AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.1.8 THERMODYNAMICS

SCORE	PERCENTAGE
/581	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

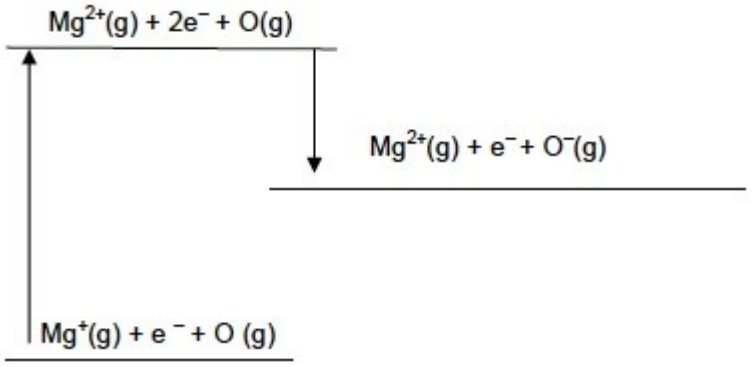
Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a)



One mark for each level with correct state symbols

1
1
1

(b) $\Delta_f H = \Delta_a H$ (Mg) + ½ $\Delta_{BD} H$ (O_2) + $\Delta_{1st\ IE} H$ (Mg) + $\Delta_{2nd\ IE} H$ (Mg) +

1

$\Delta_{1st\ EA} H$ (O) + $\Delta_{2nd\ EA} H$(O) + $\Delta_{LE} H$ (MgO)

- 602 = 150 + (½ × 496) + 736 +1450 – 142 + 844 + $\Delta_{LE} H$ (MgO)

1

$\Delta_{LE} H$ (MgO) = -3888 / -3890 (kJ mol^{-1})

Allow answers to 2sf or more
1 mark for +3888 or +3890
1 mark for -4136 or -4140 (not 496 × ½)

1

[6]

Q2.

A

[1]

Q3.

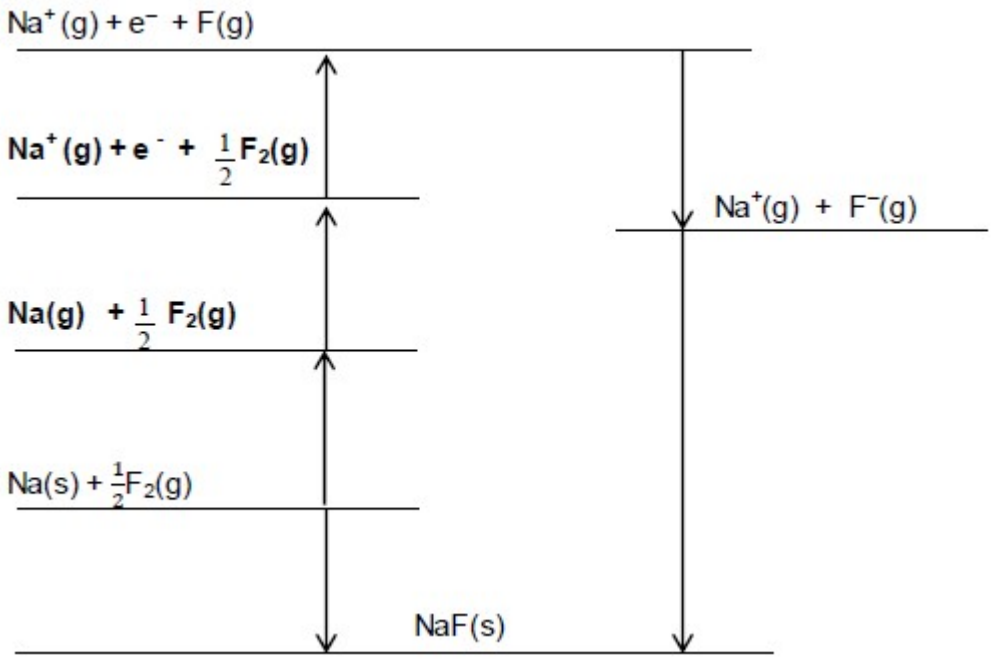
D

[1]

Q4.

STEMUP.CO.UK

(a)



or
M2 Na(g) + F(g)
M1 Na(s) + F(g)
or
M2 = Na(g) + F(g)
M1 = Na(g) + 0.5F_2(g)

2

(b) LE = −109 − 494 − 158/2 + 348 − 569

1

= −903 (kJ mol^{-1})

1

(c) NaCl enthalpy of lattice formation will be less negative **OR** less exothermic

1

Cl^- ion bigger (than F^-)

1

So attraction of halide ion to Na^+ is weaker
Allow so ionic bonding is stronger

1

(d) Amount of NaF = 1/42 = 2.38 × 10^{-2} mol

1

Amount of F_2 = (2.38 × 10^{-2})/2 = 1.19 × 10^{-2} mol

1

$V = nRT/p$ = (1.19 × 10^{-2} × 8.31 × 298)/100000

1

V = 2.95 × 10^{-4} m^3

= 295 cm^3

STEMUP.CO.UK

1

[11]

Q5.

(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 = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6$ 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) $\Delta H_{solution} = \Delta H_{lattice} + \Delta H$(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]

Q6.

(a) Enthalpy change or heat energy change when 1 mol of solid ionic compound/substance or 1 mol of ionic lattice

1

is formed from its gaseous ions.

1

Allow: enthalpy change for:

STEMUP.CO.UK

M^+ (g) + X^- (g) ⟶ MX (s) or Ag^+ (g) + I^- (g) ⟶ AgI (s)

CE=0/2 if describing wrong process (e.g. ΔH of lattice dissociation or ΔH of formation / or heat energy required)

Ignore heat energy released

(b) lattice dissociation energy= (112 + 464 + 293) = + 869 ($kJmol^{-}1$)

1

lattice formation energy = − 869 ($kJ\ mol^{-}1$)

(+)869 = 1 mark

1

(c) AgI contains <u>covalent</u> character

CE=0/2 if atoms/molecules

For M1, allow the following:

not completely ionic / ions not spherical / ions distorted / some covalent bonding

1

Forces / bonds (holding the lattice together) are stronger

Ignore covalent bonds stronger (than ionic bonds)

Ignore electronegativity

Ignore references to energy

1

(d) $AgNO_3$
<u>yellow</u> ppt

Ignore ammonia/acidified/nitric acid/sulfuric acid

1

or

Cl_2 or Br_2
brown solution/black ppt

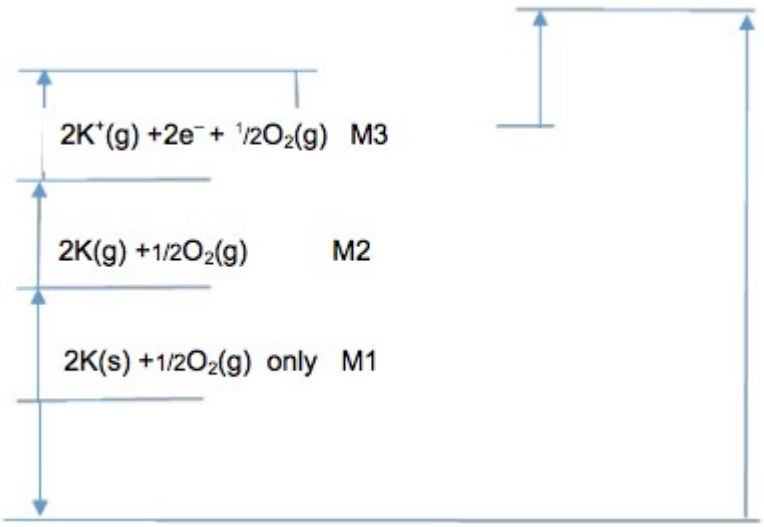
M2 dependent on correct M1 but mark on from Ag^+ or Tollens

1

[8]

Q7.

(a) (i)



STEMUP.CO.UK

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]

Q8.

(a) $MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$

State symbols essential

Do not allow this equation with H_2O on the LHS

STEMUP.CO.UK

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]

Q9.

(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: $+ e^- + F(g)$

STEMUP.CO.UK

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

STEMUP.CO.UK

CE = 0 for mention of chlorine not chloride ion, molecules, atoms, macromolecular, mean bond enthalpy, intermolecular forces (imf), electronegativity

1

[12]

Q10.

