Preview

Lesson Starter

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

- If 2 mol of HCl react, how many moles of H_2 are obtained?
- How many moles of Mg will react with 2 mol of HCl?
- If 4 mol of HCl react, how many mol of each product are produced?
- How would you convert from moles of substances to masses?

Objective

- **Define** *stoichiometry.*
- **Describe** the importance of the *mole ratio* in stoichiometric calculations.
- **Write** a mole ratio relating two substances in a chemical equation.

Stoichiometry Definition

- **Composition stoichiometry** deals with the mass relationships of elements in compounds.

- **Reaction stoichiometry** involves the mass relationships between reactants and products in a chemical reaction.

End Of Slide

Stoichiometry

Click below to watch the Visual Concept.

Visual Concept

Reaction Stoichiometry Problems

Problem Type 1: *Given* and *unknown* quantities are amounts in moles.

Amount of *given* substance (mol)

↓

Amount of *unknown* substance (mol)

Problem Type 2: *Given* is an amount in moles and *unknown* is a mass

Amount of *given* substance (mol)

↓

Amount of *unknown* substance (mol)

↓

Mass of unknown substance (g)

End Of Slide

Reaction Stoichiometry Problems, *continued*

Problem Type 3: *Given* is a mass and *unknown* is an amount in moles.

Mass of *given* substance (g)

↓

Amount of *given* substance (mol)

↓

Amount of *unknown* substance (mol)

Problem Type 4: *Given* is a mass and *unknown* is a mass.

Mass of a *given* substance (g)

↓

Amount of *given* substance (mol)

↓

Amount of *unknown* substance (mol)

↓

Mass of unknown substance (g)

Mole Ratio

- **A mole ratio** is a conversion factor that relates the amounts in moles of any two substances involved in a chemical reaction

Example: $2Al_2O_3(l) \rightarrow 4Al(s) + 3O_2(g)$

Mole Ratios: $\frac{2\text{ mol }Al_2O_3}{4\text{ mol Al}}$, $\frac{2\text{ mol }Al_2O_3}{3\text{ mol }O_2}$, $\frac{4\text{ mol Al}}{3\text{ mol }O_2}$

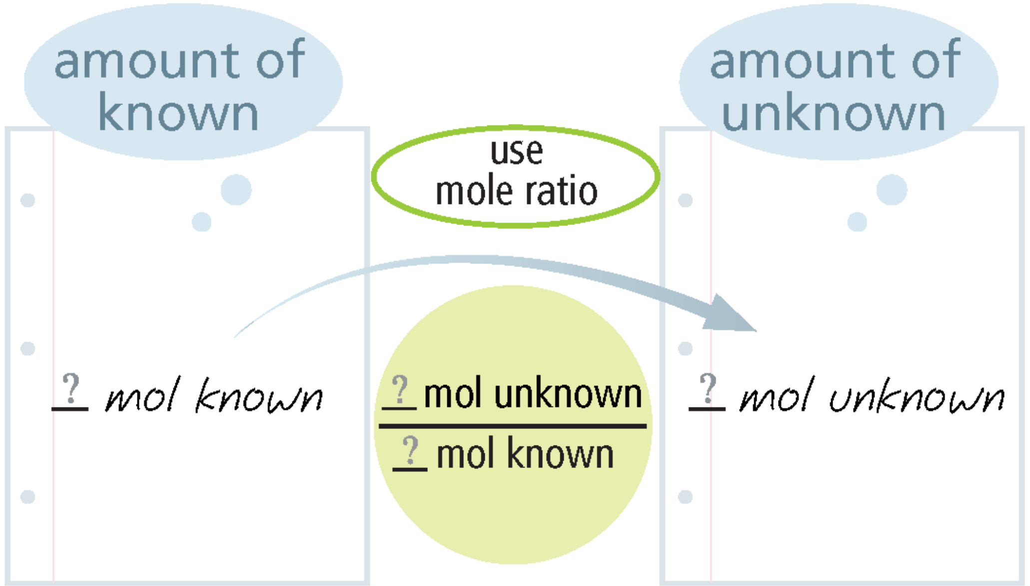
End Of Slide

Converting Between Amounts in Moles

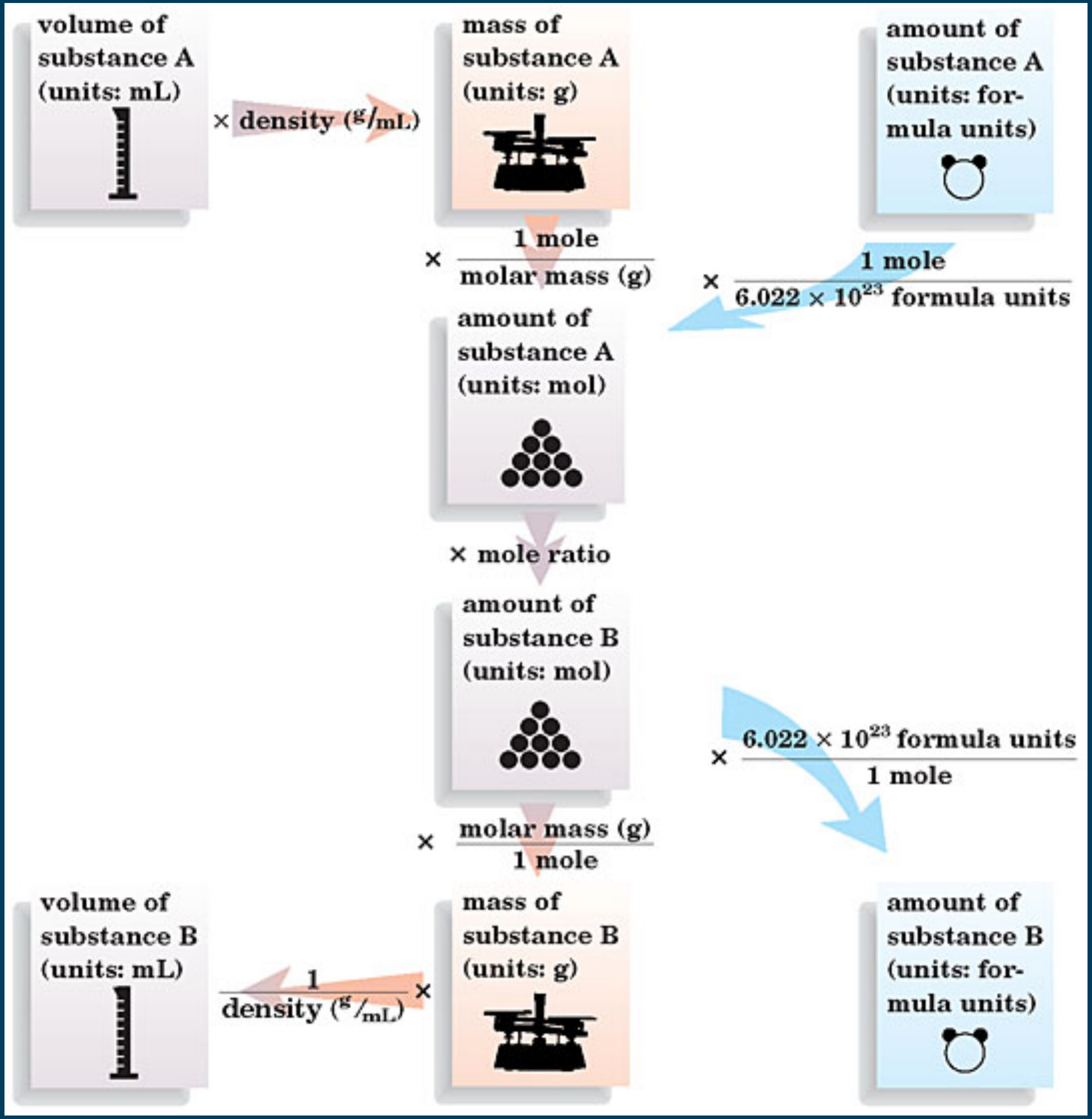
1. Identify the amount in moles that you know from the problem.

