1. Nov/2021/Paper_41/No.4

Separate samples of 0.02 mol of calcium carbonate and 0.02 mol of barium carbonate are heated until completely decomposed to the metal oxide and carbon dioxide.

(a) State which of these two Group 2 carbonates requires the **higher** temperature before it begins to decompose. Explain your answer.

.....

.....

..... [2]

(b) After decomposition is complete, the 0.02 mol sample of calcium oxide is taken and added to 2.00 dm^3 of water. A solution is formed with no solid present. Dilute sulfuric acid is then added dropwise until a precipitate is seen.

The same procedure is repeated with the 0.02 mol sample of barium oxide, using the same concentration solution of dilute sulfuric acid.

Identify the sample to which **most** sulfuric acid must be added to cause a precipitate to appear.

Explain your answer. You should refer to the solubilities of the precipitates and relevant energy terms in your answer.

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..... [3]

(c) **(i)** Calculate the mass, in g, of CO_2 produced by the decomposition of 0.020 moles of calcium carbonate.

mass of CO_2 = ... g [1]

(ii) Calculate the minimum mass, in g, of propane that would, on complete combustion, produce the same mass of CO_2 calculated in **(c)(i)**.
Give your answer to three significant figures.

mass of propane = ... g [2]

[Total: 8]

2. Nov/2021/Paper_42/No.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.

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..... [2]

(iii) The lattice energies of sodium chloride, NaC*l*, 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]

3. Nov/2021/Paper_42/No.4

Separate samples of 0.01 mol of magnesium nitrate and 0.01 mol of strontium nitrate are heated until completely decomposed to the metal oxide, nitrogen dioxide and oxygen.

(a) State which of these two Group 2 nitrates requires the **higher** temperature before it begins to decompose. Explain your answer.

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..... [2]

(b) After decomposition is complete the 0.01 mol sample of magnesium oxide is taken and increasing amounts of water are added to it, with stirring, until no solid remains.

This procedure is repeated with the 0.01 mol sample of strontium oxide.

Identify the sample to which most water must be added to cause all the solid to dissolve. Explain your answer by reference to the solubilities of the products formed when water is added to the oxides. You should refer to relevant energy terms in your answer.

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..... [3]

(c) The nitrogen dioxide given off by the decomposition of 0.0100 mol of strontium nitrate is dissolved in water. The oxidising agent $H_2O_2(aq)$ is then added to give 150.0 cm^3 of a solution in which nitric acid, HNO_3, is the only nitrogen-containing product.

(i) Calculate the concentration, in mol dm^{-3}, of HNO_3 in the 150.0 cm^3 of solution.

concentration = ... mol dm^{-3} [1]

(ii) The HNO_3 present in 25.0 cm^3 of this solution is neutralised using 0.125 mol dm^{-3} NaOH(aq).

Calculate the minimum volume, in cm^3, of NaOH(aq) needed. Give your answer to three significant figures.

volume = ... cm^3 [1]

[Total: 7]

4. June/2021/Paper_41/No.1

(a) The carbonates and hydroxides of Group 2 elements show similar trends in thermal stability.

Suggest and explain the variation in the trend in the thermal stability of the Group 2 hydroxides.

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..... [3]

(b) Calcium hydroxide is slightly soluble in water.

(i) Write an equation to show the dissociation of calcium hydroxide, $Ca(OH)_2(s)$, in aqueous solution. Include state symbols.

..... $\rightleftharpoons$ ..... [1]

(ii) Calculate the solubility, in mol dm^{-3}, of $Ca(OH)_2$.
[K_{sp}: $Ca(OH)_2$, 5.02×10^{-6} mol^3 dm^{-9}]

solubility = ... mol dm^{-3} [2]

(iii) Suggest how the solubility of $Ca(OH)_2$ in aqueous NaOH compares to its solubility in water.

Explain your reasoning.

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..... [1]

[Total: 7]

(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 cm^3 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 cm^3 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]