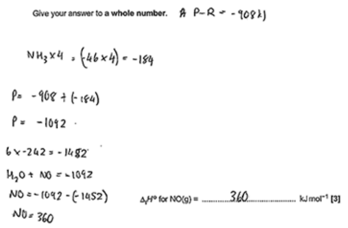
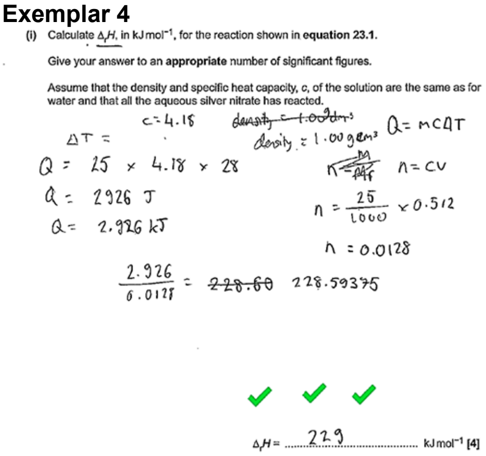
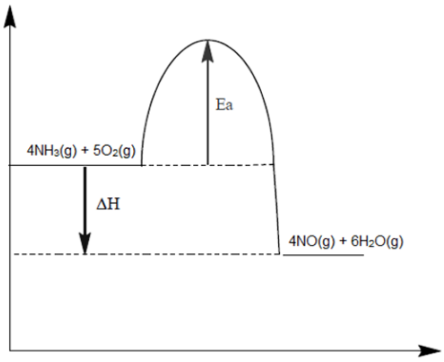
Mark scheme - Enthalpy

Question			Answer/Indicative content	Marks	Guidance
1		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 $\Delta H_{298}\ \theta$* **ALLOW** 1×10^5 Pa, 101 kPa, 1.01×10^5 Pa, 1 atm, 1 bar **<u>Examiner's Comments</u>** Only just over half of the candidates were able to quote standard conditions for enthalpy measurements. Errors included an incorrect temperature, often 273 and 293 K, or incorrect pressure (e.g. 1000 kPa, 100 atm). Candidates are reminded that 'room temperature' is not a standard temperature – a specific figure must be stated.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = (+)90 (kJ mol^{-1}) award 3 marks** **IF answer = −90 (kJ mol^{-1}) award 2 marks** **IF answer = (+)360 (kJ mol^{-1}) award 2 marks** --- **Use of $\Delta_f H$ values and balancing numbers** ± (4 × −46) **OR** ± 184 **AND** ± (6 × −242) **OR** ± 1452 seen anywhere ✓ **Correct subtraction using ΔH = −908** 4 × Δ_fH(NO) = (4 × −46) − (6 × −242) − 908 = −184 + 1452 − 908 = (+)**360** (kJ mol^{-1}) ✓ **Calculation of Δ_fH(NO) formation by ÷4** $\Delta_f H(NO) = \frac{360}{4}$ = **(+)90** (kJ mol^{-1}) ✓	3 (AO2.6×3)	FULL ANNOTATIONS MUST BE USED --- **ALLOW ECF if common errors not seen** **IF ΔH of −908 has NOT been used, ONLY award 1st mark** --- **COMMON ERRORS** **1 mark** Incorrect signs(s) **AND** missing ÷4 ±2544 from ± (184 + 1452 + 908) ±728 from ± (184 + 1452 − 908) ±2176 from ± (−184 + 1452 + 908) -360 from − (−184 + 1452 − 908) **2 marks** Incorrect signs(s) ±636 from ± (184 + 1452 + 908) = ± 2544÷4 ±182 from ± (184 + 1452 − 908) = ± 728÷4 ±544 from ± (−184 + 1452 + 908) = ± 2176÷4 -90 from − (−184 + 1452 − 908) = − 360÷4 **<u>Examiner's Comments</u>**

					Exemplar 6  Most candidates were able to make some progress with the enthalpy calculation. Most recognised that the provided $\Delta_f H$ values had to be multiplied by the balancing numbers in the equation. Correct processing of these values with ΔH for the reaction discriminated well between candidates. The response shows a response that was given 2 out of the 3 available marks. The candidate has correctly calculated +360 kJ mol^{-1} from their enthalpy cycle but has not realised that this value is for 4 mol NH_3 and must be divided by 4 to obtain the enthalpy change of formation of 1 mol of NH_3. It was impressive that the correct answer of +90 kJ mol^{-1} was achieved by about one-third of candidates.
			Total	**4**	
2		i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF $\Delta_r H$ = −457 OR −458 (kJ mol^{-1}) award 4 marks** **IF $\Delta_r H$ = ±229 OR 457 (kJ mol^{-1}) award 3 marks** ----------------------------------- ***Energy released in J OR kJ*** = 25.0 × 4.18 × 28.0 = 2926 (J) **OR** 2.926 (kJ)✓ ***Correctly calculates n($AgNO_3$)*** $= 0.512 \times \frac{25.0}{1000} = 1.28 \times 10^{-2}$ (mol) ✓ **Δ*H* per mole $AgNO_3$ in kJ AND 3 SF** *Answer **MUST** divide energy by n($AgNO_3$)* $\pm\frac{2.926}{1.28 \times 10^{-2}}$ = ±228.59375 = ±229 (kJ) ✓ **3 SF** needed Sign **NOT** needed **Δ*H* for 2 mol $AgNO_3$ AND – sign AND** 3 SF Δ*H*r = 2 × −228.59375 = −457 (kJ $^{mol-1}$) OR 2 × −229 = −458 (kJ $^{mol-1}$) ✓	4	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW ECF** throughout -------------------------------------- **ALLOW** 2930 J **OR** 2.93 kJ **DO NOT ALLOW** < 3 SF **IGNORE** any sign **and** units *i.e. **ALLOW** correctly calculated number in J **OR** kJ* -- **Alternative approach** using 1 mol Mg Energy released = 2926 (J) OR 2.926 (kJ) ✓ *n*($AgNO_3$) = 1.28×10^{-2} (mol) ✓ $n(Mg) = \frac{1.28 \times 10^{-2}}{2}$ = 6.4×10^{-3} (mol) ✓ $\Delta H_r = \frac{2.926}{6.4 \times 10^{-3}}$ = –457 (kJ mol^{-1}) **– sign AND** 3 SF needed **<u>Examiner's Comments</u>**

