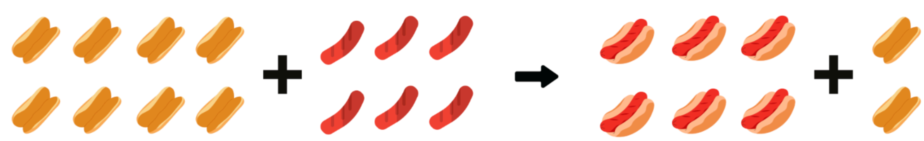
Limiting Reagents Stoichiometry

What is a Limiting Reagent?

- The limiting reagent is the reactant that gets used up first in a chemical reaction.
- It limits how much product can be formed.

Analogy

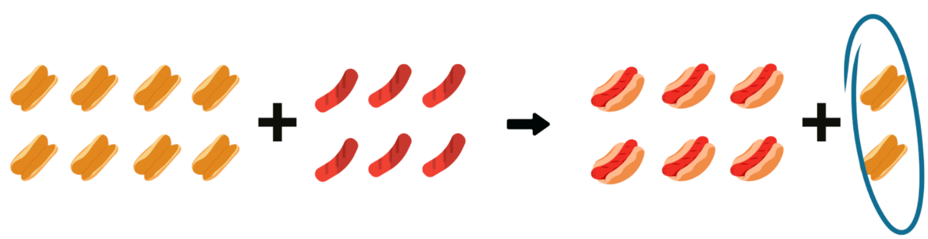
- You have 8 buns and 6 wieners. How many hot dogs can you make?



- What's the limiting reagent?
  - Wieners

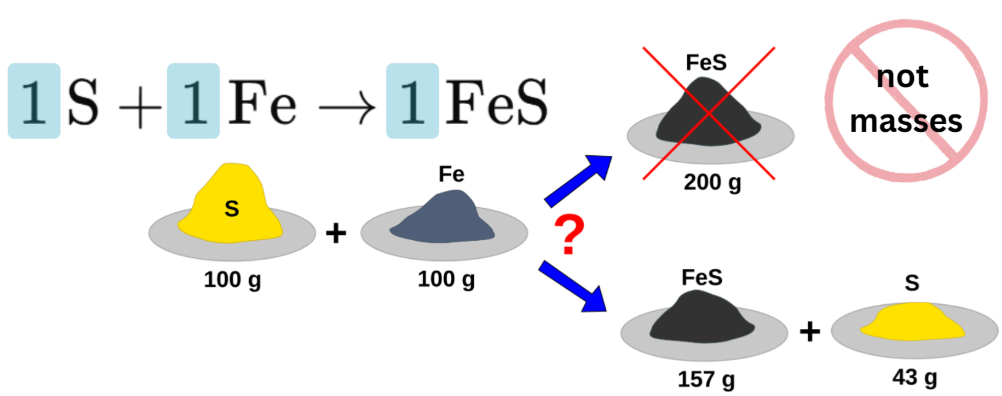
What is an Excess Reagent?

- The excess reagent is the reactant that is "leftover" when the reaction is over.



- The excess reagent in this analogy are the two remaining buns.

We determine the limiting reagent using MOLAR RATIOS from the balanced chemical equation.



The Steps:

1. Write the balanced chemical equation.
2. Convert all given quantities to moles.
3. Calculate how much product could be formed from each reactant. The limiting reagent (the one that runs out first) is the reactant that would produce the least amount of product.
4. Use the limiting reagent to calculate the amount of product formed.

Calculation #1:

What is the limiting reagent when 28.0 g of N_2 reacts with 6.0 g of H_2 to produce ammonia?

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Convert all given quantities to moles.

Moles of N_2: $\frac{28.0\ \text{g}}{28.02\ \text{g/mol}} = 1.00\ \text{mol}\ N_2$

Moles of H_2: $\frac{6.0\ \text{g}}{2.02\ \text{g/mol}} = 2.97\ \text{mol}\ H_2$

$$1.00\ \text{mol}\ N_2 \times \frac{2\ \text{mol}\ NH_3}{1\ \text{mol}\ N_2} = \boxed{\cancel{2.00\ \text{mol}\ NH_3}}$$

$$2.97\ \text{mol}\ H_2 \times \frac{2\ \text{mol}\ NH_3}{3\ \text{mol}\ H_2} = \boxed{1.98\ \text{mol}\ NH_3}$$

H_2 ran out when only 1.98 mol of NH_3 was produced. H_2 is the limiting reagent.

