Born-Haber Cycles

Mark Scheme 2

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Born-Haber Cycles
Paper Type	Theory
Booklet	Mark Scheme 2

Time Allowed: **60 minutes**

Score: **/50**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a (i)** heterogeneous: different states **AND** homogeneous: same state [1]

(ii) the correct allocation of the terms *heterogeneous* and *homogeneous* to common catalysts [1]

example of heterogeneous, e.g. Fe (in the Haber process) linked to correct system [1]
equation, e.g. $N_2 + 3H_2 \longrightarrow 2NH_3$ [1]

how catalyst works, adsorption (onto the surface) [1]
ecf for non-iron catalyst

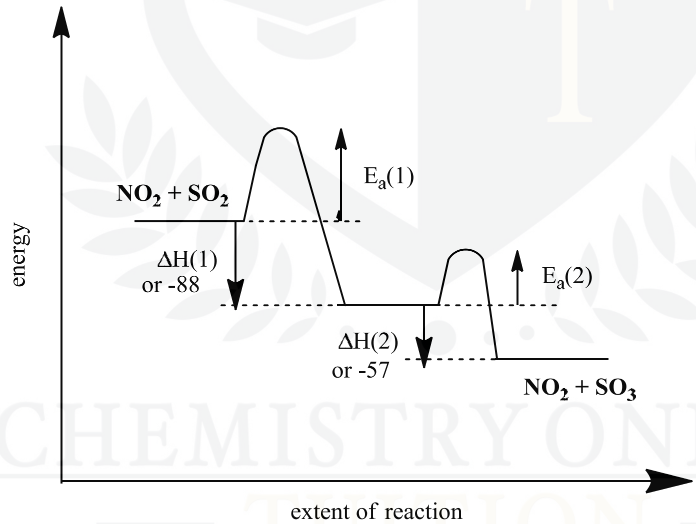
example of homogeneous, e.g. Fe^{3+} or Fe^{2+} (in $S_2O_8^{2-} + I^-$) linked to correct system [1]

equation, e.g. $S_2O_8^{2-} + 2I^- \longrightarrow 2SO_4^{2-} + I_2$ [1]

how catalyst works, e.g. $Fe^{3+} + I^- \longrightarrow Fe^{2+} + ½I_2$ [1]
ecf for non-iron catalyst

[8]

(b)



both E_a shown, with $E_a(1) > E_a(2)$ [1]
both ΔH shown, with $\Delta H(1) > \Delta H(2)$ [1]

[2]

[Total: 10]

2 **(a** $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$ (1) [1]

(b) **(i)** step 1 electrophilic (1)
addition (1)
step 2 elimination **or** dehydrohalogenation (1)

(ii) reagent $NaOH/KOH/OH^-$ (1)
conditions in alcohol/ethanol (1)
only allow conditions mark if reagent is correct [5]

(c) **Q** is CH_3CHO (as minimum) (1)
R is CH_3CO_2H (as minimum) (1)

(ii) step 3 is addition (1)
step 4 is oxidation/redox (1) [4]

(d) **(i)** **combustion**
$C_2H_2(g) + \mathbf{{}^5/_2}O_2(g) \rightarrow \mathbf{2}CO_2(g) + H_2O(l)$ **or**
equation must be for the combustion of one mole of C_2H_2
H_2O must be shown as liquid (1)
correct state symbols in this equation (1)

formation
$2C(s) + H_2(g) \rightarrow C_2H_2(g)$
no mark for state symbols here (1)

(ii) let **Z** be $\Delta H^\ominus_f$ of C_2H_2

	C_2H_2 +	$^5/_2O_2$ →	$2CO_2$ +	H_2O
$\Delta H^\ominus_f$	**Z**	0	2(-394)	-286

$\Delta H^\ominus_c = -1300 = 2(-394) + (-286) - \mathbf{Z}$ (1)

whence $\mathbf{Z} = 2(-394) + (-286) - (-1300)$

$= \mathbf{+}226\ kJ\ mol^{-1}$
value (1)
sign (1)
allow ecf on wrong equation [6]

[Total: 16]

3 **(a)** N≡N triple bond is (very) strong
or the N_2 molecule has no polarity [1]

(b) $3Mg(s) \rightarrow 3Mg^{2+}(g)$ $\Delta H_1 = 3 \times 148 + 3 \times 2186 = 7002$
$N_2(g) \rightarrow 2N^{3-}(g)$ $\Delta H_2 = 994 + 2 \times 2148 = 5290$

LE $= -\Delta H_1 - \Delta H_2 - 461 =$ **–12,753** (kJ mol^{-1}) (–[1] for each error) [3]

(c) **(i)** $Li_3N + 3H_2O \rightarrow NH_3 + 3LiOH$ (balanced equation) [1]

(ii) advantage: no high pressure/temperature/catalyst needed/standard conditions used [1]

disadvantage: Li is expensive
or Li would need to be recycled/removed
or LiOH by-product is corrosive/strongly basic
or this would be a batch, rather than continuous process [1]

(d) **(i)** Li_3N: 100 × 14/35 = 40% N [1]
urea: 100 × 28/60 = 47% N [1]

(ii) amide [1]

(iii) $NH_2CONH_2 + H_2O \rightarrow 2NH_3 + CO_2$
or $\rightarrow NH_2CO_2H + NH_3$
or $NH_2CONH_2 + 2H_2O \rightarrow 2NH_3 + H_2CO_3$ [1]

(iv) The LiOH would be strongly alkaline
or would increase the pH of the soil
or would 'burn' the crops/reduce plant growth/stunt plants
or would contaminate the environment [1]

[Total: 12]

4 **(a** enthalpy change when 1 mol of a compound is formed (1)
from its elements (1)
in their standard states under standard conditions (1) [3]

(b) $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$

ΔH_f^o/kJ mol^{-1} +50.6 –241.8

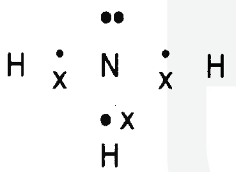
$\Delta H^o_{reaction} = 2(-241.8) - (+50.6)$ (1)

$= -534.2$ kJ mol^{-1} (1)

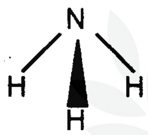
(ii) E_a is too high (1)

(iii) products are H_2O and N_2 which are harmless/non toxic
or are already present in the atmosphere (1) [4]

(c) **(** 'dot-and-cross' diagram (1)

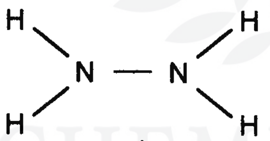


(ii)



(1)

(iii) minimum is



allow bond angle around N atom between 109° and 104° (1) [4]

(d) –2 (1) [1]

[Total: 12]