Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	Bonds are breaking **AND** endothermic **OR** energy is required/needed ✓ **IGNORE** ‘overcome’ for ‘break’	1	**IGNORE** ‘more energy needed to break bonds than released in making bonds’ *Unclear whether response refers to bond breaking or overall enthalpy change* **Examiner’s Comments** Most candidates were aware that a bond enthalpy is a measure of the energy to break bonds. Most went on to link the positive sign to an endothermic reaction which requires energy. Some candidates linked bond enthalpies to bond formation instead. A significant number of responses described an endothermic reaction, instead of bond enthalpy, in terms of the energy required to break bonds being greater than the energy to make bonds. This was the answer to a different question and could not be given marks.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF bond enthalpy = (+)413 (kJ mol^{-1}) award 3 marks** --- *Energy for bonds made (3 × H−H + 1 × C=O)* **1 mark** 3 × 436 + 1 × 1077 **OR** 1308 + 1077 **OR 2385** (kJ)✓ **IGNORE** sign	3	**COMMON ERRORS** — **ECF for other numbers** **315.5 OR 316** → 2 marks — *Wrong sign for 195* Bonds made = 2385 ✓ -195 + 2385 - 928 = 1262 × 1262/4 = **315.5 OR 316** ✓ **ECF** **877** → 2 marks — *Wrong sign for 928*

			4C−H bond enthalpy correctly calculated **1 mark** 4 × C-H bond enthalpy = 195 + 2385 - (2 × O-H) = 195 + 2385 - 2 × 464 = 195 + 2385 - 928 **1652** (kJ mol^{-1}) ✓ **IGNORE** sign *C-H bond enthalpy correctly calculated* **1 mark** **This mark is **NOT** available from **TWO** previous errors **OR** from *ΔH* = 195 **not** being used ** C–H bond enthalpy = $\frac{1652}{4}$ = (+)**413** kJ mol^{-1} ✓ **For the final answer**, **DO NOT ALLOW** value with a negative sign --- - **COMMON ERRORS** **−413** → 2 marks *Wrong sign for answer* **304** → 2 marks *2 mol of H_2 instead of 3 mol:* 2 × 436 + 1 × 1077 = 872 + 1077 = 1949 × 195 + 1949 − 928 = 1216 ECF ✓ 1216/4 = **304** ECF ✓		Bonds made = 2385 ✓ 195 + 2385 + 928 = 3508 × 3508/4 = **877** ✓ **ECF** **364** → 1 mark *Missing ΔH, (195)* *Potentially 2 errors: missing 195 and sign for 195* Bonds made = 2385 ✓ 2385 - 928 = 1457 × 1457/4 = 364/ 364.3 /364.25 × **NO ECF** **779.5 OR 780** → 1 mark *Wrong sign for 928 **AND** 195* Bonds made = 2385 ✓ -195 + 2385 + 928 = 3118 × 3118/4 = **779.5** × **NO ECF** **529** → 2 marks *1 O-H instead of 2 O-H:* Bonds made = 2385 ✓ 195 + 2385 - 464 = 2116 × 2116/4 = **529** ✓ **ECF** **181** → 2 marks *4 O-H instead of 2 O-H:*

					Bonds made = 2385 ✓ 195 + 2385 - 1856 = 724 × 724/4 = **181** ✓ **ECF** **Examiner's Comments** This question differentiated well, with about half the candidates obtaining the correct bond enthalpy of +413 kJ mol^{-1}. With ECF, few candidates scored 0 marks. Most candidates calculated the energy involved in making 3 H-H bonds and 1 C≡O bond as 2385 kJ mol^{-1}. This value had to be incorporated with the energy associated with breaking bonds and the enthalpy change of -195 kJ mol^{-1}. It was this step where problems arose. There were many errors with signs and the lowest attaining candidates sometimes omitted the enthalpy change completely in their calculation. The commonest error of 315.5 kJ mol^{-1} was the result of using the wrong sign for the enthalpy change. With ECF, this was still given 2 of the 3 available marks.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF energy released = 7.15 × 10^5 kJ, award 2 marks** --- $n(H_2) = \frac{60.0 \times 10^3}{24.0} = \mathbf{2500}$ (mol) ✓ Energy released = 2500 × 285.8 = **7.15 × 10^5** kJ ✓ **3SF AND standard form** required **IGNORE** sign i.e. **ALLOW + OR - OR** no sign	2	**ALLOW ECF ONLY** from incorrect $n(H_2)$ based on with incorrect unit conversion from m^3 e.g. $n(H_2) = \frac{60.0 \times 10^2}{24.0} = 250$ (mol) × 250 × 285.8 = 7.15 × 10^4 kJ ECF ✓ So **ALLOW** 1 mark for: ±7.15 × 10^x (unit conversion) 7.145 × 10^5 *(not 3SF)* 715000 *(not standard form)* ---

					---------------------- **ALLOW** use of ideal gas equation with a sensible temperature (290-298K) and pressure (100/101/101325 kPa) e.g. e.g. At 293K and 100 kPa, $n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 293} = 2463...$ (mol) → 2463 × 285.8 = **7.04 × 10^5** kJ e.g. At 298K and 100 kPa, $n(H_2) = \frac{100 \times 10^3 \times 60.0}{8.314 \times 298} = 2421.7...$ (mol) → 2421.7 × 285.8 = **6.92 × 10^5** kJ **ALLOW** use of 8.31 for *R* (same answers) 293K → 2464.24 × 285.8 = **7.04 × 10^5** kJ 298K → 2422.89 × 285.8 = **6.92 × 10^5 kJ** **Examiner's Comments** Unlike the standard bond enthalpy calculation in Question 2 (a) (ii), this question required candidates to apply their understanding of enthalpy changes to a new context relevant to energy. Candidates also had to interconvert units and provide an answer to 3 significant figures in standard form. Apart from the chemistry, there were various mathematical skills to use. Candidates found this question much more demanding than Question 2 (a) (ii), with only just over a half gaining marks. The first step involved working out that the number of moles of hydrogen gas in 60 m^3 at RTP is 2500 mol. Candidates then had to apply their understanding of $\Delta_f H$ to calculate the energy as 7.15 × 10^5 kJ.

					Common mistakes included: • multiplying 60 m^3 by the enthalpy change of 285.8 kJ mol^{-1} (omitting to calculate the moles of H_2 - a lack of understanding) • using more than 3 significant figures, e.g. 7.145 instead of 7.15 • making an error with powers of 10 in the mole calculation (usuallysually by not converting 60 m^3 into 60,000 dm^3, leading to 2.5 moles). This type of question looks simple but makes for an excellent way of developing application and mathematical skills.
			Total	**6**	
2			**FIRST, CHECK THE ANSWER ON ANSWER LINE IF bond enthalpy = (+)391 (kJ mol^{-1}) award 3 marks** **ALLOW ECF Throughout** **FULL ANNOTATIONS MUST BE USED** **Energy for bonds made (N≡N + 4 × O−H)** = 945 + 4 × 464 **OR** 945 + 1856 **OR 2801** ✓ **IGNORE** sign **4 N–H bond enthalpy correctly calculated** 4 × N−H = 2801 − 581−158 −498 = **1564** ✓ **N-H bond enthalpy**	3	**COMMON ERRORS (allow rounding down to whole number)** **−391** → **2 marks** *Wrong sign for N–H bond enthalpy* **159** → **2 marks** *2 × O-H instead of 4 × O-H* 945 + 2 × 464 = 1873 × 1873 − 581 − 158 − 498 = 636 ✓ Then 636/4 = **159** ✓ **681.5** → **2 marks** *Wrong sign for −581* 945 + 4 × 464 = 2801 ✓ 2801 − −581 − 158 − 498 = 2726 ✓ Then 2726/4 = **681.5** ×

			ONLY ALLOW from use of at least 4 Δ*H* values $\text{N–H bond enthalpy} = \frac{1564}{4} = (+)\mathbf{391}\ \text{kJ mol}^{-1}$ ✓ -- **ALLOW ECF throughout, where calculation shown** **See common errors** For other answer, work on: x = Energy for bonds made (N≡N + 4 × O−H) 4 N−H = x − 1237 **OR** x − 581 − 158 − 498 656 $\text{N–H} = \frac{x-1237}{4}$ **233.75 → 1 mark** *158 instead of 945 and 158 omitted from N_2H_4* 158 + 4 × 464 = 2014 ✗ 2014 − 581 − 0 − 498 = 935 ✗ Then 935/4 = **233.75** ✓ **155.83 → 0 marks** *As above but ÷6 instead of ÷4* Then 935/6 = **155.83** ✗ **194.25 → 2 marks** *158 instead of 945* 158 + 4 × 464 = 2014 ✗ 2014 − 581 − 158 − 498 = 777 ✓		**536.25 → 2 marks** (Δ*H, −581* omitted) 945 + 4 × 464 = 2801 ✓ 2801 − 0 − 158 − 498 = 2145 ✗ Then 2145/4 = **536.25** ✓ **445.25 → 2 marks** *945 omitted* 0 + (4 × 464) = 1856 ✗ 1856 − 581 − 158 − 498 = 619 ✓ Then 619/4 = **154.75** ✓ **194.25 → 2 marks** *158 instead of 945* 158 + (4 × 464) = 2014 ✗ 2014 − 581 − 158 − 498 = 777 ✓ 777/4 = **194.25** ✓ **−37.75 → 2 marks** *158 used instead of 945 and 2 × O−H* 158 + (2 × 464) = 1086 ✗ 1086 − 581 − 158 − 498 = −151 ✓ −151/4 = **−37.75** ✓ **−1009.5 → 2 marks** *Wrong sign for 2801*

