

STOICHIOMETRY

An interesting area of chemistry called stoichiometry examines the quantitative relationship between reactants and products in chemical processes. Stoichiometry predicts the quantities of substances consumed or created during a reaction by carefully examining the atoms and molecules' ratios. Stoichiometry is important whether you're solving equations, figuring out reactant quantities, or discovering the complexities of chemical reactions.

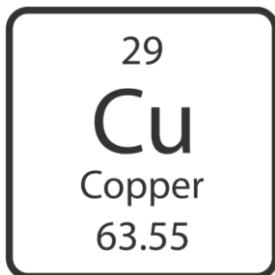
Chemical Composition (Bauer et al., 2018)

Mass Number (A)

A whole number represents the number of protons and neutrons in an atom.

Atomic Mass

The average number of protons and neutrons for all natural isotopes of an element.



$^{63}_{29}Cu$	69.17 %	62.930 amu
$^{63}_{29}Cu$	30.83 %	64.928 amu

Get the average of the atomic mass unit of the isotopes.

$$\text{Atomic mass of copper} = [(69.17\%) (62.930) + (30.83\%) (64.928)]/2 \\ = 64.546 \text{ amu}$$

Avogadro's Number

The number of atoms, molecules, or particles in a mole. Represented as N_A in some books, the value is equal to **6.022 x 10²³ per mol**

Example: 1 mol of Cu = 6.022×10^{23} atoms = 63.55g

1 mol of Cl = 6.022×10^{23} atoms = 35.45g

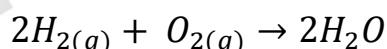
1 mol of C = 6.022×10^{23} atoms = 12.011g

Mole

The mass of a substance contains 6.022×10^{23} particles. In chemical reactions, the number of elements and compounds in the reaction is usually given by the ratio of the moles.

Example: In the equation below, 2 moles of H₂ and 1 mole of O₂ are needed to produce 1 mole of

H₂O or water



Percent Composition (Libretexts, 2021)

The percent composition is constant, whatever the sample size, and it follows the law of definite proportions. It is a convenient way to express composition for any sample size. The mass of each component is converted to a percentage of the total mass of the sample. The percent composition of any element *E* is calculated as:

$$\%E = \frac{\text{mass of } E}{\text{mass of sample}} \times 100\%$$

Example: Given PCl_5 , find the percent composition of each element by mass.

1. Atomic mass of P = 30.974 g/mol and Cl = 35.453 g/mol
2. Since there are 1 atom of P and 5 atoms of Cl in the compound, the total mass is $\text{PCl}_5 = 30.974 + 5(35.453) = 208.235$ g/mol
3. To find the percent composition:

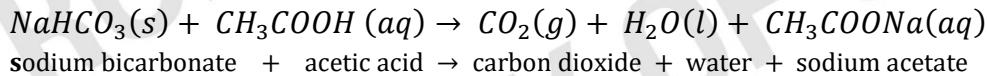
$$\%P = \frac{30.974}{208.235} \times 100\% = 14.87\%$$

$$\%Cl = \frac{177.265}{208.235} \times 100\% = 85.13\%$$

Chemical Reactions and Chemical Equations (Bauer et al., 2018; Tro, 2023)

Chemical Reaction is a process in which a substance or substances are changed into one or more new substances. The general equation is written as:

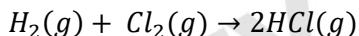
Reactants → Products



- Reactants (starting substances) are placed on the left side.
- Products (substances produced) are placed on the right.
- The arrow points towards the direction of the reaction.

Balancing Chemical Equations

Chemical reactions follow the law of conservation of mass. No atoms are created or destroyed; they are just rearranged. For a chemical equation to be balanced, the same number and types of atoms appear on the left and right sides of the equation.



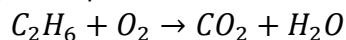
<u>Reactants</u>	<u>Products</u>
$\text{H}_2 \rightarrow \text{H} - 2$	$2\text{HCl} \rightarrow 2\text{H} + 2\text{Cl} \rightarrow \text{H} - 2$
$\text{Cl}_2 \rightarrow \text{Cl} - 2$	$2\text{HCl} \rightarrow 2\text{H} + 2\text{Cl} \rightarrow \text{Cl} - 2$

Steps in balancing chemical equations:

- a. Identify the reactants and products and write their correct formulas.
- b. Write down your given equation.
- c. Write down the number of atoms per element that you have on each side of the equation.
- d. Always leave hydrogen and oxygen for last.
- e. Select the element that appears in only a single molecule of reactants and only a single molecule of products.

f. Add coefficient/s to the atom on the right of the equation to balance it with the atoms on the left of the equation.

Example: ethane reacts with oxygen gas and produces carbon dioxide and water.



<u>Reactants</u>	<u>Products</u>
C - 2	C - 1
H - 6	H - 2
O - 2	O - 2 + 1 = 3

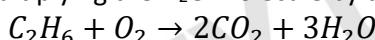
To balance the carbon atoms on both sides, convert the carbon atom in the reactant to two (2)



Count the atoms:

<u>Reactants</u>	<u>Products</u>
C - 2	C - 2
H - 6	H - 2
O - 2	O - 2(2) + 1 = 5

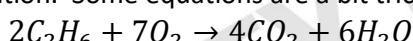
Balance the hydrogen atoms by multiplying the H_2O molecule by three (3)



Count the atoms:

<u>Reactants</u>	<u>Products</u>
C - 2	C - 2
H - 6	H - 6
O - 2	O - 2(2) + 3 = 7

Notice that we cannot balance the oxygen atoms using a whole number multiplier to O_2 because that would result in an even count all the time. It means we need to modify all the coefficients and find the combination to balance the equation. Some equations are a bit trickier and challenging to balance.

