

Unit 7 Stoichiometry

Stoichiometry- calculating quantities in a chemical reaction.



particles (atoms) 2 + 2 = 4

mass (molar) 2g + 254g = 256g

molar volume 22.4L + 22.4L = 44.8L

moles 1 + 1 = 2



particles (atoms) 2 + 6 = 8

mass (molar) 28g + 6g = 34g

molar volume 22.4L + 67.2L \neq 44.8L

moles 1 + 3 \neq 2

Note: only mass and particles (number of atoms) are conserved in ALL reactions.



moles 1 + 1 = 2

mole ratios $\frac{1 \text{ mol H}_2}{1 \text{ mol I}_2}$ or $\frac{2 \text{ mol HI}}{1 \text{ mol H}_2}$ or $\frac{1 \text{ mol I}_2}{2 \text{ mol HI}}$



moles 1 + 3 ≠ 2

mole ratios $\frac{1 \text{ mol N}_2}{3 \text{ mol H}_2}$ or $\frac{2 \text{ mol NH}_3}{1 \text{ mol N}_2}$ or $\frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3}$

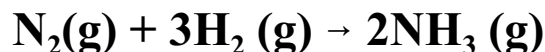
Problem:

How many moles of H_2 are needed to produce 6 moles of NH_3 ?

$$\frac{6 \text{ mol NH}_3}{1} \times \frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3} = 9 \text{ mol H}_2$$

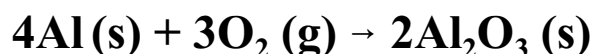
Unit 7 Stoichiometry More sample problems

Example 1. How many moles of ammonia are produced when 0.6 moles of nitrogen reacts with hydrogen?



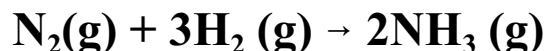
$$\frac{0.6 \text{ mol } \cancel{\text{N}_2}}{\cancel{1 \text{ mol } \text{N}_2}} \times \frac{2 \text{ mol NH}_3}{3 \text{ mol } \cancel{\text{H}_2}} = 1.2 \text{ mol NH}_3$$

Example 2. How many moles of aluminum are needed to form 3.7 moles of aluminum trioxide?



$$\frac{3.7 \text{ mol } \cancel{\text{Al}_2\text{O}_3}}{\cancel{2 \text{ mol } \text{Al}_2\text{O}_3}} \times \frac{4 \text{ mol Al}}{3 \text{ mol } \cancel{\text{O}_2}} = 7.4 \text{ mol Al}$$

Example 3. Calculate the number of grams of ammonia produced by the reaction of 5.4 g of hydrogen with an excess of nitrogen.



Step 1. Convert grams to moles.

$$\frac{5.4 \text{ g } \cancel{\text{H}_2}}{\cancel{2 \text{ gram } \text{H}_2}} \times \frac{1 \text{ mol H}_2}{2 \text{ gram } \cancel{\text{H}_2}} = 2.7 \text{ moles H}_2$$

Step 2. Convert moles reactant to moles product.

$$\frac{2.7 \text{ mol } \cancel{\text{H}_2}}{\cancel{3 \text{ mol } \text{H}_2}} \times \frac{2 \text{ mol NH}_3}{3 \text{ mol } \cancel{\text{H}_2}} = 1.8 \text{ mol NH}_3$$

Step 3. Convert moles back to grams.

$$\frac{1.8 \text{ mol } \cancel{\text{NH}_3}}{\cancel{1 \text{ mol } \text{NH}_3}} \times \frac{17 \text{ g NH}_3}{1 \text{ mol } \cancel{\text{NH}_3}} = 31 \text{ g NH}_3$$

Example 4. How many molecules of oxygen are produced when a sample of 29.2g of water is decomposed by electrolysis?



