

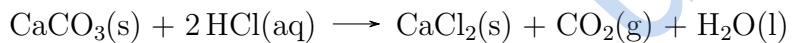
# CHM 101 Holiday Assignment Stoichiometry Problems with Solutions

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## Problem 1

**Question:** The following reaction was carried out:



If 10.0 grams of  $\text{CaCO}_3$  was used, calculate:

- (a) The volume of  $\text{CO}_2$  (at STP) produced from the complete reaction
- (b) The mass of  $\text{CaCl}_2$  produced
- (c) How many moles of  $\text{H}_2\text{O}$  was produced

**Solution:**

**Step 1: Calculate molar masses**

$$M_{\text{CaCO}_3} = 40.0 + 12.0 + 3(16.0) = 100.0 \text{ g/mol}$$

$$M_{\text{CaCl}_2} = 40.0 + 2(35.5) = 111.0 \text{ g/mol}$$

$$M_{\text{CO}_2} = 12.0 + 2(16.0) = 44.0 \text{ g/mol}$$

$$M_{\text{H}_2\text{O}} = 2(1.0) + 16.0 = 18.0 \text{ g/mol}$$

**Step 2: Calculate moles of  $\text{CaCO}_3$**

$$n_{\text{CaCO}_3} = \frac{10.0 \text{ g}}{100.0 \text{ g/mol}} = 0.100 \text{ mol}$$

**Step 3: Use stoichiometry ratios (from balanced equation)** From the balanced equation:  $1 \text{ mol CaCO}_3 \rightarrow 1 \text{ mol CO}_2 \rightarrow 1 \text{ mol CaCl}_2 \rightarrow 1 \text{ mol H}_2\text{O}$

**(a) Volume of  $\text{CO}_2$  at STP:**

$$n_{\text{CO}_2} = 0.100 \text{ mol}$$

At STP, 1 mol = 22.4 L:

$$V_{\text{CO}_2} = 0.100 \text{ mol} \times 22.4 \text{ L/mol} = 2.24 \text{ L}$$

(b) Mass of  $\text{CaCl}_2$ :

$$n_{\text{CaCl}_2} = 0.100 \text{ mol}$$

$$m_{\text{CaCl}_2} = 0.100 \text{ mol} \times 111.0 \text{ g/mol} = 11.1 \text{ g}$$

(c) Moles of  $\text{H}_2\text{O}$ :

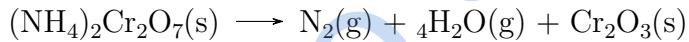
$$n_{\text{H}_2\text{O}} = 0.100 \text{ mol}$$

**Answer 1:**

- (a) 2.24 L of  $\text{CO}_2$  at STP
- (b) 11.1 g of  $\text{CaCl}_2$
- (c) 0.100 mol of  $\text{H}_2\text{O}$

**Problem 2**

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



Calculate the mass of  $\text{Cr}_2\text{O}_3$  formed.

**Solution:**

**Step 1: Calculate molar mass of  $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$**

$$2 \times N : 2 \times 14.0 = 28.0$$

$$8 \times H : 8 \times 1.0 = 8.0$$

$$2 \times Cr : 2 \times 52.0 = 104.0$$

$$7 \times O : 7 \times 16.0 = 112.0$$

$$\text{Total} = 28.0 + 8.0 + 104.0 + 112.0 = 252.0 \text{ g/mol}$$

**Step 2: Calculate moles of  $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$**

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

**Step 3: Stoichiometry to find moles of  $\text{Cr}_2\text{O}_3$**  From the equation: 1 mol  $(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \rightarrow$  1 mol  $\text{Cr}_2\text{O}_3$

$$n_{\text{Cr}_2\text{O}_3} = 0.00333 \text{ mol}$$

**Step 4: Calculate mass of  $\text{Cr}_2\text{O}_3$**

$$M_{\text{Cr}_2\text{O}_3} = 2(52.0) + 3(16.0) = 104.0 + 48.0 = 152.0 \text{ g/mol}$$

$$m_{\text{Cr}_2\text{O}_3} = 0.00333 \text{ mol} \times 152.0 \text{ g/mol} = 0.506 \text{ g}$$

## Answer 2:

0.506 g of  $\text{Cr}_2\text{O}_3$

## Problem 3

**Question:** Calculate the mass of solid product obtained when 16.8 g of  $\text{NaHCO}_3$  was strongly heated until there was no further change.

