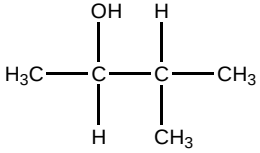
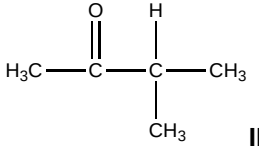
Question			Answer	Mark	Guidance
1	(a)		Method 1: 100% **OR** (only) one product **OR** no waste product **OR** addition (reaction) ✓ Method 2: < 100% **AND** two products **OR** (also) produces NaBr **OR** (There is a) waste product **OR** substitution (reaction) ✓	**2**	**ALLOW** co-product or by-product for waste product For '< 100%' **ALLOW** not 100% **OR** method 2 has a low(er) atom economy (compared to method 1) **IGNORE** produces Br^-/ Na^+ **DO NOT ALLOW** incorrect waste products e.g. Br_2, HBr, Br, Na **ALLOW** correctly calculated value of 42 or 41.8 up to calculator value of 41.83154324 correctly rounded for second mark **DO NOT ALLOW** incorrect values for the atom economy of method 2. **ALLOW ONLY** 1 mark for a statement that both methods have 100% atom economy.
	(b)		Acid ✓	**1**	**ALLOW** H^+ / named mineral acid / H_2SO_4 / H_3PO_4 **DO NOT ALLOW** 'weak acid' e.g. ethanoic acid **IGNORE** pressure **IGNORE** temperature

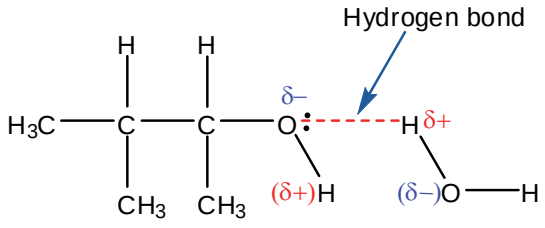
Question			Answer	Mark	Guidance
	(c)	(i)	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**IGNORE** energy required **OR** energy released **DO NOT ALLOW** bonds formed
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = –42 (kJ mol^{-1}) 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 x C–H

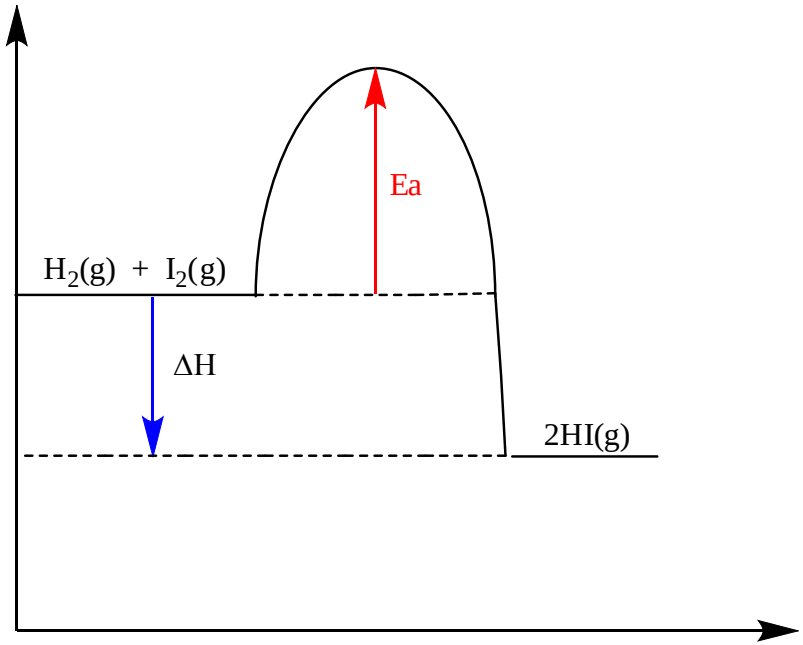
Question			Answer	Mark	Guidance
	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF mass = 8.21 (g) award 3 marks** **Actual** $n(C_4H_9OH)$ produced = $\frac{3.552}{74}$ = 0.048 (mol) ✓ **theoretical** $n(C_4H_9OH) = n(C_4H_9Br) = 0.048 \times \frac{100}{80}$ = 0.06 (mol) ✓ Mass of C_4H_9Br = 0.06 × 136.9 = 8.21 (g) ✓ ***3 SF required***	**3**	**ALLOW ECF** at each stage **ALLOW** expected mass $C_4H_9OH = 3.552 \times \frac{100}{80}$ = 4.44 (g) **ALLOW** Mass C_4H_9Br reacted = 0.048 × 136.9 = 6.5712 (g) **ALLOW** Mass of C_4H_9Br used $= 6.5712 \times \frac{100}{80}$ = 8.21 (g) **DO NOT ALLOW** 8.22 (*from use of 137 as M_r of C_4H_9Br*)
			Total	**11**	

