TOPICAL PAST PAPERS

AS & A Level Chemistry (9701) Paper 4

[Structured questions]

Exam Series: February/March 2018 – May/June 2025

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 Papers
- Subtitle: Exam Practice Worksheets With Answer Scheme
- Examination board: Cambridge Assessment International Education (CAIE)
- Subject code: 9701
- Years covered: February/March 2018 – May/June 2025
- Paper: 4
- Number of pages: 1024
- Number of questions: 321

Contents

Chapter 1

Chemical energetics

1.1 Lattice energy and Born-Haber cycles

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 C*l*, 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^{-1}
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_2(s)	–208
lattice energy, ΔH°_{latt}, of zinc iodide, ZnI_2(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, $I_2(s) \rightarrow I_2(g)$	+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^{-1} [3]

(c) Predict how $\Delta H^{\ominus}_{\text{latt}}$ of CdI_2(s) differs from $\Delta H^{\ominus}_{\text{latt}}$ of ZnI_2(s).
Place a tick (✓) in the appropriate box in Table 3.2.

Table 3.2

$\Delta H^{\ominus}_{\text{latt}}$ of CdI_2(s) is less negative than $\Delta H^{\ominus}_{\text{latt}}$ of ZnI_2(s)	$\Delta H^{\ominus}_{\text{latt}}$ of CdI_2(s) is the same as $\Delta H^{\ominus}_{\text{latt}}$ of ZnI_2(s)	$\Delta H^{\ominus}_{\text{latt}}$ of CdI_2(s) is more negative than $\Delta H^{\ominus}_{\text{latt}}$ of ZnI_2(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^{-1}
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 $\frac{1}{2}O_2(g) + 2e^- \rightarrow O^{2-}(g)$	+951
enthalpy change for $Ca(s) \rightarrow Ca^{2+}(g) + 2e^-$	+1933
lattice energy of CaO(s)	–3517

(c) Oxygen exists as O_2 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^{-1} [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^{-1} [2]

(f) The lattice energy of lithium fluoride, LiF(s), is –1022 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, $\Delta H^{\ominus}_{latt}$, of radium sulfide, RaS, is –2612 kJ mol^{-1}.

(a) Define $\Delta H^{\ominus}_{latt}$.

....

.... [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 / kJ mol^{-1}
enthalpy change for $Ra(s) \rightarrow Ra^{2+}(g) + 2e^-$	+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 $\frac{1}{8}S_8(s) + 2e^- \rightarrow S^{2-}(g)$	+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 S_8 molecules in the solid state.

Use the data in this question to calculate the enthalpy change for the reaction $S_8(s) \rightarrow 8S(g)$.

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

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

standard enthalpy change, $\Delta H_f^\ominus$ = ... $kJ\,mol^{-1}$ [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 $-771\,kJ\,mol^{-1}$ and $-2612\,kJ\,mol^{-1}$, 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, $ZnBr_2(s)$.

You might find it helpful to construct an energy cycle.

electron affinity of Br(g) = $-325\,kJ\,mol^{-1}$
enthalpy change of atomisation of Zn(s) = $+131\,kJ\,mol^{-1}$
enthalpy change of vaporisation of $Br_2(l)$ = $+31\,kJ\,mol^{-1}$
lattice energy of $ZnBr_2(s)$ = $-2678\,kJ\,mol^{-1}$

enthalpy change of formation of $ZnBr_2(s)$ = ... $kJ\,mol^{-1}$ [4]

(c) The lattice energies of $ZnBr_2$, $ZnCl_2$ and ZnO are shown.

compound	lattice energy / kJ mol^{-1}
$ZnBr_2$	–2678
$ZnCl_2$	–2734
ZnO	–3971

(i) Explain why there is a difference between the lattice energies of $ZnBr_2$ and $ZnCl_2$.

....

.... [1]

(ii) Explain why there is a difference between the lattice energies of $ZnCl_2$ and ZnO.

....

.... [1]

[Total: 10]

5. 9701_s18_qp_41 Q: 1

Sodium oxide, Na_2O, 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 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, $\Delta H^{\ominus}_{latt}$ $Na_2O(s)$.

energy change	value / kJ mol^{-1}
standard enthalpy change of formation of sodium oxide, $\Delta H^{\ominus}_{f}$ $Na_2O(s)$	–416
standard enthalpy change of atomisation of sodium, $\Delta H^{\ominus}_{at}$ Na(s)	+109
electron affinity of O(g)	–142
electron affinity of $O^{-}(g)$	+844

$\Delta H^{\ominus}_{latt}$ $Na_2O(s)$ = ... kJ mol^{-1} [4]

(e) State how $\Delta H^{\ominus}_{latt}$ $Na_2S(s)$ differs from $\Delta H^{\ominus}_{latt}$ $Na_2O(s)$.
Indicate this by placing a tick (✓) in the appropriate box in the table.

$\Delta H^{\ominus}_{latt}$ $Na_2S(s)$ is more exothermic than $\Delta H^{\ominus}_{latt}$ $Na_2O(s)$	$\Delta H^{\ominus}_{latt}$ $Na_2S(s)$ is the same as $\Delta H^{\ominus}_{latt}$ $Na_2O(s)$	$\Delta H^{\ominus}_{latt}$ $Na_2S(s)$ is less exothermic than $\Delta H^{\ominus}_{latt}$ $Na_2O(s)$

Explain your answer.

....

....

....
[2]

[Total: 15]

1.2 Enthalpies of solution and hydration

6. 9701_s25_qp_44 Q: 8

(a) **(i)** Define lattice energy, ΔH_{latt}.

....

.... [2]

(ii) Define enthalpy change of solution, ΔH_{sol}.

....

.... [1]

(b) The enthalpy change of hydration can be represented by ΔH_{hyd}.

Write the mathematical expression for the ΔH_{sol} of NaCl in terms of $\Delta H_{latt}(NaCl)$, $\Delta H_{hyd}(Na^+)$ and $\Delta H_{hyd}(Cl^-)$.

$\Delta H_{sol}(NaCl)$ = ... [1]

(c) Complete the Born–Haber cycle in Fig. 8.1 for the ionic solid NaCl.

Include state symbols of relevant species.