					Candidates are well-versed with the relationship q = mcΔT and most were able to calculate that 2.926 kJ of energy was released in this reaction. It was also common to see the amount of $AgNO_3$ correctly calculated as 1.28 × 10^{-3} mol. Candidates were expected to determine the amount of energy released from 1 mol AgNO3 as 229 kJ and finally to multiply this value by 2 for the molar quantities in the equation to match the 'enthalpy change of reaction'. It was common to see −229 given as the final answer but this was rarely multiplied by 2. The question also required the final answer to be given to an appropriate number of significant figures. Many candidates seemed to be unaware that this reflects the least significant figure provided in the data, in this case 3 significant figures. The exemplar shows a typical response for 3 of the available 4 marks. Many omitted the negative sign in their Δ*H* value to consider the exothermicity of the reaction. Candidates are also advised to only round at the end of a multi-step calculation. Rounding of intermediate values introduces rounding errors in the final answer. Answer = −457 kJ mol^{-1} **Exemplar 4**  (i) Calculate $\Delta_r H$, in kJ mol^{-1}, for the reaction shown in **equation 23.1**. Give your answer to an **appropriate** number of significant figures. Assume that the density and specific heat capacity, *c*, of the solution are the same as for water and that all the aqueous silver nitrate has reacted. c = 4.18 ~~density = 1.00~~ density = 1.00 gcm³ Q = mcΔT ΔT = Q = 25 × 4.18 × 28 n = cv Q = 2926 J n = 25/1000 × 0.512 Q = 2.926 kJ n = 0.0128 2.926/0.0128 = ~~228.60~~ 228.59375 $\Delta_r H$ = 229 kJ mol^{-1} [4]
		ii	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓ **State symbols required** **White** precipitate **AND** $AgNO_3/Ag^+$ **NOT ALL** reacted **OR** **NO** white precipitate **AND** AgNO3/Ag^+ **ALL** reacted ✓	**2**	**ALLOW** $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$ Observation needs to be linked to conclusion **Examiner's Comments** Most candidates recognised that silver nitrate and chloride ions react together to form a white precipitate, but many did not make the link between this observation and whether any silver nitrate was left unreacted. Many

					candidates did not give a correct equation, with missing or incorrect state symbols being common. This question discriminated extremely well.
			Total	**6**	
3	a		**FIRST CHECK ON ANSWER LINE** **If answer = (+) 431.5 (kJ mol^{-1}) award 2 marks** **If answer = −431.5 (kJ mol^{-1}) award 1 mark** (wrong sign) ___ **2 × H–C*l* bond enthalpy correctly calculated** = +436 +243 +184 = +863 (kJ mol^{-1}) ✓ **H–C*l* bond enthalpy correctly calculated** +863/2 = (+)431.5 (kJ mol^{-1}) ✓	2	**ALLOW** to **3 SF** i.e. 432 **ALLOW** 1 mark for (+)247.5 / 248 (wrong expression) i.e. (436+243−184)/2 **Examiner's Comments** Most candidates made a good attempt at this question. The most common mistake was to use the wrong sign when incorporating the enthalpy change into the calculation, or not to incorporate it at all.
	b	i	$Br_2(l) \rightarrow Br_2(g)$ ✓	1	**Examiner's Comments** A good attempt by many candidates but some lost marks by having the wrong state of bromine, even though the question stated it was a liquid changing to a gas. Many added water or oxygen, some confused the equation with bond enthalpy and answers such as $Br_{2\,(l)} \rightarrow 2Br_{(g)}$ were commonly seen.
		ii	Endothermic **AND** Energy required to overcome induced dipole–dipole forces/London forces ✓	1	**Mark independently of 3 (d) (i)** **ALLOW** endo to break **intermolecular** forces/bonds **ALLOW** bonds between molecules **DO NOT ALLOW** van der Waals' forces **Examiner's Comments** The majority of candidates answered this question incorrectly. Only 10% of candidates mentioned intermolecular/London forces. Most stated 'exothermic' or described breaking covalent bonds.
			Total	**4**	

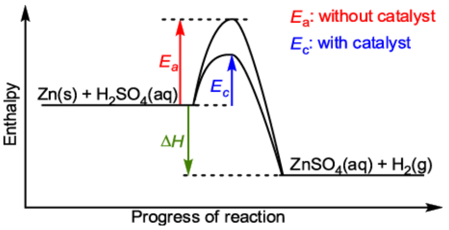
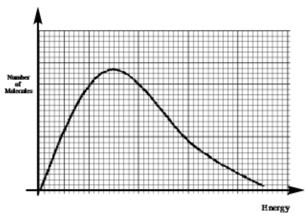
4		i	 **Reactants, products and E_a** Reactants on LHS $\mathbf{4NH_{3(g)} + 5O_{2(g)}}$ **AND** Products on RHS $\mathbf{4NO_{(g)} + 6H_2O_{(g)}}$ **AND** Activation energy correctly labelled / E_a ✓ **Δ*H*** Δ*H* labelled with product below reactant **AND** Arrow downwards ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols ALLOW 1 mark for a correctly labelled endothermic diagram **ALLOW** no arrowhead or arrowheads at both end of E_a line. $\mathbf{E_a}$ E_a line must reach maximum (or near to maximum) on curve For E_a, **ALLOW** AE **OR** A_E **DO NOT ALLOW** −Δ*H* **DO NOT ALLOW** double headed arrow on Δ*H* **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. **ALLOW** −905 for Δ*H* **<u>Examiner's Comments</u>** Most candidates were able to gain the first mark, but many lost the second mark by putting a double headed arrow or −ΔH.
		ii	**FIRST CHECK ON ANSWER LINE** **If answer = 6.79×10^7 (kJ) award 4 marks** **If answer = 2.72×10^8 (kJ) award 3 marks** (no ÷ 4) ——————————————— **n(NH_3)** $= \frac{5.1 \times 10^6}{17} = 3.00 \times 10^5$ (mol) ✓ **Stoichiometry and Δ*H*** 1 mol NH_3 releases $\frac{905}{4}$ **OR** 226.25 (kJ) ✓ **Energy released** $(3.00 \times 10^5) \times \frac{905}{4}$ **OR** 67875000 (kJ) ✓ **Final answer to 3SF AND standard form**	4	**IGNORE** (-) SIGN Throughout: **IGNORE** trailing zeroes in intermediate working, e.g. For *n*(NH_3) **ALLOW** 3×10^5 for 3.00×10^5 ——————————————— – **ALLOW ECF** from incorrect *n*(NH_3) **OR** 905/4 **ALLOW 3 SF** up to calc value correctly rounded. Value will depend on intermediate rounding **Common Errors**

