CrackingCHEM
GCSE | A-LEVEL
UNDERSTAND • APPLY • SUCCEED

OCR A H432

Energetics I

Original exam questions | TEST IT → EXAM STYLE → HARDER MIXED → STRETCH

SPECIFICATION-LED. CALCULATION-PRECISE. PRACTICAL-READY.

OCR A SPECIFICATION	3.2.1(a–e) + direct methods from (h) | enthalpy and calorimetry		
TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	10	5	1
24 QUESTIONS ORIGINAL		164 MARKS TOTAL	

FINAL NOTES-ALIGNED EDITION | PROFILES • CALORIMETRY • PAG3 • EVALUATION

Independent practice material. Every question is original and mapped to OCR A Chemistry A H432 specification version 3.1 (May 2026).

START HERE

How to use this pack

Attempt independently, then compare the first lost mark with the model answer

1	Attempt TEST IT first, then work through the sections in order without using the notes.
2	Keep ΔT, q and ΔH separate: thermometer change, energy gained or lost by the solution, then molar reaction enthalpy.
3	For calorimetry, use the mass actually heated and the correct reacting amount or moles of water formed.
4	For evaluation, trace cause → measurement → q or n → the direction of the calculated ΔH.

OCR A BOUNDARY	This pack assesses OCR A 3.2.1(a–e) and direct enthalpy determinations: signs, profiles, definitions, q = mcΔT, calorimetry, cooling correction and uncertainty.
HELD BACK	Hess cycles, indirect determination and average bond-enthalpy calculations are not assessed. These belong to Energetics II.
QUESTION PAGES	There are no mole grids, route strips or calculation scaffolds. Each written part has one more dotted line than its marks; calculation parts have two further working lines.
CALCULATION STANDARD	Show a logical route, keep unrounded values until the end, include units and give molar enthalpies to 3 significant figures unless told otherwise.

SECTION A

TEST IT

Eight direct checks of the finished-notes mastery outcomes

QUESTION 1

TEST IT

A reaction mixture absorbs 3.8 kJ of energy from the surrounding water.

(a) State whether the reaction is exothermic or endothermic. **[1 mark]**

(b) State the sign of ΔH. **[1 mark]**

(c) State how the temperature of the surrounding water changes. **[1 mark]**

(d) Compare the enthalpy of the products with the enthalpy of the reactants. **[1 mark]**

QUESTION 2

TEST IT

For a reaction, the relative enthalpies are: reactants 48 kJ mol^{-1}; products 92 kJ mol^{-1}; peak of the pathway 132 kJ mol^{-1}.

(a) Calculate ΔH. **[1 mark]**

(b) Calculate the activation energy, E_a, for the forward reaction. **[1 mark]**

(c) State what is meant by activation energy. **[1 mark]**

(d) Draw a labelled enthalpy profile for the reaction. Show ΔH and E_a using correctly directed arrows. **[3 marks]**

PROFILE DRAWING AREA

QUESTION 3

TEST IT

(a) State the standard pressure and the temperature normally used for tabulated standard enthalpy changes. **[2 marks]**

(b) Give the standard state of (i) bromine and (ii) carbon at this temperature. **[2 marks]**

(c) State the standard concentration used for a solution. **[1 mark]**

QUESTION 4

TEST IT

(a) Define standard enthalpy change of formation. **[2 marks]**

(b) Define standard enthalpy change of combustion. **[2 marks]**

(c) Define standard enthalpy change of neutralisation. **[2 marks]**

QUESTION 5

TEST IT

Write equations, including state symbols. Each equation must correspond to exactly one mole of the named substance.

(a) The standard enthalpy change of formation of $Fe_2O_3(s)$. **[2 marks]**

(b) The standard enthalpy change of combustion of butan-1-ol, $C_4H_9OH(l)$. **[3 marks]**

QUESTION 6

TEST IT

A reaction raises the temperature of 82.0 g of solution from 19.50 °C to 26.80 °C. Use c = 4.18 J g^{-1} K^{-1}.

(a) Calculate ΔT. **[1 mark]**

(b) Calculate q for the solution, including its sign. **[2 marks]**

(c) State the energy change of the reacting system under the usual calorimetry assumptions. **[1 mark]**

QUESTION 7

TEST IT

25.0 cm^3 of 1.00 mol dm^{-3} HCl is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} NaOH. The temperature rises by 6.80 K.

Assume density of each solution = 1.00 g cm^{-3}, c = 4.18 J g^{-1} K^{-1} and no energy is transferred to the cup or air.

(a) Calculate the enthalpy change of neutralisation. **[6 marks]**

QUESTION 8

TEST IT

A spirit burner loses 0.512 g of methanol, CH_3OH. The fuel heats 125.0 g of water by 16.7 K. Use M(CH_3OH) = 32.0 g mol^{-1} and c(water) = 4.18 J g^{-1} K^{-1}.

(a) State the mass used in (i) q = mcΔT and (ii) n = m/M. **[2 marks]**

(b) Calculate the experimental enthalpy change of combustion of methanol. **[4 marks]**

SECTION B

EXAM STYLE

Original OCR-style applications with calculation, interpretation and practical work

QUESTION 9

EXAM STYLE

For the reaction X → Y, the relative enthalpies are: X = −20 kJ mol^{-1}; peak = +65 kJ mol^{-1}; Y = −78 kJ mol^{-1}.