			Then 777/4 = **194.25** ✓ **129.5 → 1 mark** *As above but ÷6 instead of ÷4* Then 777/6 = **129.5** × **484.75 → 2 marks** *158 instead of 945. Then wrong sign for −581* 158 + (4 × 464) = 2014 × 2014 − − 581 − 158 − 498 = 1939 ✓ Then 1939/4 = **484.75** ✓ **721 → 2 marks** *−158 omitted and wrong signs for 581 and 498* 945 + (4 × 464) = 2801 ✓ 2801 - −581 − 0 − −498 = 2884 × Then 2884/4 = **721** ✓		945 + 4 × 464 = 945 + 928 = 2801 ✓ −2801 − 581 − 158 − 498 = −4035 × Then −4035/4 = **- 1009.5** ✓ **430.5 → 2 marks** (−*158* omitted) 945 + (4 × 464) = 2801 ✓ 2801 − 581 − 0 − 498 = 1722 × 1722/4 = **430.5** ✓ **536.25 → 2 marks** (Δ*H*, *−581* omitted) 945 + 4 × 464 = 945 + 928 = 2801 ✓ 2801 − 0 − 158 − 498 = 2145 × Then 2145/4 = **536.25** ✓ **719 → 2 marks** *Wrong signs for 158 and 498* 945 + 4 × 464 = 945 + 928 = 2801 ✓ 2801 − 581 + 158 + 498 = 2876 × Then 2876/4 = **719** ✓ **449.5 → 1 mark** *Wrong sign for -581 and 2 × O−H* 945 + 2 × 464 = 945 + 928 = 1873 ×	

					1873 − −581 − 158 − 498 = 1798 × Then 1798/4 = **449.5** ✓ **489** → **1 mark** 2 × *O−H instead of 4 × O−H* *Wrong sign for −581 and −158 omitted* 945 + 2 × 464 = 945 + 928 = 1873 × 1873 − −581 − 0 − 498 = 1956 × Then 1946/4 = **489** ✓ **43** → **2 marks** *No 4 × O−H* 945 + 1 × 464 = 1409 × 1409 − 581 − 158 − 498 = 172 ✓ Then 172/4 = **43** ✓ **Examiner's Comments** This bond energy calculation contained more values than in recent papers and many candidates found analysing the data difficult. Despite this, the question discriminated extremely well with about half the candidates obtaining the correct enthalpy change of 391 kJ mol^{-1} for all 3 marks, despite an incorrect final response. Successful responses showed that some candidates had clearly practised this type of problem and they recognised that there were going to be three stages to the calculation: • use of 945 and 4' −464 to obtain 2801

					• correct incorporation of the other ΔH values to obtain 1564 for 4 N−H • division by 4 for 1 N−H bond to obtain 391 kJ mol^{-1} As with all multi-stage calculations, error carried forward was applied, allowing credit to be given for a correct method. The commonest errors were: • use of 2 O−H instead of 4 O−H in the 1st step. • use of 158 for N−N in the 1st step instead of 945 for N≡N (Did these candidates not recall that N_2 has a triple bond?) • omission of some data for the second step.
			Total	**3**	
3			**C**	1	**<u>Examiner's Comments</u>** This question was answered well with most candidates correctly selecting C.
			Total	**1**	
4			**A**	1	**<u>Examiner's Comments</u>** Most candidates were aware that heat increases the number of molecules that have energy greater than the activation energy (A).
			Total	**1**	
5		i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF answer = 0.455 award 4 marks** **AND** IF units = $atm^{1/2}$ award 5 marks ---	5	**IF** there is an alternative answer, check for any **ECF** credit possible using working below. --

Equilibrium moles ✓
N SO_3 = 1.35 , *n* O_2 = 0.45(0) **AND** *n* total = 2.7(0)

Partial pressures ✓

$p(SO_3)$	$\frac{1.35}{2.7(0)} \times 2.80$ **OR** 1.4(0)
$p(SO_2)$	$\frac{0.900}{2.7(0)} \times 2.80$ **OR** 0.933
$p(O_2)$	$\frac{0.450}{2.7(0)} \times 2.80$ **OR** 0.467

$(K_p) = \frac{p(SO_2)\ p(O_2)^{1/2}}{p(SO_3)}$
OR $(K_p =) \frac{(0.933) \times (0.467)^{1/2}}{(1.40)}$ ✓ ✓

Answer to 3 SF
K_p= 0.455 ✓

Units
Substitution of units into correct K_p expression
$\frac{atm^1 \times atm^{1/2}}{atm^1} = atm^{½}$ ✓ ✓

ALLOW 3SF or more unless there is a trailing zero
e.g. **ALLOW** $p(SO_3)$ = 1.4, n total =2.7

ALLOW all marks to be awarded if atmospheres are converted into other pressure units e.g. to kPa.

ALLOW use of fractions for intermediate working

ALLOW $(K_p) = \frac{p(SO_2)\ p^{1/2}(O_2)}{p(SO_3)}$
ALLOW
$K_p^2 = \frac{p(SO_2)^2 \times p(O_2)}{p(SO_3)^2}$

IGNORE [ ] (we are just looking for the calculation)

ALLOW ECF for units of an incorrect K_p expression

ALLOW $atm^{0.5}$

DO NOT ALLOW $\sqrt{atm}$

Common errors
4 marks
(3 marks for calculation + unit mark)

0.207 (from expression $\frac{p(SO_2)^2 \times p(O_2)}{p(SO_3)^2}$) Unit: atm
2.20 (from inverted expression) Unit: $atm^{-1/2}$

Examiner's Comments

Candidates tend to find Kp calculations difficult and so a strategy to work their way through them could include:

- Write the Kp expression using the molar ratio given in the question. Care should be taken not to change the molar ratio to help an easier calculation. Square brackets should not be used as these represent concentration.
- Calculation of initial moles present, with careful consideration of the use of appropriate significant figures
- Calculation of the change in moles present

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- Deduction of the number of moles present at equilibrium
- Determination of total moles present at equilibrium

These steps are often best completed as RICE tables (Ratio, Initial, Change, Equilibrium) and should look to use the appropriate amount of significant figures to avoid having a rounding error in the final answer.

? **Misconception**

K_p values are for the equation as stated. Candidates should recognise that changing the stoichiometry of the equation changes the K_p value.

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<tr><td></td><td></td><td>ii</td><td>

ΔH is +ve / endothermic (in forward direction).
AND
(At higher temperature,) equilibrium shifts to right hand side ✓

(T_2) has greater K_p value
OR $7.7 \times 10^{-2} > 3.3 \times 10^{-5}$ ✓

</td><td>2</td><td>

ORA throughout

ALLOW towards the products for right hand side
ALLOW increases yield of products

DO NOT ALLOW T_1 has greater K_p value

Examiner's Comments

Candidates performed well with this question and many stated that K_p would increase. Some identified the forward reaction as endothermic but did not link this to equilibrium being shifted to the right, thus increasing the ratio within the K_p expression. A few candidates sought to incorrectly explain the effect by using Le Chatelier effect on pressure.

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<tr><td></td><td></td><td>iii</td><td>

One mark per correct row ✓ ✓

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<tr><th>Change</th><th>Decrease</th><th>No change</th><th>Increase</th></tr>
<tr><td>No catalyst</td><td></td><td>✓</td><td></td></tr>
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</td><td>2</td><td>

Examiner's Comments

This proved a challenging question where candidates did not stick to the principle that K_p (or K_a) values only change due to temperature changes.

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<tr><td></td><td></td><td></td><td>Total</td><td>9</td><td></td></tr>
<tr><td>6</td><td></td><td></td><td>Complete circuit AND voltmeter AND labelled salt bridge linking two half-cells ✓

Pt AND Fe^{2+} AND Fe^{3+} ✓

Pt AND H_2 AND H^+ AND delivery system for H_2 gas ✓

Standard conditions
1 mol dm^{-3}
AND
Temperature: 298 K / 25 °C
AND
Pressure: 1 atm / 100 kPa/101 kPa ✓</td><td>4</td><td>Electrodes / salt bridge must at least touch the surface of solutions
ALLOW small gaps in circuit wires

ALLOW half-cells drawn on either side

ALLOW a formula of a strong acid for H^+

<u>For standard conditions:</u>

Can be awarded if all quoted on standard condition line or in labelled diagram.

ALLOW 1M

ALLOW equimolar solutions for Fe^{2+} AND Fe^{3+} only. i.e. need 1 mol dm^{-3} for $[H^+]$

IGNORE H_2SO_4 in diagram unless concentration is stated with a value other than 0.5 $moldm^{-3}$

DO NOT ALLOW if any concentration is incorrect

<u>Examiner's Comments</u>

Successful candidates drew a complete circuit and voltmeter with the labelled salt bridge dipped into the two solutions. Both cells had Pt as the electrodes. One cell contained 1 $moldm^{-3}$ Fe^{2+} and Fe^{3+} where the other had a delivery mechanism for H_2 (at 1 atm) and H^+ (at 1 mol dm-3). Standard temperature of 298K (or 25°C) was stated.

