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Stoichiometry

Chapter 10

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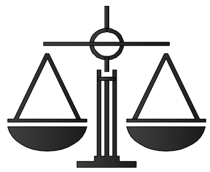

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Stoichiometry

- **Mole calculations based on balanced chemical equations.**
- **The coefficients in a balanced equation indicate the moles needed for a reaction.**

$$N_{2(g)} + 3I_{2(s)} \rightarrow 2NI_{3(s)}$$

$$\text{mol } N_2 + \quad \text{mol } I_2 \rightarrow \quad \text{mol } NI_3$$

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Interpreting a Chemical Equation

$$N_{2(g)} + 3I_{2(s)} \rightarrow 2NI_{3(s)}$$

$$1 \text{ mol } N_2 + 3 \text{ mol } I_2 \rightarrow 2 \text{ mol } NI_3$$

- **The coefficients give us the mol ratios for the reaction**

$$\frac{3 \text{ mol } I_2}{1 \text{ mol } N_2} \qquad \frac{\text{mol } I_2}{\text{mol } NI_3} \qquad \frac{\text{mol } N_2}{\text{mol } NI_3}$$

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Mole ratio

- A mol ratio is the ratio of the coefficients in the balanced equation.
- A mol ratio is a conversion factor from moles of known to moles of unknown.

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Using a mol ratio

$N_{2(g)} + 3I_{2(s)} \rightarrow 2NI_{3(s)}$

5.50 mol N_2 will make how many moles of NI_3?

Known: ➡ **Unknown:**

5.50 mol N_2 x

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Using a mol ratio

$N_{2(g)} + 3I_{2(s)} \rightarrow 2NI_{3(s)}$

How many moles of I_2 are needed to make 2.51 mol of NI_3?

Known: ➡ **Unknown:**

2.51 mol NI_3 x

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Using a mol ratio

$2Al_{(s)} + 3HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$

How many moles of Al are needed to make 0.0935 mol of H_2?

Known: .0935 mol H_2 → Unknown:

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Using a mol ratio

$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$

How many moles of Al are needed to consume .193 mol HCl?

Known: .193 mol HCl → Unknown:

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Review: Grams to moles

To convert from grams to moles, we divide by the molar mass.

Calculate the number of moles of barium hydride contained in 1.05 g.

Known: 1.05 g BaH_2 → Unknown:

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Mass to Moles Conversions

$3Na_2CO_{3(aq)} + 2Al(NO_3)_{3(aq)} \rightarrow Al_2(CO_3)_{3(s)} + 6NaNO_{3(aq)}$

How many moles of Al_2CO_3 can be made from the reaction of 1.91 g Na_2CO_3 with excess $Al(NO_3)_3$?

1.91 g Na_2CO_3 → mol Na_2CO_3 → mol $Al_2(CO_3)_3$

Known: 1.91 g Na_2CO_3 → Unknown: mol $Al_2(CO_3)_3$

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Review: Moles to Grams

To convert from moles to grams, we multiply by the molar mass.

Calculate the mass of 3.952 mol hydrogen gas.

Known: 3.952 mol H_2 → Unknown: g H_2

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Moles to Mass Conversions

$3Na_2CO_{3(aq)} + 2Al(NO_3)_{3(aq)} \rightarrow Al_2(CO_3)_{3(s)} + 6NaNO_{3(aq)}$

What mass of $Al(NO_3)_3$ is needed to react with .093 mol Na_2CO_3?

.093 mol Na_2CO_3 → mol $Al(NO_3)_3$ → g $Al(NO_3)_3$

Known: .093 mol Na_2CO_3 → Unknown: g $Al(NO_3)_3$

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Mass to Mass Conversions

Now we'll put it all together!

Mass of Known → **Mass of Unknown**

g known → **mol known** → **mol unknown** → **g unknown**

÷ by MM of known | **x Mol ratio** | **x by MM of unknown**

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Mass to Mass Conversions

$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$

How many grams of Al are needed to make 2.85 g H_2?

2.85 g H_2 → mol H_2 → mol Al → g Al

Known: 2.85 g H_2 → Unknown: g Al

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Mass to Mass Conversions

$3Na_2CO_{3(aq)} + 2Al(NO_3)_{3(aq)} \rightarrow Al_2(CO_3)_{3(s)} + 6NaNO_{3(aq)}$

How many grams of Al_2CO_3 can be made from the reaction of 2.42 g Na_2CO_3 with excess $Al(NO_3)_3$?