Question			Answer	Mark	Guidance
2	(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)** **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✓	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC **Note:** *q* = 180 × 4.18 × 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**
		(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

Question			Answer	Mark	Guidance
	(b)	(i)	$5C(s) + 6H_2(g) + ½O_2(g) \longrightarrow C_5H_{12}O(l)$ ✓	1	Balancing numbers **AND** species **AND** states all required **DO NOT ALLOW** multiples of this equation
		(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** **OR** (–)3686 ✓ (–)1716 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

Question	Answer	Mark	Guidance
(c)	**QWC:** Evidence of the **IR** absorption at 1720 (cm^{-1}) for presence of C=O/carbonyl group ✓ **QWC**: No carboxylic acid OH absorption in IR **OR** no peak between 2500–3300 cm^{-1} **AND** so **J** is a secondary alcohol **OR** so **K** is a ketone ✓ **Alcohol J**  ✓✓ **Compound K** Structure of a carbonyl compound that could be obtained from alcohol **J** ✓ **Equation** Balanced equation for conversion of **J** to **K** ✓ **e.** $CH_3CHOHCH(CH_3)_2 + [O] \longrightarrow CH_3COCH(CH_3)_2 + H_2O$	**6**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **BOTH IR** at ~1720 (cm^{-1}) **AND** C=O required **ALLOW** ranges from *Data Sheet*, i.e. C=O within range 1640–1750 cm^{-1}; **IGNORE** any reference to C-O absorption For structures of **J** and **K**, **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** any names given for **J** and **K** **ALLOW** 1 mark for the structure of an alcohol with the molecular formula $C_5H_{12}O$ **DO NOT ALLOW** pentan-1-ol (*primary and unbranched*) or 2-methylbutan-2-ol (*branched but tertiary*) **DO NOT ALLOW** any marks for **J** and **K** if more than one structure is given for **J** **Note:** 'sticks' in either **J** and/or **K** will lose only 1 mark **ALLOW** 1 mark for:  **IF** a structure is not given for **J** **NOTE:** structures for **J** and **K** could be awarded from the equation, even if not labelled. **ALLOW** molecular formulae in equation i.e. $C_5H_{12}O + [O] \longrightarrow C_5H_{10}O + H_2O$ **DO NOT ALLOW** equations that form a carboxylic acid

Question			Answer	Mark	Guidance
	(d)		**Labelled** diagram showing at least one H-bond between alcohol molecule and water ✓ e.  	1	**IF** diagram is not labelled **ALLOW** Hydrogen bonds / H bonds from text Diagram should include role of an O lone pair and dipole charges on each end of H bond. **IGNORE** alcohol R group, even if wrong **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	17	

Question			Answer	Mark	Guidance
3	(a)		**There are 3 marking points required for 2 marks**  H_2 and I_2 on LHS **AND** 2HI on RHS **AND** correctly labelled Ea ✓ Δ*H* labelled with product below reactant **AND** arrow downwards ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **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 Δ*H* labelled **ALLOW** –9 as an alternative label for Δ*H*. **IF** Δ*H* is labelled **IGNORE** any numerical value. **DO NOT ALLOW** –ΔH. **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
	(b)		(+)182 ✓	1	This is the **ONLY** acceptable answer

