of the route taken if the initial and final conditions remain the same.

Using standard enthalpies of combustion:

$\Delta H = \Sigma\Delta_c H^{\ominus}(\text{reactants}) - \Sigma\Delta_c H^{\ominus}(\text{products})$

Using standard enthalpies of formation:

$\Delta H = \Sigma\Delta_f H^{\ominus}(\text{products}) - \Sigma\Delta_f H^{\ominus}(\text{reactants})$

Practice questions ❓

7 Silver(I) nitrate decomposes according to the equation below.

$$2AgNO_3(s) \rightarrow 2Ag(s) + O_2(g) + 2NO_2(g)$$
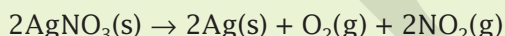
The standard enthalpy of formation values of two compounds are given in the table below.

Compound	Enthalpy of formation/kJ mol⁻¹
$AgNO_3(s)$	−123
$NO_2(g)$	+33

Use the data in the table to determine the enthalpy change of decomposition of silver(I) nitrate per mole of silver(I) nitrate. **2 marks**

Worked example

$\Delta H = \Sigma\Delta_f H^{\ominus}(\text{products}) - \Sigma\Delta_f H^{\ominus}(\text{reactants})$ ◄— The enthalpy change for the reaction is $\Delta H = \Sigma\Delta_f H^{\ominus}(\text{products}) - \Sigma\Delta_f H^{\ominus}(\text{reactants})$.

$\Delta H = 2(+33) - 2(-123)$ ✓ $= +312\,kJ$ ✓ ◄— Note that the enthalpy of formation values for Ag(s) and O₂(g) are not given as they are elements in their standard states so their enthalpy of formation values are zero.

Per mole of $AgNO_3 = \dfrac{312}{2} = +156\,kJ\,mol^{-1}$

As this is a thermal decomposition, it would be expected that the value is positive (endothermic).

The equation given is for 2 moles of AgNO₃ so the final answer is divided by 2.

8 If the standard enthalpies of formation of propane (C_3H_8), carbon dioxide and water are –104, –394 and –286 kJ mol^{-1} respectively, the enthalpy of combustion of propane in kJ mol^{-1} is:

1 mark

A –2222 ◯   B –2430 ◯   C –576 ◯   D –784 ◯

9 Carbon dioxide is formed when carbon burns in an excess of oxygen. The reaction is exothermic. If there is insufficient oxygen when carbon burns, carbon monoxide is formed. Hess's law may be used to calculate the standard enthalpy of combustion of carbon monoxide.

a **i** State Hess's law.

1 mark

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ii Write an equation for the combustion of carbon monoxide, including relevant state symbols.

1 mark

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b Calculate the standard enthalpy of combustion of carbon monoxide using the data given below.

3 marks

Compound	Enthalpy of formation/kJ mol^{-1}
CO_2	–394
CO	–110

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10 Hexane (C_6H_{14}) is a liquid alkane.

a Write an equation which would have an enthalpy value the same as the enthalpy of formation of hexane. Include state symbols.

1 mark

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b Calculate the enthalpy of formation of hexane using the values given in the table below.

2 marks

Compound	$\Delta_c H^\ominus$/kJ mol^{-1}
C_6H_{14}(l)	–4195
C(s)	–394
H_2(g)	–286

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11 One of the constituents of petrol is octane (C_8H_{18}(l)). The standard enthalpy of combustion of octane is –5476 kJ mol^{-1}.

The following data are provided.

Substance	$\Delta_f H^\ominus$/kJ mol^{-1}
CO_2(g)	–394
H_2O(l)	–286

a Write an equation to represent the standard enthalpy of combustion of octane. Include state symbols. **1 mark**

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b Calculate the value for $\Delta_f H^\ominus$ for C_8H_{18}(l). **3 marks**

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12 Lead(II) sulfide reacts with oxygen to form lead(II) oxide and sulfur dioxide according to the equation below.

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$
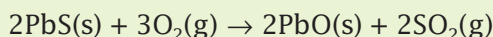
The enthalpy of formation values are given in the table below.