(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

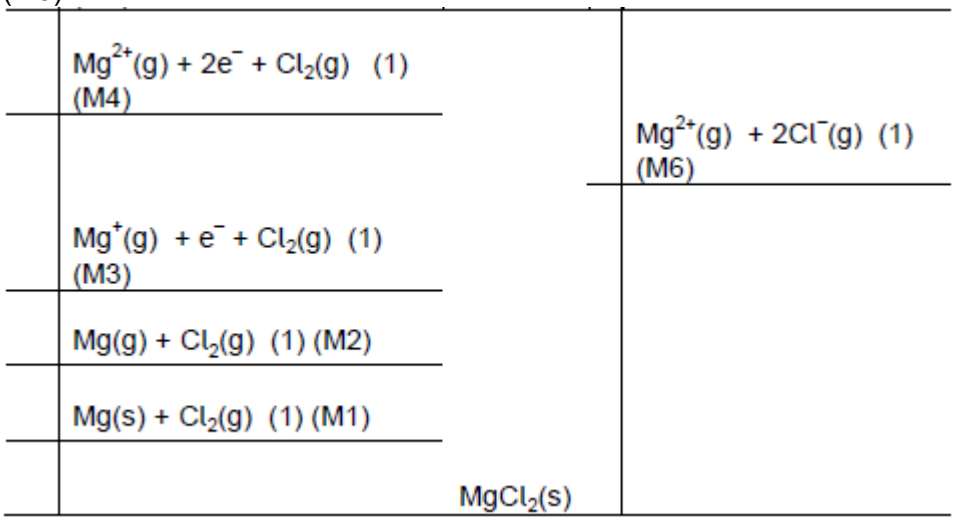
Cannot score M2 unless M1 scored

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) $+2\Delta H_a(Cl) = -2EA(Cl) - LE(MgCl_2)$

STEMUP.CO.UK

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]

Q11.

(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

STEMUP.CO.UK

(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

(ΔG = 0 so) $T = \Delta H / \Delta S$

1

T = 77 × 1000 / 33 = 2333 <u>K</u> (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)

STEMUP.CO.UK

Answer with units must be linked to correct M2

For M3, <u>units must be correct</u>

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]

Q12.

(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

STEMUP.CO.UK

= 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]

Q13.

(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 + $\Delta H_{hyd}\ Br^-$ 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

STEMUP.CO.UK

−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]

Q14.

(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

STEMUP.CO.UK

(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 <u>to the nucleus/protons</u>

1

(c) Fluor<u>ide</u> (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]

Q15.

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

STEMUP.CO.UK

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

STEMUP.CO.UK

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

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]

Q16.

(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 × 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

STEMUP.CO.UK

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]

Q17.

(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

STEMUP.CO.UK

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]

Q18.

(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

STEMUP.CO.UK

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]

Q19.

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

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

STEMUP.CO.UK

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]

Q20.

(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

STEMUP.CO.UK

(ii) Greater

Electronegativity argument or mention of intermolecular, CE =0

1

Chloride ions 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]

Q21.

(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

STEMUP.CO.UK

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]

Q22.

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

1

(ii) The negative S^- ion

1

repels the added electron

1

STEMUP.CO.UK

(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 $\Delta G < 0$

1

ΔS is positive and large as a gas is evolved

1

$T\Delta S$ 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 $T\Delta S$ is larger than ΔH and ΔG is positive

1

[18]

Q23.

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

1

(b) $S^-(g)$

1

(c) The negative S^- ion

1

repels the electron being added

STEMUP.CO.UK

1

(d) (i) Enthalpy of atomisation of sulphur

1

(ii) Second ionisation enthalpy of calcium

1

(iii) Second electron affinity of sulphur

1

(e) Electron more strongly attracted

1

nearer to the nucleus or attracted by Ca^+ ion

1

(f) Correct cycle

e.g. + 178 + 279 + 590 +1145 – 200 + E – 3013 + 482 = 0

1

= 539

1

Allow one mark for – 539

[11]

Q24.

A

[1]

Q25.

(a) (i) Δ*H* atomisation/sublimation of magnesium

1

(ii) Bond/dissociation enthalpy of Cl-Cl

OR 2 × *H* atomisation of chlorine

1

(iii) Second ionisation enthalpy of magnesium

1

(iv) 2 × electron affinity of chlorine

1

(v) Lattice formation enthalpy of $MgCl_2$

1

(b) Equation $2MgCl(s) \rightarrow MgCl_2(s) + Mg(s)$

State symbols not required but penalise if incorrect

1

Calculation ΔH reaction = $\Sigma \Delta H_f$ products – $\Sigma \Delta H_f$ reactants

1

= – 653 – (2 × –133)

STEMUP.CO.UK

1

= – 427 (kJmol^{-1})

Allow +427 to score (1) mark

Other answers; award (1) for a correct ΔH reaction expression

1

(c) ΔH soln $MgCl_2$ = – ΔH Lat.form. + ΔH hyd.Mg^{2+} + 2ΔH hyd.Cl^-

1

or cycle
= 2502 – 1920 – (2 × 364)

1

= – 146 (kJmol^{-1})

Allow + 146 to score (1) mark

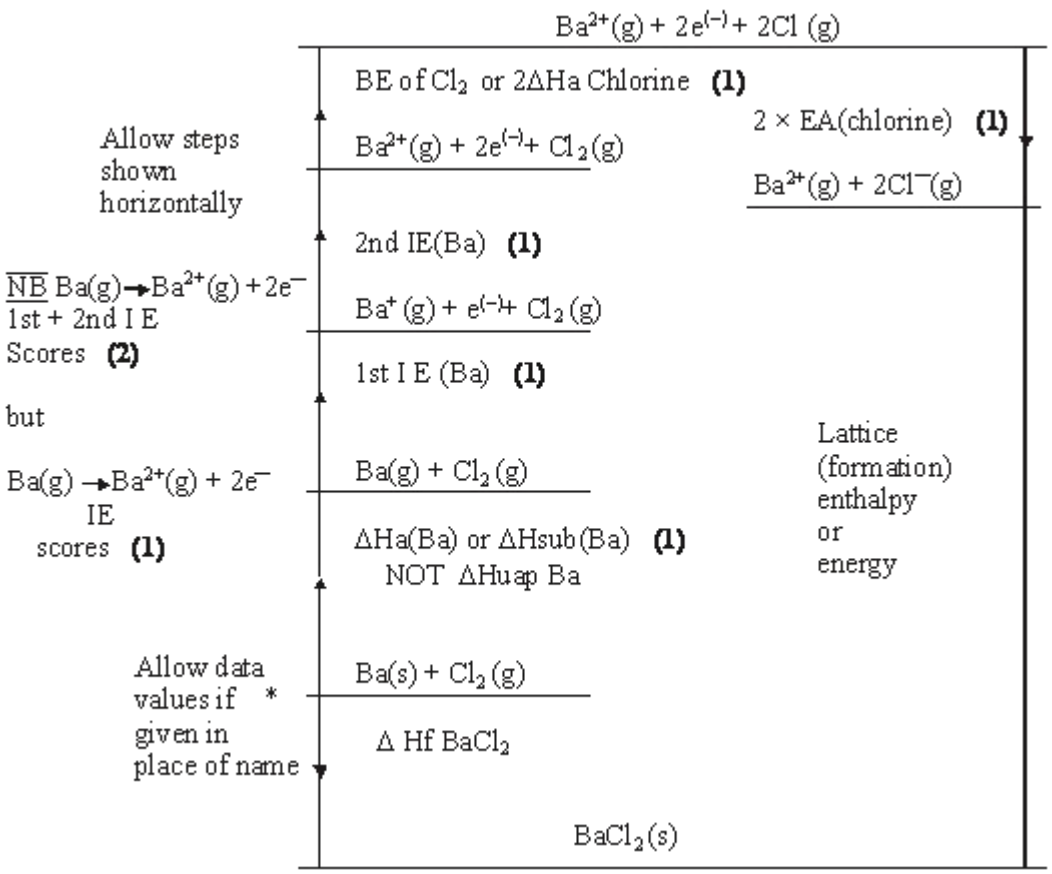
Other answers; award (1) for a correct ΔH soln $MgCl_2$ expression/cycle

1

[12]

Q26.

(a) (i)



ONLY consider species involved in the step marked

(ii) Cycling clockwise about (*)

STEMUP.CO.UK

CE if step missing

$\Delta H_a Ba + 1^{st}$ IEBa + 2^{nd} IE Ba + $2\Delta H_a Cl$ + 2EACl + LE – $\Delta H_f BaCl_2$ = 0 **(1)**
+180 + 503 + 965 + 2 × 122 + 2EA –2056 + 859 = 0 **(1)**
EA = –695/2 = – (347 to 348) **(1)**

Ignore units

Calculation –1 for each error

Mark conseq.

