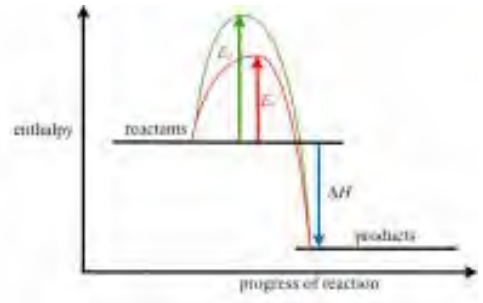
Question			Expected Answers	Marks	Additional Guidance
1	(a)	(i)	The enthalpy change for the complete combustion ✓ of 1 mol (of a substance) ✓	2	**ALLOW** energy change for combustion in excess oxygen **OR** energy released during complete combustion **OR** energy change for combustion in excess air **NOT** energy required This mark is not stand alone but must relate to statement about an enthalpy change even if the statement was not awarded a mark
	(b)	(i)	56.430 (kJ) ✓	1	**ALLOW** 56.43 (kJ) **OR** 56.4 kJ ✓ **OR** 56 kJ **ALLOW** -56.43 i.e. ignore sign
		(ii)	M_r [$CH_3(CH_2)_4OH$] = 88.0 ✓ n = 0.0200 mol ✓	2	**ALLOW** 88 **ALLOW** 0.02 **OR** ecf from wrong M_r **ALLOW** full marks for 0.02 with no working out
		(iii)	(–)2821.5 ✓ = (–)2820 (3 SF) ✓ correct minus sign ✓	3	**ALLOW correct substitution into formula**(b)(i) ÷ (b)(ii) e.g. 56.4 ÷ 0.02 this is essentially a mark for the working **ALLOW** ecf from i.e. answer from (b)(i) ÷ (b)(ii) The minus mark is stand alone and is independent of the numerical answer
	(c)	(i)	pressure: 100 kPa **OR** 101 kPa **AND** temperature: 298 K **OR** 25 °C ✓	1	**units needed** **ALLOW** 1 bar **OR** 1 atm **OR** 760 mmHg **ALLOW** any stated temperature so for example 100kPa and 40^oC would be credited with a mark **IGNORE** any reference to moles or concentration
		(ii)	6C(s) + 7H_2(g) → C_6H_{14}(l) ✓	1	**ALLOW** graphite / gr
		(iii)	many different hydrocarbons would form **OR** activation energy too high **OR** reaction too slow **OR** they don't react together ✓	1	**ALLOW** can form different isomers **OR** can form different structures **IGNORE** reaction may be reversible

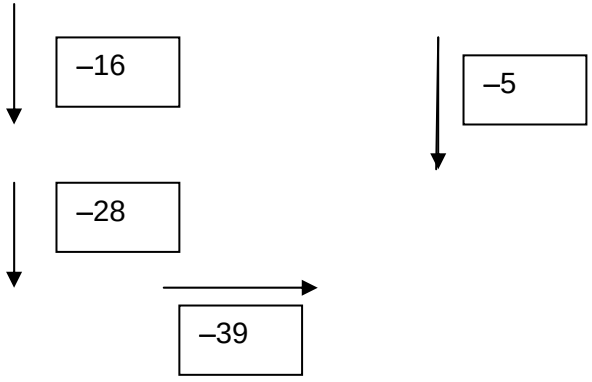
Question			Expected Answers	Marks	Additional Guidance
		(iv)	6 × –394 + 7 × –286 shown **OR** calculated as –4366 ✓ –4366 and –4163 added **OR** subtracted ✓ correct answer –4366 – (–4163) = –203 ✓	3	**ALLOW THREE** marks for –203 on its own with no working out or written on the answer line **ALLOW TWO** marks for +203,+3483, +1513, +1767 or -8529 on its own with no working out **ALLOW ONE** mark for or –3483, –1513, –1767 or +8529 on its own with no working out units **NOT** needed Positive sign not needed for endothermic answers
			Total	14	

