M1.(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

$MX(s) \rightarrow M^+(g) + X^-(g)$ (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) + ΔH_a (Ag) + I.E(Ag) +EA(Cl) − $\Delta H_f^{\ominus}$

Or cycle

If $AgCl_2$, 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 $AgCl_2$

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]

M2.(a) Chlor<u>ide</u> (ions) are smaller (than brom<u>ide</u> ions)

Must state or imply ions.

Allow chlor<u>ide</u> has greater charge density (than bromide).

Penalise <u>chlorine ions</u> once only (max 2 / 3).

1

So the force of attraction between chloride ions and water is stronger

This can be implied from M1 and M3 but do not allow intermolecular forces.

1

Chloride ions attract the δ+ on H of water / electron deficient H on water

Allow attraction between ions and polar / dipole water.

*Penalise H^+ (ions) and mention of hydrogen bonding for **M3***

Ignore any reference to electronegativity.

Note: If water not mentioned can score M1 only.

1

(b) $\Delta H_{solution} = \Delta H_L + \Delta H_{hyd}$ K^+ ions + ΔH_{hyd} Br^- ions / = 670 − 322 − 335

Allow $\Delta H_{solution} = \Delta H_L + \Sigma\Delta H_{hyd}$

1

= (+)13 (kJ mol^{-1})

Ignore units even if incorrect.

+13 scores M1 and M2

−13 scores 0

−16 scores M2 only (transcription error).

1

(c) (i) The entropy change is positive / entropy increases

ΔS is negative loses M1 and M3

1

Because 1 mol (solid) → 2 mol (aqueous ions) / no of particles increases

Allow the aqueous ions are more disordered (than the solid).

Mention of atoms / molecules loses M2

1

Therefore $T\Delta S > \Delta H$

1

(ii) Amount of KCl = 5/M_r = 5/74.6 = 0.067(0) mol

If moles of KCl not worked out can score M3, M4 only
(answer to M4 likely to be 205.7 K)

1

Heat absorbed = 17.2 × 0.0670 = 1.153 kJ

Process mark for M1 × 17.2

1

Heat absorbed = mass × sp ht × ΔT

(1.153 × 1000) = 20 × 4.18 × ΔT

If calculation uses 25 g not 20, lose M3 only (M4 = 11.04, M5 = 287)

1

ΔT = 1.153 × 1000 / (20 × 4.18) = 13.8 K

If 1000 not used, can only score M1, M2, M3

M4 is for a correct ΔT

Note that 311.8 K scores 4 (M1, M2, M3, M4).

1

T = 298 − 13.8 = 284(.2) K

If final temperature is negative, M5 = 0

Allow no units for final temp, penalise wrong units.

1

[13]

M3.(a) $MgCl_2(s) \rightarrow Mg^{2+}(g) + 2Cl^-(g)$

1

(b) The magnesium ion is smaller / has a smaller radius / greater charge density (than the calcium ion)

If not ionic or if molecules / IMF / metallic / covalent / bond pair / electronegativity mentioned, CE = 0

1

Attraction between ions / to the chloride ion stronger

Allow ionic bonds stronger

Do not allow any reference to polarisation or covalent character

Mark independently

1

(c) The oxide ion has a greater charge / charge density than the chloride ion

If not ionic or if molecules / IMF / metallic / covalent / bond pair mentioned, CE = 0

Allow oxide ion smaller than chloride ion

1

So it attracts the magnesium ion more strongly

Allow ionic bonds stronger

Mark independently

1

(d) $\Delta H_{solution} = \Delta H_{L} + \Sigma\Delta H_{hyd}$ Mg^{2+} ions + $\Sigma\Delta H_{hyd}$ Cl^{-} ions

Allow correct cycle

1

$-155 = 2493 + \Delta H_{hyd}$ Mg^{2+} ions $- 2 \times 364$

ΔH_{hyd} Mg^{2+} ions $= -155 - 2493 + 728$

1

$= -1920$ (kJ mol^{-1})

Ignore units

Allow max 1 for +1920

Answer of + or −1610, CE = 0

Answer of −2284, CE = 0

1

(e) Water is polar / O on water has a delta negative charge

Allow <u>O</u> (not water) has lone pairs (can score on diagram)

1

Mg^{2+} ion / $^{+}$ve ion / + charge attracts (negative) O on a water molecule

Allow Mg^{2+} attracts lone pair(s)

M2 must be stated in words (QoL)

Ignore mention of co-ordinate bonds

CE = 0 if O^{2-} or water ionic or H bonding

1

(f) Magnesium oxide reacts with water / forms $Mg(OH)_2$

Allow MgO does not dissolve in water / sparingly soluble / insoluble

1

[11]

M4.(a) Standard pressure (100 kPa) (and a stated temperature)

Allow standard conditions. Do not allow standard states

Allow any temperature

Allow 1 bar but not 1atm

Apply list principle if extra wrong conditions given

Penalise reference to concentrations

1

(b) Hydrogen bonds between water molecules

1

Energy must be supplied in order to break (or loosen) them

Allow M2 if intermolecular forces mentioned

Otherwise cannot score M2

CE = 0/2 if covalent or ionic bonds broken

1

(c) $T = \Delta H / \Delta S$

1

$= (6.03 \times 1000)/22.1$

1

$= 273$ K

Allow 272 to 273; units K must be given

Allow 0°C if units given
0.273 (with or without units) scores 1/3 only
Must score M2 in order to score M3
Negative temperature can score M1 only

1

(d) The heat given out escapes

1

(e) (Red end of white) <u>light</u> (in visible spectrum) <u>absorbed</u> by ice

Allow complementary colour to blue absorbed

1

Blue light / observed light is reflected / transmitted / left

Penalise emission of blue light

1

[9]

M5.(a) <u>Enthalpy change</u>/heat energy change when <u>one mole</u> of <u>gaseous atoms</u>

Allow explanation with an equation that includes state symbols

1

Form (one mole of) gaseous negative ions (with a single charge)

If ionisation/ionisation energy implied, CE=0 for both marks
Ignore conditions

1

(b) Fluorine (atom) is smaller than chlorine/shielding is less/ outer electrons closer to nucleus

Fluorine molecules/ions/charge density CE=0 for both marks

1

(Bond pair of) electrons attracted more strongly to the nucleus/protons

1

(c) Fluoride (ions) smaller (than chloride) / have larger charge density

Any reference to electronegativity CE=0

1

So (negative charge) attracts (δ+ hydrogen on) water more strongly

Allow H on water, do not allow O on water

Allow F^- hydrogen bonds to water, chloride ion does not

Mark independently

1

(d) (i) ΔH(solution) = LE + Σ(hydration enthalpies) / correct cycle

AgF_2 or other wrong formula CE = 0

Ignore state symbols in cycle

1

LE = -20 -(-464 + -506)

1

= (+) 950 kJ mol^{-1}

Ignore no units, penalise M3 for wrong units

-950 scores max 1 mark out of 3

990 loses M3 but M1 and M2 may be correct

808 is transfer error (AE) scores 2 marks

848 max 1 if M1 correct

1456 CE=0 (results from AgF_2)

1

(ii) There is an increase in the number of particles / more disorder / less order

Allow incorrect formulae and numbers provided number increases

Do not penalise reference to atoms/molecules

Ignore incorrect reference to liquid rather than solution

1

(iii) Entropy change is positive/entropy increases and enthalpy change negative/exothermic 1

So ΔG is (always) negative 1

[12]