### Solution:

#### Step 1: Write the decomposition reaction



#### Step 2: Calculate molar masses

$$M_{\text{NaHCO}_3} = 23.0 + 1.0 + 12.0 + 48.0 = 84.0 \text{ g/mol}$$

$$M_{\text{Na}_2\text{CO}_3} = 2(23.0) + 12.0 + 48.0 = 106.0 \text{ g/mol}$$

#### Step 3: Calculate moles of $\text{NaHCO}_3$

$$n_{\text{NaHCO}_3} = \frac{16.8 \text{ g}}{84.0 \text{ g/mol}} = 0.200 \text{ mol}$$

**Step 4: Stoichiometry to find moles of  $\text{Na}_2\text{CO}_3$**  From the equation: 2 mol  $\text{NaHCO}_3 \rightarrow$  1 mol  $\text{Na}_2\text{CO}_3$

$$n_{\text{Na}_2\text{CO}_3} = \frac{0.200 \text{ mol}}{2} = 0.100 \text{ mol}$$

#### Step 5: Calculate mass of $\text{Na}_2\text{CO}_3$

$$m_{\text{Na}_2\text{CO}_3} = 0.100 \text{ mol} \times 106.0 \text{ g/mol} = 10.6 \text{ g}$$

## Answer 3:

10.6 g of  $\text{Na}_2\text{CO}_3$

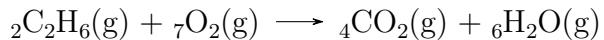
## Problem 4

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

- Which gas was supplied in excess?
- Calculate the volume of the excess gas remaining at the end of the reaction
- Calculate the volume of  $\text{CO}_2$  produced

## Solution:

**Step 1: Write the balanced combustion reaction**



**Step 2: Use volume ratios (at constant T and P)** From the equation: 2 volumes  $\text{C}_2\text{H}_6 \rightarrow$  7 volumes  $\text{O}_2 \rightarrow$  4 volumes  $\text{CO}_2$

**Step 3: Calculate required  $\text{O}_2$  for 10 mL  $\text{C}_2\text{H}_6$**

$$V_{\text{O}_2\text{required}} = 10 \text{ mL} \times \frac{7}{2} = 35 \text{ mL}$$

**(a) Identify excess gas:** Given  $V_{\text{O}_2\text{supplied}} = 50 \text{ mL}$ , required = 35 mL

$\text{O}_2$  is in excess

**(b) Calculate excess  $\text{O}_2$  remaining:**

$$V_{\text{O}_2\text{excess}} = 50 \text{ mL} - 35 \text{ mL} = 15 \text{ mL}$$

**(c) Calculate volume of  $\text{CO}_2$  produced:**

$$V_{\text{CO}_2} = 10 \text{ mL} \times \frac{4}{2} = 20 \text{ mL}$$

## Answer 4:

- (a)  $\text{O}_2$  was in excess
- (b) 15 mL of  $\text{O}_2$  remaining
- (c) 20 mL of  $\text{CO}_2$  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**



### 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<sub>2</sub>** From the equation: 2 mol Al  $\rightarrow$  3 mol H<sub>2</sub>

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

### 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:

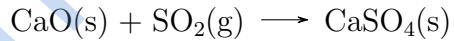
2.49 L of H<sub>2</sub> at STP

## Problem 6

**Question:** Calcium oxide is used to remove sulfur dioxide generated in coal-burning power plants to produce CaSO<sub>4</sub>. What mass of calcium oxide is required to react completely with  $1.4 \times 10^3$  L of sulfur dioxide?