*Notes: –695 scores **(2)***
*+(347 to 348) scores **(2)***
*–(286 to 287) scores **(2)***
*+(286 to 287) scores **(1)***
*–573 scores **(1)***
*+573 scores **(0)***

9

(b) $\Delta S = \Sigma S$ products – ΣS reactants
= (63 +223) – 124 = 162 **(1)**

$\Delta G = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$ or $T = \Delta H/\Delta S$ **(1)**

or used correctly

$\Delta H = 859 \times 10^3$ **(1)** = T × 162
T = (5 300 to 5304) K **(1)**

Penalise if units °C

–1 for each error + mark conseq.

4

[13]

Q27.

D

[1]

Q28.

D

[1]

STEMUP.CO.UK

Q1.

(a) Over 50% of students answered this part correctly, but some failed to gain maximum marks by omitting state symbols or electrons in the equations.

(b) This was answered less well with many students failing to divide the bond dissociation energy for oxygen by two. Some calculated the enthalpy of lattice dissociation rather than formation. Just over a third of students scored zero here.

Q2.

On this question with a 47% success rate, C, followed by B, were the commonest incorrect responses. Students choosing C either failed to remember that the standard enthalpy change refers to starting from the element in its standard state, or thought that iodine is a gas. Those choosing B presumably thought that the molar reference in the definition is to the starting element rather than to a mole of atoms being formed.

Q3.

The correct response was only the third most 'popular' choice for this question, suggesting that this concept is not well known. Poor agreement between theoretical and experimental lattice energy values suggests that the ionic compound has covalent character. This is due to anion polarisation and is most likely when the cation is small with a high charge density and the anion is large (D, chosen by only 23.1% of students). A and C were chosen more often than the correct answer, but the fluoride ion is very resistant to polarisation due to its small size, so fluorides usually match the ionic model and have good agreement between theoretical and experimental values.

Q6.

(a) The definition was only given by the best students. Some students gave definitions of other enthalpy changes, particularly the enthalpy of formation of a substance. Many students missed the idea that a solid was being formed and some thought that the solid ionic lattice was formed from one mole of gaseous ions.

(b) Many students were uncertain about the sign of the enthalpy change for lattice formation and +869 kJ mol^{-1} was a common wrong answer.

(c) Many students understood that the lattice was not perfectly ionic and had some covalent character. Linking the covalent character with stronger bonding eluded all but the strongest students.

(d) The reagent silver nitrate was well known, and this was generally followed by the correct colour of the precipitate. Some students used a more reactive halogen as the reagent and this was given full credit; however, observations for this were less well known.

Q7.

The Born Haber cycle in part (a)(i) was completed well by the majority of students; common errors included use of the symbol K_2 for elemental potassium, missing state symbols and missing electrons. The calculation in part (a)(ii) was not straightforward; many students failed to multiply the enthalpy changes for potassium by 2 and some

STEMUP.CO.UK

included a x2 factor for the atomisation of oxygen. The explanation in part (b) was quite a challenge for many students. Many commented on the relative size of the atoms rather than the ions and a common incorrect explanation referred to attraction between the nucleus and the electrons.

Q8.

The equation in part (a) was generally well known but common errors included the formation of Mg^{+}, the formation of one mole of chloride ions and the inclusion of water as a reagent. The calculation in part (b) was well done by many students; a common error was a failure to use 2x the enthalpy of hydration of the chloride ion. Students generally used their answer to part (b) to give a good explanation in part (c).

Q9.

Students found this question difficult. In part (a), answers omitting or giving incorrect state symbols were common. In part (b), weaker students often mixed up electron affinity with ionisation or with electronegativity. Many correct answers to part (c) were seen but too often students omitted to include a half before F_2 on the bottom two lines and also omitted to show an electron on the top two lines. The calculation in part (c)(ii) was often correct but many answers stopped at the value of 79 kJ mol^{-1}, therefore giving the atomisation enthalpy of fluorine rather than the bond enthalpy. Answers to part (d)(i) were usually correct but not succinct. In part (d)(ii), many students lost marks due to a lack of precision in their use of language. Silver chloride does not contain atoms, molecules or intermolecular forces and electronegativity is not relevant to ionic solids.

Q10.

Many students failed to score 2 marks in part (a) for the definition of electron affinity. Common mistakes were to refer to energy rather than enthalpy change, to omit one mole of atoms or ions and to refer to chlorine molecules rather than atoms. Part (b) was usually answered well but some state symbols and electrons were common omissions. Good students scored full marks for part (c) but a very common error amongst others was to use the value of 121 kJ mol^{-1} for the atomisation of chlorine instead of doubling that value to allow for 2 mol of chlorine atoms. In part (d)(i) a common omission was a failure to mention that magnesium ions are smaller than those of sodium and a common error was to suggest that the ions would be attracted to O^{2-} ions in water. Answers to part (d)(ii) were usually correct.

Q11.

Answers to part (a) usually gained both marks but some students lost a mark because they gave imprecise answers. Most students calculated the enthalpy of hydration correctly for part (b) but part (c) was found to be more challenging and only the highest-scoring students were able to describe the interaction between a chloride ion and a polar water molecule. In part (d), the calculation of temperature was usually correct but most students did not mention that, at this temperature, water would no longer be a liquid. The value for the entropy change in part (e) was usually correct but the units were sometimes missing or incorrect. A number of students omitted the negative sign for this entropy change possibly in the mistaken belief that entropy would always increase when a solid dissolves.

Q12.

Most students answered part (a) well but weaker students sometimes confused lattice enthalpy with enthalpy of formation or with enthalpy of solution. Parts (b) and (c) were also answered well although in part (c), some students incorrectly suggested mass to charge

ratio. Parts (d) and (e) were answered less well; the main errors in part (d) were either to use an incorrect formula of $AgCl_2$ for silver chloride or to use 60.5 instead of 121 for the enthalpy of atomisation for chlorine.

Q13.

This question proved to be difficult. In part (a), most students scored one mark for mentioning that the ionic radius of the chloride ion is less than that for the bromide ion. However, many weaker students lost this mark because they did not make reference to a chloride ion; often, just chlorine was mentioned. Only the best students went on to discuss how a chloride ion is attracted to the partially positive hydrogen atom in a water molecule. Others referred incorrectly to intermolecular forces or to hydrogen bonding. About 60% of students gained both marks for the calculation in part (b). In part (c)(i), most students stated that the entropy would increase but many did not clearly explain why and also that the TΔS term would outweigh the positive enthalpy change. Although about a quarter of all students scored at least 4 marks in part (c)(ii), less than 10% went on to score full marks by subtracting the temperature change from 298 K. Marks were generally low because many students did not recognise that the heat absorbed could be calculated by multiplying the enthalpy of solution by the amount in moles of potassium chloride. Weak students also used a wrong value for the mass of water heated – usually 25 g or 5.00 g.

Q14.

In part (a), it was disappointing to find that students continue to be unable to give precise definitions of thermodynamic terms. Many students failed to score full marks for recalling the meaning of the term electron affinity. Common errors were to mention energy instead of enthalpy change, a failure to mention one mole and omitting to state that the atoms and then the ions formed must be in the gaseous state. In part (b), mention of molecules or ions rather than atoms spoiled some answers and only the best students mentioned attraction of a bonding pair of electrons to the fluorine nucleus. Answers to part (c) were often disappointing with only about 22% of students scoring both marks. Students at this level should appreciate that electronegativity is a property of atoms in molecules and has no place in an explanation of the hydration enthalpy of an ion. Students also lost marks for referring to fluorine rather than to the fluoride ion. The most common error in part (d)(i) was to use the wrong sign for the enthalpy of solution. Students may have been more likely to obtain a correct answer if they had drawn out a cycle but few did. Another fairly common error was to use the incorrect formula of AgF_2 for silver fluoride. It is pleasing to report that parts (d)(ii) and (iii) were answered well by most students.

Q15.

Most answers to part (a) were correct and scored all three marks. The most common error was to confuse enthalpy of lattice dissociation with enthalpy of formation. Part (b) was not answered so well. Weak students often confused electron affinity with ionisation. Part (c) was answered well and many correct answers were seen. Answers to part (d) were less good. The most common error was to confuse atomisation enthalpy for oxygen with bond enthalpy and therefore to use a value of 124 kJ mol^{-1} in the calculation instead of 248 kJ mol^{-1}. Another common error was to give a negative value for the answer – presumably due to confusion of the enthalpy of lattice formation with the required enthalpy of lattice dissociation. About half of all students gave a correct answer to part (e). Answers to part (f) were often wrong. The usual error was a failure to use a factor of 1000 in order to make enthalpy and entropy have the same units. Part (g) was answered well and those students who calculated a negative entropy change in part (f) usually scored full marks.

