1

(a) Enthalpy change (to separate) 1 mol of an (ionic) substance into its ions

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 ions 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]

2

(a) Chloride (ions) are smaller (than bromide ions)

Must state or imply ions.

Allow chloride has greater charge density (than bromide).

Penalise chlorine ions 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 $\underline{T\Delta S > \Delta H}$

1

(ii) Amount of KCl = $5/M_r = 5/74.6 = \underline{0.067(0) \text{ mol}}$

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

$(1.153 \times 1000) = 20 \times 4.18 \times \Delta T$

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

1

$\Delta T = 1.153 \times 1000 / (20 \times 4.18) = 13.8$ 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]

3 (a) (i) (At 0 K) particles are stationary / not moving / not vibrating

Allow have zero energy.

Ignore atoms / ions.

1

No disorder / perfect order / maximum order

Mark independently.

1

(ii) As *T* increases, particles start to move / vibrate

Ignore atoms / ions.

Allow have more energy.

If change in state, CE = 0

1

Disorder / randomness increases / order decreases

1

(iii) Mark <u>on temperature axis</u> vertically below second 'step'

Must be marked as a line, an 'x' , T_b or 'boiling point' <u>on the temperature axis</u>.

1

(iv) L_2 corresponds to boiling / evaporating / condensing / l → g / g → l

And L1 corresponds to melting / freezing / s → l / l → s

There must be a clear link between L_1, L_2 and the change in state.

1

Bigger change in <u>disorder</u> for L_2 / boiling compared with L_1 / melting

M2 answer must be in terms of changes in state and not absolute states eg must refer to change from liquid to gas not just gas.

Ignore reference to atoms even if incorrect.

1

(b) (i) $\Delta G = \Delta H - T\Delta S$

1

$\Delta H = c$ and $(-)\Delta S = m$ / ΔH and ΔS are constants (approx)

Allow ΔH is the intercept, and $(-)\Delta S$ is the slope / gradient.

Can only score M2 if M1 is correct.

1

(ii) Because the entropy change / ΔS is positive / $T\Delta S$ gets bigger

Allow $-T\Delta S$ gets more negative

1

(iii) <u>Not</u> feasible / <u>un</u>feasible / <u>not</u> spontaneous

1

(c) (i) + 44.5 J K^{-1} mol^{-1}

Allow answer without units but if units given they must be correct (including mol^{-1})

1

(c) (ii) At 5440 $\Delta H = T\Delta S$

= 5440 × 44.5 = 242 080

1

(***OR*** using given value = 5440 × 98 = 533 120)

Mark is for answer to (c)(i) × 5440

1

$\Delta H = 242$ kJ mol^{-1}

(***OR*** using given value $\Delta H = 533$ kJ mol^{-1})

Mark is for correct answer to M2 with correct units (J mol^{-1} or kJ mol^{-1}) linked to answer.

If answer consequentially correct based on (c)(i) except for incorrect sign (eg −242), max 1 / 3 provided units are correct.

1

[15]

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

1

(b) The magnesium <u>ion</u> 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 O (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]

5 (a) $\Delta G = \Delta H - T\Delta S$

Or expression $\Delta H - T\Delta S$ must be evaluated

1

If ΔG / expression <=0 reaction is feasible

Or any explanation that this expression <=0

Do not allow just $\Delta G = 0$

1

(b) The molecules become more disordered / random when water changes from a liquid to a gas / evaporates

For M1 must refer to change in state AND increase in disorder

1

Therefore the entropy change is positive / Entropy increases

Only score M2 if M1 awarded

1

$T\Delta S > \Delta H$

Allow M3 for T is large / high (provided M2 is scored)

1

ΔG<0

Mark M3, M4 independently

1

(c) (i) Condition is $T = \Delta H / \Delta S$

1

ΔS = 189 −205 / 2 − 131 = −44.5;

1

ΔH = −242 therefore T = (−242 × 1000) / −44.5)

1

= 5438 K (allow 5400 − 5500 K)

Units essential (so 5438 alone scores 3 out of 4)
2719 K allow score of 2
5.4 (K) scores 2 for M1 and M2 only
1646 (K) scores 1 for M1 only

1

(ii) It would decompose into hydrogen and oxygen / its elements

Can score this mark if mentioned in M2

1

Because ΔG for this reaction would be <= 0

Allow the reverse reaction / decomposition is feasible
Only score M2 if M1 awarded

1

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

Allow correct substituted values instead of symbols

1

ΔS = 70−189 = −119 JK^{-1} mol^{-1}

1

ΔH = (−119 × 373) / 1000 = −44.4 kJ (mol^{-1}) (allow −44 to −45)

