Question	Expected Answers	Marks
1 (a)(i) *	the enthalpy change when <u>1 mole</u> (in words) of compound/substance ✓ [N.B NOT element in its standard state, and NOT 1 mol of elements, if a compound is being made] (is formed from its) <u>elements</u> under standard conditions *or* at 100 kPa } and a stated temperature *or* at room temperature and pressure } ✓	[2]
(ii)	$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$ *balanced for 1 mole of water* ✓ *state symbols (u/c -anything on left, but has to be H₂O(l) on RHS)* ✓	[2]

(b)
 	
 *
	$x - 75 - 2(286) = -394$ $[x = 75 + 572 - 394]$ *(x 2)* ✓
	                            (correct +/- signs) ✓
	 $x = (+)253$ $(kJ\ mol^{-1})$ ✓ ecf
	          correct ans $\Rightarrow$ [3] marks.
	 Award [2] for any of the following· -33, +103, -253, -891, +1041
	 Award [1] for any of the following: +33, -183, -605, +755, -1041
		[3]

(c) (i)	enthalpy
	
	        $N_2(g) + 3H_2(g)$
	
	        progress of reaction
	
	 look for. *ΔH shown as exothermic o r- 92 kJ mol⁻¹* ✓
	           E_{act} or 68 kJ mol⁻¹ from reactants to trans. state ✓
	           *product labelled correctly **after** transition state* ✓
		[3]

(ii)	$92 + 68 = 160$ $(kJ\ mol^{-1})$ ✓ (no ecf)	[1] total 11

Question	Expected Answers	Marks
2 (a)	$C_6H_6(l) + 7\frac{1}{2}O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$ (*or 15/2*) *Correct formulae and state symbols* ✓ *balanced for 1 mole of C_6H_6* ✓	[2]
(b) ✱	$x - 3267 = 3(-1301)$ *(x 3)* ✓ *(correct +/- signs)* ✓ $x = -636$ (kJ mol^{-1}) ✓ ecf *correct ans ⇒ [3] marks.* *Award [2] for any of the following: +636, +1966, ±7170, +665* *Award [1] for any of the following: -1966, ±4568, -665* **If no other mark has been awarded,** *you could award [1] for 3 x (-)1301*	[3]
(c) (i)	(rate) increases ✓ more molecules have $E > E_a$ *or* enough energy to react (at higher T)✓ collision rate increases (with T) *or* there are more (effective) collisions ✓ *N B. there is no mark for "molecules go faster/have more energy"*	[3]
(ii)	(rate) increases ✓ (because they are closer together) molecules collide more often *or* more collisions *or* more molecules in contact with the catalyst ✓ *N.B. no mark for molecules go faster/have more energy*	[2]
(d) ✱	it's a catalyst *or* it speeds up the reaction ✓ by <u>lowering E_{act}</u> *or* providing alternative route with <u>lower energy</u> *or* adsorbs/forms (temporary) bonds with the reagents ✓ *N.B. no mark for "provides surface" or "extra surface area"*	[2] total 12

Question	Expected Answers	Marks
3 (a) *	• forward rate = reverse rate (*not concentration of reactants and products are equal*) • can be approached from either direction *or* reversible reaction *or* (constant) change from reactants to products and vice versa • no change in overall macroscopic properties (*or* one specified property, e.g. colour/concentration) *or* appears to have stopped • takes place in a closed system . *(any two bullet points)* ✓✓	[2]
(b) *	a change in conditions *or* a disturbance will cause a shift in the (position of) <u>equilibrium</u> ✓ in the direction that minimises/opposes/reduces/attempts to balance out/ the effect of the change ✓ *N.B. do not accept "cancels" or "equals" or "balances" or "restores" without the "attempt"*	[2]
(c)	solution would turn <u>yellow</u> (allow yellow-green) ✓ *(do not allow this mark if candidate says it goes yellow and then back to green again!)* (increasing/added [H^+] pushes) the <u>equilibrium</u> to left hand side *or* <u>equilibrium</u> shifts to form more HIn ecf ✓ *ecf: if candidate states that the colour goes blue, then the first mark is lost, but the second can be awarded for stating that the eqm. goes to the **right***	[2]
(d) * *	(colour goes from yellow to) <u>green</u> u/c ✓ then to <u>blue</u> (allow blue-green) ✓ *(do not allow this mark if candidate says it goes blue and then back to green again!)* *N.B. allow e.c.f for **both** these marks as follows·* *if candidate has said in (c) that colour goes blue, then these two marks are for (blue to) gree n[1], and yellow(-green) [1] (don't allow "blue" in both!)* OH^- reacts with/removes H^+ (*or* equation) *or* is a proton acceptor *or* neutralises the acid ✓ *N.B. not just "OH- is a base"* shifting the <u>equilibrium</u> to the right hand side *or* <u>equilibrium</u> shifts to form more In⁻ ecf ✓ *(the word "equilibrium" need only appear once in parts (c) and (d) If it is omitted from **both** (c) and (d), deduct [1] only. If it is omitted from only **one** part, allow full marks (as long as the chemistry is correct!))*	[4] total 10

Question	Expected Answers	Marks

4 (a)	a strong acid is
	
	     completely ionised/dissociated (to $H^+(aq)$)
	or gives 1 mol of $H^+(aq)$ for each 1 mol of HA ✓
	
	a weak acid is
	     incompletely ionised/dissociated (NOT unionised)
	or gives less than 1 mol of $H^+(aq)$ for each 1 mol of HA ✓
	