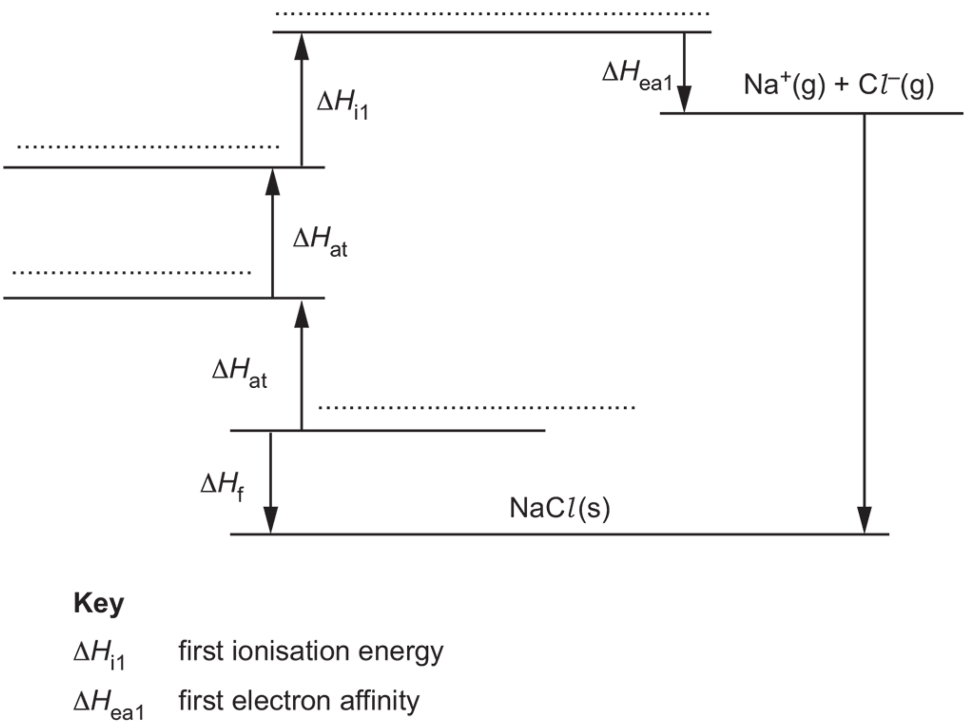


Fig. 8.1

[3]

(d) Predict which of the ions, Cl^- or NO_3^-, has the more negative enthalpy change of hydration.

Explain your answer.

....

....

....

....

.... [2]

[Total: 9]

Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4\,\text{C}\,\text{mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J}\,\text{g}^{-1}\,\text{K}^{-1}$)

7. 9701_s24_qp_42 Q: 1

(a) Describe the trend in the solubility of the sulfates of magnesium, calcium and strontium.

Explain your answer.

.... > .... > ....
most soluble least soluble

....

....

....

....

....

....
[4]

(b) Define lattice energy, ΔH_{latt}.

....

.... [2]

(c) State and explain the main factors that affect the magnitude of lattice energies.

....

....

....

....

.... [2]

(d) Table 1.1 shows some energy changes.

Table 1.1

energy change	value / kJ mol^{-1}
standard enthalpy change of atomisation of potassium	+89
first ionisation energy of potassium	+419
second ionisation energy of potassium	+3070
standard enthalpy change of atomisation of sulfur	+279
S–S bond energy	+265
first ionisation energy of sulfur	+1000
second ionisation energy of sulfur	+2260
first electron affinity of sulfur	–200
second electron affinity of sulfur	+640
standard enthalpy change of formation of potassium sulfide, $K_2S(s)$	–381

(i) Born–Haber cycles can be used to determine the lattice energies of ionic compounds.

Complete the Born–Haber cycle in Fig. 1.1 for potassium sulfide, $K_2S(s)$.

Include state symbols for all of the species.

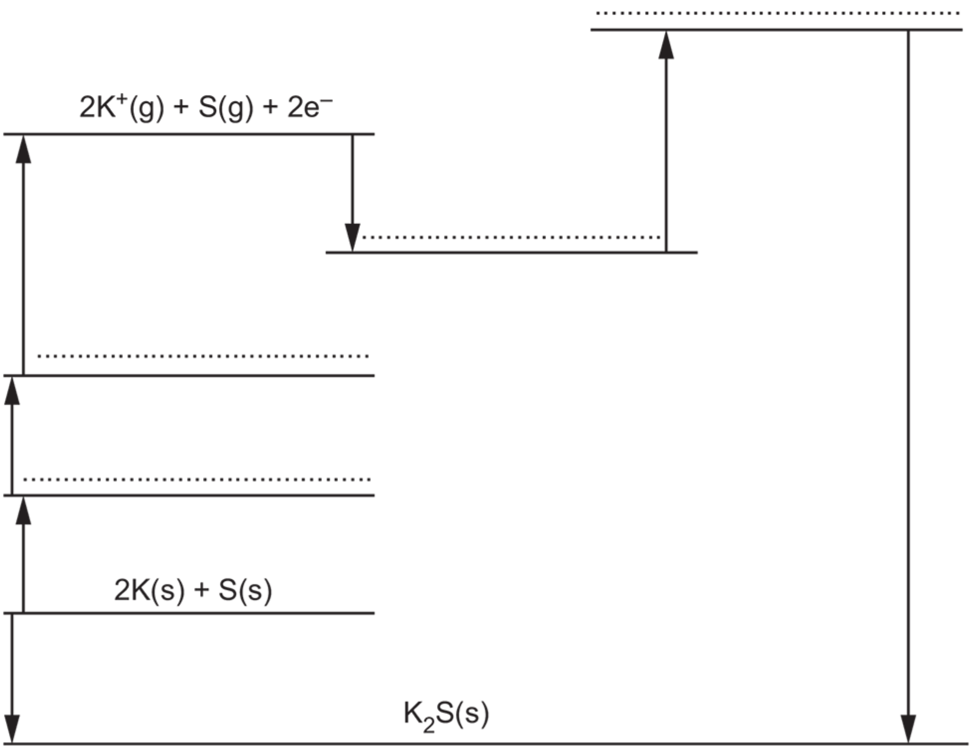


Fig. 1.1

[3]

(ii) Calculate the lattice energy, $\Delta H^{\ominus}_{\text{latt}}$, of $K_2S(s)$ using relevant data from Table 1.1.

Show your working.

$\Delta H^{\ominus}_{\text{latt}}$ of $K_2S(s)$ = ... kJ mol^{-1} [2]

[Total: 13]

8. 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^{-1}
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, $CaBr_2$(s)	–103.1
standard enthalpy change of formation of calcium bromide, $CaBr_2$(s)	–682.8
standard enthalpy change of hydration of Ca^{2+}	–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, $\Delta H^{\ominus}_{\mathrm{latt}}$, of $CaBr_2(s)$.

It may be helpful to draw a labelled energy cycle.

Show your working.

$\Delta H^{\ominus}_{\mathrm{latt}}$ of $CaBr_2(s)$ = ... kJ mol^{-1} [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, $\Delta H^{\ominus}_{\mathrm{hyd}}$, of Br^-.

It may be helpful to draw a labelled energy cycle.