2. Using coefficients from the balanced equation, set up the mole ratio with the known substance on bottom and the unknown substance on top.

3. Multiply the original amount by the mole ratio.



Stoichiometry Calculations



Molar Mass as a Conversion Factor

Click below to watch the Visual Concept.

Visual Concept

Preview

- Lesson Starter
- Objective
- Conversions of Quantities in Moles
- Conversions of Amounts in Moles to Mass
- Mass-Mass to Calculations
- Solving Various Types of Stoichiometry Problems

Lesson Starter

Acid-Base Neutralization Reaction Demonstration

- What is the equation for the reaction of HCl with NaOH?
- What is the mole ratio of HCl to NaOH?

Objective

- **Calculate** the amount in moles of a reactant or a product from the amount in moles of a different reactant or product.

- **Calculate** the mass of a reactant or a product from the amount in moles of a different reactant or product.

End Of Slide

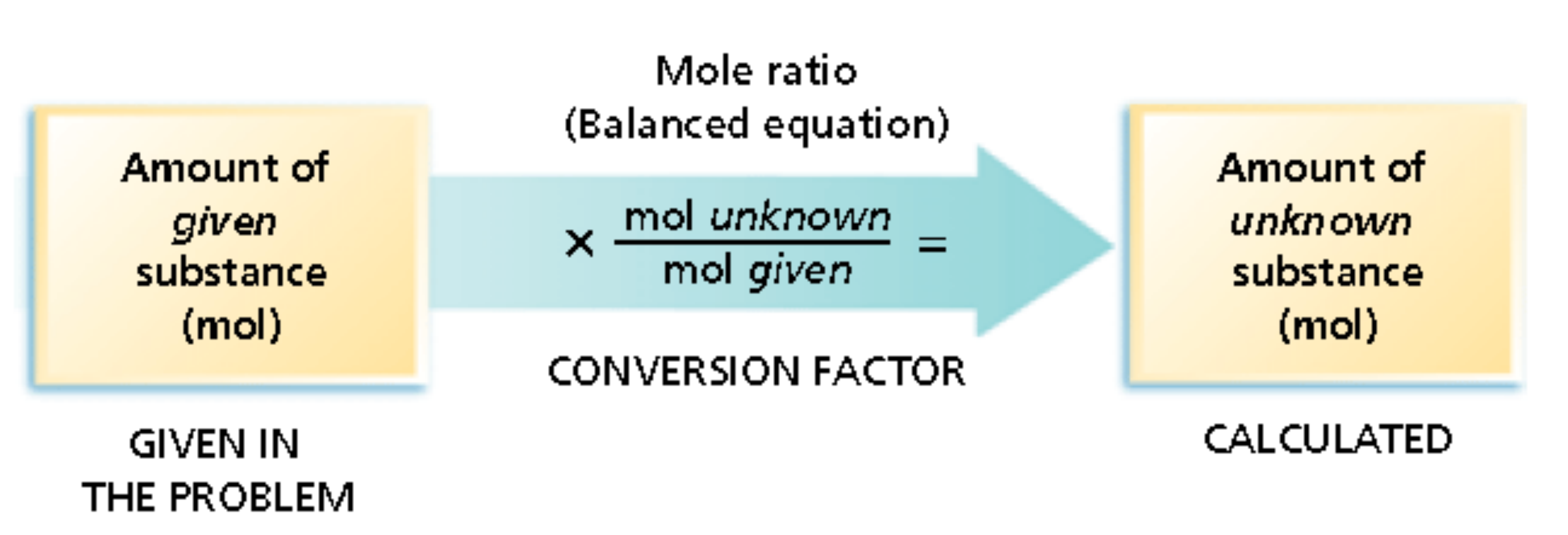
Objectives, *continued*

- **Calculate** the amount in moles of a reactant or a product from the mass of a different reactant or product.

- **Calculate** the mass of a reactant or a product from the mass of a different reactant or product.