(a) Calculate (i) ΔH for X → Y, (ii) E_a for X → Y and (iii) E_a for Y → X. **[3 marks]**

(b) Draw a labelled enthalpy profile showing the reactant and product levels and all three quantities. **[4 marks]**

PROFILE DRAWING AREA

QUESTION 10

EXAM STYLE

For the reaction: $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta_rH^\circ = -566$ kJ mol^{-1}

(a) Determine the enthalpy change when 1.00 mol of CO_2 is formed by this reaction. **[1 mark]**

(b) Determine Δ_rH° for the reverse of the equation as written. **[1 mark]**

(c) Explain why the equation does not represent the standard enthalpy change of formation of CO_2. **[2 marks]**

(d) Write the equation that does represent the standard enthalpy change of formation of $CO_2(g)$. Include state symbols. **[2 marks]**

QUESTION 11

EXAM STYLE

40.0 cm^3 of 0.800 mol dm^{-3} HNO_3 is mixed with 30.0 cm^3 of 1.20 mol dm^{-3} KOH. The temperature rises by 6.25 K.

Assume density = 1.00 g cm^{-3} and c = 4.18 J g^{-1} K^{-1}.

(a) Calculate the enthalpy change of neutralisation. **[8 marks]**

QUESTION 12

EXAM STYLE

25.0 cm^3 of 0.550 mol dm^{-3} H_2SO_4 is mixed with 45.0 cm^3 of 0.500 mol dm^{-3} NaOH. The temperature rises by 4.40 K.

$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

Assume density = 1.00 g cm^{-3} and c = 4.18 J g^{-1} K^{-1}.

(a) Determine the enthalpy change of neutralisation. **[8 marks]**

QUESTION 13

EXAM STYLE

4.25 g of ammonium nitrate, NH_4NO_3, dissolves completely in 80.0 g of water. The temperature falls by 4.60 K.

Use $M(NH_4NO_3)$ = 80.0 g mol^{-1} and c(solution) = 4.18 J g^{-1} K^{-1}. Assume the complete mixture is the mass whose temperature changes.

(a) Calculate the experimental molar enthalpy change for the dissolving process. **[7 marks]**

QUESTION 14

EXAM STYLE

A spirit burner loses 0.444 g of propan-1-ol, C_3H_7OH. The fuel heats 175.0 g of water from 20.4 °C to 37.6 °C.

Use $M(C_3H_7OH)$ = 60.0 g mol^{-1}, c(water) = 4.18 J g^{-1} K^{-1} and accepted ΔcH = −2021 kJ mol^{-1}.

(a) Write the equation for complete combustion of one mole of propan-1-ol, including state symbols. **[2 marks]**

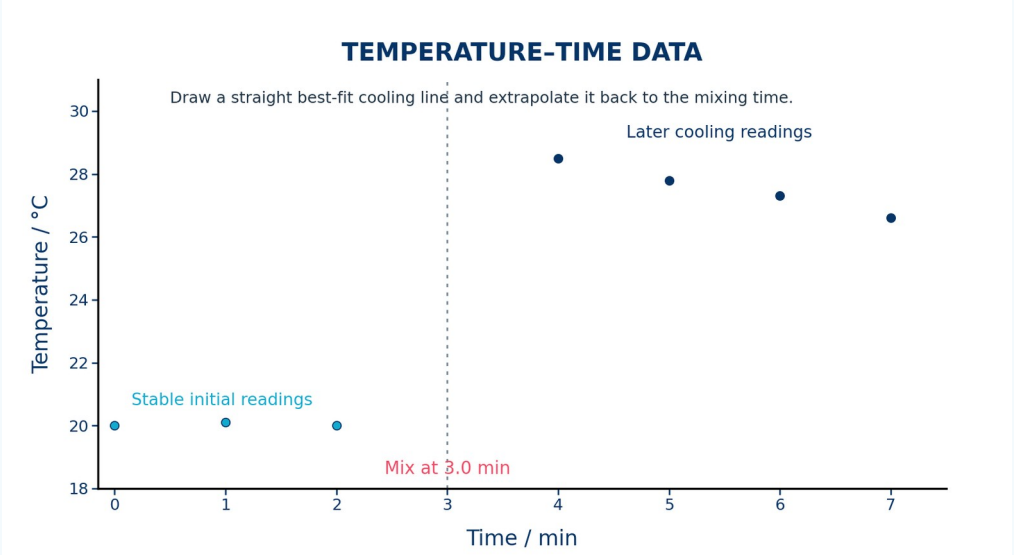
(b) Calculate the experimental ΔcH. **[4 marks]**

(c) Calculate the percentage difference from the accepted magnitude. **[2 marks]**

QUESTION 15

EXAM STYLE

The graph shows temperature readings for an exothermic reaction. The reactants were mixed at 3.0 min.



(a) On the graph, draw a straight best-fit line through the later cooling readings and extrapolate it back to 3.0 min. **[2 marks]**

(b) Use your graph to determine the corrected temperature at the mixing time. **[1 mark]**

(c) Calculate the corrected temperature rise. **[1 mark]**

(d) The highest directly recorded temperature was 28.5 °C. Calculate the uncorrected temperature rise. **[1 mark]**

(e) State how cooling correction affects a calculated exothermic enthalpy change. **[1 mark]**

QUESTION 16

EXAM STYLE

In a combustion experiment, each temperature reading has uncertainty ±0.10 °C and the measured temperature rise is 5.60 °C. Each balance reading has uncertainty ±0.01 g and the burner mass loss is 0.480 g.