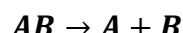


Count the atoms:

<u>Reactants</u>	<u>Products</u>
C - 4	C - 4
H - 12	H - 12
O - 14	O - 4(2) + 6 = 14

Types of Chemical Reactions in Aqueous Solution

Decomposition reaction – a reactant breaks down into two or more products.



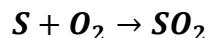
Example: Calcium carbonate decomposes to Calcium oxide and carbon dioxide



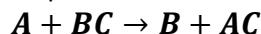
Synthesis reaction – two or more reactants form a single product.



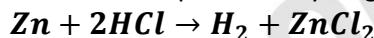
Example: Sulfur and oxygen produce sulfur dioxide



Single displacement reaction – one element replaces another in a compound.



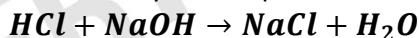
Example: Zinc and hydrochloric acid reaction produces hydrogen and zinc chloride



Double displacement – two ionic compounds exchange ions.



Example: Hydrochloric acid and sodium hydroxide produce sodium chloride and water



Combustion reaction – a hydrocarbon (a compound containing carbon and hydrogen) reacts with oxygen to form carbon dioxide and water.



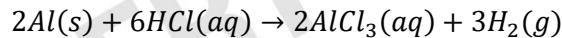
Example: Methane and oxygen produce carbon dioxide and water



Mass-Mole Relationships in Chemical Reactions

Chemical reaction problems require conversion from mass to mole to reaction ratios and sometimes density. Recall molar mass, the mass in grams of one mole of an atom, a molecule, or a compound. Two (2) moles of a substance mean times two (2) of its mass in grams. The coefficients in a chemical equation represent the ratio of the molecules in moles. For example, two (2) moles of water are formed from 2 moles of hydrogen atom (H_2) and one mole of oxygen atom (O_2). Stoichiometric calculations are a series of conversions using these factors.

Example: A hydrochloric acid solution consists of 28.0% HCl by mass and has a 1.14 g/mL density. What volume of this solution is required to react completely with 1.87 g Al?



Steps:

1. Convert the 1.87g Al to mols Aluminum: $1.87g Al \times \frac{1\ mol\ Al}{26.98g\ Al} = 0.0693\ mol\ Al$
2. Convert mols Al to mols HCl: $0.0693\ mol\ Al \times \frac{6\ mol\ HCl}{2\ mol\ Al} = 0.208\ mol\ HCl$
3. Convert mols of HCl to g HCl: $0.208\ mol\ HCl \times \frac{36.46g\ HCl}{1\ mol\ HCl} = 7.58g\ HCl$
4. Use percentage to get mass of solution: $7.58g\ HCl \times \frac{100g\ solution}{28g\ HCl} = 27.1g\ HCl\ solution$
5. Convert mass to volume by using density: $27.1g \times \frac{1mL}{1.14g} = 23.8mL\ HCl\ solution$

Writing References

- Balancing chemical equations* (By University of Colorado). (2024). PhET Interactive Simulations. Retrieved March 18, 2024, from https://phet.colorado.edu/sims/html/balancing-chemical-equations/latest/balancing-chemical-equations_all.html
- Bayquen, A., Peña, G., & Ramos, J. (2023). *Exploring Life Through Science Series: General Chemistry 1 and 2*. Phoenix Publishing House.
- Bauer, R. C., Birk, J. P., & Marks, P. (2024). *Introduction to chemistry* (6th ed.). McGraw-Hill Education.
- Chemistry 1e (OpenSTAX)*. (2023, March 25). Chemistry LibreTexts.
[https://chem.libretexts.org/Bookshelves/General_Chemistry/Chemistry_1e_\(OpenSTAX\)](https://chem.libretexts.org/Bookshelves/General_Chemistry/Chemistry_1e_(OpenSTAX))
- Libretexts. (2023, January 30). *The Mole and Avogadro's constant*. Chemistry LibreTexts.
[https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_\(Physical_and_Theoretical_Chemistry\)/Atomic_Theory/The_Mole_and_Avogadro's_Constant](https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Atomic_Theory/The_Mole_and_Avogadro's_Constant)
- Libretexts. (2021, December 26). 2.10: percent composition. Chemistry LibreTexts.
[https://chem.libretexts.org/Courses/University_of_Arkansas_Little_Rock/Chem_1402%3A_General_Chemistry_1_\(Kattoum\)/Text/2%3A_Atoms%2C_Molecules%2C_and_Ions/5.13%3A_Percent_Composition](https://chem.libretexts.org/Courses/University_of_Arkansas_Little_Rock/Chem_1402%3A_General_Chemistry_1_(Kattoum)/Text/2%3A_Atoms%2C_Molecules%2C_and_Ions/5.13%3A_Percent_Composition)
- Petrucci, R. H., Petrucci, R., Herring, F. G., Madura, J., & Bissonnette, C. (2017). *General Chemistry: Principles and Modern Applications*. Pearson Education.
- Silberberg, M. S., & Amateis, P. (2024). *Chemistry: The Molecular Nature of Matter and Change*.
- Tro, N. (2023). *Introductory chemistry, Global Edition*. Pearson.
- Types of chemical reactions*. (n.d.). Chemistry Learner. <https://www.chemistrylearner.com/wp-content/uploads/2020/08/Types-of-chemical-reactions.jpg>