Mark schemes

Q1.

(a) Heat (energy) change at constant pressure

Ignore conditions even if wrong

Ignore energy change

1

(b) M2 $Ca^{2+}(g) + 2\ e^- + Cl_2(g)$

Alternative M2 $Ca^+(g) + e^- + 2\ Cl(g)$

1

M3 $Ca^{2+}(g) + 2\ Cl^-(g)$

1

M1 $Ca(s) + Cl_2(g)$

1

(c) M1 –795 + LE = 193 + 590 +1150 + (**2** x 121) + (**2** x –364)

Numbers and factors used correctly from cycle

1

M2 LE = (+) 2242 ($kJ\ mol^{-1}$)

Rearrangement to calculate LE

If one or both factors of 2 missing award 1 mark for (+) 2485, (+)2121 or (+)2606 ($kJ\ mol^{-1}$)

Allow 1 mark for – 2242 ($kJ\ mol^{-1}$)

1

(d) $MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq)$

Allow $MgCl_2(s) \rightleftharpoons Mg^{2+}(aq) + 2\ Cl^-(aq)$

Allow $MgCl_2(s) + aq \rightleftharpoons Mg^{2+}(aq) + 2\ Cl^-(aq)$

1

(e) M1 ΔH soln $MgCl_2$ = ΔH latt diss+ ΔH hyd Mg^{2+} + **2**ΔH hyd Cl^-
OR 2493 –1920 + (**2** x –364)

M1 for expression with or without numbers

1

M2 = – 155 ($kJ\ mol^{-1}$)

M2 for answer

If factor of 2 missing for ΔH hyd Cl^-, allow 1 mark for 209

1

(f) M1 Ca^{2+} (ion) bigger/lower charge to size ratio (than Mg^{2+})

Allow converse answers

M1 Do not accept Ca^{2+} is a bigger atom/molecule

M1 Allow Ca^{2+} has more shells/ more distance of outer e to nucleus

Ignore more shielding

1

M2 weaker attraction/bond to ($O^{\delta-}$ in) water

1

[11]

Q2.

(a) CO_2 / gas is more disordered (than solid)

Allow answers based on carbon

Ignore CO_2 is a gas and C is a solid

1

(b) 0 K

Units essential

*Allow absolute zero **OR** –273 ^oC*

1

(c) M1 $\Delta H = (\mathbf{3}^x - 394) - (-1669 \times \mathbf{2})$

M1 correct expression

1

M2 = 2156 (kJ mol^{-1})

M2 if –2156 seen allow 1 mark out M1 and M2

1

M3 $\Delta S = (28 \times \mathbf{4} + 214 \times \mathbf{3}) - (51 \times \mathbf{2} + 6 \times \mathbf{3})$

M3 correct expression

1

M4 = 634 (J K^{-1} mol^{-1})

M4 if – 634 allow 1 mark from M4 and M4

1

M5 $\Delta G = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$ or $T = \Delta H \div \Delta S$

M5 expression or rearranged expression or with numbers

1

M6 ΔS = 0.634 kJ $K^{-1}mol^{-1}$

M6 ΔS = M4 ÷ 1000

1

M7 $T = \frac{2156}{0.634}$ = 3400 to 3401 (K)

M7 = M2 ÷ M6 but must be a positive answer

1

[9]

Q3.

(a) **M1**

$\Delta_f H = \Delta_a H$ (Sr) + $2\Delta_a H$ (Cl) + $\Delta_{1st\ IE} H$ (Sr) + $\Delta_{2nd\ IE} H$ (Sr) + $2\Delta_{EA} H$ (Cl) + $\Delta_{LE} H$ (Sr)

Or

$-828 = 164 + (2 \times 121) + 548 + 1060 + (2 \times \Delta_{EA}H) + (-2112)$

1

M2 $2 \times \Delta_{EA}H = -730$

1

M3 $\Delta_{EA}H = -365$ (kJ mol^{-1})

*Allow **M3** = **M2**÷2*

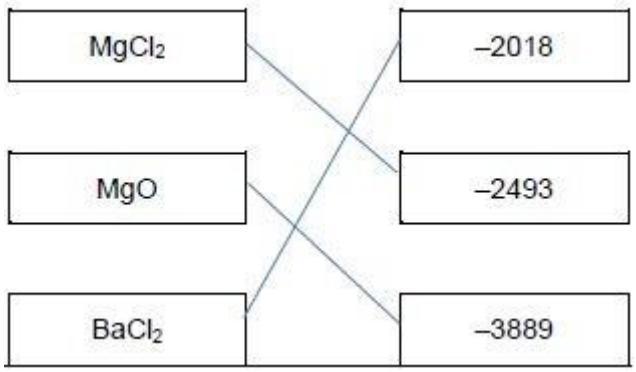
(+) 365, –304.5, and –730 = 2 marks

(+) 304.5, (+) 730 and –609 = 1 mark

(+) 609 = 0 marks 1

1

(b)



