Answer **all** questions in the spaces provided

0 1 This question is about silver iodide.

0 1 . 1 Define the term enthalpy of lattice formation.

[2 marks]

0 1 . 2 Some enthalpy change data are shown in **Table 1**.

Table 1

	Enthalpy change / kJ mol^{-1}
$AgI(s) \rightarrow Ag^+(aq) + I^-(aq)$	+112
$Ag^+(g) \rightarrow Ag^+(aq)$	–464
$I^-(g) \rightarrow I^-(aq)$	–293

Use the data in **Table 1** to calculate the enthalpy of lattice formation of silver iodide.

[2 marks]

Enthalpy of lattice formation _____ kJ mol^{-1}

0 1 . 3 A calculation of the enthalpy of lattice formation of silver iodide based on a perfect ionic model gives a smaller numerical value than the value calculated in Question **1.2**

Explain this difference.

[2 marks]

0 1 . 4 Identify a reagent that could be used to indicate the presence of iodide ions in an aqueous solution and describe the observation made.

[2 marks]

Reagent _____

Observation _____

_____

8

Turn over for the next question

Answer **all** questions in the spaces provided.

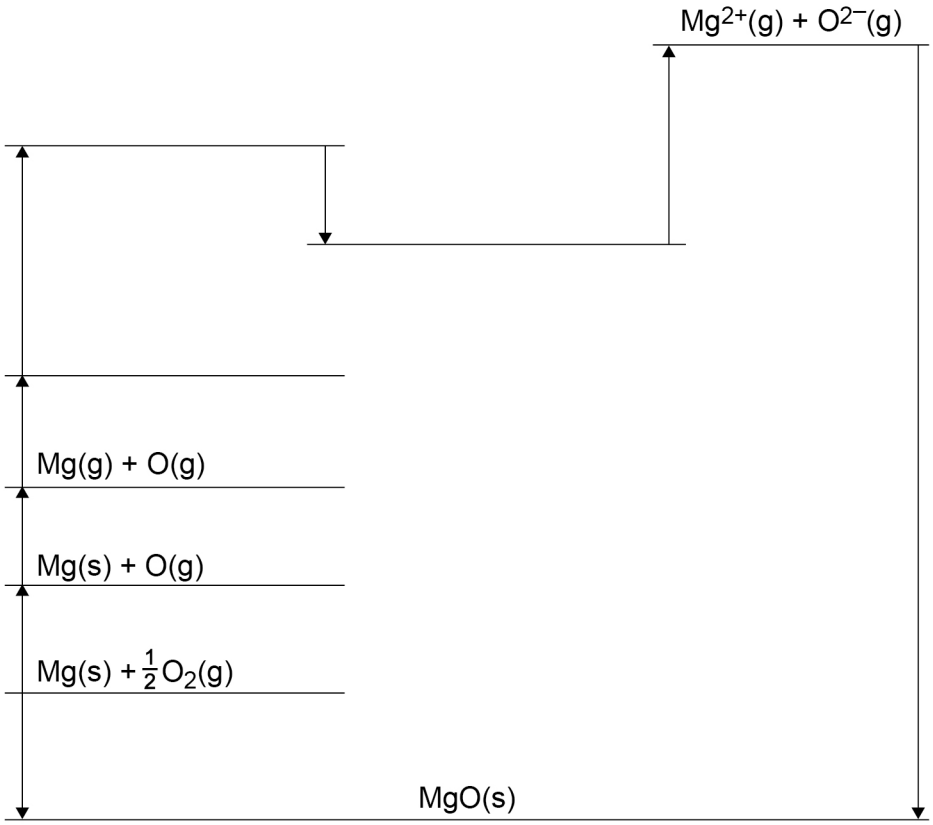
0 1 This question is about lattice enthalpies.

0 1 . 1 **Figure 1** shows a Born–Haber cycle for the formation of magnesium oxide.

Complete **Figure 1** by writing the missing symbols on the appropriate energy levels.

[3 marks]

Figure 1



0 1 . 2 **Table 1** contains some thermodynamic data.

