Mark schemes

1

(a) (i) (Enthalpy change for formation of) 1 mol (of CaF_2) from its ions

allow heat energy change

do not allow energy or wrong formula for CaF_2

penalise 1 mol of ions

CE=0 if atoms or elements or molecules mentioned

ignore conditions

1

ions in the gaseous state

ions can be mentioned in M1 to score in M2

allow fluorine ions

$Ca^{2+}(g) + 2F^-(g) \rightarrow CaF_2$ scores M1 and M2

1

(ii) (enthalpy change when) 1 mol of gaseous (fluoride) ions (is converted) into aqueous ions / an aqueous solution

allow $F^-(g) \rightarrow F^-(aq)$ (ignore + aq)

do not penalise energy instead of enthalpy

allow fluorine ions

do not allow F^- ions surrounded by water

1

(b) water is polar / H on water is $\delta+$ / is electron deficient / is unshielded

1

penalise H^+ on water 1 mark

(F^- ions) attract water / $\delta+$ on H / hydrogen

allow H on water forms H-bonds with F^-

allow fluorine ions

penalise co-ordinate bonds for M2

penalise attraction to O for M2

1

(c) $\Delta H = -(-2611) - 1650 + 2x - 506$

ignore cycles

M1 is for numbers and signs correct in expression

1

$= -51$ (kJ mol^{-1})

correct answer scores 2

ignore units even if incorrect

1

[7]

2 (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]

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

1

$= 944/2 + 3/2 \times 436 - 3 \times 388$

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

$= 193 - (192/2 + 131 \times 3/2)$

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]

4

(a) Enthalpy change for the formation of 1 mol of gaseous atoms

allow heat energy change for enthalpy change

1

From the element (in its standard state)

ignore reference to conditions

1

Enthalpy change to separate 1 mol of an ionic lattice/solid/compound

enthalpy change not required but penalise energy

1

Into (its component) gaseous ions

mark all points independently

1

(b) $\Delta H_L = {}^{-}\Delta H_f + \Delta H_a$ + I.E. + 1/2E(Cl-Cl) + EA

Or correct Born-Haber cycle drawn out

1

= +411 + 109 + 494 + 121 – 364

1

= +771 (kJ mol^{-1})

–771 scores 2/3

+892 scores 1/3

–51 scores 1/3

–892 scores zero

+51 scores zero *ignore units*

1

(c) (i) Ions are perfect spheres (or point charges)

1

Only electrostatic attraction/no covalent interaction

mention of molecules/intermolecular forces/covalent bonds CE = 0

allow ionic bonding only

If mention of atoms CE = 0 for M2

1

(ii) Ionic

Allow no covalent character/bonding

1

(iii) Ionic with additional covalent bonding

Or has covalent character/partially covalent

Allow mention of polarisation of ions or description of polarisation

1

[11]

5 (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 ~~θ~~ in ΔG°

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 <u>K</u>

Allow 7230 to 7350 <u>K</u> (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]

6 (a) $CaF_2(s) \rightarrow Ca^{2+}(g) + 2F^-(g)$

1

(b) (i) Enthalpy change for formation of 1 mol of substance

Allow heat energy change, NOT energy

1

From its elements

1

Reactants and products/all substances in their standard states

Or normal states at 298 K, 1 bar (100 kPa)

1

(ii) $Ca(s) + F_2(g) \rightarrow CaF_2(s)$

1

(iii) $\Delta H_f(CaF_2) = \Delta H_a(Ca) + 1st\ IE(Ca) + 2^{nd}\ IE(Ca) + BE(F_2) + 2 \times EA(F) - \Delta H_L(CaF_2)$

Or labelled diagram

1

$= 193 + 590 + 1150 + 158 + (2 \times -348) - 2602$

1

$= -1207\ kJ\ mol^{-1}$

Correct answer scores 3
–842 scores 2 (transfer error)
–859 scores 1 only (using one E.A.)
Units not required, wrong units lose 1 mark

1

(c) Electrostatic attraction stronger/ionic bonding stronger/attraction between ions stronger/more energy to separate ions

Molecular attraction/atoms/intermolecular forces CE=0

1

Because fluoride (ion) smaller than chloride

Do not allow F or fluorine

1

(d) (i) $\Delta H = \Delta H_L + \Sigma\Delta H_{hyd} = 2237 - 1650 + (2 \times -364)$

Can be on cycle/diagram

1

$= -141\ kJ\ mol^{-1}$

Correct answer scores 2
Units not required, wrong units lose 1 mark

1

(ii) Decreases

If ans to (d)(i) positive allow increases

1

Reaction exothermic/ΔH –ve

If (d)(i) +ve allow endothermic/ΔH + ve

1

(Equilibrium) shifts to left/backwards
(as temperature rises)/equilibrium
opposes the change

If (d) (i) +ve allow shifts to right/forwards/equilibrium opposes the change

If no answer to (d) (i) assume –ve ΔH used
If effect deduced incorrectly from any ΔH CE = 0 for these 3 marks

1

(e) u.v. absorbed: electrons/they move to higher energy (levels)/electrons excited

1

visible light given out: electrons/they fall back down/move to lower energy (levels)

Must refer to absorbing u.v. NOT visible light or this must be implied.