Step 1. Convert grams to moles.

$$\frac{29.2 \text{ g H}_2\text{O}}{18 \text{ g H}_2\text{O}} \times \frac{1 \text{ mole H}_2\text{O}}{1} = 1.62 \text{ mol H}_2\text{O}$$

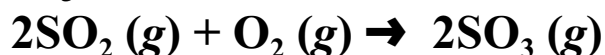
Step 2. Convert moles reactant to moles product.

$$\frac{1.62 \text{ mol H}_2\text{O}}{2 \text{ mol H}_2\text{O}} \times \frac{1 \text{ mole O}_2}{1} = 0.81 \text{ mol O}_2$$

Step 3. Convert moles product to molecules product.

$$\frac{0.81 \text{ mol O}_2}{1 \text{ mol O}_2} \times \frac{6.02 \times 10^{23} \text{ molecules O}_2}{1} = 4.9 \times 10^{23} \text{ molecules O}_2$$

Example 5. Assuming STP, how many liters of oxygen are needed to produce 19.8 liters SO₃ ?



Step 1. Convert volume to moles

$$\frac{19.8 \text{ l SO}_3}{22.4 \text{ l}} \times \frac{1 \text{ mol}}{1} = 0.884 \text{ mol SO}_3$$

Step 2. Convert moles product to moles reactant

$$\frac{0.884 \text{ mol SO}_3}{2 \text{ mol SO}_3} \times \frac{1 \text{ mol O}_2}{1} = 0.442 \text{ mol O}_2$$

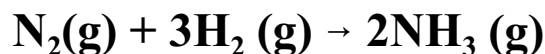
Step 3. Convert moles to volume

$$\frac{0.442 \text{ mol O}_2}{1 \text{ mol}} \times \frac{22.4 \text{ l}}{1} = 9.9 \text{ l O}_2$$

Example Problems done in one line/one step

Example 3.

Calculate the number of grams of ammonia produced by the reaction of 5.4 g of hydrogen with an excess of nitrogen.



$$\frac{5.4 \text{ g H}_2}{1} \times \frac{1 \text{ mol H}_2}{2 \text{ gram H}_2} \times \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} \times \frac{17 \text{ g NH}_3}{1 \text{ mol NH}_3} = 31 \text{ g NH}_3$$

Example 4.

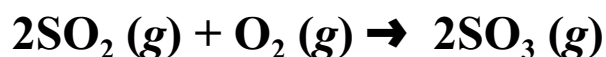
How many molecules of oxygen are produced when a sample of 29.2 g of water is decomposed by electrolysis?



$$\frac{29.2 \text{ g H}_2\text{O}}{1} \times \frac{1 \text{ mole H}_2\text{O}}{18 \text{ g H}_2\text{O}} \times \frac{1 \text{ mole O}_2}{2 \text{ mol H}_2\text{O}} \times \frac{6.02 \times 10^{23} \text{ molecules O}_2}{1 \text{ mol O}_2} = 4.9 \times 10^{23} \text{ molecules O}_2$$

Example 5.

Assuming STP, how many liters of oxygen are needed to produce 19.8 liters SO₃?



$$\frac{19.8 \text{ l SO}_3}{1} \times \frac{1 \text{ mol}}{22.4 \text{ l}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol SO}_3} \times \frac{22.4 \text{ l}}{1 \text{ mol}} = 9.9 \text{ l O}_2$$

Limiting Reagent and Percent Yield

Theoretical yield- amount of product (maximum) that could be formed in a reaction.

Actual yield- how much product is actually produced.

Percent yield- how much product is produced compared to how much was expected.

$$\text{Percent Yield} = \frac{(\text{Actual yield})}{(\text{Theoretical yield})} \times 100$$

Limiting Reagent- the first substance used up in an experiment; i.e. completely reacted.

Excess reagent- the substance left over in an experiment, i.e. did not completely react.

Example Problem: If we start with 6.70 mol Na and 3.20 mol Cl₂ what is the limiting reagent?



$$\frac{6.70 \text{ mol Na}}{\quad} \times \frac{1 \text{ mol Cl}_2}{2 \text{ mol Na}} = 3.35 \text{ mol Cl}_2$$

Since 3.35 mol Cl₂ is required to react with 6.70 mol Na, Cl₂ is the limiting reagent and Na is the excess reagent.

$$\frac{3.20 \text{ mol Cl}_2}{\quad} \times \frac{2 \text{ mol Na}}{1 \text{ mol Cl}_2} = 6.40 \text{ mol Na}$$

Since Cl₂ is limiting, the theoretical yield is 6.40 mol NaCl = 374.4g.

If only 337g was produced, what is the percent yield?

$$\text{Percent Yield} = \frac{337\text{g}}{374.4\text{g}} \times 100 = 90\%$$