MOLE TO MOLE RATIO

When nitrogen and hydrogen gas are heated under the correct conditions, ammonia gas (NH₃) is formed.

a. RXN: \( \text{1N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3 \)

b. How many moles of nitrogen react with three moles of hydrogen? \( 1 \text{ mol N$_2$} \)

c. How many moles of nitrogen react with six moles of hydrogen? \( 2 \text{ mol N$_2$} \)

d. How many moles of ammonia would be formed if 6 moles of hydrogen react with plenty of nitrogen? \( 4 \text{ mol NH}_3 \)

e. How many moles of ammonia would be formed if 2.54 moles of nitrogen react with plenty of hydrogen? \( 5.08 \text{ mol NH}_3 \)

f. How many moles of ammonia could be formed if 3.50 moles of hydrogen react with excess nitrogen? \( 2.3 \text{ mol H}_2 \)

g. How many moles of nitrogen are needed to react with 6.9 moles of hydrogen? \( 2.3 \text{ mol N$_2$} \)
When potassium chlorate is heated it breaks down to potassium chloride and oxygen. Write a balanced equation for the reaction below:

RXN: \[ 2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2 \]

a. How many moles of potassium chloride will be produced if 6.2 moles of potassium chlorate break down?

\[
\begin{array}{c|c}
6.2 \text{ mol KClO}_3 & 2 \text{ mol KCl} \\
2 \text{ mol KClO}_3 & 2 \text{ mol KCl}
\end{array}
\]

_6.2 \text{ mol KClO}_3___

b. How many moles of oxygen are formed if 4.9 moles of potassium chloride are formed?

\[
\begin{array}{c|c}
4.9 \text{ mol KCl} & 3 \text{ mol O}_2 \\
2 \text{ mol KCl} & 2 \text{ mol KCl}
\end{array}
\]

_7.35 \text{ mol O}_2___

c. How many moles of potassium chlorate must break down in order to produce 0.95 moles of oxygen?

\[
\begin{array}{c|c}
0.95 \text{ mol O}_2 & 2 \text{ mol KClO}_3 \\
3 \text{ mol O}_2 & 3 \text{ mol KClO}_3
\end{array}
\]

_0.63 \text{ mol KClO}_3___
MOLE TO MASS/VOLUME PROBLEMS

When fluorine gas is bubbled through a solution of aluminum iodide, elemental iodine and aqueous aluminum fluoride are formed. Write and balance the reaction below:

RXN: \(3 \text{F}_2 + 2 \text{AlI}_3 \rightarrow 3 \text{I}_2 + 2 \text{AlF}_3\)

1. How many \textit{moles of fluorine} gas are needed to react with \textit{2.50 moles of aluminum iodide}?

\[
\begin{array}{c|c|c}
2.5 \text{ mol AlI}_3 & 3 \text{ mol F}_2 & \text{2 mol AlI}_3 \\
\hline
\text{3 mol F}_2 & \text{2 mol AlI}_3 & \_3.75 \text{ mol F}_2 \\
\end{array}
\]

2. What \textit{mass of iodine} will form if \textit{4.20 moles of fluorine} gas react with excess aluminum iodide?

\[
\begin{array}{c|c|c|c}
4.20 \text{ mol F}_2 & 2 \text{ mol I}_2 & 253.8 \text{ g I}_2 & \text{3 mol F}_2 \\
\hline
\text{3 mol F}_2 & \text{1 mol I}_2 & \_1065.96 \text{ g I}_2 \\
\end{array}
\]

3. What \textit{mass of fluorine} gas is needed to react with \textit{2.15 moles of aluminum iodide}?

\[
\begin{array}{c|c|c|c}
2.15 \text{ mol AlI}_3 & 3 \text{ mol F}_2 & 38.0 \text{ g F}_2 \\
\hline
\text{2 mol AlI}_3 & \text{1 mol F}_2 & \_122.55 \text{ g F}_2 \\
\end{array}
\]

4. What \textit{volume of fluorine gas}, at STP, was used if \textit{0.55 moles aluminum fluoride} were formed?

\[
\begin{array}{c|c|c|c}
0.55 \text{ mol AlF}_3 & 3 \text{ mol F}_2 & 22.4 \text{ L F}_2 \\
\hline
\text{2 mol AlF}_3 & \text{1 mol F}_2 & \_18.48 \text{ L F}_2 \\
\end{array}
\]
1. When iron is heated in pure oxygen, iron(III) oxide is formed. Write a balanced equation for the reaction below.