Common errors included: not have solutions in the beakers, used Fe or Fe^{2+} electrodes, the hydrogen cell was missing and/or the H_2 with a device for adding it. A few candidates</td></tr>
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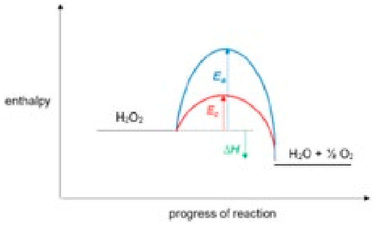
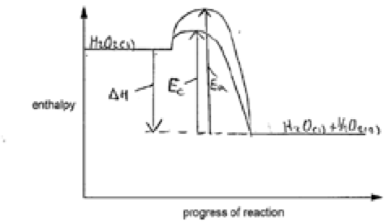
					suggested two cells with only Fe^{2+} one side and only Fe^{3+} on the other.
			Total	**4**	
7			**A**	1	**ALLOW** −56 (correct numerical answer) **Examiner's Comments** The correct answer was A. Some candidates showed full working in the space provided. B and C were common errors. Those who selected C did not take into account the need to half the reaction's enthalpy change to meet the definition requirements of one mole of water.
			Total	**1**	
8			**B**	1	**Examiner's Comments** The correct answer was B. Candidates had a good knowledge of the Boltzmann distribution and few incorrect responses were seen.
			Total	**1**	
9			**C**	1	**Examiner's Comments** The correct answer was C. Most candidates chose the correct answer but a few selected A. The position of the element is based on its atomic number.
			Total	**1**	
10	a	i	**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = −117 kJ mol^{-1}, award 4 marks.** -- $\Delta H = -286 - (-188)$ $= -98$ kJ mol^{-1} ✓	4	**ALLOW ECF** throughout **ALLOW** −98000 − (298 × 62.5) **Common Errors for Δ*G*** ***3 marks*** *−18700 (ΔS not converted to kJ)* −493 ($\Delta H = -286 + (-188) = -474$) *−147 (ΔS = 165: not halving 205)* *− 99.6 (T not converted to K)* *−18.7 (ΔH not converted J but ΔS J*

			ΔS = 70 + ½(205) − 110 = 62.5 (J K^{-1} mol^{-1}) or 0.0625 (kJ K^{-1} mol^{-1}) ✓ ΔG = $\Delta H - T\Delta S$ = −98 − (298 × 0.0625) ✓ ΔG = −117 kJ mol^{-1} **(3SF)** ✓		K^{-1} mol^{-1}) (+)79.4 (−188 − (−286) = +98) ***2 marks*** *(+) 117 (incorrect signs for ΔH and ΔS)* ***Final Answer MUST BE 3 SF*** **Examiner's Comments** Almost all candidates had a good attempt at this calculation, with many gaining full marks. Most were able to calculate the entropy change. Almost all could reproduce the equation for free energy. Of those who did not get the correct final answer, the most common error was not converting the entropy value into kJ and / or the temperature to K. There were a few candidates who did not manipulate the equation correctly. A few candidates incorrectly calculated ΔS, obtaining the value of 165 J K^{-1} mol^{-1} or ΔH, obtaining -474 kJ mol^{-1}. Candidates were given ECF in these cases.
		ii	(Rate of reaction) slow **OR** Activation energy high ✓	1	**ALLOW** Δ*G* takes no account of rate of reaction **ALLOW** molecules do not have sufficient energy to equal or exceed the activation energy. **IGNORE** molecules do not have sufficient energy to react. **DO NOT ALLOW** there is not enough activation energy **Examiner's Comments** Lots of good answers from candidates were seen for this question. A few candidates attempted the explanation via a ΔG / ΔS argument and misinterpreted the comment within the question.
	b	i		3	**Care** enthalpy profile must match Δ*H* **sign** in16 a) i) – check calculation **ALLOW** endothermic profile as **ECF** from + Δ*H* calculated in 16 a) i) for all

			 H_2O_2 on LHS **AND** H_2O + ½ O_2 on RHS **AND** **Δ*H*** labelled with product line below reactant line **AND** Arrow downwards ✓ ***E*** E_a correctly labelled ✓ E_c correctly labelled with $E_c < E_a$ ✓		three marks State symbols not required **Δ*H* DO NOT ALLOW −**Δ*H* **DO NOT ALLOW** double headed arrow on Δ*H* **ALLOW** Δ*H* arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line. **E_a and E_c** **ALLOW** no arrowhead or arrowheads at both end of E_a or E_c lines E_a or E_c lines must reach maximum (**or near to maximum**) on curve **ALLOW** overlapping lines **OR** lines on side reaching maximum For E_a, **ALLOW** AE **OR** A_E **OR** Eact **OR** suitable alternatives **ALLOW ECF** marks for **E_a and E_c** for correctly labelled endothermic diagram from a −Δ*H* value (from16 a) i)) **Examiner's Comments** This question proved more difficult for candidates with lots of inaccuracies. The profile was dependent on the calculation for ΔH in Question 16 (a)(i). The arrowhead for ΔH needs to be pointing from the reactants to the products. The activation energies, again, need to start at the reactant line and go to the maximum level of the curve. Those that needed to draw an endothermic profile were far more likely to make an error with the E_a and E_c arrows, often starting from the product line or even from the base line of the graph. A significant number of candidates did not add arrows and instead labelled the curves E_a and E_c. Some candidates drew a Boltzmann distribution curve scoring 0 marks.

					Exemplar 1  The candidate has the correct exothermic profile but has the incorrect starting point for the activation energy going from the product line.
		ii	(MnO_2) is in different phase/state (to the reactant / H_2O_2) **OR** catalyst is a solid **AND** reactant is liquid ✓	1	**ASSUME** 'it' is MnO_2 **ALLOW** 'species in the reaction' **IGNORE** references to products **Examiner's Comments** This was a well answered question. A few candidates, incorrectly, suggested that it was heterogeneous due to the reactants and products being in different states, and did not mention the catalyst.
		iii	Mn is +2 **AND** +3 **OR** Mn is +1 **AND** +6 ✓	1	+ required **ALLOW** 2+ and 3+ **DO NOT ALLOW** Mn^{2+} Mn^{3+} **DO NOT ALLOW** + 4 (this is the oxidation state in MnO_2) **Examiner's Comments** This question proved more challenging for candidates. Candidates stating +4 was the most common error; this is the oxidation state in MnO_2. Some candidates stated fractions, negative values and gave the state symbol instead i.e. solid and liquid.
			Total	**10**	
11			**C**	1	

					Examiner's Comments The correct answer was C. This question was answered well, alongside Q2. Candidates should aim to separate explanations regarding chemical and physical properties. B was a common wrong answer and a few candidates suggested that the covalent bonds need to be broken, selecting A.
			Total	**1**	
12	a		(The enthalpy change) for the stated equation ✓	1	**ALLOW** reaction in molar quantities/stoichiometric ratio as shown/stated/given/in equation **IGNORE** standard states or conditions **DO NOT ALLOW** Energy released (can't assume reaction is exothermic) **Examiner's Comments** The term was not well known, with only a small proportion of candidates scoring this mark. Many gave the definition for enthalpy change of combustion or formation or bond enthalpy. Many referred to one mole of either reactants or products or bonds, or sometimes a combination of these. Lower-attaining candidates often said it was the temperature change.
	b		**Level 3 (5-6 marks)** Calculates **CORRECT** enthalpy change **AND** states **multiple** assumptions **AND** improvements *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculates **CORRECT** enthalpy change **OR** Correctly calculates the moles **AND**	1	**Indicative Scientific Points** **Energy change from $mc\Delta T$** Energy in J **OR** kJ $q = 100.0 \times 4.18 \times 18.6 = 7774.8$(J) **OR** 7.7748 (kJ) **ΔH in kJ mol^{-1}** $n(Cu(NO_3)_2) = 0.05$ (mol) $\Delta H = -q/n = 7.7748/0.05 = -155$ kJ mol^{-1} (3 SF) **ALLOW** -156 kJ mol^{-1} (use of 7.775 kJ) **ALLOW** answer in J mol^{-1} if units are given **ALLOW** a single slip/rounding errors **Assumptions and Improvements**

			attempts the calculation of q **AND** states **multiple** assumptions **OR** improvements. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence*. **Level 1 (1-2 marks)** Attempts any part of the calculation **AND** states **an** assumption **OR an** improvement. **OR** Correctly calculates the moles **AND** attempts calculation of q **OR** States **multiple** assumptions **OR** improvements *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **0 marks** *No response or no response worthy of credit.*		**(NOT INCLUSIVE)** ***Assumptions*** • density of solution is 1 g cm^{-3}/same as water • *c* of solution is same as water • ignore the mass and *c* of zinc • no heat escapes the system/lost to surroundings • mass of solution remains constant • no water lost/evaporated • reaction goes to completion • reaction completed under standard conditions • measurements recorded are accurate ***Improvements*** • polystyrene cup /thermos flask • use a lid • more precise thermometer • more precise balance • measure mass of solution • use burette to measure volume • use a cooling curve • use standard conditions Aspects of the communication statement might typically have been met when calculations have been completed in a logical order, and for L3 or L2 (where level awarded for calculation only) the use of the correct sign with the final answer given to 3 or 4 significant figures. **Examiner's Comments** The calculation of enthalpy change was generally well-answered and the majority of candidates were able to recall the equation $q = mc\Delta T$. Many candidates forgot the minus sign or gave a positive sign for final enthalpy change. Errors in calculation were most commonly for using an incorrect mass, usually by finding the mass of copper(II) nitrate (from moles and M_r). Some also used the wrong value for the heat capacity, selecting the value

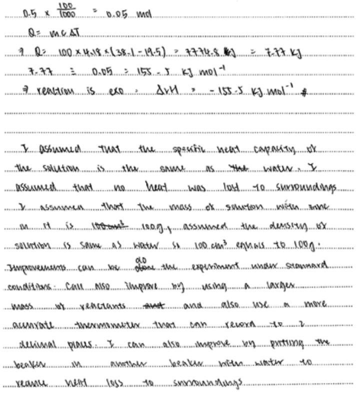
for R from the data sheet instead. Many gave the final answer to an inappropriate six significant figures.

Candidates often found it challenging to give appropriate assumptions and improvements, limiting the level achieved to Level 2.

However, many candidates did correctly give the assumptions that the specific heat capacity and density of the solution was the same as water. This is usually stated for the candidates with these types of questions. The most common improvements suggested were use of a polystyrene cup, adding a lid or using a thermometer with a higher resolution. Quite a few candidates suggested using a larger volume of solution which would indeed reduce the % uncertainty in the volume measurement. However, it would lead to a smaller temperature change, increasing the % uncertainty in the temperature measurement.