If you were not able to answer **(c)(i)**, use –2500 kJ mol^{-1} as your value for $\Delta H^{\ominus}_{\mathrm{latt}}$ of $CaBr_2(s)$. This is **not** the correct value.

Show your working.

$\Delta H^{\ominus}_{\mathrm{hyd}}$ of Br^- = ... kJ mol^{-1} [2]

(iii) The enthalpy change of hydration of the Br^- ion is more negative than the enthalpy change of hydration of the I^- ion. Explain why.

....

....

.... [2]

[Total: 9]

9. 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, $Br_2(l)$, is shown.

$$Br_2(l) \rightarrow 2Br(g)$$

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 $Br_2(l)$, $\Delta H^{\ominus}_{vap}$.
  The enthalpy change of atomisation of bromine, ΔH_{at}, = +112 kJ mol^{-1}.

$\Delta H^{\ominus}_{vap}$ = ... kJ mol^{-1} [3]

(d) Suggest how the $\Delta H^{\ominus}_{vap}$ of iodine, $I_2(l)$, would compare to that of bromine, $Br_2(l)$. 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 $Br^-(g)$ is **more** exothermic than that of $I^-(g)$.

....

....

.... [2]

[Total: 9]

1.3 Entropy change, ΔS

10. 9701_s25_qp_41 Q: 4

Table 4.1 gives the enthalpy changes of hydration, ΔH_{hyd}, of three ions, F^-, K^+ and Ca^{2+}.

Table 4.1

ion	ΔH_{hyd} / $kJ\,mol^{-1}$
F^-	–506
K^+	–322
Ca^{2+}	–1650

(a) **(i)** Define enthalpy change of hydration.

....

....

.... [1]

(ii) Explain the relative magnitudes of the enthalpy changes of hydration of K^+ and Ca^{2+}.

....

....

....

.... [2]

(iii) Define lattice energy.

....

.... [1]

(iv) The lattice energy, ΔH_{latt}, of calcium fluoride, CaF_2, is –2602 $kJ\,mol^{-1}$.

Calculate the enthalpy change of solution, ΔH_{sol}, in $kJ\,mol^{-1}$, of CaF_2.

ΔH_{sol} of CaF_2 = ... $kJ\,mol^{-1}$ [2]

(b) The formation of CaF_2 at 298 K is shown.

$$Ca(s) + F_2(g) \rightarrow CaF_2(s) \qquad \Delta H^\ominus = -1214\,kJ\,mol^{-1}$$
$$\Delta G^\ominus = -1162\,kJ\,mol^{-1}$$

Calculate the entropy change, $\Delta S^\ominus$, in $J\,K^{-1}\,mol^{-1}$, for this reaction.

$\Delta S^\ominus$ = ... $J\,K^{-1}\,mol^{-1}$ [2]

[Total: 8]

11. 9701_s25_qp_42 Q: 3

(a) Define entropy.

....

.... [1]

(b) Fig. 3.1 shows how the entropy, *S*, of a pure substance changes with temperature, *T*.

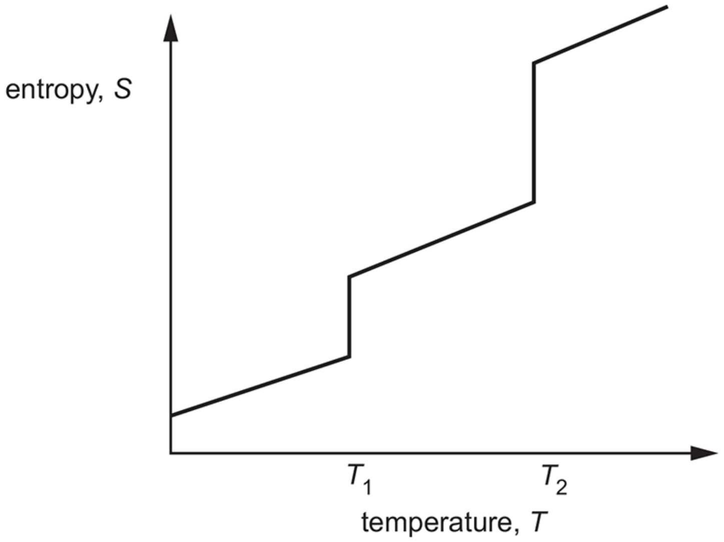


Fig. 3.1

(i) Identify the process occurring at each of the temperatures T_1 and T_2.

T_1 .... T_2 .... [1]

(ii) Explain why the entropy change, ΔS, at T_2 is bigger than the entropy change at T_1.

....

....

.... [1]

(c) The equation for the reduction of iron(III) oxide by carbon monoxide at 450 °C is shown.

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \qquad \Delta G^{\ominus} = -36.2\,kJ\,mol^{-1}$$

Table 3.1 shows the enthalpy of formation, $\Delta H_f^{\ominus}$, and the entropy, $S^{\ominus}$, for some substances.

Table 3.1

	$Fe_2O_3(s)$	$CO(g)$	$Fe(s)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–824.2	–110.5	0.0	–393.5
$S^{\ominus}$ / J K^{-1} mol^{-1}	87.4	to be calculated	27.3	213.8

Use the data in Table 3.1 to calculate the entropy, $S^{\ominus}$, of carbon monoxide at 450 °C.

Show your working.

$S^{\ominus}$ of CO(g) = ... J K^{-1} mol^{-1} [3]

(d) Iron(II) oxide can also be reduced to iron by carbon monoxide, as shown.

$$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g) \qquad \Delta H^{\ominus} = -11.1\,kJ\,mol^{-1}$$
$$\Delta S^{\ominus} = -15.2\,J\,K^{-1}\,mol^{-1}$$

State the effect of increasing temperature on the feasibility of this reaction.

Explain your answer.

....

....

....

.... [2]

[Total: 8]

1.4 Gibbs free energy change, ΔG

12. 9701_s24_qp_42 Q: 3

(a) Carbon disulfide, CS_2, is flammable and reacts readily with oxygen, as shown in reaction 1.

reaction 1 $CS_2(g) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$

Table 3.1 shows the standard enthalpy of formation, $\Delta H_f^\ominus$, and the standard entropy, $S^\ominus$, for some substances.

Table 3.1

	$CS_2(g)$	$O_2(g)$	$CO_2(g)$	$SO_2(g)$
$\Delta H_f^\ominus$ / kJ mol^{-1}	116.7	0.0	–393.5	–296.8
$S^\ominus$ / J K^{-1} mol^{-1}	237.8	205.2	213.8	248.2

Calculate the standard Gibbs free energy change, $\Delta G^\ominus$, in kJ mol^{-1}, for reaction 1 at 25 °C.

