

# TOPICAL PAST PAPER QUESTIONS WORKSHEETS

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## AS & A Level Chemistry (9701) Paper 4

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**Exam Series: Feb/Mar 2017 – May/June 2023**

**Format Type A:**

Answers to all questions are provided as an appendix



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# Introduction

Each Topical Past Paper Questions Compilation contains a comprehensive collection of hundreds of questions and corresponding answer schemes, presented in worksheet format. The questions are carefully arranged according to their respective chapters and topics, which align with the latest IGCSE or AS/A Level subject content. Here are the key features of these resources:

1. The workbook covers a wide range of topics, which are organized according to the latest syllabus content for Cambridge IGCSE or AS/A Level exams.
2. Each topic includes numerous questions, allowing students to practice and reinforce their understanding of key concepts and skills.
3. The questions are accompanied by detailed answer schemes, which provide clear explanations and guidance for students to improve their performance.
4. The workbook's format is user-friendly, with worksheets that are easy to read and navigate.
5. This workbook is an ideal resource for students who want to familiarize themselves with the types of questions that may appear in their exams and to develop their problem-solving and analytical skills.

Overall, Topical Past Paper Questions Workbooks are a valuable tool for students preparing for IGCSE or AS/A level exams, providing them with the opportunity to practice and refine their knowledge and skills in a structured and comprehensive manner. To provide a clearer description of this book's specifications, here are some key details:

- Title: Cambridge AS & A Level Chemistry (9701) Paper 4 Topical Past Paper Questions
- Subtitle: Exam Practice Worksheets With Answer Scheme
- Examination board: Cambridge Assessment International Education (CAIE)
- Subject code: 9701
- Years covered: Feb/Mar 2017 – May/June 2023
- Paper: 4
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# Chapter 1

## Chemical energetics

1. 9701\_s22\_qp\_42 Q: 3

**(a) (i)** Define first electron affinity.

.....

.....

..... [2]

**(ii)** The first electron affinity of an atom is usually an exothermic process, whereas the second electron affinity is an endothermic process.

Suggest why.

.....

..... [1]

**(iii)** Describe the general trend in first electron affinities for Cl, Br and I. Explain your answer.

.....

.....

..... [2]

**(b)** Table 3.1 shows energy changes to be used in this question and in (c).**Table 3.1**

energy change	value/kJ mol <sup>-1</sup>
standard enthalpy change of atomisation of zinc	+131
first ionisation energy of zinc	+906
second ionisation energy of zinc	+1733
standard enthalpy change of formation of ZnI <sub>2</sub> (s)	-208
lattice energy, $\Delta H_{\text{latt}}^{\circ}$ , of zinc iodide, ZnI <sub>2</sub> (s)	-2605
first ionisation energy of iodine	+1008
second ionisation energy of iodine	+1846
I–I bond energy	+151
enthalpy change of sublimation of iodine, I <sub>2</sub> (s) → I <sub>2</sub> (g)	+62



Calculate the first electron affinity for iodine. Use relevant data from Table 3.1 in your working. It may be helpful to draw a labelled energy cycle. Show all working.

first electron affinity for iodine = ..... kJ mol<sup>-1</sup> [3]

- (c) Predict how  $\Delta H_{\text{latt}}^{\circ}$  of CdI<sub>2</sub>(s) differs from  $\Delta H_{\text{latt}}^{\circ}$  of ZnI<sub>2</sub>(s). Place a tick (✓) in the appropriate box in Table 3.2.

**Table 3.2**

$\Delta H_{\text{latt}}^{\circ}$ of CdI <sub>2</sub> (s) is less negative than $\Delta H_{\text{latt}}^{\circ}$ of ZnI <sub>2</sub> (s)	$\Delta H_{\text{latt}}^{\circ}$ of CdI <sub>2</sub> (s) is the same as $\Delta H_{\text{latt}}^{\circ}$ of ZnI <sub>2</sub> (s)	$\Delta H_{\text{latt}}^{\circ}$ of CdI <sub>2</sub> (s) is more negative than $\Delta H_{\text{latt}}^{\circ}$ of ZnI <sub>2</sub> (s)

Explain your answer.

.....  
 ..... [1]

[Total: 9]

2. 9701\_w21\_qp\_41 Q: 3

(a) Define the term *electron affinity*.

.....  
 ..... [2]

(b) Write an equation for the process corresponding to the **second** ionisation energy of calcium. Include state symbols.

..... [1]

Some data relating to calcium and oxygen are listed. Select relevant data from this list for your answers to parts (c), (d) and (e).

process	value/kJ mol <sup>-1</sup>
first ionisation energy of oxygen	+1310
second ionisation energy of oxygen	+3390
first electron affinity of oxygen	-142
second electron affinity of oxygen	+844
enthalpy change for $\frac{1}{2}\text{O}_2(\text{g}) + 2\text{e}^- \rightarrow \text{O}^{2-}(\text{g})$	+951
enthalpy change for $\text{Ca}(\text{s}) \rightarrow \text{Ca}^{2+}(\text{g}) + 2\text{e}^-$	+1933
lattice energy of CaO(s)	-3517

(c) Oxygen exists as O<sub>2</sub> molecules.

Use the data in this question to calculate a value for the bond energy of the O=O bond. Show all your working.

bond energy = ..... kJ mol<sup>-1</sup> [3]

(d) (i) Suggest why the first electron affinity of oxygen is negative.

.....  
..... [1]

(ii) Suggest why the second electron affinity of oxygen is positive.

.....  
..... [1]

(e) Calculate the enthalpy of formation of calcium oxide, CaO(s).

enthalpy of formation = ..... kJ mol<sup>-1</sup> [2]

(f) The lattice energy of lithium fluoride, LiF(s), is  $-1022 \text{ kJ mol}^{-1}$ .

Identify the factor that causes the lattice energy of calcium oxide to be more exothermic than that of lithium fluoride. Explain why this factor causes the difference in lattice energies.

.....  
..... [2]

[Total: 12]

---

3. 9701\_w21\_qp\_42 Q: 1

Radium is a Group 2 element.

The predicted lattice energy,  $\Delta H_{\text{latt}}^{\ominus}$ , of radium sulfide, RaS, is  $-2612 \text{ kJ mol}^{-1}$ .

(a) Define  $\Delta H_{\text{latt}}^{\ominus}$ .

.....  
 ..... [2]

Some data relating to radium and sulfur are listed. Select relevant data from this list for use in your answers to parts (b) to (e).

process	value/ $\text{kJ mol}^{-1}$
enthalpy change for $\text{Ra(s)} \rightarrow \text{Ra}^{2+}(\text{g}) + 2\text{e}^{-}$	+1619
first ionisation energy of sulfur	+1000
second ionisation energy of sulfur	+2260
first electron affinity of sulfur	-200
second electron affinity of sulfur	+532
enthalpy change for $\frac{1}{8}\text{S}_8(\text{s}) + 2\text{e}^{-} \rightarrow \text{S}^{2-}(\text{g})$	+555
lattice energy of RaS(s)	-2612

(b) Write an equation for the process corresponding to the **second** electron affinity of sulfur. Include state symbols.

