CHM 101 Holiday Assignment
Stoichiometry Problems with Solutions

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Problem 1

Question: The following reaction was carried out:

$$\mathrm{CaCO_3(s) + 2\,HCl(aq) \longrightarrow CaCl_2(s) + CO_2(g) + H_2O(l)}$$

If 10.0 grams of $\mathrm{CaCO_3}$ was used, calculate:

(a) The volume of $\mathrm{CO_2}$ (at STP) produced from the complete reaction

(b) The mass of $\mathrm{CaCl_2}$ produced

(c) How many moles of $\mathrm{H_2O}$ was produced

Solution:

Step 1: Calculate molar masses

$$M_{\mathrm{CaCO_3}} = 40.0 + 12.0 + 3(16.0) = 100.0 \text{ g/mol}$$
$$M_{\mathrm{CaCl_2}} = 40.0 + 2(35.5) = 111.0 \text{ g/mol}$$
$$M_{\mathrm{CO_2}} = 12.0 + 2(16.0) = 44.0 \text{ g/mol}$$
$$M_{\mathrm{H_2O}} = 2(1.0) + 16.0 = 18.0 \text{ g/mol}$$

Step 2: Calculate moles of $\mathrm{CaCO_3}$

$$n_{\mathrm{CaCO_3}} = \frac{10.0 \text{ g}}{100.0 \text{ g/mol}} = 0.100 \text{ mol}$$

Step 3: Use stoichiometry ratios (from balanced equation) From the balanced equation: 1 mol $\mathrm{CaCO_3}$ → 1 mol $\mathrm{CO_2}$ → 1 mol $\mathrm{CaCl_2}$ → 1 mol $\mathrm{H_2O}$

(a) Volume of $\mathrm{CO_2}$ at STP:

$$n_{\mathrm{CO_2}} = 0.100 \text{ mol}$$

At STP, 1 mol = 22.4 L:

$$V_{CO_2} = 0.100 \text{ mol} \times 22.4 \text{ L/mol} = 2.24 \text{ L}$$

(b) Mass of $CaCl_2$:

$$n_{CaCl_2} = 0.100 \text{ mol}$$

$$m_{CaCl_2} = 0.100 \text{ mol} \times 111.0 \text{ g/mol} = 11.1 \text{ g}$$

(c) Moles of H_2O:

$$n_{H_2O} = 0.100 \text{ mol}$$

Answer 1:

(a) 2.24 L of CO_2 at STP

(b) 11.1 g of $CaCl_2$

(c) 0.100 mol of H_2O

Problem 2

Question: 0.84 g of ammonium dichromate is decomposed according to the reaction:

$$(NH_4)_2Cr_2O_7(s) \longrightarrow N_2(g) + {}_4H_2O(g) + Cr_2O_3(s)$$

Calculate the mass of Cr_2O_3 formed.

Solution:

Step 1: Calculate molar mass of $(NH_4)_2Cr_2O_7$

$$2 \times N : 2 \times 14.0 = 28.0$$
$$8 \times H : 8 \times 1.0 = 8.0$$
$$2 \times Cr : 2 \times 52.0 = 104.0$$
$$7 \times O : 7 \times 16.0 = 112.0$$
$$\text{Total} = 28.0 + 8.0 + 104.0 + 112.0 = 252.0 \text{ g/mol}$$

Step 2: Calculate moles of $(NH_4)_2Cr_2O_7$

$$n = \frac{0.84 \text{ g}}{252.0 \text{ g/mol}} = 0.00333 \text{ mol}$$

Step 3: Stoichiometry to find moles of Cr_2O_3 From the equation: 1 mol $(NH_4)_2Cr_2O_7 \rightarrow$ 1 mol Cr_2O_3

$$n_{Cr_2O_3} = 0.00333 \text{ mol}$$

Step 4: Calculate mass of Cr_2O_3

$$M_{Cr_2O_3} = 2(52.0) + 3(16.0) = 104.0 + 48.0 = 152.0 \text{ g/mol}$$

$$m_{Cr_2O_3} = 0.00333 \text{ mol} \times 152.0 \text{ g/mol} = 0.506 \text{ g}$$

Answer 2:

0.506 g of Cr_2O_3

Problem 3

Question: Calculate the mass of solid product obtained when 16.8 g of $NaHCO_3$ was strongly heated until there was no further change.

