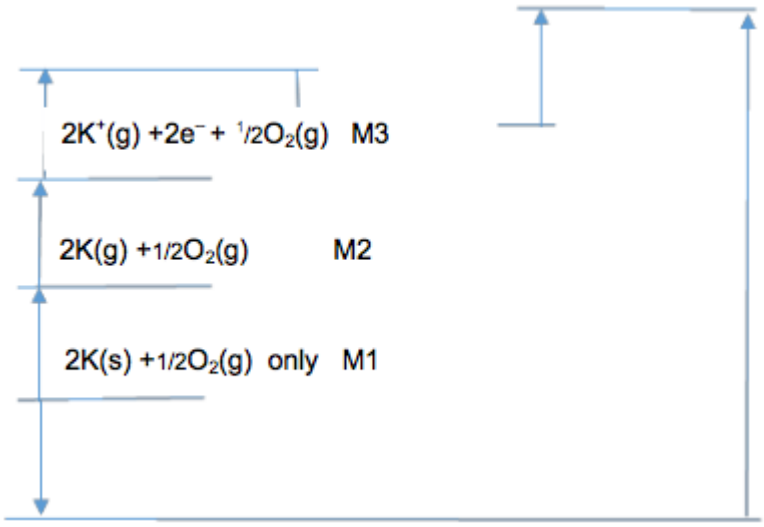
Mark schemes

1

(a) (i)



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 × 90) + 248 + (2 × 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) ions 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) $\Delta H^{\ominus} = \Sigma \Delta H_f^{\ominus}$ products - $\Sigma \Delta H_f^{\ominus}$ reactants

1

or (2 × –395) – (2 × –297)

= –196 (kJ mol^{-1})

Penalise incorrect units, ignore missing units

1

(b) $\Delta S^{\ominus} = \Sigma S^{\ominus}$ products - $\Sigma S^{\ominus}$ reactants

1

= (2 × 256) – 205 – (2 × 248)

= –189 $JK^{-1}\ mol^{-1}$

Allow -0.189 kJ K^{-1} mol^{-1}

Units must be given and must match value

1

(c) Causes an increase in order / a decrease in disorder

Allow products more ordered / products less disordered

If answer to (b) is +ve, allow products are less ordered / causes an increase in disorder / causes a decrease in order

1

(d) $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$

Do not insist on standard state symbol

1

= –196 – 323 (–189/1000)

If conversion of T or ΔS incorrect, then can only score M1

1

= –134.9 kJ mol^{-1}

Must have correct units

Allow answers in J mol^{-1}

–135 kJ mol^{-1}

If both alternative values used then -169(.3) kJ mol^{-1}

Allow alternative ΔH and/or alternative ΔS in calculation

1

(e) Feasible because ΔG is negative

Allow mark if a correct deduction from answer to (d)

Both a reference to feasibility and to ΔG needed

1

(f) (i) (The catalyst is in) a different state or phase (from the reactants)

1

(ii) $SO_2 + V_2O_5 \longrightarrow SO_3 + V_2O_4$

Allow $2VO_2$ instead of V_2O_4

Allow multiples

1

$\frac{1}{2}O_2 + V_2O_4 \rightarrow V_2O_5$

Must have equations in this order

1

(iii) Surface area is increased

1

(iv) So that the catalyst is not poisoned

Allow correct reference to the blocking active sites

1

[14]

4 (a) $\Delta S = 238 + 189 - 214 - 3 \times 131 = -180$ J K^{-1} mol^{-1}

1

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

1

$= -49 - \frac{523 \times (-180)}{1000}$

1

$= +45.1$ kJ mol^{-1}

Units essential

1

(b) When $\Delta G = 0$, $\Delta H = T\Delta S$ therefore $T = \Delta H / \Delta S$

1

$= -49 \times 1000 / -180 = 272$ (K)

Mark consequentially to ΔS in part (a)

1

(c) Diagram marks

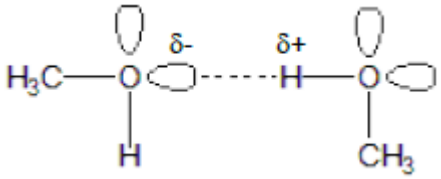


Diagram of a molecule showing O–H bond and two lone pairs on each oxygen

1

Labels on diagram showing δ+ and δ- charges

Allow explanation of position of δ+ and δ- charges on H and O

1

Diagram showing δ+ hydrogen on one molecule attracted to lone pair on a second molecule

1

Explanation mark

Hydrogen bonding (the name mentioned) is a strong enough force (to hold methanol molecules together in a liquid)

1

[10]

5 (a) An electron pair on the ligand

1

Is donated from the ligand to the central metal ion

1

(b) Blue precipitate

1

Dissolves to give a dark blue solution

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

1

$Cu(H_2O)_4(OH)_2 + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$

1

(c) $[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2NCH_2CH_2NH_2 \longrightarrow [Cu(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+} + 4NH_3$