..... [1]

(c) Sulfur exists as  $\text{S}_8$  molecules in the solid state.

Use the data in this question to calculate the enthalpy change for the reaction  $\text{S}_8(\text{s}) \rightarrow 8\text{S}(\text{g})$ .

enthalpy change = .....  $\text{kJ mol}^{-1}$  [3]

(d) Calculate the standard enthalpy change of formation,  $\Delta H_f^\ominus$ , of radium sulfide.

standard enthalpy change,  $\Delta H_f^\ominus = \dots\dots\dots$   $\text{kJ mol}^{-1}$  [2]

(e) (i) State the **two** major factors that affect the numerical magnitude of a lattice energy.

.....  
 ..... [2]

(ii) For **each** factor you have identified in (e)(i), state whether it tends to make the lattice energy of radium sulfide more or less exothermic than that of sodium chloride.

Explain your answer.

.....  
 .....  
 .....  
 ..... [2]

(iii) The lattice energies of sodium chloride, NaCl, and radium sulfide, RaS, are  $-771 \text{ kJ mol}^{-1}$  and  $-2612 \text{ kJ mol}^{-1}$ , respectively.

Identify the **dominant** factor in determining the relative numerical magnitudes of the lattice energies of radium sulfide and sodium chloride.

Explain your answer.

.....  
 ..... [1]

[Total: 13]

4. 9701\_s20\_qp\_42 Q: 7

(a) (i) Define the term *electron affinity*.

.....  
.....  
..... [2]

(ii) Define the term *lattice energy*.

.....  
.....  
..... [2]

(b) Use the following data and relevant data from the *Data Booklet* to calculate a value for the enthalpy change of formation of zinc bromide,  $\text{ZnBr}_2(\text{s})$ .

You might find it helpful to construct an energy cycle.

electron affinity of  $\text{Br}(\text{g})$  =  $-325 \text{ kJ mol}^{-1}$   
enthalpy change of atomisation of  $\text{Zn}(\text{s})$  =  $+131 \text{ kJ mol}^{-1}$   
enthalpy change of vaporisation of  $\text{Br}_2(\text{l})$  =  $+31 \text{ kJ mol}^{-1}$   
lattice energy of  $\text{ZnBr}_2(\text{s})$  =  $-2678 \text{ kJ mol}^{-1}$

enthalpy change of formation of  $\text{ZnBr}_2(\text{s})$  = .....  $\text{kJ mol}^{-1}$  [4]

(c) The lattice energies of  $\text{ZnBr}_2$ ,  $\text{ZnCl}_2$  and  $\text{ZnO}$  are shown.

compound	lattice energy / $\text{kJ mol}^{-1}$
$\text{ZnBr}_2$	-2678
$\text{ZnCl}_2$	-2734
$\text{ZnO}$	-3971

(i) Explain why there is a difference between the lattice energies of  $\text{ZnBr}_2$  and  $\text{ZnCl}_2$ .

.....  
..... [1]

(ii) Explain why there is a difference between the lattice energies of  $\text{ZnCl}_2$  and  $\text{ZnO}$ .

.....  
..... [1]

---

[Total: 10]

5. 9701\_s18\_qp\_41 Q: 1

Sodium oxide,  $\text{Na}_2\text{O}$ , is a white crystalline solid with a high melting point.

- (a) Write an equation for the reaction of sodium with oxygen, forming sodium oxide. Include state symbols.

..... [2]

- (b) Explain why sodium oxide has a high melting point.

.....  
.....  
.....  
..... [2]

- (c) When sodium oxide reacts with water an alkaline solution is obtained.

- (i) Explain why the solution obtained is alkaline. You should use the Brønsted-Lowry theory of acids and bases in your answer.

.....  
.....  
.....  
..... [2]

- (ii) Calculate the pH of the solution obtained when 3.10 g of sodium oxide are added to  $400 \text{ cm}^3$  of water.

pH = ..... [3]



- (d) Use the data below, and other suitable data from the *Data Booklet*, to calculate the lattice energy of sodium oxide,  $\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{O}(\text{s})$ .

energy change	value / $\text{kJ mol}^{-1}$
standard enthalpy change of formation of sodium oxide, $\Delta H_f^{\ominus} \text{Na}_2\text{O}(\text{s})$	-416
standard enthalpy change of atomisation of sodium, $\Delta H_{\text{at}}^{\ominus} \text{Na}(\text{s})$	+109
electron affinity of O(g)	-142
electron affinity of $\text{O}^{-}(\text{g})$	+844

$$\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{O}(\text{s}) = \dots\dots\dots \text{kJ mol}^{-1} \quad [4]$$

- (e) State how  $\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{S}(\text{s})$  differs from  $\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{O}(\text{s})$ .  
Indicate this by placing a tick ( $\checkmark$ ) in the appropriate box in the table.

$\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{S}(\text{s})$ is more exothermic than $\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{O}(\text{s})$	$\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{S}(\text{s})$ is the same as $\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{O}(\text{s})$	$\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{S}(\text{s})$ is less exothermic than $\Delta H_{\text{latt}}^{\ominus} \text{Na}_2\text{O}(\text{s})$
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Explain your answer.

.....

.....

.....

[2]

[Total: 15]

6. 9701\_s23\_qp\_41 Q: 8

- (a) Complete Table 8.1 by placing **one** tick (✓) in each row to indicate the sign of each type of energy change under standard conditions.

Table 8.1

energy change	always positive	always negative	can be either negative or positive
lattice energy			
enthalpy change of hydration			
enthalpy change of solution			

[1]

- (b) Define enthalpy change of hydration.

.....  
 .....  
 ..... [1]

- (c) Table 8.2 shows various energy changes which can be used in the following questions.

Table 8.2

energy change	value / kJ mol <sup>-1</sup>
standard enthalpy change of atomisation of calcium	+178.2
first ionisation energy of calcium	+590
second ionisation energy of calcium	+1145
standard enthalpy change of atomisation of bromine	+111.9
Br–Br bond energy	+192.9
standard enthalpy change of solution of calcium bromide, CaBr <sub>2</sub> (s)	–103.1
standard enthalpy change of formation of calcium bromide, CaBr <sub>2</sub> (s)	–682.8
standard enthalpy change of hydration of Ca <sup>2+</sup>	–1579
first electron affinity of bromine	–324.6
first ionisation energy of bromine	+1140

- (i) Select and use relevant data from Table 8.2 to calculate the lattice energy,  $\Delta H_{\text{latt}}^{\ominus}$ , of  $\text{CaBr}_2(\text{s})$ .

It may be helpful to draw a labelled energy cycle.