Table 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation for magnesium oxide	–602
Enthalpy of atomisation for magnesium	+150
First ionisation energy for magnesium	+736
Second ionisation energy for magnesium	+1450
Bond dissociation enthalpy for oxygen	+496
First electron affinity for oxygen	–142
Second electron affinity for oxygen	+844

Calculate a value for the enthalpy of lattice formation for magnesium oxide.

[3 marks]

Enthalpy of lattice formation _____ kJ mol^{-1}

6

Turn over for the next question

9 A 5.00 g sample of potassium chloride was added to 50.0 g of water initially at 20.0 °C. The mixture was stirred and as the potassium chloride dissolved, the temperature of the solution decreased.

0 9 . 1 Describe the steps you would take to determine an accurate minimum temperature that is **not** influenced by heat from the surroundings.

[4 marks]

0 9 . 2 The temperature of the water decreased to 14.6 °C.

Calculate a value, in kJ mol^{-1}, for the enthalpy of solution of potassium chloride.

You should assume that only the 50.0 g of water changes in temperature and that the specific heat capacity of water is 4.18 J K^{-1} g^{-1}.
Give your answer to the appropriate number of significant figures.

[4 marks]

Enthalpy of solution = _____ kJ mol^{-1}

0 9 . 3 The enthalpy of solution of calcium chloride is –82.9 kJ mol^{-1}.
The enthalpies of hydration for calcium ions and chloride ions are –1650 and –364 kJ mol^{-1}, respectively.

Use these values to calculate a value for the lattice enthalpy of dissociation of calcium chloride.

[2 marks]

Lattice enthalpy of dissociation = _____ kJ mol^{-1}

0 9 . 4 Explain why your answer to Question **9.3** is different from the lattice enthalpy of dissociation for magnesium chloride.

[2 marks]

_____

_____

_____

_____

_____

0 5 Titanium(IV) chloride can be made from titanium(IV) oxide as shown in the equation.

$TiO_2(s) + 2C(s) + 2Cl_2(g) \rightarrow 2CO(g) + TiCl_4(l)$ $\Delta H^{\ominus} = -60.0$ kJ mol^{-1}

0 5 . 1 Some entropy data are shown in **Table 3**.

Table 3

Substance	$TiO_2(s)$	$C(s)$	$Cl_2(g)$	$CO(g)$	$TiCl_4(l)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	50.2	5.70	223	198	253

Use the equation and the data in **Table 3** to calculate the Gibbs free-energy change for this reaction at 989 °C
Give your answer to the appropriate number of significant figures.

Use your answer to explain whether this reaction is feasible.

[6 marks]

Gibbs free-energy change _____ kJ mol^{-1}

Explanation _____

_____

6

Section A

Answer **all** questions in the spaces provided

0 1 Anhydrous magnesium chloride, $MgCl_2$, can absorb water to form the hydrated salt $MgCl_2.4H_2O$

$$MgCl_2(s) + 4H_2O(l) \rightarrow MgCl_2.4H_2O(s)$$

0 1 . 1 Suggest **one** reason why the enthalpy change for this reaction cannot be determined directly by calorimetry.

[1 mark]

0 1 . 2 Some enthalpies of solution are shown in **Table 1**.

Table 1

Salt	Enthalpy of solution / kJ mol^{-1}
$MgCl_2(s)$	−155
$MgCl_2.4H_2O(s)$	−39

Calculate the enthalpy change for the absorption of water by $MgCl_2(s)$ to form $MgCl_2.4H_2O(s)$.

[2 marks]

Enthalpy change _____ kJ mol^{-1}

0 1 . 3 Describe how you would carry out an experiment to determine the enthalpy of solution of anhydrous magnesium chloride.
You should use about 0.8 g of anhydrous magnesium chloride.

Explain how your results could be used to calculate the enthalpy of solution.

[6 marks]

0 1 . 4 Anhydrous magnesium chloride can be formed by direct reaction between its elements.

$$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$

The free-energy change, ΔG, for this reaction varies with temperature as shown in **Table 2**.

