CHAPTER 2 AMOUNT OF SUBSTANCE

1 Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 ($M_r = 101.1$) was heated strongly until fully decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

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(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of $1.22 \times 10^{-4}\,m^3$.
State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant $R = 8.31\,J\,K^{-1}\,mol^{-1}$)

Ideal gas equation .....

Moles of oxygen .....

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(5 marks)

(b) Compound **Y** contains 45.9% of potassium and 16.5% of nitrogen by mass, the remainder being oxygen.

(i) State what is meant by the term *empirical formula*.

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(ii) Use the data above to calculate the empirical formula of **Y**.

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(4 marks)

(c) Deduce an equation for the decomposition of KNO_3 into **Y** and oxygen.

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(1 mark)

2 Ammonia is used to make nitric acid (HNO_3) by the Ostwald Process.
Three reactions occur in this process.

Reaction **1** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

Reaction **2** $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Reaction **3** $3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$

(a) In one production run, the gases formed in Reaction **1** occupied a total volume of $4.31\,m^3$ at 25 °C and 100 kPa.

Calculate the amount, in moles, of NO produced.
Give your answer to 3 significant figures.
(The gas constant $R = 8.31\,J\,K^{-1}\,mol^{-1}$)

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(4 marks)

(b) In another production run, 3.00 kg of ammonia gas were used in Reaction **1** and all of the NO gas produced was used to make NO_2 gas in Reaction **2**.

(i) Calculate the amount, in moles, of ammonia in 3.00 kg.

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(2 marks)

(ii) Calculate the mass of NO_2 formed from 3.00 kg of ammonia in Reaction **2** assuming an 80.0% yield.
Give your answer in kilograms.
(If you have been unable to calculate an answer for part **(b) (i)**, you may assume a value of 163 mol. This is **not** the correct answer.)

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(3 marks)

(c) Consider Reaction **3** in this process.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

Calculate the concentration of nitric acid produced when 0.543 mol of NO_2 is reacted with water and the solution is made up to 250 cm^3.

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(2 marks)

(d) Suggest why a leak of NO_2 gas from the Ostwald Process will cause atmospheric pollution.

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(1 mark)

(e) Give **one** reason why excess air is used in the Ostwald Process.

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(1 mark)

(f) Ammonia reacts with nitric acid as shown in this equation.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Deduce the type of reaction occurring.

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(1 mark)

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.

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(3 marks)

(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.

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(4 marks)

(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.

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(4 marks)

4 In this question give all your answers to the appropriate number of significant figures.

Magnesium nitrate decomposes on heating to form magnesium oxide, nitrogen dioxide and oxygen as shown in the following equation.

$$2Mg(NO_3)_2(s) \longrightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) Thermal decomposition of a sample of magnesium nitrate produced 0.741 g of magnesium oxide.

(i) Calculate the amount, in moles, of MgO in 0.741 g of magnesium oxide.

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(2 marks)

(ii) Calculate the total amount, in moles, of gas produced from this sample of magnesium nitrate.

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(1 mark)

(b) In another experiment, a different sample of magnesium nitrate decomposed to produce 0.402 mol of gas. Calculate the volume, in dm^3, that this gas would occupy at 333 K and 1.00×10^5 Pa.
(The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$)

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(3 marks)

(c) A 0.0152 mol sample of magnesium oxide, produced from the decomposition of magnesium nitrate, was reacted with hydrochloric acid.

$$MgO + 2HCl \longrightarrow MgCl_2 + H_2O$$

This 0.0152 mol sample of magnesium oxide required 32.4 cm^3 of hydrochloric acid for complete reaction. Use this information to calculate the concentration, in mol dm^{-3} of the hydrochloric acid.

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(1 mark)