			$= 6.79 \times 10^7$ (kJ) ✓ *standard form* **AND** *3 SF required*		1.09×10^9 (× 4 instead of ÷ 4) 3 marks 2.72×10^8 (no ÷ 4) 3 marks 6.79×10^1 (no tonnes → g) 3 marks **Examiner's Comments** Most candidates were able to convert from tonnes to moles and then went on to complete the majority of the calculation steps. Many omitted to divide by 4 and were credited 3 marks. Some candidates lost marks by not stating the answer to standard form or quoted their answer to more than 3 significant figures. A number of candidates attempted to use Q = mcΔT and did not get very far in the calculation.
			Total	**6**	
5		i	(because energy is needed to break) induced dipole–dipole interactions / London forces between molecules (1)	1	**allow** forces of attraction between molecules **OR** van der Waals' forces **ignore** reference to strong or weak
		ii	Bond breaking (+193) + (+151) = (+)344 **AND** Bond making 2(−175) = (−)350 (1) $\Delta_f H = \frac{(+344)+(-350)}{2} = -3$ (kJ mol^{-1})(1)	2	Correct answer scores 2 marks
			Total	**3**	
6		i	**More** energy is **released** by **forming** bonds than energy **required** when **breaking** bonds ✓	**1**	**ORA** Response needs link between energy, breaking and making bonds **ALLOW** 'bond breaking is endothermic' **AND** 'bond making is exothermic' **ALLOW** within labelled energy diagram **Examiner's Comments** Able candidates provided well- constructed and structured responses, which demonstrated their clear understanding of this key concept. Weaker candidates often responded in terms of bond making requiring energy and that breaking bonds releasing energy. Many responses referred to more bonds instead of more energy.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF bond enthalpy = (+)612 (kJ mol^{-1}) award 3 marks** **IF bond enthalpy = (−)316 (kJ mol^{-1}) award 2 marks**	**3**	**FULL ANNOTATIONS MUST BE USED** ---

			Energy for bonds made (4 × C=O + 4 × O–H) 4 × 805 + 4 × 464 **OR** 3220 + 1856 **OR** 5076 (kJ) ✓ *Energy for bonds broken (4 × C–H + 3 × O=O)* 4 × 413 + 3 × 498 **OR** 1652 + 1494 **OR** 3146 (kJ) ✓ *C=C bond enthalpy correctly calculated* C=C bond enthalpy = −1318 − 3146 + 5076 = (+)612 kJ mol^{-1} ✓ *Mark is for answer*		**IGNORE** sign **IGNORE** sign ------------------------------------ **ALLOW ECF** **DO NOT ALLOW** – sign **COMMON ERRORS** + 2106 omission of 3O=O **2 marks** −3248 −1318 + 3146 − 5076 **2 marks** **Examiner's Comments** This question tested both chemical and mathematical ability. Two marks were available for calculating the energies involved in bond making and bond breaking. Many candidates miscounted the number of bonds involved in the calculation, especially for 3 × O=O and 4 × O−H. Candidates can avoid this error by drawing out each molecule and counting the bonds being broken and made. In calculating the bond enthalpy, weaker candidates often omitted the enthalpy change of reaction, −1318 kJ mol^{-1}, instead simply subtracting the energies already calculated for bonds broken and bonds made. Answer: 612 kJ mol^{-1}
			Total	**4**	
7	a		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = −3919.5 (kJ mol^{-1}) award 3 marks** **IF enthalpy change**	**3**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IF there is an alternative answer, check to see if there is any ECF credit possible**

			= (+)3919.5 (kJ mol^{-1}) award 2 marks .... *Working for CO_2 **AND** H_2O seen anywhere (1 mark)* 6 × (−)393.5 **AND** 6 × (−)285.8 **OR (−)**2361 **AND (−)**1714.8 **OR (−)**4075.8 ✓ *Calculates Δ_cH* **A further 2 marks** for correct answer **AND** correct sign = (6 × −393.5) + (6 × −285.8) − (−156.3) = −3919.5 (kJ mol^{-1}) ✓ ✓		**ALLOW 3 marks for** Δ_cH = −3920 ***FINAL a****nswer rounded to 3 SF* **Common incorrect answers are shown below** **ALLOW 2 marks for** Δ_cH = −3924 *From Δ_cH = (6 χ−394 + 6 ×−286) − (−156)* *Data rounded to 3 sig figs* **ALLOW 2 marks for** Δ_cH = −4232.1 *All data added together* *(6 × −393.5) + (6 × −285.8) + (−156.3)* **ALLOW 1 mark for** ΔcH = (+)4232.1 **Examiner's Comment:** This calculation was generally well answered but there were a variety of errors that could lead to candidates scoring just one or two marks. These included incorrect signs associated with the data during the calculation, adding all the data together or missing out the sign associated with the final answer.
	b	i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = −2510 (kJ mol^{-1}) award 4 marks** **IF answer = 2508 / 2507 (kJ mol^{-1}) award 3 marks** *(not rounded to 3SF, ignore sign)* **IF answer = + 2510 (kJ mol^{-1}) award 3 marks** *(incorrect sign)* **IF answer = −2510000 (kJ mol^{-1}) award 3 marks** *(used J instead of kJ)* .... *Moles* n(C_6H_{14}) = 0.0150 mol ✓ *Energy* q calculated correctly = 37620 (J) **OR** 37.620 (kJ) ✓	**4**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** moles = 1.29/86.0 **IGNORE** trailing zeros

			Calculating ΔH Correctly calculates ΔH in $kJ\ mol^{-1}$ **AND** to **3 or more SF** ✓ *Rounding **AND** sign* calculated value of Δ*H* rounded **to 3 SF** **AND** '-'sign ✓		*q* = 200 × 4.18 × 45.0 **ALLOW** correctly rounded to 3 sig figs: 37.6 kJ **ALLOW** ECF from incorrect q **ALLOW ECF** from incorrect molar mass or incorrect moles of hexane to 3 SF or more correctly rounded **IGNORE** sign at this intermediate stage **IGNORE** working ΔH = 37.62/0.015 = 2508 ($kJ\ mol^{-1}$) ΔH = 37.6/0.015 = 2507 ($kJ\ mol^{-1}$) ΔH = −2510 ($kJ\ mol^{-1}$) Final answer must have '−' **sign** and **3 SF** **Examiner's Comments** A high proportion of candidates lost marks on this question for a variety of reasons including errors in the calculation of moles and / or energy change. Many candidates did not express their final answer to three significant figures and so failed to score the final mark. An incorrect or missing sign also resulted in loss of the final mark.
		ii	**Any two from the following:** ✓ ✓ • Heat released to the surroundings • Incomplete combustion • Non-standard conditions	3	**ALLOW** heat loss **ALLOW** incomplete reaction **OR** not everything burns **IGNORE** reference to evaporation **Examiner's Comment:** Almost all candidates scored at least one mark for this well-rehearsed practical question. There was some confusion regarding the use of average bond enthalpy values obtained from a data book which was not relevant to this question.
			Total	**9**	

