TOPICAL PAST PAPER QUESTIONS WORKSHEETS

AS & A Level Chemistry (9701) Paper 4

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

Format Type B:
Each question is followed by its answer scheme

Introduction

Each Topical Past Paper Questions Workbook 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: 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

- Number of pages: 864

- Number of questions: 268

Contents

Chapter 1

Chemical energetics

1. 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, $\Delta H_{latt}^{\ominus}$, of $CaBr_2$(s).

It may be helpful to draw a labelled energy cycle.

Show your working.

$$\Delta H_{latt}^{\ominus} \text{ of } CaBr_2\text{(s)} = \text{.............................. } kJ\,mol^{-1} \text{ [3]}$$

(ii) Select and use relevant data from Table 8.2 and your answer to **(c)(i)** to calculate the standard enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$, 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 $\Delta H_{latt}^{\ominus}$ of $CaBr_2$(s). This is **not** the correct value.

Show your working.

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

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]

Answer:

Question	Answer	Marks
(a)	<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	1
(b)	The energy / enthalpy change when 1 mole of gaseous ions is dissolved in water	1
(c)(i)	**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	3

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

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

Table 3.2

$\Delta H^{\ominus}_{latt}$ of $CdI_2(s)$ is less negative than $\Delta H^{\ominus}_{latt}$ of $ZnI_2(s)$	$\Delta H^{\ominus}_{latt}$ of $CdI_2(s)$ is the same as $\Delta H^{\ominus}_{latt}$ of $ZnI_2(s)$	$\Delta H^{\ominus}_{latt}$ of $CdI_2(s)$ is more negative than $\Delta H^{\ominus}_{latt}$ of $ZnI_2(s)$

Explain your answer.

....

.... [1]

[Total: 9]

Answer:

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

Question	Answer	Marks

(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**

3. 9701_w22_qp_41 Q: 1

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

Table 1.1

energy change	value/kJ mol^{-1}
standard enthalpy change of solution, $\Delta H^{\ominus}_{sol}$, of KCl	+15
lattice energy, $\Delta H^{\ominus}_{latt}$, of KC$l$(s)	−701
standard enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$, of K$^+$	−322
standard enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$, of Cl^-	−364
standard enthalpy change of solution, $\Delta H^{\ominus}_{sol}$, of MgCl_2	−155
lattice energy, $\Delta H^{\ominus}_{latt}$, of MgC$l_2$(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.

KCl(s)
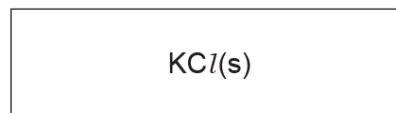
[2]

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

$\Delta H^{\ominus}_{hyd}$ of magnesium ions, 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]

Answer:

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** $2 \times$ −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**

Question	Answer	Marks

(e)(ii)	ΔS is positive
	    AND KCl(s) → K^+(aq) + Cl^-(aq) /
	        ionic lattice solid forms aqueous **ions** OWTTE [1]
	OR
	ΔS is positive
	    AND ΔG is (therefore becomes) negative /
	        $T\Delta S$ is greater than ΔH_{sol} OWTTE [1]
		1

(e)(iii)	**more soluble**
	AND ΔG is more negative at higher T /
	    $T\Delta S$ is more positive at higher T /
	    $-T\Delta S$ is more negative at higher **ecf from (e)(ii)** [sign ΔS]
		1

4. 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
$-342\,kJ\,mol^{-1}$	
$-364\,kJ\,mol^{-1}$	
$-386\,kJ\,mol^{-1}$	

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]

Answer:

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

5. 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]

Answer:

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

6. 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]

Answer:

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**

7. 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]

Answer:

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)	O²⁻ is a smallest ion/smaller ion than Cl⁻ **AND** O²⁻ has the highest charge/ higher charge than Cl⁻ (so attraction between O²⁻ and Zn^{2+} is larger)	1

8. 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]

Answer:

Question	Answer	Marks
(a)	<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	1
(b)	(energy change) when **1 mole** of **gaseous atoms** are formed (from an element in its standard state)	1
(c)	**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 $\Delta H^{\ominus}_{vap}$ (= (2 × 112) − (193)) = **+31** kJ mol⁻¹ [scores M2 and M3]	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)	**M1**: Br⁻ has a smaller ionic radii **M2**: stronger (ion-dipole) attractions with water molecules	2

9. 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, ΔH_f°, for $K_3PO_4(s)$	−2035
standard enthalpy change, ΔH°, for $P(s) + 2O_2(g) + 3e^- \rightarrow PO_4^{3-}(aq)$	−1284
standard enthalpy change, ΔH°, 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.

