M1.(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 ΔH 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) $\Delta G = \Delta H - T\Delta S$

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

1

$\Delta S = (-602 - (-570)) \times 1000/ 298$

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 ∆S is –ve in 1(f)
If ∆S is +ve in 1(f) can only score M1

1

[16]

M2. (a) $KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq)$

do not allow equations with H_2O
allow aq and the word 'water' in equation

1

(b) increase in disorder because solid → solution / increase in number of particles / 1 mol (solid) gives 2 mol (ions/particles) / particles are more mobile

allow random or chaos instead of disorder
penalise if molecules/atoms stated instead of ions
allow any reference to increase in number of particles even if number of particles wrong

1

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

1

$T = \Delta H/\Delta S = (34.9 \times 1000)/117$

also scores M1

1

= 298 K

correct answer scores 3, units essential
0.298 scores M1 only

1

(d) (i) positive / increases / $\Delta G > 0$

Allow more positive

1

(ii) if ans to (d) (i) positive, dissolving is no longer spontaneous / no longer feasible / potassium nitrate does not dissolve / less soluble

if ans to (d) (i) negative, dissolving is spontaneous / feasible / potassium nitrate dissolves / more soluble

If no mention of change to ΔG in (d)(i),
Mark = 0 for (d)(ii)

1

[7]

M3. (a) (i) $\Delta H = \Sigma$ bonds broken $-\Sigma$ bonds formed

1

= 944/2 + 3/2 × 436 –3 × 388

1

= –38 (kJ mol^{-1})

ignore units even if incorrect
correct answer scores 3
–76 scores 2/3
+38 scores 1/3

1

(ii) mean / average bond enthalpies are from a range of compounds
or
mean / average bond enthalpies differ from those in a single compound / ammonia

1

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

1

= 193 – (192/2 + 131 × 3/2)

1

= –99.5 J K^{-1} mol^{-1}

units essential for M3
correct answer with units scores 3
–199 J K^{-1} mol^{-1} & –99.5 score 2/3

–199 and + 99.5 J K^{-1} mol^{-1} score 1/3

1

(c) (i) $\Delta G = \Delta H - T\Delta S = -46 + 800 \times 99.5/1000$

mark is for putting in numbers with 1000

if factor of 1000 used incorrectly CE = 0

1

= 33.6 or 33600

allow 33 to 34 (or 33000 to 34000)

1

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

correct units for answer essential

if answer to part (b) is wrong or if -112 used, mark consequentially e.g.

- *–199 gives 113 to 114 kJ mol^{-1} (scores 3/3)*
- *–112 gives 43 to 44 kJ mol^{-1} (scores 3/3)*

1

(ii) If answer to (c) (i) is positive: not feasible / not spontaneous

If answer to (c) (i) is negative: feasible / spontaneous

if no answer to (c) (i) award zero marks

1

[11]

M4. (a) Particles are in maximum state of order

(or perfect order or completely ordered or perfect crystal or minimum disorder or no disorder)

(entropy is zero at 0 k by definition)

1

(b) (Ice) melts

(or freezes or changes from solid to liquid or from liquid to solid)

1

(c) Increase in disorder

1

Bigger (at T_2)

1

Second mark only given if first mark has been awarded

(d) (i) Moles of water = 1.53/18 (= 0.085)

1

Heat change per mole = 3.49/0.085 = 41.1 (kJ mol^{-1})

(allow 41 to 41.1, two sig. figs.)

(penalise –41 (negative value), also penalise wrong units but allow kJ only)

1

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

1

(iii) $\Delta H = T\Delta S$ or $\Delta S = \Delta H/T$

(penalise if contradiction)

1

ΔS = 41.1/373 = 0.110 kJ K^{-1} (mol^{-1}) (or 110 (J K^{-1} (mol^{-1}))

(allow 2 sig. figs.)

(if use value given of 45, answer is 0.12 (or 120 to 121)

(if ΔH is negative in (d) (i), allow negative answer)

(if ΔH is negative in (d) (i), allow positive answer)

(if ΔH is positive in (d) (i), penalise negative answer)

1

Correct units as above (mol^{-1} not essential)

1

[10]

M5. (a) Because it is a gas compared with solid carbon

Mark independently

1

Nitrogen is more disordered/random/chaotic/free to move

1

(b) 0 K/–273 C/absolute zero

1

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

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

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

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

Ignore ~~e~~ in $\Delta G^{\ominus}$

1

(d) ΔG is less than or equal to zero ($\Delta G \leq 0$)

Allow ΔG is less than zero ($\Delta G < 0$)

Allow ΔG is equal to zero ($\Delta G = 0$)

Allow ΔG is negative

1

(e) When $\Delta G = 0$ $T = \underline{\Delta H/\Delta S}$

1

$\Delta H = +90.4$

Allow $\Delta H = +90$

1

$\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$

1

$\Delta S = 211.1 - 205.3/2 - 192.2/2 = \underline{12.35}$

1

$T = (90.4 \times 1000)/12.35 = 7320$ K/7319.8 $\underline{\text{K}}$

Allow 7230 to 7350 $\underline{\text{K}}$ (Note 7.32 K scores 4 marks)

Units of temperature essential to score the mark

1

(f) Activation energy is high

Allow chemical explanation of activation energy

Allow needs route with lower activation energy

Allow catalyst lowers activation energy

1

(g) $\Delta H = 1.9$ (kJ mol^{-1})

1

$\Delta S = 2.4 - 5.7 = -3.3$ (J K^{-1} mol^{-1})

for M1 and M2 allow no units, penalise wrong units

1

ΔG is always positive

This mark can only be scored if ΔH is +ve and ΔS is –ve

1

[14]