Table 2

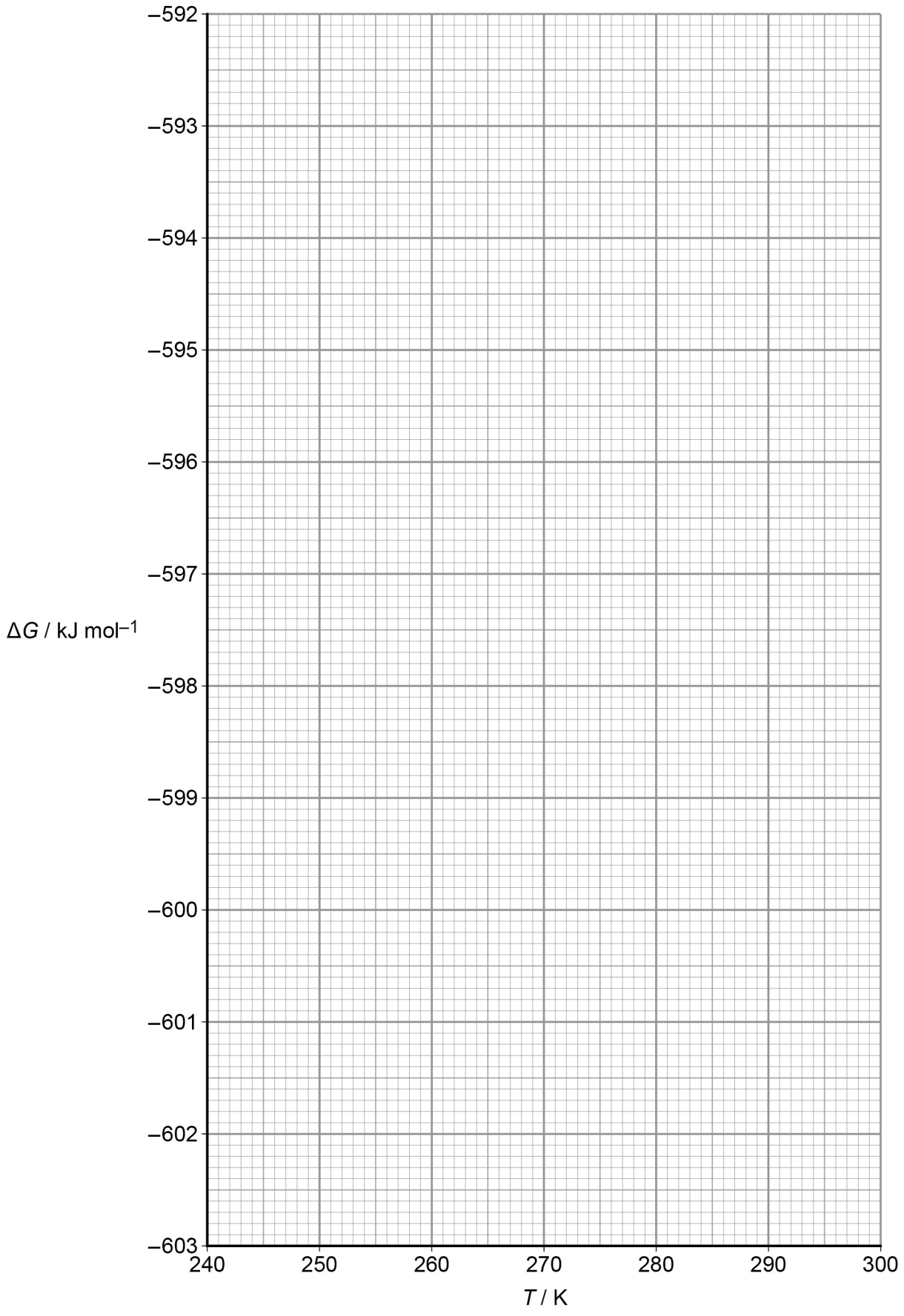
T / K	ΔG / kJ mol^{-1}
298	−592.5
288	−594.2
273	−596.7
260	−598.8
240	−602.2

Use these data to plot a graph of free-energy change against temperature on the grid opposite.

Calculate the gradient of the line on your graph and hence calculate the entropy change, ΔS, in J K^{-1} mol^{-1}, for the formation of anhydrous magnesium chloride from its elements.