Some confused the question with a calculation of enthalpy change of combustion and gave improvements accordingly, e.g. ‘use a copper or bomb calorimeter’, ‘draft shields’, ‘heat for longer’, ‘position of flame and supplies of oxygen’.

Exemplar 2



$0.5 \times \frac{100}{1000} = 0.05$ mol
$Q = mc\Delta T$
∴ $Q = 100 \times 4.18 \times (38.1 - 19.5) = 7774.8$ [illegible] $= 7.77$ kJ
$7.77 \div 0.05 = 155.5$ kJ mol^{-1}
∴ reaction is exo ∴ $\Delta_r H = -155.5$ kJ mol^{-1} #

I assumed that the specific heat capacity of
the solution is the same as ~~the~~ water. I
assumed that no heat was lost to surroundings
I assumed that the mass of solution with zinc
in it is ~~100cm³~~ 100g, I assumed the density of
solution is same as water so 100 cm³ equals to 100g.
Improvements can be do ~~done~~ the experiment under standard
conditions. Can also improve by using a larger
mass of reactants ~~and~~ and also use a more
accurate thermometer that can record to 2
decimal places. I can also improve by putting the
beaker in another beaker with water to
reduce heat loss to surroundings

This response achieved Level 3 - 6 marks. There is a correct calculation for ΔH, the final value has a correct negative sign and is given to 4 significant figures. Lots of valid

					assumptions and improvements are given.
	c		Half the energy/q **OR** volume/mass of solution **AND** half the moles ✓ Temperature change would be same✓	2	**ALLOW** response that links the same proportionality/ratio of energy/volume/mass of solution to number of moles **ALLOW** same amount of energy (released) per mole **ALLOW both marks** if seen by a calculation i.e. q = 50.0 x 4.18 x 18.6 = 3887.4(J) **OR** 3.8874(kJ) $n(Cu(NO_3)_2)$= 0.025 (mol) ΔH = (–) q/n = 3.8874/0.025 = (–)155 kJ mol^{-1}✓ Use of same temperature✓ May need to check answer in 3b to compare **IGNORE** Sign **Examiner's Comments** There was a lot of misunderstanding associated with this question, with many candidates failing to score any marks. Many said that nothing would change as the concentration was still the same or because the same bonds were being broken and formed. Under a quarter of students scored 1 mark, usually for making the link between the drop in volume to a change in the q and n values. A few did state that the temperature didn't change. Only a small proportion scored both marks, usually by showing by calculation that the temperature change was the same, moles was half and energy was half. Some did believe that the temperature changed, either that it decreased as less reacted or increased as there was less volume to heat. A wide variety of alternative responses were given including: 'Enthalpy change the same regardless of mass used'

					‘Number of moles doesn’t impact energy required as it is the same bonds breaking’ ‘Energy to break and form bonds will still be the same with any volume’ ‘Amount of energy required to make the new bond would be the same’ ‘Only concentration has an effect on bond enthalpy values not volume’ ‘Decrease in volume increases concentration’ ‘$Cu(NO_3)_2$ would still run out first so enthalpy change is the same’ ‘Zn is in excess so it doesn’t matter how much volume we use because Zn and $Cu(NO_3)_2$ still 1:1 ratio.’ ‘Mole ratio is still the same’ or ‘same molar ratio’ wasn’t enough.
			Total	**9**	
13		i	Rubidium chlorate(**VII**) ✓	1 (AO 1.1)	**ALLOW** Rubidium(I) chlorate(VII) Rubidium chloroate(VII) **IGNORE** Rubidium (VII)chlorate Rubidium chlorate(IIV) Rubidium chlorate (7) Rubidium perchlorate **<u>Examiner’s Comments</u>** Candidates had difficulty in naming a compound using Roman numerals for an element which can have different oxidation numbers. For the name of $RbClO_4$, many omitted the number entirely, showing just rubidium chlorate. Many inventive names such as rubidium chlorotetraoxide were seen. Some candidates wrote the correct VII before chlorate and many different Roman oxidation numbers were seen. Roman numerals’ use in naming compounds is part of chemical

					nomenclature, included in the specification.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 54.0 OR 54.1 OR 54.2 (kJ mol^{-1}) award 3 marks** -- **Energy change from mcΔT** Energy in J **OR** kJ = 102 × 4.18 × 1.5 **OR** 639.54 (J) **OR** 0.63954 (kJ) ✓ -- **Amount in mol of RbClO$_3$** $n(\text{RbClO}_3) = \frac{2.00}{169}$ **OR** 0.0118…….. (mol) ✓ -- **Δ$_{\text{sol}}$*H*(RbClO$_3$)** $= \frac{0.63954}{0.0118.....} =$ (+) **54.0** ✓ *From unrounded values, ΔH = 54.04113* *Examples of mixed acceptable intermediate rounding, e.g.* $\frac{0.640}{0.0118}$ *ΔH = 54.237 → 54.2* $\frac{0.63954}{0.01183}$ *ΔH = 54.06 → 54.1*	3 (AO 2.8 ×3)	**ALLOW ECF throughout** **IGNORE** sign **IGNORE RE and SF in 1st 2 marks** 0.01183431953 unrounded **ALLOW** 54 (from 54.0) **CARE 54.00 is a rounding error** -- **COMMON ERRORS** **52.98 OR 53.14 2 marks** 100 instead of 102: Energy = 100 × 4.18 × 1.5 = 627 J From unrounded *n*, Δ*H* = $\frac{0.627}{0.0118.....}$ = **52.98** kJ mol^{-1} **OR** 53.0 (3SF) **OR** 53 From rounded 0.0118, Δ*H* = $\frac{0.627}{0.0118}$ = 53.14 **OR** 53.1 -- **0.02078 OR 0.0208 1 mark** 102 and 2 swapped: Energy = 2 × 4.18 × 1.5 = 12.54 J *n* = $\frac{102}{169}$ = 0.60355…… **ECF** Δ*H* = $\frac{0.01254}{0.60355.....}$ = **0.0208** kJ mol^{-1} ---------------------------------- **1.06 2 marks**

102 for *n* instead of 2.00:
$n = \frac{102}{169} = 0.60355……$
$\Delta H = \frac{0.63954}{0.60355.....} =$ **1.06** kJ mol^{-1}

OR

2 for energy instead of 102
Energy = 2 × 4.18 × 1.5 = 12.54 J
$\Delta H = \frac{0.01254}{0.0118.....} =$ **1.06** kJ mol^{-1}

107.4 – 107.7 **2 marks**

8.314 for c instead of 4.18:
Energy = 102 × 8.314 × 1.5 = 1272 J
Energy = 102 × 8.31 × 1.5 = 1271.4 J
ΔH = **107.4 – 107.7** kJ mol^{-1}
depends on intermediate rounding
CHECK

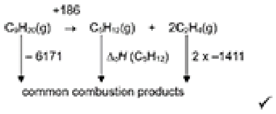
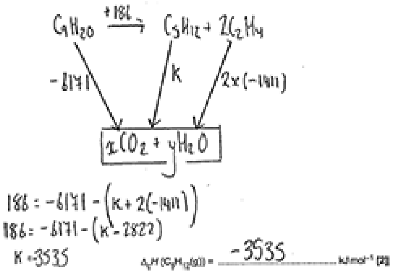
Apply **ECF** for any other comparable responses. If in doubt contact TL

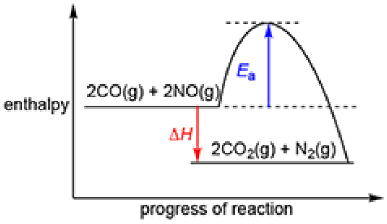
Examiner's Comments

This question was a good discriminator, producing marks across the whole 3 mark range. More successful candidates correctly calculated the energy change, moles of $RbClO_3$ and enthalpy change of solution. However, there were pitfalls for many including the following:

- calculating the energy change using the mass of water rather than the mass of the solution. This was despite the suppled information that the specific heat capacity of the solution is the same as for water. Candidates should understand that *m* in $mc\Delta T$ is the mass of the substance that produces ΔT
- calculating an incorrect value for the molar mass of $RbClO_3$.

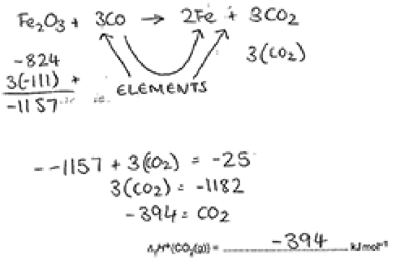
					Instead of 169, this was often seen as 120.5 (using the atomic number of 37 for Rb, rather than the mass number of 85.5) and 185 (for $RbClO_4$) • using values of *m* at the wrong stages in the calculation. e.g. 2 g with the energy change and 102 g or 100 g with the moles calculation • calculating the correct numerical value for the enthalpy change of solution, but then placing a '–' sign in front of the value, despite ΔT being for a decrease in temperature. Finally, as with all multi-step calculations, candidates are advised to use calculator values throughout. Any intermediate rounding introduces rounding errors in the final value. The final value can be rounded either to the significant figures demanded by the question or to the lowest number of significant figures used in the provided data.
			Total	**4**	
14	a		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –4950 award 3 marks** -- ○ $q = mc\Delta T$ $= 150 \times 4.18 \times 10.5$ $= 6583.5$ (J) **OR** 6.5835 (kJ) ✓ ○ $n(C_7H_{16})$ $\frac{0.133}{100} = 1.33 \times 10^{-3}$ ✓ • $\Delta_cH = q \div n$ $= \frac{6.5835}{1.33\times10^{-3}}$	3 (AO 2.4 × 1) (AO 2.8 × 2)	**ALLOW** 3 SF up to the calculated value Ignore RE after 3SF **IGNORE** sign **ALLOW** ECF from incorrect *q* and/or *n* **Common errors for 2 marks** +4950 kJ mol^{-1} (wrong sign) -5077 (use of 0.0013 and 6.6 2SF) -5064 (use of 0.0013 2SF) -4962 (use of 6.6kJ use of 2SF) **<u>Examiner's Comments</u>** Many candidates calculated the correct value of q and scored all three marks. Common errors saw some candidates using the incorrect mass, of either 0.133 or that added to or

