Chemistry 11

Stoichiometry IV

Name: Key
Date:
Block:

1. Limiting & Excess Reactants

Limiting & Excess

To make 36 cookies, 20 muffins and 1 loaf of banana bread, it requires:

- 6 eggs
- 8 cups of flour
- 3 cups of butter
- 5 bananas

What is the balanced reaction?

$6\text{ eggs} + 8\text{ flour} + 3\text{ butter} + 5\text{ bananas} \rightarrow 36\text{ cookies} + 20\text{ muffins} + 1\text{ banana bread}$

How many cookies could you make if you had 6 cups of flour and 6 eggs and 1 cup of butter?

With 6 cups of flour...

$$6\text{ cups of flour} \times \frac{36\text{ cookies}}{8\text{ flour}} = 27\text{ cookies}$$

With 6 eggs...

$$6\text{ eggs} \times \frac{36\text{ cookies}}{6\text{ eggs}} = 36\text{ cookies}$$

With 1 cup of butter...

$$1\text{ cup butter} \times \frac{36\text{ cookies}}{3\text{ cups butter}} = 12\text{ cookies}$$

The limiting ingredient is:

butter

The ingredients you have left over are: flour, eggs

How many muffins could you make if you had 12.5 cups of flour and 8 eggs and 5 cups of butter?

$$12.5\text{ cups flour} \times \frac{20\text{ muffins}}{8\text{ cups flour}} = 31.25 = 31\text{ muffins.}$$

$$8\text{ eggs} \times \frac{20\text{ muffins}}{6\text{ eggs}} = \boxed{26\text{ muffins}}$$

$$5\text{ cups butter} \times \frac{20\text{ muffins}}{3\text{ cups butter}} = 33\text{ muffins.}$$

When reactions occur, the reactants come together in proportions which do not react completely with each other, because one reactant is in excess. **We cannot tell which reactant is in excess just by looking at their masses.** We have to carry out preliminary calculations to determine the limiting reactant.

Example 1.
16.4 g of zinc and 0.300 mol of H_2SO_4 are mixed and reacted together. Hydrogen and $ZnSO_4$ are produced. What <u>volume</u> of H_2 gas is produced at standard temperature and pressure?

⇒ What is the balanced chemical equation? *What is the question asking for? What does the question give us?*

$Zn + H_2SO_4 \longrightarrow H_2 + ZnSO_4$

given 16.4g Zn
0.300mol H_2SO_4

find: L H_2?

⇒ Calculate the L of H_2 produced from 16.4 g of Zn.

$$16.4g\ Zn \times \frac{1mol\ Zn}{65.39g\ Zn} \times \frac{1mol\ H_2}{1mol\ Zn} \times \frac{22.4L\ H_2}{1mol\ H_2} = 5.62L\ H_2$$

⇒ Calculate the L of H_2 produced from 0.300 mol of H_2SO_4

$$0.300mol\ H_2SO_4 \times \frac{1mol\ H_2}{1mol\ H_2SO_4} \times \frac{22.4L\ H_2}{1mol\ H_2} = 6.72L\ H_2$$

⇒ Which is the limiting reactant?

Zn

⇒ Which is the excess reactant?

H_2SO_4

⇒ How much of the excess reactant do you have left over?

* Start with limiting reactant and convert to excess reactant to determine how much was used!

$$16.4g\ Zn \times \frac{1mol\ Zn}{65.39g\ Zn} \times \frac{1mol\ H_2SO_4}{1mol\ Zn} = 0.251mol\ H_2SO_4$$

have − used = excess

$0.300mol - 0.251mol = 0.049mol\ H_2SO_4$

Example 2.
Aluminum is burned with O_2 to give Al_2O_3. 74.0 g of aluminum are mixed and reacted with 56.0 g of O_2. What mass of aluminum oxide is produced?

⇒ Balanced reaction: *What does the question give us? What are we looking for?*

$$4\,Al + 3\,O_2 \longrightarrow 2\,Al_2O_3$$

given: 74.0 g Al
56.0 g O_2

find: ? g Al_2O_3

⇒ Calculation using 74.0 g of Al.

$$74.0\text{ g Al} \times \frac{1\text{ mol Al}}{26.98\text{ g Al}} \times \frac{2\text{ mol } Al_2O_3}{4\text{ mol Al}} \times \frac{101.96\text{ g } Al_2O_3}{1\text{ mol } Al_2O_3} = 139.8\text{ g}$$

$$= 140.\text{ g } Al_2O_3$$

⇒ Calculation using 56.0 g of O_2.

$$56.0\text{ g } O_2 \times \frac{1\text{ mol } O_2}{32.00\text{ g } O_2} \times \frac{2\text{ mol } Al_2O_3}{3\text{ mol } O_2} \times \frac{101.96\text{ g } Al_2O_3}{1\text{ mol } Al_2O_3} = \boxed{119\text{ g } Al_2O_3}$$

⇒ What is the limiting reactant?