8		i	 Zn and H_2SO_4 on LHS **AND** $ZnSO_4$ + H_2 on RHS ✓ Δ*H* labelled with product below reactant **AND** arrow downwards ✓ E_a **AND** E_c correctly labelled with E_c below E_a ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** state symbols. Δ***H***: **DO NOT ALLOW** −Δ*H* **ALLOW** this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line $\boldsymbol{E_a}$: **ALLOW** no arrowhead or arrowheads at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve **OR** span approximately 80% of the distance between reactants and maximum regardless of position **ALLOW** AE or A_E for E_a **Examiner's Comments** Many candidates are well-prepared for this type of question however there are still some issues regarding the use of double headed arrows to indicate an enthalpy change. Whilst allowed by the examiners for showing activation energies, a correct single headed arrow was required to illustrate Δ*H*. A small proportion of candidates omitted hydrogen as a product, despite it being stated in the question.
		ii	 Correct drawing of a Boltzmann distribution curve ✓ Axes labelled y axis: (number of) molecules **AND** x axis: (kinetic) energy ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the origin. Curve must not touch the x-axis at higher energy **IGNORE** a slight inflexion on the curve

			Catalyst lowers the activation energy (by providing an alternative route) ✓ **QWC** - (With a catalyst a) greater proportion of molecules with energy greater than activation energy **OR** (With a catalyst a) greater proportion of molecules with energy equal to the activation energy **OR** (With a catalyst there is a) greater area under curve above the activation energy ✓		**DO NOT ALLOW** two curves **DO NOT ALLOW** a curve that bends up at the end by more than one small square **ALLOW** particles instead of molecules on y axis **DO NOT ALLOW** enthalpy for x-axis label **DO NOT ALLOW** atoms instead of particles or molecules **ALLOW ECF** for the subsequent use of atoms (instead of molecules or particles) **ALLOW** annotations on Boltzmann distribution diagram **QWC** requires more molecules have / exceed activation energy / E_a. **IGNORE** more molecules have enough energy to react for the **QWC** mark (as not linked to E_a) **ORA** if states the effect with no catalyst **IGNORE** (more) successful collisions **Examiner's Comments** Candidates are very familiar with the Boltzmann distribution curve and there were many examples of excellent diagrams. The majority of candidates scored maximum marks in this part. Failure to identify that more molecules have an energy greater than the activation energy when a catalyst is used, was a common reason why only three marks were scored.
			Total	**7**	
9	a	i	**IF $\Delta H_r = -347$ (kJ mol^{-1}) award 4 marks** **IF $\Delta H_r = (+)347$ (kJ mol^{-1}) award 3 marks (incorrect sign)** **…………………………………………………………** **Moles** Amount, $n(CuSO_4)$, calculated correctly = 0.0125 (mol) ✓ **Energy** *q* calculated correctly = 4336.75 (J) **OR** 4.33675 (kJ) ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Note:** $q = 25.0 \times 4.18 \times 41.5$ **ALLOW** 3 SF up to calculator value of 4336.75

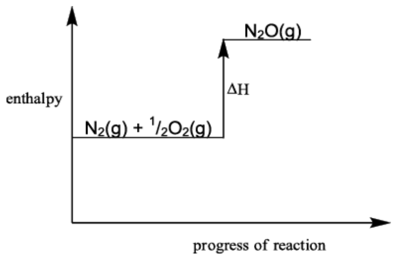
			Calculating Δ*H* correctly calculates *ΔH* in kJ mol^{-1} to 3 or more sig figs ✓ **Rounding and Sign** calculated value of *ΔH* rounded to 3 sig. fig. with minus sign ✓		J **IGNORE** sign **IGNORE** working **Note:** from 4336.75 J and 0.0125 mol Δ*H* = (-)346.940 kJ mol^{-1} **IGNORE** sign at this intermediate stage **ALLOW ECF** from *n*($CuSO_4$) and / or energy released Final answer must have **correct sign** and **three sig figs** Answer is still −347 from rounding of *q* to 4340 J **Examiner's Comments** Almost all candidates recognised the first step of this unstructured calculation was to use the *mc ΔT* expression to determine the energy change. The majority of the cohort subsequently divided this by the moles of $CuSO_4$ to obtain a value for ΔH_r. A significant proportion of responses did not include a sign for the enthalpy change and so only scored three marks. A small number of candidates gave incomplete responses, often rounding the energy change to three significant figures, rather than processing it further. Answer: −347 kJ mol^{-1}
		ii	Minimum mass = 0.0125 × 24.3 × 1.25 = 0.38(0) g ✓	3	**ALLOW ECF** for mass correctly rounded to 2 dp from incorrect moles of $CuSO_4$ in **3(a)(i)** **Examiner's Comments** The majority of candidates were able to link the moles of $CuSO_4$ with the balanced equation to determine the moles of Mg reacting and hence suggest a mass. However, only the strongest candidates were able to scale the quantity required to take into account the excess.
	b	i	(enthalpy change that occurs) when one mole of a substance ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** one mole of a compound **OR** one mole of an element **ALLOW** combusts in excess oxygen

