A-Level Chemistry

Born-Haber Cycles

Mark Scheme

Time available: 61 minutes
Marks available: 56 marks

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1.

(a) Heat (energy) change at constant pressure

Ignore conditions even if wrong

Ignore energy change

1

(b) M2 $Ca^{2+}(g) + 2\ e^- + Cl_2(g)$

Alternative M2 $Ca^+(g) + e^- + 2\ Cl(g)$

1

M3 $Ca^{2+}(g) + 2\ Cl^-(g)$

1

M1 $Ca(s) + Cl_2(g)$

1

(c) M1 –795 + LE = 193 + 590 +1150 + (**2** x 121) + (**2** x –364)

Numbers and factors used correctly from cycle

1

M2 LE = (+) 2242 ($kJ\ mol^{-1}$)

Rearrangement to calculate LE

If one or both factors of 2 missing award 1 mark for (+) 2485, (+)2121 or (+)2606 ($kJ\ mol^{-1}$)

Allow 1 mark for – 2242 ($kJ\ mol^{-1}$)

1

(d) $MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq)$

Allow $MgCl_2(s) \rightleftharpoons Mg^{2+}(aq) + 2\ Cl^-(aq)$

Allow $MgCl_2(s) + aq \rightleftharpoons Mg^{2+}(aq) + 2\ Cl^-(aq)$

1

(e) M1 ΔH soln $MgCl_2$ = ΔH latt diss+ ΔH hyd Mg^{2+} + **2**ΔH hyd Cl^-
OR 2493 –1920 + (**2** x –364)

M1 for expression with or without numbers

1

M2 = – 155 ($kJ\ mol^{-1}$)

M2 for answer

If factor of 2 missing for ΔH hyd Cl^-, allow 1 mark for 209

1

(f) M1 Ca^{2+} (ion) bigger/lower charge to size ratio (than Mg^{2+})

Allow converse answers

M1 Do not accept Ca^{2+} is a bigger atom/molecule

M1 Allow Ca^{2+} has more shells/ more distance of outer e to nucleus

Ignore more shielding

1

M2 weaker attraction/bond to ($O^{\delta-}$ in) water

1

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2. (a) **M1**

$\Delta_f H = \Delta_a H$ (Sr) + $2\Delta_a H$ (Cl) + $\Delta_{1st\ IE} H$ (Sr) + $\Delta_{2nd\ IE} H$ (Sr) + $2\Delta_{EA} H$ (Cl) + $\Delta_{LE} H$ (Sr)

Or

$-828 = 164 + (2 \times 121) + 548 + 1060 + (2 \times \Delta_{EA} H) + (-2112)$

1

M2 $2 \times \Delta_{EA} H = -730$

1

M3 $\Delta_{EA} H = -365$ (kJ mol^{-1})

*Allow **M3** = **M2**÷2*

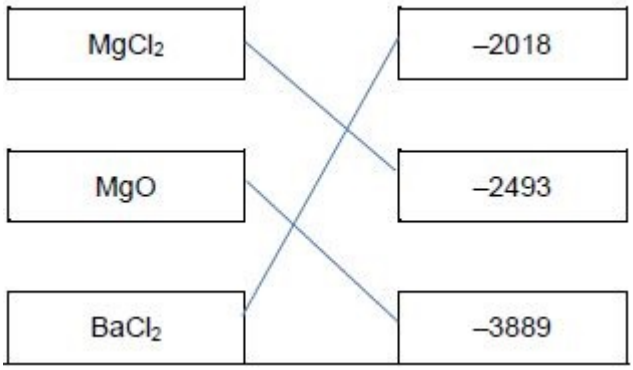
(+) 365, –304.5, and –730 = 2 marks

(+) 304.5, (+) 730 and –609 = 1 mark

(+) 609 = 0 marks 1

1

(b)



All three lines must be shown

1

(c) (Has) covalent character or partial covalent bonding (as well as ionic bonding)

*Allow chloride **ion** has been polarised or chloride **ion** distorted*

Ignore not perfectly ionic

Ignore ions are not spheres

Do not allow references to molecules or ions with covalent character

Do not allow it is covalently bonded alone

1

(d) **M1** (From Li^+ to K^+) size (of ion) increases OR charge density (of ion) decreases

M1 *Allow K+ has more shells or larger distance between nucleus and outer electrons or larger ionic radius*

Do not allow atomic radius or molecules

1

M2 (Electrostatic) attraction between metal ion and $O^{\delta-}$ of water decreases or attraction between lone pair on O and + ion decreases