\[ 4 \text{ Fe} + 3 \text{ O}_2 \rightarrow 2 \text{ Fe}_2\text{O}_3 \]

What type of reaction is this? synthesis

---

a. How many moles of iron are needed to react with 2.5 moles of oxygen?

\[
\frac{2.5 \text{ mol O}_2}{3 \text{ mol O}_2} = 4 \text{ mol Fe} = 3.3 \text{ mol Fe}
\]

b. What mass of iron must react with excess oxygen in order to form 4.81 moles of iron(III) oxide?

\[
\frac{4.81 \text{ mol Fe}_2\text{O}_3}{2 \text{ mol Fe}_2\text{O}_3} = 4 \text{ mol Fe} = 55.8 \text{ g Fe}
\]

---

c. What mass of iron is needed to react with 40.0 g of oxygen?

\[
\frac{40.0 \text{ g O}_2}{32 \text{ g O}_2} = 1 \text{ mol O}_2 = 4 \text{ mol Fe} = 55.8 \text{ g Fe}
\]

---

d. What mass of iron(III) oxide can be formed from the reaction of 10.2 g of iron with excess oxygen?

\[
\frac{10.2 \text{ g Fe}}{55.8 \text{ g Fe}} = 1 \text{ mol Fe} = 2 \text{ mol Fe}_2\text{O}_3 = 159.6 \text{ g Fe}_2\text{O}_3
\]

---

e. What mass of oxygen is needed to react with 12.7 g of iron?

\[
\frac{12.7 \text{ g Fe}}{55.8 \text{ g Fe}} = 1 \text{ mol Fe} = 3 \text{ mol O}_2 = 32 \text{ g O}_2
\]

---

f. What mass of iron(III) oxide will be formed if 10.0 L of oxygen at STP react with excess iron?

\[
\frac{10.0 \text{ L O}_2}{22.4 \text{ L O}_2} = 1 \text{ mol O}_2 = 2 \text{ mol Fe}_2\text{O}_3 = 159.6 \text{ g Fe}_2\text{O}_3
\]
2. Barium hydroxide reacts with hydrochloric acid to form barium chloride and water. Write a balanced equation for the reaction below.

\[
\text{Ba(OH)}_2 + 2 \text{HCl} \rightarrow \text{BaCl}_2 + 2 \text{H}_2\text{O}
\]

What type of reaction is this? double displacement

a. What mass of barium chloride will form if 14.0g of barium hydroxide reacts with excess hydrochloric acid?

\[
\begin{array}{c|c|c|c}
14.0 \text{g Ba(OH)}_2 & 1 \text{ mol Ba(OH)}_2 & 1 \text{ mol BaCl}_2 & 208.3 \text{ g BaCl}_2 \\
171.3 \text{ g Ba(OH)}_2 & 1 \text{ mol Ba(OH)}_2 & 1 \text{ mol BaCl}_2 & \\
\end{array}
\]

\[17 \text{ g BaCl}_2\]

b. How many grams of hydrochloric acid are needed to react with 15.0g of barium hydroxide?

\[
\begin{array}{c|c|c|c}
15.0 \text{ g Ba(OH)}_2 & 1 \text{ mol Ba(OH)}_2 & 2 \text{ mol HCl} & 36.5 \text{ g HCl} \\
171.3 \text{ g Ba(OH)}_2 & 1 \text{ mol Ba(OH)}_2 & 1 \text{ mol HCl} & \\
\end{array}
\]

\[6.4 \text{ g HCl}\]

c. What mass of barium chloride will form if 5.98g of hydrochloric acid react with excess barium hydroxide?

\[
\begin{array}{c|c|c|c}
5.98 \text{ g HCl} & 1 \text{ mol HCl} & 1 \text{ mol BaCl}_2 & 208.3 \text{ g BaCl}_2 \\
36.5 \text{ g HCl} & 2 \text{ mol HCl} & 1 \text{ mol BaCl}_2 & \\
\end{array}
\]

\[17.1 \text{ g BaCl}_2\]
PER CENT YIELD

\[
\frac{\text{actual yield}}{\text{theoretical yield}} \times 100
\]

Propane gas burns in oxygen according to the reaction below:

\[\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}\]

A student burns 20.0L of propane gas in excess oxygen at STP. Determine the volume of carbon dioxide that should form in the reaction.

\[
\begin{array}{c|c|c|c|c}
20.0 \text{ L C}_3\text{H}_8 & 1 \text{ mol C}_3\text{H}_8 & 3 \text{ mol CO}_2 & 22.4 \text{ L CO}_2 & 60.0 \text{ L CO}_2 \\
22.4 \text{ L C}_3\text{H}_8 & 1 \text{ mol C}_3\text{H}_8 & 1 \text{ mol CO}_2 &
\end{array}
\]

The reaction only produces 48.0L of carbon dioxide. What is the percent yield?

