1(a) 400 - 550 °C *or* 670 – 825 K (assume Celsius if no units specified) ✓ [1]

(b) (i) rate/reaction is (too) slow *or* "time consuming" (ignore ref. to "yield", but don't award mark if candidate states that "**equilibrium** yield is low") ✓ [1]

(ii) equilibrium/reaction is pushed over to left hand side *or* yield is decreased ✓ [1]

or less ammonia is formed (NOT "is expensive")

(c) (i) *either* the rate *or* the (equilibrium) yield will increase (*or* more NH_3 formed) ✓ [1]

(ii) costs will be high *or* safety will be compromised *or* is dangerous ✓ [1]
(NOT environmental problems)

(d) they are recycled/re-used/put back in/re-reacted ✓ [1]

(e) *any 2 of:* as, or to make, fertilisers *or* refrigerants;
to make nitric acid, polyamides, explosives, dyes ✓✓ [2]
(NOT "in agriculture", "as a feedstock", "in gunpowder". If "making" is not mentioned in the appropriate context, deduct [1] max)

8

2(a) *any 2 of:*

- forward rate/reaction = reverse rate/reaction
  (*a statement that the concentration of reactants and products are equal* ***negates***)
- 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 ✓✓ [2]

(b) bonds broken: 4 x (S-Cl) = 4 x 255 = **1020** ✓
(*or* 2 x (S-Cl) = 2 x 255 = ***510***)

bonds formed: 2 x (S-Cl) + 1 x (S-S) +1 x (Cl-Cl) = 2 x 255 + 266 + 242 =**1018**✓
(*or 1 x (S-S) + 1 x (Cl-Cl)* = *266 + 242* =***508***)

ΔH = (+)2 kJ mol^{-1} ans.(i.e. broken – formed) ✓(e.c.f.) [3]

(possible e.c.f values:: - 2 *or* +268 *or* ± 2038 *or* ±1018 as a result of 510 + 518 [2])
(there may be others!) -268 [1]

allow "working" marks for: sum of bonds on l.h.s. ✓
sum of bonds on r.h.s. ✓

(c) because is positive *or* reaction is endothermic ✓(consistent with ans. in b)
equilibrium/reaction will move to right hand side ✓(consistent with ans. in b)
but not by very much because ΔH is so small ✓ [3]
alternative for last 2 marks: ΔH ~ 0 [1], therefore only a slight effect on equilibrium [1]

8 max 7

3(a) (i) the enthalpy change when **1 mole** of compound/substance/element/molecule ✓

is **completely** burned *or* burned in **an excess** of oxygen ✓

at 1 atm + 298 K (*or* "a stated temperature" – in words)
or under **standard conditions** (of T and P) ✓ [3]

(ii) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$ (balancing for 1 mole propane) ✓
(st. symbols, as long as oxygen is used) ✓ [2]

(b) (i) $C(s) + H_2(g)$ do not easily combine (at 298K) *or* E_{act} is too high
or if they did, different hydrocarbons (e.g. CH_4) would be produced as well ✓ [1]
[do NOT allow "isomers are formed"]

(ii) $\Delta H^\circ_f = 3 \times \Delta H_c(C) + 4 \times \Delta H_c(H_2) - \Delta H_c(C_3H_8)$

$= -1182 - 1144 + 2220$

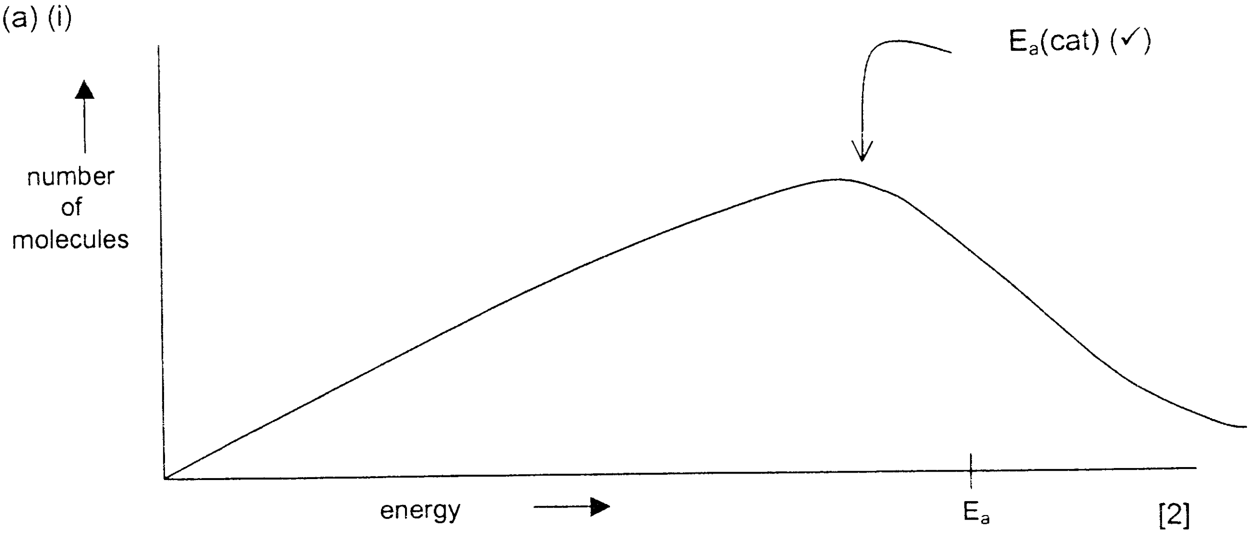
$= -2326 + 2220 =$ **-106** kJ mol^{-1} (e.c.f. see below) ✓✓✓ [3]