(a) Calculate the absolute and percentage uncertainty in ΔT. **[2 marks]**

(b) Calculate the absolute and percentage uncertainty in the burner mass loss. **[2 marks]**

(c) Ignoring all other uncertainties, estimate the maximum percentage uncertainty in the calculated molar enthalpy and identify the larger contribution. **[3 marks]**

QUESTION 17

EXAM STYLE

Describe how a student should determine an enthalpy change of neutralisation using aqueous acid and aqueous alkali.

Your answer should include the measurements, procedure and treatment of the results needed to obtain a reliable molar value.

(a) Write your method. **[7 marks]**

QUESTION 18

EXAM STYLE

A student burns ethanol beneath a container holding 100.0 g of water.

Measurement	Value
Burner mass before heating / g	142.840
Burner mass after heating / g	142.320
Initial water temperature / °C	18.0
Final water temperature / °C	31.0

Use M(ethanol) = 46.0 g mol^{-1} and c(water) = 4.18 J g^{-1} K^{-1}.

(a) Calculate the experimental enthalpy change of combustion. **[4 marks]**

(b) Explain one reason why the result is likely to be less negative than the accepted value. **[2 marks]**

(c) Explain why repeating the same method does not necessarily remove this error. **[1 mark]**

SECTION C — HARDER MIXED

Less scaffolded problems combining calculation, judgement and error analysis

QUESTION 19

HARDER MIXED

20.0 cm^3 of 1.50 mol dm^{-3} HCl is mixed with 30.0 cm^3 of 0.800 mol dm^{-3} NaOH. The temperature rises by 6.50 K. Assume density = 1.00 g cm^{-3}.

> **A student writes:**
> q = 20.0 × 4.18 × 6.50 = 543.4 J
> $n(H_2O)$ = 0.0200 × 1.50 = 0.0300 mol
> $\Delta_{neut}H$ = +543.4 ÷ (1000 × 0.0300) = +18.1 kJ mol^{-1}

(a) Identify three errors in the student's working. **[3 marks]**

(b) Calculate the correct enthalpy change of neutralisation. **[5 marks]**

QUESTION 20

HARDER MIXED

In each run, 25.0 cm^3 of 1.00 mol dm^{-3} HCl is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} NaOH.

Run	Initial temperature / °C	Corrected maximum / °C
1	20.20	26.95
2	20.10	26.90

Assume density = 1.00 g cm^{-3} and c = 4.18 J g^{-1} K^{-1}. The accepted value is −57.3 kJ mol^{-1}.

(a) Calculate $\Delta_{neut}H$ for each run. **[4 marks]**

(b) Calculate the mean. **[1 mark]**

(c) Calculate the percentage difference between the mean magnitude and the accepted magnitude. **[1 mark]**

(d) Comment separately on repeatability and accuracy. **[2 marks]**

QUESTION 21

HARDER MIXED

35.0 cm^3 of 0.800 mol dm^{-3} $CaCl_2$ is mixed with 50.0 cm^3 of 0.500 mol dm^{-3} Na_2CO_3. The temperature rises by 2.85 K.

$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$

Assume density = 1.00 g cm^{-3} and c = 4.18 J g^{-1} K^{-1}.

(a) Calculate $\Delta_r H$ for the equation as written. **[8 marks]**

QUESTION 22

HARDER MIXED

Two fuels are tested using the same mass of water. Use c(water) = 4.18 J g^{-1} K^{-1}.

Fuel	M / g mol^{-1}	Mass burned / g	Water mass / g	ΔT / K
Methanol	32.0	0.780	200.0	18.0
Ethanol	46.0	0.920	200.0	23.5

(a) Calculate the experimental ΔcH for each fuel. **[4 marks]**

(b) State which fuel has the more exothermic experimental molar enthalpy of combustion. **[1 mark]**

(c) Explain why comparing ΔT alone would not be a valid molar comparison. **[1 mark]**

(d) Explain one systematic limitation and its effect on the calculated values. **[2 marks]**

QUESTION 23

HARDER MIXED

25.0 cm^3 of 1.00 mol dm^{-3} HCl is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} NaOH at 180 s. The initial temperature is 20.00 °C.

The later cooling line passes through:

Time / s	240	360
Temperature / °C	26.50	25.70

Assume linear cooling, density = 1.00 g cm^{-3} and c = 4.18 J g^{-1} K^{-1}. Each temperature reading has uncertainty ±0.10 °C.

(a) Determine the corrected temperature at 180 s. **[2 marks]**

(b) Calculate the corrected ΔT. **[1 mark]**

(c) Calculate $\Delta_{neut}H$. **[4 marks]**

(d) Calculate the maximum percentage uncertainty in the corrected ΔT. **[2 marks]**

SECTION D

STRETCH / SYNOPTIC

A final challenge linking correction, energy, stoichiometry and measurement quality

QUESTION 24

STRETCH

40.0 cm^3 of H_2SO_4 of unknown concentration is mixed with 60.0 cm^3 of 1.20 mol dm^{-3} NaOH. Both solutions start at 19.40 °C. A cooling correction gives 25.65 °C at the mixing time.

Assume density = 1.00 g cm^{-3}, c = 4.18 J g^{-1} K^{-1}, $\Delta_{neut}H$ = −57.0 kJ mol^{-1} per mole of water formed, and H_2SO_4 is limiting.