All three lines must be shown

1

(c) (Has) covalent character or partial covalent bonding (as well as ionic bonding)

*Allow chloride **ion** has been polarised or chloride **ion** distorted*

Ignore not perfectly ionic

Ignore ions are not spheres

Do not allow references to molecules or ions with covalent character

Do not allow it is covalently bonded alone

1

(d) **M1** (From Li^+ to K^+) size (of ion) increases OR charge density (of ion) decreases

***M1** Allow K+ has more shells or larger distance between nucleus and outer electrons or larger ionic radius*

Do not allow atomic radius or molecules

1

M2 (Electrostatic) attraction between metal ion and $O^{\delta-}$ of water decreases or attraction between lone pair on O and + ion decreases

M2** Not dependent on **M1

Allow converse arguments

1

(e) **M1** $\Delta_{sol}H = \Delta_{LEdissociation}H + \Delta_{hyd}H\ (Ca^{2+}) + 2x\ \Delta_{hyd}H\ (Br^-)$
or
M1 $-110 = 2176 + (-1650) + 2x\ \Delta_{hyd}H\ (Br^-)$

1

M2 $(2x\ \Delta_{hyd}H\ (Br^-)) = -636$

1

M3 $\Delta_{hyd}H\ (Br^-) = -318$ (kJ mol^{-1})
*Allow **M3** = **M2** ÷ 2*
(+)1858, (+)318 and –636 = 2 marks
+3716, –1858 and (+)636 = 1 mark
–3716 = 0 marks

1

[10]

Q4.

(a) **M1** $\Delta H = (-201 + -242) - (-394)$

1

M2 $\Delta H = -49$ (kJ mol^{-1})
Allow consequential marking
***M2** 1 mark for ΔH = +49 (kJ mol^{-1})*

1

M3 $\Delta S = \underline{-180}$ (J K^{-1} mol^{-1})

1

M4 $\underline{\Delta G = \Delta H - T\Delta S}$
M4** Recall this equation. If **M4** incorrect cannot score **M6

1

M5 $\Delta G = -49 - \left(890 \times -\frac{180}{1000}\right)$ or **M3**÷1000
***M5** Conversion of ΔS into kJ mol^{-1}*
ΔG = ***M2*** $- \frac{(890 \times M3)}{1000}$

1

M6 $\Delta G = 111$ (kJ mol^{-1})
*If ΔS not converted to kJ in **M5**, answer is +160151 kJ mol^{-1} = 5 marks*

1

(b) **M1** ΔH = intercept of y axis = 145 (kJ mol^{-1})
***M1** Value between 144 and 146 kJ mol^{-1}*

1

M2 Gradient = -Δ*S* or a negative value

1

M3 Gradient x 1000

1

M4 Δ*S* = +167 to +173 (J K^{-1} mol^{-1})

M4 *+0.167 to +0.173 scores 2 for ΔS*

−167 to −173 scores 2 for ΔS

−0.167 to −0.173 scores 1 for ΔS

1

(c) Above 845 K reaction becomes (thermodynamically) feasible OR Below 845 K reaction is not (thermodynamically) feasible

Allow 845 to 860

1

[11]

Q5.

(a) Top line $Cs^+(g) + e^- + I(g)$

1

Lower line $Cs(s) + \frac{1}{2}I_2(s)$

1

(b) 79 + × + 376 − 314 = −337 +585

1

So enthalpy change = 107 (kJ mol^{-1})

Allow I mark for -107 (kJ mol^{-1})

Allow answer to 2sf or more

1

(c) (Almost/Mostly) purely/ perfectly ionic

If ionic not mentioned, allow no/little covalent bonding/character

Penalise references to atoms/molecules

Ignore electronegativity

1

(d) **M1** ΔS = [(82.8 + $\frac{1}{2}$ × 117) −130] = 11.3 (J K^{-1} mol^{-1})