Q16.

STEMUP.CO.UK

In part (a), about half of all students knew the meaning of the symbol. Answers to part (b) were very disappointing. Answers were characterised by a lack of precise language and a lack of understanding that hydrogen bonds between water molecules must be broken when ice melts. Students are expected to understand that the bonds broken are between the molecules. It is pleasing to report that answers to part (c) were almost always correct. However, in part (d) this 'how science works' question was not understood and only 11% of students gained a mark. Part (e), however, was answered correctly by the great majority of students and it is pleasing to report that the concept of colour was understood well, despite the context being unfamiliar.

Q17.

Part (a) was usually correct. In parts (b) and (c), however, marks were often low. Too often students referred to molecules or atoms or intermolecular forces of various kinds. Even when students recognised that magnesium chloride and magnesium oxide are purely ionic, most were still unable to answer the questions. It seems that the students who answered this paper did not appreciate that they could assume a perfect ionic crystal in which the force of attraction between ions depends only on their charge and distance apart and that the distance apart is the sum of the ionic radii of the positive and the negative ions. In part (d), many students did not understand how to draw a cycle or create a formula that combined the lattice enthalpy, hydration enthalpy and enthalpy of solution using the correct + and/or – signs. Another common error was a failure to recognise that two moles of chloride ions were involved. Higher-scoring students answered part (e) well but weaker students showed a lack of understanding by suggesting that water was ionised or that the magnesium ions could hydrogen bond with water.

Q18.

The scores for this question were generally very low. It was disappointing to find that many candidates could not give correct meanings for thermodynamic terms. In part (a)(i) common errors were to state energy instead of enthalpy, to omit to mention that ions must be in the gaseous state and to state incorrectly formation from elements rather than from gaseous ions. It is clear that some candidates confused enthalpy of lattice formation with enthalpy of formation. In part (a)(ii) only the best candidates mentioned formation of aqueous ions from gaseous ions. Answers to part (b) were also very often disappointing and confused. The polar nature of water was confused with ions and a significant number of candidates described incorrectly an attraction between fluorine and an oxide (O^{2-}) ion or between fluoride and an H+ ion. Answers to part (c) were also often incorrect. The usual mistakes were to calculate an endothermic value or to fail to recognise that the formula of calcium fluoride indicates that one mole of calcium fluoride contains two moles of fluoride ions.

Q19.

Answers to part (a) were disappointing. Very few candidates scored all four marks and the average score was less than half marks. Typical errors were a failure to mention the formation of one mole of atoms and also to omit to state that the atoms and ions formed should be gaseous. In part (b), only the best candidates gained full marks. Most candidates either failed to use the correct enthalpy change for the formation of one mole of chlorine atoms, using the bond enthalpy without halving it, or incorrectly doubled the electron affinity of chlorine. In part (c)(i), very few candidates were able to give a full explanation of the term perfect ionic model but answers to parts (c)(ii) and (c)(iii) were usually correct.

Q20.

STEMUP.CO.UK

This question also proved to be very testing. In part 4(a) the majority of candidates did not realise that the chlorine-chlorine bond enthalpy is twice the enthalpy of atomisation. In part (b) only 20% of candidates could suggest correctly why the chlorine-chlorine bond is stronger than that in bromine. Many answers confused bond enthalpy with ionisation energy. Answers to parts (d)(i) and (d)(ii) were reasonable but answers to the new Specification material in parts (e)(ii) and (e)(iii) were rarely good enough to gain full marks. Candidates did not recognise that additional covalent interactions in an ionic lattice will result in a requirement for more energy to separate the particles in the lattice.

Q21.

It was surprising that only about half of candidates answered part (a) correctly. In many cases, either state symbols were incorrect or the products were not ions. In part (b)(i) the majority of candidates lost a mark because they failed to mention that all substances must be in their standard states. Answers to part (b)(ii) were also disappointing. Again state symbols were often wrong and also fluorine was not shown as F_2. Good candidates were successful with part (b)(iii) but weaker candidates often scored zero. The most common mistakes were a failure to multiply the electron affinity by 2 and incorrectly using twice the bond enthalpy of fluorine, presumably because it was confused with enthalpy of atomisation. Only the very best candidates gave sensible explanations in part (c). Other candidates often referred to intermolecular forces showing a lack of ability to use Unit 1 material. Answers to parts (d)(i) and (ii) were of a higher standard. Most candidates made progress with part (e) but weaker candidates often incorrectly offered an explanation for the colour of a compound caused by transmission of some visible light rather than suggesting that visible light is emitted after the UV light has been absorbed.

Q23.

Almost all candidates gave a correct electronic arrangement for the ion S^{2-} in part (a) and, in part (b), identified species **X** as $S^-(g)$. Many, however, failed to state in part (c) that repulsion between the negative S^- ion and the added electron would result in Step **F** being an endothermic process. Part (d) was generally well answered but 'enthalpy of sublimation' was not accepted for Step **B** as gaseous sulphur does not consist of single sulphur atoms. There were relatively few fully correct answers to part (e). Candidates who stated that 'more energy is needed' were merely repeating the question and not giving an explanation. Part (f) was well answered with many candidates scoring full marks.

Q25.

Although candidates were specifically told in part (a) to note the direction of the indicated enthalpy change and the number of moles of species involved in the Born-Haber cycle, a significant number of candidates lost marks by failing to take this advice. Almost all candidates gave a correct equation for the disproportionation of MgCl in part (b) and many candidates scored full marks for the calculations required in parts (b) and (c). Sadly it was often impossible to award part scores to candidates who did not complete these calculations correctly as they did not give the necessary steps. Candidates must be encouraged to always show their working.

Q26.

All of the required enthalpy changes involved in the Born-Haber cycle for the formation of $BaCl_2$ were given in section (ii) of part (a) and the question specifically stated that a full labelled cycle was required with symbols for all species. Nevertheless, many candidates lost marks when they omitted state symbols, electrons and steps and gave incorrect species.

STEMUP.CO.UK

Consequential marks were awarded in (a)(ii) and only candidates who made three errors failed to score in this section. Part (b) was well answered. Candidates who failed to convert the values of the enthalpy and entropy changes into the same units lost one mark as did those who chose the wrong value for the enthalpy of the reaction from the data given.

STEMUP.CO.UK

Q1.

(a) (ΔS = Σ(*S products*) - Σ(*S reactants*))

= [(4 × 211) + (6 × 189)] - [(4 × 193) + (5 × 205)] = (1978 – 1797)

1

181 (J K^{-1} mol^{-1})

1

(b) ($\Delta G = \Delta H - T\Delta S$) = - 905 - (600 + 273) × 181 × 10^{-3}

If answer to (a) is incorrect, mark consequentially:
- 905 - (873 × (a) × 10^{-3})

1

ΔG = - 1063 / -1060 (kJ mol^{-1})

If alternative value of ΔS = 211 used, answer = -1089 (kJ mol^{-1})

1

(c) ΔG becomes more negative/less positive

Ignore increase/decrease/larger/smaller ΔG

1

The entropy change / Δ*S* is positive / *T*Δ*S* gets bigger / -*T*Δ*S* gets more negative.

Consequential on wrong (a)
If candidate does a calculation in (a) to produce ΔS negative then allow ΔG becomes less negative or more positive

1

(d) Reactant(s) adsorbed onto the (platinum surface) / (platinum) provides a surface / active sites

1

Reaction (on the surface) or bond breaking(weakening) / bond making occurs (on the surface)

1

Desorption (of the product) or wtte

1

(e) (Oxidation state changes from) -3 to +2 OR (+) 5

1

(f) $2NH_3 + 2O_2 \rightarrow N_2O + 3H_2O$

Allow multiples
Ignore state symbols

1

[11]

Q2.

ΔS = *Σ*$_S$ products – *ΣS* reactants or
253 + (2 × 198) – (2 × 223 + 2 × 5.7 + 50.2) (= 649 – 507.6)

STEMUP.CO.UK

This expression could also score M1

1

$\Delta S = 141(.4)$ (J $K^{-1}mol^{-1}$)

This scores M1 and M2

Allow ecf for M3, M4 and M5 from incorrect M2

1

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

1

$\Delta G = -60 - (\underline{1262} \times 141(.4) \times 10^{-3})$

This expression also scores M3.