### Solution:

#### Step 1: Write the balanced reaction



**Step 2: Calculate moles of SO<sub>2</sub>** At STP:  $1.4 \times 10^3 \text{ L} = 1400 \text{ L}$

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

**Step 3: Stoichiometry to find moles of CaO** From the equation: 1 mol SO<sub>2</sub>  $\rightarrow$  1 mol CaO

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

### Step 4: Calculate mass of CaO

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

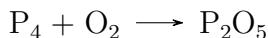
$$m_{\text{CaO}} = 62.5 \text{ mol} \times 56.0 \text{ g/mol} = 3500 \text{ g} = 3.50 \text{ kg}$$

### Answer 6:

3.50 kg of CaO

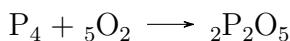
### Problem 7

**Question:** Balance the equation and calculate the volume of O<sub>2</sub> required to produce 75.0 g of P<sub>2</sub>O<sub>5</sub> at STP.



#### Solution:

##### Step 1: Balance the equation



##### Step 2: Calculate molar mass of P<sub>2</sub>O<sub>5</sub>

$$M_{\text{P}_2\text{O}_5} = 2(31.0) + 5(16.0) = 62.0 + 80.0 = 142.0 \text{ g/mol}$$

##### Step 3: Calculate moles of P<sub>2</sub>O<sub>5</sub>

$$n_{\text{P}_2\text{O}_5} = \frac{75.0 \text{ g}}{142.0 \text{ g/mol}} = 0.528 \text{ mol}$$

**Step 4: Stoichiometry to find moles of O<sub>2</sub>** From the equation: 2 mol P<sub>2</sub>O<sub>5</sub> → 5 mol O<sub>2</sub>

$$n_{\text{O}_2} = 0.528 \text{ mol} \times \frac{5}{2} = 1.32 \text{ mol}$$

##### Step 5: Calculate volume at STP

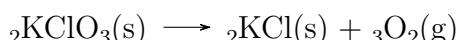
$$V_{\text{O}_2} = 1.32 \text{ mol} \times 22.4 \text{ L/mol} = 29.6 \text{ L}$$

### Answer 7:

Balanced equation:  $\text{P}_4 + 5\text{O}_2 \longrightarrow 2\text{P}_2\text{O}_5$   
29.6 L of O<sub>2</sub> at STP

### Problem 8

**Question:** Oxygen gas is sometimes prepared in labs by the thermal decomposition of potassium chlorate (KClO<sub>3</sub>). The balanced chemical equation is:



If 5.150 grams decompose, what volume of O<sub>2</sub> would be obtained at STP?

**Solution:**

**Step 1: Calculate molar mass of  $\text{KClO}_3$**

$$M_{\text{KClO}_3} = 39.0 + 35.5 + 3(16.0) = 39.0 + 35.5 + 48.0 = 122.5 \text{ g/mol}$$

**Step 2: Calculate moles of  $\text{KClO}_3$**

$$n_{\text{KClO}_3} = \frac{5.150 \text{ g}}{122.5 \text{ g/mol}} = 0.04204 \text{ mol}$$

**Step 3: Stoichiometry to find moles of  $\text{O}_2$**  From the equation: 2 mol  $\text{KClO}_3 \rightarrow$  3 mol  $\text{O}_2$

$$n_{\text{O}_2} = 0.04204 \text{ mol} \times \frac{3}{2} = 0.06306 \text{ mol}$$

**Step 4: Calculate volume at STP**

$$V_{\text{O}_2} = 0.06306 \text{ mol} \times 22.4 \text{ L/mol} = 1.412 \text{ L}$$

**Answer 8:**

1.41 L of  $\text{O}_2$  at STP