End of Slide

Conversions of Quantities in Moles

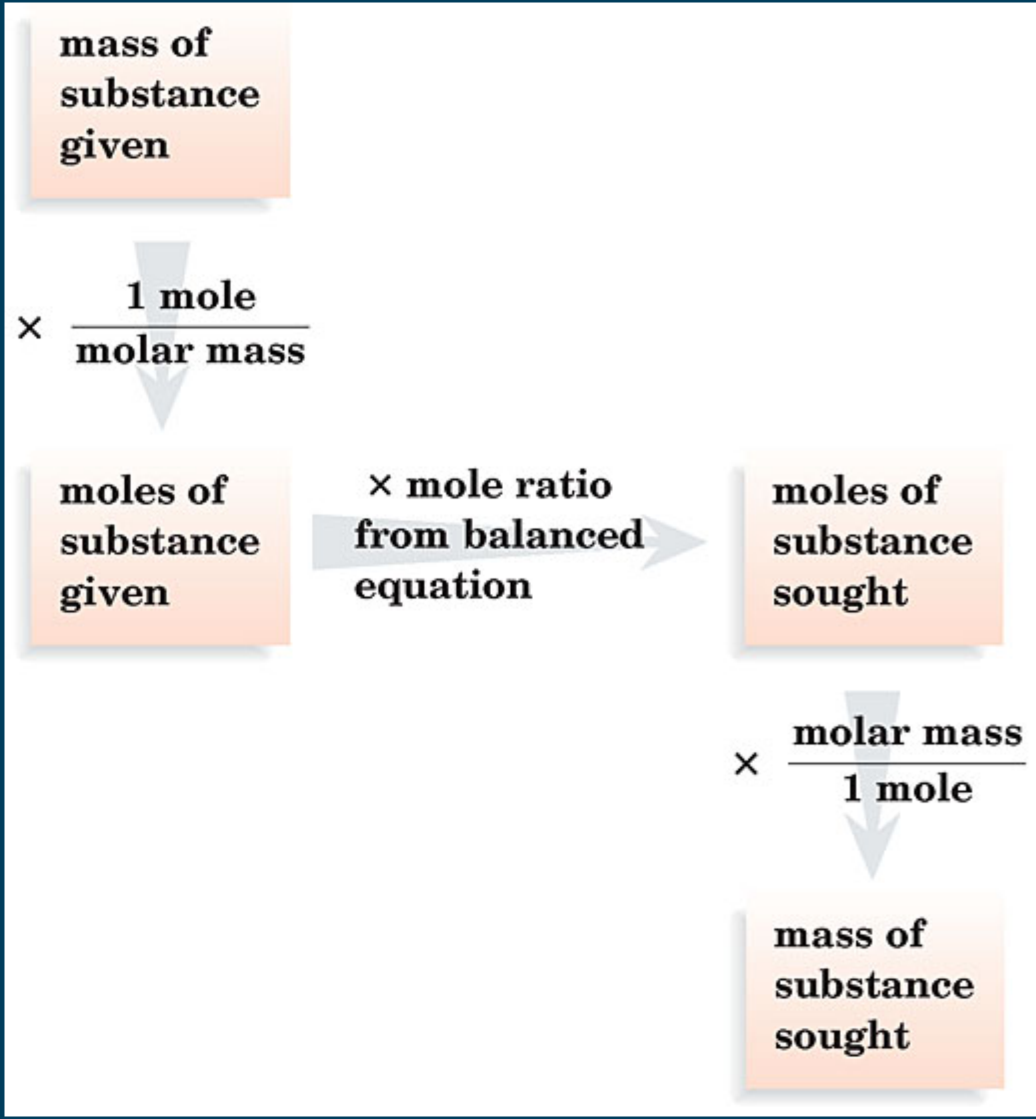


Conversion of Quantities in Moles

Click below to watch the Visual Concept.

Visual Concept

Solving Mass-Mass Stoichiometry Problems



Conversions of Quantities in Moles, *continued*

Sample Problem A

In a spacecraft, the carbon dioxide exhaled by astronauts can be removed by its reaction with lithium hydroxide, LiOH, according to the following chemical equation.

$$CO_2(g) + 2LiOH(s) \rightarrow Li_2CO_3(s) + H_2O(l)$$

How many moles of lithium hydroxide are required to react with 20 mol CO_2, the average amount exhaled by a person each day?

End Of Slide

Conversions of Quantities in Moles, *continued*

Sample Problem A Solution

$$CO_2(g) + 2LiOH(s) \rightarrow Li_2CO_3(s) + H_2O(l)$$

Given: amount of CO_2 = 20 mol

Unknown: amount of LiOH (mol)

Solution:

mol ratio

$$\text{mol } CO_2 \times \frac{\text{mol LiOH}}{\text{mol } CO_2} = \text{mol LiOH}$$

$$20 \text{ mol } CO_2 \times \frac{2 \text{ mol LiOH}}{1 \text{ mol } CO_2} = 40 \text{ mol LiOH}$$

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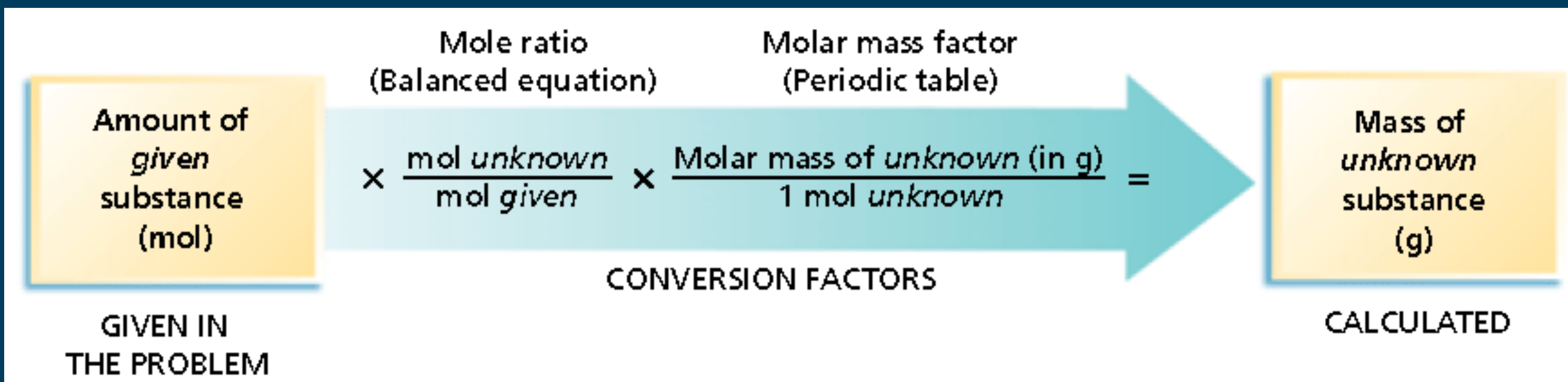
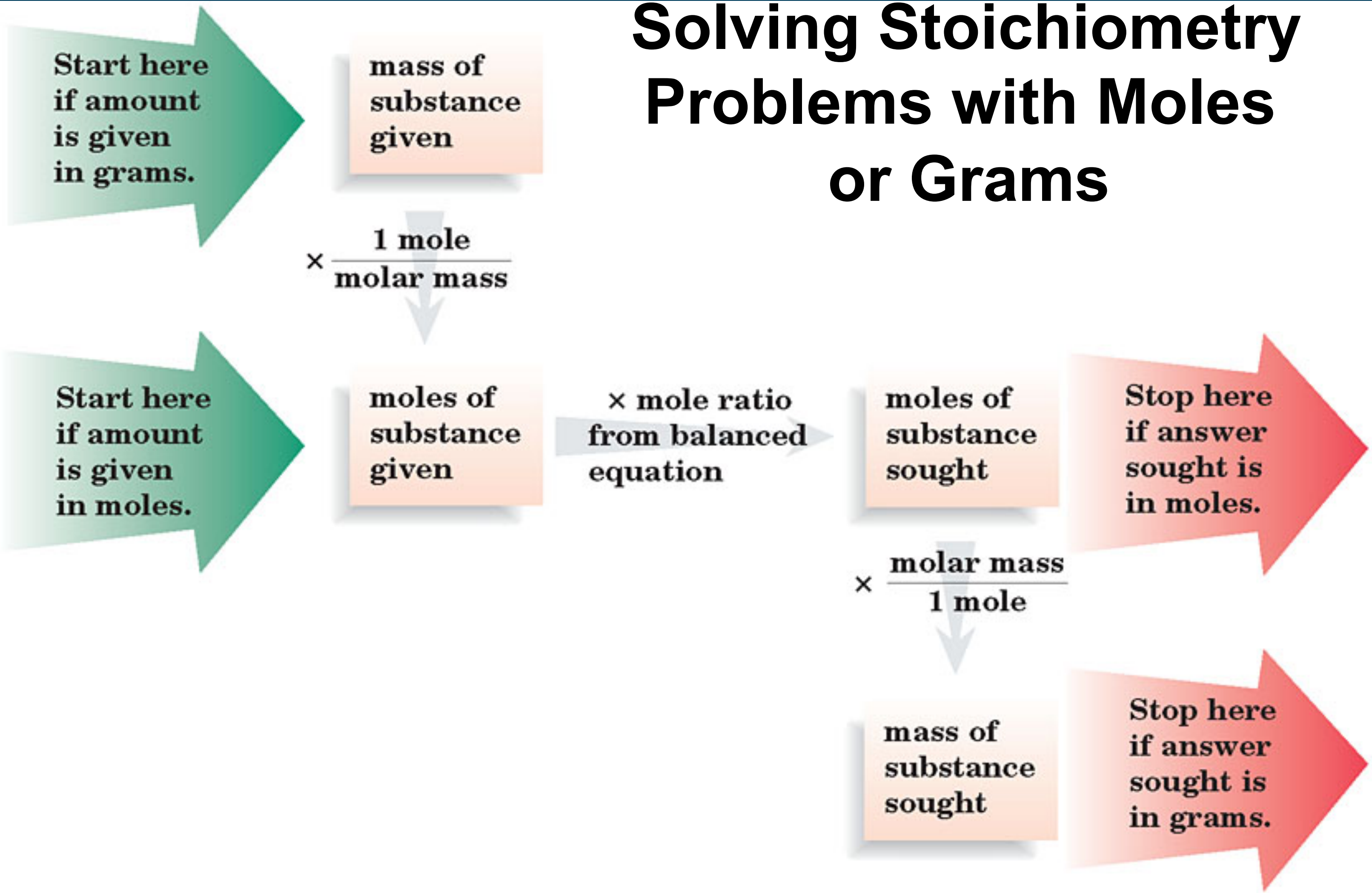
Conversions of Amounts in Moles to Mass



