Mark schemes

1

(a) (i)

2K$^+$(g) +2e$^-$ + ½O$_2$(g)   M3

2K(g) +½O$_2$(g)   M2

2K(s) +½O$_2$(g) only M1
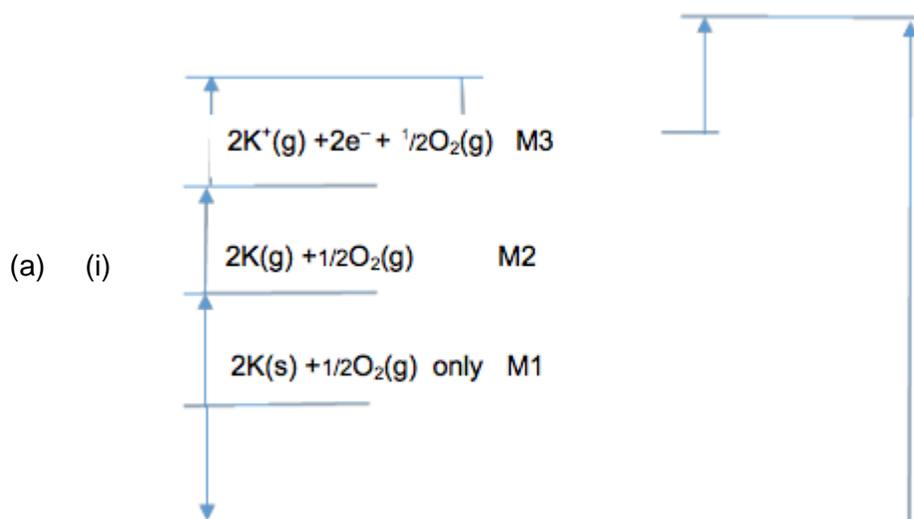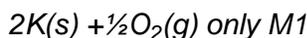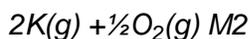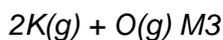
Mark each line independently, but follow one route only

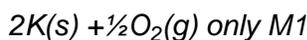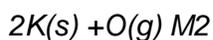*Must have state symbols, but ignore s.s. on electrons*

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) $(2 \times 90) + 248 + (2 \times 418) - 142 + 844 = -362 +$ 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) <u>ions</u> 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]

2   (a) $MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^{-}(aq)$

State symbols essential

Do not allow this equation with H_2O on the LHS

Ignore + aq on the LHS

Allow H_2O written over the arrow / allow equation written as an equilibrium

Allow correct equations to form $[Mg(H_2O)_6]^{2+}$ ions

1

(b) $\Delta H_{soln} MgCl_2 = LE + (\Delta H_{hyd}Mg^{2+}) + 2(\Delta H_{hyd}Cl^{-})$

$\Delta H_{soln} MgCl_2 = 2493 - 1920 + (2 \times -364)$

$= -155$ (kJ mol-1)

M1 for expression in words or with correct numbers

Ignore units, but penalise incorrect units

1
1

(c)   M1: Solubility decreases (as temp increases)

M2: the enthalpy of solution is exothermic / reaction is exothermic / backwards reaction is endothermic

M3: (According to Le Chatelier) the equilibrium moves to absorb heat/reduce temperature/oppose the increase in temperature (in the endothermic direction)

If M1 is incorrect then CE=0/3

If answer to (b) is a +ve value, allow:

M1: Solubility increases (as temp increases)

M2: Enthalpy of solution is endothermic etc

M3: (According to Le Chatelier) the equilibrium moves to absorb heat/reduce the temperature/oppose the increase in temperature (in the endothermic direction)

1
1
1

[6]

3 (a) Start a clock when KCl is added to water

1

Record the temperature every subsequent minute for about 5 minutes
Allow record the temperature at regular time intervals until some time after all the solid has dissolved for M2

1

Plot a graph of temperature vs time

1

Extrapolate back to time of mixing = 0 and determine the temperature

1

(b) Heat taken in = $m \times c \times \Delta T$ = 50 × 4.18 × 5.4 = 1128.6 J
Max 2 if 14.6 °C used as ΔT

1

Moles of KCl = 5.00 / 74.6 = 0.0670

1

Enthalpy change per mole = +1128.6 / 0.0670 = 16 839 J mol^{-1}

1

= +16.8 (kJ mol^{-1})
Answer must be given to this precision

1

(c) $\Delta H_{solution}$ = $\Delta H_{lattice}$ + ΔH(hydration of calcium ions) + 2 × ΔH(hydration of chloride ions)