Question			Expected Answers	Marks	Additional Guidance
2	(a)		high pressure as fewer moles (of gas) on right-hand side OR high pressure as volume of products less than that of reactants ✓ low temperature as (forward) reaction is exothermic ✓	2	**ALLOW** ora **ALLOW** fewer particles **OR** fewer molecules **ALLOW** ora
	(b)		Too expensive to use a high pressure ✓ Too slow to use a low temperature ✓	2	**ALLOW** high pressures provide a safety risk **OR** high pressure is too dangerous **ALLOW** with low temperature molecules cannot overcome activation barrier
	(c)	(i)	$Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓ overall: $O_3 + O \rightarrow 2O_2$ ✓ **OR** $Cl + CH_4 \rightarrow CH_3 + HCl$ ✓ $CH_3 + Cl_2 \rightarrow CH_3Cl + Cl$ ✓ overall: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ ✓	3	Marks must come from one or other of the radical process and not from both of them. If two processes are described then an incorrect step in one process will contradict a correct step in the other process. **ALLOW** overall equation mark even if the steps are wrong the radicals do **NOT** need a single dot **IGNORE** any state symbols **ALLOW** $Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O_3 \rightarrow Cl + 2O_2$ ✓ overall: $2O_3 \rightarrow 3O_2$ ✓ **ALLOW** any saturated hydrocarbon including cyclic **ALLOW** ecf for second step and overall reaction if wrong hydrocarbon used e.g. C_2H_4 is used in first step

Question			Expected Answers	Marks	Additional Guidance
		(ii)	Δ*H* shown **and** products below reactants ✓ E_a shown ✓ E_c shown < E_a ✓  	3	**NOT** double headed arrows but apply ecf for more than one double headed arrow **ALLOW** one mark if two correctly labelled curves are drawn but the arrows are not shown or are incorrectly drawn The arrows must be positioned as closely as possible to the maximum height of the curves but allow some degree of bod
	(d)		**Any FOUR from:** catalyst not used up in reaction ✓ reactions take place at lower temperatures ✓ with lower energy demand **OR** lower activation energy **OR** use less fuel ✓ so less carbon dioxide emitted into atmosphere **OR** so fossil fuels last longer ✓ different reactions can be used ✓ with better atom economy **OR** less waste ✓ less hazardous chemicals ✓ catalysts or enzymes can generate specific products ✓	4	 **ALLOW** catalysts can work at room temperature **OR** enzymes work at room temperature **IGNORE** cheaper
			Total	**14**	

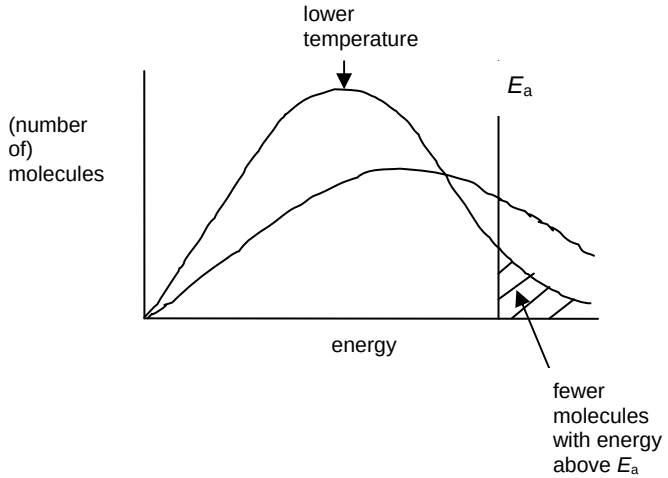
Question			er	Marks	Guidance
3	(a)	(	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 2.68 (kJ) award 2 marks** $q = mc\Delta T$ **OR** = 50.0 × 4.18 × 12.8 ✓ = 2.68 (kJ) ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** ecf only from using mass of 50.486 **ALLOW** 2675.2 J **IGNORE** sign If mass used is 50.486 answer is 2701.202944 **ALLOW** 2.7 **OR** 2.675 **OR** 2.6752 **DO NOT ALLOW** 3 **IGNORE** sign If mass used is 50.486 answer is 2.7, 2.70, 2.701 up to calculated value of 2.701202944 correctly rounded **ALLOW** one mark for using 4.2 and correctly calculating q in kJ to at least 2 sig figs
		(ii)	amount = 0.02(00) (mol) ✓	1	**ALLOW** $1/50$ **IGNORE** trailing zeroes