Solving Stoichiometry Problems with Moles or Grams



Conversions of Amounts in Moles to Mass, *continued*

Sample Problem B

In photosynthesis, plants use energy from the sun to produce glucose, $C_6H_{12}O_6$, and oxygen from the reaction of carbon dioxide and water.

What mass, in grams, of glucose is produced when 3.00 mol of water react with carbon dioxide?

Conversions of Amounts in Moles to Mass, *continued*

Sample Problem B Solution

Given: amount of H_2O = 3.00 mol

Unknown: mass of $C_6H_{12}O_6$ produced (g)

Solution:

Balanced Equation: $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

mol ratio — *molar mass factor*

$$\text{mol } H_2O \times \frac{\text{mol } C_6H_{12}O_6}{\text{mol } H_2O} \times \frac{\text{g } C_6H_{12}O_6}{\text{mol } C_6H_{12}O_6} = \text{g } C_6H_{12}O_6$$

$$3.00 \text{ mol } H_2O \times \frac{1 \text{ mol } C_6H_{12}O_6}{6 \text{ mol } H_2O} \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} =$$

$90.1 \text{ g } C_6H_{12}O_6$

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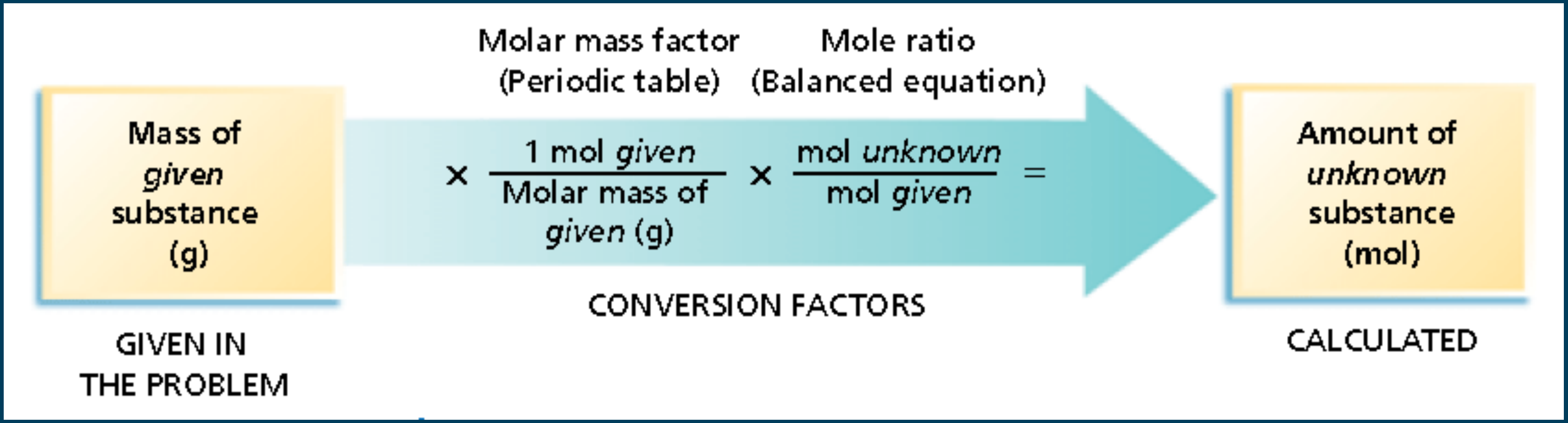
Conversions of Mass to Amounts in Moles



Mass and Number of Moles of an Unknown

Click below to watch the Visual Concept.

Visual Concept

Conversions of Mass to Amounts in Moles, *continued*

Sample Problem D

The first step in the industrial manufacture of nitric acid is the catalytic oxidation of ammonia.

$NH_3(g) + O_2(g) \rightarrow NO(g) + H_2O(g)$ (unbalanced)

The reaction is run using 824 g NH_3 and excess oxygen.

a. How many moles of NO are formed?

b. How many moles of H_2O are formed?