O_2

⇒ What mass of aluminum oxide is actually produced?

119 g Al_2O_3

⇒ What is the excess reactant and how much of it is left over? Excess is Al

$$56.0\text{ g } O_2 \times \frac{1\text{ mol } O_2}{32.00\text{ g } O_2} \times \frac{4\text{ mol Al}}{3\text{ mol } O_2} \times \frac{26.98\text{ g Al}}{1\text{ mol Al}} = 63.0\text{ g Al}$$

have − used = excess

$$74.0\text{ g} - 63.0\text{ g} = \boxed{11.0\text{ g Al}}$$

Practice 1.
Balance the following equation.

$2\ VO + 3\ Fe_2O_3 \rightarrow \_\_\_\ V_2O_5 + 6\ FeO$

2.00 g of VO is reacted with 5.75 g Fe_2O_3.

a) What mass of V_2O_5 is produced? *(2.18 g V_2O_5)*

$$2.00\text{g VO} \times \frac{1\text{mol VO}}{66.94\text{g VO}} \times \frac{1\text{mol } V_2O_5}{2\text{mol VO}} \times \frac{181.88\text{g } V_2O_5}{1\text{mol } V_2O_5} = 2.72\text{g } V_2O_5$$

$$5.75\text{g } Fe_2O_3 \times \frac{1\text{mol } Fe_2O_3}{159.70\text{g } Fe_2O_3} \times \frac{1\text{mol } V_2O_5}{3\text{mol } Fe_2O_3} \times \frac{181.88\text{g } V_2O_5}{1\text{mol } V_2O_5} = \boxed{2.18\text{g } V_2O_5}$$

b) What is the excess reactant and how much of it is left over? *(0.39 g VO)*

↳ VO

$$5.75\text{g } Fe_2O_3 \times \frac{1\text{mol } Fe_2O_3}{159.70\text{g } Fe_2O_3} \times \frac{2\text{mol VO}}{3\text{mol } Fe_2O_3} \times \frac{66.94\text{g VO}}{1\text{mol VO}} = 1.61\text{g VO}$$

have − excess = used ⇒ 2.00 − 1.61 = $\boxed{0.39\text{g VO}}$

Practice 2.
45.0 g of zinc is reacted with 84.0 g of hydrochloric acid at STP:

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

a) What volume of H_2 is produced? What mass of $ZnCl_2$ is produced? *(15.4 L H_2, 93.8 g $ZnCl_2$)*

$$45.0\text{g Zn} \times \frac{1\text{mol Zn}}{65.39\text{g Zn}} \times \frac{1\text{mol } H_2}{1\text{mol Zn}} \times \frac{22.4\text{L } H_2}{1\text{mol } H_2} = \boxed{15.4\text{L } H_2}$$

$$84.0\text{g HCl} \times \frac{1\text{mol HCl}}{36.46\text{g HCl}} \times \frac{1\text{mol } H_2}{2\text{mol HCl}} \times \frac{22.4\text{L } H_2}{1\text{mol } H_2} = 25.8\text{L } H_2$$

$$45.0\text{g Zn} \times \frac{1\text{mol Zn}}{65.39\text{g Zn}} \times \frac{1\text{mol } ZnCl_2}{1\text{mol Zn}} \times \frac{136.29\text{g } ZnCl_2}{1\text{mol } ZnCl_2} = \boxed{93.8\text{g } ZnCl_2}$$

b) What is the excess reactant and how much of it is left over? *(33.8 g HCl)*

$$45.0\text{g Zn} \times \frac{1\text{mol Zn}}{65.39\text{g Zn}} \times \frac{2\text{mol HCl}}{1\text{mol Zn}} \times \frac{36.46\text{g HCl}}{1\text{mol HCl}} = 50.2\text{g HCl}$$

have − used = excess

84.0 − 50.2 = $\boxed{33.8\text{g HCl}}$