For M4, allow $\Delta G = -60 - (\underline{1262} \times$ their M2 $\times 10^{-3})$

1

= –238 (kJ mol^{-1}) to 3 sig figs

If calculated in joules

M4: Allow $\Delta G = -60 \times 10^3 - (\underline{1262} \times 141(.4))$

M5: Allow -$\underline{238\ 000}$ J mol^{-1} providing units shown

1

feasible since ΔG is negative/less than zero

Allow consequential M6 from their ΔG

1

[6]

Q3.

(a) Not possible to prevent some dissolving

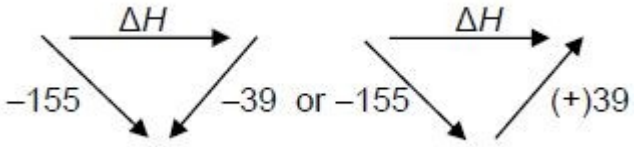
ALLOW It is soluble / dissolves / other hydrates may form / suggestions related to difficulty of measuring T (change) of a solid

1

(b) ($\Delta_{hyd}H$ =) –155 – (–39)

OR labelled cycle

Minimum needed for 'labelled cycle'



1

–116 (kJ mol^{-1})

1/2 for (+)116 or for –29 or for seeing –116 that has then be processed further

1

(c) This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question

Level 3 (5 – 6 marks)

STEMUP.CO.UK

All stages are covered and the explanation of each stage is correct and virtually complete.
Stage 2 must include use of a graphical method for Level 3 (i.e. 'highest T reached' method is max Level 2)

Answer communicates the whole explanation, including reference to enthalpy, coherently and shows a logical progression through all three stages.Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:
For the answer to be coherent there must be some indication of **how** the graph is used to find ΔT

Level 2 (3 – 4 marks)

All stages are covered (NB 'covered' means min 2 from each of stage 1 and 3) but the explanation of each stage may be incomplete or may contain inaccuracies
OR two stages covered and the explanations are generally correct and virtually complete

Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete

Level 1 (1 – 2 marks)

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies
OR only one stage is covered but the explanation is generally correct and virtually complete

Answer shows some progression between two stages

Level 0 (0 marks)

Insufficient correct Chemistry to warrant a mark

Indicative Chemistry Content

Stage 1 Method

(1a) Measures water with named appropriate apparatus
(1b) Suitable volume/mass / volume/mass in range 10 – 200 cm^3/g
(1c) Into insulated container / polystyrene cup (NOT just 'lid')
(1d) Add known mass of $MgCl_2(s)$
(1e) Use of 'before and after' weighing method. NOT 'added with washings'

Stage 2 Measurements (could mark from diagram)

(2a) Record initial temperature (min 2 measurements)
(2b) Record T at regular timed intervals for 5+ mins / until trend seen
(2c) Plot T vs time

Stage 3 Use of Results (3a and 3b could come from diagram)

(3a) Extrapolate lines to when solid added (to find initial and final T)
(3b) $T_{final} - T_{initial} = \Delta T$ / idea of finding ΔT from graph at point of addition
(3c) $q = mc\Delta T$
(3d) amount = mass/Mr ($0.80/95.3 = 8.39 \times 10^{-3}$ mol)

STEMUP.CO.UK

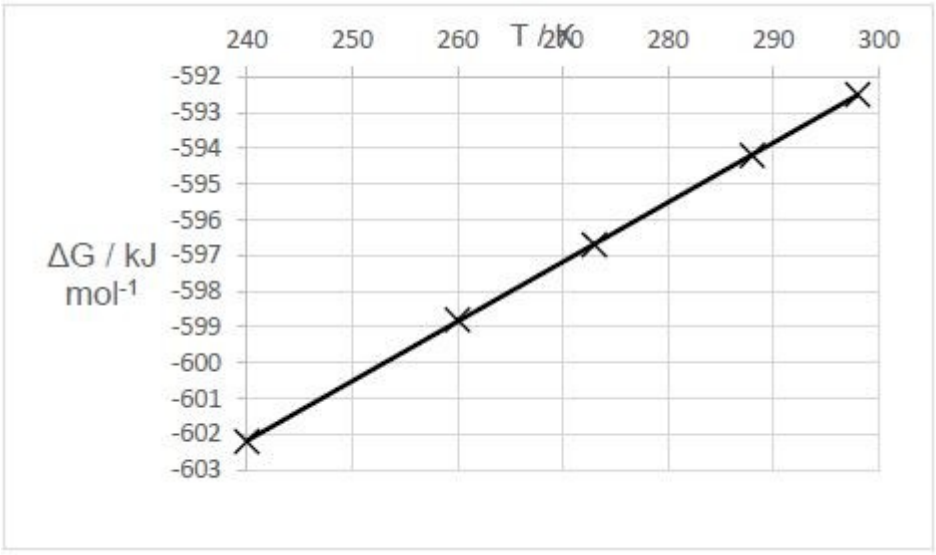
(3e) $\Delta H_{soln} = -q/8.39 \times 10^{-3}$ or in words

This could all be described in words without showing actual calculations but describing stages

If method based on 'combustion' Max Level 1

6

(d)



***M1** = 5 points correctly plotted*

***M2** = line drawn correctly (NOT if curved, doubled or kinked)*

(Check line of best fit –

*if through 250, -600.5 and 280, -595.5 +/- one small square then award **M2**, if all crosses on line award **M1** as well)*

2

Gradient = $\Delta(\Delta G)/\Delta T$ = 0.167 (kJ K^{-1} mol^{-1})

1

($\Delta G = \Delta H - T\Delta S$ so gradient = $-\Delta S$)

ΔS = –167 (J K^{-1} mol^{-1})

***M4** = unit conversion i.e. **M3** × 1000; M5 = –sign (process marks)*

*Correct answer with sign gets **M3**, **M4** and M5*

ALLOW –163 to –171

1+1

[14]

Q4.

C

[1]

Q5.

(a) Decrease

1

STEMUP.CO.UK

Increasing pressure moves equilibrium to the side of least moles i.e. backward reaction

1

To oppose the increase in pressure or to decrease the pressure

1

(b) A catalyst speeds up the rate of the forward and backward reaction

1

By the same amount

1

(c) ΔH = −111 − (−75 − 242)

1

206 (kJ mol^{-1})

1

(d) $\Delta S = 3 \times 131 + 198 - (186 + 189) = 216$ J K^{-1} mol^{-1}

1

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

1

$$0 = 206 - T\frac{216}{1000}$$

1

T = 953.7 or 954 K

1

T = 681 (°C)

If the value given in the question is used then the answer is 283 (°C)

1

[12]

Q6.

(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 × 1000 / –180 = 272 (K)

STEMUP.CO.UK

Mark consequentially to ΔS in part (a)

1

(c) Diagram marks

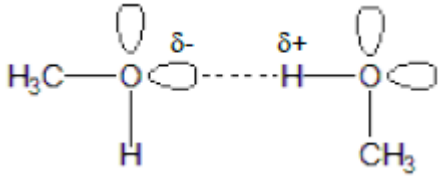


Diagram of a molecule showing O–H bond and two lone pairs on each oxygen

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]

Q7.

(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 $\underline{JK^{-1}\ mol^{-1}}$

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

STEMUP.CO.UK

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]

Q8.

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

Or correct cycle with enthalpy changes labelled

1

$= -111 - (-75 - 242)$

1

STEMUP.CO.UK

= (+)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 × 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**

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

ΔG = −41 − (1300 × −42 / 1000) (M1)

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

but allow ΔG = −41 × 1000 − (1300 × −42) (M1)

1

= +13.6 kJ mol^{-1}

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

STEMUP.CO.UK

Units essential

1

Δ*G* must be negative for the reaction to be feasible.

OR Δ*G* is positive so reaction is not feasible

1

Method 2
For reaction to be feasible Δ*G* must be negative or zero

1

T when Δ*G* = 0 = Δ*H* / Δ*S* = 976*K*

1

Δ*S* is −ve so Δ*G* 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

Δ*G* will become (more) <u>negative</u> because

<u>the −*T*Δ*S* term will be less positive / *T*Δ*S*>Δ*H*</u>

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

1

[15]

Q9.

(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) + Σ(*ΔH*hydration)

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)

STEMUP.CO.UK

+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

(ΔG = 0 so) $T = \Delta H / \Delta S$

1

T = 77 × 1000 / 33 = 2333 <u>K</u> (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, <u>units must be correct</u>

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

STEMUP.CO.UK

[13]

Q10.