Conversions of Mass to Amounts in Moles, *continued*

Sample Problem D Solution

Given: mass of NH_3 = 824 g

Unknown: **a.** amount of NO produced (mol)

b. amount of H_2O produced (mol)

Solution:

Balanced Equation: $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

molar mass factor *mol ratio*

a. $$\text{g } NH_3 \times \frac{\text{mol } NH_3}{\text{g } NH_3} \times \frac{\text{mol NO}}{\text{mol } NH_3} = \text{mol NO}$$

b. $$\text{g } NH_3 \times \frac{\text{mol } NH_3}{\text{g } NH_3} \times \frac{\text{mol } H_2O}{\text{mol } NH_3} = \text{mol } H_2O$$

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Conversions of Mass to Amounts in Moles, *continued*

Sample Problem D Solution, *continued*

molar mass factor *mol ratio*

a. $$824\ g\ NH_3 \times \frac{1\ mol\ NH_3}{17.04\ g\ NH_3} \times \frac{4\ mol\ NO}{4\ mol\ NH_3} = 48.4\ mol\ NO$$

b. $$824\ g\ NH_3 \times \frac{1\ mol\ NH_3}{17.04\ g\ NH_3} \times \frac{6\ mol\ H_2O}{4\ mol\ NH_3} = 72.5\ mol\ H_2O$$

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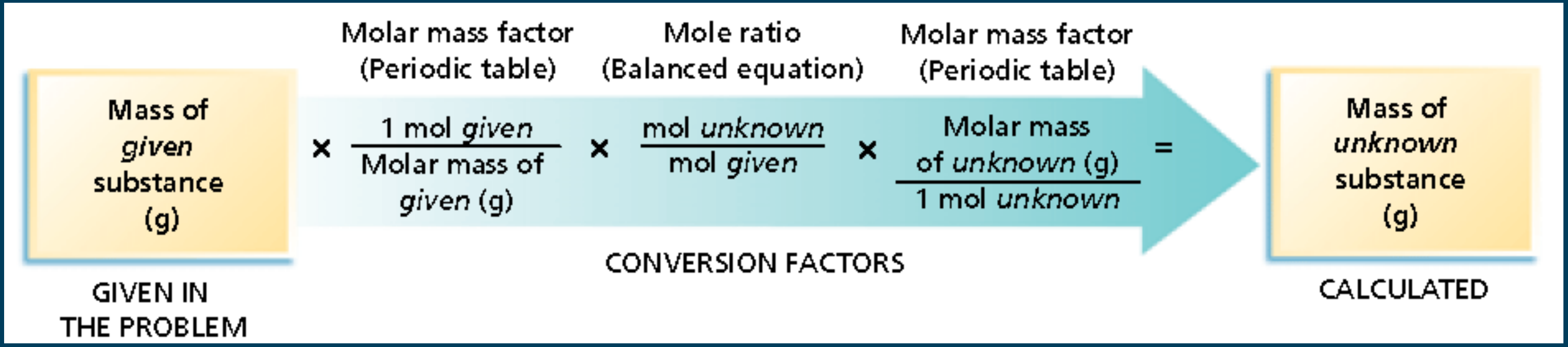
Mass-Mass to Calculations



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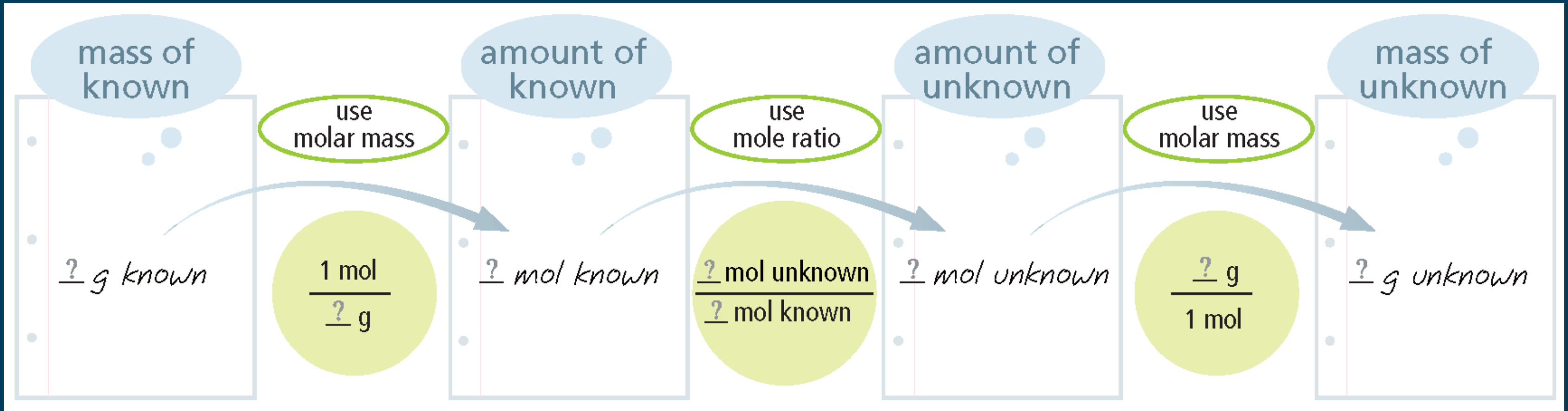
Mass-Mass Calculations

Click below to watch the Visual Concept.

Visual Concept

Solving Mass-Mass Problems



Mass-Mass to Calculations, *continued*

Sample Problem E

Tin(II) fluoride, SnF_2, is used in some toothpastes. It is made by the reaction of tin with hydrogen fluoride according to the following equation.

$$Sn(s) + 2HF(g) \rightarrow SnF_2(s) + H_2(g)$$

How many grams of SnF_2 are produced from the reaction of 30.00 g HF with Sn?

End of Slide

Mass-Mass to Calculations, *continued*

Sample Problem E Solution

Given: amount of HF = 30.00 g

Unknown: mass of SnF_2 produced (g)

Solution:

molar mass factor — *mol ratio* — *molar mass factor*

$$\text{g HF} \times \frac{\text{mol HF}}{\text{g HF}} \times \frac{\text{mol SnF}_2}{\text{mol HF}} \times \frac{\text{g SnF}_2}{\text{mol SnF}_2} = \text{g SnF}_2$$

$$\text{g HF} \times \frac{1\ \text{mol HF}}{20.01\ \text{g HF}} \times \frac{1\ \text{mol SnF}_2}{2\ \text{mol HF}} \times \frac{156.71\ \text{g SnF}_2}{1\ \text{mol SnF}_2}$$