$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

(a) Calculate the concentration of the H_2SO_4. **[6 marks]**

(b) Show that NaOH is in excess. **[1 mark]**

(c) The highest directly recorded temperature was 24.95 °C. Calculate the acid concentration obtained using this value and state the effect of omitting the correction. **[2 marks]**

(d) The initial and corrected temperatures each have uncertainty ±0.10 °C. Calculate the percentage uncertainty in the corrected ΔT. **[1 mark]**

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OCR A H432

Energetics I

Fully worked answers | OCR A-style marking guidance

SPECIFICATION-LED. CALCULATION-PRECISE. PRACTICAL-READY.

OCR A SPECIFICATION	3.2.1(a–e) + direct methods from (h) | enthalpy and calorimetry		
TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	10	5	1
24 QUESTIONS MARKED		164 MARKS EXPLAINED	

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OCR A MAP

How this pack matches the specification

The completed notes and OCR A H432 version 3.1 define the boundary

OCR A REF	WHAT IS ASSESSED	FREQUENT TRAP	QUESTIONS
3.2.1(a)	Exothermic and endothermic changes; energy flow; sign and relative enthalpy.	Confusing ΔT with ΔH, or saying only “lower”.	1, 6, 10, 13, 18–24
3.2.1(b–c)	Construct and interpret enthalpy profiles; activation energy.	Using time on the x-axis or measuring E_a from the baseline.	2, 9
3.2.1(d)	Standard conditions and states; $\Delta_r H°$; definitions of $\Delta_f H°$, $\Delta_c H°$ and $\Delta_{neut} H°$.	Losing the one-mole basis or using non-standard reactants.	3–5, 10, 14
3.2.1(e), (h); PAG3	q = mcΔT; direct cup and combustion calorimetry; correction, uncertainty and evaluation.	Wrong heated mass, wrong mole basis, or missing the reaction/solution sign change.	6–8, 11–24

BOUNDARY Hess cycles, indirect determinations and average bond-enthalpy calculations are reserved for Energetics II.

MARKING LOGIC A complete calculation identifies the heated mass, calculates q, establishes the correct reacting amount and then applies the sign and molar basis.

SECTION A

TEST IT ANSWERS

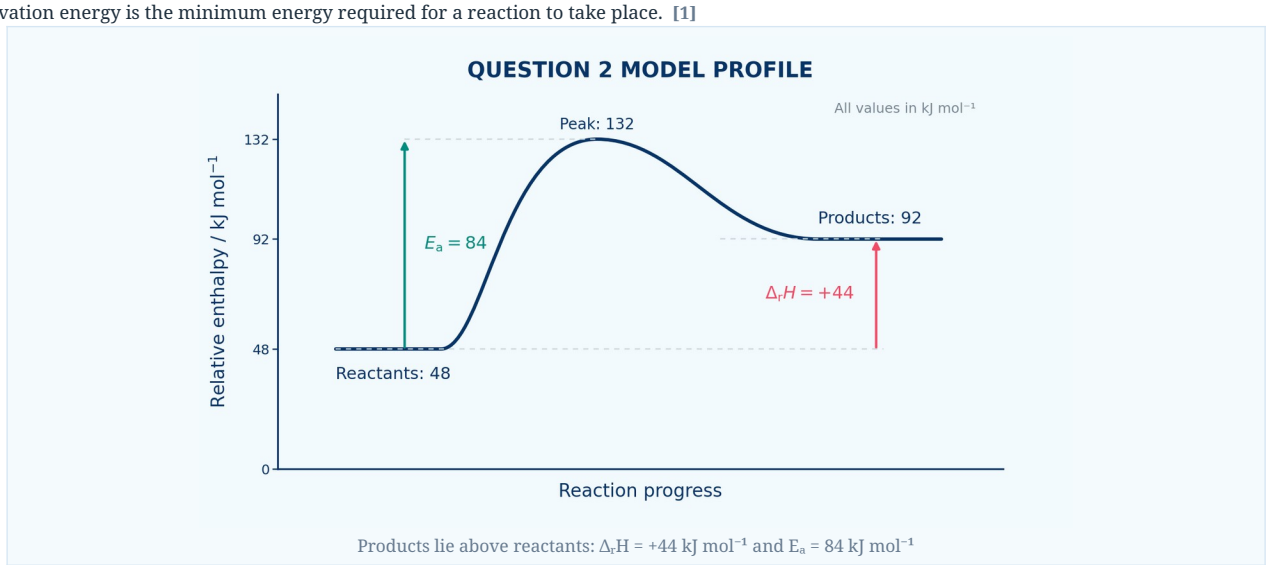
Exact terminology, correct arrows and disciplined calculation setup

QUESTION 1 | TEST IT ANSWER — 4 MARKS

Endothermic. [1]
ΔH is positive. [1]
The temperature of the surrounding water decreases. [1]
The products have a higher enthalpy than the reactants. [1]

QUESTION 2 | TEST IT ANSWER — 6 MARKS

ΔH = H(products) − H(reactants) = 92 − 48 = +44 kJ mol^{-1}. [1]
E_a(forward) = 132 − 48 = 84 kJ mol^{-1}. [1]
Activation energy is the minimum energy required for a reaction to take place. [1]



Products lie above reactants: $\Delta_r H$ = +44 kJ mol^{-1} and E_a = 84 kJ mol^{-1}

Axes labelled enthalpy and reaction progress. [1]
Product level above the reactant level; curve rises to a peak and falls to the products. [1]
ΔH runs from reactants to products; E_a runs from reactants to the peak. [1]

EXAMINER GUIDANCE Do not label the horizontal axis time. E_a is not measured from the axis baseline, and ΔH is not measured from the peak.