Substance	$\Delta_f H^\ominus$/kJ mol^{-1}
PbS(s)	−100
O$_2$(g)	0
PbO(s)	−217
SO$_2$(g)	−297

a Explain why the standard enthalpy of formation of O_2(g) is zero. **1 mark**

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b Calculate a value for the enthalpy change for the reaction of lead(II) sulfide with oxygen, using the values in the table, per mole of lead(II) sulfide. **3 marks**

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Bond enthalpies

The **mean bond enthalpy** is the enthalpy change when 1 mole of a covalent bond is broken, averaged across compounds containing the bond.

$$\Delta H = \Sigma(\text{bond enthalpies of reactants}) - \Sigma(\text{bond enthalpies of products})$$

ΔH values obtained from mean bond enthalpy calculations differ from those obtained by Hess's law/calorimetry, as the mean bond enthalpies are averages and not specific to the molecules in the reaction.

Practice questions ?

13 Using the mean bond enthalpy values given in the table below, which one of the following is the enthalpy change, in kJ mol^{-1}, for the reaction below? **1 mark**

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$$
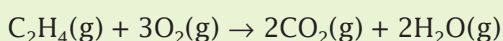
Bond	Mean bond enthalpy/kJ mol^{-1}
C=C	611
C−H	412
C=O	803
O=O	496
O−H	463

A +289

B +1317

C −289

D −1317

14 Iodine monochloride (ICl) is a solid under standard conditions. Its melting point is 27°C.

    a Use the following bond enthalpies to calculate the enthalpy change for the reaction.   **3 marks**

$$I_2(g) + Cl_2(g) \rightarrow 2ICl(g)$$
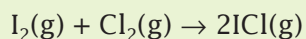
Bond	Bond enthalpy/kJ mol^{-1}
I–I	151
Cl–Cl	242
I–Cl	212

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    b Explain why the value calculated in **a** is different from the standard enthalpy of formation of ICl, which is quoted as +17.6 kJ mol^{-1}.   **1 mark**

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    c Explain why the values quoted in the table for I–I and Cl–Cl are not *mean* bond enthalpy values.   **1 mark**

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15 The equation below represents the standard enthalpy of combustion of methanol.

$$CH_3OH(l) + 1\tfrac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$
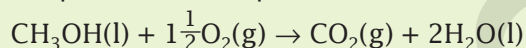
The value of $\Delta_c H^{\ominus} = -655$ kJ mol^{-1}, calculated from mean bond enthalpy values.

    a Use the mean bond enthalpy values in the table below to calculate a value for the mean bond enthalpy of the O–H bond.   **4 marks**

Bond	Mean bond enthalpy/kJ mol^{-1}
C–H	412
C–O	360
O=O	496
C=O	803

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    b The value for the enthalpy of combustion quoted in books is −755 kJ mol^{-1}. Explain why this value is different from the value quoted when obtained from mean bond enthalpy values.   **1 mark**

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Workbook answers at **www.hoddereducation.co.uk/workbookanswers**

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1 In South America, ethanol (C_2H_5OH) is used as a fuel for motor vehicles.
The enthalpy of combustion of 1 mol of ethanol can be calculated in several ways.

a The first method is by directly burning a sample of ethanol. In an experiment, the combustion of 0.400 g of ethanol raises the temperature of 100 g of water by 20.5 K. The specific heat capacity of water is 4.18 J K^{-1} g^{-1}.
Calculate the enthalpy of combustion of 1 mol of ethanol. **4 marks**

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b The enthalpy of combustion may also be determined indirectly using mean bond enthalpy values.

Bond	Mean bond enthalpy/kJ mol^{-1}
C–C	348
C–H	412
C–O	360
C=O	To be calculated
O–H	463
O=O	496

The enthalpy of combustion of ethanol from mean bond enthalpies is –1271 kJ mol^{-1}. Calculate the mean bond enthalpy of the C=O bond. **4 marks**

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c Another method of determining the enthalpy of combustion of ethanol is by using Hess's law.

i State Hess's law. **1 mark**

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ii Calculate the enthalpy of combustion of ethanol given the following enthalpy of formation data. **3 marks**

Compound	$\Delta_f H^{\ominus}$/kJ mol^{-1}
$C_2H_5OH(l)$	–278
$CO_2(g)$	–394
$H_2O(l)$	–286

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2 The equation below represents the hydration of ethene.