Question			Answer	Mark	Guidance
	(c)		**Look at answer if +63 kJ AWARD 2 marks** **If 63 (no sign) OR-63 (incorrect sign) AWARD 1 mark** No of moles of HI = 14 moles ✓ Enthalpy Change = +63 kJ ✓	**2**	**ALLOW** one mark for +126 kJ Sign and value required. **ALLOW** ECF from incorrect number of moles of HI
	(d)	**(i)**	Rate of the forward reaction is equal to the rate of the reverse reaction ✓ **OR** concentrations do not change✓	**1**	**ALLOW** both reaction**s** occur at same rate **IGNORE** conc. of reactants = conc. of products
		(ii)	 More H_2 and I_2 **OR** less HI ✓ (equilibrium position shifts) to the left **AND** (Forward) reaction is exothermic **OR** reverse reaction is endothermic **OR** in the endothermic direction✓	**2**	**Mark each point independently** **ALLOW** more reactants **OR** less products **Note: ALLOW** suitable alternatives for to the left e.g. towards reactants **OR** towards H_2 / I_2 **OR** in reverse direction **OR** favours the left. **ALLOW** gives out heat for exothermic **ALLOW** takes in heat for endothermic **IGNORE** responses in terms of rate
		(iii)	No effect **AND** Same number of (gaseous) moles on both sides ✓	**1**	 **ALLOW** same number of molecules on each side

Question			Answer	Mark	Guidance
	(e)		**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. [$\frac{436 +151+(-9)}{2}$])
			Total	**11**	

Question			Answer	Mark	Guidance
4	(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 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✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note**: q = 50.0 × 4.18 × 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
	(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

Question			Answer	Mark	Guidance
		(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
		(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✓ **OR** ± (3832 – 885) **subtraction using ΔH reaction** ±(2947-2677)= ±270 ✓ **Calculation of ΔH formation NO** 270/3 = (+)90 ✓	**3**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note:** ±2947 = ± [–1676 + (–704) + (6 x –242)] – (3 x –295)] **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
			Total	**12**	

Question			Answer	Marks	Guidance
5	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = –4596, award **3 marks.** **IF** answer = +4596 award **2 marks.**	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below
			(–)116 ✓		**ALLOW** 116 **OR** –4(+54) –5(–20) **OR** –216 + 100
			(–)4480 ✓		**ALLOW** 4480 **OR** 4(–394) + 12(–242) **OR** –1576 – 2904
			–4596 ✓		**ALLOW** ecf from $\Delta H_{products} - \Delta H_{reactants}$ **ALLOW for 2 marks** (+)4596 (cycle the wrong way round) **OR** –4364 ($\Delta H_{reactants}$ the incorrect sign) **OR** (+)4364 ($\Delta H_{products}$ the incorrect sign) **OR** –752 (moles not used for products) **OR** –4514 (moles not used for reactants) **ALLOW for 1 mark** (+)752 (moles not used for products and the cycle the wrong way round) **OR** (+)4514 (moles not used for reactants and the cycle the wrong way round) **OR** –670 (moles not used for reactants and products) **Note:** There may be other possibilities

Question			Answer	Marks	Guidance
5	(b)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = +820, award **2 marks.** **IF** answer = –820 or +1640 award **1 mark.** amount of N_2O = 10 (mol) ✓ enthalpy change = (+)820 ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** ECF, ie moles of N_2O x enthalpy of formation
		(ii)	(+)82 ✓	1	
		(iii)	(+)283 ✓	1	
	(c)		$O_3 \rightarrow O_2 + O$ **AND** $O + O_2 \rightarrow O_3$ ✓ rate of ozone decomposition (almost) equals rate of ozone formation ✓	2	**ALLOW** $O_3 \rightleftharpoons O_2 + O$ **ALLOW** $O_3 \rightarrow O_2 + O$ is reversible **ALLOW** $O + O_2 \rightarrow O_3$ is reversible **IGNORE** dots **IGNORE** other equations involving ozone, eg $O + O_3 \rightarrow 2O_2$ **IGNORE** comments about an equilibrium **ALLOW** rate of forward reaction is similar to the rate of the backward reaction if marking point 1 is awarded
	(d)		$NO + O_3 \rightarrow NO_2 + O_2$ ✓ $NO_2 + O \rightarrow NO + O_2$ ✓	2	**ALLOW** $NO_2 + O_3 \rightarrow NO + 2O_2$ ✓ **IGNORE** dots **IGNORE** $O + O_3 \rightarrow 2O_2$ **IGNORE** $2O_3 \rightarrow 3O_2$
			Total	**11**	