			= **–**4950 kJ $mol^{–1}$ **– sign required** ✓		subtracted from the 150. The temperature change was given but a few candidates added the 10.5 to 273 in order to, incorrectly, convert to K. The final mark required the candidate to link the temperature increase to an exothermic value and include a minus sign.
	b		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –3535 award 2 marks** --- 186 = $\Delta_cH(C_9H_{20})$ – $\Delta_cH(C_5H_{12})$ – 2 $\Delta_cH(C_2H_4)$ **OR** From Hess cycle with all numerical values used and correct multiples used/labelled  $\Delta_cH(C_5H_{12})$ = (–6171) – 2(–1411) -186 = –3535 kJ mol–1 ✓	2 (AO 2.2 × 2)	**IGNORE** any incorrect combustion products on bottom line. **Common errors for 1 mark** +3535 (wrong sign for final answer) +8807 (use of +6171) -9179 (use of +1411) -4946 (use of 1 x -1411) -3163 (use of +186) **For other answers**, check for a **single** transcription error or calculation error using **all values** which could merit 1 mark **Examiner's Comments** This calculation proved difficult. Many candidates did not deduce the correct cycle. Of those who did, a significant majority did not appreciate the stoichiometry and/or use the correct signs from the cycle. Many candidates scored 1 mark for this question, which was gained as an error carried forward, in the enthalpy cycle. -3163 was a common error. Exemplar 1 

					This candidate showed clarity in their working by drawing a correct Hess cycle and then applying correct multiples and directions for the enthalpy changes.
			Total	**5**	
15	a	i	$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ Correct species ✓ Balanced ✓	2 (AO2.6 ×2)	**ALLOW** multiples **IGNORE** state symbols For heptane formula, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW 1 mark** for balanced combustion equation for a different alkane (**ECF**) e.g. $C_6H_{14} + 9½O_2 \rightarrow 6CO_2 + 7H_2O$ **Examiner's Comments** Most candidates were able to construct a balanced equation for the combustion of heptane. Most were aware that CO_2 and H_2O would be the products although some generated CO, C_6H_{12} or unusual compounds such as $C_7H_{14}O$. The hardest part was the formula of heptane itself with use of hexane instead being a common error; candidates who made this error were given 1 mark, provided that their equation was balanced.
		ii	 **Reactants, products and Δ*H*** **2CO + 2NO** on LHS **AND** **$2CO_2$ + N_2** on RHS **AND**	2 (AO2.1) (AO1.2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols Δ*H* **DO NOT ALLOW** –Δ*H* **DO NOT ALLOW** double headed arrow on Δ*H* **ALLOW** Δ*H* arrow even with small gap at the top and bottom, i.e. line

			ΔH labelled with products **below** reactants **AND** **Arrow downwards** ✓ ***E_a* (independent of ΔH)** curve with arrow from reactants to top of curve **AND** E_a labelled ✓ **IF** endothermic diagram shown, **ALLOW ECF** for E_a using MS criteria		does not quite reach reactant or product line. **ALLOW** –746 for ΔH ***E_a*** **ALLOW** AE **OR** A_E **ALLOW 2** arrowheads at **each** end of E_a line **OR** no arrowhead **BUT DO NOT ALLOW** arrowhead down E_a line must reach maximum (or near to maximum) on curve **Examiner's Comments** Most candidates obtained 1 or 2 of the available marks, the commonest errors being use of a doubleheaded arrow for ΔH or a $-\Delta H$ label. Some candidates showed endothermic profiles and these could create issues with positioning of the ΔH and E_a arrows. Generally, positioning of ΔH and E_a arrows was imprecise and candidates are advised to start and finish the positions of their arrows accurately. The mark scheme did allow for some leeway but positioning of arrows could generally be improved.
		iii	Catalyst lowers activation energy **OR** Catalyst increases rate without itself changing ✓ Reaction proceeds via a different route/pathway **OR** More molecules/particles exceed activation energy ✓	2 (AO1.2 ×2)	**ALLOW** 2nd labelled curve on profile diagram in **23(a)(ii)** with lower activation energy/E_c with catalyst **ALLOW** E_c needs less energy to start reaction **ALLOW** E_c curve is lower than E_a curve **IGNORE** 'shorter route' for alternative route **IGNORE** more successful collisions **Examiner's Comments**

					Almost all candidates knew that a catalyst lowered activation energy and most were aware that an alternative pathway was made possible by a catalyst.
	b	i	298 K/25°C **AND** 100 kPa ✓	1 (AO1.1)	**ALLOW** 'a stated temperature' *To accept that other standard temperatures can be used and 298 should strictly be added as ΔH_{298}^{θ}* IF a temperature is seen, it **must** be 298/25°C **ALLOW** 1 × 10^5 Pa, 101 kPa, 1.01 × 10^5 Pa, 1 atm, 1 bar **<u>Examiner's Comments</u>** Only just over a half of candidates obtained this mark with one of the conditions being incorrect, usually as 273 K or 100 Pa. It is important that candidates learn these standard conditions.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –394 (kJ mol^{-1}) award 3 marks** **Use of $\Delta_f H$ values and balancing numbers** ± (–824) seen anywhere **AND** ± (3 × –111) **OR** ± (333) **OR** ±1157 seen anywhere ✓ **Correct subtraction for 3$\Delta_f H$(CO) using ΔH** (–25) + (–1157) *–1157 = 824 + (3 × –111)* = –1182 (kJ mol^{-1}) ✓	3 (AO2.6 ×3)	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF** throughout **COMMON ERRORS** **–1182** omission of ÷3 for $\Delta_f H$(CO$_2$) **2 marks** **(+)394** Incorrect subtraction **2 marks** **(+)1182** Incorrect subtraction **&** no ÷3 **1 mark** **–320** no ×3 for –111 **2 marks** **–960** no ×3 for –111 **AND** no ÷3 **1 mark** **–377.3 / –377** incorrect subtraction **2 mark** **–1132** incorrect subtraction **AND** no ÷3 **1 mark** **–303.3 / –303** no ×3 for –111 **AND** incorrect subtraction **1 mark** **–385.66… / –385.7** no ΔH (25) and ÷3 **2 marks**

			Calculation of $\Delta fH(CO_2)$ formation $\Delta_f H(CO_2) = \frac{-1182}{3} = -394$ (kJ mol^{-1}) ✓		**(+)385.66… / (+)385.7** no ΔH (25) and ÷3 and wrong sign **1 mark** **Examiner's Comments** This question discriminated extremely well with many obtaining the correct enthalpy change of –394 kJ mol^{-1} for 3 marks. There were 3 stages to the calculating: • Use of –824 and 3 × –111 to obtain –1157 • Correct incorporation of –25 to obtain –1182 • Division by 3 for 1 mole of CO_2 to obtain –394 kJ mol^{-1} Weak candidates usually gained the first marking point but did not get any further. Incorrect signs were common as was not dividing by 3 for the final marking point. The mark scheme allowed ECF to be applied, provided that there was some correct method in the response. Exemplar 3  Exemplar 3 is shown to illustrate a clear response, showing clearly all stages in the calculation. Unfortunately, many responses were very difficult to follow, often shown as numbers almost placed at random in the answer space. This makes it very difficult to identify any logic and to apply ECF. Exemplar 3 serves as a

					model, clear response, showing what is possible.
			Total	**10**	
16			**D**	1 (AO 1.1)	**Examiner's Comments** This question proved to be very difficult with only the highest attaining candidates obtaining the correct response of D. Options A and C were the main distractors but there didn't seem to be any clear pattern. The many candidates could not identify the correct response suggests that candidates have difficulty in understanding the real meaning of these enthalpy terms.
			Total	**1**	
17			**D**	1 (AO 1.1)	**Examiner's Comments** The theme of problems with enthalpy terms continued with Question 12, with only about half of the candidates choosing the correct option D.
			Total	**1**	
18	a	i	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF bond enthalpy = (+)805 (kJ mol^{-1}) award 4 marks** **IF bond enthalpy = (+)3220 (kJ mol^{-1}) award 3 marks** --- *Energy for bonds made: (6O–H)* 6 × 464 **OR** 2784 (kJ) ✓ *Energy for bonds broken:* *(1 C–C + 5C–H + 1C–O + 1O–H + 3O=O)* 347 + (5 × 413) + 358 + 464 + (3 × 498) **OR** 347 + 2065 + 358 + 464 + 1494 **OR** 4728 (kJ) ✓	4 (AO 2.2 ×4)	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW ECF throughout** **IGNORE** signs for first 3 marking points **Alternative method** **ALLOW** (*5O–H*) from bonds made if O-H is omitted from bonds broken. Made: 5 x 464 **OR** 2320 (kJ) ✓ Broken: 347 + (5 × 413) + 358 +(3 × 498) **OR** 4264 (kJ) ✓ 4C=O bond enthalpy = 4264 – 2320 + 1276 = (+)3220 (kJ mol–1) ✓