$\Delta H_{lattice}$ = $\Delta H_{solution}$ – ΔH(hydration of calcium ions) –2 ×ΔH(hydration of chloride ions)

1

$\Delta H_{lattice}$ = −82–9 − (−1650 + 2 × −364) = +2295 (kJ mol^{-1})

1

(d) Magnesium ion is smaller than the calcium ion

1

Therefore, it attracts the chloride ion more strongly / stronger ionic bonding

1

[12]

4 (a) The <u>enthalpy change / heat energy change / ΔH</u> for the formation of <u>one mole</u> of (chloride) ions from (chlorine) atoms

Allow enthalpy change for $Cl + e^- \rightarrow Cl^-$

Do not allow energy change

ionisation energy description is CE=0

Allow enthalpy change for the addition of 1 mol of electrons to Chlorine atoms

penalise Cl_2 and chlorine molecules CE = 0

allow chlorine ions

1

Atoms and ions in the gaseous state

Or state symbols in equation

Cannot score M2 unless M1 scored

except allow M2 if energy change rather than enthalpy change

ignore standard conditions

1

(b) $Mg^{2+}(g) + 2e^- + 2Cl(g)$ (1)
(M5)

$Mg^{2+}(g) + 2e^- + Cl_2(g)$ (1) (M4)	
	$Mg^{2+}(g) + 2Cl^-(g)$ (1) (M6)
$Mg^+(g) + e^- + Cl_2(g)$ (1) (M3)	
$Mg(g) + Cl_2(g)$ (1) (M2)	
$Mg(s) + Cl_2(g)$ (1) (M1)	
$MgCl_2(s)$	

Allow e for electrons (i.e. no charge)

State symbols essential

If no electrons allow M5 but not M3,M4

If incorrect 1 / 2 Cl_2 used allow M3 and M4 for correct electrons (scores 2 / 6)

6

(c) $-\Delta H_f(MgCl_2) + \Delta H_a(Mg) + 1^{st}$ IE(Mg) + 2nd IE(Mg) $+2\Delta H_a(Cl) = -2EA(Cl) - LE(MgCl_2)$

Allow Enthalpy of Formation = sum of other enthalpy changes (incl lattice formation)

1

$-2EA(Cl) = 642 + 150 + 736 + 1450 + 242 - 2493 = 727$

1

EA(Cl) = −364 (kJ mol⁻¹)

Allow −363 to −364
Allow M1 and M2 for −727
Allow 1 (1 out of 3) for +364 or +363 but award 2 if due to arithmetic error after correct M2
Also allow 1 for −303
Units not essential but penalise incorrect units
Look for a transcription error and mark as AE−1

1

(d) (i) Magnesium (ion) is smaller **and** more charged (than the sodium ion)
OR
magnesium (ion) has higher charge to size ratio / charge density

Do not allow wrong charge on ion if given

Do not allow similar size for M1

Do not allow mass / charge ratio

1

(magnesium ion) attracts water more strongly

.

Mark independently

Mention of intermolecular forces, (magnesium) atoms or atomic radius CE = 0

1

(ii) Enthalpy change = −LE(MgCl₂) + Σ(ΔH$_{hyd}$ions)

= 2493 + (−1920 + 2 × −364)

1

= −155 (kJ mol⁻¹)

Units not essential but penalise incorrect units

1
[15]

5   (a)   Cl(g) + e⁻ → Cl⁻(g)

State symbols essential
Allow e with no charge
This and all subsequent equations must be balanced

1

(b)   There is an <u>attraction</u> between the <u>nucleus / protons</u> 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) Chlor<u>ide</u> <u>ion</u> larger (than fluor<u>ide</u> ion) / fluor<u>ide</u> <u>ion</u> smaller (than chlor<u>ide</u> 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

<u>Attraction</u> between Ag^+ and Cl^- weaker / <u>attraction</u> 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]

6 (a) Enthalpy change / $ΔH$ when 1 mol of a gaseous ion

> *Enthalpy change for $X^{+/-}(g) → X^{+/-}(aq)$ scores M1 and M2*

1

forms aqueous ions

> *Allow heat energy change instead of enthalpy change*
>
> *Allow 1 mol applied to aqueous or gaseous ions*
>
> *If substance / atoms in M1 CE = 0*
>
> *If wrong process (eg boiling) CE = 0*

1

(b) $ΔH$(solution) = $ΔH$(lattice) + $\underline{\Sigma}$($ΔH$hydration)