Actual \[48.0 \text{ L} \times 100\] \[\text{Theoretical} 60.0 \text{ L} \]

\[\frac{48-60}{60} \times 100 \]

\[\text{80} \% \text{ yield}\]

What is the percent error?

\[\frac{48-60}{60} \times 100\]

\[\text{20} \% \text{ error}\]

Sodium chlorate decomposes to produce sodium chloride and oxygen. Write and balance the reaction. The determine the mass of sodium chloride should form if 150g of sodium chlorate decomposes?

\[
\begin{array}{c|c|c|c|c}
\text{Reaction:} & 2 \text{NaClO}_3 & \rightarrow & 2 \text{NaCl} + 3 \text{O}_2 \\
\text{150 g NaClO}_3 & 1 \text{ mol NaClO}_3 & 2 \text{ mol NaCl} & 58.5 \text{ g NaCl} \\
106.5 \text{ g NaClO}_3 & 2 \text{ mol NaClO}_3 & 1 \text{ mol NaCl} &
\end{array}
\]

\[\text{82.39 g NaCl}\]

The reaction above is carried out in lab, and 55g of sodium chloride are collected. Determine the percent yield.

\[\frac{55}{82.39} \times 100 \]

\[\text{66.7} \% \text{ yield}\]

Determine the percent error.

\[\frac{82.39-55}{82.39} \times 100\]

\[\text{33.3} \% \text{ error}\]
1. Define the terms limiting reactant, excess reactant and percent yield.

Limiting reactant – the reactant that is used up in a chemical reaction

Excess reactant – the reactant that does not get used up in a chemical reaction

2. Balance the reaction below:

\[ 4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3 \]

3. 4.0 moles of aluminum are placed in a container with 4.0 moles of oxygen. How many moles of aluminum oxide should form?

There is enough aluminum to make ___2 moles________ moles of aluminum oxide.

\[
\begin{array}{c|c|c}
4.0 \text{ moles Al} & 2 \text{ moles Al}_2\text{O}_3 & 4 \text{ moles Al} \\
\end{array}
\]

There is enough oxygen to make ___2.7 moles________ moles of aluminum oxide.

\[
\begin{array}{c|c|c}
4.0 \text{ moles O}_2 & 2 \text{ moles Al}_2\text{O}_3 & 3 \text{ moles O}_2 \\
\end{array}
\]

___2 moles________ moles of aluminum oxide will form.

The limiting reactant is ____Al______________. The excess reactant is ____O_2______________.

4. Predict the mass of aluminum oxide that will form if 20.0g of aluminum react with 15.0L of oxygen gas at STP.

There is enough aluminum to make ____37.8________ g of aluminum oxide.

\[
\begin{array}{c|c|c|c|c}
20.0 \text{ g Al} & 1 \text{ mole Al} & 2 \text{ mole Al}_2\text{O}_3 & 102 \text{ g Al}_2\text{O}_3 \\
27.0 \text{ g Al} & 4 \text{ mole Al} & 1 \text{ mole Al}_2\text{O}_3 \\
\end{array}
\]

There is enough oxygen to make ___45.5________ g of aluminum oxide

\[
\begin{array}{c|c|c|c|c}
15.0 \text{ L O}_2 & 1 \text{ mole O}_2 & 2 \text{ mole Al}_2\text{O}_3 & 102 \text{ g Al}_2\text{O}_3 \\
22.4 \text{ L O}_2 & 3 \text{ mole O}_2 & 1 \text{ mole Al}_2\text{O}_3 \\
\end{array}
\]

___45.5________ g of aluminum oxide will form.

The limiting reactant is ____O_2_______________. The excess reactant is ____Al______________.
1. Fluorine gas is bubbled through a solution of potassium iodide. The products of the reaction are potassium fluoride and iodine. Write a balanced equation for the reaction below.

\[ \underline{\text{F}_2 + 2 \text{KI} \rightarrow 2 \text{KF} + \text{I}_2} \]

a. What type of reaction is this? **single displacement**

b. 1.26g of fluorine are bubbled through a solution containing 20.15g of potassium iodide. What mass of potassium fluoride should form?