Show your working.

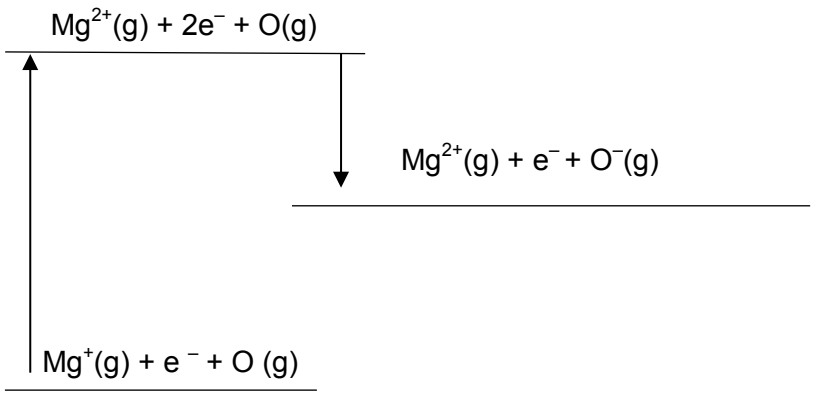
[5 marks]



ΔS _____ $J\,K^{-1}\,mol^{-1}$

14

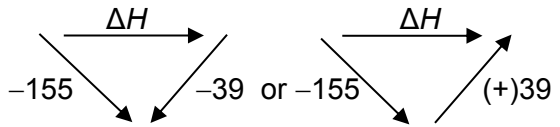
Question	Answers	Mark	Additional Comments/Guidance
01.1	Enthalpy change or heat energy change when 1 mol of solid ionic compound/substance or 1 mol of ionic lattice is formed from its gaseous ions.	1 1	Allow: enthalpy change for: $M^+ (g) + X^- (g) \rightarrow MX (s)$ or $Ag^+ (g) + I^- (g) \rightarrow AgI (s)$ CE=0/2 if describing wrong process (eg ΔH of lattice dissociation or ΔH of formation/ or heat energy required) Ignore heat energy released
01.2	lattice dissociation energy= (112 + 464 + 293) = + 869 ($kJmol^{-1}$) lattice formation energy = − 869 ($kJ\ mol^{-1}$)	1 1	 (+)869 = 1 mark
01.3	AgI contains covalent character Forces/bonds (holding the lattice together) are stronger	1 1	CE=0/2 if atoms/molecules For M1, allow the following: not completely ionic / ions not spherical / ions distorted/ some covalent bonding Ignore covalent bonds stronger (than ionic bonds) Ignore electronegativity Ignore references to energy
01.4	$AgNO_3$ yellow ppt or Cl_2 or Br_2 brown solution/black ppt	1 1	Ignore ammonia/acidified/nitric acid/sulphuric acid M2 dependent on correct M1 but mark on from Ag^+ or Tollens
Total		**8**	

Question	Answers	Additional Comments/Guidance	Mark
01.1		One mark for each level with correct state symbols	1 1 1
01.2	$\Delta_f H = \Delta_a H$ (Mg) + ½ $\Delta_{BD} H$ (O_2) + $\Delta_{1st\ IE} H$ (Mg) + $\Delta_{2nd\ IE} H$ (Mg) + $\Delta_{1st\ EA} H$ (O) + $\Delta_{2nd\ EA} H$(O) + $\Delta_{LE} H$ (MgO) - 602 = 150 + (½ x 496) + 736 +1450 – 142 + 844 + Δ_{LE}H (MgO) $\Delta_{LE} H$ (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 x 1/2)	1 1 1
Total			6

