

Section 6: Stoichiometry

The following maps the videos in this section to the Texas Essential Knowledge and Skills for Science TAC §112.35(c).

6.01 The Mole

- Chemistry (8)(A)
- Chemistry (8)(B)

6.02 Percent Composition

- Chemistry (8)(C)

6.03 Empirical and Molecular Formulas

- Chemistry (8)(C)

6.04 Balancing Equations

- Chemistry (8)(D)

6.05 Stoichiometry with Balanced Equations

- Chemistry (8)(E)

6.06 Limiting Reactants and Percent Yield

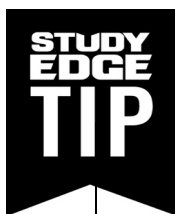
- Chemistry (8)(E)

Note: Unless stated otherwise, any sample data is fictitious and used solely for the purpose of instruction.

6.01

The Mole

In a chemical reaction, large numbers of atoms and molecules are present. It is useful to describe the amount of a reactant or product in more manageable terms. A **mole** is the SI unit for an amount of a substance, and it's defined to be equal to 6.022×10^{23} individual particles of that substance. That number is also known as **Avogadro's number**.



Think of a mole as a specific quantity, like a dozen.

For every atom, there is a specific mass called the **atomic mass**, which corresponds to one mole of that atom.

1. How many atoms of carbon are present in a sample containing 2.50 moles of carbon?

- A. 1.51×10^{24} atoms
- B. 3.10×10^{19} atoms
- C. 7.23×10^{24} atoms
- D. 9.78×10^{18} atoms

The mass of one mole of a molecule or compound is referred to as the ***molar mass***, and it can be expressed as the sum of all the atomic masses of the component atoms. Molar mass is typically measured in units of grams per mole.



Mass \leftrightarrow Moles \leftrightarrow Individual Molecules/Compounds
(formula units)

2. How many chloride ions are present in a sample of magnesium chloride with a mass of 35.5 grams?
- A. 8.81×10^{25} ions
 - B. 1.03×10^{19} ions
 - C. 4.49×10^{23} ions
 - D. 7.89×10^{18} ions

6.02

Percent Composition

The **percent composition** or **mass percentage** of an element in a molecule or compound is the ratio of the mass of the element present to the total mass of the compound or molecule, expressed as a percentage.

$$\text{Percent composition of element } X = \frac{\text{Total mass of } X \text{ in the compound}}{\text{Total mass of the compound}} \times 100$$

The law of definite proportions states that the ratio of the elements in a compound is constant, regardless of the mass of the compound. This implies that the percent composition of an element in a compound is also constant for any mass of the compound.



**STUDY
EDGE
TIP**

If the mass of a compound is not given, assume there is one mole of the compound to find mass percentage.

1. What is the mass percentage of fluorine in phosphorus pentafluoride?

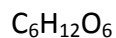
- A. 68.21%
- B. 75.41%
- C. 89.17%
- D. 29.12%

2. Sylvanite is a telluride mineral found in the Transylvania region of Romania. Sylvanite is 6.3% silver and 34.4% gold by mass. How many atoms of gold are present in a 250-kg sample of sylvanite?

6.03

Empirical and Molecular Formulas

The ***empirical formula*** of a compound is the simplest whole-number ratio of elements in the compound. The ***molecular formula*** of a compound is the actual formula of the compound as the compound appears in nature. For example, consider the molecular formula of glucose:



One of the ways to find the molecular formula of a compound experimentally is to use mass data and percent composition. However, in order to find the molecular formula from mass data, we first need to find the empirical formula.

1. Geraldine is asked to find the formula of an unknown compound containing only carbon, hydrogen, and oxygen. She was given the following elemental mass percentages: 39.33% C and 8.269% H. What is the empirical formula for this compound?

Once the empirical formula of a compound is known, we can find the molecular formula by first calculating the factor of increase from the given molar mass of the compound:

$$\text{Factor of Increase (\#)} = \frac{\text{molar mass of molecular formula}}{\text{molar mass of empirical formula}}$$

Then, we can multiply the empirical formula by the factor of increase to find the molecular formula.



Molecular Formula = (#) Empirical Formula

2. If Geraldine is told that the molar mass of the compound she was working with in the previous problem is approximately 183 grams per mole, what is the molecular formula of the compound?