			completely combusts **OR** reacts fully with oxygen ✓ 298 K / 25 °C **AND** 1 atm / 100 kPa / 101 kPa / 10^5 Pa / 1 bar ✓		**ALLOW** burns in excess oxygen Combusts in excess air is **not** sufficient **IGNORE** reference to concentration **Examiner's Comments** This definition is well known by candidates and the majority scored all three marks. A significant proportion of the cohort only scored two as the standard conditions were often omitted. Candidates should be encouraged to read questions carefully to ensure they include all the required information in their responses.
		ii	**IF answer = −281 (kJ mol^{-1}), award 2 marks** **IF answer = (+)281 (kJ mol^{-1}), award 1 mark** ………………………………………………………… Working for C **AND** H_2 seen anywhere 9 × (−)394 **AND** 10 × (−)286 **OR** (−)3546 **AND** (−)2860 **OR** (−)6406 ✓ Calculates ΔH_c correctly −6406 − −6125 = −281 kJ mol^{-1} ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IF there is an alternative answer, check to see if there is any ECF credit possible** **Common incorrect answers are shown below** **Award 1 mark for** 5445 (not used × 9 and × 10) 2871 (not used × 9) 2293 (not used × 10) **Examiner's Comments** In general candidates approached this calculation confidently and applied Hess' law accurately. Some candidates failed to take into account the mole ratios, but subsequently processed their values correctly. Consequently the majority of candidates scored one or two marks. Answer: −281 kJ mol^{-1}
	c	i	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**IGNORE** energy required **OR** energy released **DO NOT ALLOW** bonds formed **IGNORE** heterolytic / homolytic **Examiner's Comments** Most candidates were able to recall that bond enthalpy referred to the energy change occurring when bonds are broken, but weaker responses included contradictions by also mentioning bond formation. The strongest candidates were able to state that bond enthalpy referred to one mole of bonds but a significant proportion of candidates incorrectly

					referred to one mole of molecules or made no reference to this quantity.
		ii	**IF answer = (+)1062 (kJ mol^{-1}), award 3 marks** **IF answer = −1062 (kJ mol^{-1}), award 2 marks** **……………………………………………………** (ΔH for bonds broken =) 2580 (kJ mol^{-1}) **OR** 1652 **AND** 928 (kJ mol^{-1}) ✓ (ΔH for bonds formed =) 1308 (kJ mol^{-1}) ✓ (bond enthalpy CO = 2580 − 1308 − 210) = (+)1062 (kJ mol^{-1}) ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** sign **IGNORE** sign **ALLOW ECF** **IGNORE** rounding of 1062 to 1060 and credit 1062 from working **Award 2 marks for** ±1272 (from ±(2580 – 1308)) ±1482 (from ±(2580 – 1308 + 210)) **Examiner's Comments** Almost all candidates were able to process the bond enthalpy data and mole ratios to arrive at values for the energy required to break bonds in the reactants and the energy released by the formation of H–H bonds in the products. The most able candidates processed these values alongside the enthalpy change provided in the question to arrive at the correct answer. Common incorrect responses included +1482 kJ mol^{-1} and +1272 kJ mol^{-1}, the latter of which was caused by failure to use the ΔH value provided. Answer: +1062 kJ mol^{-1}.
			Total	**15**	
10	a		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF $\Delta_r H$ = −58.5 (kJ mol^{-1}) award 4 marks** __________________________ ***Energy released in J OR kJ*** = 100.0 × 4.18 × 10.5 = 4389 (J) **OR** 4.389 (kJ) ✓ ***Correctly calculates n(Pb(NO$_3$)$_2$)***	4	***FULL ANNOTATIONS MUST BE USED*** ----------------------------------- **ALLOW** 4390 J; 4.39 kJ **DO NOT ALLOW** less than 3 SF **IGNORE** units *i.e. **ALLOW** correctly calculated number in J **OR** kJ*

			$= 1.50 \times \frac{50}{1000}$ = 0.075(0) (mol) ✓ **ΔH value in J OR kJ** *Answer **MUST** divide energy by n($Pb(NO_3)_2$)* (–) $\frac{4389}{0.0750}$ **OR** (–)58520 (J) **OR** (–) $\frac{4.389}{0.0750}$ **OR** (–)58.52 (kJ) ✓*(Sign ignored and/or more than 3 SF)* Correct $\Delta_r H$ in kJ **AND** – sign AND 3 SF = –58.5 (kJ mol^{-1}) ✓		**ALLOW ECF** from *n*($Pb(NO_3)_2$) **AND/OR** Energy **ALLOW** 58500 (from 4390) **IGNORE** absence of – sign and 3 SF requirement Final mark requires – sign, kJ **AND** 3 SF **Note**: From 4390 J, $\Delta_r H$ = −58.5 (kJ mol^{-1}) (SAME) -- **Common error** −29.3 3 marks (50 g instead of 100 g in $mc\Delta T$) **Examiner's Comments** Although similar in style to unstructured direct enthalpy calculations on the legacy specification, this question was harder for two reasons. Firstly, two volumes of 50 cm^3 had to be added together to generate m as 100 g for $mc\Delta T$. Secondly, candidates were asked to quote their final answer to an 'appropriate' number of significant figures. This will be the least accurate measurement (to 3 significant figures in this example). Many incorrect answers used *m* as 50 g or quoted a final numerical value to more than 3 significant figures. Even after obtaining a correct final value for ΔH, this was often not given a negative sign to indicate the exothermic change. It is important for candidates to show clear working so that markers can see what is intended and able to apply credit using error carried forward. Answer: ΔH = −58.5 kJ mol^{-1}
	b		$Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI^2(s)$ ✓ **State symbols required**	1	**ALLOW** $Pb^{+2}(aq)$ **IGNORE** spectator ions, $K^+(aq)$ and $2NO_3^-(aq)$ on both sides

					Examiner's Comments Only the best candidates were able to construct the required equation. Even when written correctly, state symbols (asked for in the question) were often omitted or shown incorrectly. Although very similar to the ionic equation for formation of silver halides, this equation was beyond most candidates at this stage of their chemistry studies.
	c		**FIRST, CHECK ANSWER ON ANSWER LINE** **IF [KI(aq)] rounds to 3.3 mol dm^{-3}** e.g. 3.30, 3.33, 3.3 recurring --- **Method 1** [KI(aq)] for complete reaction $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{50} = 3 \text{ (mol dm}^{-3}\text{)}$ ✓ 10% greater gives 3 × 1.1 = 3.3(0) ✓ **OR**--- **Method 2** *n*(KI(aq)) required = 2.2 × 0.0750 = 0.165 mol ✓ $[\text{KI(aq)}] = 0.165 \times \frac{1000}{50} = 3.3(0) \text{ (mol dm}^{-3}\text{)}$ ✓	2	**ALLOW ECF** from incorrect *n*($Pb(NO_3)_2$) from **24(a)** **BUT** if **(a)** is incorrect but 0.0750 used here, treat as a fresh start and **IGNORE** response from **24(a)** **ALLOW** 2 marks for 3.3/3.3 recurring *Attempt at increasing concentration by 10%* $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{45} = 3.33 \text{ (mol dm}^{-3}\text{)}$ **ALLOW ECF** from incorrect *n*(KI) ______________________________ **Common errors** 3 — 1 mark (Correct for KI with no extra 10%) 1.65 — 1 mark (no factor of 2 used for KI) 2.7 — 1 mark (10% less rather than 10% more) 2.73/2.72 — 1 mark (10% increase in volume: 55 cm^3) **Examiner's Comments** This part was well attempted with many candidates able to score at least one of the two marks. Errors related to use of an incorrect mole ratio, applying 10% incorrectly, or ignoring 10% altogether. Answer: 3.30 mol dm^{-3}
			Total	**7**	
11		i	More energy is required for bond breaking than is released by bond making ✓	1	