Solution:

Step 1: Write the decomposition reaction

$$_2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

Step 2: Calculate molar masses

$$M_{NaHCO_3} = 23.0 + 1.0 + 12.0 + 48.0 = 84.0 \text{ g/mol}$$
$$M_{Na_2CO_3} = 2(23.0) + 12.0 + 48.0 = 106.0 \text{ g/mol}$$

Step 3: Calculate moles of $NaHCO_3$

$$n_{NaHCO_3} = \frac{16.8 \text{ g}}{84.0 \text{ g/mol}} = 0.200 \text{ mol}$$

Step 4: Stoichiometry to find moles of Na_2CO_3 From the equation: 2 mol $NaHCO_3$ → 1 mol Na_2CO_3

$$n_{Na_2CO_3} = \frac{0.200 \text{ mol}}{2} = 0.100 \text{ mol}$$

Step 5: Calculate mass of Na_2CO_3

$$m_{Na_2CO_3} = 0.100 \text{ mol} \times 106.0 \text{ g/mol} = 10.6 \text{ g}$$

Answer 3:

10.6 g of Na_2CO_3

Problem 4

Question: In an experiment, 10 mL of ethane was burnt in 50 mL of oxygen.

(a) Which gas was supplied in excess?

(b) Calculate the volume of the excess gas remaining at the end of the reaction

(c) Calculate the volume of CO_2 produced

Solution:

Step 1: Write the balanced combustion reaction

$$_2C_2H_6(g) + _7O_2(g) \longrightarrow _4CO_2(g) + _6H_2O(g)$$

Step 2: Use volume ratios (at constant T and P) From the equation: 2 volumes C_2H_6 → 7 volumes O_2 → 4 volumes CO_2

Step 3: Calculate required O_2 for 10 mL C_2H_6

$$V_{O_2\text{required}} = 10 \text{ mL} \times \frac{7}{2} = 35 \text{ mL}$$

(a) Identify excess gas: Given $V_{O_2\text{supplied}} = 50$ mL, required = 35 mL

$$O_2 \text{ is in excess}$$

(b) Calculate excess O_2 remaining:

$$V_{O_2\text{excess}} = 50 \text{ mL} - 35 \text{ mL} = 15 \text{ mL}$$

(c) Calculate volume of CO_2 produced:

$$V_{CO_2} = 10 \text{ mL} \times \frac{4}{2} = 20 \text{ mL}$$

Answer 4:

(a) O_2 was in excess

(b) 15 mL of O_2 remaining

(c) 20 mL of CO_2 produced

Problem 5

Question: Aluminum metal reacts rapidly with aqueous sulfuric acid to produce aqueous aluminum sulfate and hydrogen gas. Determine the volume of hydrogen gas produced at STP when a 2.00 g piece of aluminum completely reacts.

Solution:

Step 1: Write the balanced reaction

$$_2Al(s) + _3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + _3H_2(g)$$

Step 2: Calculate moles of Al

$$M_{\text{Al}} = 27.0 \text{ g/mol}$$

$$n_{\text{Al}} = \frac{2.00 \text{ g}}{27.0 \text{ g/mol}} = 0.0741 \text{ mol}$$

Step 3: Stoichiometry to find moles of H_2 From the equation: 2 mol Al $\rightarrow$ 3 mol H_2

$$n_{\text{H}_2} = 0.0741 \text{ mol} \times \frac{3}{2} = 0.111 \text{ mol}$$

Step 4: Calculate volume at STP

$$V_{\text{H}_2} = 0.111 \text{ mol} \times 22.4 \text{ L/mol} = 2.49 \text{ L}$$

Answer 5:

2.49 L of H_2 at STP

Problem 6

Question: Calcium oxide is used to remove sulfur dioxide generated in coal-burning power plants to produce $CaSO_4$. What mass of calcium oxide is required to react completely with 1.4×10^3 L of sulfur dioxide?

