1. 9701_s18_qp_42 Q4

4 **(a)** **(i)** Write an equation, including state symbols, for the reaction that takes place when a sample of anhydrous calcium nitrate, $Ca(NO_3)_2$, is heated strongly in a test-tube.

.... [2]

(ii) Describe what will be seen during this reaction.

....

....

.... [2]

(b) Describe and explain how the solubility of the Group 2 sulfates varies down the group.

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.... [4]

[Total: 8]

2.　9701_s21_qp_42 Q2

2 **(a)** State and explain the trend observed in the thermal stability of the Group 2 nitrates.

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.... [3]

(b) (i) Lead(II) nitrate, $Pb(NO_3)_2$, decomposes on heating in a similar manner to the Group 2 nitrates.

Write an equation for the decomposition of lead(II) nitrate.

.... [1]

(ii) Suggest how the ease of decomposition of $Pb(NO_3)_2$ would compare to that of $Ba(NO_3)_2$. Explain your answer. You may find it useful to refer to the *Data Booklet*.

....

.... [1]

(c) (i) Barium ethanedioate, BaC_2O_4, decomposes on heating to produce barium oxide and a mixture of two different gases.

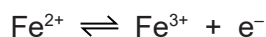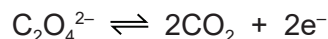Construct an equation for the decomposition of barium ethanedioate.

.... [1]

(ii) An impure sample of BaC_2O_4, of mass 0.500 g, is added to 50.0 cm³ of 0.0200 mol dm⁻³ acidified MnO_4^-(aq), an excess. A redox reaction takes place and all the BaC_2O_4 reacts.

The resulting solution, containing unreacted acidified MnO_4^-, is titrated with 0.0500 mol dm⁻³ Fe^{2+}(aq).

The end-point is reached when 30.40 cm³ of 0.0500 mol dm⁻³ Fe^{2+}(aq) has been added.

$$C_2O_4^{2-} \rightleftharpoons 2CO_2 + 2e^-$$

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$$

$$Fe^{2+} \rightleftharpoons Fe^{3+} + e^-$$

Calculate the percentage by mass of BaC_2O_4 in the 0.500 g impure sample. Show your working.
[M_r: BaC_2O_4, 225.3]

percentage by mass of BaC_2O_4 = ... [4]

(d) Barium hydroxide, $Ba(OH)_2$, is completely dissociated in aqueous solution.

Calculate the pH of 0.120 mol dm⁻³ $Ba(OH)_2$(aq) at 298 K.

pH = ... [2]

[Total: 12]

3

3. 9701_s18_qp_42 Q1

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 ....
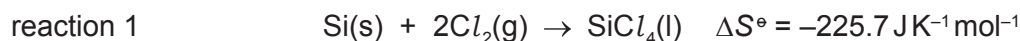
[2]

(iii) A sample of 0.8505 g of $SiCl_4$ is added to 800 cm³ 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 $\qquad$ $Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$ $\quad \Delta S^\ominus = -225.7 \, JK^{-1}mol^{-1}$

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

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

$S^\ominus$ Cl_2(g) = ... $JK^{-1}mol^{-1}$ [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.

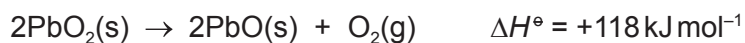temperature = ... K [2]

[Total: 13]

4.   9701_w19_qp_42 Q4

4 The table shows some standard entropy data.

substance	standard entropy, $S^{\ominus}$ /$J K^{-1} mol^{-1}$
$PbO_2(s)$	77
$PbO(s)$	69
$O_2(g)$	205

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

$$2PbO_2(s) \rightarrow 2PbO(s) + O_2(g) \qquad \Delta H^{\ominus} = +118 \, kJ \, mol^{-1}$$

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

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

5.   9701_s22_qp_43 Q1

1 **(a)** The solubility of the Group 2 sulfates decreases down the group.

Explain this trend.

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....

....

....

.... [3]

(b) Describe what is observed when magnesium and barium are reacted separately with an excess of dilute sulfuric acid.
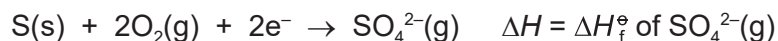
magnesium ....

barium ....
[1]

(c) The solubility product, K_{sp}, of $BaSO_4$ is $1.08 \times 10^{-10}\,mol^2\,dm^{-6}$ at 298 K.

Calculate the solubility of $BaSO_4$ in g per 100 cm³ of solution.

solubility of $BaSO_4$ = ... g per 100 cm³ of solution
[2]

(d) (i) The equation for the formation of a gaseous sulfate ion is shown.

$$S(s) + 2O_2(g) + 2e^- \rightarrow SO_4^{2-}(g) \quad \Delta H = \Delta H_f^{\ominus} \text{ of } SO_4^{2-}(g)$$

Calculate the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of $SO_4^{2-}(g)$. It may be helpful to draw a labelled energy cycle. Use relevant data from Table 1.1 in your calculations.