			4C=O bond enthalpy correctly calculated –1276 = 4728 – (4C=O + 2784) 4C=O bond enthalpy = 4728 – 2784 + 1276 **OR** (+)3220 (kJ mol^{-1}) ✓ *C=O bond enthalpy correctly calculated* C=O bond enthalpy = $\frac{3220}{4}$ = (+)805 kJ mol^{-1} ✓		**DO NOT ALLOW** – sign **COMMON ERRORS for 3 marks** -805 (Wrong Sign) (+)718(.25) (Missing C-C) (+)431.5 (Missing 3 x O=O) (+)167 (Incorrect rearrangement) **<u>Examiner's Comments</u>** Candidates' working was often unclear and very difficult to follow for this question, making it challenging to find errors and award ECF where appropriate. Despite being given the displayed formula, many were unable to correctly count the bonds in the molecules. Missing some or all of C-C, C-O and 3 x O=O from the bonds broken was often seen. Some only counted 2 x C=O bonds in the products. Some subtracted the bonds broken from bonds made or omitted the enthalpy change from their calculation. Very few candidates gave a negative value for their final bond enthalpy.
		ii	Less energy is required to break bonds in methoxymethane ✓ Energy released in bond forming is same ✓	2 (AO 3.2 × 2)	**ORA** **ALLOW** bonds in methoxymethane are weaker (than in ethanol) **IGNORE** calculations **ALLOW** Same bonds being formed **<u>Examiner's Comments</u>** Very few candidates scored both marks here. Many just gave a generic response describing an exothermic reaction i.e. 'more energy is released in bond forming than needed for bond breaking' rather than answering the question asked. It was evident from many responses that candidates are unclear that energy is needed for bond breaking and released in bond forming. Some tried to compare specific bonds but often failed to account for them all, comparing

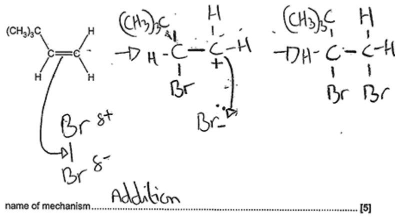
					presence of C-O and extra C-H in methoxymethane to O-H in ethanol but forgetting the C-C bond, resulting in methoxymethane having stronger bonds/more energy to break bonds. Lots didn't recognise that the same products were formed in both reactions.
	b		(The enthalpy change) for complete combustion ✓ of 1 mol (of substance)✓	2 (AO 1.1 × 2)	**DO NOT ALLOW** energy required **IGNORE** energy released **ALLOW** combustion in excess oxygen/air **OR** reacts in excess oxygen **OR** reacts completely in oxygen **ALLOW** element **OR** compound **OR** reactant **DO NOT ALLOW** atoms **IGNORE** standard states/conditions **Examiner's Comments** Approximately half of candidates scored both marks. Many lost marks for saying 'energy required' or 'energy needed' which demonstrated a lack of understanding that for an exothermic reaction this would be the activation energy not the enthalpy change. Some also had 1 mole of substance but this was reacted with 1 mole of oxygen or formed 1 mole of products.
	c	i	$\frac{2 \times 0.25}{31} \times 100 = 1.6$ % ✓	1 (AO2.8)	**ALLOW** 1 d.p. up to calculator value of 1.612903226 correctly rounded **Examiner's Comments** More than half of candidates gave the correct answer. Common mistakes included not multiplying the uncertainty by 2 for each measurement (0.81) or using the initial or final temperatures rather than the difference in their calculations.
		ii	**Level 3 (5–6 marks)** Calculates an acceptable value for $\Delta_c H$ **AND** Evaluates at least two differences	6 (AO 2.4 × 2) (AO 3.1 × 2)	*Indicative scientific points may include:* **Calculation of *q* and *n***

			from data book value **AND** suggests at least two suitable improvements. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Use of results to calculate moles of butan-1-ol **AND** an attempt to calculate *q* **AND** Evaluate at least one difference from data book value **AND** suggests at least one suitable improvement. **OR** Calculates an acceptable value for $\Delta_c H$ *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempts to calculate moles of butan-1-ol **OR** attempts to calculate *q* **AND** Evaluate at least one difference from data book value **OR** suggests at least one suitable improvement. **OR** Correct use of results to calculate moles of butan-1-ol **AND** an attempt to calculate *q* **OR** Evaluate at least one difference from data book value **AND** suggests at least one suitable improvement. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 mark**	(AO 3.3) (AO 3.4)	• mass butan-1-ol burnt = 1.31 g • **ΔT** = 31 ºC • $q = mc\Delta T$ = 200 × 4.18 × 31 = 259(16) J **OR** 25.9(16) (kJ) • n(butan-1-ol) = $\frac{1.31}{74}$ = 0.0177(017…) (mol) **<u>Calculation of $\Delta_c H$</u>** • $\Delta H = \frac{q}{0.0177017..}$ • ΔH = (–)1460 to (–)1464 (kJ mol^{-1}) **ALLOW** answer in J mol$_{-1}$ if units are given **ALLOW** a single slip/rounding errors e.g. Mr = 73 **IF** no calculation seen check **4(b)(i) /page 10** for any working. **<u>Difference from data book value</u>** • Heat losses • Incomplete combustion • Data book uses standard values • Evaporation of alcohol from wick • Evaporation of water from beaker **<u>Examples of improvements</u>** • Burn in plentiful oxygen • Draft shield • Copper can in place of beaker • Use a bomb calorimeter • Add lid to beaker • Place cap over wick when not burning • Reduce gap between burner and beaker • Use standard conditions • Use 3 DP balance **OR** digital thermometer • Heat for longer to reduce % uncertainty in

			No response or no response worthy of credit.		mass/temperature measurements **Examiner's Comments** Many candidates limited themselves to only L1 here by not calculating the enthalpy change from the student's results. Remind candidates to read the question carefully and to use all the information provided (such as tables of results). Some missed out on L3 as their evaluation lacked detail, as they needed to include at least two differences and two suitable improvements. Not all improvements given were suitable, with some suggesting candidates confusing different practicals - for example, 'use a polystyrene cup' or 'heat to a constant mass'. It was evident that some lacked understanding about complete combustion, with suggestions to 'measure mass until it doesn't change any further' or 'heat water for longer' to make sure complete combustion had occurred. Some also suggested 'using a larger mass' but further information was needed for credit to be given. **OCR support** Further information about practical skills assessed on written exams can be found in Section 3 of the practical skills handbook. If using the suggested practical activities developed by OCR, then encourage candidates to answer the extension opportunity questions to help develop a deeper understanding in preparation for written assessments. Exemplar 3

					 This exemplar shows a candidate who achieved L3 with all 6 marks given. Working for the calculation of ΔH is clear with all steps shown, in a logical order, and the final answer has correct negative sign. More than 2 differences and 2 improvements are given. The communication is clear, linking potential differences with suggestion for improvements.
		iii	Mass burnt = 0.9825 (g) ✓	1 (AO 3.4)	**ALLOW** any value from 0.98 to 0.99 g **ALLOW ECF from b(ii)** i.e. 0.75 × mass change calculated **OR** q = 150 x 4.18 x 31 = 19437 J = 19.4(37) kJ $\text{Mass burnt} = \frac{19.4(37)}{\text{calculated }\Delta H} \text{ x } 74$ **<u>Examiner's Comments</u>** Those that were more confident with the calculation in (ii) were more likely to get the answer here. ECF was occasionally seen from an incorrect mass or enthalpy change depending on method used. Many were able to work out q using 150g of water even if they had incorrectly calculated q in (ii) - such as previously using 1.31g.
			Total	**16**	
19		i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF $\Delta_r H$= -116 (kJ mol^{-1}) award 4 marks** **IF $\Delta_r H$= +116 (kJ mol^{-1}) award 3**	4 (AO2.4) (AO2.4) (AO2.8) (AO2.8)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** 5799.8 **OR** 5800 J **OR** 5.7998 **OR** 5.8 kJ **DO NOT ALLOW** < 3 SF **EXCEPT** 5.8

			marks **Energy released in J OR kJ** = 75.0 × 4.18 × 18.5 = 5799.75 (J) **OR** 5.79975 (kJ) ✓ **Correctly calculates *n*($Ba(OH)_2$) OR *n*(HNO_3)** $n(Ba(OH)_2) = 2 \times \frac{25.0}{1000} = 0.05(00)$ (mol) **OR** $n(HNO_3) = 2 \times \frac{50.0}{1000} = 0.1(00)$ (mol) ✓ ***ΔH* per mole $Ba(OH)_2$ in J OR kJ** *Answer **MUST** divide energy by n($Ba(OH)_2$ **OR** 2 × n(HNO_3))* $\pm\frac{5799.75}{0.05}$ OR $\pm 2 \times \frac{5799.75}{0.1} = \pm 115995$ (J) **OR** $\pm\frac{5.79975}{0.05}$ OR $\pm 2 \times \frac{5.79975}{0.1} = \pm 115.995$ (kJ) ✓ **Δ*H* in kJ mol'$^{-1}$ to 3 SF AND - sign** $\Delta_r H$ = -116 (kJ mol^{-1}) ✓		*(trailing zeroes)* **IGNORE** any sign **IGNORE** units ***i.e. ALLOW*** *correctly calculated* *number in J **OR** kJ **OR** no units* **ALLOW** 3SF or more **OR** use of 5800 J **OR** 5.8 kJ Sign **NOT** needed 3 **SF** needed **Common errors** **3 marks** $\frac{5799.75}{0.1} \rightarrow \mathbf{-58.0}$ no 2 × using 0.1 $\frac{5799.75}{0.15} \rightarrow \mathbf{-38.7}$ ÷ by 0.05 + 0.10 $2 \times \frac{5799.75}{0.15} \rightarrow \mathbf{-77.3}$ **2 marks** for answers above with wrong sign or not to 3 SF Other multiples by using *m* as 50 or 25: Mark using same principal Use of 50 → **-77.3 3 marks** Use of 25 → **-38.7 3 marks** **Examiner's Comments** More successful candidates followed a well-rehearsed method for processing experimental enthalpy results to arrive at an enthalpy change. The result was usually the correct answer of –116 kJ mol^{-1}. Most candidates combined the 2 volumes (25 cm^3 and 50 cm^3) to give 75 cm^3 with *m* = 75 g and then calculated the correct energy change of 5799.75 J using *mc*ΔT. Some candidates did not combine the volumes and used *m* = 25 g or 50 g instead. Most candidates worked out the amount in moles of $Ba(OH)_2$ and HNO_3. Unfortunately, these calculations were often scattered across the page with no indication of what the calculated values applied to. Some candidates incorrectly combined the moles (0.10 and 0.05) and divided this value (usually 0.15) into the energy change. The mark scheme accounted for these errors and allowed error carried forward marks to be allocated appropriately. Candidates are strongly advised to