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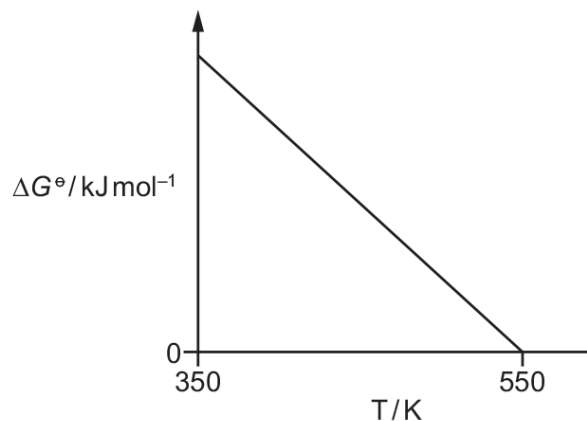
(i) Write the equation that relates $\Delta G^{\ominus}$ to $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$.

.... [1]

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

....

.... [1]

[Total: 9]

Answer:

Question	Answer	Marks

| (a) | | 1 |

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

both [1]

Question	Answer	Marks
(b)	(energy change) when **1 mole** of solute is dissolved in an infinite amount of **water** to form a dilute solution	1
(c)	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] $\Delta H^{\circ}_{sol} = (3 \times -251) + (-1284) - (-2035) = \mathbf{-2}$ (kJ mol^{-1}) [3]	3
(d)	Ca^{2+} have a higher charge / greater charge density [1] **ora** **stronger** electrostatic forces between Br$^-$ and Ca^{2+} [1]	2
(e)(i)	$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ [1]	1
(e)(ii)	TΔS is more positive **OR** −TΔS becomes more negative [1]	1

10. 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 $80\,^{\circ}C$ is cooled to $60\,^{\circ}C$

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, ΔH_{latt} $CaCl_2(s)$, takes place

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

....
[3]

(c) The reaction $ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$ is not spontaneous at room temperature.

(i) Give the full name for the term $\Delta G^{\ominus}$.

.... [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]

Answer:

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

11. 9701_w19_qp_42 Q: 4

The table shows some standard entropy data.

substance	standard entropy, S° / $JK^{-1}mol^{-1}$
$PbO_2(s)$	77
$PbO(s)$	69
$O_2(g)$	205

Lead(IV) oxide, PbO_2, decomposes to lead(II) oxide, PbO, and oxygen when heated.

$$2PbO_2(s) \rightarrow 2PbO(s) + O_2(g) \qquad \Delta H^\circ = +118\,kJ\,mol^{-1}$$
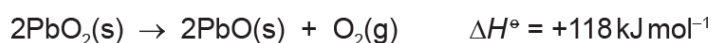
(a) Use the data to calculate the value of ΔS° for this reaction.

ΔS° = ... $JK^{-1}mol^{-1}$ [2]

(b) Use the value of ΔH° and your answer to (a) to calculate the temperature at which this reaction becomes feasible.

T = ... K [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]

Answer:

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

12. 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 cm³ 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$_2$O(s).

energy change	value / kJ mol^{-1}
standard enthalpy change of formation of sodium oxide, $\Delta H^{\ominus}_{f}$ Na$_2$O(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$_2$O(s) = ... kJ mol^{-1} [4]

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

$\Delta H^{\ominus}_{latt}$ Na$_2$S(s) is more exothermic than $\Delta H^{\ominus}_{latt}$ Na$_2$O(s)	$\Delta H^{\ominus}_{latt}$ Na$_2$S(s) is the same as $\Delta H^{\ominus}_{latt}$ Na$_2$O(s)	$\Delta H^{\ominus}_{latt}$ Na$_2$S(s) is less exothermic than $\Delta H^{\ominus}_{latt}$ Na$_2$O(s)

Explain your answer.

....

....

....

[2]

[Total: 15]

Answer:

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 $\Delta H_{lat} = -416 - (2 \times 109) - (0.5 \times 496) - (2 \times 494) - (-142 + 844) = -2572$	**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**

13. 9701_s18_qp_42 Q: 1

Silicon tetrachloride, $SiCl_4$, is formed when silicon reacts with chlorine under suitable conditions. It is a colourless liquid with a low boiling point.

(a) Explain why $SiCl_4$ has a low boiling point.

....

....

.... [2]

(b) $SiCl_4$ 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.
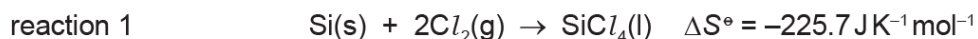
   1 ....

   2 ....
                                                                                                            [2]

 (iii) A sample of 0.8505 g of $SiCl_4$ is added to 800 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.

reaction 1 $Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$ $\Delta S^{\ominus} = -225.7\,J\,K^{-1}\,mol^{-1}$

standard entropy of silicon, $S^{\ominus}$ Si(s)	$18.7\,J\,K^{-1}\,mol^{-1}$
standard entropy of silicon tetrachloride, $S^{\ominus}$ $SiCl_4$ (l)	$239.0\,J\,K^{-1}\,mol^{-1}$

Calculate the standard entropy of chlorine, $S^{\ominus}$ Cl_2(g). Show all your working.

$S^{\ominus}$ Cl_2(g) = ... $J\,K^{-1}\,mol^{-1}$ [2]

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

....

