# Stoichiometry

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- Stoichiometry is the science of measuring the quantitative proportions or mass ratios in which chemicals elements stand to one another

## What is Stoichiometry?

- Stoichiometry is the part of chemistry that studies amounts of substances that are involved in reactions
- All reactions are dependent on how much stuff you have
- Stoichiometry helps you figure out how much of a compound you will need or maybe how much you started with.

- The coefficients used in all chemical equations show the relative amounts of each substance present
- This amount can represent either the relative number of molecules, or the relative number of moles
- The coefficients can also represent conservation of mass or volumes of gas

# Example 1

The reaction: $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$

a) How many moles of $NH_3$ would be produced from the reaction of 6 mol $H_2(g)$ and excess $N_2(g)$?
b) How many moles of $N_2(g)$ would be needed to react with exactly 9 mol $H_2(g)$?
c) How many moles of $H_2$ and $N_2$ would be needed to produce 0.4 mol $NH_3$?

# Ex. 1 (a)

$$\frac{6}{3}\mathrm{H}_2 = \frac{x}{2}\mathrm{NH}_3$$

$$x = \frac{6 \times 2}{3} = 4$$

## Ex. 1 (b)

$$\frac{9}{3}\mathrm{H_2} = \frac{x}{1}\mathrm{N_2}$$

$$x = \frac{9\times1}{3} = 3$$

## Ex. 1 (c)

$$\frac{x}{3}\mathrm{H_2} = \frac{0.4}{2}\mathrm{NH_3}$$

$$x = \frac{3\times0.4}{2} = 0.6$$

$$\frac{x}{1}\mathrm{N_2} = \frac{0.4}{2}\mathrm{NH_3}$$

$$x = \frac{1\times0.4}{2} = 0.2$$

## Example 2

- The reaction: $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$
- Calculate the number of moles of ammonia produced with 12.0g of hydrogen gas and an unlimited amount of nitrogen.

$$H_2 : \frac{12.0\ \text{g}}{2\ \text{g/mol}} = 6\ \text{mol}$$

$$\frac{6}{3} H_2 = \frac{x}{2} NH_3$$

$$x = 4\ \text{mol}$$

## Example 3

- The reaction: $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$
- Calculate the mass of ammonia produced from 1.2g of hydrogen gas reacting with an excess of nitrogen.

$$H_2 : \frac{1.2\ \text{g}}{2\ \text{g/mol}} = 0.6\ \text{mol} \qquad \frac{0.6}{3} H_2 = \frac{x}{2} NH_3$$

$$x = 0.4\ \text{mol}$$

$$NH_3 = (14\ \text{g}) + 3(1\ \text{g}) = 17\ \text{g/mol}$$

$$0.4\ \text{mol}(17\ \text{g/mol}) = 6.8\ \text{g}$$

# Example 4

- If 34.6g of Zn are reacted with an excess of hydrochloric acid at standard pressure, what is the temperature of the hydrogen gas produced if it occupies a 2.00 L container?

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

$$\mathrm{Zn}: \frac{34.6\ \mathrm{g}}{65.4\ \mathrm{g/mol}} = 0.53\ \mathrm{mol} \qquad \frac{0.53}{1}\mathrm{Zn} = \frac{x}{1}\mathrm{H_2}$$

$$x = 0.53\mathrm{mol}$$

$$\text{at STP} \quad 1\ \mathrm{mol} = 22.4\ \mathrm{L}$$

$$0.53\ \mathrm{mol} = x$$

$$x = 11.872\ \mathrm{L}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(1\ \mathrm{atm})(11.872\ \mathrm{L})}{273\ \mathrm{K}} = \frac{(1\ \mathrm{atm})(2.00\ \mathrm{L})}{T_2}$$

$$T = 46\ \mathrm{K} = -227°\mathrm{C}$$

# Example 5

- What quantity of heat is produced in the complete combustion of 60.16 g of ethane, $C_2H_6$, if the heat of combustion is 1560 kJ/mol of ethane?

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

$C_2H_6$: 2(12 g) + 6(1.01 g) = 30.06 g/mol

$$C_2H_6 : \frac{60.16\ \text{g}}{30.06\ \text{g/mol}} = 2.0\ \text{mol}$$

$$\begin{aligned} 1\ \text{mol} &= 1560\ \text{kJ} \\ 2.0\ \text{mol} &= x \\ x &= 3120\ \text{kJ} \end{aligned}$$

# Limiting Reactants

- A recipe for 2 dozen cookies requires ½ cup of butter and 3 cups of flour
- If you have 1 cup of butter and 8 cups of flour, how many cookies can you make?
  - 4 dozen
  - You are **limited** by the amount of butter that you have

- In chemical reactions, the same is true
- We are limited to the amount of products we get by the amount of reactants that we have
- Usually, one of those reactants will control how much product is produced
- This reactant is known as the **limiting reactant** (or reagent)
  - Note: this is not necessarily the reactant with the smallest number of moles

# Example 1

- The reaction: $C_3H_8 + 10O_2 \rightarrow 3CO_2 + 4H_2O$
- If we start with 14.8g of $C_3H_8$ and 3.44g of $O_2$, determine the limiting reactant.

$$C_3H_8 : \frac{14.8\ \text{g}}{44.08\ \text{g/mol}} = 0.3358\ \text{mol} \qquad O_2 : \frac{3.44\ \text{g}}{32\ \text{g/mol}} = 0.1075\ \text{mol}$$

$$\frac{0.3358}{1} C_3H_8 = \frac{x}{10} O_2$$

$$x = 3.358\ \text{mol}$$

Since we only have 0.1075 mol $O_2$, $O_2$ is the limiting reactant

## Example 2

- The reaction: $4Al_2O_3 + 9Fe \rightarrow 3Fe_3O_4 + 8Al$
- If 25.4g of $Al_2O_3$ is reacted with 40.2g of Fe, determine the limiting reactant.

$$Al_2O_3 : \frac{25.4\text{ g}}{102\text{ g/mol}} = 0.249\text{ mol} \qquad Fe : \frac{40.2\text{ g}}{55.8\text{ g/mol}} = 0.720\text{ mol}$$

$$\frac{0.249}{4} Al_2O_3 = \frac{x}{9} Fe$$

$$x = 0.560\text{ mol}$$

Since we have 0.720 mol Fe, $Al_2O_3$ is the limiting reactant

## Note

- The limiting reactant is used to determine the amount of products that are produced.