(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 on temperature axis vertically below second 'step'

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

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 disorder 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 (−)ΔS 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 -TΔS gets more negative

1

(iii) Not feasible / unfeasible / not spontaneous

1

STEMUP.CO.UK

(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

ΔH = 242 kJ mol^{-1}

(***OR*** using given value ΔH = 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]

Q11.

(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

$\Delta G < 0$

Mark M3, M4 independently

1

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

1

STEMUP.CO.UK

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]

Q12.

(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

STEMUP.CO.UK

(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]

Q13.

(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)

STEMUP.CO.UK

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]

Q14.

(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]

STEMUP.CO.UK

Q15.

(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

STEMUP.CO.UK

Allow reaction (very) slow

1

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

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

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

1

[16]

Q16.

(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

STEMUP.CO.UK

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]

Q17.

(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

STEMUP.CO.UK

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]

Q18.

(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 ɵ in $\Delta G^{ɵ}$

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

ΔH = +90.4

Allow ΔH = +90

1

ΔS = ΣS(products) – ΣS(reactants)

STEMUP.CO.UK

1

ΔS = 211.1 – 205.3/2 – 192.2/2 = <u>12.35</u>

1

T = (90.4 × 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) ΔH = 1.9 (kJ mol^{-1})

1

ΔS = 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]

Q19.

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

1

= –201 – 242 – (–394)

1

= –49 kJ mol^{-1}

+49 kJ mol^{-1} = 1 mark

units not required, wrong units lose 1 mark

1

(b) $\Delta S = \Sigma S$(products) – ΣS(reactants)

1

= 238 + 189 – (214 + 3 × 131)

1

= –180 J K^{-1} 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

STEMUP.CO.UK

(Δ*S* is negative so) at high temp –*T*Δ*S* (is positive and) greater than Δ*H*/large

Do not award M2 or M3 if positive ΔS value used

1

So Δ*G* > 0

Independent mark unless positive ΔS value used

1

(Limiting condition Δ*G* = 0 so) *T* = Δ*H*/Δ*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]

STEMUP.CO.UK

Q20.

(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 $\Delta G < 0$ **1**

ΔS is positive and large as a gas is evolved **1**

$T\Delta S$ 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 $T\Delta S$ is larger than ΔH and ΔG is positive **1**

[18]

Q21.

STEMUP.CO.UK

(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]

Q22.

C

[1]

Q23.

C

[1]

STEMUP.CO.UK

Q24.

B

[1]

Q25.

A

[1]

Q26.

(a) *M1* $K_p = (_PY)^3 . (_PZ)^2 / (_PW)^2 . (_PX)$ *NB [ ] wrong*

1

M2 temperature

1

M3 increase

1

M4 particles have more energy or greater velocity/speed

1

M5 more collisions with $E > E_a$ or more successful collisions

1

M6 Reaction exothermic or converse

1

M7 Equilibrium moves in the left

1

Marks for other answers

Increase in pressure or concentration	*allow M1, M5, M6*	*Max 3*
Addition of a catalyst;	*allow M1, M5, M6*	*Max 3*
Decrease in temperature;	*allow M1, M2, M6*	*Max 3*
Two or more changes made;	*allow M1, M6*	*Max 2*

(b) (i) Advantage; reaction goes to completion, not reversible or faster

1

Disadvantage; reaction vigorous/dangerous

(exothermic must be qualified)

or HCl(g) evolved/toxic
or CH_3COCl expensive

NB Allow converse answers
Do not allow reactions with other reagents e.g. water or ease of separation

1

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

1

$\Delta S = (259 + 187) - (201 + 161)$

1

STEMUP.CO.UK

ΔS = 84 (JK^{-1} mol^{-1}) *(Ignore units)*

*Allow – 84 to score **(1)** mark*

1

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

1

= – 21.6 – 298 × 84/1000
= – 46.6 kJ mol^{-1} or – 46 600 J mol^{-1}

1

*Allow **(2)** for – 46.6 without units*

(Mark ΔG consequentially to incorrect ⊿S)

(e.g. ⊿S = –84 gives ⊿G = +3.4 kJ mol^{-1})

1

[15]

Q27.

(a) *Standard enthalpy change, $\Delta H^{\ominus}$*: $\Delta H_R = \Sigma\Delta H_{f\text{products}} - \Sigma\Delta H_{f\text{reactants}}$ **(1)**
or cycle

ΔH_R = (0 + [2 × –242]) – (4 × –92) **(1)**
= -484 + 368
= –116 (kJ mol^{-1})

Allow max 1 for +116

Standard entropy change, $\Delta S^{\ominus}$: $\Delta S = \Sigma\Delta H_{f\text{ products}} - \Sigma\Delta H_{f\text{ reactants}}$

ΔS = ([2 × 223] + [2 × 189]) - (205 + [4 × 187]) **(1)**

= 824 – 953

= –129 ($J K^{-1}$ mol^{-1})

allow max one for +129

6

(b) (i) *Effect*: Equilibrium displaced to right / to products **(1)**
Explanation: Reaction is endothermic **(1)**
Constraint reduced **(1)**

mark separately

(ii) Feasible when $\Delta G \leq 0$ **(1)**

$\Delta G = \Delta H - T\Delta S$ **(1)**

$T = \Delta H/\Delta S$ = 208 × 1000 **(1)** / 253

= 822 K **(1)**

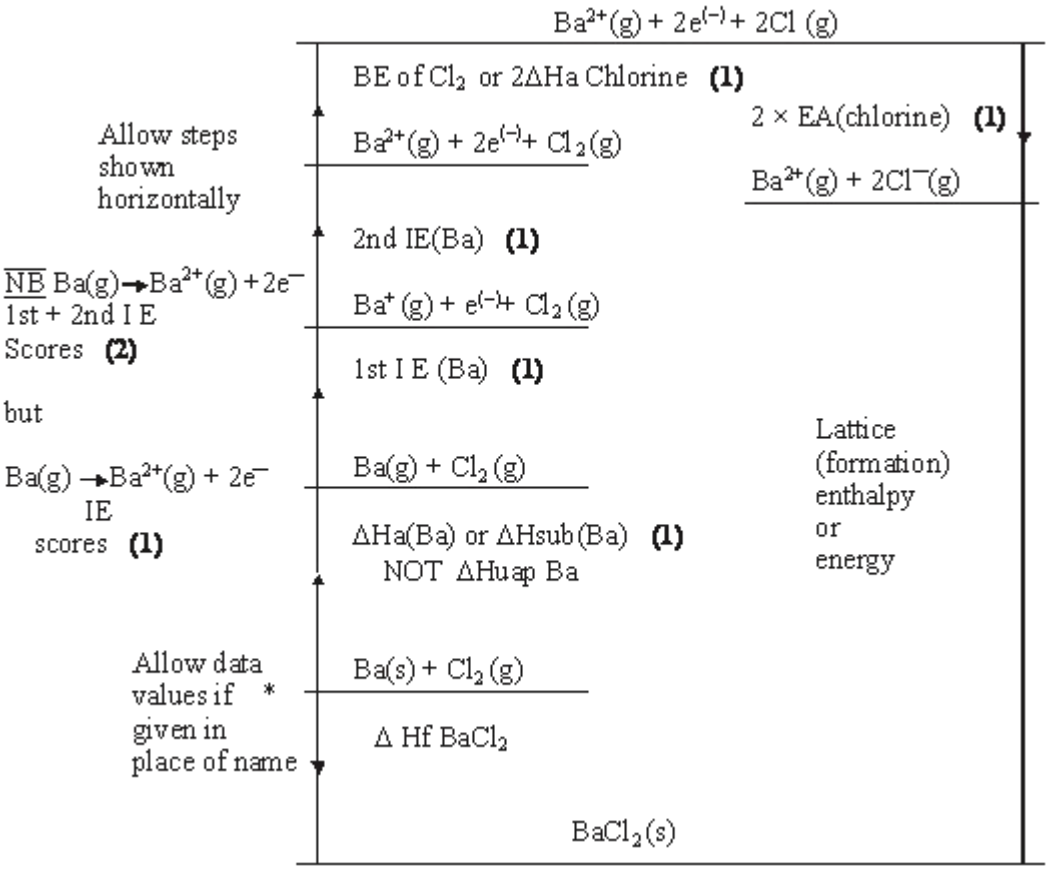
7

[13]

Q28.