QUESTION 3 | TEST IT ANSWER — 5 MARKS

Standard pressure = 100 kPa. [1]
The temperature normally used for tabulated values = 298 K. [1]
Bromine: $Br_2(l)$. [1]
Carbon: C(s, graphite). [1]
Standard concentration = 1 mol dm^{-3}. [1]

QUESTION 4 | TEST IT ANSWER — 6 MARKS

(a) Standard enthalpy change of formation
The enthalpy change when one mole of a compound is formed from its constituent elements. [1]
All substances are in their standard states under standard conditions. [1]
(b) Standard enthalpy change of combustion
The enthalpy change when one mole of a substance is completely burned in oxygen. [1]
All substances are in their standard states under standard conditions. [1]
(c) Standard enthalpy change of neutralisation
The enthalpy change when an acid and an alkali react to form one mole of water. [1]
The reaction occurs under standard conditions. [1]

QUESTION 5 | TEST IT ANSWER — 5 MARKS

(a) $2Fe(s) + \frac{3}{2}O_2(g) \rightarrow Fe_2O_3(s)$
Correct species and coefficients form exactly one mole of Fe_2O_3. [1]
All state symbols are correct. [1]
(b) $C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$
Correct combustion products. [1]
Balanced for exactly one mole of butan-1-ol. [1]
All state symbols are correct. [1]

EXAMINER GUIDANCE Fractions are acceptable where chemically correct. Doubling the whole equation loses the required one-mole basis.

QUESTION 6 | TEST IT ANSWER — 4 MARKS

$\Delta T = 26.80 - 19.50 = 7.30$ K. [1]
$q(solution) = mc\Delta T = 82.0 \times 4.18 \times 7.30 = +2502$ J $= +2.50$ kJ. [2]
The reacting system loses 2.50 kJ, so its energy change is −2.50 kJ. [1]

QUESTION 7 | TEST IT ANSWER — 6 MARKS

Mass heated = 25.0 + 25.0 = 50.0 g. [1]
$q(solution) = 50.0 \times 4.18 \times 6.80 = 1421.2$ J. [1]
$n(HCl) = 0.0250 \times 1.00 = 0.0250$ mol. [1]
$n(NaOH) = 0.0250$ mol, so $n(H_2O) = 0.0250$ mol. [1]
$\Delta_{neut}H = -q/(1000n) = -1421.2 \div (1000 \times 0.0250)$. [1]
$\Delta_{neut}H = -56.8$ kJ mol^{-1}. [1]

EXAMINER GUIDANCE The denominator is the amount of water formed. The negative sign converts energy gained by the solution into energy released by the reaction.

QUESTION 8 | TEST IT ANSWER — 6 MARKS

Use 125.0 g, the mass of water heated, in $q = mc\Delta T$. [1]
Use 0.512 g, the mass of methanol burned, in $n = m/M$. [1]
$q(water) = 125.0 \times 4.18 \times 16.7 = 8725.75$ J. [1]
$n(CH_3OH) = 0.512 \div 32.0 = 0.0160$ mol. [1]
$\Delta cH = -8725.75 \div (1000 \times 0.0160)$. [1]
Experimental $\Delta cH = -545$ kJ mol^{-1}. [1]

EXAMINER GUIDANCE Keep the two masses separate: water mass belongs in q; fuel mass loss belongs in n.

SECTION B

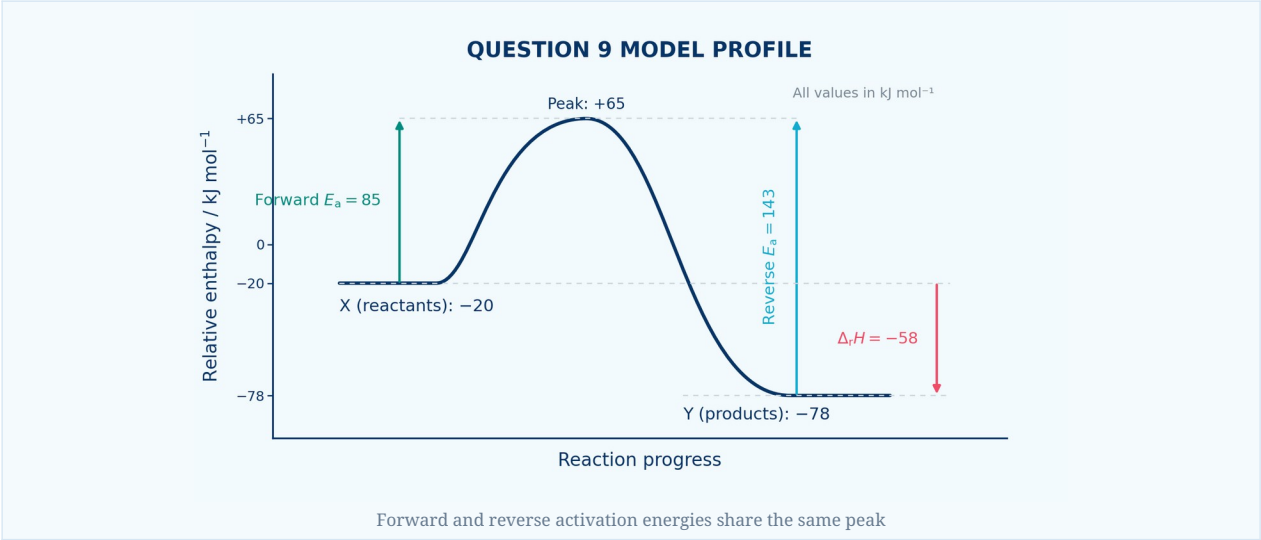
EXAM STYLE ANSWERS

Worked routes, precise one-mole bases and practical interpretation

QUESTION 9 | EXAM STYLE ANSWER

7 MARKS

$\Delta H(X \rightarrow Y) = -78 - (-20) = -58$ kJ mol^{-1}. [1]
E_a(forward) = 65 − (−20) = 85 kJ mol^{-1}. [1]
E_a(reverse) = 65 − (−78) = 143 kJ mol^{-1}. [1]