$\Delta G^\ominus$ = ... kJ mol^{-1} [3]

(b) Carbon disulfide reacts with chlorine to form tetrachloromethane, as shown in reaction 2.

reaction 2 $CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$ $\Delta H^\ominus = -261.6$ kJ mol^{-1}

$\Delta S^\ominus = -365.5$ J K^{-1} mol^{-1}

Calculate the maximum temperature, in K, for reaction 2 to be feasible.

temperature = ... K [2]

[Total: 5]

13. 9701_w24_qp_41 Q: 2

(a) Predict and explain the variation in enthalpy change of hydration for the ions F^-, Cl^-, Br^- and I^-.

....

....

.... [2]

(b) Fig. 2.1 shows an incomplete energy cycle involving calcium fluoride, CaF_2.

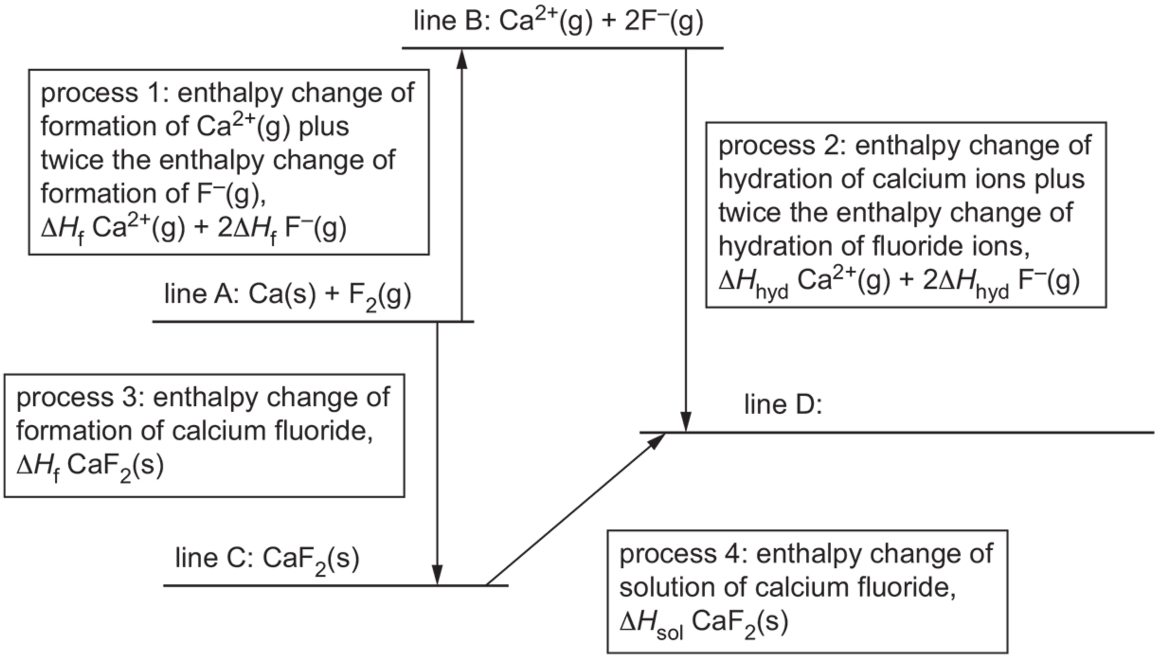


Fig. 2.1

(i) Complete line D. Include state symbols. [1]

(ii) The value of the enthalpy change for process 1 can be calculated using the values of **five** other enthalpy changes which are **not** referred to in Fig. 2.1.

process 1: $Ca(s) + F_2(g) \rightarrow Ca^{2+}(g) + 2F^-(g)$

Identify these **five** other enthalpy changes, using either names or symbols.

....

....

....

....

.... [2]

(iii) Define lattice energy, ΔH_{latt}.

....

....

.... [2]

(iv) Complete the expression to give the mathematical relationship between ΔH_{latt} of calcium fluoride and the enthalpy changes for processes 1 and 3.

ΔH_{latt} =

[1]

(c) Use data from Table 2.1 to calculate a value for the hydration energy, ΔH_{hyd}, of fluoride ions, $F^-(g)$.

Table 2.1

	value / kJ mol^{-1}
enthalpy change of solution of calcium fluoride, $CaF_2(s)$	+13
overall enthalpy change of process 1 in Fig. 2.1	+1395
enthalpy change of formation of calcium fluoride	–1214
enthalpy change of hydration of $Ca^{2+}(g)$	–1650

ΔH_{hyd} $F^-(g)$ = ... kJ mol^{-1} [2]

(d) Define entropy.

....

.... [1]

(e) At 298 K, the Gibbs free energy change, ΔG, for the solution of compound **T** is +6.00 kJ mol^{-1}.

The enthalpy change of solution, ΔH_{sol}, of compound **T** is +30.0 kJ mol^{-1} at 298 K.

Calculate the value of the entropy change, ΔS, for the solution of compound **T** at 298 K.

ΔS = ... J K^{-1} mol^{-1} [2]

(f) Predict whether compound **T** becomes more or less soluble as the water is heated from 298 K to 360 K. Explain your answer.

....

.... [1]

[Total: 14]

14. 9701_w24_qp_42 Q: 2

(a) Predict and explain the variation in enthalpy change of hydration for the ions Na^+, Mg^{2+} and Al^{3+}.

....

....

....

....

.... [3]

(b) Fig. 2.1 shows an incomplete energy cycle.

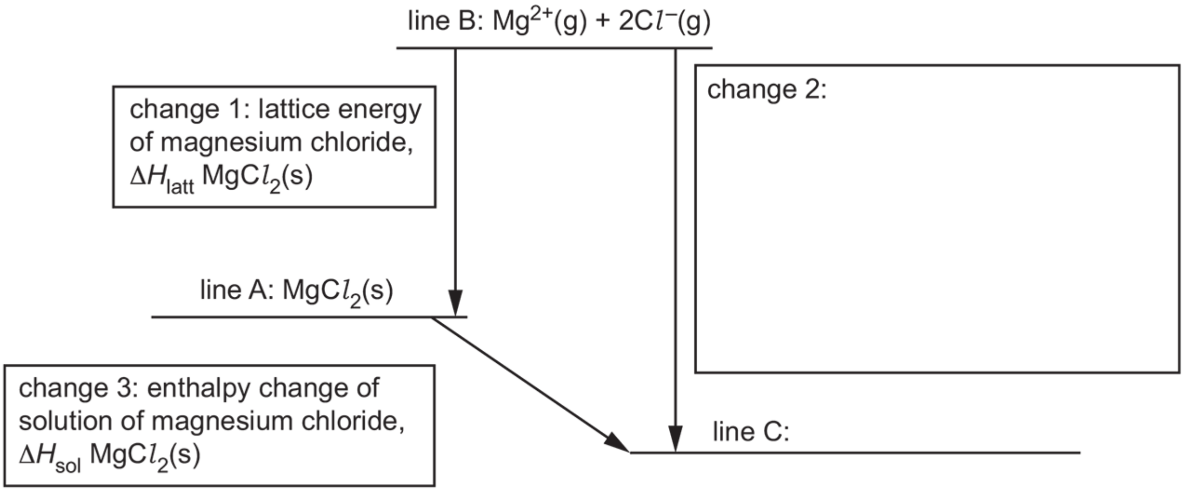


Fig. 2.1

(i) Complete line C on Fig. 2.1. Include state symbols. [1]

(ii) Use **both** words **and** symbols to identify change 2 on Fig. 2.1.