					Examiner's Comments The poor quality of answers observed surprised the Examiners as this question had featured a number of times on legacy papers which would have been used in Centres to prepare candidates for this examination. Many candidates were not able to explain that bond breaking requires energy whereas bond making produces energy. For the reaction to be endothermic more energy is required to break bonds than is evolved when bonds are formed. In their answers candidates frequently stated that both processes required energy or that more bonds were broken than were formed.
		ii	Enthalpy profile diagram • ΔH labelled **OR** 82 on vertical arrow • Products above reactants (either chemical symbols or the words products and reactants) • Arrow upwards ✓ Formulae **AND** state symbols $N_2(g) + ½O_2(g) \rightarrow N_2O(g)$ ✓	2	 **IGNORE** activation energy **DO NOT ALLOW** multiples of equation: 1 mole of N_2O is formed **Examiner's Comments** Half of the candidates scored zero for this question, many failing to label the enthalpy change or to show this as an arrow pointing upwards. Although the question stated that the activation energy was not required, candidates frequently included it in their diagrams and then labelled it ΔH. Many Candidates did not write the formula of the reactants or products and those who did multiplied the species by two so as the diagram did not represent the enthalpy of formation.
			Total	**3**	
1 2		i	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**IGNORE** energy required **OR** energy released **DO NOT ALLOW** bonds formed **Examiner's Comments** Candidates were required to recall the definition of bond enthalpy in this question and a range of responses were seen. Most candidates recognised that bond breaking was important, but weaker responses included

					contradictions by also referring to bond formation. The strongest candidates were able to state that bond enthalpy referred to one mole of bonds but it was not uncommon to see answers such as 'one mole of compound' and 'one mole of substance'.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = −42 (kJ mol^{-1}) award 3 marks** **IF enthalpy change = +42 (kJ mol^{-1}) award 2 marks** (Energy for bonds broken) = 5538 (kJ) ✓ (Energy for bonds made) = 5580 (kJ) ✓ ΔH_r = −42 (kJ mol^{-1}) ✓	3	**IF there is an alternative answer, check to see if there is any ECF credit possible.** two common incorrect answers are: −970 (kJ mol^{-1}) award 2 marks +970 (kJ mol^{-1}) award 1 mark **IGNORE** signs **ALLOW** 1076 (bonds broken); 1118 (bonds made) Correct sign required **ALLOW ECF** for bonds broken – bonds made **IF** at least one molar ratio is used e.g. 8 × C–H **Examiner's Comments** Candidates approached this question well and the majority of responses were clearly and logically presented. The strongest candidates were able to identify all the bonds broken and formed and calculate the correct enthalpy change. Some candidates carried out the final step incorrectly, arriving at a value of +42 kJ mol^{-1}. A common mistake was to omit the bonds broken in water, giving an enthalpy change of −970 kJ mol^{-1}. Other mistakes were seen and error carried forward marks were awarded where appropriate. Candidates are advised to draw displayed formulae to help identify the number of each type of bond to be used in their calculation. Answer: −42 kJ mol^{-1}
			Total	**5**	
13	a	i	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF ΔH_c = −2260 (kJ mol^{-1}) award 4 marks** **IF ΔH_c = (+)2260 (kJ mol^{-1}) award 3 marks (incorrect sign)** **IF ΔH_c = (±)2257(.2) (kJ mol^{-1}) award 3 marks (not 3 sf)**	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**

			Moles Amount, *n*, $C_5H_{12}O$ calculated correctly = 0.0175 (mol) ✓ **Energy** *q* calculated correctly = 39501 (J) **OR** 39.5(01) (kJ) ✓ **Calculating ΔH** correctly calculates ΔH in kJ mol^{-1} to 3 or more sig figs ✓ **Rounding and Sign** calculated value of ΔH rounded to 3 sig. fig. with minus sign✓		**Note**: $q = 180 \times 4.18 \times 52.5$ **ALLOW** 39501 **OR** correctly rounded to 3 sig. fig. (J) **IGNORE** sign **IGNORE** working **Note**: from 39501 J and 0.0175 mol ΔH = (−)2257.2 kJ mol^{-1} **IGNORE** sign at this intermediate stage **ALLOW** ECF from incorrect q and / or incorrect n Final answer must have **correct sign** and **three sig figs** **Examiner's Comments** Candidates coped well with this unstructured calculation. Almost all candidates recognised the first step was to use the *mc*ΔT expression to determine the energy change and subsequently divided this by the moles of alcohol **J** to obtain a value for ΔH_c. A significant proportion of responses across the whole ability range did not include a sign for the enthalpy change or did not round the final answer to three significant figures and so only scored three marks. Candidates should be aware that when a question includes a requirement to round the final answer to a stated number of significant figures, failure to do so will prevent full marks from being awarded. Answer: −2260 kJ mol^{-1}
		ii	**ANY TWO FROM THE FOLLOWING ✓✓** incomplete combustion non-standard conditions evaporation of alcohol / water specific heat capacity of beaker / apparatus	2	**IGNORE** heat loss (*in question*) **ALLOW** burns incompletely **IGNORE** incomplete reaction **Examiner's Comments** This question proved hard for candidates and although one of incomplete combustion or reference to non-standard conditions was