6.04

Balancing Equations

Chemical equations are like the sentences of chemistry. The compounds are the words and the elements are the letters.

- On the left side of the arrow you have **reactants**. Think of these as your beginning materials.
- On the right side of the arrow you have **products**. Think of these as your ending materials.

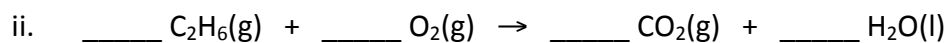
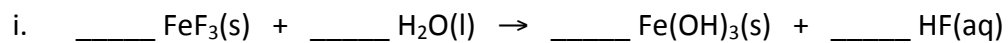
A chemical equation shows how a chemical reaction reorganizes reactants into an arrangement of products. Remember the law of conservation of matter.

- The numbers next to reactants and products are called **stoichiometric coefficients**. They indicate how many moles of each molecule you need to have, or how many moles you are going to make.
- You can manipulate the stoichiometric coefficients to make your reaction balanced, but you **cannot** change the chemical ratio of the compounds.

Balancing Tips

- Make sure you are very comfortable with the process of naming molecules, compounds and ions.
- Start with compounds, not diatomic or lone metals.
- Always check to make sure that the number of atoms on the left matches the number of atoms on the right, and make sure to indicate the states of matter of the products and reactants whenever possible.

1. Balance the following equations using the lowest possible whole numbers:

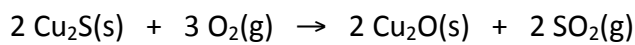


6.05

Stoichiometry with Balanced Equations

Stoichiometry studies how reactants and products are numerically related to one another in a balanced chemical reaction. In order to perform stoichiometric calculations, you first need to master balancing equations.

In a balanced chemical equation, we call the numbers in front of each reactant or product the **stoichiometric coefficients**. The coefficients determine the ratios in which the components of the chemical equation are related to each other. The ratios always refer to moles and atoms, never masses. Consider the reaction below:



- For every ____ moles of Cu_2S that react according to the equation above, ____ moles of O_2 are consumed, and ____ moles of SO_2 can be produced.
 - Remember that these ratios never refer to the mass of a reactant or product, only to the moles or atoms.
 - We can use mass in stoichiometric calculations, but it must be converted to moles first.
1. If 125 grams of oxygen gas react according to the equation above, how many grams of copper(I) oxide are expected to be formed?

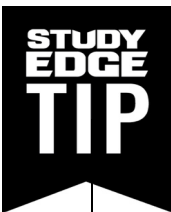
6.06

Limiting Reactants and Percentage Yield

Safety Note: Any chemicals mentioned in this video are potentially harmful and should be handled with the appropriate safety precautions.

When a reaction occurs, it is possible that one of the reactants is in short supply, and it prevents the reaction from going further.

- The **limiting reactant (LR)** is the reactant that will stop the progress of the reaction and keep the other reactants from reacting completely.
- The **excess reactant (XS)**, if any, is left behind when the limiting reactant is fully consumed by the reaction.
- The **theoretical yield (TY)** is the maximum amount of product(s) that a reaction can be expected to make, and it will always come from the limiting reactant(s). This yield can be determined by doing stoichiometry.
- If all the reactants are stoichiometrically equal—i.e., they all run out at the same time—then there is no excess reactant.



If you are given the amount of more than one reactant, you need to find the LR.

1. Solid potassium metal reacts violently with water to form aqueous potassium hydroxide and hydrogen gas, which immediately ignites. In a laboratory experiment, a 15.0-gram sample of potassium is dropped into a beaker containing 75.0 grams of liquid water. Assume the reaction reaches completion. Identify the limiting reactant, the excess reactant, and the theoretical yield of hydrogen gas produced.

A reaction rarely produces the expected yield that is calculated from stoichiometry alone. Scientists use the idea of **percentage yield** to gauge how close they were to the expected yield, compared to a perfectly run experiment.

- The theoretical yield is the result obtained from stoichiometry. This is sometimes referred to as the “perfect” reaction yield.
- The **actual yield** is the amount that is obtained when the experiment is actually run in a laboratory.

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

2. In a chemistry lab, Taylor reacts 15.0 grams of potassium metal with 75.0 grams of liquid water, according to the reaction provided in the previous problem. If Taylor collects 0.250 grams of hydrogen gas, what is the percentage yield of this experiment?

8A 18

Actinides