M2 *Not dependent on* ***M1***

Allow converse arguments

1

(e) **M1** $\Delta_{sol}H = \Delta_{LEdissociation}H + \Delta_{hyd}H\ (Ca^{2+}) + 2x\ \Delta_{hyd}H\ (Br^-)$
or
M1 $-110 = 2176 + (-1650) + 2x\ \Delta_{hyd}H\ (Br^-)$

1

M2 $(2x\ \Delta_{hyd}H\ (Br^-)) = -636$

1

M3 $\Delta_{hyd}H\ (Br^-) = -318$ (kJ mol^{-1})

Allow ***M3*** *=* ***M2*** *÷ 2*

(+)1858, (+)318 and –636 = 2 marks

+3716, –1858 and (+)636 = 1 mark

–3716 = 0 marks

1

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3. (a) Top line $Cs^+(g) + e^- + I(g)$

1

Lower line $Cs(s) + \frac{1}{2}I_2(s)$

1

(b) $79 + \times + 376 - 314 = -337 + 585$

1

So enthalpy change = 107 (kJ mol^{-1})

Allow I mark for -107 (kJ mol^{-1})

Allow answer to 2sf or more

1

(c) (Almost/Mostly) purely/ perfectly ionic

If ionic not mentioned, allow no/little covalent bonding/character

Penalise references to atoms/molecules

Ignore electronegativity

1

(d) **M1** $\Delta S = [(82.8 + \frac{1}{2} \times 117) - 130] = \underline{11.3}$ (J K^{-1} mol^{-1})

M1 *Correct entropy change value*

1

M2 $\Delta G = \Delta H - T\Delta S$

M2 *equation or equation with numbers*

1

M3 $\Delta G = 337 - 298 \times 11.3 \times 10^{-3}$ OR $337000 - 298 \times 11.3$

M3 *for converting units:*

ΔS into kJK^{-1} mol^{-1} or ΔH into J mol^{-1}

1

M4 ΔG = (+)334 $\underline{kJ\ mol^{-1}}$ or 334000 $\underline{J\ mol^{-1}}$

M4 *answer with correct units*

*Any negative answer loses **M4***

1

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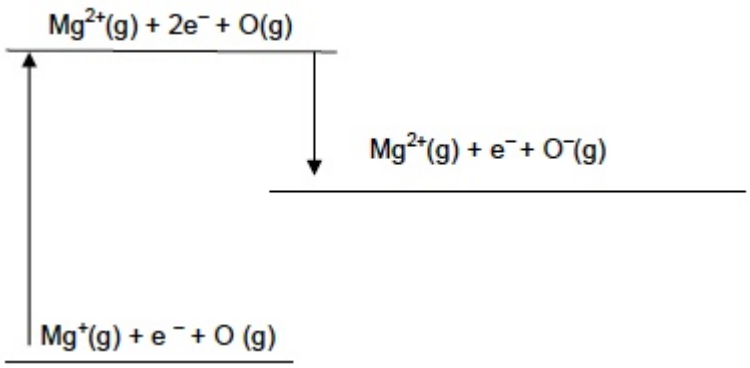
4. (a)



One mark for each level with correct state symbols

1
1
1

(b) $\Delta_f H = \Delta_a H$ (Mg) + ½ $\Delta_{BD} H$ (O_2) + $\Delta_{1st\ IE} H$ (Mg) + $\Delta_{2nd\ IE} H$ (Mg) +

1

$\Delta_{1st\ EA} H$ (O) + $\Delta_{2nd\ EA} H$(O) + $\Delta_{LE} H$ (MgO)

- 602 = 150 + (½ × 496) + 736 +1450 – 142 + 844 + $\Delta_{LE} H$ (MgO)

1

$\Delta_{LE} H$ (MgO) = -3888 / -3890 (kJ mol^{-1})

Allow answers to 2sf or more

1 mark for +3888 or +3890

1 mark for -4136 or -4140 (not 496 × ½)

1

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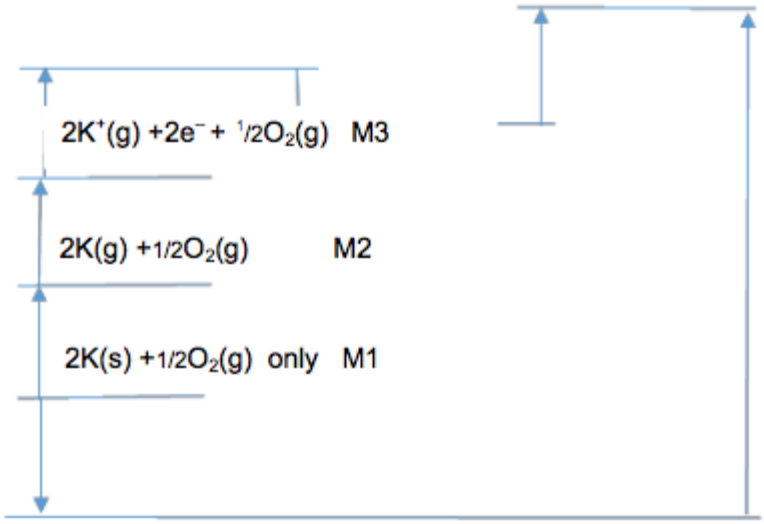
5.

