Born-Haber Cycles

Mark Scheme 5

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Born-Haber Cycles
Paper Type	Theory
Booklet	Mark Scheme 5

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

Grade Boundaries:

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

1 **(a) (i)** $CH_3Br(g) \longrightarrow CH_3(g) + Br(g)$ [1]

(ii) $^1/_3\, Al Cl_3(g) \longrightarrow {}^1/_3 Al(g) + Cl(g)$ [2]
or $AlCl_3(g) \longrightarrow AlCl_2(g) + Cl(g)$
($AlCl_3(g) \longrightarrow Al(g) + 3Cl(g)$ for (1) mark)

[3]

(b) bond energies decrease from Cl_2 to I_2 [1]
due to increasing bond length *or* increase in number of electron shells [1]
which causes less effective orbital overlap *or* less attraction for the shared pair [1]

(ii) *either* because fluorine is electronegative, (hence each F wants to keep its electrons to itself)
or because the bond length is so short there is repulsion between the lone pairs (on F)
or repulsion between the nuclei (of F) [1]

[4 max 3]

(c) for chlorine:
ΔH = E(H – H) + E(Cl – Cl) – 2E(H – Cl) = 436 + 242 – (2 × 431)
= **–184** kJ mol^{-1} [2]
for iodine:
ΔH = E(H – H) + E(I – I) – 2E(H – I) = 436 + 151 – (2 × 299)
= **–11** kJ mol^{-1} [1]

(ii) Hydrides become less thermally stable down the group from Cl to I [1]
as the H–X bond energy decreases (more than does the X–X bond energy) [1]

[5]

(d)

	Na	**O**	**Br**
	15.2 / 23	31.8 / 16	53.0 / 79.9
$\Rightarrow$	0.661	1.99	0.663
$\div$ 0.661 $\Rightarrow$	1.0	3.0	1.0

[1]

thus **$NaBrO_3$** [1]

(ii) $3Br_2 + 6NaOH \longrightarrow NaBrO_3 + 5NaBr + 3H_2O$
or $3Br_2 + 6OH^- \longrightarrow BrO_3^- + 5Br^- + 3H_2O$
specie [1]
balancing [1]
[4]

[Total: 15]

2 **(a)** $CH_3OH(l) + {}^3/_2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
the enthalpy change/heat change/heat evolved when
one mole of CH_3OH (1)
is completely burned **or**
is burned in an excess of air/oxygen (1) [3]

(b) $\Delta H^{\ominus}_{reaction} = -283 + 2(-286) - (-726)$ (1)
$= -129$ kJ mol^{-1} (1)
correct sign (1) [3]

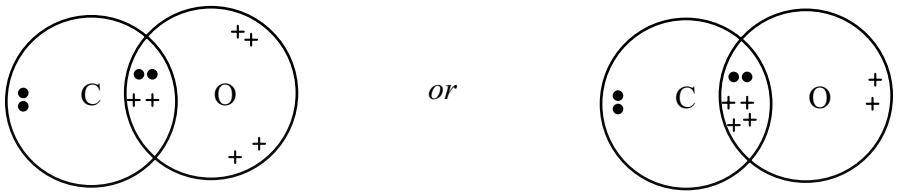
(c) **pressure**
increases rate (1)
by increasing frequency of collisions **or**
by increasing concentration of reactants (1)

temperature
increases rate (1)
because more molecules have energy $> E_a$ (1)

catalyst
increases rate (1)
by providing an alternative route of lower E_a (1) [6]

[Total: 12]

3 **(a) (i)**



[1]

(ii) incomplete combustion (of hydrocarbon fuels) *or* insufficient O_2/air

(iii) $NO + CO \rightarrow \frac{1}{2}N_2 + CO_2$
or $CO + \frac{1}{2}O_2 \rightarrow CO_2$
equation needs to be balanced [1]
[3]

(b) $\Delta H = 394 - 2 \times 111 = (+)172$ kJ mol^{-1} [2]
[2]

(c) (i) ligand exchange/displacement/replacement/substitution [1]

(ii)

- d-orbitals are split (by the ligand field) *or* orbitals near ligands are at higher energy
- the splitting/energy gap depends on the ligands (surrounding the ion) *or* the metal (ion)
- when an electron moves from lower to higher orbital/energy level *or* is promoted/ excited
- light/a photon is absorbed *or* colour seen/reflected/transmitted is complement of colour absorbed ("emitted" contradicts this mark)
- different energy gap means different frequency absorbed means different colour

5 × [1]

(iii) from rows 1 and 3: rate3/rate1 = 2.0 which also equals $[[complex]_3]/[[complex]_1]$ [1]
(*or* this working mark can be awarded for any valid calculation that shows that order w.r.t. complex is
Thus order w.r.t. [complex] = 1 **and** order w.r.t. [CO] is zero [1]
rate equation: **rate = k[complex]** [1]

(iv) mechanism 2 [1]
it's the only one that does **not** involve CO in the rate determining step *or* rate depends on [complex] only. [1]
[11 max 10]

[Total: 15]

4 **(a** the overall enthalpy change/energy change/ΔH for a reaction (1)

is independent of the route taken **or**
is independent of the number of steps involved
provided the initial and final conditions are the same (1) [2]

(b) (i) $K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$ (1)

(ii) heat produced = m × c × δT = 30.0 × 4.18 × 5.2
= 652.08 J per 0.0200 mol of K_2CO_3 (1)

(iii) 0.020 mol $K_2CO_3 \equiv$ 652.08 J

1 mol $K_2CO_3 \equiv \frac{652.08 \times 1}{0.0200}$ = 32604 J

enthalpy change = –32.60 kJmol^{-1} (1)

(iv) to prevent the formation of $KHCO_3$ **or**
to ensure complete neutralisation (1) [4]

(c) (i) $KHCO_3 + HCl \rightarrow KCl + H_2O + CO_2$ (1)

(ii) heat absorbed = m × c × δT = 30.0 × 4.18 × 3.7
= 463.98 J per 0.0200 mol of $KHCO_3$ (1)

(iii) 0.020 mol $KHCO_3 \equiv$ 463.98 J

1 mol $KHCO_3 \equiv \frac{463.98 \times 1}{0.0200}$ = 23199 J

enthalpy change = +23.20 kJmol^{-1} (1)

(d) ΔH = 2 × (+23.20) – (–32.60) = +79.00 kJ mol^{-1} (2)

[Total: 11]