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$
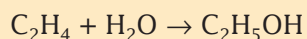
ΔH for this reaction, calculated using mean bond enthalpy values, is $-46\,kJ\,mol^{-1}$.

The table below shows some mean bond enthalpy values.

Bond	Mean bond enthalpy/kJ mol⁻¹
C=C	611
C–H	To be calculated
C–O	360
C–C	348
O–H	463

a Calculate the value of the mean bond enthalpy for the C–H bond. **3 marks**

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b The enthalpy of formation values for C_2H_4(g), H_2O(l) and C_2H_5OH(l) are $+52\,kJ\,mol^{-1}$, $-286\,kJ\,mol^{-1}$ and $-278\,kJ\,mol^{-1}$.

Using Hess's law, calculate a value for the enthalpy of hydration of ethene. **3 marks**

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c Suggest why the values of the enthalpy of hydration of ethene are different when calculated using Hess's law and using mean bond enthalpy values. **1 mark**

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3 This question relates to required practical 2.

In an experiment to determine the enthalpy of neutralisation between sodium hydroxide solution and hydrochloric acid, the following experiment was carried out.

- $50.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ sodium hydroxide solution were placed in a polystyrene cup.
- The temperature was recorded every minute for 3 minutes.
- At the fourth minute, $50.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ hydrochloric acid were added and the mixture was stirred. The temperature was not recorded at the fourth minute.
- The temperature was recorded at 1-minute intervals for the next 6 minutes.

A graph of the results is plotted below.
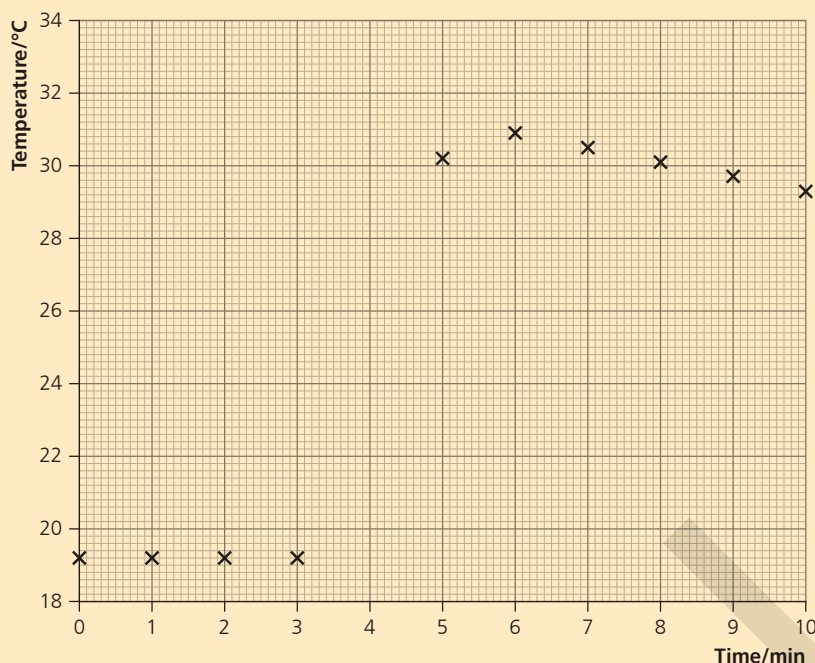
a Use the graph above to find the temperature rise ΔT at the fourth minute.
Show your working on the graph by drawing suitable lines of best fit. **4 marks**

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ΔT = ...°C

b Write the equation for the reaction between sodium hydroxide and
hydrochloric acid. **1 mark**

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c Calculate the amount of water formed, in moles. **2 marks**

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d Use your value of ΔT and your answer to **c** to calculate the enthalpy of
neutralisation of sodium hydroxide with hydrochloric acid per mole
of water formed. The density of the reaction mixture is $1.00\,g\,cm^{-3}$ and
the specific heat capacity of the reaction mixture is $4.18\,J\,K^{-1}\,g^{-1}$. **3 marks**

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e The value for the enthalpy of neutralisation of a strong acid with a strong
base quoted in books is $-57.3\,kJ\,mol^{-1}$. Suggest why the value obtained in
d is different from the quoted value. **1 mark**

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Total 30 marks