OR +77 = +905 − 464 + $ΔH$(hydration, Cl⁻)

OR $ΔH$(hydration, Cl⁻) = +77 −905 + 464

> *Allow any one of these three for M1 even if one is incorrect*

1

= −364 (kJ mol⁻¹)

> *Allow no units, penalise incorrect units, allow kJ mol⁻*
>
> *Allow lower case j for J (Joules)*
>
> *+364 does not score M2 but look back for correct M1*

1

(c) Water is polar / water has Hδ+

1

(Chloride ion) attracts (the H in) water molecules

(note chloride ion can be implied from the question stem)

> *Idea that there is a force of <u>attraction</u> between the chloride ion and water*
>
> *Do not allow H bonds / dipole–dipole / vdW / intermolecular but ignore loose mention of bonding*
>
> *Do not allow just chlorine or chlorine atoms / ion*
>
> *Mark independently*

1

(d) $\Delta G = \Delta H - T\Delta S$

> *Look for this equation in part (d) and / or (e); equation can be stated or implied by correct use. Record the mark in part (d)*

1

$(\Delta G = 0$ so$)$ $T = \Delta H / \Delta S$

1

$T = 77 \times 1000 / 33 = 2333$ <u>K</u> (allow range 2300 to 2333.3)

> *Units essential, allow lower case k for K (Kelvin)*
>
> *Correct answer with units scores M1, M2 and M3*
>
> *2.3 (K) scores M1 and M2 but not M3*

1

Above the boiling point of water (therefore too high to be sensible) / water would evaporate

> *Can only score this mark if M3 >373 K*

1

(e) $\Delta S = (\Delta H - \Delta G) / T$ OR $\Delta S = (\Delta G - \Delta H) / -T$

1

$= ((-15 + 9) \times 1000) / 298$ OR $(-15 + 9) / 298$

1

$= -20$ J K^{-1} mol^{-1} OR -0.020 kJ K^{-1} mol^{-1}

(allow -20 to -20.2)   (allow -0.020 to -0.0202)

> *Answer with units must be linked to correct M2*
>
> *For M3, <u>units must be correct</u>*
>
> *Correct answer with appropriate units scores M1, M2 and M3 and possibly M1 in part (d) if not already given*
>
> *Correct answer without units scores M1 and M2 and possibly M1 in part (d) if not already given*
>
> *Answer of $-240 / -0.24$ means temperature of 25 used instead of 298 so scores M1 only*
>
> *If ans = $+20 / +0.020$ assume AE and look back to see if M1 and possibly M2 are scored*

1

[13]

7 (a) Enthalpy change (to separate) 1 mol of an (ionic) substance into its <u>ions</u>

> *If ionisation or hydration / solution, CE = 0*
> *If atoms / molecules / elements mentioned, CE = 0*
> *Allow heat energy change but not energy change alone.*
> *If forms 1 mol ions, lose M1*

1

Forms <u>ions</u> in the gaseous state

> *If lattice formation not dissociation, allow M2 only.*
> *Ignore conditions.*
> *Allow enthalpy change for*
> *MX(s) → M⁺(g) + X⁻(g) (or similar) for M1 and M2*

1

(b) Any **one** of:

- Ions are point charges
- Ions are perfect spheres
- Only electrostatic attraction / bonds (between ions)
- No covalent interaction / character
- Only ionic bonding / no polarisation of ions

> *If atoms / molecules mentioned, CE = 0*

1 max

(c) (Ionic) radius / distance between ions / size

> *Allow in any order.*
> *Do not allow charge / mass or mass / charge.*

1

(Ionic) charge / charge density

> *Do not allow 'atomic radius'.*

1

(d) $\Delta H_L = \Delta H_a$ (chlorine) $+ \Delta H_a$ (Ag) $+$ I.E(Ag) $+$EA(Cl) $- \Delta H_f^{\ominus}$

> *Or cycle*
> *If AgCl₂, CE=0 / 3*

1

= 121 + 289 + 732 − 364 + 127

1

= (+) 905 (kJ mol⁻¹)

> *Allow 1 for −905*
> *Allow 1 for (+)844.5 (use of 121 / 2)*
> *Ignore units even if incorrect.*

1

(e) M1 Greater

> *Do not penalise AgCl₂*

1

M2 (Born-Haber cycle method allows for additional) covalent interaction

        Allow AgCl has covalent character.

        Only score M2 if M1 is correct

OR

M1 Equal

M2 AgCl is perfectly ionic / no covalent character

1

[10]