Use changes 1 and 3 as examples of how this should be done.

[2]

(iii) Calculate a value for the lattice energy of magnesium chloride, ΔH_{latt} $MgCl_2(s)$, by selecting and using appropriate data from Table 2.1.

Table 2.1

energy change	value / $kJ\,mol^{-1}$
enthalpy change of solution of magnesium chloride	–155
enthalpy change of formation of magnesium chloride	–642
first ionisation energy of magnesium	+736
second ionisation energy of magnesium	+1450
electron affinity of chlorine	–349
enthalpy change of hydration of Mg^{2+}	–1920
enthalpy change of hydration of Cl^-	–364

ΔH_{latt} $MgCl_2(s)$ = ... $kJ\,mol^{-1}$ [3]

(c) Define entropy.

....

.... [1]

(d) At 25 °C the enthalpy change of solution of compound **Z** is +26 $kJ\,mol^{-1}$. The entropy change of solution of **Z** at the same temperature is +52 $J\,K^{-1}\,mol^{-1}$.

Calculate the value of the Gibbs free energy change, ΔG, for the solution of **Z** at 25 °C.

ΔG = ... $kJ\,mol^{-1}$ [2]

(e) **(i)** Use your answer to **(d)** to predict whether or not **Z** is soluble in water at 25 °C. Explain your answer.

....

.... [1]

(ii) Predict whether **Z** becomes more or less soluble as the water is heated from 25 °C to 95 °C. Explain your answer.

....

.... [1]

[Total: 14]

15. 9701_w22_qp_41 Q: 1

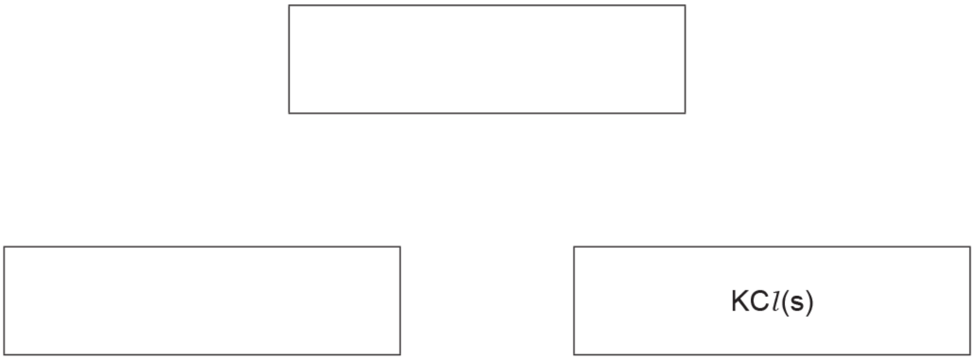
Potassium chloride, $\mathrm{KC}l$, and magnesium chloride, $\mathrm{MgC}l_2$, are both ionic solids.

Table 1.1

energy change	value / kJ mol^{-1}
standard enthalpy change of solution, $\Delta H^{\ominus}_{\mathrm{sol}}$, of $\mathrm{KC}l$	+15
lattice energy, $\Delta H^{\ominus}_{\mathrm{latt}}$, of $\mathrm{KC}l\mathrm{(s)}$	–701
standard enthalpy change of hydration, $\Delta H^{\ominus}_{\mathrm{hyd}}$, of $\mathrm{K^+}$	–322
standard enthalpy change of hydration, $\Delta H^{\ominus}_{\mathrm{hyd}}$, of $\mathrm{C}l^-$	–364
standard enthalpy change of solution, $\Delta H^{\ominus}_{\mathrm{sol}}$, of $\mathrm{MgC}l_2$	–155
lattice energy, $\Delta H^{\ominus}_{\mathrm{latt}}$, of $\mathrm{MgC}l_2\mathrm{(s)}$	–2493

(a) Complete the energy cycle involving the enthalpy change of solution and the lattice energy of potassium chloride, $\mathrm{KC}l$, 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, $\mathrm{Mg^{2+}}$. Show your working.

$\Delta H^{\ominus}_{\mathrm{hyd}}$ of magnesium ions, $\mathrm{Mg^{2+}}$ = ... kJ mol^{-1} [2]

(c) Explain the reasons why the lattice energy of $MgCl_2$ is more exothermic than the lattice energy of 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 °C.

Explain the solubility of potassium chloride by reference to change in entropy, ΔS.

....

.... [1]

(iii) Use the Gibbs equation and your answer to **(e)(ii)** to predict whether potassium chloride is more soluble in water at 20 °C or at 80 °C. Explain your answer.

....

....

.... [1]

[Total: 11]

16. 9701_w22_qp_42 Q: 1

Calcium chloride, $CaCl_2$, is an ionic solid.

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

Table 1.1

energy change	value / kJ mol^{-1}
lattice energy, $\Delta H^{\ominus}_{latt}$, $CaCl_2(s)$	–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, $\Delta H^{\ominus}_{f}$, of calcium chloride. It may be helpful to draw an energy cycle. Show all your working.

$\Delta H^{\ominus}_{f}(CaCl_2(s))$ = ... kJ mol^{-1} [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 **one** tick (✓) in this column
$-342\,\text{kJ mol}^{-1}$	
$-364\,\text{kJ mol}^{-1}$	
$-386\,\text{kJ mol}^{-1}$	

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^{-1}
standard enthalpy change of solution of $CaCl_2(s)$	-83
standard enthalpy change of hydration of $Ca^{2+}(g)$	-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, $Cl^-(g)$. It may be helpful to draw an energy cycle. Show all your working.

$\Delta H^{\ominus}_{hyd}(Cl^-(g))$ = ... kJ mol^{-1} [2]

(e) Calcium fluoride, $CaF_2(s)$, can be synthesised directly from its elements.

The value of $\Delta H_f^{\ominus}(CaF_2(s))$ is –1214 kJ mol^{-1}.

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

The sign of the entropy change is ....

explanation ....

....