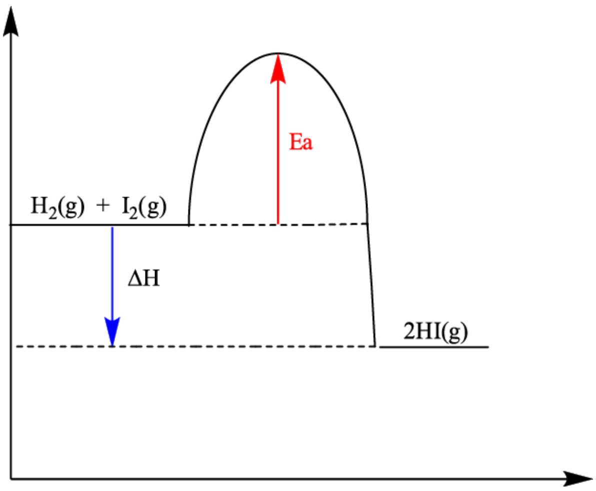
					frequently mentioned, such responses were often accompanied by vaguer statements. These statements included reference to data books containing average values, or mention of human or equipment error, e.g. the mass of alcohol was measured incorrectly. Consequently many candidates scored one, with only the best candidates securing both marks.
	b	i	$5C(s) + 6H_2(g) + ½O_2(g) \rightarrow C_5H_{12}O(l)$ ✓	1	Balancing numbers **AND** species **AND** states all required **DO NOT ALLOW** multiples of this equation **Examiner's Comments** Many candidates were able to provide a correctly balanced equation for the enthalpy of formation of alcohol **J**. However, it was often the case that no state symbol was provided for **J**. A significant proportion of candidates suggested an incorrect state symbol for **J**, *viz*. (aq). While others gave no state symbols at all. Candidates should be encouraged to check questions carefully when asked to give an equation to avoid omitting required information.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = −3320 (kJ mol⁻¹) award 3 marks** **IF enthalpy change = (+)3320 (kJ mol⁻¹) award 2 marks** ………………………………………………… Working for CO_2 **AND** H_2O seen anywhere 5 × (−)394 **AND** 6 × (−)286 **OR** (−)1970 **AND** (−)1716 **OR** (−)3686 ✓ Calculates ΔH_c **A further 2 marks** for correct answer **AND** correct sign = 5 × −394 + 6 × −286 − −366 = −3320 (kJ mol^{-1}) ✓✓ **A further 1 mark** for correct answer **AND** incorrect or no sign = (+)3320 (kJ mol^{-1}) ✓ *Cycle wrong way around:* *−366 − (5 × −394 + 6 × −286)*	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IF there is an alternative answer, check to see if there is any ECF credit possible** **Common incorrect answers are shown below** **Award 2 marks for** −1744 **OR** −1890 **OR** −314 **OR** −4052 **Award 1 mark for** 1744 **OR** 1890 **OR** 314 **OR** 4052 **Examiner's Comments** Candidates appeared well prepared for this type of calculation and the majority scored full marks. A significant proportion failed to give the correct sign, and received two marks. Answer: −3320 kJ mol^{-1}
			Total	**10**	

14	a		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = −38.3 (kJ mol⁻¹) award 4 marks** **IF answer = (+)38.3 (kJ mol⁻¹) award 3 marks (incorrect sign)** **IF answer = -38,300 (kJ mol⁻¹) award 3 marks (used J instead of kJ).** **Energy** q calculated correctly = 1149.5(J)✓ **OR** 1.1495 (kJ) ✓ **Moles** Amount, n, of Na_2CO_3 calculated correctly= 0.03(00) ✓ **Calculating Δ*H*** correctly calculates ΔH in kJ mol^{-1} to 3 or more sig figs✓ **Rounding and Sign** calculated value of ΔH rounded to 3 sig. fig. with minus sign✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note**: $q = 50.0 \times 4.18 \times 5.5$ **ALLOW** 1149.5 **OR** correctly rounded to 3 sig figs (J) **IGNORE** sign **IGNORE** working **ALLOW** 53.18 × 4.18 × 5.5 **OR** 1222.6082 **OR** 1220 OR correctly rounded to 3 or more sig figs in J or kJ **IGNORE** working **IGNORE** trailing zeros **IGNORE** sign at this intermediate stage **ALLOW** ECF from incorrect q and / or incorrect n Final answer must have **correct sign** and **three sig figs** **ALLOW** −40.8 kJ mol^{-1} if 53.18 used in calculation of q **ALLOW** −40.7 kJ mol^{-1} if q is rounded to 1220 from 53.18 earlier **Examiner's Comments** Candidates coped well with this unstructured calculation. Almost all candidates recognised the first step was to use the $mc\Delta T$ expression to determine the energy change and subsequently divided this by the moles of Na_2CO_3 to obtain a value for ΔH_r. A significant proportion of responses across the whole ability range did not include a sign for the enthalpy change. Candidates should be encouraged to quote all enthalpy changes with the appropriate sign, so that they receive the credit they deserve. Common incorrect responses included using the mass of the carbonate rather than the volume of acid as m in the $mc\Delta T$ expression. Some candidates used the moles of HC*l* rather than Na_2CO_3 when calculating ΔH_r. Error carried forward marks were awarded, where

					appropriate, in each of these cases. Consequently the majority of candidates scored in this part. The most common marks were 3 and 4, which were awarded in roughly equal proportions.
	b	i	(Enthalpy change) when one mole of a compound ✓ is formed from its elements ✓ 298 K / 25 °C **AND** 1 atm / 100 kPa / 101 kPa / 1 bar ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** one mole of substance **OR** one mole of product **DO NOT ALLOW** one mole of element **IGNORE** reference to concentration **Examiner's Comments** Candidate were well prepared to quote this definition and many candidates scored full marks. Some candidates neglected to give the standard conditions or quoted incorrect values.
		ii	$\frac{1}{2}N_2(g) + 2H_2(g) + \frac{1}{2}Cl_2(g) + 2O_2(g) \rightarrow NH_4ClO_4(s)$ correct species ✓ correct state symbols **and** balancing ✓	2	**Second mark can only be awarded if all species in the equation are correct** **DO NOT ALLOW** multiples of this equation **Examiner's Comments** This question required candidates to apply the knowledge of the definition given in the previous part and provide an equation for the formation of ammonium chlorate(VII). Stronger candidates were able to do this, but some balanced the equation incorrectly and formed two moles of the compound. It was common to see incorrect formulae and weaker candidates were unable to state the formula of chlorine, which was given as C*l*. Nitrogen was also show as N. Candidates should be aware that being able to state formulae of elements is required at this level.
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = (+)90 award 3 marks** **IF answer = −90 award 2 marks** **IF answer = ±270 award 2 marks** **IF answer = ±2947 award 1 mark** **Processing ΔH_f values** ±(3832 − 885) ±2947✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note**: ±2947 = ± [−1676 + (−704) + (6 x −242)] − (3 x −295)]