Show your working.

$$\Delta H_{\text{latt}}^{\ominus} \text{ of } \text{CaBr}_2(\text{s}) = \dots\dots\dots \text{ kJ mol}^{-1} \text{ [3]}$$

- (ii) Select and use relevant data from Table 8.2 and your answer to (c)(i) to calculate the standard enthalpy change of hydration,  $\Delta H_{\text{hyd}}^{\ominus}$ , of  $\text{Br}^-$ .

It may be helpful to draw a labelled energy cycle.

If you were not able to answer (c)(i), use  $-2500 \text{ kJ mol}^{-1}$  as your value for  $\Delta H_{\text{latt}}^{\ominus}$  of  $\text{CaBr}_2(\text{s})$ . This is **not** the correct value.

Show your working.

$$\Delta H_{\text{hyd}}^{\ominus} \text{ of } \text{Br}^- = \dots\dots\dots \text{ kJ mol}^{-1} \text{ [2]}$$

- iii) The enthalpy change of hydration of the  $\text{Br}^-$  ion is more negative than the enthalpy change of hydration of the  $\text{I}^-$  ion. Explain why.

.....  
 .....  
 ..... [2]

[Total: 9]

7. 9701\_s19\_qp\_41 Q: 6

- (a) Complete the table by placing **one** tick (✓) in each row to indicate the sign of each type of energy change under standard conditions.

energy change	always positive	always negative	either negative or positive
bond energy			
enthalpy change of formation			

[1]

- (b) Explain what is meant by the term *enthalpy change of atomisation*.

.....  
 ..... [1]

- (c) The overall reaction for the atomisation of liquid bromine molecules, Br<sub>2</sub>(l), is shown.



This happens via a two-step process.

- Construct a **labelled** energy cycle to represent this atomisation process, including state symbols.
- Use your cycle and relevant data from the *Data Booklet* to calculate the enthalpy change of vaporisation of Br<sub>2</sub>(l),  $\Delta H_{\text{vap}}^{\ominus}$ .  
 The enthalpy change of atomisation of bromine,  $\Delta H_{\text{at}}^{\ominus} = +112 \text{ kJ mol}^{-1}$ .

$$\Delta H_{\text{vap}}^{\ominus} = \dots\dots\dots \text{kJ mol}^{-1} \quad [3]$$

- (d) Suggest how the  $\Delta H_{\text{vap}}^{\ominus}$  of iodine, I<sub>2</sub>(l), would compare to that of bromine, Br<sub>2</sub>(l). Explain your answer.

.....  
 ..... [1]

(e) (i) Explain what is meant by the term *enthalpy change of hydration*.

.....  
..... [1]

(ii) Suggest why the enthalpy change of hydration of  $\text{Br}^-(\text{g})$  is **more** exothermic than that of  $\text{I}^-(\text{g})$ .

.....  
.....  
..... [2]

[Total: 9]

---

8. 9701\_s17\_qp\_41 Q: 1

**(a)** Describe and explain the variation in the solubilities of the hydroxides of the Group 2 elements.

.....

.....

.....

.....

.....

.....

..... [4]

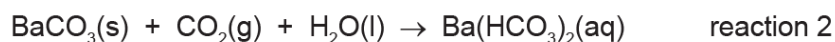
The table lists the standard enthalpy changes of formation,  $\Delta H_f^\ominus$ , for some compounds and aqueous ions.

species	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
Ba <sup>2+</sup> (aq)	-538
OH <sup>-</sup> (aq)	-230
CO <sub>2</sub> (g)	-394
BaCO <sub>3</sub> (s)	-1216
H <sub>2</sub> O(l)	-286

**(b) (i)** Reaction 1 occurs when CO<sub>2</sub>(g) is bubbled through an aqueous solution of Ba(OH)<sub>2</sub>.Use the data in the table to calculate the standard enthalpy change for reaction 1,  $\Delta H_{r1}^\ominus$ .

$$\Delta H_{r1}^\ominus = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

If  $\text{CO}_2(\text{g})$  is bubbled through an aqueous solution of  $\text{Ba}(\text{OH})_2$  for a long time, the precipitated  $\text{BaCO}_3(\text{s})$  dissolves, as shown in reaction 2.



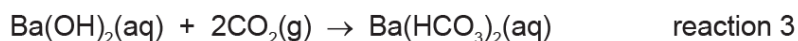
The standard enthalpy change for reaction 2,  $\Delta H_{r2}^\circ = -26 \text{ kJ mol}^{-1}$ .

- (ii) Use this information and the data in the table to calculate the standard enthalpy change of formation of the  $\text{HCO}_3^-(\text{aq})$  ion.

$$\Delta H_f^\circ \text{HCO}_3^-(\text{aq}) = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

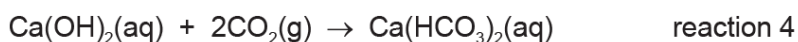
- (iii) The overall process is shown by reaction 3.

Use your answer to (ii), and the data given in the table, to calculate the standard enthalpy change for reaction 3,  $\Delta H_{r3}^\circ$ .



$$\Delta H_{r3}^\circ = \dots\dots\dots \text{ kJ mol}^{-1} \quad [1]$$

- (iv) How would the value of  $\Delta H_{r3}^\circ$  compare with the value of  $\Delta H_{r4}^\circ$  for the similar reaction with  $\text{Ca}(\text{OH})_2(\text{aq})$  as shown in reaction 4? Explain your answer.



.....  
 .....  
 ..... [2]

- (c) The standard entropy change for reaction 1 is  $\Delta S_{r1}^\circ$ .

Suggest, with a reason, how the standard entropy change for reaction 3 might compare with  $\Delta S_{r1}^\circ$ .

.....  
 .....  
 ..... [2]

[Total: 13]

9. 9701\_w22\_qp\_41 Q: 1

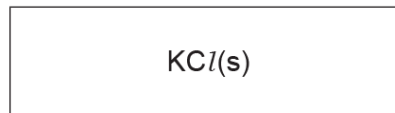
Potassium chloride,  $KCl$ , and magnesium chloride,  $MgCl_2$ , are both ionic solids.

Table 1.1

energy change	value / $\text{kJ mol}^{-1}$
standard enthalpy change of solution, $\Delta H_{\text{sol}}^{\ominus}$ of $KCl$	+15
lattice energy, $\Delta H_{\text{latt}}^{\ominus}$ of $KCl(s)$	-701
standard enthalpy change of hydration, $\Delta H_{\text{hyd}}^{\ominus}$ of $K^+$	-322
standard enthalpy change of hydration, $\Delta H_{\text{hyd}}^{\ominus}$ of $Cl^-$	-364
standard enthalpy change of solution, $\Delta H_{\text{sol}}^{\ominus}$ of $MgCl_2$	-155
lattice energy, $\Delta H_{\text{latt}}^{\ominus}$ of $MgCl_2(s)$	-2493

- (a) Complete the energy cycle involving the enthalpy change of solution and the lattice energy of potassium chloride,  $KCl$ , and the relevant enthalpy changes of hydration. Label your diagram.