[1]

(ii) Use the value of $\Delta H_f^{\ominus}(CaF_2(s))$ 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]

17. 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^{-1}
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.

$\Delta H^\ominus_{sol}$ = ... kJ mol^{-1} [3]

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

compound	lattice energy value / kJ mol^{-1}
$CaBr_2(s)$	–2176
KBr(s)	–679

Suggest an explanation for why $\Delta H^{\ominus}_{latt}$ $CaBr_2$ is **more** exothermic than $\Delta H^{\ominus}_{latt}$ KBr.

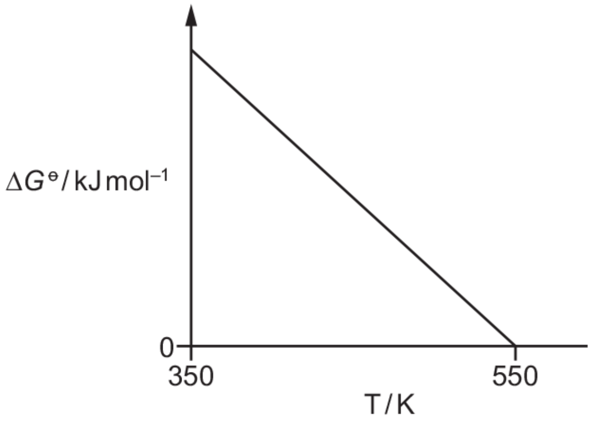
....

....

.... [2]

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

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



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

.... [1]

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

....

.... [1]

[Total: 9]

Appendix A

Answers

1. 9701_s22_ms_42 Q: 3

Question	Answer	Marks
(a)(i)	• enthalpy change / energy change • one mole of electrons • (gained by) **one mole** of **gaseous atoms** two for one mark, three for two marks	2
(a)(ii)	(energy required to overcome) the repulsion between the electron and anion / negative ion	1
(a)(iii)	• less negative / less exothermic down the group • greater the distance between the nucleus and (the shells of the) electrons **OR** atomic radii increases **OR** more shielding by inner shells • the less **attraction** between nucleus and incoming electron (and the less energy released) two for one mark, three for two marks	2
(b)	**M1** use of correct seven numbers only in calculation / energy cycle **M2** only 2 × used correctly **M3** correct signs and evaluation ecf $-208 = 131 + 906 + 1733 + 62 + 151 + 2x - 2605$ $2x = -586$ $x = -293$ kJ mol^{-1}	3
(c)	first box ticked **AND** Cd^{2+} larger / Cd^{2+} lower charge density **AND** less attraction between the ions / weaker ionic bonds	1

2. 9701_w21_ms_41 Q: 3

Question	Answer	Marks
(a)	• enthalpy/energy change • one mole of electrons gained • by one mole of atoms • gaseous (atoms)	2
(b)	Ca^{+}(g) → Ca^{2+}(g) + e^{-} [1]	1

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

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3. 9701_w21_ms_42 Q: 1

Question	Answer	Marks
(a)	• enthalpy / energy change / given out / evolved / released • one mole is formed / made [1] • of compound / solid / lattice / crystal • (from) **gaseous ions** [1]	2
(b)b	$S^-(g) + e^- \rightarrow S^{2-}(g)$ [1]	1
(c)c	(555 + 200 – 532 = 223, 223 × 8 = 1784) M1 selecting correct data 555, 200, 532 **only**, (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 only, (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 ΔH°_{latt} of radium sulfide) less exothermic since the ions are larger [1] M2 (charge tends to make ΔH°_{latt} of radium sulfide) less exothermic since the ions are more highly charged [1]	2
(e)(iii)	(ionic) charge (since) **AND** ΔH°_{latt} of radium sulfide is more exothermic [1]	1

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4. 9701_s20_ms_42 Q: 7

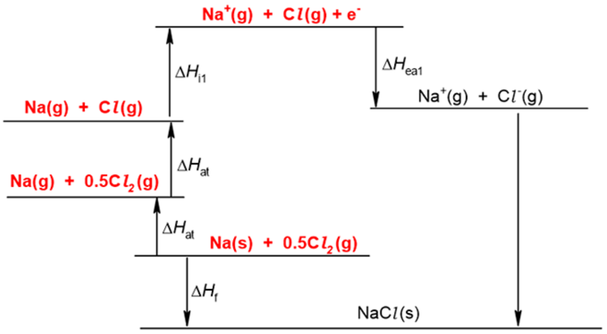
Question	Answer	Marks
(a)(i)	- energy change - when one electron is added - to each atom /ion in one mole of - gaseous atoms /ions Award one mark for two correct statements. Award two marks for four correct statements	**2**
(a)(ii)	**M1** energy change when 1 mole of an ionic compound is formed **M2** from gas phase ions/ gaseous ions	**2**

Question	Answer	Marks
(b)	**M1** use of data (with no multipliers) 31, 131, -2678 **M2** extraction of data 908, 1730, 193 **M3** use of (2 x-325) **M4** evaluation of <u>their</u> expression correctly, as shown $\Delta H_f(ZnBr_2)$ = 131 + (908 +1730) + 193 + 31 + (2 x-325) + (-2678) = **-335** kJ mol^{-1} [4]	**4**
(c)(i)	Br^- is a largest ion/larger ion than Cl so attraction between Br^- and Zn^{2+} is smaller	**1**
(c)(ii)	O^{2-} is a smallest ion/smaller ion than Cl **AND** O^{2-} has the highest charge/ higher charge than Cl (so attraction between O^{2-} and Zn^{2+} is larger)	**1**

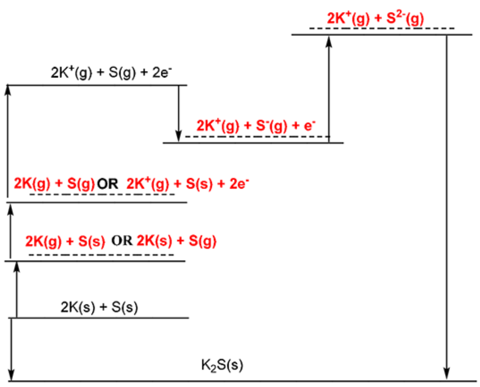
5. 9701_s18_ms_41 Q: 1

Question	Answer	Marks
(a)	$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$	
	balanced with all formulae correct	**1**
	state symbols	**1**
(b)	giant ionic	**1**
	strong bond / attraction between **AND** positive and negative ions / anions and cations / Na^+ and O^{2-} / oppositely charged ions	**1**
(c)(i)	the reaction produces sodium hydroxide / hydroxide ions / OH^- ions	**1**
	the hydroxide ions can receive / accept H^+ ions / protons	**1**
(c)(ii)	Calculation of Na_2O moles 3.10 g / 62 **OR** 0.05	**1**
	Calculation of $[OH^-]$ 0.05 × (2 / 0.400) = 0.25 mol dm^{-3}	**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 ΔH_{lat} = –416 – (2 × 109) – (0.5 × 496) – (2 × 494) – (–142 + 844) = –2572	**1**
(e)	the lattice energy of Na_2S is less exothermic	**1**
	the sulfide ion is larger than the oxide ion / S^{2-} larger than O^2 / ionic radii quoted 0.184 nm and 0.140 nm **AND** less attraction (between the ions)/bonds are weaker	**1**