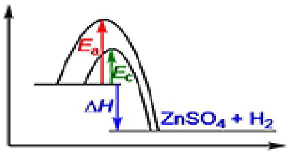
					organise their calculation in a coherent way and to show what each calculated value applies to so that error carried forward can be applied for mistakes. Exemplar 3  Exemplar 3 illustrates a common misconception of less successful responses when using of *mc*ΔT: misunderstanding the meaning of m in the equation *q* = *mc*ΔT, used for finding the energy change *q* from experimental results. **Misconception** In the equation q = *mc*ΔT, mass m is the mass of the substance that changes temperature by ΔT. This substance has a specific heat capacity, c. Looking at the experimental results, the substance changing temperature is the mixture of the two solutions, which have volumes of 25 cm^3 and 50 cm^3. This is where the thermometer has been placed. The information states that the density of the solutions is the same as for water, 1.00 g cm^{-3}. Therefore, the mass *m* that changes temperature ΔT is 75.0 g and the energy change is 75.0 × 4.18 × 18.5 J. This candidate has correctly calculated the moles of one of the reactants, $Ba(OH)_2$, as 0.0500 but has then calculated its mass as 75.0 × 4.18 × 18.5 J = 8.565 g and has used this in *mc*ΔT. So the key message is that m in *mc*ΔT is where the thermometer has been placed.
		ii	**Reason for incorrect conclusion** neutralisation forms **1 mol H_2O** **OR** $\Delta_r H$ forms 2 mol **H_2O** ✓	2 (AO3.2 ×1)	**H_2O essential** **IGNORE** sign, even if wrong **ALLOW** 2 SF, e.g. 58

			Value for $\Delta_{neut}H = \pm \frac{\text{answer to 25a(i)}}{2}$ (kJ mol^{-1}) ✓ 2 SF or more **2 SF or more**		**Examiner's Comments** Many candidates correctly identified that neutralisation is the formation of 1 mole of water, whereas this equation forms 2 moles of water. Significantly fewer were then able to use their answer to the calculation in Question 25 (a) (i) to determine a value for the neutralisation enthalpy as half of that value. This was a novel question, not used in previous examinations, and many candidates coped with the challenge admirably.
			Total	**6**	
20			**A**	1(AO2.2)	**Examiner's Comments** Candidates answered this question reasonably well with most choosing either the correct option A, or the incorrect D (the same numerical value but with the wrong sign). Energy cycles and Hess' law seemed to be well known with most candidates drawing their cycle by the question. Candidates should take care with the direction of the arrows as these travel in different directions for formation and combustion problems. The incorrect option D was the result of arrows in the wrong direction.
			Total	**1**	
21	a	i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF *T* = 52.4 °C OR 52.5 °C award 4 marks** **IF *T* = 32.4 (°C) award 3 marks** **---** ***Correctly calculates n($AgNO_3$)*** $= 0.400 \times \frac{100.0}{1000}$ **OR** 0.04(00) (mol) ✓ ***Energy released per mole of $AgNO_3$ in J OR kJ***	4 (AO1.2) (AO2.4) (AO2.8) (AO2.8)	***FULL ANNOTATIONS MUST BE USED*** **---** **ALLOW ECF** throughout **---** **ALLOW** 13.6 kJ **OR** 13600 J (to 3SF) **DO NOT ALLOW** < 3 SF **IGNORE** any sign **and** units *i.e.* ***ALLOW*** *correctly calculated value in J* ***OR*** *kJ* **--**

			$= \frac{678 \times 0.0400}{2}$ **OR** 13.56 (kJ) **OR** 13560 (J) ✓ ***Correctly calculates ΔT*** $\Delta T = \frac{13560}{100 \times 4.18}$ **OR** 32.4 (°C) ✓ ***Maximum temperature reached*** = 32.4… + 20.0 = 52.4 °C ✓ **3 SF required**		-- **ALLOW ECF ONLY** from calculated Δ*T* +*20* °C **Common errors** **3 marks** **84.9 ºC (not divided** $\frac{\Delta H}{2}$) **<u>Examiner's Comments</u>** Many candidates made some attempt at this unusual twist on a Q = mcΔT calculation, but only a minority of candidates produced a fully correct answer. A temperature of 84.9 °C was seen much more often than 52.4 °C. The calculation of n($AgNO_3$) was performed well. Common errors were not dividing the moles by 2, not recognising the need to calculate the energy released per mole of $AgNO_3$, confusing the mass of water with the mass of the silver nitrate solid or of using an energy in kJ alongside a value of c based on J.
		ii	Maximum temperature is the same **AND** Half the energy/ moles **AND** half the mass/volume	1 (AO3.4)	**ALLOW** response that links the same proportionality/ratio of volume/mass and energy/moles **ALLOW** if seen by a calculation **<u>Examiner's Comments</u>** Although there were a few well explained, correct answers, this question proved challenging for most candidates. Candidates needed to link the changes as a proportion (e.g. half) to be given the mark. Candidates often only considered the change to energy or mass, but not both, e.g. dealt only with the decrease in moles reacting leading to a smaller temperature rise.

	b	i	(Enthalpy change) when 1 mole of a compound is formed from its elements ✓	1 (AO1.1×1)	**ALLOW** energy required **OR** energy released **ALLOW** one mole of product/substance **DO NOT ALLOW** 1 mole of element **DO NOT ALLOW** is formed from its **gaseous** elements when 1 mole of a **solid** compound when 1 mole of a **gaseous** compound **Examiner's Comments** The majority of candidates gave the required definition correctly, frequently going beyond to include ideas about standard states and conditions. The smaller number of incorrect responses covered a range of errors, including assuming that 1 mole of elements were reacting and (perhaps as a result of later work on lattice enthalpies) bringing in a requirement for the compound or the elements to be gaseous.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **If answer = (+)90 award 2 marks** -- $4(\Delta_f H^{\ominus}.NO) = -1172 - 6(-286) + 4(-46)$ $= -1172 + 1716 - 184$ $= (+)360$ (kJ mol^{-1}) ✓ $\Delta_f H^{\ominus}.NO = \frac{360}{4} = (+)90$ (kJ mol^{-1}) ✓	2 (AO2.2×2)	**ALLOW ECF** providing all values are used **ALLOW** one transcription error in the values used for M2 **Common error** 1 mark -90 (wrong sign) **Examiner's Comments** This calculation proved difficult. Many candidates did not deduce the correct cycle. Of those who did, a significant majority did not appreciate the stoichiometry and/or use the correct signs from the cycle. Many students scored 1 mark for this question which was gained as an error carried forward, providing all the values had been used in the enthalpy cycle. -90 was a common error.
			Total	**8**	

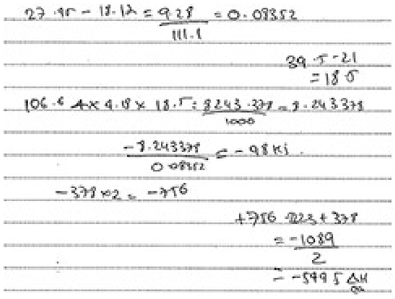
22			**A**	1(AO2.2)	**Examiner's Comments** This was another challenging question, with fewer candidates choosing the correct answer of A. The distractor, D, was obtained by swapping products and reactants in the calculation or in an incorrect enthalpy cycle. Candidates should have ruled out C and D straight away as enthalpy of combustion is always exothermic. Where working was shown, candidates omitted one or more of the multiples in the bonds formed or broken.
			Total	**1**	
23			**A**	1(AO2.1)	**Examiner's Comments** Only some candidates chose the correct answer of A. Option D was a common incorrect answer through not recognising that the enthalpy change for condensation is negative.
			Total	**1**	
24		i	More vigorous bubbling ✓ Zinc dissolves/disappears more quickly ✓	2 (AO 2.7 × 2)	**AW**, e.g. bubbles/fizzes more quickly For 1 alternative marking point **ALLOW** responses related to displacement of Cu from $CuSO_4$ by Zn: **EITHER** red/brown/black precipitate/solid formed **OR** (blue solution) turns colourless **Examiner's Comments** Candidates found this question very challenging. Most recognised that the addition of the catalyst would speed up the reaction but could not translate this into observations for this specific practical. For example, "reacts faster", "releases more hydrogen" or "stops reacting quicker". Giving candidates the opportunity to observe a range of both familiar and unfamiliar reactions, noting qualitative observations can help to improve their skills here. Many