(a) (i)



Mark each line independently, but follow one route only

Must have state symbols, but ignore s.s. on electrons

Penalise lack of state symbols each time

Alternative answers

2K(g) + O(g) M3

2K(g) +½O_2(g) M2

2K(s) +½O_2(g) only M1

or

2K(g) + O(g) M3

2K(s) +O(g) M2

2K(s) +½O_2(g) only M1

1
1
1

(ii) (2 × 90) + 248 + (2 × 418) – 142 + 844 = – 362 + Lattice enthalpy of dissociation

Enthalpy of lattice dissociation = (+) 2328 (kJmol^{-1})

M1 for (2 × 90) and (2 × 418)

M2 for a correct expression (either in numbers or with words/formulae)

M3 for answer

2328 kJmol^{-1} scores 3 marks

Allow answers given to 3sf

Answer of 1820, scores zero marks as two errors in calculation.

Answers of 2238, 1910, 2204 max = 1 mark only since one chemical error in calculation (incorrect/missing factor of 2)

Allow 1 mark for answer of -2328 (kJmol^{-1})

Penalise incorrect units by one mark

3

(b) K^+ (ion)/K ion is bigger (than Na^+ ion)

K^+ has lower charge density / Na^+ has higher charge density

Ignore K atom is bigger

1

(Electrostatic) attraction between (oppositely charged) ions is weaker

If attraction is between incorrect ions, then lose M2

Attraction between molecules/atoms or mention of intermolecular forces CE=0/2

Allow converse for Na_2O if explicit

1

[8]

6. (a) $Cl(g) + e^- \rightarrow Cl^-(g)$

State symbols essential

Allow e with no charge

This and all subsequent equations must be balanced

1

(b) There is an attraction between the nucleus / protons and (the added) electron(s)

1

Energy is released (when the electron is gained)

Allow product more stable / product has lower energy

Allow reaction exothermic / heat released

Allow reference to chlorine rather than fluorine

Wrong process eg ionisation, boiling CE = 0

1

(c) (i) Top line: $+ e^- + F(g)$

Penalise missing / wrong state symbols one mark only

Penalise Fl or Cl one mark only

1

Second line from top : $+ e^- + \frac{1}{2}F_2(g)$

Mark independently

Allow e with no charge

1

Bottom two lines: $+\frac{1}{2}F_2(g)$

Penalise each lack of an electron in M1 and M2 each time

1

(ii) $\frac{1}{2}$E(F–F) + 732 + 289 + +203 = 348 + 955

$\frac{1}{2}$E(F–F) = 79

1

E(F–F) = 158 (kJ mol^{-1})

Award one mark (M2) if M1 wrong but answer = M1 × 2

Ignore no units, penalise wrong units but allow kJ mol^{-}

Any negative answer, CE = 0

1

(d) (i) Experimental lattice enthalpy value allows for / includes covalent interaction / non–spherical ions / distorted ions / polarisation

OR AgF has covalent character

Allow discussion of AgCl instead of AgF

CE = 0 for mention of molecules, atoms, macromolecular, mean bond enthalpy, intermolecular forces (imf), electronegativity

1

Theoretical lattice enthalpy value assumes only ionic interaction / point charges / no covalent / perfect spheres / perfectly ionic

OR AgF is not perfectly ionic

1

(ii) Chloride ion larger (than fluoride ion) / fluoride ion smaller (than chloride ion)

Penalise chlorine ion once only

Allow Cl^{-} and F^{-} instead of names of ions

Allow chloride ion has smaller charge density / smaller charge to size ratio but penalise mass to charge ratio

1

Attraction between Ag^{+} and Cl^{-} weaker / attraction between Ag^{+} and F^{-} stronger

For M2 Cl^{-} and F^{-} can be implied from an answer to M1

Mark M1 and M2 independently provided no contradiction

CE = 0 for mention of chlorine not chloride ion, molecules, atoms, macromolecular, mean bond enthalpy, intermolecular forces (imf), electronegativity

1

[12]