Forward and reverse activation energies share the same peak

Axes labelled correctly; Y lies below X. [2]
Pathway reaches the stated peak; all three arrows start and finish at the correct levels. [2]

QUESTION 10 | EXAM STYLE ANSWER

6 MARKS

For 1.00 mol of CO_2 formed: −566 ÷ 2 = −283 kJ. [1]
Reversing the equation changes the sign: $\Delta_r H^\circ = +566$ kJ mol^{-1}. [1]
CO is a compound, not an element. [1]
The reactants therefore are not all constituent elements in their standard states. [1]
$C(s, \text{graphite}) + O_2(g) \rightarrow CO_2(g)$
Equation forms exactly one mole of CO_2 from the elements. [1]
Correct standard states, including graphite. [1]

QUESTION 11 | EXAM STYLE ANSWER — 8 MARKS

$n(HNO_3) = 0.0400 \times 0.800 = 0.0320$ mol. [1]
$n(KOH) = 0.0300 \times 1.20 = 0.0360$ mol. [1]
HNO_3 is limiting, so $n(H_2O) = 0.0320$ mol. [1]
Total solution mass = 40.0 + 30.0 = 70.0 g. [1]
$q = 70.0 \times 4.18 \times 6.25 = 1828.75$ J. [1]
$\Delta_{neut}H = -1828.75 \div (1000 \times 0.0320)$. [1]
$\Delta_{neut}H = -57.1$ kJ mol^{-1}. [1]
The sign is negative because the solution gains energy released by the reaction. [1]

QUESTION 12 | EXAM STYLE ANSWER — 8 MARKS

$n(H_2SO_4) = 0.0250 \times 0.550 = 0.01375$ mol. [1]
$n(NaOH) = 0.0450 \times 0.500 = 0.0225$ mol. [1]
0.01375 mol H_2SO_4 would need 0.0275 mol NaOH, so NaOH is limiting. [1]
The NaOH:H_2O ratio is 1:1, so $n(H_2O) = 0.0225$ mol. [1]
Total solution mass = 70.0 g. [1]
$q = 70.0 \times 4.18 \times 4.40 = 1287.44$ J. [1]
$\Delta_{neut}H = -1287.44 \div (1000 \times 0.0225)$. [1]
$\Delta_{neut}H = -57.2$ kJ mol^{-1}. [1]

EXAMINER GUIDANCE Do not divide by the moles of sulfuric acid. Neutralisation enthalpy is per mole of water formed.

QUESTION 13 | EXAM STYLE ANSWER — 7 MARKS

Mass of the mixture = 80.0 + 4.25 = 84.25 g (84.3 g). [1]
$\Delta T = -4.60$ K. [1]
$q(solution) = 84.25 \times 4.18 \times (-4.60) = -1619.96$ J. [1]
$n(NH_4NO_3) = 4.25 \div 80.0 = 0.053125$ mol. [1]
The dissolving process gains +1619.96 J from the solution. [1]
Molar enthalpy = $+1619.96 \div (1000 \times 0.053125)$. [1]
Experimental molar enthalpy change = +30.5 kJ mol^{-1}. [1]

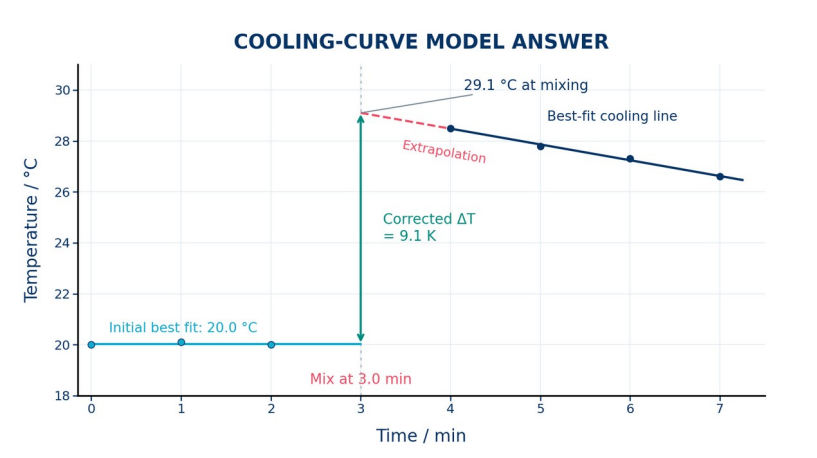
QUESTION 14 | EXAM STYLE ANSWER — 8 MARKS

$C_3H_7OH(l) + \frac{9}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$
Balanced for complete combustion of exactly one mole. [1]
All state symbols are correct. [1]
$\Delta T = 37.6 - 20.4 = 17.2$ K; $q = 175.0 \times 4.18 \times 17.2 = 12\,581.8$ J. [1]
n(fuel) = 0.444 ÷ 60.0 = 0.00740 mol. [1]
$\Delta cH = -12\,581.8 \div (1000 \times 0.00740) = -1.70 \times 10^3$ kJ mol^{-1}. [2]
Percentage difference = $|1700.24 - 2021| \div 2021 \times 100$. [1]
Percentage difference = 15.9%. [1]

EXAMINER GUIDANCE 84.1% is the proportion of the accepted magnitude recovered, not the percentage difference.