			OR ± (3832 − 885) **subtraction using ΔH reaction** ±(2947–2677)= ±270 ✓ **Calculation of ΔH formation NO** 270/3 = (+)90 ✓		**ALLOW ECF** for dividing by 3 from working that includes at least one ΔH_f and one balancing number and ΔH (−2677) for 1 mark **Examiner's Comments** The majority of candidates made a good attempt at this question and provided structured responses. The most common approach adopted by candidates was to use the ΔHf data given in the table and the stoichiometry ratios from the equation to calculate the difference between the reactants and products, −2497 kJ mol^{-1}. This value was then subtracted from the enthalpy change of the reaction to give +270 kJ mol^{-1}. The strongest candidates recognised the need to divide this by three to obtain the enthalpy change of formation of NO. Some candidates carried out their subtractions in the intermediate stages incorrectly and consequently arrived at a value of −90 kJ mol^{-1}. This response received two marks. Error carried forward credit was awarded to candidates who incorrectly processed ΔH_f data, stoichiometric ratios and the enthalpy change of the reaction provided their final answer was divided by three. Consequently the majority of candidates scored at least one mark in this question.
			Total	**12**	
15	a		(+)182 ✓	1	This is the **ONLY** acceptable answer **Examiner's Comments** Most candidates were able to correctly process the E_a and ΔH values provided to calculate the activation energy of the reverse reaction. Some candidates subtracted ΔH from the E_a value to give an answer of 164 kJ mol^{-1}. Other candidates reversed the sign of the activation energy provided to give —173 kJ mol^{-1}.
	b		**Look at answer if +63 kJ AWARD 2 marksIf 63 (no sign) OR-63 (incorrect sign) AWARD 1 mark** No of moles of HI = 14 moles ✓	2	**ALLOW** one mark for +126 kJ Sign and value required. **ALLOW** ECF from incorrect number of moles

			Enthalpy Change = +63 kJ ✓		of HI **Examiner's Comments** Many candidates were able to tackle the first part of this question confidently to obtain the correct value for the moles of hydrogen iodide that decomposed. The second marking point proved more difficult, and candidates were expected to scale the enthalpy change given, in addition to providing the correct sign for this process, which is the reverse reaction of the equilibrium shown. The very best candidates were able to achieve the second mark. Common errors included incorrect scaling, to give the enthalpy change as +126 kJ mol^{-1} ,or showing the incorrect sign, −63 kJ mol^{-1} or not providing the sign, 63 kJ mol^{-1}.
	c		**Look at answer if (+)298 AWARD 2 marks** **If answer is -298 AWARD 1 mark (incorrect sign)** **2 x H-I bond enthalpy correctly calculated** (436 +151-(-9) =) (+)596 ✓ **H-I bond enthalpy correctly calculated** (Bond energy for H-I $\frac{(+)596}{2}$ =) (+)298 kJ mol^{-1} ✓	2	**ALLOW** 1 mark for (+)293.5 kJ mol^{-1} (bonds broken divided by 2) **ALLOW** 1 mark for (+)289 kJ mol^{-1} (incorrect expression i.e. $\frac{[436 + 151 + (-9)]}{2}$) **Examiner's Comments** This question required candidates to process the bond enthalpy data and value for Δ*H* to obtain a value of the bond enthalpy of H—I. In general the responses were much better than for a similar question asked in the January 2012 session and most candidates were able to score at least one mark. The most common error was a failure to divide by two, resulting in an answer of +596 kJ mol^{-1}. Another common incorrect response included the incorrect subtraction of Δ*H* from the bond enthalpy to give a value of +289 kJ mol^{-1}. Some candidates neglected to use Δ*H* and arrived at a value of +293.5 kJ mol^{-1}. All these responses received one mark. This question discriminated well and the most able candidates scored both marks.
	d		**There are 3 marking points required for 2 marks**	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**

			 H_2 and I_2 on LHS **AND** 2HI on RHS **AND** correctly labelled Ea ✓ ΔH labelled with product below reactant **AND** arrow downwards ✓		**IGNORE** state symbols. E_a: **ALLOW** (+)173 only as an alternative label for Ea **ALLOW** no arrowhead or arrowheads at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve **OR** span approximately 80% of the distance between reactants and maximum regardless of position **ALLOW** AE or A_E for E_a ΔH: **IF** there is no ΔH labelled **ALLOW** −9 as an alternative label for ΔH. **IF** ΔH is labelled **IGNORE** any numerical value. **DO NOT ALLOW** $-\Delta H$. **ALLOW** this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line **Examiner's Comments** Many candidates are well-rehearsed for this type of question, however there are still some issues regarding the use of double headed arrows to indicate an enthalpy change. Whilst allowed by the examiners for showing E_a, a correct single headed arrow was required to illustrate ΔH.
			Total	**7**	
16		i	$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$ (1)	1	**allow** multiples
		ii	*Energy (into water) mark* 70.0 × 4.18 × 16.5 = 4827.9 (J) or 4.8279 (kJ) (1) *amount of substance mark* $n(H_2O) = \frac{35.0}{1000} \times 2.40 = 0.084(0)$ (mol) $\Delta_{neut}H$ *mark* (−)4.8279 / 0.084(0) = (−)57.475 **OR** (−)57.48 **OR** (−)57.5 (1) Correctly rounded to at least 3 significant figures	3	**allow** rounding to 4828 **OR** 4830 **allow** amount of substance mark to be based upon either HC*l* or NaOH **allow ecf** for $\frac{\text{Energy (into water) mark}}{\text{Amount of substance mark}}$
		iii	1 mole of water had been formed (1)	1	
		iv	$\frac{2 \times 0.5}{16.5} \times 100 = 6\%$ (1)	1	

			Total	**6**	
1 7	a		One mole of butane completely combusts in oxygen	1	**allow** One mole forms CO_2 and H_2O only
	b		**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = +215 (kJ mol^{-1}) award 2 marks **IF** answer = −215 (kJ mol^{-1}) award 1 mark -- RHS (−2877 + (2 x −2058) = (−)6993 (kJ mol^{-1}) (1) ($\Delta_r H$ =) −6778 + (+6993) = +215 (kJ mol^{-1}) (1)	2	**ignore** incorrect sign at this stage **sign required** for final answer
			Total	**3**	