6. 9701_s25_ms_44 Q: 8

Question	Answer	Marks
(a)(i)	**M1:** energy change / released when 1 mole of a (ionic) solid / lattice / crystal / compound is formed **M2:** from gas (phase) ions / gaseous ions (under standard conditions)	2
(a)(ii)	(enthalpy change when) 1 mole of a substance / solid / solute / molecule **AND** dissolves in water (to give a solution of infinite dilution)	1
(b)	$\Delta H_{sol}(NaCl) = \Delta H_{hyd}(Na^+) + \Delta H_{hyd}(Cl^-) - \Delta H_{latt}(NaCl)$	1
(c)	 **M1 / M2:** any two [1] all four [2] **M3:** all state symbols for the formula are present and correct	3
(d)	**M1:** (more exothermic because) Cl^- **OR** NO_3^- because its (ionic) radius / size is smaller **M2:** (more exothermic because) (ion-dipole) attraction / bond between it and water is stronger **OR** **M1:** NO_3^- because it has lone pairs on O / more lone pairs **M2:** which can form hydrogen bonds with water	2

7. 9701_s24_ms_42 Q: 1

Question	Answer	Marks
(a)	**M1** magnesium > calcium > strontium **M2** ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative **M3** ΔH_{latt} changes less **OR** ΔH_{hyd} is dominant factor **M4** ΔH_{sol} becomes less exothermic / less negative / more positive / more endothermic	**4**
(b)	**M1** ΔH / energy change when 1 mole of an ionic solid / compound is formed **M2** from gaseous ions (under standard conditions)	**2**
(c)	**M1** as ionic radii increases **AND** ΔH_{latt} less exothermic **M2** as ionic charge increases **AND** ΔH_{latt} increases/more exothermic	**2**
(d)(i)	 any two [1] any three [2] all four [3]	**3**
(d)(ii)	**M1** selection of **ONLY** six correct values (–381, 89, 419, 279, –200, 640) **AND** use of × 2 as only multiplier with K **M2** correct evaluation of data used ecf $-381 = (89 \times 2) + (419 \times 2) + 279 + (-200) + 640 + \Delta H^{o}_{latt}$ $\Delta H^{o}_{latt} = -2116$ (kJ mol^{-1})	**2**

8. 9701_s23_ms_41 Q: 8

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>(a)</td><td>
<table>
<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>
All correct for one mark</td><td>1</td></tr>
<tr><td>(b)</td><td>The energy / enthalpy change when 1 mole of gaseous ions is dissolved in water</td><td>1</td></tr>
<tr><td>(c)(i)</td><td>M1 use of correct six numbers only
682.8 178.2 590 1145 111.9 324.6
M2 2× used correctly with Br (2 × 111.9 and 2 × 324.6)
M3 correct signs and evaluation to give –2170.6 kJ mol^{-1}</td><td>3</td></tr>
</table>

Question	Answer	Marks
(c)(ii)	**M1** use of correct three numbers only 2170.6 103.1 and 1579 **M2** correct signs & evaluation –347 kJ mol^{-1}	**2**
(c)(iii)	**M1** Br$^-$ has a smaller ionic radius **M2** Br$^-$ has stronger attractive forces with water molecules	**2**

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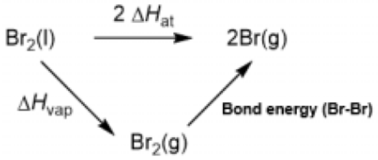
9. 9701_s19_ms_41 Q: 6

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>(a)</td><td><table>
<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>
both ticks correct</td><td>1</td></tr>
<tr><td>(b)</td><td>(energy change) when 1 mole of gaseous atoms are formed (from an element in its standard state)</td><td>1</td></tr>
<tr><td>(c)</td><td>

M1: correct cycle: formulae and state symbols
M2: use of 1 × 193 and 2 × (112)
M3: for the correct sum and answer ecf from M2
ΔH°_{vap} (= (2 × 112) – (193)) = +31 kJ mol^{-1} [scores M2 and M3]</td><td>3</td></tr>
<tr><td>(d)</td><td>more endothermic and greater Van der Waals / London / induced dipole-dipole forces both</td><td>1</td></tr>
<tr><td>(e)(i)</td><td>(energy change) when 1 mole of gaseous ions is dissolved in (an excess of) water</td><td>1</td></tr>
<tr><td>(e)(ii)</td><td>M1: Br$^-$ has a smaller ionic radii
M2: stronger (ion-dipole) attractions with water molecules</td><td>2</td></tr>
</table>

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10. 9701_s25_ms_41 Q: 4

Question	Answer	Marks
(a)(i)	energy change when one mole of gaseous ions dissolves in water	**1**
(a)(ii)	**M1:** K$^+$ has larger radius **AND** K$^+$ has smaller charge **M2:** Ca^{2+} has larger attraction for H_2O	**2**
(a)(iii)	energy change when one mole of **ionic** solid forms from gaseous ions	**1**
(a)(iv)	**M1:** –1650–(2 × 506) + 2602 **M2:** –60	**2**
(b)	**M1:** $\Delta G = \Delta H - T\Delta S$ **AND** T = 298 **M2:** –174.5 [1]	**2**

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11. 9701_s25_ms_42 Q: 3

Question	Answer	Marks
(a)(i)	number of possible arrangements of particles/molecules **AND** energy in a system	**1**
(b)(i)	T_1 melting **OR** solid to liquid T_2 boiling **OR** liquid to gas	**1**
(b)(ii)	change in disorder from a liquid to a gas is much bigger than solid to liquid **OR** change in intermolecular distance between liquid & gas is much bigger than solid to liquid	**1**
(c)	**M1:** $\Delta H^\circ_r = (3 \times -393.5) - ((-824.2) + (3 \times -110.5)) = -24.8$ (kJ mol^{-1}) **M2:** $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ **AND** T= 723 used **M3:** $(24800 - 36200) \div 723 = -[3 \times 213.8 + 2 \times 27.3) - (87.4) - (3x)]$ $-15.8 = -608.6 + 3x$, so $3x = 592.8$, so $x = 197.6 / 198$ (J K^{-1} mol^{-1}) min 3sf	**3**
(d)	• (as temperature increases) the reaction is less feasible • as ΔG° becomes less negative / (more) positive • due to $T\Delta S$ becoming more negative / $-T\Delta S$ (becoming more) positive **M1 / M2:** any two of the above bullets [1] all three [2]	**2**