State symbols should be used.



[2]

- (b) Use the data in Table 1.1 to calculate the enthalpy change of hydration of magnesium ions,  $Mg^{2+}$ . Show your working.

$$\Delta H_{\text{hyd}}^{\ominus} \text{ of magnesium ions, } Mg^{2+} = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$



- (c) Explain the reasons why the lattice energy of  $\text{MgCl}_2$  is more exothermic than the lattice energy of  $\text{KCl}$ .

.....  
 .....  
 .....  
 ..... [2]

- (d) Define the following terms.

(i) enthalpy change of atomisation .....  
 ..... [1]

(ii) first electron affinity .....  
 ..... [1]

- (e) (i) Explain what is meant by entropy,  $S$ .

.....  
 ..... [1]

- (ii) Potassium chloride is very soluble in water at  $20^\circ\text{C}$ .

Explain the solubility of potassium chloride by reference to change in entropy,  $\Delta S$ .

.....  
 ..... [1]

- (iii) Use the Gibbs equation and your answer to (e)(ii) to predict whether potassium chloride is more soluble in water at  $20^\circ\text{C}$  or at  $80^\circ\text{C}$ . Explain your answer.

.....  
 .....  
 ..... [1]

[Total: 11]

10. 9701\_w22\_qp\_42 Q: 1

Calcium chloride,  $\text{CaCl}_2$ , is an ionic solid.

The values of some energy changes are shown in Table 1.1.

**Table 1.1**

energy change	value/ $\text{kJ mol}^{-1}$
lattice energy, $\Delta H_{\text{latt}}^{\circ}$ , $\text{CaCl}_2(\text{s})$	-2237
standard enthalpy change of atomisation of calcium	+193
first ionisation energy of calcium	+590
second ionisation energy of calcium	+1150
standard enthalpy change of atomisation of chlorine	+121
first electron affinity of chlorine	-364

(a) Define lattice energy.

.....  
 ..... [1]

(b) Use the data in Table 1.1 to calculate the standard enthalpy change of formation,  $\Delta H_{\text{f}}^{\circ}$ , of calcium chloride. It may be helpful to draw an energy cycle. Show all your working.

$$\Delta H_{\text{f}}^{\circ}(\text{CaCl}_2(\text{s})) = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

- (c) Three possible values for the first electron affinity of bromine are shown in Table 1.2. One of them is correct.

Place a tick by the correct value. Explain your choice.

**Table 1.2**

possible values	place <b>one</b> tick (✓) in this column
-342 kJ mol <sup>-1</sup>	
-364 kJ mol <sup>-1</sup>	
-386 kJ mol <sup>-1</sup>	

explanation .....

..... [1]

- (d) The enthalpy change of hydration of the chloride ion can be calculated using the lattice energy of calcium chloride and the data shown in Table 1.3.

**Table 1.3**

energy change	value/kJ mol <sup>-1</sup>
standard enthalpy change of solution of CaCl <sub>2</sub> (s)	-83
standard enthalpy change of hydration of Ca <sup>2+</sup> (g)	-1650

- (i) Define the following terms.

enthalpy change of solution .....

.....

enthalpy change of hydration .....

..... [2]

- (ii) Calculate the standard enthalpy change of hydration of the chloride ion, Cl<sup>-</sup>(g). It may be helpful to draw an energy cycle. Show all your working.

$$\Delta H_{\text{hyd}}^{\ominus}(\text{Cl}^{-}(\text{g})) = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

- (e) Calcium fluoride,  $\text{CaF}_2(\text{s})$ , can be synthesised directly from its elements.

The value of  $\Delta H_f^\circ(\text{CaF}_2(\text{s}))$  is  $-1214 \text{ kJ mol}^{-1}$ .

- (i) Predict the sign of the entropy change,  $\Delta S^\circ$ , for this synthesis. Explain your answer.

The sign of the entropy change is .....

explanation .....

..... [1]

- (ii) Use the value of  $\Delta H_f^\circ(\text{CaF}_2(\text{s}))$  given in (e) and your answer to (e)(i) to predict how the feasibility for this synthesis will change with increasing temperature.

.....

.....

.....

..... [2]

[Total: 11]

11. 9701\_s19\_qp\_42 Q: 5

- (a) Complete the table by placing **one** tick (✓) in each row to indicate the sign of each type of energy change under standard conditions.

energy change	always positive	always negative	either negative or positive
lattice energy			
enthalpy change of neutralisation			

[1]

- (b) Define, in words, the term *enthalpy change of solution*.

.....  
 ..... [1]

- (c) The following enthalpy changes are given.

enthalpy change	value / kJ mol <sup>-1</sup>
standard enthalpy change of formation, $\Delta H_f^\ominus$ , for $K_3PO_4(s)$	-2035
standard enthalpy change, $\Delta H^\ominus$ , for $P(s) + 2O_2(g) + 3e^- \rightarrow PO_4^{3-}(aq)$	-1284
standard enthalpy change, $\Delta H^\ominus$ , for $K(s) \rightarrow K^+(aq) + e^-$	-251

Determine the standard enthalpy change of solution of potassium phosphate,  $K_3PO_4(s)$ . It may be helpful to draw a labelled energy cycle.

$$\Delta H_{sol}^\ominus = \dots\dots\dots \text{kJ mol}^{-1} \quad [3]$$

(d) Some lattice energy values are shown in the table.

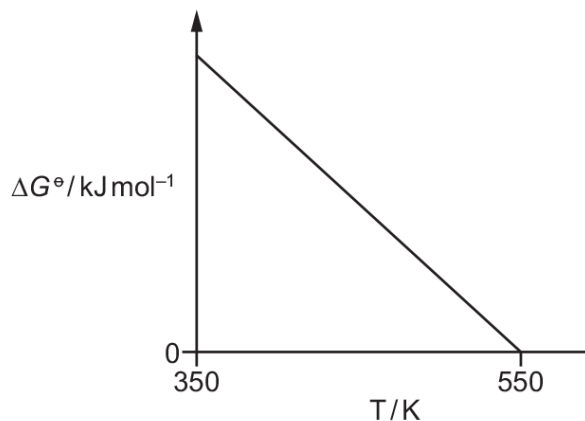
compound	lattice energy value / $\text{kJ mol}^{-1}$
$\text{CaBr}_2(\text{s})$	-2176
$\text{KBr}(\text{s})$	-679

Suggest an explanation for why  $\Delta H_{\text{latt}}^\circ$   $\text{CaBr}_2$  is **more** exothermic than  $\Delta H_{\text{latt}}^\circ$   $\text{KBr}$ .