Question			er	Marks	Guidance
3	(a)	(ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = -134 (kJ) award 3 marks** **IF answer = +134 (kJ) award 2 marks** 2.68 ÷ 0.02 ✓ Correctly calculates the value to 3 sig figs ✓ – sign ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** ECF i.e. $\frac{(i)}{(ii)}$ This is dependant on the previous mark **ALLOW** ECF If 2.68, 2.675 or 2.6752 and moles of 0.02answer is (-)134 If mass of magnesium included answer is (-)135 If 2.7 kJ and moles of 0.02 used answer is (-)135 **ALLOW** only answers to three significant figures **–** sign is **independent** of answer
	(b)	(	(Enthalpy change) when one mole of a compound ✓ is formed from its elements ✓ at 25 ^{o}C/298 K **AND** 1 atmosphere/101 kPa ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** (energy change) when one mole of a substance/molecule/product **DO NOT ALLOW** enthalpy change for one mole of product**s** **DO NOT ALLOW** one mole of reactants **ALLOW** any stated temperature and 1 bar/1000/mb/100kPa/100000Pa/101000Pa/101000Nm^{-2} etc **IGNORE** reference to concentration

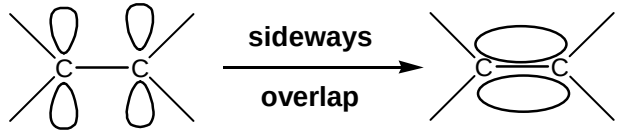
Question			er	Marks	Guidance
3	(b)	(ii)	Correct labelling of enthalpy cycle  Two or three boxes correct ✓ **BUT** all four boxes correct ✓✓ ΔH_f –792 (kJ mol^{-1}) ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** ECF from wrong enthalpy changes in the boxes
			Total	**12**	

Question			er	Marks	Guidance
4	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 431.5 (kJ mol^{-1}) award 2 marks** Energy required to break bonds = (+)679 kJ ✓ so bond enthalpy = (+)431.5 ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** (+)432 **ALLOW** one mark in this question for –431.5 **OR** (+)863 **ALLOW** ecf for bond enthalpy = 0.5 x (–184 + energy required to break bonds)
	(b)		more concentrated (particles) **OR** more particles per (unit) volume ✓ more collisions per second **OR** more frequent collisions ✓	2	**Must state somewhere in the answer that the rate is faster for full marks** **ALLOW ORA** if lower pressure is specified **ALLOW** particles are closer together **OR** more crowded particles **OR** more particles in the same space **OR** same number of particles in a smaller volume **ALLOW** molecules for particles but **DO NOT ALLOW** atoms **DO NOT ALLOW** 'area' instead of 'volume' **ALLOW** collisions more often **OR** increased rate of collision **OR** collisions are more likely **OR** there is a greater chance of collisions 'More collisions' is **not** sufficient **IGNORE** successful

Question			er	Marks	Guidance
4	(c)			5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** Assume answers refer to lower temperature and rate decreases unless specified otherwise **ALLOW** ORA i.e. correct explanation for why higher temperatures increase rate if clearly specified **ALLOW** particles instead of molecules throughout question **DO NOT ALLOW** atoms the first time it appears in the answer
			y-axis label is '(number of) molecules' **AND** *x*-axis label is 'energy' **AND** one correct curve ✓		Boltzmann distribution - must start at origin and must not end up at 0 on *y*-axis i.e. must not touch *x*-axis
			Correct curve for lower temperature (labelled) ✓		Maximum of curve to left **AND** higher than maximum of higher temperature curve **AND** below higher temp line at higher energy as shown in diagram below **IGNORE** minor point of inflexion of both curves
			Activation energy does not change **OR** clearly labelled on diagram, e.g. E_a **OR** E ✓		
			Fewer molecules have energy above activation energy **OR** fewer molecules have enough energy to react ✓		**ALLOW** ORA for higher temperature if specified Fewer molecules have enough energy to collide successfully is worth one mark
			So fewer **successful** collisions ✓		Fewer collisions per second is **not** sufficient

