Acid-base and redox reaction – 2021/20 GCE Chemistry A Component 01

1. Nov/2021/Paper_H432/01/No.18(a _ c)

A student carries out an experiment to determine the percentage by mass of copper in an ore containing copper in its +2 oxidation state.

The student is provided with a sample of the copper ore, 1 mol dm^{-3} potassium iodide, KI(aq), and 0.0200 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.

The student's method is outlined below.

Step 1 Add an excess of warm nitric acid to 2.50 g of the ore.
The copper(II) compounds in the ore react, forming aqueous copper(II) nitrate.

Step 2 Filter the mixture to remove the unreacted rock. Neutralise the filtrate.

Step 3 Add an excess of aqueous potassium iodide, KI(aq).
A precipitate of copper(I) iodide and a solution of iodine, I_2(aq), forms.

Step 4 Titrate the mixture from **Step 3** using 0.0200 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$ in the burette.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

26.55 cm^3 of 0.0200 mol dm^{-3} $Na_2S_2O_3$ are required to reach the end point.

(a) In **Step 1**, the student observed that bubbles of gas were produced.

Suggest the formula of the copper(II) compound which reacted with HNO_3 to form the gas, and write a full equation for the reaction.

Formula: .....

Equation: ..... **[2]**

(b) Write an **ionic** equation, including state symbols, for the reaction in **Step 3**.

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

(c) Suggest a suitable indicator for this titration and state the colour change at the end point in **Step 4**.

Indicator: .....

Colour from ..... to ..... **[1]**

2. Nov/2020/Paper_H432/01/No.1

Several students titrate 25.00 cm^3 of the same solution of sodium hydroxide, NaOH(aq) with hydrochloric acid, HC*l*(aq).

One student obtains a smaller titre than the other students.

Which procedure explains the smaller titre?

A The burette readings are taken from the top of the meniscus instead of the bottom of the meniscus.

B The conical flask is rinsed with water before carrying out the titration.

C An air bubble is released from the jet of the burette during the titration.

D The pipette is rinsed with water before filling with NaOH(aq).

Your answer ☐ **[1]**

3. Nov/2020/Paper_H432/01/No.4

Phosphoric acid is a tribasic acid.

What is the mass of $Ca(OH)_2$ that completely neutralises 100 cm^3 of 0.100 mol dm^{-3} phosphoric acid?

A 0.49 g

B 0.74 g

C 1.11 g

D 2.22 g

Your answer ☐ **[1]**

4. Nov/2020/Paper_H432/03/No.4

A student carries out an investigation to identify two metals, **M** and **X**, by two different methods.

(a) The student is provided with a sample of metal **M**.

The student analyses metal **M** using a 'back-titration' technique:

- The metal is reacted with excess acid.
- The resulting solution is titrated to determine the amount of acid remaining after the reaction.

Stage 1

The student adds 100 cm^3 of 2.10 $mol\,dm^{-3}$ HCl(aq) to 6.90 g of **M**.
An excess of HCl(aq) has been used to ensure that all of metal **M** reacts.

A redox reaction occurs, forming a solution containing **M** in the +2 oxidation state.

Stage 2

The resulting solution from **Stage 1** is made up to 250.0 cm^3 with distilled water.

Stage 3

A 25.00 cm^3 sample of the diluted solution from **Stage 2** is titrated with 0.320 $mol\,dm^{-3}$ NaOH(aq).

The NaOH(aq) reacts with excess HCl(aq) that remains in **Stage 1**:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

The student repeats the titration to obtain concordant titres.

Titration results (The trial titre has been omitted.)
The burette readings have been recorded to the nearest 0.05 cm^3.

	1	2	3
Final reading / cm^3	27.80	37.55	32.20
Initial reading / cm^3	0.50	10.00	5.00

(i) In **Stage 1**, a redox reaction takes place between **M** and HCl(aq), forming hydrogen and a solution containing **M** in the +2 oxidation state.

Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.

Overall equation .....

Oxidation half-equation .....

Reduction half-equation .....

[3]

(ii) In **Stage 1**, suggest **two** observations that would confirm that all of metal **M** has reacted.

1 .....

.....

2 .....

.....

[2]

(iii) In **Stage 3**, write the ionic equation for the reaction taking place in the titration.

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

(iv) Metal **M** can be identified following the steps below.

1. The amount, in mol, of excess HCl(aq) that remains after the reaction of **M** with HCl(aq).
2. The amount, in mol, of HCl(aq) that reacted with **M**.
3. The identity of metal **M**.

Analyse the results to identify metal **M**.

Metal **M** = ... **[6]**

(b) The student is provided with the carbonate of an unknown metal, $\mathbf{X}_2CO_3$.

The student measures the mass loss when the $\mathbf{X}_2CO_3$ is reacted with an **excess** of hydrochloric acid. The equation is shown below.

$$\mathbf{X}_2CO_3(s) + 2HCl(aq) \rightarrow 2\mathbf{X}Cl(aq) + CO_2(g) + H_2O(l)$$

The reaction is carried out using this method:

Step 1 Add 100 cm^3 $HCl(aq)$ to a conical flask and weigh.

Step 2 Add $\mathbf{X}_2CO_3$ to the conical flask and immediately reweigh.

Step 3 After 5 minutes, reweigh the conical flask and contents.

Results

Mass of conical flask + $HCl(aq)$	172.93 g
Mass of conical flask + $\mathbf{X}_2CO_3$ + $HCl(aq)$ before reaction	187.50 g
Mass of conical flask + contents after 5 minutes	184.75 g

(i) Calculate the amount, in mol, of CO_2 released in the reaction.

Amount of CO_2 = ... mol **[1]**

(ii) Calculate the molar mass of $\mathbf{X}_2CO_3$ and identify metal **X**.

Molar mass of $\mathbf{X}_2CO_3$ = ... $g\,mol^{-1}$ Metal **X** = ...**[3]**

(c) After analysing the results, the student was told that their molar mass of $\mathbf{X}_2CO_3$ was incorrect.

The student evaluated the experiment for possible reasons for the incorrect result.

(i) The student wondered whether the reaction was complete when the mass was recorded after 5 minutes (**Step 3**).

How could the student modify the experimental procedure to be confident that the reaction was complete?

.....

.....

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

(ii) The student finds out that carbon dioxide is slightly soluble in water.

State and explain how the solubility of CO_2 would affect the calculated molar mass of $\mathbf{X}_2CO_3$.

.....

.....

.....

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