1

[17]

7 (a) $\Delta H = \Sigma\Delta H_f(\text{products}) - \Sigma\Delta H_f(\text{reactants})$

1

$= -201 - 242 - (-394)$

1

$= -49 \text{ kJ mol}^{-1}$

+49 kJ mol^{-1} = 1 mark
units not required, wrong units lose 1 mark

1

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

1

$= 238 + 189 - (214 + 3 \times 131)$

1

$= -180 \text{ J K}^{-1} \text{ mol}^{-1}$

+180 = 1 mark
units not required, wrong units lose 1 mark

1

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

If use G not ΔG penalise M1 but not M2 and M3

1

(ΔS is negative so) at high temp $-T\Delta S$ (is positive and) greater than ΔH/large

Do not award M2 or M3 if positive ΔS value used

1

So $\Delta G > 0$

Independent mark unless positive ΔS value used

1

(Limiting condition $\Delta G = 0$ so) $T = \Delta H/\Delta S$

1

= 272 K

Allow 297-298 if used given values.
Do not award M5 if T –ve or if M4 should give T –ve

1

Reaction is too slow at this temperature/to speed up the reaction

1

(d) $CH_3OH + 3/2O_2 \rightarrow CO_2 + 2H_2O$

Allow multiples.
Ignore state symbols.
Do not allow equation for wrong compound but mark on provided number of moles increases or stays the same.
If no equation or equation that gives a decrease in the number of moles,
CE = 0

1

2.5 mol give 3 mol (gases)

Allow statement 'increase in number of moles/molecules'
If numerical values given, they must match the equation in M1
Ignore the effect of incorrect state symbols on the number of moles of particles unless used correctly

1

Therefore Δ*S* is positive/entropy increases

If correct deduction from wrong equation is ΔS = 0 or ΔS very small must say H –ve

1

(combustion exothermic so Δ*H* –ve so Δ*H* – *T*Δ*S*) and hence
Δ*G* always negative (less than zero)

1

Allow G instead of ΔG
Can score 3 out of 4 marks if equation wrong but leads to increase or no change in number of moles
M4 dependent on M3

Note, if equation wrong AND there is an incorrect deduction about the change in number of moles, CE = 0

(e) CO_2/CO/CH_4 may be produced during H_2 manufacture/building the plant/transport /operating the plant

1

[17]

8 (a) 242

Units not essential

1

(b) Bond is shorter or bonding pair closer to nucleus

Allow Cl is a smaller atom
Allow fewer electron shells
do not allow smaller molecules

1

So attraction (between nucleus and) (to) bond pair is stronger

Allow shared pair (or bonding electrons) held more tightly
Mention of Cl^- loses M2

1

(c) Net attraction between the chlorine nucleus and the extra electron

Allow Cl^- ion more stable than Cl

1

(d) (i) step 1 $Ag(s) \rightarrow Ag(g)$ only change

1

step 2 $Ag(s) \rightarrow Ag^+(g) + e^-$ only change

1

step 3 $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ only change

This step can be first, second or third

1

(ii) 127 + 289 + 732 + 121 – 364

1

= 905 kJ mol^{-1}

–905 scores 1 mark only

1

(e) (i) Ions can be regarded as point charges (or perfect spheres)

Allow no polarisation
***OR** only bonding is ionic*
***OR** no covalent character*

1

(ii) Greater

Electronegativity argument or mention of intermolecular,
CE =0

1

Chloride <u>ions</u> are smaller than bromide

Mark independently but see above

1

They are attracted more strongly to the silver ions

Mark independently

1

(iii) AgCl has covalent character

Ignore reference to molecules

1

Forces in the lattice are stronger than pure ionic attractions

Allow stronger bonding OR additional/extra bonding

1

[15]

9 (a) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

1

(ii) The negative S^- ion

1

repels the added electron

1

(iii) Step B is the atomisation enthalpy of sulphur

1

Step D is the second ionisation enthalpy of calcium

1

(iv) Electrons nearer to the nucleus

1

Electrons removed from a positive species or more strongly attracted

1

(v) +178 +279 +590 +1145 -200 + 539 + G + 482 = 0

1

G + 3013 = 0 hence G = –3013

1

(b) The model used assumes the ions are spherical and in a lattice

1

The calculated value is smaller than the cycle value or stronger attraction

1

Indicating some covalent character or ions are polarised

1

(c) (i) For a reaction to occur ΔG < 0

1

ΔS is positive and large as a gas is evolved

1

TΔS is larger than ΔH and ΔG is negative

1

(ii) ΔS is negative

1

Four moles gaseous reactant forming or more moles of gaseous product

1

At high temperature TΔS is larger than ΔH and ΔG is positive

1

[18]

10 (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

$\Delta S = 41.1/373 = 0.110$ 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]