.....  
 .....  
 ..... [2]

(e) For a particular gas phase reaction the variation in standard Gibbs free energy change,  $\Delta G^\circ$ , with temperature is shown.

Assume standard enthalpy change,  $\Delta H^\circ$ , and standard entropy change,  $\Delta S^\circ$ , remain constant with temperature.



(i) Write the equation that relates  $\Delta G^\circ$  to  $\Delta H^\circ$  and  $\Delta S^\circ$ .

..... [1]

(ii) Use this equation to explain why  $\Delta G^\circ$  becomes **less** positive as temperature increases in this reaction.

.....  
 ..... [1]

[Total: 9]

12. 9701\_w19\_qp\_41 Q: 3

(a) Explain what is meant by the term *entropy of a system*.

.....  
 ..... [1]

(b) State and explain whether the entropy change of each of the following processes is positive or negative. Do not consider the entropy change of the surroundings.

- liquid water at 80 °C is cooled to 60 °C

The entropy change is ..... because .....  
 .....

- solid calcium chloride is added to water and the mixture is stirred

The entropy change is ..... because .....  
 .....

- the change corresponding to the lattice energy of calcium chloride,  $\Delta H_{\text{latt}} \text{CaCl}_2(\text{s})$ , takes place

The entropy change is ..... because .....  
 ..... [3]

(c) The reaction  $\text{ZnCO}_3(\text{s}) \rightarrow \text{ZnO}(\text{s}) + \text{CO}_2(\text{g})$  is not spontaneous at room temperature.

- (i) Give the full name for the term  $\Delta G^\circ$ .

..... [1]

- (ii) Describe how the temperature at which the reaction becomes spontaneous can be calculated. Include an equation in your answer.

equation .....  
 .....  
 .....  
 ..... [2]

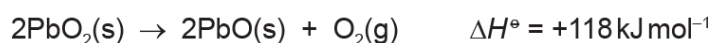
[Total: 7]

13. 9701\_w19\_qp\_42 Q: 4

The table shows some standard entropy data.

substance	standard entropy, $S^\ominus$ / $\text{JK}^{-1} \text{mol}^{-1}$
$\text{PbO}_2(\text{s})$	77
$\text{PbO}(\text{s})$	69
$\text{O}_2(\text{g})$	205

Lead(IV) oxide,  $\text{PbO}_2$ , decomposes to lead(II) oxide,  $\text{PbO}$ , and oxygen when heated.



(a) Use the data to calculate the value of  $\Delta S^\ominus$  for this reaction.

$$\Delta S^\ominus = \dots\dots\dots \text{JK}^{-1} \text{mol}^{-1} \quad [2]$$

(b) Use the value of  $\Delta H^\ominus$  and your answer to (a) to calculate the temperature at which this reaction becomes feasible.

$$T = \dots\dots\dots \text{K} \quad [3]$$

(c) Solid lead(II) oxide can be made by heating lead metal in air.

Predict the **sign** of the standard entropy change of this reaction. Explain your answer.

.....  
 ..... [1]

[Total: 6]



14. 9701\_s18\_qp\_42 Q: 1

Silicon tetrachloride,  $\text{SiCl}_4$ , is formed when silicon reacts with chlorine under suitable conditions. It is a colourless liquid with a low boiling point.

(a) Explain why  $\text{SiCl}_4$  has a low boiling point.

.....  
 .....  
 ..... [2]

(b)  $\text{SiCl}_4$  reacts with water to produce an acidic solution.

(i) Write an equation for this reaction.

..... [1]

(ii) Describe **two** visual observations when silicon tetrachloride is added drop by drop to a small amount of water.

1 .....

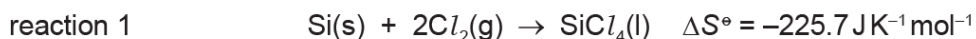
2 ..... [2]

(iii) A sample of 0.8505 g of  $\text{SiCl}_4$  is added to 800  $\text{cm}^3$  of water. All of the soluble acidic product is dissolved in the water.

Calculate the pH of the solution obtained.

pH = ..... [3]

- (c) (i) Silicon tetrachloride can be prepared according to reaction 1.



standard entropy of silicon, $S^\circ \text{ Si(s)}$	$18.7 \text{ JK}^{-1} \text{ mol}^{-1}$
standard entropy of silicon tetrachloride, $S^\circ \text{ SiCl}_4(\text{l})$	$239.0 \text{ JK}^{-1} \text{ mol}^{-1}$

Calculate the standard entropy of chlorine,  $S^\circ \text{ Cl}_2(\text{g})$ . Show all your working.

$$S^\circ \text{ Cl}_2(\text{g}) = \dots\dots\dots \text{ JK}^{-1} \text{ mol}^{-1} \quad [2]$$

- (ii) Explain why the entropy change for reaction 1 is negative.

.....  
 ..... [1]

- (d) The standard enthalpy change of formation of silicon tetrachloride,  $\Delta H_f^\circ \text{ SiCl}_4(\text{l})$ , is  $-640 \text{ kJ mol}^{-1}$ .

Reaction 1 is spontaneous at lower temperatures, but it is not spontaneous at very high temperatures.

Calculate the temperature above which reaction 1 is **not** spontaneous.

$$\text{temperature} = \dots\dots\dots \text{ K} \quad [2]$$

[Total: 13]

# Appendix A

## Answers

1. 9701\_s22\_ms\_42 Q: 3

Question	Answer	Marks
(a)(i)	<ul style="list-style-type: none"> <li>enthalpy change / energy change</li> <li>one mole of electrons</li> <li>(gained by) <b>one mole of gaseous atoms</b></li> </ul> <p>two for one mark, three for two marks</p>	2
(a)(ii)	(energy required to overcome) the repulsion between the electron and anion / negative ion	1

Question	Answer	Marks
(a)(iii)	<ul style="list-style-type: none"> <li>less negative / less exothermic down the group</li> <li>greater the distance between the nucleus and (the shells of the) electrons  <b>OR</b> atomic radii increases  <b>OR</b> more shielding by inner shells</li> <li>the less <b>attraction</b> between nucleus and incoming electron (and the less energy released)</li> </ul> <p>two for one mark, three for two marks</p>	2
(b)	<p><b>M1</b> use of correct seven numbers only in calculation / energy cycle  <b>M2</b> only 2 × used correctly  <b>M3</b> correct signs and evaluation ecf</p> $\begin{aligned} -208 &= 131 + 906 + 1733 + 62 + 151 + 2x - 2605 \\ 2x &= -586 \\ x &= -293 \text{ kJ mol}^{-1} \end{aligned}$	3
(c)	<p>first box ticked  <b>AND</b> Cd<sup>2+</sup> larger / Cd<sup>2+</sup> lower charge density  <b>AND</b> less attraction between the ions / weaker ionic bonds</p>	1