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12. 9701_s24_ms_42 Q: 3

Question	Answer	Marks
(a)	**M1** $\Delta S^\circ = (213.8 + 2 \times 248.2) - (237.8 + 3 \times 205.2)$ $\Delta S^\circ = -143.2$ (J K^{-1} mol^{-1}) **M2** $\Delta H^\circ = (-393.5 + 2 \times -296.8) - (116.7)$ $\Delta H^\circ = -1103.8$ (kJ mol^{-1}) **M3** $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G^\circ = -1103.8 - (298 \times -0.1432) = -1061.1$ to -1061.4 (kJ mol^{-1}) ecf min 3sf	**3**
(b)	**M1** $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ **AND** $\Delta G^\circ = 0$ **OR** $T = \Delta H^\circ / \Delta S^\circ$ [1] **M2** $T = 261.6 \div 0.3655 = 715.7 / 716 / 715$ K min 3sf	**2**

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13. 9701_w24_ms_41 Q: 2

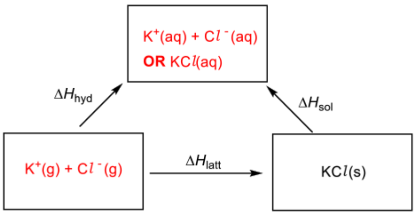
Question	Answer	Marks
(a)	becomes less negative/less exothermic (down the group / from F to I) **AND** due to increase in (ionic) radius / size [1] decreased attraction to **water** **OR** weaker ion-dipole force to water [1]	**2**
(b)(i)	$CaF_2(aq)$ **OR** $Ca^{2+}(aq) + 2F^-(aq)$ [1]	**1**
(b)(ii)	• atomisation energy of **Ca** / $\Delta H_{at(o)m))}$ • atomisation energy of **F**$_{(2)}$ / $\Delta H_{at(o)m))}$ **OR F-F** bond energy / BE of **F-F** • first ionisation energy / IE$_1$ of **Ca** / ΔH_{i1} • second ionisation energy / IE$_2$ of **Ca** / ΔH_{i2} • (first) electron affinity /EA of **F** / ΔH_{ea} any three for [1] ALL five [2]	**2**

Question	Answer	Marks
(b)(iii)	energy change / energy released when one mole of an ionic compound is formed [1] <u>from</u> its **gas**eous **ion(s)** [1]	**2**
(b)(iv)	(ΔH_{latt} =) (change) 3 – (change) 1 [1] **OR** (ΔH_{latt} =) $\Delta H_f(CaF_2(s)) - \Delta H_f(Ca^{2+}(g)) - 2\Delta H_f(F^-(g))$	**1**
(c)	expression involves four correct numbers (13, 1395, 1214, 1650) **AND** 2 times [1] 1395 – 1650 + 2x = –1214+13 $\Delta H_f(F^-(g))$ × = –473 [1] ecf correct answer [2]	**2**
(d)	number of possible **arrangements** of **particles / energy** in a **system** [1]	**1**
(e)	states or clearly uses $\Delta G = \Delta H - T\Delta S$ [1] **OR** 6000 = 30 000 – (298 × ΔS) ΔS = (+)80.5(4) [1] min 3sf ecf correct answer [2]	**2**
(f)	becomes **more** soluble **AND** ΔS is positive / $T\Delta S$ is positive / $-T\Delta S$ is negative (as T inc) [1] (so ΔG becomes more negative)	**1**

14. 9701_w24_ms_42 Q: 2

Question	Answer	Marks
(a)	ΔH_{hyd} increases from left to right due to increase in charge [1] ionic radius decreases from left to right [1] causing increased attractive force to water molecules [1]	**3**
(b)(i)	Mg^{2+} (aq) + 2Cl^- (aq) [1]	**1**
(b)(ii)	Enthalpy change of hydration of magnesium ions and chloride ions [1] $\Delta H_{hyd}Mg^{2+} + 2\Delta H_{hyd}Cl^-$ [1]	**2**
(b)(iii)	Selects 155, 1920 and 364 only [1] 2 × 364 [1] answer –2493 [1]	**3**
(c)	The number of arrangements of the particles and of the energy in the system [1]	**1**
(d)	$\Delta G = \Delta H - T\Delta S$ [1] answer +10.5 [1]	**2**
(e)(i)	No, ΔG is positive [1]	**1**
(e)(ii)	Becomes more / soluble **because** ΔG becomes more negative / less positive / smaller / closer to zero [1]	**1**

15. 9701_w22_ms_41 Q: 1

Question	Answer	Marks
(a)	 M1 K^+ (g) and Cl^- (g) **AND** KCl (aq) **OR** K^+ (aq) + Cl^- (aq) M2 three correct directional arrows COND M1	**2**
(b)	use of data –155, –2493 **AND** 2 × –364 [1] ΔH_{hyd} Mg^{2+} = **–1920** (kJ mol^{-1}) [1] min 3sf	**2**
(c)	• Mg^{2+} is **smaller** (than K^+) • Mg^{2+} is **greater charge** (than K^+) • greater **attraction** between Mg^{2+} and Cl^-/**between the ions** (in $MgCl_2$) **OR** stronger ionic bonds (in $MgCl_2$)	**2**
(d)(i)	enthalpy change when **one mole** of **gaseous atoms** formed from the **element** (in its standard state at 298 K)	**1**
(d)(ii)	enthalpy change when every atom in one mole of gaseous atoms gains one electron **OR** 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**
(e)(ii)	ΔS is positive **AND** $KCl(s) \rightarrow K^+(aq) + Cl^-(aq)$ / ionic lattice solid forms aqueous **ions OWTTE** [1] **OR** ΔS is positive **AND** ΔG is (therefore becomes) negative / TΔS is greater than ΔH_{sol} **OWTTE** [1]	**1**
(e)(iii)	**more soluble** **AND** ΔG is more negative at higher T / TΔS is more positive at higher T / –TΔS is more negative at higher **ecf from (e)(ii)** [sign ΔS]	**1**

16. 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 × 121) – (2 × 364)) [1] = –790 [1]	**2**
(c)	–342 **and** 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)	negative **and** reduction in number of gas molecules	**1**
(e)(ii)	TΔS becomes more negative [1] less feasible **AND** ΔG becomes positive [1]	**2**

17. 9701_s19_ms_42 Q: 5

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