Born-Haber Cycles

Mark Scheme 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Born-Haber Cycles
Paper Type	Theory
Booklet	Mark Scheme 1

Time Allowed: **63 minutes**

Score: **/52**

Percentage: **/100**

Grade Boundaries:

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

1 **(a)** $K_P = \dfrac{p(NO)^4\, p(H_2O)^6}{p(NH_3)^4\, p(O_2)^5}$ (1)

atmospheres **or** Pa **or** kPa (1)
allow ecf on incorrect powers [2]

(b) (increasing temperature
yield of NO is decreased **or** reaction moves to LHS (1)
forward reaction is exothermic (1)

(ii) decreasing the pressure
yield of NO is increased **or** reaction moves to RHS (1)
more moles/molecules of gas on RHS **or**
fewer moles/molecules of gas on LHS (1)

(c) let $\Delta H_f^{\ominus}$ for NO be y kJ mol^{-1}

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

$\Delta H_f^{\ominus}$ $4 \times (-46.0)$ $4y$ $6 \times (-242)$ (1)

$\Delta H^{\ominus}_{reaction} = 4y + [6 \times (-242)] - [4 \times (-46.0)]$ (1)
$= 4y - 1452 + 184$

$\Delta H^{\ominus}_{reaction}$ is –906 kJmol^{-1} so
$4y = -906 + 1452 - 184 = 362$ (1)
whence y = $\Delta H_f^{\ominus}$ for NO = +90.5 kJ mol^{-1}
+ sign is require (1)

[Total: 10]

2 **(a)** $C(s) + O_2(g) \rightarrow CO_2(g)$ (1)
the enthalpy change/energy change/heat change when
one mole of a compound/CO_2 (1)
is formed from its elements in their standard states (1) [3]

(b) (i)

	$CO_2(g)$	+	$3H_2(g)$	$\rightleftharpoons$	$CH_3OH(g)$	+	$H_2O(g)$
$\Delta H^{\ominus}_f$/kJ mol^{-1}	–39		0		–20		–24

$\Delta H^{\ominus}_{reaction}$ = –201 + (–242) – (–394) (1)
–49 kJ mol^{-1} (1)
correct sign (1)

(ii) removal of CO_2 from the atmosphere (1)
CO_2 is a greenhouse gas/causes global warming (1) [5]

(c) In this part, in each case, the 'effect' must be correctly stated
in order to gain the explanation mark.

higher temperature
yield is reduced/equilibrium goes to LHS (1)
because forward reaction is exothermic/reverse reaction is endothermic (1)

higher pressure
yield is increased **or** equilibrium goes to RHS (1)
fewer moles/molecules on RHS **or** more moles/molecules on LHS (1)

use of catalyst
yield does not change (1)
forward and backward rates speeded up by same amount (1) [6]

[Total: 14]

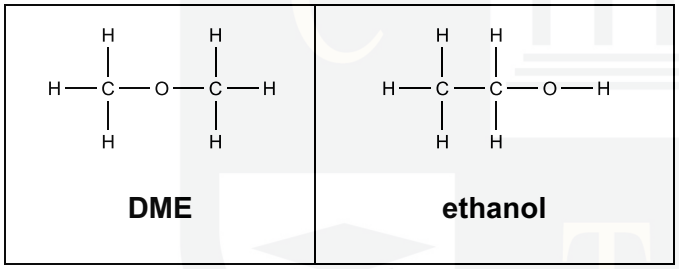
3 **(a)** $CH_3OCH_3(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
the enthalpy change/heat change/heat evolved when
one mole of CH_3OCH_3/a compound (1)
is completely burned **or**
burned in an excess of air/oxygen (1) [3]

(b)

	$2CH_3OH(l)$	$\rightarrow$	$CH_3OCH_3(g)$	+	$H_2O(l)$
$\Delta H^{\ominus}_f$/kJ mol^{-1}	2(–239)		**–1**		

$\Delta H^{\ominus}_{reaction}$ = –184 + (–286) – 2(–239) (1)
= +8 kJ mol^{-1} (1)
correct sign (1)

(c) **(i)**



both correct (1)

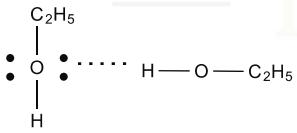
(ii) structural isomerism **or** functional group isomerism (1) [2]

(d) **(i)** hydrogen bonds (1)

(ii) lone pair on O atom of C_2H_5OH (

correct dipole $O^{\delta-}$—$H^{\delta+}$ on bond in one molecule of ethanol (1)

hydrogen bond shown between lone pair of an O atom and a hydrogen atom, i.



(1) [4]

[Total: 12]

4 **(a) (i)** enthalpy/energy change/released when 1 mol of ions… [1
in the gas phase (are dissolved in) water [1]

(ii) $Mg^{2+}(g)$ + aq (*or* H_2O) $\rightarrow$ $Mg^{2+}(aq)$ *or* $[Mg(H_2O)_6]^{2+}$ [1]

(iii) Mg^{2+} has a smaller radius/size or greater charge density than Ca^{2+} (**ions** required) [1]

(iv) O^{2-} reacts with water to give OH^- *or equation*: $O^{2-} + H_2O \rightarrow 2OH^-$ [1]
[5]

(b) (apparatus: "insulated" calorimeter, water and thermometer)
- measure (known volume/mass of) water *or* stated volume of water (into calorimeter)
- take the temperature (of the water – NOT the $MgCl_2$)
- weigh out known mass of $MgCl_2$ *or* stated mass of $MgCl_2$
- take final/highest/constant temperature *or* record temperature change/rise 4 × [1]

[4]

(c) (i) $\Delta H^{\ominus}_{sol} = 641 - 801 = -160$ kJ mol^{-1} [1]

(ii) $\Delta H^{\ominus}_{hyd} = (1890 - 2526 - 160)/2 = -398$ kJ mol^{-1} [2]
[3]

(d)
- solubility: $MgSO_4 > BaSO_4$ *or* decreases down the group
- because ΔH_{sol} is more endothermic for $BaSO_4$ *or* more exothermic for $MgSO_4$
- due to larger r_{ion} *or* smaller charge density of Ba^{2+} (ion has to be mentioned)
- leading to smaller LE and HE *or* LE and HE decrease
- but difference in HE (between Mg^{2+} and Ba^{2+}) is larger than the difference in LE (between $MgSO_4$ and $BaSO_4$)
or HE is dominant *or* HE decreases more than LE any 4 points [4]

[4]

[Total: 16]