$$= 117.5\ \text{g SnF}_2$$

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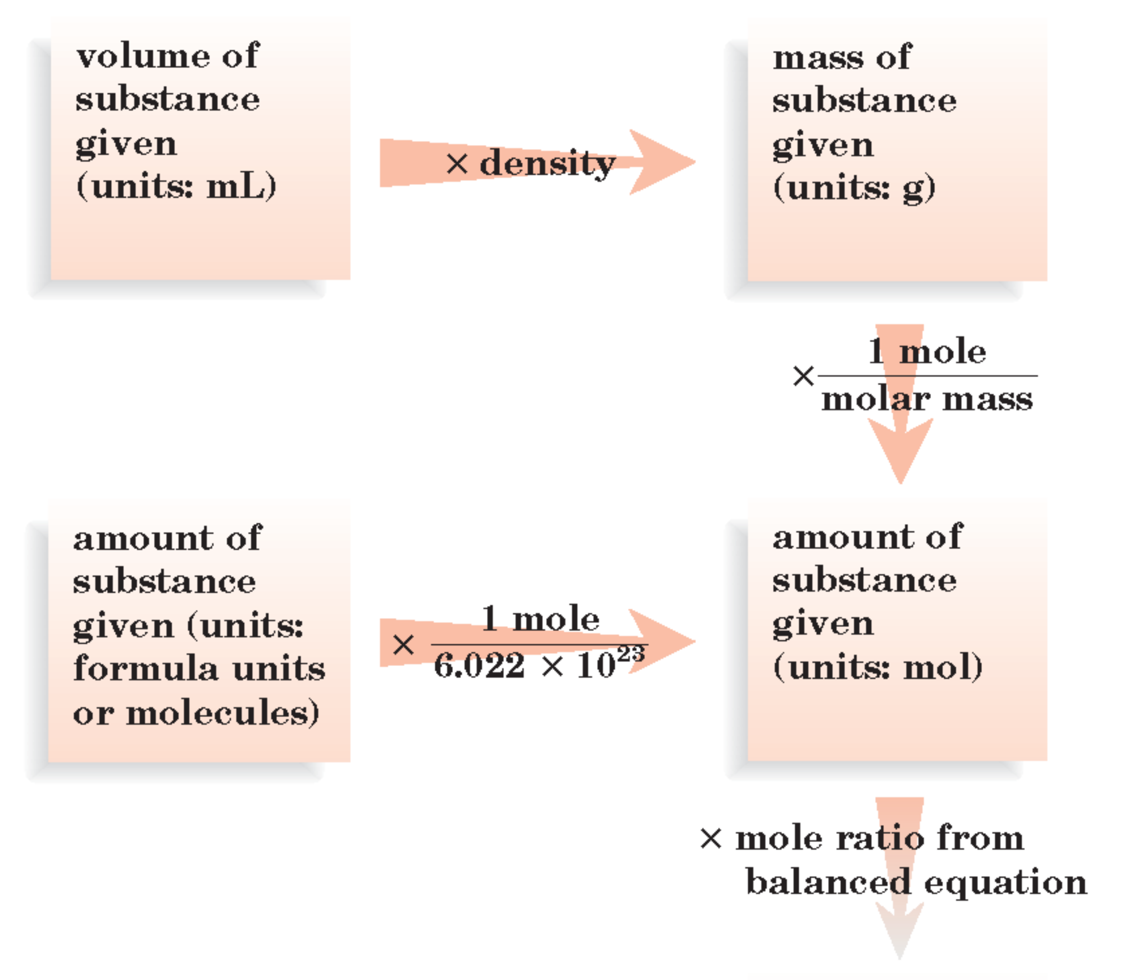
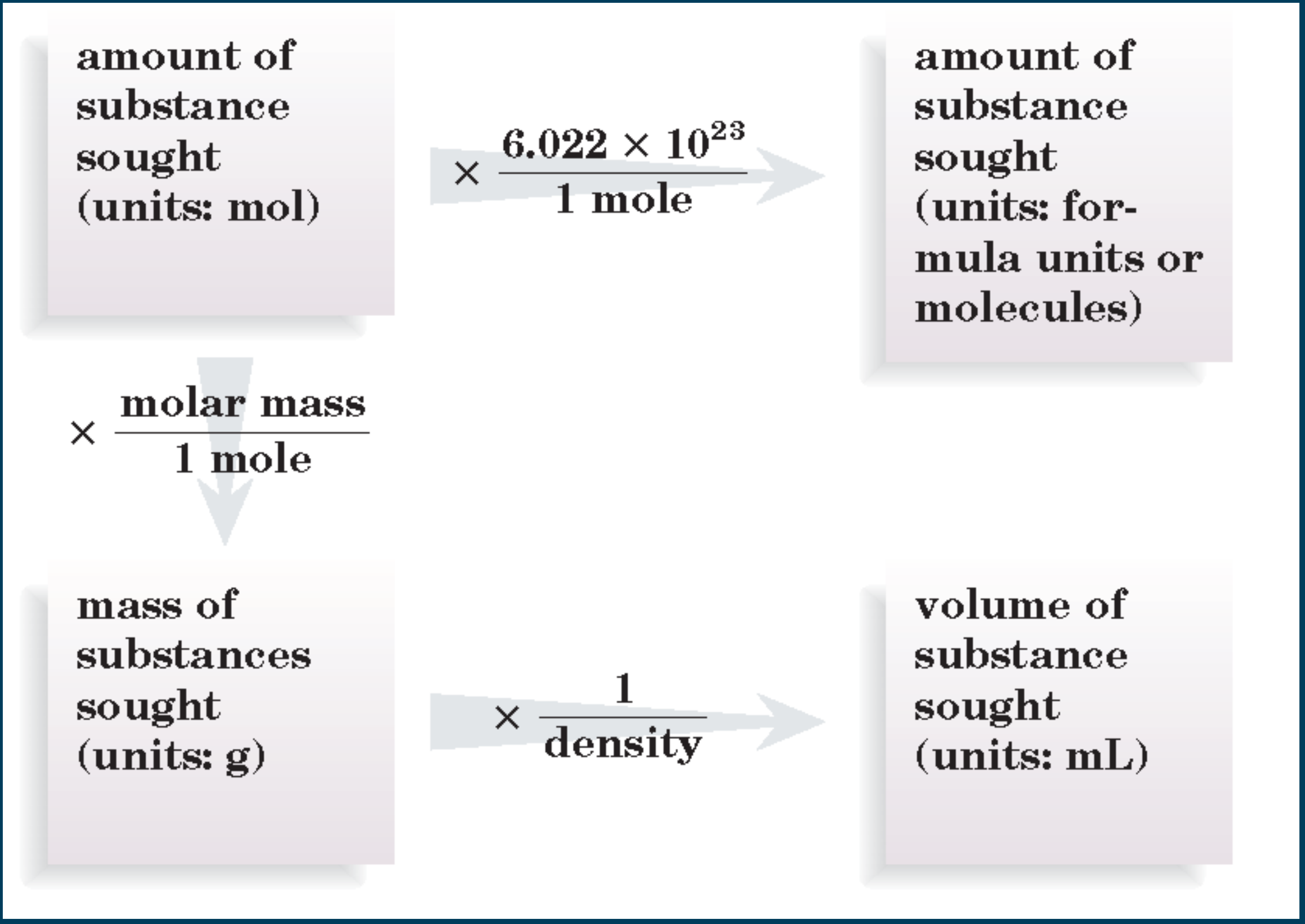
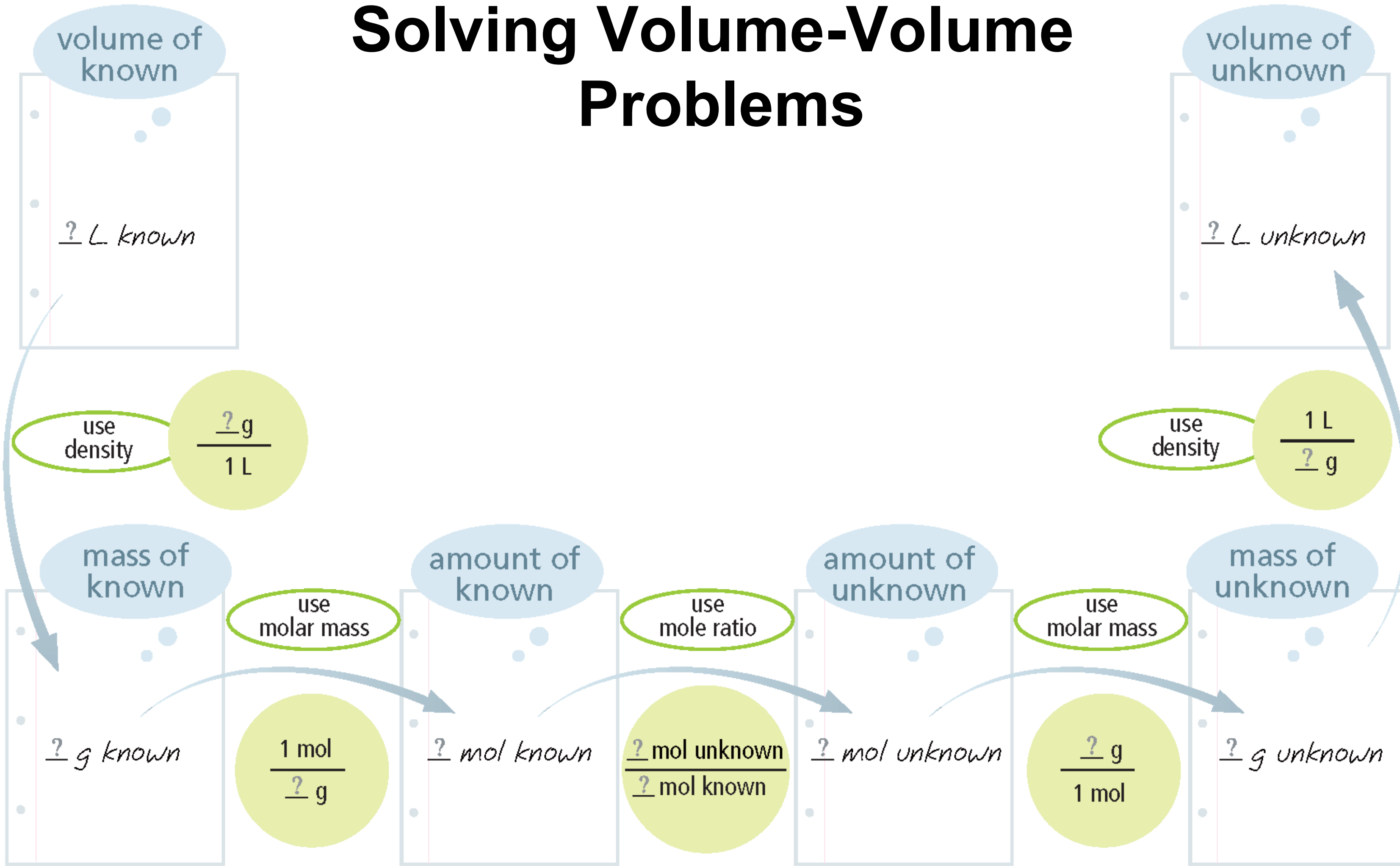
Solving Various Types of Stoichiometry Problems