QUESTION 15 | EXAM STYLE ANSWER

6 MARKS



Accept a sensible straight best-fit line and a reading within ±0.2 °C of 29.1 °C

Straight best-fit line through the later cooling readings. [1]
Line extrapolated backwards to the 3.0 min mixing time. [1]
Corrected temperature at mixing ≈ 29.1 °C. [1]
Corrected ΔT = 29.1 − 20.0 = 9.1 K. [1]
Uncorrected ΔT = 28.5 − 20.0 = 8.5 K. [1]
Correction increases q, so an exothermic ΔH becomes more negative. [1]

QUESTION 16 | EXAM STYLE ANSWER

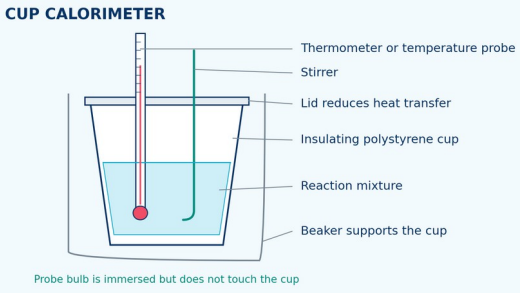
7 MARKS

Absolute uncertainty in ΔT = 0.10 + 0.10 = ±0.20 °C. [1]
% uncertainty in ΔT = 0.20 ÷ 5.60 × 100 = 3.57% (3.6%). [1]
Absolute uncertainty in mass loss = 0.01 + 0.01 = ±0.02 g. [1]
% uncertainty in mass loss = 0.02 ÷ 0.480 × 100 = 4.17% (4.2%). [1]
Maximum combined percentage uncertainty = 3.57 + 4.17. [1]
Maximum = 7.74% (7.7%). [1]
The mass-loss measurement contributes the larger percentage uncertainty. [1]

QUESTION 17 | EXAM STYLE ANSWER

7 MARKS

Measure known volumes and concentrations of acid and alkali. [1]
Allow both solutions to reach the same initial temperature and record it. [1]
Use a supported polystyrene cup and lid to reduce energy transfer. [1]
Add the second solution quickly, replace the lid and stir. [1]
Keep the probe immersed without touching the cup. [1]
Record temperature against time and obtain the maximum or cooling-corrected ΔT. [1]
Use total solution mass for q; find $n(H_2O)$ from the limiting reactant; calculate $\Delta_{neut}H = -q(J) \div [1000n(H_2O)]$. [1]



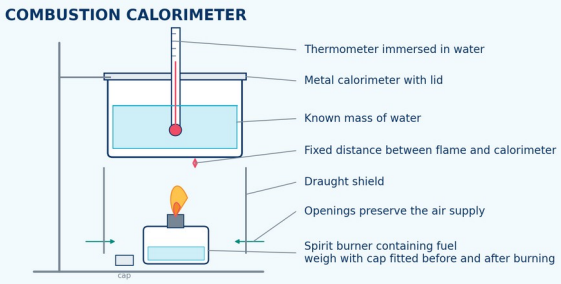
A suitable supported and covered cup calorimeter

QUESTION 18 | EXAM STYLE ANSWER

7 MARKS

Mass burned = 142.840 − 142.320 = 0.520 g. [1]
q = 100.0 × 4.18 × (31.0 − 18.0) = 5434 J. [1]
n(ethanol) = 0.520 ÷ 46.0 = 0.01130 mol. [1]
Experimental ΔcH = −5434 ÷ (1000 × 0.01130) = −481 kJ mol^{-1}. [1]
Example cause: energy is transferred to the apparatus or air. [1]
Measured ΔT and q are too small, so ΔcH is less negative. [1]
Repeats reveal random variation but do not remove a systematic heat-loss error. [1]

EXAMINER GUIDANCE Incomplete combustion is also acceptable only when the effect chain ends with a less-negative calculated value.



Correct combustion-calorimetry arrangement

SECTION C HARDER MIXED ANSWERS

Error correction, unfamiliar contexts and linked calculations

QUESTION 19 | HARDER MIXED ANSWER

8 MARKS

Any three errors: total mass should be 50.0 g; NaOH is limiting; n(H_2O) is 0.0240 mol; the sign must be negative. [3]
n(HCl) = 0.0200 × 1.50 = 0.0300 mol; n(NaOH) = 0.0300 × 0.800 = 0.0240 mol, so NaOH limits. [1]
n(H_2O) = 0.0240 mol. [1]
q = 50.0 × 4.18 × 6.50 = 1358.5 J. [1]
$\Delta_{neut}H$ = −1358.5 ÷ (1000 × 0.0240). [1]
Correct $\Delta_{neut}H$ = −56.6 kJ mol^{-1}. [1]