STEMUP.CO.UK

(a) (i)



ONLY consider species involved in the step marked

(ii) Cycling clockwise about (*)

CE if step missing

$\Delta H_a Ba + 1^{st}$ IEBa + 2^{nd} IE Ba + $2\Delta H_a Cl$ + 2EACl + LE – $\Delta H_f BaCl_2 = 0$ **(1)**
+180 + 503 + 965 + 2 × 122 + 2EA –2056 + 859 = 0 **(1)**
EA = –695/2 = – (347 to 348) **(1)**

Ignore units

Calculation –1 for each error

Mark conseq.

*Notes: –695 scores **(2)***
*+(347 to 348) scores **(2)***
*–(286 to 287) scores **(2)***
*+(286 to 287) scores **(1)***
*–573 scores **(1)***
*+573 scores **(0)***

9

(b) $\Delta S = \Sigma S$ products – ΣS reactants
= (63 +223) – 124 = 162 **(1)**

$\Delta G = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$ or $T = \Delta H/\Delta S$ **(1)**

or used correctly

$\Delta H = 859 \times 10^3$ **(1)** $= T \times 162$
T = (5 300 to 5304) K **(1)**

STEMUP.CO.UK

Penalise if units °C
–1 for each error + mark conseq.

4

[13]

Q29.

B

[1]

Q30.

C

[1]

Q31.

(a) (i) *Standard enthalpy change*:
$\Delta H_R = \Sigma\Delta H_f$(products) - $\Sigma\Delta H_f$(reactants) **(1)**
or cycle

ΔH_R = ([2 × 0] + [3 × –393.5]) - (-824.2 + [3 × -110.5]) **(1)**
= -24.8 (kJ mol^{-1}) **(1)**
Allow + 24.8 max one

Standard entropy change: $\Delta S = \Sigma S$(products) - ΣS(reactants) **(1)**

ΔS = ([2 × 27.3] + [3 × 213.6]) - (87.4 + [3 × 197.6]) **(1)**
= (54.6 + 640.8) - (87.4 + 592.8) **(1)**
= 15.2 ($JK^{-1}mol^{-1}$) **(1)**
Allow -15.2 max one

(ii) $\Delta G = \Delta H - T\Delta S$ **(1)**
ΔH negative and $-T\Delta S$ is negative **(or ΔS positive or or correct calc) (1)**
Hence ΔG is always negative
(or feasible when $\Delta G \leq 0$) (1)

9

(b) $\Delta G = O = \Delta H - T\Delta S$ Hence $\Delta H = T\Delta S$ **(1)**
T **=** $\Delta H / \Delta S$ = 492.7 × 1000 / 542.6 **(1)**
= 908 K **(1)**
penalise missing 1000 by one mark

3

(c) ΔG (b) = ΔG (a)
(492.7 × 10^3 - T × 542.6) = (-24.8 × 10^3 - T × 15.2) **(1)**
517.5 × 10^3 = 527.4 T **(1)**
T = 981.2 K**(1)**
Allow 980 - 982
Penalise missing 1000 by one mark

3

[15]

STEMUP.CO.UK

Q32.

C

[1]

Q33.

A

[1]

Q34.

B

[1]

STEMUP.CO.UK

Q1.

(a) Nearly all students (91.1%) gained both marks here.

(b) Although 73.9% of students scored two marks, common errors here included a failure to convert temperature into kelvin or using inconsistent energy units.

(c) Students found the explanation in this part more challenging and many could not state that the Gibbs free-energy would become more negative. Many students, however, scored the second mark for a correct reference to a change in entropy.

(d) Many students discussed the general principles of homogeneous catalysis or the lowering of activation energy rather than the reaction on the platinum surface. The mark most commonly missed was the idea that the product desorbed from or left the surface of the catalyst. Surprisingly, over 10% of students made no attempt at this question.

(e) 74.4% of students answered this correctly, although a few students thought the oxidation state of N in ammonia was +3.

(f) Many students gave hydrogen as the other product or failed to balance an equation in which water was the other product.

Q2.

Most students calculated ΔS correctly and gave the correct expression for ΔG. Many students then went on to calculate the value of ΔG correctly. Some students failed to convert the temperature to a value in kelvins, some failed to convert the energy into kilojoules, and some did not give the value of ΔG to the required precision.

Q3.

(a) This proved to be a much tougher starter question than had been anticipated, with only 12% of students earning the mark. Students did not recognise that enthalpy change could not be measured directly. In this case, the enthalpy change was for the formation of a hydrated salt from an anhydrous one, with the expected answer being that it would be impossible to prevent some salt dissolving during the addition of water to the anhydrous salt. An alternative answer, related to the difficulty in measuring the temperature of a solid, was also allowed.

Some students' answers revealed confusion between calorimetry and colorimetry, with suggested answers including the lack of colour change during the reaction. Some students also seemed to believe that calorimetry is only possible if something is being burned.

(b) This calculation was answered reasonably well, with less than 20% of students failing to score. There was confusion about the 'direction' around the Hess Cycle, and evidence of many students thinking that an equation of the form $\Delta H = \Sigma \Delta H_f$(products) - $\Sigma \Delta H_f$(reactants) can be used universally, when it only applies to the specific use of enthalpies of formation.

(c) Most students' encounter with this 'extended response' style of question produced a good spread of marks, although 37% of students failed to score. This was usually due to a completely inappropriate method being described, with incorrect answers

STEMUP.CO.UK

such as: “making a solution of magnesium chloride”, “using it to fill a spirit burner and lighting it under a beaker of water” and “putting a solution of magnesium chloride in a polystyrene cup and heating it over a Bunsen burner”. Other incorrect answers included descriptions of the preparation of a standard solution followed by a titration and the addition of magnesium chloride to acid instead of to water.

This question was marked using a ‘levels of response’ mark scheme. The key to success was for students to concentrate first on the inclusion of as much correct chemistry as possible to ensure access to Level 3 (worth 5 or 6 marks). Within a level, the mark awarded depended on the clarity and coherence of an answer, together with a clear, logical progression through the description. Appropriate apparatus and quantities should have been mentioned as necessary. For example, rather than writing ‘add water to a container’, a good start to the answer would be to write ‘A measuring cylinder was used to measure 50 cm^3 of water into a polystyrene cup’.

Despite the fact that many students suggested in part (a), that it is difficult to measure the temperature of a solid, many then suggested putting the magnesium chloride into the polystyrene cup first and then recording its initial temperature, before adding the water.

(d) This was a challenging question, but one for which it proved relatively easy to score two marks; nearly 20% of students scored full marks here. Most students could successfully plot the points and draw a best fit line, although the negative scale on the y-axis confused some. Most students were also able to calculate the gradient of their line, although, as mentioned previously, it was not always clear what their suggested answer was. The calculation of ΔS proved trickier, with many trying to use the relationship $\Delta G = \Delta H - T\Delta S$, and either ignoring their calculated gradient or substituting it in for ΔH. Relatively few students recognised that this equation can be taken as $y = mx + c$ ($y = c – xm$ in this case) so that this graph of ΔG (y) vs T (x) gives a straight line with a gradient of −ΔS.

Q7.

Most students scored highly in part (a). Incorrect units for entropy change were often seen in part (b). Students generally understood the concept of disorder and scored the mark in part (c). The majority of students could use their own values to calculate the free-energy change in part (d); common errors included incorrect units, failure to convert temperature into Kelvins and using a mixture of joules and kilojoules in their calculation. The relationship between ΔG and feasibility was well known in part (e). The meaning of heterogeneous was well known in part (f)(i) and the equations in part (f)(ii) were generally well known. Students answered part (f)(iii) well although in part (f)(iv) a few referred to impurities being produced without any reference to poisoning of the catalyst.

Q8.

The calculations in parts (a)(i) and (a)(ii) were usually correct although errors in part (a)(ii) sometimes occurred due to a failure to recognise the three moles of hydrogen. Parts (b) and (c) were also answered well and it was pleasing to see that most students ensured that the enthalpy and entropy changes were in the same units before calculating the temperature. Part (d)(i) was answered well by many students though many of these scored only 2 out of the three marks available because the units of free energy were omitted. Students should be encouraged to remember to give units for all numerical answers. Part (d)(ii) proved to be very challenging and only the best students were able to express in words why a lowering of the temperature would eventually lead to a negative value for the free-energy change.

STEMUP.CO.UK

Q9.

Answers to part (a) usually gained both marks but some students lost a mark because they gave imprecise answers. Most students calculated the enthalpy of hydration correctly for part (b) but part (c) was found to be more challenging and only the highest-scoring students were able to describe the interaction between a chloride ion and a polar water molecule. In part (d), the calculation of temperature was usually correct but most students did not mention that, at this temperature, water would no longer be a liquid. The value for the entropy change in part (e) was usually correct but the units were sometimes missing or incorrect. A number of students omitted the negative sign for this entropy change possibly in the mistaken belief that entropy would always increase when a solid dissolves.

