M1.(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

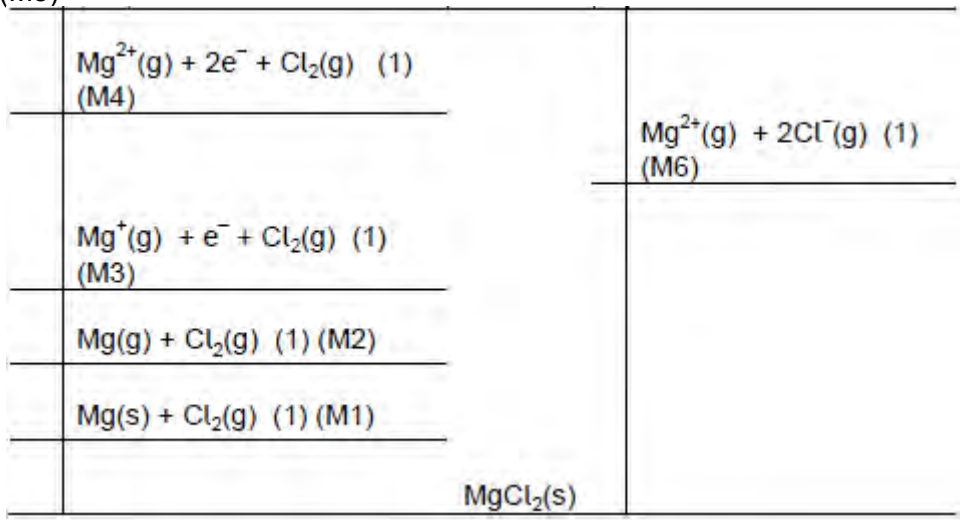
Cannot score M2 unless M1 scored

except allow M2 if energy change rather than enthalpy change

ignore standard conditions

1

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



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) + 2^{nd} 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($MgCl_2$) + Σ(ΔH_{hyd}ions)

= 2493 + (−1920 + 2 × −364)

1

= −155 (kJ mol^{-1})

Units not essential but penalise incorrect units

1

[15]

M2.(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 untilsome 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 = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6$ 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) $\Delta H_{solution} = \Delta H_{lattice} + \Delta H$(hydration of calcium ions) + 2 × ΔH(hydration of chloride ions)

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

1

$\Delta H_{lattice} = -82-9 - (-1650 + 2 \times -364) = +2295$ (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]

M3.(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]

M4.(a) Enthalpy change / ΔH when 1 mol of a gaseous ion
Enthalpy change for $X^{+/-}(g) \rightarrow X^{+/-}(aq)$ 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) + $\underline{\Sigma}$(ΔHhydration)

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]