.... [1]

(d) The standard enthalpy change of formation of silicon tetrachloride, $\Delta H_f^{\ominus}$ $SiCl_4$(l), is $-640\,kJ\,mol^{-1}$.

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.

temperature = ... K [2]

[Total: 13]

Answer:

| 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 **AND** small amount of energy to break	1
(b)(i)	$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ or $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$	1
(b)(ii)	white solid	1
	steamy fumes / white fumes / misty fumes	1
(b)(iii)	moles of $SiCl_4$ = 0.8505 / 170.1 = 0.005	1
	conc of H^+ (0.005) $\times$ 4 / 0.8 = 0.025	1
	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 = ΔH / ΔS or T = (640 000 / 225.7)	1
	2836 / 2840 (2835.6)	1

14. 9701_m17_qp_42 Q: 2

(a) Complete the table using ticks (✓) to indicate whether the sign of each type of energy change, under standard conditions, is always positive, always negative or could be either positive or negative.

energy change	always positive	always negative	either positive or negative
electron affinity			
enthalpy change of atomisation			
ionisation energy			
lattice energy			

[2]

(b) The Born-Haber cycle for magnesium chloride is shown.
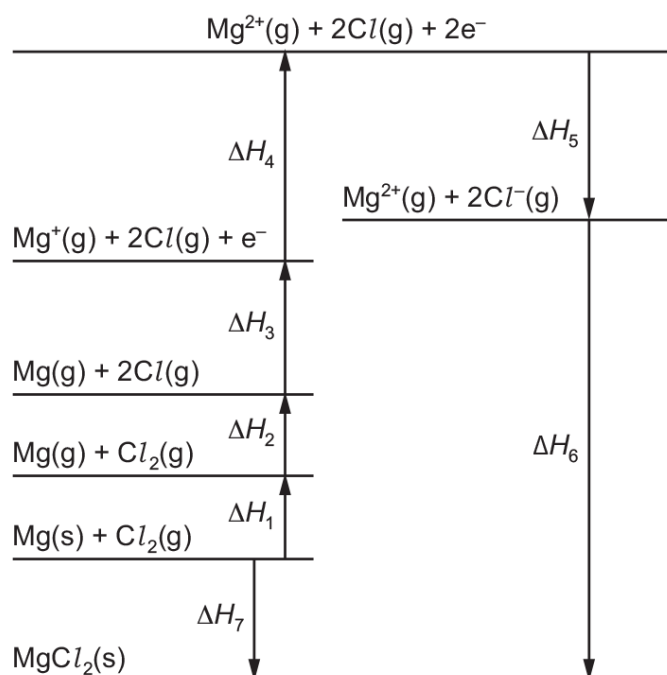
(i) Explain why ΔH_4 is greater than ΔH_3.

....

.... [1]

(ii) What names are given to the enthalpy changes ΔH_6 and ΔH_7?

ΔH_6 ....

ΔH_7 ....
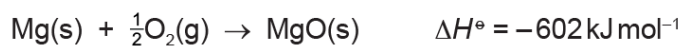
[1]

(c) Chlorine is in Group 17.

Suggest the trend in the first electron affinity of the elements in Group 17. Explain your answer.

....

....

.... [2]

(d) The equation for the formation of magnesium oxide from its elements is shown.

$$Mg(s) + \tfrac{1}{2}O_2(g) \rightarrow MgO(s) \qquad \Delta H^\ominus = -602\,kJ\,mol^{-1}$$

substance	$S^\ominus/J\,K^{-1}\,mol^{-1}$
$Mg(s)$	32.7
$O_2(g)$	205
$MgO(s)$	26.9

Use the equation and the data given in the table to calculate $\Delta G^\ominus$ for the reaction at 25 °C.

$\Delta G^\ominus$ = ...   units ....

[4]

[Total: 10]

Answer:

Question	Answer	Marks
(a)	<table><tr><td>enthalpy change</td><td>positive</td><td>negative</td><td>either positive or negative</td></tr><tr><td>electron affinity</td><td></td><td></td><td>✓</td></tr><tr><td>enthalpy change of atomisation</td><td>✓</td><td></td><td></td></tr><tr><td>enthalpy change of ionisation</td><td>✓</td><td></td><td></td></tr><tr><td>lattice enthalpy</td><td></td><td>✓</td><td></td></tr></table>	**2**
(b)(i)	the second electron is removed from a (more) positively charged ion	**1**
(b)(ii)	ΔH_6 is lattice (energy / enthalpy) **AND** ΔH_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)	**M1** correct use of $\Delta G = \Delta H - T\Delta S$	**1**
	M2 $\Delta S = 26.9 - (32.7 + 102.5) = -108.3\,J\,K^{-1}\,mol^{-1}$ **OR** $-0.1083\,kJ\,K^{-1}\,mol^{-1}$	**1**
	M3 $\Delta G = -602 - (298 \times (-0.1083)) = -570$	**1**
	M4 units: $kJ\,mol^{-1}$	**1**