Q10.

This question was answered well by most students except for parts (a)(iv) and (b)(ii). In part (a)(iv), students were asked to explain why one line on the Figure 1 was longer than the other in terms of the behaviour of molecules. A question of this type demands an answer that compares one feature with another. Most students did not discuss the change in disorder accompanying a change in state and did not compare melting with boiling. In part (b)(ii), many students did not explain that the $T\Delta S$ term in the equation would increase as T increases.

Q11.

Part (a) was answered well by most students. In part (b), most students scored the first 2 marks for a recognition that the entropy increases when water becomes more disordered as it changes into a gas. Only the highest-scoring students went on to explain that the free energy change is negative when the $T\Delta S$ term is greater than ΔH. Good students were able to score full marks for part (c)(i). A common error amongst weaker students was a failure to recognise that only half a mole of oxygen is involved. Part (c)(ii) also discriminated well with only the highest-scoring students giving a correct reason why water would change into hydrogen and oxygen. In part (d), good students usually scored full marks but weaker students did not get beyond a statement that $\Delta H = T\Delta S$.

Q12.

It is pleasing to report that a majority of students scored very well in this question. Some students did lose a mark for a lack of precision in their calculation of the slope giving an answer of 0.1 instead of the expected 0.098.

Q13.

This question, except for part (d), was answered well by many students of all abilities. In part (d), only the best students appreciated that the reaction would not be feasible above 794 K and, therefore, predicted that this temperature is exceeded in internal combustion engines.

Q14.

In part (a), about half of all students knew the meaning of the symbol. Answers to part (b) were very disappointing. Answers were characterised by a lack of precise language and a lack of understanding that hydrogen bonds between water molecules must be broken when ice melts. Students are expected to understand that the bonds broken are between the molecules. It is pleasing to report that answers to part (c) were almost always correct. However, in part (d) this ‘how science works’ question was not understood and only 11% of students gained a mark. Part (e), however, was answered correctly by the great majority of students and it is pleasing to report that the concept of colour was understood

STEMUP.CO.UK

well, despite the context being unfamiliar.

Q15.

Most answers to part (a) were correct and scored all three marks. The most common error was to confuse enthalpy of lattice dissociation with enthalpy of formation. Part (b) was not answered so well. Weak students often confused electron affinity with ionisation. Part (c) was answered well and many correct answers were seen. Answers to part (d) were less good. The most common error was to confuse atomisation enthalpy for oxygen with bond enthalpy and therefore to use a value of 124 kJ mol^{-1} in the calculation instead of 248 kJ mol^{-1}. Another common error was to give a negative value for the answer – presumably due to confusion of the enthalpy of lattice formation with the required enthalpy of lattice dissociation. About half of all students gave a correct answer to part (e). Answers to part (f) were often wrong. The usual error was a failure to use a factor of 1000 in order to make enthalpy and entropy have the same units. Part (g) was answered well and those students who calculated a negative entropy change in part (f) usually scored full marks.

Q16.

This question also produced very low scores, especially in parts (a) and (b). It was very disappointing to find that only 27% of candidates could write a correct equation for part (a). Most candidates appear to think that when potassium nitrate dissolves in water, it forms potassium hydroxide and nitric acid. In part (b) many candidates confused the liquid and the aqueous states of an ionic compound; they often stated incorrectly that potassium nitrate became a liquid when it dissolved in water. Answers to the remainder of the question were very often correct.

Q17.

Only 28% of candidates gained all three marks in part (a)(i). The usual error was a failure to follow the instruction in the question that required an enthalpy change for only one mole of ammonia. In part (a)(ii) many candidates were unable to explain clearly that individual bond enthalpies in a specific compound will differ from data book values of mean bond enthalpies that are an average of bond enthalpy values from a range of different compounds. The remainder of this question was well answered by most candidates.

Q18.

This question proved to be easier than Question 1. Most candidates scored full marks in part (a) but part (b) was answered less well and was not attempted by a significant number of candidates. Parts (c) and (d) were answered correctly by almost all candidates. A majority of candidates scored full marks for part (e). The most common error was, as usual, a failure to convert the entropy term into kJ, the same units as the enthalpy change. In part (f), over half of the candidates did not recognise that this question was concerned with rate of reaction and hence the activation energy and they attempted to argue incorrectly in terms of thermodynamics. Just over half of all candidates gained full marks for part (e). A common error was to give a value with the wrong sign for the enthalpy change or for the entropy change.

Q19.

In this question, parts (a) and (b) were answered well but the remainder of the question proved to be much more difficult. In part (c) the most difficult part of the question concerned an explanation why the reaction was not feasible at high temperatures. Candidates were expected to argue that, because the entropy change was negative, the term $-T\Delta S$ was positive and large at high values of T so that the entropy effect would

STEMUP.CO.UK

more than compensate for a negative enthalpy change leading to positive ΔG values. Only the best candidates were able to argue in these terms. The calculation of temperature caused problems for weaker candidates who failed to use the factor of 1000 to ensure that ΔH and $T\Delta S$ were in the same units. In part (d) it was rather distressing to discover the large number of candidates who were unable to write a balanced equation for the combustion of methanol. Some candidates did not read the question carefully and failed to register that the combustion was in the gas phase. Answers to part (e) were very disappointing. Candidates should realise that re-stating the question to suggest that the reactants are not carbon neutral is not sufficient to gain a mark. Also, it was not generally recognised that the term 'carbon neutral' refers not to carbon but to the balance of carbon-containing gases in the atmosphere.

Q21.

This question also produced a wide range of marks. A major misconception was to relate entropy directly to the energy of particles rather than to their disorder. Most candidates gave a correct answer to part (b). In part (c) weak candidates often discussed the breaking of bonds rather than referring to disorder. Others just reiterated the question by stating that the entropy would increase. Good candidates usually gained one mark by stating that the disorder of particles increases when a liquid changes to a gas but only the best candidates answered the question fully by referring also to the smaller change in order on melting. It was pleasing to note that part (d) was answered correctly by many candidates. Marks were sometimes lost when giving units in part (d)(iii) that did not tally with the numerical answer. For example, when the numerical answer should have corresponded to J K^{-1} mol^{-1} the units were frequently given as kJ K^{-1} mol^{-1}.

Q26.

Many candidates gave a correct expression for the equilibrium constant, K_p, for the reaction given in part (a). Some, who gave correct indices, lost a mark as they included square brackets, which are specific used to indicate concentration, in their expression. Identifying the one change which would increase the rate of reaction and decrease the value of K_p proved challenging but part marks were awarded for answers which addressed either of the two required changes. Candidates who gave more than one change of condition were able to score one mark for a correct K_p expression. There were many vague answers to part (b)(i), some of which assumed there were other reactants present with the most common example being water in Reaction 2. By contrast, (b)(ii) was very well answered with many candidates scoring full marks. Most candidates now remember to use either kJ mol^{-1} or J mol^{-1} throughout these calculations but a small number still failed to do this. Consequential marks were awarded in each part of the calculation.

Q27.

This question was very well answered with many candidates scoring full, or nearly full marks. Just a few of the weaker candidates made errors when calculating the standard enthalpy change, $\Delta H^{\ominus}$, and the standard entropy change, $\Delta S^{\ominus}$, and marks were awarded consequentially to an arithmetic error. In part (b), most deduced correctly the effect of an increase in temperature on the equilibrium reaction but not all gave a full explanation of their answer. The calculation of the minimum temperature for the reaction to be feasible was also well done with few failing to use the same units for the enthalpy and the entropy changes.

Q28.

All of the required enthalpy changes involved in the Born-Haber cycle for the formation of $BaCl_2$ were given in section (ii) of part (a) and the question specifically stated that a full

STEMUP.CO.UK

labelled cycle was required with symbols for all species. Nevertheless, many candidates lost marks when they omitted state symbols, electrons and steps and gave incorrect species.

Consequential marks were awarded in (a)(ii) and only candidates who made three errors failed to score in this section. Part (b) was well answered. Candidates who failed to convert the values of the enthalpy and entropy changes into the same units lost one mark as did those who chose the wrong value for the enthalpy of the reaction from the data given.

Q31.

It is pleasing to report that this question was well answered with many candidates scoring full marks for the calculation in parts (a) and (b). Part (c) was intended to be more testing, and so it proved. Nevertheless, a pleasing number of the better candidates made correct deductions.

In part (c), full marks could be scored consequentially by candidates who had made errors in part (a)

STEMUP.CO.UK