2. 9701\_w21\_ms\_41 Q: 3

Question	Answer	Marks
(a)	<ul style="list-style-type: none"> <li>enthalpy/energy change</li> <li>one mole of electrons gained</li> <li>by one mole of atoms</li> <li>gaseous (atoms)</li> </ul>	2
(b)	Ca <sup>+</sup> (g) → Ca <sup>2+</sup> (g) + e <sup>-</sup> [1]	1

Question	Answer	Marks
(c)	M1: selecting correct data 951, 844, 142 only M2: evaluation to give 249 ( $\Delta H_{\text{atom}}$ ) <b>OR</b> $2(951) = \text{BE} - 2(142) + 2(844)$ M3: evaluation to 498 ( $2 \times 249$ ) ecf M2  $951 = \Delta H_{\text{atom}} - 142 + 844$ $\Delta H_{\text{atom}} = 249$ $\text{BE} = 498 \text{ (kJ mol}^{-1}\text{)}$ [3]	3
(d)(i)	<b>attraction</b> between nucleus / protons / nuclear charge and electron [1]	1
(d)(ii)	<b>repulsion</b> between 1- ion / electrons of $\text{O}^-$ and electron [1]	1
(e)	M1: selecting correct data 951, 1933, 3517 only (ignore signs) M2: evaluation to give -633 ( $\Delta H_f$ ) ecf  $\Delta H_f = 951 + 1933 - 3517 = -633 \text{ (kJ mol}^{-1}\text{)}$ [2]	2
(f)	ionic charge / charge density (of the ions) [1]  greater (attractive) force between the ions [1]	2

3. 9701\_w21\_ms\_42 Q: 1

Question	Answer	Marks
(a)	<ul style="list-style-type: none"> <li>enthalpy / energy change / given out / evolved / released</li> <li>one mole is formed / made [1]</li> <li>of compound / solid / lattice / crystal</li> <li>(from) gaseous ions [1]</li> </ul>	2
(b)b	$\text{S}^-(\text{g}) + \text{e}^- \rightarrow \text{S}^{2-}(\text{g})$ [1]	1
(c)c	$(555 + 200 - 532 = 223, 223 \times 8 = 1784)$ M1 selecting correct data 555, 200, 532 <b>only</b> , (ignore signs and multipliers) [1] M2 evaluation to give +223 [1] M3 multiplying M2 by 8 and evaluation ans (+) 1784 [1]	3
(d)	$(1619 + 555 - 2612 = -438)$ M1 selecting correct data 1619 555 2612 <b>only</b> , (ignore signs and multipliers) [1] M2 evaluation to give -438 [1]	2
(e)(i)	ionic radius / size / sum of ionic radii [1]  ionic charge / product of ionic charges [1]	2
(e)(ii)	M1 (size tends to make $\Delta H_{\text{latt}}^\circ$ of radium sulfide) less exothermic since the ions are larger [1] M2 (charge tends to make $\Delta H_{\text{latt}}^\circ$ of radium sulfide) less exothermic since the ions are more highly charged [1]	2
(e)(iii)	(ionic) charge (since)  <b>AND</b>  $\Delta H_{\text{latt}}^\circ$ of radium sulfide is more exothermic [1]	1

## 4. 9701\_s20\_ms\_42 Q: 7

Question	Answer	Marks
(a)(i)	<ul style="list-style-type: none"> <li>energy change</li> <li>when one electron is added</li> <li>to each atom /ion in one mole of</li> <li>gaseous atoms /ions</li> </ul> <p>Award one mark for two correct statements. Award two marks for four correct statements</p>	2
(a)(ii)	<p><b>M1</b> energy change when 1 mole of an ionic compound is formed  <b>M2</b> from gas phase ions/ gaseous ions</p>	2

Question	Answer	Marks
(b)	<p><b>M1</b> use of data (with no multipliers) 31, 131, -2678  <b>M2</b> extraction of data 908, 1730, 193  <b>M3</b> use of (2 x-325)  <b>M4</b> evaluation of their expression correctly, as shown</p> $\Delta H_f(\text{ZnBr}_2) = 131 + (908 + 1730) + 193 + 31 + (2 \times -325) + (-2678)$ $= -335 \text{ kJ mol}^{-1} \quad [4]$	4
(c)(i)	Br is a largest ion/larger ion than Cl so attraction between Br and Zn <sup>2+</sup> is smaller	1
(c)(ii)	O <sup>2-</sup> is a smallest ion/smaller ion than Cl <b>AND</b> O <sup>2-</sup> has the highest charge/ higher charge than Cl (so attraction between O <sup>2-</sup> and Zn <sup>2+</sup> is larger)	1

## 5. 9701\_s18\_ms\_41 Q: 1

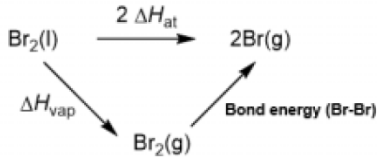
Question	Answer	Marks
(a)	4Na(s) + O <sub>2</sub> (g) → 2Na <sub>2</sub> O(s)	
	balanced with all formulae correct	1
	state symbols	1
(b)	giant ionic	1
	strong bond / attraction between <b>AND</b> positive and negative ions / anions and cations / Na <sup>+</sup> and O <sup>2-</sup> / oppositely charged ions	1
(c)(i)	the reaction produces sodium hydroxide / hydroxide ions / OH <sup>-</sup> ions	1
	the hydroxide ions can receive / accept H <sup>+</sup> ions / protons	1
(c)(ii)	Calculation of Na <sub>2</sub> O moles 3.10 g / 62 <b>OR</b> 0.05	1
	Calculation of [OH <sup>-</sup> ] 0.05 × (2 / 0.400) = 0.25 mol dm <sup>-3</sup>	1
	Calculation of pH -log 0.25 = 0.60 14 - 0.60 = 13.40	1
(d)	use of (2 × 109) or 218 and (2 × 494) or 988	1
	use of (0.5 × 496) or 248	1
	use of 416, 142, 844	1
	evaluation of expression correctly $\Delta H_{\text{lat}} = -416 - (2 \times 109) - (0.5 \times 496) - (2 \times 494) - (-142 + 844) = -2572$	1
(e)	the lattice energy of Na <sub>2</sub> S is less exothermic	1
	the sulfide ion is larger than the oxide ion / S <sup>2-</sup> larger than O <sup>2-</sup> / ionic radii quoted 0.184 nm and 0.140 nm <b>AND</b> less attraction (between the ions)/bonds are weaker	1