2.42 g Na_2CO_3 → mol Na_2CO_3 → mol $Al_2(CO_3)_3$ → g $Al_2(CO_3)_3$

Known: 2.42 g Na_2CO_3 → Unknown: g $Al_2(CO_3)_3$

Work this following the pattern.

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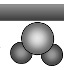
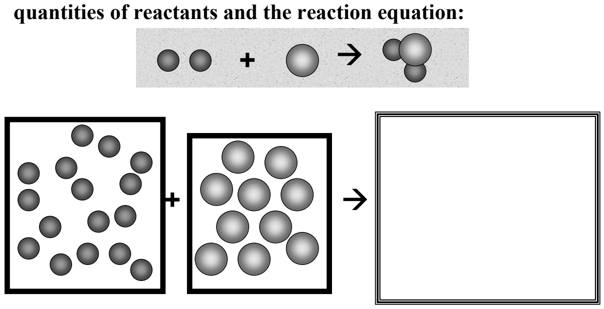
Concept Problem

Determine the number of  that can be made given these quantities of reactants and the reaction equation:



How many green balls do you have left?
How many blue balls do you have left?
Which ball produced limited the amount of product you can make?

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Limiting Reagent

- **The reactant that limits the amount of product that can be made.**
- **The reactant that is completely used up in the reaction.**

Which of the two balls was the limiting reagent?

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Excess Reagent

- **The reactant that is not completely used up in the reaction.**

Which reactant is the excess reactant?

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Limiting Reactant Problem

- **Given the starting quantities of two reactants, determine the theoretical yield of product.**
- **The limiting reagent determines the maximum amount of product that can be made (the theoretical yield).**

Theoretical yield: The maximum amount of product that can be made according to the balanced chemical equation.

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Limiting Reactant Problem

Technique for solving the problem:

- **Convert reactant 1 to mol product**
- **Convert reactant 2 to mol product**
- **Compare answers. The smaller answer is the theoretical yield.**

Each of the above conversions is based on the assumption that the other reactant is in excess.

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Limiting Reactant Problem

Calculate the number of moles of water that can be made by the reaction of 1.51 mol H_2 with 0.932 mol O_2.

- **Write your equation:**

- **Calculate the theoretical yield of H_2O assuming H_2 is the limiting reactant and that O_2 is the excess reactant.**
- **Calculate the theoretical yield of H_2O assuming that O_2 is the limiting reactant and that H_2 is the excess reactant.**

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Limiting Reactant Problem

continued

Assuming that H_2 is limiting

Assuming that O_2 is limiting

So what is the maximum yield of H_2O?

Each of the needed conversions is based on the assumption that the other reactant is in excess.

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Limiting Reactant Problem

Calculate the mass of copper that can be made from the combination of 15.0 g aluminum with 25.0 g copper(II) sulfate.

What kind of reaction is this?

Write the equation!

Write the equation.
Calculate the mass of Cu that can be made from 15.0 g Al assuming excess $CuSO_4$.
Calculate the mass of Cu that can be made from 25.0 g $CuSO_4$ assuming excess Al.
Compare answers. The smaller answer is the most Cu that can be made because you have run out of the limiting reagent.

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Limiting Reactant Problem

continued

$$2Al_{(s)} + 3CuSO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 3Cu_{(s)}$$

1. **Assume Al is limiting and $CuSO_4$ is in excess.**
2. **Assume $CuSO_4$ is limiting and Al is in excess.**
3. **Compare answers.**

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Actual Yield

- **The actual yield of a chemical reaction is the experimental result.**
- **The actual yield is always less than the theoretical yield due to experimental losses and errors along the way.**

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Actual Yield continued

- **Consider a reaction in which you transfer 15 mL of reactant into a beaker. Will all of the reactant make it into the beaker, or will some remain in the graduated cylinder?**
- **If all of the reactant isn't available for reaction, your yield is decreased!**

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Percent Yield

•To determine the efficiency of a process for making a compound, chemists compute the percent yield of the reaction.

$$\%\ \text{Yield} = \left(\frac{\text{Actual Yield}}{\text{Theoretical Yield}}\right) \times 100\%$$

The theoretical yield is the result calculated using stoichiometry.

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Percent Yield

- **Calculate the % yield of PCl_3 that results from reacting 5.00 g P with excess Cl_2 if only 17.2 g of PCl_3 were recovered.**

1. Write the equation.

2. Compute the expected yield of PCl_3 from 5.00 g P with xs Cl_2.

3. Compute the % Yield.