Limiting Reactants

In a reaction, there will be a reactant that will produce a smaller amount of product; this is called the limiting reactant.
- It will "limit" how much product is made in a reaction.

- The other reactant is called the excess reactant. It will produce the largest amount of product.
- When the amount of the limiting reactant runs out, the reaction stops.
- To figure out the limiting reactant, you must do 2 separate math problems identifying the same unknown.

\[ \text{H}_2 + \text{Cl}_2 \rightarrow 2 \text{HCl} \]
- Ratios (1\text{H}_2: 1\text{Cl}_2: 2\text{HCl}) (1\text{Cl}_2: 2\text{HCl})
- If you have 2 mol of \text{H}_2, it will make 4 mol of \text{HCl}
- If you have 2 mol of \text{Cl}_2, it will make 4 mol of \text{HCl}
- So, if you combine 2 mol of \text{H}_2 and \text{Cl}_2, it will produce 4 mol of \text{HCl} (both reactants will be used up)
- If you have 2 mol of \text{H}_2 and 1 mol of \text{Cl}_2, how much \text{HCl} will be produced?
- What is the limiting reactant?

Limiting Reactants and Percent Yield

If you had 12 bicycle seats and 48 tires, which will limit the number of complete bikes that can be made?

\[
\begin{align*}
\text{Seats:} & \quad \frac{12 \text{ Seats}}{1} \times \frac{1 \text{ Complete Bike}}{1 \text{ Seat}} = 12 \text{ Complete Bikes} \\
\text{Tires:} & \quad \frac{48 \text{ Tires}}{1} \times \frac{1 \text{ Complete Bike}}{2 \text{ Tires}} = 24 \text{ Complete Bikes}
\end{align*}
\]

Which is the limiting reactant? Seats or tires?
**Limiting Reactant Problem**

$\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$

If you reacted 135 g of $\text{P}_4\text{O}_{10}$ with 70.0 g of $\text{H}_2\text{O}$, which would be the limiting reactant?

\[
\frac{135 \text{ g } \text{P}_4\text{O}_{10}}{283.89 \text{ g } \text{P}_4\text{O}_{10}} \times \frac{4 \text{ mol } \text{H}_3\text{PO}_4}{1 \text{ mol } \text{P}_4\text{O}_{10}} = 186 \text{ g } \text{H}_3\text{PO}_4
\]

\[
\frac{70.0 \text{ g } \text{H}_2\text{O}}{18.02 \text{ g } \text{H}_2\text{O}} \times \frac{4 \text{ mol } \text{H}_3\text{PO}_4}{1 \text{ mol } \text{H}_2\text{O}} = 254 \text{ g } \text{H}_3\text{PO}_4
\]

Which is the limiting reactant? Why?

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**Percent Yield**

- Percent Yield is a calculation that identifies the efficiency of a chemical reaction in a lab situation.
  - It shows how "close to perfection" a reaction was completed in a lab.

- Percent Yield is calculated by comparing Actual Yield and Theoretical Yield.
  - Percent Yield = (Actual Yield / Theoretical Yield) × 100
  - Actual Yield is the amount of product observed from lab.
  - This is what you actually measure in a lab.
  - Theoretical Yield is predicted amount of product based on stoichiometric calculations.
    - This is what a "perfect" reaction would produce.
    - Use stoichiometric calculation to determine amount of product

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**Actual vs. Theoretical**

- **Actual Yield**
  - This is what you get "experimentally"
  - Measured from an experiment or lab
  - NOT calculated with stoichiometry

- **Theoretical Yield**
  - This would be the result of a "perfect" reaction
  - Calculated using stoichiometry

- Theoretical is like a 100% test score, actual is what you really got, and percent yield would be your percentage on the test.

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**Percent Yield**

- Many times, the actual yield does not equal theoretical yield
- Possible Reasons:
  - Reactants are impure
  - Some product might have been lost
  - Other substances might have been formed
  - Calculation, estimation, human errors
- If you know the amounts of the reactants used, the theoretical yield can be calculated. Comparing this to the measured amount of product (actual yield) will allow for the percent yield to be calculated.
Percent Yield Example

- \( \text{C}_5\text{H}_{12} + 8\text{O}_2 \rightarrow 5\text{CO}_2 + 6\text{H}_2\text{O} \)
- How many grams of carbon dioxide are formed when 61.5g of \( \text{C}_5\text{H}_{12} \) are burned in oxygen?
  - Use stoichiometric calculation to find grams of \( \text{CO}_2 \)
    - Answer = 187 g (this is theoretical yield)
- In a lab, 165 g of \( \text{CO}_2 \) was produced (this is actual yield)
- What is the percent yield?
  - 88.2% yield (meaning the answer is 88.2% correct from a perfect reaction)