A-Level Chemistry

The Mole and Avogadro's Constant

Question Paper

Time available: 52 minutes
Marks available: 48 marks

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1. A student does an experiment to determine the percentage by mass of sodium chlorate(I), NaClO, in a sample of bleach solution.

Method:

- Dilute a 10.0 cm^3 sample of bleach solution to 100 cm^3 with distilled water.
- Transfer 25.0 cm^3 of the diluted bleach solution to a conical flask and acidify using sulfuric acid.
- Add excess potassium iodide to the conical flask to form a brown solution containing $I_2(aq)$.
- Add 0.100 mol dm^{-3} sodium thiosulfate solution ($Na_2S_2O_3$) to the conical flask from a burette until the brown solution containing $I_2(aq)$ becomes a colourless solution containing $I^-(aq)$.

The student uses 33.50 cm^3 of sodium thiosulfate solution.

The density of the original bleach solution is 1.20 g cm^{-3}

The equations for the reactions in this experiment are

$$ClO^-(aq) + 2\ H^+(aq) + 2\ I^-(aq) \rightarrow Cl^-(aq) + H_2O(l) + I_2(aq)$$

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

(a) Use all the information given to calculate the percentage by mass of NaClO in the original bleach solution.

Give your answer to 3 significant figures.

Percentage by mass _____

(7)

(b) The total uncertainty from two readings and an end point error in using a burette is ± 0.15 cm^3

What is the total percentage uncertainty in using the burette in this experiment?

Tick (✓) **one** box.

0.45% ☐

0.90% ☐

1.34% ☐

(1)

(Total 8 marks)

2. This question is about a white solid, $MHCO_3$, that dissolves in water and reacts with hydrochloric acid to give a salt.

$$MHCO_3 + HCl \longrightarrow MCl + H_2O + CO_2$$

A student was asked to design an experiment to determine a value for the M_r of $MHCO_3$. The student dissolved 1464 mg of $MHCO_3$ in water and made the solution up to 250 cm^3.
25.0 cm^3 samples of the solution were titrated with 0.102 mol dm^{-3} hydrochloric acid. The results are shown in the table.

	Rough	**1**	**2**	**3**
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

(a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the $MHCO_3$ solution.

(3)

(b) Calculate the amount, in moles, of $MHCO_3$ in 250 cm^3 of the solution.
Then calculate the experimental value for the M_r of $MHCO_3$.
Give your answer to the appropriate number of significant figures.

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_____

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_____

(3)

(c) The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

Suggestion _____

_____

Justification _____

_____

_____

(2)

(d) Another student is required to make up 250 cm^3 of an aqueous solution that contains a known mass of $MHCO_3$. The student is provided with a sample bottle containing the $MHCO_3$.

Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

(6)

(Total 14 marks)

3. Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer x in $ZnSO_4.xH_2O$
Show your working.

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

(3)

(Total 14 marks)

4. Norgessaltpeter was the first nitrogen fertiliser to be manufactured in Norway. It has the formula $Ca(NO_3)_2$

(a) Norgessaltpeter can be made by the reaction of calcium carbonate with dilute nitric acid as shown by the following equation.

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

In an experiment, an excess of powdered calcium carbonate was added to 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid.

(i) Calculate the amount, in moles, of HNO_3 in 36.2 cm^3 of 0.586 mol dm^{-3} nitric acid. Give your answer to 3 significant figures.

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(1)

(ii) Calculate the amount, in moles, of $CaCO_3$ that reacted with the nitric acid. Give your answer to 3 significant figures.

_____

_____

(1)

(iii) Calculate the minimum mass of powdered $CaCO_3$ that should be added to react with all of the nitric acid.

Give your answer to 3 significant figures.

_____

_____

_____

(2)

(iv) State the type of reaction that occurs when calcium carbonate reacts with nitric acid.

_____

(1)

(b) Norgessaltpeter decomposes on heating as shown by the following equation.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

A sample of Norgessaltpeter was decomposed completely.

The gases produced occupied a volume of $3.50 \times 10^{-3}\ m^3$ at a pressure of 100 kPa and a temperature of 31 °C.
(The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$)

(i) Calculate the total amount, in moles, of gases produced.

_____

_____

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_____

(3)

(ii) Hence calculate the amount, in moles, of oxygen produced.

_____

_____

(1)

(c) Hydrated calcium nitrate can be represented by the formula $Ca(NO_3)_2.xH_2O$ where x is an integer.

A 6.04 g sample of $Ca(NO_3)_2.xH_2O$ contains 1.84 g of water of crystallisation.

Use this information to calculate a value for x.
Show your working.

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(3)

(Total 12 marks)