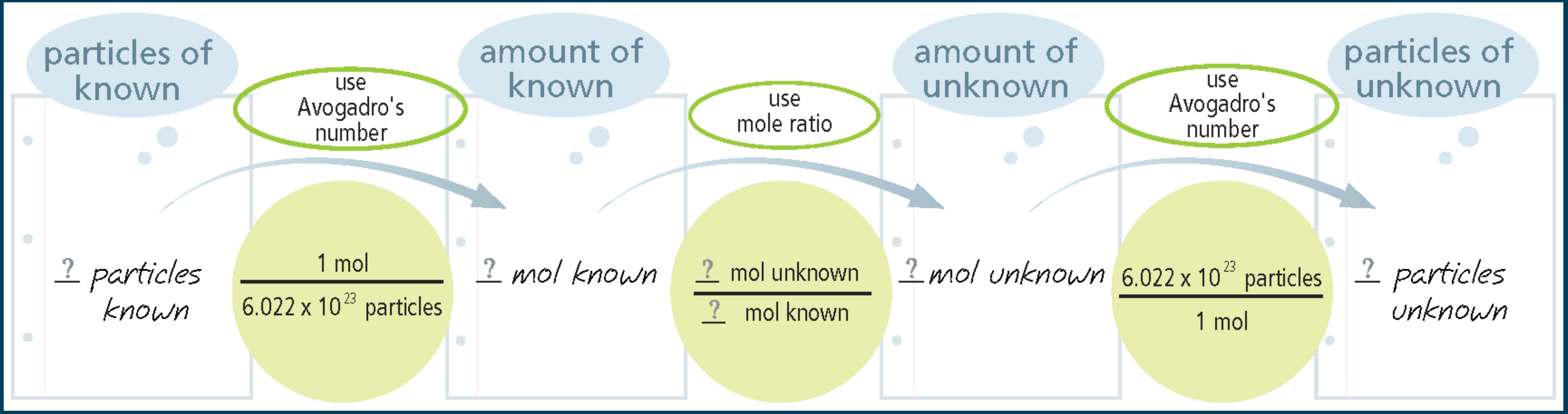
Solving Various Types of Stoichiometry Problems