\[
\begin{array}{c|c|c|c}
1.26 \text{ g F}_2 & 1 \text{ mol F}_2 & 2 \text{ mol KF} & 58.1 \text{ g KF} \\
38 \text{ g F}_2 & 1 \text{ mol F}_2 & 1 \text{ mol KF} & \\
\end{array}
= 3.9 \text{ g KF}
\]

\[
\begin{array}{c|c|c|c}
20.15 \text{ g KI} & 1 \text{ mol KI} & 2 \text{ mol KF} & 58.1 \text{ g KF} \\
166 \text{ g KI} & 2 \text{ mol KI} & 1 \text{ mol KF} & \\
\end{array}
= 7.1 \text{ g KF}
\]

___3.9 g KF__________

c. identify the limiting reactant: _F_2__________

d. identify the excess reactant: _KI__________
SAMPLE PROBLEM: FINDING THE MASS OF EXCESS REACTANT

What mass of copper(II) iodide will be formed if 35.0g of copper are placed in a solution containing 90.0g of silver iodide?

a. Balanced Reaction: ___ Cu + 2 AgI \( \rightarrow \) CuI\(_2\) + 2 Ag ________________

b. Find the expected yield if copper is the limiting reactant:

\[
\begin{array}{c|c|c|c}
35.0g \text{ Cu} & 1 \text{ mol Cu} & 1 \text{ mol CuI}_2 & 317.3g \text{ CuI}_2 \\
63.5g & 1 \text{ mol Cu} & 1 \text{ mol CuI}_2 & \\
\end{array}
\]

\( = 174.9g \text{ CuI}_2 \)

c. Find the expected yield if silver iodide is the limiting reactant:

\[
\begin{array}{c|c|c|c}
90.0g \text{ AgI} & 1 \text{ mol AgI} & 1 \text{ mol CuI}_2 & 317.3g \text{ CuI}_2 \\
234.8g & 2 \text{ mol AgI} & 1 \text{ mol CuI}_2 & \\
\end{array}
\]

\( = 60.8g \text{ CuI}_2 \)

d. The limiting reactant is ___AgI___________. The excess reactant is ___Cu______.

e. Use the \textit{limiting reactant} to determine how much of the excess reactant does react.

\[
\begin{array}{c|c|c|c}
90.0g \text{ AgI} & 1 \text{ mol AgI} & 1 \text{ mol Cu} & 63.5g \\
234.8g & 2 \text{ mol AgI} & 1 \text{ mol CuI}_2 & \\
\end{array}
\]

\( = 12.2g \text{ Cu reacted} \)

f. Subtract the amount that reacts from the amount you started with to find the mass remaining.

\[
35.0g \text{ Cu} - 12.2g \text{ Cu} = 22.8g \text{ Cu remain}
\]
**FINDING THE MASS OF EXCESS REACTANT**

The next step in the limiting reactant process is determining the amount of excess reactant remaining following the reaction. There is a sample problem on the next page. Follow the steps of the sample problem if you get lost!

**Try the problem below:**

1. What mass of carbon dioxide will be formed if 50.0g of propane gas are burned in 40L of pure oxygen at STP?

   a. Balanced Reaction: \( \text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O} \)

   b. Find the expected yield if propane is the limiting reactant:

   \[
   \frac{50.0 \text{ g C}_3\text{H}_8}{44 \text{ g C}_3\text{H}_8} \times \frac{1 \text{ mole C}_3\text{H}_8}{1 \text{ mole CO}_2} \times \frac{3 \text{ mole CO}_2}{1 \text{ mole C}_3\text{H}_8} = 150 \text{ g CO}_2
   \]

   c. Find the expected yield if oxygen is the limiting reactant:

   \[
   \frac{40 \text{ L O}_2}{22.4 \text{ L O}_2} \times \frac{1 \text{ mole O}_2}{1 \text{ mole CO}_2} \times \frac{3 \text{ mole CO}_2}{5 \text{ mole O}_2} = 47.1 \text{ g CO}_2
   \]

   d. The limiting reactant is \( \text{CO}_2 \). The excess reactant is \( \text{C}_3\text{H}_8 \).

   e. Use the *limiting reactant* to determine how much of the excess reactant does react.

   \[
   \frac{40 \text{ L O}_2}{22.4 \text{ L O}_2} \times \frac{1 \text{ mole O}_2}{5 \text{ mole O}_2} \times \frac{1 \text{ mole C}_3\text{H}_8}{1 \text{ mole C}_3\text{H}_8} = 15.7 \text{ g C}_3\text{H}_8
   \]

   f. Subtract the amount that reacts from the amount you started with to find the mass remaining.

   \[50.0 \text{ g} - 15.7 \text{ g} = 34.4 \text{ g C}_3\text{H}_8\text{ remain}\]