Question	Marking guidance	Mark	AO	Comments
09.1	Start a clock when KCl is added to water	1	AO3 2b	
	Record the temperature every subsequent minute for about 5 minutes	1	AO3 2b	Allow record the temperature at regular time intervals until some time after all the solid has dissolved for M2
	Plot a graph of temperature vs time	1	AO3 2a	
	Extrapolate back to time of mixing = 0 and determine the temperature	1	AO3 2a	
09.2	Heat taken in = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6$ J	1	AO2h	Max 2 if 14.6 °C used as ΔT
	Moles of KCl = 5.00/74.6 = 0.0670	1	AO2h	
	Enthalpy change per mole = +1128.6/0.0670 = 16 839 J mol^{-1}	1	AO2h	
	= +16.8 (kJ mol^{-1})	1	AO1b	Answer must be given to this precision
09.3	$\Delta H_{solution} = \Delta H_{lattice} + \Delta$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	AO2f	
	$\Delta H_{lattice}$ = –82.9 – (–1650 + 2 × –364) = +2295 (kJ mol^{-1})	1	AO2f	
09.4	Magnesium ion is smaller than the calcium ion	1	AO2a	
	Therefore, it attracts the chloride ion more strongly / stronger ionic bonding	1	AO2a	

Question	Answers	Mark	Additional Comments/Guidance
05.1	$\Delta S = \Sigma S$ products – ΣS reactants or 253 + (2 x 198) – (2 x 223 + 2 x 5.7 + 50.2) (= 649 – 507.6)	1	This expression could also score M1
	ΔS = 141(.4) (J $K^{-1}mol^{-1}$)	1	This scores M1 and M2 Allow ecf for M3, M4 and M5 from incorrect M2
	$\Delta G = \Delta H - T\Delta S$	1	
	ΔG = -60 - (<u>1262</u> x 141(.4) x 10^{-3})	1	This expression also scores M3. For M4, allow ΔG = -60 - (<u>1262</u> x their M2 x 10^{-3}) <u>If calculated in joules</u> M4: Allow ΔG = -60x10^3 - (1262 x 141(.4))
	= –238 (kJ mol^{-1}) to 3 sig figs	1	M5: Allow -<u>238 000</u> J mol^{-1} providing units shown
	feasible since ΔG is negative/less than zero	1	Allow consequential M6 from their ΔG
Total		**6**	

Section A

Question	Answers	Mark	Additional Comments/Guidance
01.1	Not possible to prevent some dissolving	1	ALLOW It is soluble / dissolves / other hydrates may form / suggestions related to difficulty of measuring T (change) of a solid
01.2	($\Delta_{hyd}H$ =) –155 – (–39)	1	OR labelled cycle Minimum needed for 'labelled cycle' 
	–116 (kJ mol^{-1})	1	1/2 for (+)116 or for −29 or for seeing –116 that has then be processed further

01.3 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. 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

6

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)

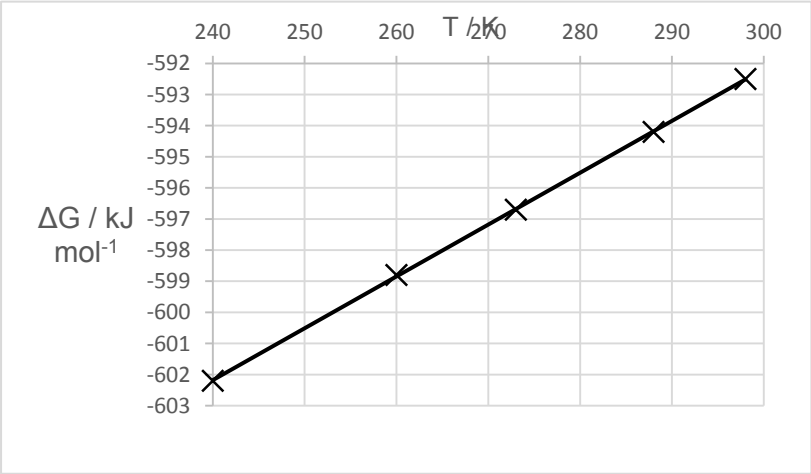
(2a) Record initial temperature (min 2 measurements)
(2b) Record T at regular timed intervals for 5+ mins / until trend seen
(2c) Plot T vs time

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/M_r ($0.80/95.3 = 8.39 \times 10^{-3}$ 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

Question	Answers	Mark	Additional Comments/Guidance
01.4		2	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)
	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})	1+1	M4 = unit conversion i.e. M3 x1000; M5 = –sign (process marks) Correct answer with sign gets M3, M4 and M5 ALLOW –163 to –171

Total		14	