6. 9701\_s23\_ms\_41 Q: 8

Question	Answer	Marks																
(a)	<table border="1"> <tr> <td>energy change</td> <td>always positive</td> <td>always negative</td> <td>either negative or positive</td> </tr> <tr> <td>lattice energy</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>enthalpy of hydration</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>enthalpy of solution</td> <td></td> <td></td> <td>✓</td> </tr> </table> <p style="text-align: center;">All correct for one mark</p>	energy change	always positive	always negative	either negative or positive	lattice energy		✓		enthalpy of hydration		✓		enthalpy of solution			✓	1
energy change	always positive	always negative	either negative or positive															
lattice energy		✓																
enthalpy of hydration		✓																
enthalpy of solution			✓															
(b)	The energy / enthalpy change when 1 mole of gaseous ions is dissolved in water	1																
(c)(i)	<b>M1</b> use of correct six numbers only 682.8 178.2 590 1145 111.9 324.6 <b>M2</b> 2× used correctly with Br (2 × 111.9 and 2 × 324.6) <b>M3</b> correct signs and evaluation to give -2170.6 kJ mol <sup>-1</sup>	3																

Question	Answer	Marks
(c)(ii)	<b>M1</b> use of correct three numbers only 2170.6 103.1 and 1579 <b>M2</b> correct signs & evaluation -347 kJ mol <sup>-1</sup>	2
(c)(iii)	<b>M1</b> Br <sup>-</sup> has a smaller ionic radius <b>M2</b> Br <sup>-</sup> has stronger attractive forces with water molecules	2

7. 9701\_s19\_ms\_41 Q: 6

Question	Answer	Marks												
(a)	<table border="1"> <tr> <td>energy change</td> <td>always positive</td> <td>always negative</td> <td>either negative or positive</td> </tr> <tr> <td>bond energy</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>enthalpy of formation</td> <td></td> <td></td> <td>✓</td> </tr> </table> <p>both ticks correct</p>	energy change	always positive	always negative	either negative or positive	bond energy	✓			enthalpy of formation			✓	1
energy change	always positive	always negative	either negative or positive											
bond energy	✓													
enthalpy of formation			✓											
(b)	(energy change) when 1 mole of gaseous atoms are formed (from an element in its standard state)	1												
(c)	 <p> <b>M1:</b> correct cycle: formulae and state symbols  <b>M2:</b> use of 1 × 193 and 2 × (112)  <b>M3:</b> for the correct sum and answer ecf from M2  <math>\Delta H_{\text{vap}}^{\text{Br}} (= (2 \times 112) - (193)) = +31 \text{ kJ mol}^{-1}</math> [scores M2 and M3]         </p>	3												
(d)	more endothermic and greater Van der Waals / London / induced dipole-dipole forces both	1												
(e)(i)	(energy change) when 1 mole of gaseous ions is dissolved in (an excess of) water	1												
(e)(ii)	<b>M1:</b> Br has a smaller ionic radii <b>M2:</b> stronger (ion-dipole) attractions with water molecules	2												

8. 9701\_s17\_ms\_41 Q: 1

Question	Answer	Marks
(a)	solubility increases down the group	1
	$\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both <b>decrease</b> or $\Delta H_{\text{latt}}$ and $\Delta H_{\text{hyd}}$ both become less exothermic / more endothermic	1
	$\Delta H_{\text{latt}}$ decreases / changes more (than $\Delta H_{\text{hyd}}$ as $\text{OH}^-$ being smaller than $\text{M}^{2+}$ )	1
	$\Delta H_{\text{sol}}$ becomes more exothermic / more negative / less endothermic / less positive	1
(b)(i)	$\Delta H_{\text{r1}} - (538 + 2 \times 230 + 394) = -(1216 + 286)$	1
	$\Delta H_{\text{r1}} - 1392 = -1502$	
	$\Delta H_{\text{r1}} = -110$	1
(b)(ii)	let $\Delta H(\text{HCO}_3^-(\text{aq})) = y$	1
	$2y - 538 = -1216 - 394 - 286 - 26$	
	$y = -692$	1
(b)(iii)	$\Delta H_{\text{r3}} - 538 - 2(230 + 394) = -538 - 2(692)$	1
	$\Delta H_{\text{r3}} = -136$	
(b)(iv)	$\Delta H_{\text{r3}}$ will be identical to $\Delta H_{\text{r4}}$ , / unchanged	1
	as the reaction is the same, or: $2\text{OH}^-(\text{aq}) + 2\text{CO}_2(\text{g}) \longrightarrow 2\text{HCO}_3^-(\text{aq})$ or metal ions stay in solution/metal ions are unchanged / are spectators	1

Question	Answer	Marks
(c)	more <b>gaseous moles</b> are being consumed (in reaction 3) or more <b>CO<sub>2</sub></b> moles are being consumed (in reaction 3)	1
	$\Delta S$ is therefore expected to be <b>more negative/less positive</b> for reaction 3.	1
	<b>Total:</b>	<b>13</b>

9. 9701\_w22\_ms\_41 Q: 1

Question	Answer	Marks
(a)	<div style="text-align: center;"> </div> <p>M1 <math>K^+(g)</math> and <math>Cl^-(g)</math>  <b>AND</b>  <math>KCl(aq)</math> <b>OR</b> <math>K^+(aq) + Cl^-(aq)</math></p> <p>M2 three correct directional arrows COND M1</p>	2
(b)	<p>use of data <math>-155, -2493</math> <b>AND</b> <math>2 \times -364</math> [1]</p> <p><math>\Delta H_{hyd} Mg^{2+} = -1920</math> (<math>kJ\ mol^{-1}</math>) [1] min 3sf</p>	2
(c)	<ul style="list-style-type: none"> <li><math>Mg^{2+}</math> is <b>smaller</b> (than <math>K^+</math>)</li> <li><math>Mg^{2+}</math> is <b>greater charge</b> (than <math>K^+</math>)</li> <li><b>greater attraction</b> between <math>Mg^{2+}</math> and <math>Cl^-</math> / <b>between the ions</b> (in <math>MgCl_2</math>)  <b>OR</b> stronger ionic bonds (in <math>MgCl_2</math>)</li> </ul>	2
(d)(i)	enthalpy change when <b>one mole of gaseous atoms</b> formed from the <b>element</b> (in its standard state at 298 K)	1
(d)(ii)	enthalpy change when every atom in one mole of gaseous atoms gains one electron <b>OR</b> one mole of gaseous atoms gains one mole of electrons	1
(e)(i)	number of possible arrangements of particles and energy in a system	1

Question	Answer	Marks
(e)(ii)	<p><math>\Delta S</math> is positive  <b>AND</b> <math>KCl(s) \rightarrow K^+(aq) + Cl^-(aq)</math> / ionic lattice solid forms aqueous ions <b>OWTTE</b> [1]</p> <p><b>OR</b>  <math>\Delta S</math> is positive  <b>AND</b> <math>\Delta G</math> is (therefore becomes) negative / <math>T\Delta S</math> is greater than <math>\Delta H_{sol}</math> <b>OWTTE</b> [1]</p>	1
(e)(iii)	<p><b>more soluble</b>  <b>AND</b> <math>\Delta G</math> is more negative at higher T / <math>T\Delta S</math> is more positive at higher T / <math>-T\Delta S</math> is more negative at higher <b>ecf from (e)(ii)</b> [sign <math>\Delta S</math>]</p>	1