M1 *Correct entropy change value*

1

M2 ΔG = ΔH − TΔS

M2 *equation or equation with numbers*

1

M3 ΔG = 337 − 298 × 11.3 × 10^{-3} OR 337000 − 298 × 11.3

M3 *for converting units:*

ΔS into kJK^{-1} mol^{-1} or ΔH into J mol^{-1}

1

M4 ΔG = (+)334 kJ mol^{-1} or 334000 J mol^{-1}

M4 *answer with correct units*

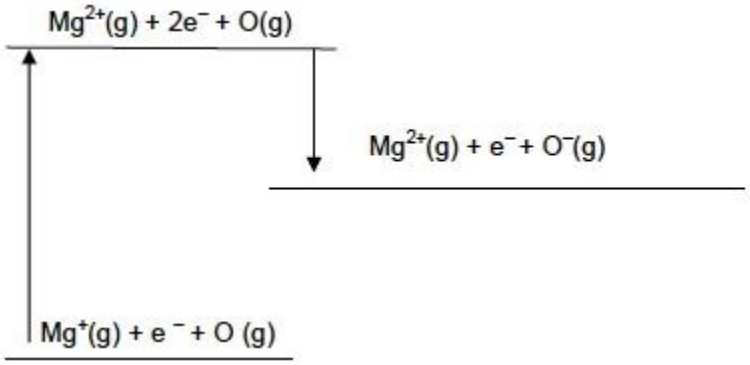
Any negative answer loses ***M4***

1

[9]

Q6.

(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]

Q7.

A

[1]

Q8.

D

[1]

Q9.

(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:

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 covalent 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) $AgNO_3$
yellow 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]

Q10.

$\Delta S = \Sigma S$ products – ΣS reactants or
253 + (2 × 198) – (2 × 223 + 2 × 5.7 + 50.2) (= 649 – 507.6)

This expression could also score M1

1

ΔS = 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

ΔG = -60 - (<u>1262</u> × 141(.4) × 10^{-3})
This expression also scores M3.
For M4, allow ΔG = -60 - (<u>1262</u> × their M2 × 10^{-3})

1

= –238 (kJ mol^{-1}) to 3 sig figs
<u>If calculated in joules</u>
M4: Allow ΔG = -60 × 10^3 - (<u>1262</u> × 141(.4))
M5: Allow -<u>238 000</u> J mol^{-1} providing units shown

1

feasible since ΔG is negative/less than zero
Allow consequential M6 from their ΔG

1

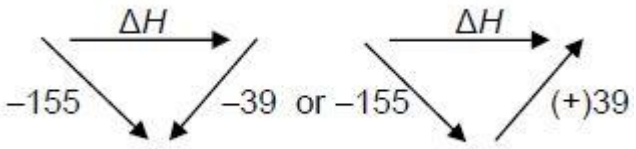
[6]

Q11.

(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)

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

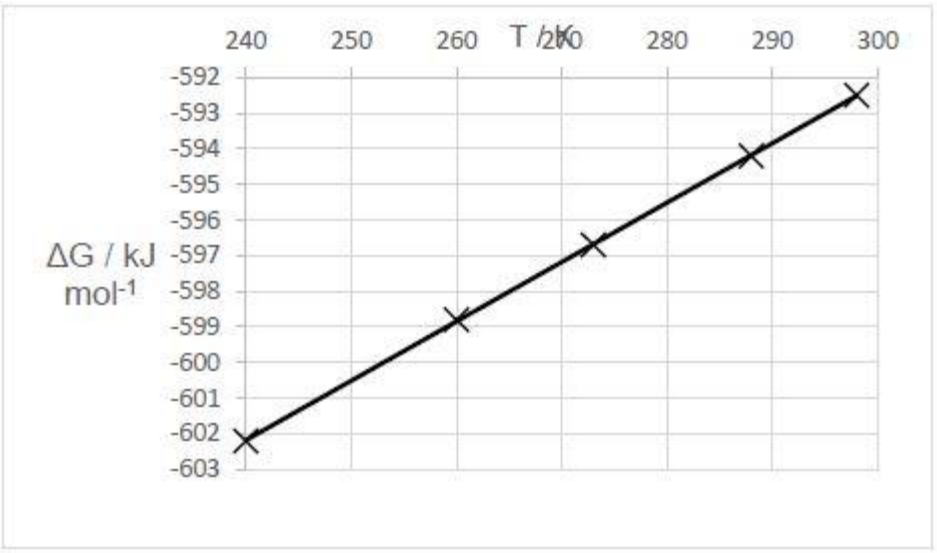
(3c) $q = mc\Delta T$
(3d) amount = mass/Mr ($0.80/95.3 = 8.39 \times 10^{-3}$ mol)
(3e) $\Delta H_{soln} = -q/8.39 \times 10^{-3}$ or in words

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]

Q12.

C

[1]