	N.B. if neither of the above two marks can be awarded, you can award [1] for the statement that "strong acids donate protons/H+ more readily than weak acids
		[2]
		
		[1]

(b) (i)	$$CaCO_3 + 2HA \longrightarrow CaA_2 + H_2O + CO_2 \quad ✓$$ *or* $$CaCO_3 + 2H^+ \longrightarrow Ca^{2+} + H_2O + CO_2$$ *or* $$CO_3^{2-} + 2H^+ \longrightarrow H_2O + CO_2$$	

(ii)	• (average) energy/speed/movement <u>of molecules/particles</u> increases with temperature
	• more (molecules) have $E > E_a$ (at higher T) *or* have enough energy to react
	  N.B. do not allow this point if candidate has stated that the E_a decreases with temperature
	• activation energy is the minimum energy molecules need in order to react
	• collision rate *or* number of collisions increases (with T)
	             (any three bullet points)✓✓✓
	
	N.B. the first two bullet points could be read into two labelled Boltzmann distribution curves, showing E_a
		[3]
		total 6

Question	Expected Answers	Marks
5 (a) (i)	the energy/enthalpy/heat required to break ✓ 1 mole of bonds *or* a bond per molecule in 1 mole ✓ *N.B. do not allow "(energy needed to break the bonds in) 1 mole of compound"*	[2]
(ii)	$\frac{1}{4}CH_4(g) \longrightarrow \frac{1}{4}C + H$ *(i.e balanced for 1 mol of H)* ✓✓✓ *If the above three marks cannot be awarded (this is more than likely!), allow the following·* Any equation with $CH_4(g)$ on the left hand side ✓ Any equation showing the breaking of a CH bond, e.g. C + 4H *or* CH_3 + H on the right hand side ✓	[3]
(b)	total BE on left = 2(C-C) + 8(C-H) + 5(O=O) = +6488 kJ ✓ total BE on right = 6(C=O) + 8(O-H) = +8542 kJ ✓ *N.B. if neither of these two marks can be awarded, you could award [1] if all of the correct multipliers (2, 8, 5, 6, 8) have been used.* ΔH = 6488-8542 = **-2054** (kJ mol^{-1}) ✓ ecf *([3] for correct ans)* *(ecf: award the mark for correctly taking **their** total BE on right from **their** total BE on left. **Not** vice versa. If you cannot clearly see which is BE on right and which is BE on left, don't award this mark)*	[3]
(c) (i)	*either:* average bond energies are not applicable to particular bonds *or.* ΔH_c is for $H_2O(l)$, whereas bond energies are for gases ✓ *N.B. ingore any ref. to changes in conditions/temperature etc.*	[1]

(ii)	
	-4200
	
	$\Delta H_c/kJ\ mol^{-1}$
	
	-2200 |————————————————
	      3 4 5 6
	      number of carbon atoms
	         *plotting of points **and** a straight line* ✓
		[1]
		
		[1]

(iv)	-3450 to -3550 (kJ mol^{-1}) (ignore absence of sign, but do not allow +)✓ (allow e.c.f. - correct interpretation of incorrect graph) Successive members/molecules/compounds/formulae increase by a regular/fixed/the same amount (of C and/or H) *or* by a CH_2 group ✓	[1] 12 max 11

Question	Expected Answers	Marks
6 (a)	• mention of **two** of the following *as pollutants*, or *as products of combustion* or *as being present in exhaust gases*: carbon monoxide, nitrogen monoxide, nitrogen dioxide, unburned hydrocarbons (ignore any ref to sulphur compounds) • heterogeneous (catalysis) (*not heterolytic!*) • needs a high temperature • (reactants) <u>adsorbed</u> onto the catalyst's surface • weakly/temporarily bonded to the catalyst • bonds in reactants are weakened • (products easily) desorbed after reaction *or* lost/released from surface • description of how one of the pollutants undergoes transformation into harmless products, e.g. $$CO + NO \longrightarrow CO_2 + \tfrac{1}{2}N_2$$ $$(or\ 2CO + O_2 \longrightarrow 2CO_2$$ $$or\ 2NO \longrightarrow N_2 + O_2$$ $$or\ h/c + O_2 \longrightarrow CO_2 + H_2O)$$ (*or* in words - equation does not need to be balanced) *any five bullet points* ✓ ✓ ✓ ✓ *Q of WC:* Look for two things here; the overall account must read clearly, and make sense grammatically (ignore spellings), and in addition at least **one** of the following words should be used correctly in a suitable context: heterogeneous, catalyst, adsorption, desorption., oxidation, reduction *Indicate this mark as* Q✓	[6]
(b)	• Haber process converts nitrogen/N_2 (from the air hence cheap and plentiful) into ammonia/NH_3 *or* in an (unbalance) equation *ammonia is used* • as a refrigerant *and to make* • fertilizers • such as ammonia itself, ammonium sulphate *or* other ammonium salt *or* urea etc. • which are needed for more crops/food),. *and nitric acid, which is used to make* • explosives *or* a named N-containing explosive, • polyamides/nylon, • dyes etc. *any 4 bullet points* ✓ ✓ ✓ ✓	[4] total 10