10. 9701\_w22\_ms\_42 Q: 1

Question	Answer	Marks
(a)	(energy change) when one mole of ionic solid is formed from gaseous ions	1
(b)	$(-2237 + 193 + 590 + 1150 + (2 \times 121) - (2 \times 364))$ [1] $= -790$ [1]	2
(c)	$-342$ <b>and</b> Br atom has larger radius	1
(d)(i)	energy change when one mole dissolves in water [1] energy change when one mole of gaseous ions dissolves in water [1]	2
(d)(ii)	$(-2237 - 83 + 1650) / 2$ [1] $= -335$ [1]	2
(e)(i)	<b>negative and</b> reduction in number of gas molecules	1
(e)(ii)	$T\Delta S$ becomes more negative [1] less feasible <b>AND</b> $\Delta G$ becomes positive [1]	2



11. 9701\_s19\_ms\_42 Q: 5

Question	Answer	Marks												
(a)	<table border="1"> <tr> <td>energy change</td> <td>always positive</td> <td>always negative</td> <td>either negative or positive</td> </tr> <tr> <td>lattice energy</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>enthalpy of neutralisation</td> <td></td> <td>✓</td> <td></td> </tr> </table> <p style="text-align: right;"><b>both [1]</b></p>	energy change	always positive	always negative	either negative or positive	lattice energy		✓		enthalpy of neutralisation		✓		<b>1</b>
energy change	always positive	always negative	either negative or positive											
lattice energy		✓												
enthalpy of neutralisation		✓												
(b)	(energy change) when <b>1 mole</b> of solute is dissolved in an infinite amount of <b>water</b> to form a dilute solution	<b>1</b>												
(c)	calculation of $\Delta H_{\text{sol}}^{\circ}$ with $-251$ , $-1284$ and $-2035$ only and two correct signs [1] calculation of $\Delta H_{\text{sol}}^{\circ}$ with $-251$ , $-1284$ and $-2035$ only and correct signs <b>OR</b> calculation of $\Delta H_{\text{sol}}^{\circ}$ with $(-251 \times 3)$ , $-1284$ and $-2035$ only and two correct signs [2] $\Delta H_{\text{sol}}^{\circ} = (3 \times -251) + (-1284) - (-2035) = -2 \text{ (kJ mol}^{-1}\text{)}$ [3]	<b>3</b>												
(d)	$\text{Ca}^{2+}$ have a higher charge / greater charge density [1] <b>ora</b> <b>stronger</b> electrostatic forces between $\text{Br}^{-}$ and $\text{Ca}^{2+}$ [1]	<b>2</b>												
(e)(i)	$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ [1]	<b>1</b>												
(e)(ii)	$T\Delta S$ is more positive <b>OR</b> $-T\Delta S$ becomes more negative [1]	<b>1</b>												

12. 9701\_w19\_ms\_41 Q: 3

Question	Answer	Marks
(a)	<b>a measure / degree of disorder / randomness</b> of a system	<b>1</b>
(b)	<b>M1:</b> negative – molecules have less energy in the system <b>M2:</b> positive – solid being converted into an aqueous solution <b>M3:</b> negative – gaseous ions being converted into a solid	<b>3</b>
(c)(i)	(standard) Gibbs free energy <u>change</u>	<b>1</b>
(c)(ii)	<b>M1:</b> $(\Delta)G = \Delta H - T\Delta S$ <b>M2:</b> description of calculating the minimum value of T for which $\Delta G$ is zero / becomes negative <b>OR</b> $T = \Delta H / \Delta S$ [1]	<b>2</b>

13. 9701\_w19\_ms\_42 Q: 4

Question	Answer	Marks
(a)	<b>M1:</b> correct use of stoichiometry <b>M2:</b> answer + 189	<b>2</b>
(b)	<b>M1:</b> States or uses correct form of Gibbs equation $\Delta G = \Delta H - T\Delta S$ <b>M2:</b> appreciates / includes $\Delta G = 0$ at temperature required <b>M3:</b> uses 1000 correctly and answer +624(.339) Award 3 marks for correct answer	<b>3</b>
(c)	negative <b>and</b> decrease in number / amount of gas molecules	<b>1</b>

14. 9701\_s18\_ms\_42 Q: 1

Question	Answer	Marks
(a)	simple molecular / simple covalent	1
	weak London forces / id-id forces / VDW forces or London forces / id-id forces / VDW forces <b>AND</b> small amount of energy to break	1
(b)(i)	$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$ or $\text{SiCl}_4 + 4\text{H}_2\text{O} \rightarrow \text{Si}(\text{OH})_4 + 4\text{HCl}$	1
(b)(ii)	white solid	1
	steamy fumes / white fumes / misty fumes	1
(b)(iii)	moles of $\text{SiCl}_4 = 0.8505 / 170.1 = 0.005$	1
	conc of $\text{H}^+ (0.005) \times 4 / 0.8 = 0.025$	1
	$\text{pH} = -\log(0.025) = 1.6$	1
(c)(i)	$-225.7 = 239.0 - (18.7 + 2x)$	1
	$x = +223$	1
(c)(ii)	decrease in number of moles of gas / more moles of gas on left / reactants (ora)	1
(d)	use of $\Delta G = \Delta H - T\Delta S$ with $\Delta G = 0 / \Delta G > 0$ or $T = \Delta H / \Delta S$ or $T = (640\,000 / 225.7)$	1
	2836 / 2840 (2835.6)	1

15. 9701\_m17\_ms\_42 Q: 2

Question	Answer	Marks			
(a)	enthalpy change	positive	negative	either positive or negative	2
	electron affinity			✓	
	enthalpy change of atomisation	✓			
	enthalpy change of ionisation	✓			
	lattice enthalpy		✓		
(b)(i)	the second electron is removed from a (more) positively charged ion	1			
(b)(ii)	$\Delta H_6$ is lattice (energy/enthalpy) <b>AND</b> $\Delta H_7$ is (energy/enthalpy of) formation	1			
(c)	the electron affinity becomes less exothermic/negative down the Group 17	1			
	electron affinity depends (mainly) on the electron-nucleus distance which increases down Group 17	1			
(d)	<b>M1</b> correct use of $\Delta G = \Delta H - T\Delta S$	1			
	<b>M2</b> $\Delta S = 26.9 - (32.7 + 102.5) = -108.3 \text{ J K}^{-1} \text{ mol}^{-1}$ <b>OR</b> $-0.1083 \text{ kJ K}^{-1} \text{ mol}^{-1}$	1			
	<b>M3</b> $\Delta G = -602 - (298 \times (-0.1083)) = -570$	1			
	<b>M4</b> units: $\text{kJ mol}^{-1}$	1			