Use the limiting reagent to calculate the amount of product formed.

$$1.98\ \text{mol}\ NH_3 \times \frac{17.03\ \text{g}}{\text{mol}} = \boxed{33.7\ \text{g}\ NH_3}$$

Calculation #2:

a) Calculate the mass of carbon dioxide produced when 44.0 grams of propane and 200.0 grams of oxygen gas react.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Moles of C_3H_8: $\frac{44.0\ \text{g}}{44.10\ \text{g/mol}} = 1.00\ \text{mol}\ C_3H_8$

Moles of O_2: $\frac{200.0\ \text{g}}{32.00\ \text{g/mol}} = 6.25\ \text{mol}\ O_2$

$$1.00\ \text{mol}\ C_3H_8 \times \frac{3\ \text{mol}\ CO_2}{1\ \text{mol}\ C_3H_8} = 3.00\ \text{mol}\ CO_2$$

$$6.25\ \text{mol}\ O_2 \times \frac{3\ \text{mol}\ CO_2}{5\ \text{mol}\ O_2} = \cancel{3.75\ \text{mol}\ CO_2}$$

C_3H_8 ran out when only 3.00 mol of CO_2 was produced. C_3H_8 is the limiting reagent.

$$3.00\ \text{mol}\ CO_2 \times \frac{44.01\ \text{g}}{\text{mol}} = \boxed{132\ \text{g}\ CO_2}$$

b) Determine the mass of the 'excess reactant' that remains unreacted after the reaction is complete.

$$\mathrm{C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O}$$

- Recall, we had 6.25 mol of oxygen available:

$$\frac{200.0\ \mathrm{g\ O_2}}{32.00\ \mathrm{g/mol}} = 6.25\ \mathrm{mol\ O_2}$$

- Recall, we reacted 1.00 mol of our limiting reagent, propane:

$$1.00\ \mathrm{mol\ C_3H_8} \times \frac{5\ \mathrm{mol\ O_2}}{1\ \mathrm{mol\ C_3H_8}} = 5.00\ \mathrm{mol\ O_2\ required}$$

- We must calculate moles of O_2 remaining:

$$6.25\ \mathrm{mol\ available} - 5.00\ \mathrm{mol\ used} = 1.25\ \mathrm{mol\ O_2}_{remaining}$$

- Finally, we must convert remaining O_2 to mass:

$$1.25\ \mathrm{mol} \times 32.00\ \frac{\mathrm{g}}{\mathrm{mol}} = \boxed{40.0\ \mathrm{g\ O_2}}$$

Calculation #3:

Calculate the mass of hydrogen gas produced when 12.0 grams of magnesium and 30.0 grams of hydrochloric acid react. Also determine the mass of the excess reactant that remains unreacted.

$$\mathrm{Mg + 2HCl \rightarrow MgCl_2 + H_2}$$

Moles of Mg: $\frac{12.0\ \mathrm{g\ Mg}}{24.31\ \mathrm{g/mol}} = 0.494\ \mathrm{mol\ Mg}$

Moles of HCl: $\frac{30.0\ \mathrm{g\ HCl}}{36.46\ \mathrm{g/mol}} = 0.823\ \mathrm{mol\ HCl}$

$$0.494\ \mathrm{mol\ Mg} \times \frac{1\ \mathrm{mol\ H_2}}{1\ \mathrm{mol\ Mg}} = \cancel{0.494\ \mathrm{mol\ H_2}}$$

$$0.823\ \mathrm{mol\ HCl} \times \frac{1\ \mathrm{mol\ H_2}}{2\ \mathrm{mol\ HCl}} = 0.411\ \mathrm{mol\ H_2}$$

HCl ran out when only 0.411 mol of H_2 was produced. HCl is the limiting reagent.

$$0.411\ \mathrm{mol\ H_2} \times 2.02\ \frac{\mathrm{g}}{\mathrm{mol}} = \boxed{0.830\ \mathrm{g\ H_2}}$$

Mass of the excess reactant that remains:

$0.411\ \mathrm{mol\ Mg\ used}$

Excess Mg = $0.494 - 0.411 = 0.083\ \mathrm{mol}$

$$0.083\ \mathrm{mol} \times 24.31\ \frac{\mathrm{g}}{\mathrm{mol}} = \boxed{2.02\ \mathrm{g\ Mg\ remaining}}$$