Question			er	Marks	Guidance
					
	(d)	(	$Cl_2 \rightarrow 2Cl$ ✓	1	No need to show radicals with a 'dot'
		(ii)	HCl + H ✓ HCl + Cl ✓	2	No need to show radicals with a 'dot'
		(iii)	***Any two from:*** $H + H \rightarrow H_2$ ✓ $Cl + Cl \rightarrow Cl_2$ ✓ $H + Cl \rightarrow HCl$ ✓	2	No need to show radicals with a 'dot'
			Total	**14**	

Question			Answer	Mark	Guidance
5	(a)		(enthalpy change when) the number of moles of reactants ✓ as specified in the (balanced) equation react together ✓	 2	**ALLOW** (enthalpy change when) the number of moles of products **ALLOW** molar quantities / amounts Enthalpy change that occurs during a reaction is **not** sufficient
	(b)	(i)	$Q = 50 \times 4.2 \times 11.0$ ✓ 2.3 ✓	 2	**ALLOW** 2310 J ✓ 2300j **ALLOW** use 4.18 for c which gives 2.299 J **ALLOW** two marks for 2.31 / 2.310 with no working out **ALLOW ECF** ie Q divided by 1000 **IGNORE** any sign quoted
		(ii)	moles = 0.200 ✓	1	**ALLOW** 0.2 / 0.20
		(iii)	$\Delta H_r = 2 \times (2.3 \div 0.200)$ ✓ 23 ✓ + sign ✓	 3	**ALLOW ECF** from answer from 2 × [**(i)** ÷ answer to **(ii)**] Answer from 2 × [**(i)** ÷ answer to **(ii)**] must have only **2 sig figs** + sign **must** be written for 'sign mark' **+** sign is **independent** of answer **ALLOW** answers per mole of NH_4SCN $\Delta H_r = 2.3 \div 0.200$ for one mark 12 for the second mark + sign for t e third mark **NOTE** If $c = 4.18$ has been used in **b(i)**, $\Delta H_r = +11$ by **ECF** for calculation per mole of NH_4SCN

Question			Answer	Mark	Guidance
	(c)	(i)	(Enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**ALLOW** energy required rather than enthalpy change **DO NOT ALLOW** energy released **DO NOT ALLOW** bonds formed
		(ii)	(Sideways) overlap of p orbitals ✓ Forming a π/pi bond ✓	2	**IGNORE** reference to σ bonds **IGNORE** incorrect diagram This diagram would score one mark – the π bond needs to be labelled for second mark  **2p orbitals**
		(iii)	π bond is weaker (than the σ bond) **OR** σ bond is stronger (than the π bond) ✓	1	There are two types of bonds is **not** sufficient **DO NOT ALLOW** π bond is stronger than the σ bond **ALLOW** the two bonds in double bond are not the same strength
		(iv)	bonds broken = (+)4010 **AND** bonds formed = (–)3931 Overall enthalpy change = +79 ✓	2	**ALLOW** Bonds broken = (+)690 **AND** bonds formed = (–)611✓ **ALLOW** 79 without a sign **ALLOW** –79 for one mark overall **ALLOW ECF** from incorrect enthalpy changes calculated for bonds broken and made

Question			Answer	Mark	Guidance
	(c)	(v)	Bond enthalpies may not be the same as the average bond enthalpy **OR** The idea that bonds have different strengths in different environments ✓	1	**DO NOT ALLOW** answers involving heat loss **OR** the use of non standard conditions Average bond enthalpies are used is **NOT** sufficient
			Total	**16**	