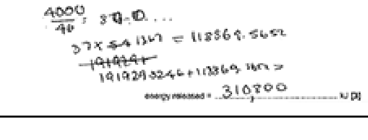
					just noted that one tube would be blue and the other colourless rather than considering the reaction taking place. Some indicated that only 1 tube would react and the other would not. A few candidates recognised that a competing displacement reaction would take place between Zn and $CuSO_4$ so were given marks for this.
		ii	 ΔH ΔH labelled with product ($ZnSO_4$ + H_2) below reactant **AND** Arrow downwards ✓ E_a E_a correctly labelled ✓ E_c E_c correctly labelled with $E_c < E_a$ ✓	3 (AO 2.1) (AO 1.1) (AO 1.1)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols ΔH **DO NOT ALLOW** $-\Delta H$ **DO NOT ALLOW** double headed arrow on ΔH **ALLOW** ΔH arrow even with small gap at the top and bottom, i .e. line does not quite reach reactant or product line. **E_a and E_c** **ALLOW** no arrowhead or arrowheads at both end of E_a or E_c lines E_a or E_c lines must reach maximum (or near to maximum) on curve For E_a, **ALLOW** AE **OR** A_E **ALLOW** marks for **E_a and E_c** for correctly labelled endothermic diagram (i.e. **ECF** from ΔH) **<u>Examiner's Comments</u>** Less than half of all candidates managed to gain all 3 marks giving the correct enthalpy profile diagram. Many demonstrated a lack of understanding about what an enthalpy profile diagram shows as seen by labelling of curves for E_a/E_c rather than the enthalpy change or arrows for ΔH extending to the x-axis. Other errors also seen included, -ΔH,

					double headed ΔH arrow, activation energy lines starting at products, endothermic profiles, E_a and E_c the wrong way round and missing or incorrect labels. Some candidates found it tricky to give activation lines for both catalysed and uncatalysed reactions on the same diagram, these often overlapped or did not extend to the top of the energy barrier.
			Total	**5**	
25			**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF answer = (+)198 award 3 marks** **--** *Energy for bonds broken* *(1 × C−C + 5 × C−H + 1 × C−O + 7 × O−H)* 347 + 5(415) + 358 + 7(464) **OR** 6028 (kJ) ✓ *Energy for bonds made (6 × H−H + 4 × C=O)* 6 × 435 + 4 × 805 **OR** 2610 + 3220 **OR** 5830 (kJ) ✓ *ΔH correctly calculated from above* Δ*H* = 6028 − 5830 = (+)198 (kJ mol^{-1}) ✓	3 (AO 2.2 × 2) (AO 2.6)	**FULL ANNOTATIONS MUST BE USED** **---** **IGNORE** sign **IGNORE** sign **--------------------------------------** **ALLOW ECF** **DO NOT ALLOW** − sign **Common errors for 2 marks** −198 (incorrect cycle) −149 (missed C-C from bonds broken) −2586 (missing 6 x O-H from H_2O) **Examiner's Comments** Despite the structures being drawn out with displayed formula, a significant number of candidates did not correctly count all the bonds. Common errors included missing C-C from ethanol or O-H bonds in water. Most candidates set out their working clearly, so it was easy to identify any errors in calculation steps and award ECF appropriately. Some also had the calculation the wrong way round (made – broken) missing the essential idea that energy

					is needed to break bonds and released to make bonds, as well as link to endothermic changes being positive and exothermic changes being negative. **Assessment for learning** It is important to evaluate candidates understanding of enthalpy changes and build on prior knowledge from KS4. We have produced a transition guide for KS4 to KS5 on enthalpy: https:/www.ocr.org.uk/Images/361305-enthalpy-changes-ks4-ks5.pdf. This includes a checkpoint task which is very useful for checking understanding of this topic, including the difference between endothermic and exothermic reaction, drawing profile diagrams, and calculating enthalpy changes from bond enthalpies.
			Total	**3**	
26	a		**Level 3 (5-6 marks)** Calculates **correct** enthalpy change with correct - sign for $\Delta_{hy}H$ (Ca^{2+}), allowing for acceptable errors. *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculates a value of $\Delta_{Sol}H$ ($CaCl_2$(s)) from the: Energy change **AND** Amount in mol of $CaCl_2$. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Processes experimental data to obtain the: Energy change from $mc\Delta T$ **OR**	6 (4 ×AO3.1) (2 ×AO3.2)	*Indicative scientific points may include:* **1. Processing experimental data** **Energy change from $mc\Delta T$** • Energy in J **OR** kJ = **106.6** × 4.18 × **18.5** = 8243.378 (J) **OR** 8.243378 (kJ) *3SF or more* **Amount in mol of $CaCl_2$** • $n(CaCl_2) = \frac{9.28}{111.1} = 0.0835........$ (mol) 0.08352835284 unrounded -- **2. ± value of ΔsolH($CaCl2$(s))** $= \pm\frac{8.24.....}{0.0835....} = \pm 98.68957929$ ($kJ\ mol^{-1}$) *3 SF or more.* From 3 SF: $\frac{8.24}{0.0835} = 98.7$ -- **3. CORRECT $\Delta_{hy}H(Ca^{2+})$ calculated with signs** $\Delta_{hy}H(Ca^{2+})$ = L.E. + $\Delta_{Sol}H(CaCl_2)$ - 2 $\Delta_{hy}H(Cl^-)$ = -2223 + (-98.7) - (2 × -378)

			Amount in mol of $CaCl_2$. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks -** No response or no response worthy of credit.		= **-1566** (kJ mol^{-1}) *3SF or more with correct - sign* From unrounded values, -1565.689579 --- **See next page for examples of acceptable errors** **Acceptable errors** **ALLOW** omission of trailing zeroes **ALLOW** minor slips in rounding, transcription errors, etc throughout **ALLOW** one small error, e.g. subtracting mass of $CaCl_2$ for m m = 106.60 - 9.28 = 97.32 q = 7.5257556 (kJ) $\Delta solH$ = 90.09821629 (kJ mol^{-1}) $\Delta hyH(Ca^{2+})$ = -1557 (kJ mol^{-1}) **OR** adding mass of $CaCl_2$ for m m = 106.60 + 9.28 = 115.88 q = 8.9610004 kJ $\Delta_{sol}H$ = 107.2809423 (kJ mol^{-1}) $\Delta_{hy}H(Ca^{2+})$ = -1574 (kJ mol^{-1}) **Examiner's Comments** This question was assessed by level of response (LoR). Candidates were required to process raw experimental results to determine one enthalpy change, and then to determine a second enthalpy change by using an energy cycle. Levels were determined by the accuracy of the candidates' processing of the results, calculations and use of the energy cycle. Marks within a level were determined by communication. This question discriminated extremely well. Level 3 candidates used the mass of solution as 106.6 g with $mc\Delta T$ to obtain an energy change of 8.24 kJ. They then divided this value by the moles of $CaCl_2$ that reacted (0.0835 mol) to obtain the enthalpy change of -98.7 kJ mol^{-1}. Finally, they constructed an energy cycle which they then used to obtain the second enthalpy change of -1566 kJ mol^{-1}. Level 2 candidates determined the first enthalpy change but may have used the approximate mass of 100 g for the mass of solution from the

					experimental method. Their energy cycle was often incorrect or absent, with the second enthalpy change calculated incorrectly. Level 1 candidates often calculated the initial energy change using *mc*Δ*T* but made little further correct progress. Less successful responses used the solid mass of calcium chloride (9.28 g) instead of the mass of the solution in their *mcΔT* calculation. Overall, mathematical skills were displayed well but some basic errors were made, particularly with subtractions. This may have been the result of mis-keying values into a calculator and believing the answer displayed. Exemplar 3  Exemplar 3 is a Level 2 response. The candidate has calculated the initial energy change, the moles of calcium chloride and the first enthalpy change using a correct method. This response has not been given marks for the communication strand of Level 3 because there is nothing to indicate what the numbers refer to. The response could be summarised as a mass of numbers scrawled across the page. Unfortunately, this is the pattern of many responses. So, this response was given 3/6 marks.
	b	i	$C_8H_{18} + C_2H_5OH + 15\frac{1}{2} O_2 \rightarrow 10 CO_2 + 12 H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples e.g. $2 C_8H_{18} + 2 C_2H_5OH + 31 O_2 \rightarrow 20 CO_2 + 24 H_2O$ **ALLOW** $C_{10}H_{24}O$ for $C_8H_{18} + C_2H_5OH$

					Combining ethanol and octane! **Examiner's Comments** Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and C_2H_5OH were usually seen although some candidates combined these as a 'mixture formula' of $C_{10}H_{24}O$ (which was accepted). The balancing of the equation using $15½O_2$ was the hardest part of the equation and many different balancing numbers for O2 were seen ($10CO_2$ and $12H_2O$ where usually correct). Less successful responses often attempted a combustion equation using octane OR ethanol, but not both. This is not an easy equation to construct, and the context was novel. Overall candidates made a good attempt at this question.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks** -- *M*(C_8H_{18}) = 114 **AND** *M*(C_2H_5OH) = 46 **OR** 1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓ 50 mol C_8H_{18} **OR** 50 mol C_2H_5OH **OR** 50 mol (C_8H_{18} + C_2H_5OH) **OR** 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓ Energy = (50 × 5470) + (50 × 1367) **OR** 50 × (5470 + 1367) **OR** 50 × 6837 **OR** 273500 + 68350 **=341850(kJ)✓**	3 (3 ×AO2.2)	**IGNORE** sign throughout **ALLOW** approach based on mass for 2nd mark *m*(C_8H_{18}) = (114/160) × 8000 = 5700 g **AND** *m*(C_2H_5OH) = (46/160) × 8000 = 2300 g Energy = 5700/114 × 5470 + 2300/46 × 1367 = 341850 (kJ) **ALLOW 2 SF or more** correctly rounded -- **Common errors** **310800 → 2 marks** *Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)* **Example**  energy released when 4kg of C_8H_{18} burnt– $\frac{4000}{114}$ = 35 moles... → 5470 × 35 = 191929.8246 KJ released $\frac{4000}{46}$ = 87.0... 87 × 1367 = 118869.5652 ~~191929+~~ 191929.8246 + 118869.5652 = energy released = 310800 kJ [3]

					Examiner's Comments This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.
			Total	**10**	