Reactions Involving a Limiting Reactant

• In a given reaction, there is not enough of one reagent to use up the other reagent completely.
• The reagent in short supply limits the quantity of product that can be formed.

Reactants: 2 NO(g) + O₂(g) → 2 NO₂(g)
Limiting reactant = 
Excess reactant = 

React solid Zn with 0.100 mol HCl (aq)
Zn + 2 HCl → ZnCl₂ + H₂

React solid Zn with 0.100 mol HCl (aq)
Zn + 2 HCl → ZnCl₂ + H₂

Reaction to be Studied
2 Al + 3 Cl₂ → Al₂Cl₆
PROBLEM: Mix 5.40 g of Al with 8.10 g of Cl₂. How many grams of Al₂Cl₆ can form?

Step 1 of LR problem: compare actual mole ratio of reactants to theoretical mole ratio.

\[
\begin{align*}
\text{Reactants must be in the mole ratio} \\
\frac{\text{mol Cl}_2}{\text{mol Al}} = \frac{3}{2}
\end{align*}
\]

Deciding on the Limiting Reactant

\[
\begin{align*}
\text{If } \frac{\text{mol Cl}_2}{\text{mol Al}} > \frac{3}{2} \quad \text{then there is not enough Al to use up all the Cl}_2, \text{ and the limiting reagent is Al} \\
\text{If } \frac{\text{mol Cl}_2}{\text{mol Al}} < \frac{3}{2} \quad \text{then there is not enough Cl}_2 \text{ to use up all the Al, and the limiting reagent is Cl}_2
\end{align*}
\]

Step 2 of LR problem: Calculate moles of each reactant

We have 5.40 g of Al and 8.10 g of Cl₂

\[
\begin{align*}
5.40 \text{ g Al} \cdot \frac{1 \text{ mol}}{27.0 \text{ g}} &= 0.200 \text{ mol Al} \\
8.10 \text{ g Cl}_2 \cdot \frac{1 \text{ mol}}{70.9 \text{ g}} &= 0.114 \text{ mol Cl}_2
\end{align*}
\]
Find mole ratio of reactants

\[ \text{mol } \text{Cl}_2 \div \text{mol Al} = \frac{0.114 \text{ mol}}{0.200 \text{ mol}} = 0.57 \]

This should be 3/2 or 1.5/1 if reactants are present in the exact stoichiometric ratio.

Limiting reagent is \text{Cl}_2

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Mix 5.40 g of Al with 8.10 g of \text{Cl}_2. What mass of \text{Al}_2\text{Cl}_6 can form?

\[ 2 \text{ Al} + 3 \text{ Cl}_2 \rightarrow \text{Al}_2\text{Cl}_6 \]

Limiting reactant = \text{Cl}_2

Base all calcs. on \text{Cl}_2

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CALCULATIONS: calculate mass of \text{Al}_2\text{Cl}_6 expected.

Step 1: Calculate moles of \text{Al}_2\text{Cl}_6 expected based on LR.

\[ 0.114 \text{ mol Cl}_2 \times \frac{1 \text{ mol } \text{Al}_2\text{Cl}_6}{3 \text{ mol Cl}_2} = 0.0380 \text{ mol } \text{Al}_2\text{Cl}_6 \]

Step 2: Calculate mass of \text{Al}_2\text{Cl}_6 expected based on LR.

\[ 0.0380 \text{ mol } \text{Al}_2\text{Cl}_6 \times \frac{266.4 \text{ g } \text{Al}_2\text{Cl}_6}{1 \text{ mol }} = 10.1 \text{ g } \text{Al}_2\text{Cl}_6 \]

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Calculating Excess Al

How much of which reactant will remain when reaction is complete?

• \text{Cl}_2 was the limiting reactant. Therefore, Al was present in excess. But how much?
  • First find how much Al was required.
  • Then find how much Al is in excess.

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Calculating Excess Al

\[ 2 \text{ Al} + 3 \text{ Cl}_2 \rightarrow \text{ products} \]

\[ 0.200 \text{ mol Al} \times 0.114 \text{ mol } \text{LR} = 0.0760 \text{ mol Al req'd} \]

\[ 0.114 \text{ mol Cl}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol Cl}_2} = 0.0760 \text{ mol Al required} \]

Excess Al = Al available - Al required

\[ = 0.200 \text{ mol } - 0.0760 \text{ mol} \]

\[ = 0.124 \text{ mol Al in excess} \]