Table 1.1

energy change	value/$kJ\,mol^{-1}$
lattice energy of barium sulfate, $BaSO_4(s)$	−2469
standard enthalpy change of formation of barium sulfate	−1473
standard enthalpy change of atomisation of barium	+180
first ionisation energy of barium	+503
second ionisation energy of barium	+965
standard enthalpy change of atomisation of sulfur	+279
standard enthalpy change for $S(g) \rightarrow S^{2-}(g)$	+440
standard enthalpy change for $O(g) \rightarrow O^{2-}(g)$	+657
O=O bond energy	+496

$\Delta H_f^{\ominus}$ of $SO_4^{2-}(g) = $ .... $kJ\,mol^{-1}$ [3]

8

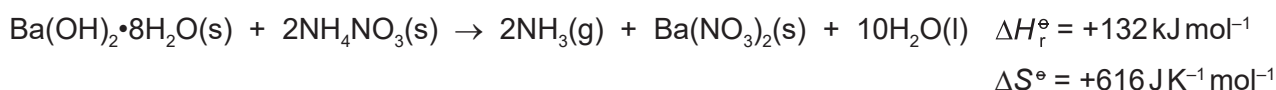**(ii)** Suggest how the lattice energy of $BaSO_4(s)$ differs from the lattice energy of $Cs_2SO_4(s)$. Explain your answer.

....

....

.... [2]

(e) The reaction of solid hydrated barium hydroxide, $Ba(OH)_2 \cdot 8H_2O$, with ammonium salts is endothermic.

(i) Calculate the **minimum** temperature at which the reaction of $Ba(OH)_2 \cdot 8H_2O$ with NH_4NO_3 becomes feasible. Show all your working.

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4NO_3(s) \rightarrow 2NH_3(g) + Ba(NO_3)_2(s) + 10H_2O(l) \quad \Delta H_r^{\ominus} = +132\,kJ\,mol^{-1}$$

$$\Delta S^{\ominus} = +616\,J\,K^{-1}\,mol^{-1}$$

temperature = ... °C [2]

(ii) Barium hydroxide reacts readily with ammonium chloride on mixing at room temperature.

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \rightarrow 2NH_3(g) + BaCl_2 \cdot 2H_2O(s) + 8H_2O(l) \quad \Delta H_r^{\ominus} = +133\,kJ\,mol^{-1}$$
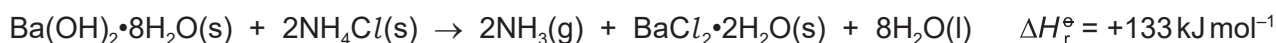
Some relevant standard entropies are given in Table 1.2.

Table 1.2

substance	$Ba(OH)_2 \cdot 8H_2O(s)$	$NH_4Cl(s)$	$NH_3(g)$	$BaCl_2 \cdot 2H_2O(s)$	$H_2O(l)$
$S^{\ominus}/J\,K^{-1}\,mol^{-1}$	427	95	192	203	70

Calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, for this reaction at 25 °C.

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

[Total: 16]

6. 9701_w19_qp_43 Q5

5 Silver sulfide, Ag_2S, is very insoluble in water.

(a) (i) Write an expression for the solubility product, K_{sp}, of $Ag_2S(s)$.

K_{sp} =

[1]

(ii) The solubility of $Ag_2S(s)$ in water at 298 K is 1.16×10^{-17} mol dm^{-3}.

Calculate the numerical value of the solubility product, K_{sp}, of $Ag_2S(s)$ at 298 K.

K_{sp} = ... [2]

(iii) Calculate the minimum volume of water needed to dissolve 1.00 g of $Ag_2S(s)$ under standard conditions.

volume = ... dm^3 [2]

(b) Bromic(I) acid, HOBr(aq), is a weak acid. Its K_a is $2.0 \times 10^{-9}\,mol\,dm^{-3}$.

(i) Calculate the pH of $0.20\,mol\,dm^{-3}$ HOBr(aq).

pH = ... [2]

(ii) $5.0\,cm^3$ of $0.20\,mol\,dm^{-3}$ potassium hydroxide, KOH, are added to $20.0\,cm^3$ of $0.20\,mol\,dm^{-3}$ HOBr(aq).

Calculate the pH of the buffer solution produced.

pH = ... [2]

[Total: 9]

7.   9701_s19_qp_43 Q6

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]

12

(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]

8.   9701_w19_qp_41 Q3

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, 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]

9. 9701_w19_qp_42 Q5

5 **(a)** Describe fully what would be seen when magnesium and strontium are heated separately in oxygen.

magnesium ....

strontium ....

[2]

(b) (i) Write an equation for each of the following processes. Include state symbols.

calcium is burned in air

....

calcium carbonate is heated strongly

....

[2]

(ii) Calcium hydroxide is formed when water is added to calcium oxide. Calcium hydroxide and calcium carbonate are both used in agriculture.

Describe the main benefit of adding calcium hydroxide or calcium carbonate to soil.

....

.... [1]

(iii) Explain why the Group 2 hydroxides become more soluble down the group.

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.... [3]

(c) Describe the observations, if any, that you would make when:

● a few drops of NaOH(aq) are added to $BaCl_2$(aq)

....

● a few drops of H_2SO_4(aq) are added to $BaCl_2$(aq).

....

[2]

(d) Describe and explain how the thermal stability of the Group 2 carbonates varies down the group.

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.... [3]

[Total: 13]

10.   9701_s20_qp_41 Q2

2 **(a) (i)** Describe and explain the trend in the solubility of the Group 2 hydroxides down the group.

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.... [4]

Group 2 hydroxides decompose on heating to give the corresponding metal oxide and water vapour.

(ii) Suggest which of $Mg(OH)_2$ and $Sr(OH)_2$ will decompose at a **lower** temperature.

Explain your answer.

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.... [2]

[Total: 6]