1

(d) Cu–N bonds formed have similar enthalpy / energy to Cu–N bonds broken

1

And the same number of bonds broken and made

1

(e) 3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive

1

Therefore, the free-energy change is negative

M2 can only be awarded if M1 is correct

1

[11]

6 (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)

$\Delta H_{lattice} = \Delta H_{solution} - \Delta H$(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]

7

(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

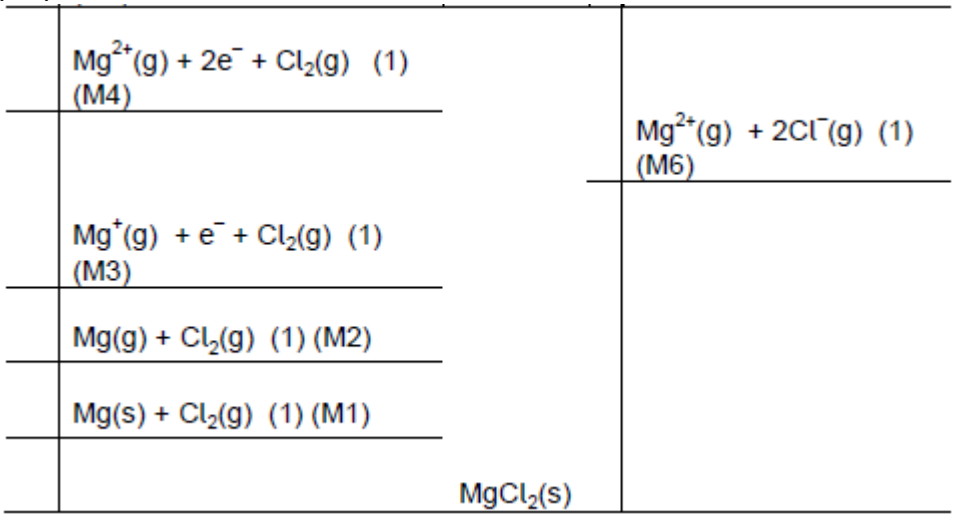
Cannot score M2 unless M1 scored

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]

8 (a) (i) ΔH = Σ(enthalpies formation products) − Σ(enthalpies formation reactants)

Or correct cycle with enthalpy changes labelled

1

= −111 −(−75 − 242)

1

= (+)206 (kJ mol⁻1)

−206 scores 1 only

Units not essential if ans in kJ mol^{-1} but penalise incorrect units

1

(ii) ΔS = Σ(entropies of products) − Σ(entropies reactants)

= 198 + 3 × 131 − (186 + 189)

1

= (+) 216 (J K^{-1} mol^{-1})
OR
0.216 kJ K^{-1} mol^{-1}

Units not essential but penalise incorrect units

1

(b) When $\Delta G = 0$ OR $\Delta H = T\Delta S$

1

$T = \Delta H / \Delta S$

M2 also scores M1

1

$= 206 \times 1000 / 216$

Allow error carried forward from (a)(i) and (a)(ii)

Ignore unexplained change of sign from − to +

1

= 954 K

Allow 953 − 955, Units of K essential, must be +ve

If values from (a)(i) and (a)(ii) lead to negative value in M3 allow M1 to M3 but do not allow negative temperature for M4

If negative value changed to positive for M4, allow M4

1

(c) To speed up the rate of reaction OR wtte

Allow so that more molecules have energy greater than the activation energy

IF T in (b) > 1300 allow answers such as;

to reduce energy cost

to slow down reaction

do NOT allow to increase rate

1

(d) (i) **Method 1**

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

$\Delta G = -41 - (1300 \times -42 / 1000)$ (M1)

If 42 and not 42 / 1000 used can score M3 only

but allow $\Delta G = -41 \times 1000 - (1300 \times -42)$ (M1)

1

$= +13.6$ kJ mol^{-1}

$= 13600$ J mol^{-1} (M2)

Units essential

1

ΔG must be negative for the reaction to be feasible.

OR ΔG is positive so reaction is not feasible

1

Method 2

For reaction to be feasible ΔG must be negative or zero

1

T when $\Delta G = 0 = \Delta H / \Delta S = 976K$

1

ΔS is −ve so ΔG must be +ve at temperatures above 976K / at 1300 *K*

1

(ii) If the temperature is lowered

(Ignore reference to catalyst and / or pressure)

Alternative mark scheme (if T is calculated)

Allow T reduced to 976 K or lower M1

1

ΔG will become (more) negative because

the $-T\Delta S$ term will be less positive / $T\Delta S > \Delta H$

At this temperature (the reaction becomes feasible because) ΔG < = 0 M2

1

[15]

9

(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]

10 (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 × 1000 / 33 = 2333 K (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) × 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, units must be correct

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]