QUESTION 20 | HARDER MIXED ANSWER

8 MARKS

Run 1: ΔT = 6.75 K; q = 50.0 × 4.18 × 6.75 = 1410.75 J. [1]
Run 1: $\Delta_{neut}H$ = −1410.75 ÷ (1000 × 0.0250) = −56.43 kJ mol^{-1}. [1]
Run 2: ΔT = 6.80 K; q = 1421.2 J. [1]
Run 2: $\Delta_{neut}H$ = −56.848 kJ mol^{-1}. [1]
Mean = (−56.43 − 56.848) ÷ 2 = −56.6 kJ mol^{-1} to 3 s.f. [1]
Percentage difference = |56.639 − 57.3| ÷ 57.3 × 100 = 1.15%. [1]
The close results show good repeatability. [1]
The mean is close to the accepted value, so accuracy is also good within the assumptions. [1]

QUESTION 21 | HARDER MIXED ANSWER

8 MARKS

n($CaCl_2$) = 0.0350 × 0.800 = 0.0280 mol. [1]
n(Na_2CO_3) = 0.0500 × 0.500 = 0.0250 mol, so Na_2CO_3 is limiting. [1]
Total solution mass = 85.0 g. [1]
q = 85.0 × 4.18 × 2.85 = 1012.605 J. [1]
The 1:1 equation extent is 0.0250 mol; 0.0250 mol $CaCO_3$ forms. [1]
Δ_rH = −1012.605 ÷ (1000 × 0.0250). [1]
Δ_rH = −40.5 kJ mol^{-1} for the equation as written. [1]
The value is negative because the reacting system releases energy. [1]

QUESTION 22 | HARDER MIXED ANSWER

8 MARKS

Methanol

q = 200.0 × 4.18 × 18.0 = 15 048 J. [1]
n = 0.780 ÷ 32.0 = 0.024375 mol; ΔcH = −15 048 ÷ (1000 × 0.024375) = −617 kJ mol^{-1}. [1]

Ethanol

q = 200.0 × 4.18 × 23.5 = 19 646 J. [1]
n = 0.920 ÷ 46.0 = 0.0200 mol; ΔcH = −19 646 ÷ (1000 × 0.0200) = −982 kJ mol^{-1}. [1]
Ethanol has the more exothermic experimental molar value. [1]
ΔT alone is invalid because different amounts in moles were burned. [1]
Example limitation: energy escapes to the surroundings. [1]
q is too small, so both calculated ΔcH values are less negative. [1]

QUESTION 23 | HARDER MIXED ANSWER

9 MARKS

Cooling rate = (26.50 − 25.70) ÷ 120 = 0.006667 °C s^{-1}. [1]
Corrected T at 180 s = 26.50 + (60 × 0.006667) = 26.90 °C. [1]
Corrected ΔT = 26.90 − 20.00 = 6.90 K. [1]
q = 50.0 × 4.18 × 6.90 = 1442.1 J. [1]
n(H_2O) = 0.0250 mol. [1]
$\Delta_{neut}H$ = −1442.1 ÷ (1000 × 0.0250). [1]
$\Delta_{neut}H$ = −57.7 kJ mol^{-1}. [1]
$T_{180} = 1.5T_{240} − 0.5T_{360}$, so its maximum uncertainty is ±0.20 °C; adding the initial reading gives ±0.30 °C in ΔT. [1]
% uncertainty = 0.30 ÷ 6.90 × 100 = 4.35%. [1]

SECTION D — STRETCH / SYNOPTIC ANSWER

A complete route connecting correction, energy, stoichiometry and uncertainty

QUESTION 24 | STRETCH ANSWER

10 MARKS

Corrected ΔT = 25.65 − 19.40 = 6.25 K. [1]
q = 100.0 × 4.18 × 6.25 = 2612.5 J = 2.6125 kJ. [1]
n(H_2O) = 2.6125 ÷ 57.0 = 0.04583 mol. [2]
n(H_2SO_4) = 0.04583 ÷ 2 = 0.02292 mol. [1]
c(H_2SO_4) = 0.02292 ÷ 0.0400 = 0.573 mol dm^{-3}. [1]
n(NaOH) available = 0.0600 × 1.20 = 0.0720 mol; only 0.04583 mol is required, so NaOH is in excess. [1]

Without cooling correction

ΔT = 24.95 − 19.40 = 5.55 K; q = 2319.9 J; n(H_2O) = 0.04070 mol; c(H_2SO_4) = 0.509 mol dm^{-3}. [1]
Omitting the correction underestimates the concentration because heat loss makes ΔT and q too small. [1]
Uncertainty in ΔT = 0.10 + 0.10 = 0.20 °C; % uncertainty = 0.20 ÷ 6.25 × 100 = 3.20%. [1]

EXAMINER GUIDANCE Common losses: forgetting the per-mole-of-water basis; missing the 2:1 water:H_2SO_4 ratio; using only one solution volume for mass; or carrying the negative sign into a negative amount.

Checked calculation route

STEP	CHECKED WORKING
Temperature	ΔT = 25.65 − 19.40 = 6.25 K
Heat	q = 100.0 × 4.18 × 6.25 = 2612.5 J = 2.6125 kJ
Water formed	n(H_2O) = 2.6125 ÷ 57.0 = 0.04583 mol
Sulfuric acid	n(H_2SO_4) = 0.04583 ÷ 2 = 0.02292 mol
Concentration	c = 0.02292 ÷ 0.0400 = 0.573 mol dm^{-3}
Check	n(NaOH) = 1.20 × 0.0600 = 0.0720 mol; this exceeds the 0.04583 mol required.