

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: $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$

- How many moles of NH_3 would be produced from the reaction of 6 mol $\text{H}_2(\text{g})$ and excess $\text{N}_2(\text{g})$?
- How many moles of $\text{N}_2(\text{g})$ would be needed to react with exactly 9 mol $\text{H}_2(\text{g})$?
- How many moles of H_2 and N_2 would be needed to produce 0.4 mol NH_3 ?

Ex. 1 (a)

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

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

Ex. 1 (b)

$$\frac{9}{3}\text{H}_2 = \frac{x}{1}\text{N}_2$$

$$x = \frac{9 \times 1}{3} = 3$$

Ex. 1 (c)

$$\frac{x}{3}\text{H}_2 = \frac{0.4}{2}\text{NH}_3$$

$$x = \frac{3 \times 0.4}{2} = 0.6$$

$$\frac{x}{1}\text{N}_2 = \frac{0.4}{2}\text{NH}_3$$

$$x = \frac{1 \times 0.4}{2} = 0.2$$

Example 2

- The reaction: $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$
- Calculate the number of moles of ammonia produced with 12.0g of hydrogen gas and an unlimited amount of nitrogen.

$$\text{H}_2 : \frac{12.0 \text{ g}}{2 \text{ g/mol}} = 6 \text{ mol} \qquad \frac{6}{3} \text{H}_2 = \frac{x}{2} \text{NH}_3$$

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

Example 3

- The reaction: $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$
- Calculate the mass of ammonia produced from 1.2g of hydrogen gas reacting with an excess of nitrogen.

$$\text{H}_2 : \frac{1.2 \text{ g}}{2 \text{ g/mol}} = 0.6 \text{ mol} \quad \frac{0.6}{3} \text{H}_2 = \frac{x}{2} \text{NH}_3$$

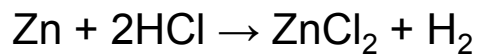
$$x = 0.4 \text{ mol}$$

$$\text{NH}_3 = (14 \text{ g}) + 3(1 \text{ g}) = 17 \text{ g/mol}$$

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

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?



$$\text{Zn} : \frac{34.6 \text{ g}}{65.4 \text{ g/mol}} = 0.53 \text{ mol} \qquad \frac{0.53}{1} \text{ Zn} = \frac{x}{1} \text{ H}_2$$

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

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

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

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

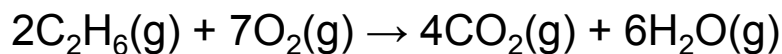
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

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

$$T = 46 \text{ K} = -227^\circ\text{C}$$

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?



$$\text{C}_2\text{H}_6: 2(12 \text{ g}) + 6(1.01 \text{ g}) = 30.06 \text{ g/mol}$$

$$\text{C}_2\text{H}_6: \frac{60.16 \text{ g}}{30.06 \text{ g/mol}} = 2.0 \text{ mol}$$

$$1 \text{ mol} = 1560 \text{ kJ}$$

$$2.0 \text{ mol} = x$$

$$x = 3120 \text{ kJ}$$

Limiting Reactants

- A recipe for 2 dozen cookies requires $\frac{1}{2}$ 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: $\text{C}_3\text{H}_8 + 10\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$
- If we start with 14.8g of C_3H_8 and 3.44g of O_2 , determine the limiting reactant.

$$\text{C}_3\text{H}_8 : \frac{14.8 \text{ g}}{44.08 \text{ g/mol}} = 0.3358 \text{ mol} \quad \text{O}_2 : \frac{3.44 \text{ g}}{32 \text{ g/mol}} = 0.1075 \text{ mol}$$

$$\frac{0.3358}{1} \text{C}_3\text{H}_8 = \frac{x}{10} \text{O}_2$$

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

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

Example 2

- The reaction: $4\text{Al}_2\text{O}_3 + 9\text{Fe} \rightarrow 3\text{Fe}_3\text{O}_4 + 8\text{Al}$
- If 25.4g of Al_2O_3 is reacted with 40.2g of Fe, determine the limiting reactant.

$$\text{Al}_2\text{O}_3 : \frac{25.4 \text{ g}}{102 \text{ g/mol}} = 0.249 \text{ mol} \quad \text{Fe} : \frac{40.2 \text{ g}}{55.8 \text{ g/mol}} = 0.720 \text{ mol}$$

$$\frac{0.249}{4} \text{Al}_2\text{O}_3 = \frac{x}{9} \text{Fe}$$

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

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.