possible e.c.f values: +106 *or* -1250 *or* +1540 *or* ± 4546 [2]
+1250 *or* -1540 *or* ± 2112 *or* ± 2182 *or* ± 2258 [1]

for other answers see if you can award any of the following "working" marks

allow "working marks" for
- use of the correct multipliers (3,4,1) ✓
- use of the correct ΔH°_c values **and** the correct signs ✓
- last mark is for "left – right" correctly calculated ✓

4(a) (i)



[2]

curve starts at (0,0) and then peaks ✓ then falls off more gradually ✓
(it should NOT be symmetrical *or* meet the x-axis)

(ii) the (minimum) energy required by the reacting molecules in order for them to react ✓ [1]

or (minimum) energy for a reaction to take place
or (minimum) energy to produce a reaction
or energy barrier to a reaction [NOT *just* the energy needed to break bonds]

(iii) see E_a(cat) on graph above: E_a(cat) must be to the left of E_a ✓ [1]

(b) catalysts offer an alternative route [*or* binds substrate *or* adsorbs reactant] ✓
of lower activation energy ✓
so more molecules have E > E_a *or* more molecules can react
or more collisions are successful in bringing about a reaction ✓
homogeneous - same phase/state, *heterogeneous* - different phases/states ✓

examples:*(in the examples accept unbalanced equations as long as the starting materials and products are (virtually) correct)*

(homogeneous) e.g. $Cl^{\bullet}$ in the stratosphere ✓
catalysing $2O_3 \longrightarrow 3O_2$ (*or* two propagation equations) ✓

or e.g. H^+ during esterification
catalysing $RCO_2H + ROH \longrightarrow RCO_2R + H_2O$

or enzymes/zymase in fermentation
catalysing $C_6H_{12}O_6 \longrightarrow 2C_2H_6O + 2CO_2$

(heterogeneous) e.g. Pt in catalytic converters ✓
catalysing $NO + CO \longrightarrow \frac{1}{2}N_2 + CO_2$ ✓

or e.g. Fe in Haber
catalysing $N_2 + 3H_2 \longrightarrow 2NH_3$

(in general: identity of catalyst ✓ equation ✓)
(deduct [1] if the stated catalysts are not described in the right homo-heterogeneous context)
8 marking points max[7]

Q of w C:At least two clauses/sentences that express a logical sequence of ideas.✓ [1]

5(a) H^+/H_3O^+ *or* "hydrogen" ✓ [1]

(b) strong: completely ionised/dissociated ✓
weak: incompletely/partially ionised/dissociated ✓ [2]

(c) $2H^+(aq) + Mg(s) \longrightarrow Mg^{2+}(aq) + H_2(g)$ ✓ balancing ✓ state symbols [2]

[N.B. *ionic* equation needed]

(d) (i) methanoic acid only partially ionises *or* $HCO_2H \rightleftharpoons HCO_2^- + H^+$ ($\rightleftharpoons$ needed)✓
or is a poor proton donor *or* ionises/dissociates less (than HCl)
or is a weak acid *or* H^+ harder to lose

(equilibrium lies over to the l.h.side, so) only a small $[H^+(aq)]$ *or* less H^+ ions
or small concentration means slow rate of reaction ✓
[2]

(ii)(As $H^+(aq)$ is used up by reaction with $CaCO_3(s)$)
the equilibrium continually moves (to the r.h. side) ✓

So eventually all the HCO_2H reacts
or same concentration/no of moles of reactant give the same amount of product ✓ [2]

9