Allow −44000 to −45000 J (mol^{-1})
Answer must have correct units of kJ or J

1

[15]

6

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

Ignore ɵ

1

(b) 0.098 or 98

Allow 0.097 to 0.099/97 to 99
Allow 0.1 only if 0.098 shown in working

1

kJ K^{-1} mol^{-1} J K^{-1} mol^{-1}

Allow in any order

Unless slope is approx. 100(90-110) accept only kJ K^{-1} mol^{-1}. If no slope value given, allow either units

1

$-\Delta S/\Delta S$

1

(c) ΔG becomes negative

Mark independently unless ΔG +ve then CE = 0

1

So reaction becomes spontaneous/feasible

Or reaction can occur below this temperature

Or reaction is not feasible above this temperature

1

(d) Ammonia liquefies (so entropy data wrong/different)

Allow any mention of change in state or implied change in state even if incorrect

eg freezing/boiling

1

[7]

7

(a) Enthalpy change/heat energy change when one mole of gaseous atoms

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]

8

(a) $\Delta H = \Sigma(\Delta H_f$ products) - $\Sigma(\Delta H_f$ reactants)

Allow correct cycle

1

/= +34 - +90

= -56 kJ mol^{-1}

Ignore no units, penalise incorrect units

1

(b) $\Delta S = \Sigma(S$ products) - $\Sigma(S$ reactants)

1

/= 240 - (205 +211/2)

= -70.5 J K^{-1} mol^{-1} / -0.0705 kJ K^{-1} mol^{-1}

Ignore no units, penalise incorrect units

Allow -70 to -71/-.070 to -.071

1

(c) $T = \Delta H/\Delta S$ / T = (Ans to part(a) ×1000)/ans to part(b)

Mark consequentially on answers to parts (a) and (b)

1

/= -56/(-70.5 ÷ 1000)
= 794 K (789 to 800 K)

Must have correct units

Ignore signs; allow + or – and –ve temps

1

(d) Temperatures exceed this value

1

(e) $N_2 + O_2 \rightarrow 2NO$

Allow multiples

1

(f) there is no change in the number of moles (of gases)

Can only score these marks if the equation in (e) has equal number of moles on each side

Numbers, if stated must match equation

1

So entropy/disorder stays (approximately) constant / entropy/disorder change is very small / $\Delta S=0$ / $T\Delta S=0$

1

[10]

9

(a) Enthalpy change when 1 mol of an (ionic) compound/lattice (under standard conditions)

Allow heat energy change

1

Is dissociated/broken/separated into its (component) ions

1

The ions being in the gaseous state (at infinite separation)

Mark independently. Ignore any conditions.

1

(b) There is an attractive force between the nucleus of an O atom and an external electron.

Allow any statement that implies attraction between the nucleus and an electron

1

(c) $Mg^{2+}(g) + O(g) + 2e^-$

Ignore lack of state symbols

Penalise incorrect state symbols

1

$Mg^{2+}(g) + O^-(g) + e^-$

1

$Mg^{2+}(g) + O^{2-}(g)$

1

First new level for Mg^{2+} and O above last on L

If levels are not correct allow if steps are in correct order

with arrows in the correct direction and correct ∆H values

1

Next level for Mg^{2+} and O^- below that

Next level for Mg^{2+} and O^{2-} above that and also above that for Mg^{2+} and O

Allow +124

Allow M4 with incorrect number of electrons

(d) LE MgO = 602 + 150 + 736 + 1450 + 248 – 142 + 844

Note use of 124 instead of 248 CE=0

1

= +3888 kJ mol^{-1}

Allow 1 for –3888

Allow no units

Penalise wrong units

1

(e) Forms a protective layer/barrier of MgO / MgO prevents oxygen attacking Mg

Allow activation energy is (very) high

Allow reaction (very) slow

1

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

$\Delta S = \frac{(\Delta H - \Delta G)}{T}$

1

ΔS = (–602 – (–570)) × 1000/ 298

1

= –107 J K^{-1} mol^{-1} / –0.107 kJ K^{-1} mol^{-1}

If units not correct or missing, lose mark

Allow –107 to –108

+107 with correct units scores max 1/3

1

(g) 1 mol of solid and 0.5 mol of gas reactants form 1 mol solid products

Decrease in number of moles (of gas/species)

Allow gas converted into solid

Numbers of moles/species, if given, must be correct

1

System becomes more ordered

Allow consequential provided ΔS is –ve in 1(f)

If ΔS is +ve in 1(f) can only score M1

1

[16]

10 (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) light (in visible spectrum) absorbed by ice

Allow complementary colour to blue absorbed

1

Blue light / observed light is reflected / transmitted / left

Penalise emission of blue light

1

[9]