Solution:

Step 1: Write the balanced reaction

$$\text{CaO(s)} + \text{SO}_2\text{(g)} \longrightarrow \text{CaSO}_4\text{(s)}$$

Step 2: Calculate moles of SO_2 At STP: 1.4×10^3 L = 1400 L

$$n_{\text{SO}_2} = \frac{1400 \text{ L}}{22.4 \text{ L/mol}} = 62.5 \text{ mol}$$

Step 3: Stoichiometry to find moles of CaO From the equation: 1 mol SO_2 $\rightarrow$ 1 mol CaO

$$n_{\text{CaO}} = 62.5 \text{ mol}$$

Step 4: Calculate mass of CaO

$$M_{\text{CaO}} = 40.0 + 16.0 = 56.0 \text{ g/mol}$$

$$m_{\text{CaO}} = 62.5 \text{ mol} \times 56.0 \text{ g/mol} = 3500 \text{ g} = 3.50 \text{ kg}$$

Answer 6:

3.50 kg of CaO

Problem 7

Question: Balance the equation and calculate the volume of O_2 required to produce 75.0 g of P_2O_5 at STP.

$$P_4 + O_2 \longrightarrow P_2O_5$$

Solution:

Step 1: Balance the equation

$$P_4 + {}_5O_2 \longrightarrow {}_2P_2O_5$$

Step 2: Calculate molar mass of P_2O_5

$$M_{P_2O_5} = 2(31.0) + 5(16.0) = 62.0 + 80.0 = 142.0 \text{ g/mol}$$

Step 3: Calculate moles of P_2O_5

$$n_{P_2O_5} = \frac{75.0 \text{ g}}{142.0 \text{ g/mol}} = 0.528 \text{ mol}$$

Step 4: Stoichiometry to find moles of O_2 From the equation: 2 mol P_2O_5 $\rightarrow$ 5 mol O_2

$$n_{O_2} = 0.528 \text{ mol} \times \frac{5}{2} = 1.32 \text{ mol}$$

Step 5: Calculate volume at STP

$$V_{O_2} = 1.32 \text{ mol} \times 22.4 \text{ L/mol} = 29.6 \text{ L}$$

Answer 7:

Balanced equation: $P_4 + {}_5O_2 \longrightarrow {}_2P_2O_5$
29.6 L of O_2 at STP

Problem 8

Question: Oxygen gas is sometimes prepared in labs by the thermal decomposition of potassium chlorate ($KClO_3$). The balanced chemical equation is:

$${}_2KClO_3(s) \longrightarrow {}_2KCl(s) + {}_3O_2(g)$$

If 5.150 grams decompose, what volume of O_2 would be obtained at STP?

Solution:

Step 1: Calculate molar mass of $KClO_3$

$$M_{KClO_3} = 39.0 + 35.5 + 3(16.0) = 39.0 + 35.5 + 48.0 = 122.5 \text{ g/mol}$$

Step 2: Calculate moles of $KClO_3$

$$n_{KClO_3} = \frac{5.150 \text{ g}}{122.5 \text{ g/mol}} = 0.04204 \text{ mol}$$

Step 3: Stoichiometry to find moles of O_2 From the equation: 2 mol $KClO_3 \rightarrow$ 3 mol O_2

$$n_{O_2} = 0.04204 \text{ mol} \times \frac{3}{2} = 0.06306 \text{ mol}$$

Step 4: Calculate volume at STP

$$V_{O_2} = 0.06306 \text{ mol} \times 22.4 \text{ L/mol} = 1.412 \text{ L}$$

Answer 8:

1.41 L of O_2 at STP