Solving Volume-Volume Problems



Solving Particle Problems



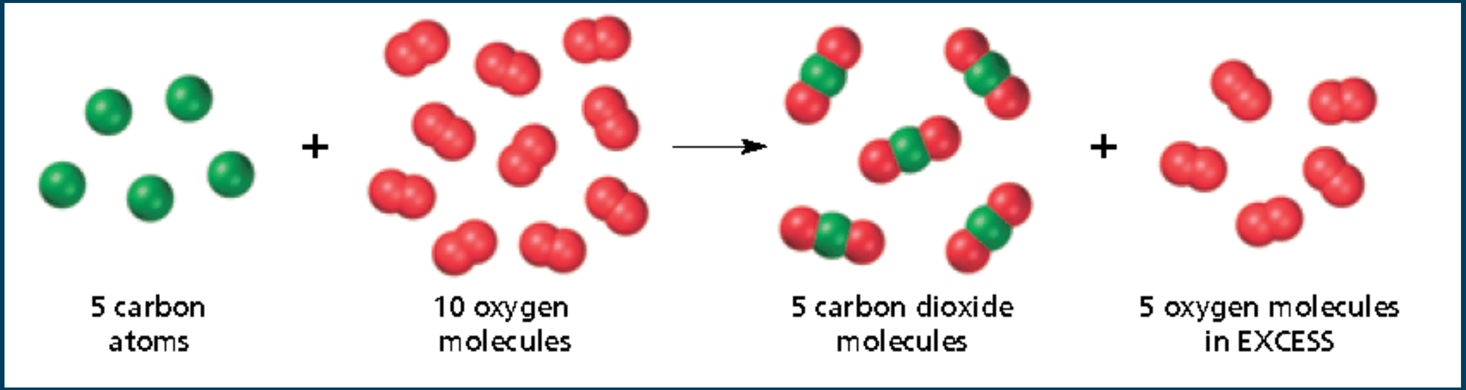
Preview

Objectives

- **Describe** a method for determining which of two reactants is a limiting reactant.
- **Calculate** the amount in moles or mass in grams of a product, given the amounts in moles or masses in grams of two reactants, one of which is in excess.
- **Distinguish** between theoretical yield, actual yield, and percentage yield.
- **Calculate** percentage yield, given the actual yield and quantity of a reactant.

Limiting Reactants

- The **limiting reactant** is the reactant that limits the amount of the other reactant that can combine and the amount of product that can form in a chemical reaction.
- The **excess reactant** is the substance that is not used up completely in a reaction.



Limiting Reactants and Excess Reactants

Click below to watch the Visual Concept.

Visual Concept

Limited Reactants, *continued*

Sample Problem F

Silicon dioxide (quartz) is usually quite unreactive but reacts readily with hydrogen fluoride according to the following equation.

$$SiO_2(s) + 4HF(g) \rightarrow SiF_4(g) + 2H_2O(l)$$

If 6.0 mol HF is added to 4.5 mol SiO_2, which is the limiting reactant?

End Of Slide

Limited Reactants, *continued*

Sample Problem F Solution

$$SiO_2(s) + 4HF(g) \rightarrow SiF_4(g) + 2H_2O(l)$$

Given: amount of HF = 6.0 mol

amount of SiO_2 = 4.5 mol

Unknown: limiting reactant

Solution:

mole ratio

$$\text{mol HF} \times \frac{\text{mol SiF}_4}{\text{mol HF}} = \text{mol SiF}_4 \text{ produced}$$

$$\text{mol SiO}_2 \times \frac{\text{mol SiF}_4}{\text{mol SiO}_2} = \text{mol SiF}_4 \text{ produced}$$

End Of Slide

Limited Reactants, *continued*

Sample Problem F Solution, *continued*

$$SiO_2(s) + 4HF(g) \rightarrow SiF_4(g) + 2H_2O(l)$$

$$4.5 \text{ mol } SiO_2 \times \frac{1 \text{ mol } SiF_4}{1 \text{ mol } SiO_2} = 4.5 \text{ mol } SiF_4 \text{ produced}$$

$$6.0 \text{ mol HF} \times \frac{1 \text{ mol } SiF_4}{4 \text{ mol HF}} = 1.5 \text{ mol } SiF_4 \text{ produced}$$

HF is the limiting reactant.

End Of Slide

Percentage Yield

- The **theoretical yield** is the maximum amount of product that can be produced from a given amount of reactant.
- The **actual yield** of a product is the measured amount of that product obtained from a reaction.
- The **percentage yield** is the ratio of the actual yield to the theoretical yield, multiplied by 100.

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theorectical yield}} \times 100$$

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Comparing Actual and Theoretical Yield

Click below to watch the Visual Concept.

Visual Concept

Percentage Yield, *continued*

Sample Problem H

Chlorobenzene, C_6H_5Cl, is used in the production of many important chemicals, such as aspirin, dyes, and disinfectants. One industrial method of preparing chlorobenzene is to react benzene, C_6H_6, with chlorine, as represented by the following equation.

$$C_6H_6\,(l) + Cl_2(g) \rightarrow C_6H_5Cl(l) + HCl(g)$$

When 36.8 g C_6H_6 react with an excess of Cl2, the actual yield of C_6H_5Cl is 38.8 g.

What is the percentage yield of C_6H_5Cl?

End Of Slide

Percentage Yield, *continued*

Sample Problem H Solution

$$C_6H_6\ (l) + Cl_2(g) \rightarrow C_6H_5Cl(l) + HCl(g)$$

Given: mass of C_6H_6 = 36.8 g

mass of Cl_2 = excess

actual yield of C_6H_5Cl = 38.8 g

Unknown: percentage yield of C_6H_5Cl

Solution:

Theoretical yield

$$g\ C_6H_6 \times \underbrace{\frac{mol\ C_6H_6}{g\ C_6H_6}}_{\textit{molar mass factor}} \times \underbrace{\frac{mol\ C_6H_5Cl}{mol\ C_6H_6}}_{\textit{mol ratio}} \times \underbrace{\frac{g\ C_6H_5Cl}{mol\ C_6H_5Cl}}_{\textit{molar mass}} = g\ C_6H_5Cl$$

End Of Slide

Percentage Yield, *continued*

Sample Problem H Solution, *continued*

$$C_6H_6(l) + Cl_2(g) \rightarrow C_6H_5Cl(l) + HCl(g)$$

Theoretical yield

$$36.8\ g\ C_6H_6 \times \frac{1\ mol\ C_6H_6}{78.12\ g\ C_6H_6} \times \frac{1\ mol\ C_6H_5Cl}{1\ mol\ C_6H_6} \times \frac{112.56\ g\ C_6H_5Cl}{1\ mol\ C_6H_5Cl}$$

$$= 53.0\ g\ C_6H_5Cl$$

Percentage yield

$$\text{percentage yield } C_6H_5Cl = \frac{\text{actual yield}}{\text{theorectical yield}} \times 100$$

$$\text{percentage yield} = \frac{38.8\ g}{53.0\ g} \times 100 = 73.2\%$$

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End of Chapter 9 Show

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