MATTER AND ITS PROPERTIES

Chemistry is often referred to as the "central science." Due to its interrelated nature, it is integral to a wide range of STEM (Science, Technology, Engineering, and Mathematics) fields. The language and principles of chemistry are relevant in numerous areas, such as biology, medicine, materials science, forensics, and environmental science, among others.

Physics' fundamental concepts are crucial for comprehending various aspects of chemistry, with significant overlap observed in subdisciplines like chemical physics and nuclear chemistry. Tools from mathematics, computer science, and information theory are indispensable for calculating, interpreting, describing, and making sense of the chemical world.

Biochemistry, where biology and chemistry intersect, is vital for understanding the intricate factors and processes that sustain life. Chemical engineering, materials science, and nanotechnology utilize chemical principles and empirical findings to create useful substances, from gasoline and fabrics to electronics.

Fields like agriculture, food science, and veterinary science contribute to the world's sustenance through food and drink. Medicine, pharmacology, biotechnology, and botany work towards identifying and producing substances that promote health.

Environmental science, geology, oceanography, and atmospheric science employ chemical concepts to enhance our understanding and preservation of our physical world. Lastly, chemical ideas also aid in understanding the universe in astronomy and cosmology.

Matter and its Properties (Bauer, 2024)

Matter, present everywhere, is characterized as anything that has mass and occupies space. The presence of solids and liquids as matter is more evident: their occupation of space is visible, and their weight indicates their mass. Gases, too, are a form of matter; the fact that a balloon expands (or volume increases) when filled with gas demonstrates that gases occupy space.

Representations of Matter

The state of matter refers to the unique forms that distinct phases of matter can assume. In everyday life, we encounter four states of matter: solid, liquid, gas, and plasma. Several other states, like Bose-Einstein condensate and neutron degenerate matter, are believed to exist only under extreme conditions, such as ultra-cold or ultra-dense environments. There are also states like quark-gluon plasmas that are currently theoretical but potentially achievable.

The particulate nature of matter is summarized by the following:

a. Matter is made of tiny particles.
b. There is empty space between the particles.
c. Some forces act between the particles.
d. The particles are in constant motion.

The characteristics of the most common states of matter are differentiated in this table:

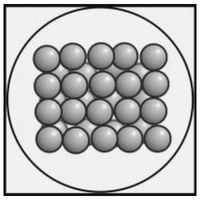
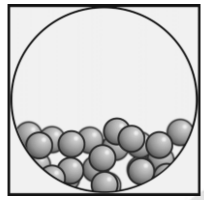
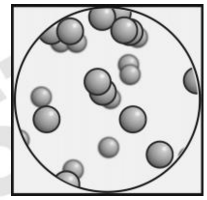
Solid	Liquid	Gas
		
Relatively rigid *Strong intermolecular forces	Fluid flows freely *Weak intermolecular forces	Fluid flows freely *Intermolecular forces are negligible
Definite volume and shape	Takes the shape of the container Forms a horizontal surface Has fixed volume	Expands to fill the container
Atoms are attached to each other	The atoms and molecules are loosely bonded	The atoms and molecules move freely and spread apart from one another
Examples: Soil, Paper, Iron	Water, Oil	Oxygen, Helium, Carbon Dioxide

Table 1. Characteristics of the Physical States of Matter

Plasma, often called the fourth state of matter, is an ionized gas, meaning that some of its electrons are free from their atoms, giving the plasma the ability to conduct electricity and respond to magnetic fields. Plasma can be found in stars, lightning, neon lights, and plasma TVs. Plasma is also used for many applications, such as fusion energy, plasma medicine, and plasma propulsion. Plasma is a fascinating and complex state of matter with many properties and behaviors that differ from the other states.

Physical Properties of Matter

- Properties are the traits that allow us to distinguish between varied materials. A physical property is a feature of matter that does not depend on its chemical makeup.
- Any characteristic that can be measured, such as an object's color, density, mass, volume, length, malleability, melting point, hardness, temperature, and more, are considered properties of matter.

A. Intensive Properties

An intensive property is a mechanical property that emerges from the collective behavior of atoms or molecules, signifying that it is a local physical characteristic that does not depend on the system's size or the amount of material present. Intensive properties are those that remain constant regardless of the quantity of matter.

B. Extensive Properties

An extensive property is a characteristic that relies on the quantity of matter in a sample. Such properties are determined by the system's size or the amount of matter it contains. Extensive properties are those where the value of a property for the entire system equals the sum of the values for its parts.

Extensive Property	Intensive Property
Mass, Weight Amount of substance (moles) Length, Area, Volume Internal Energy (Q) Enthalpy (ΔH) Entropy (ΔS) Gibbs Free Energy (ΔG)	Boiling Point, Melting Point Specific Heat Capacity Density Conductivity (electrical, thermal) Temperature Chemical Properties (Color, Flammability, Combustibility, Solubility, Odor, Corrosiveness) Luster, Hardness, Ductility, Malleability

Table 2. Extensive and Intensive Properties

Chemical Properties of Matter

Chemical properties are attributes that can only be identified or observed when matter transforms into a specific form. Examples of chemical properties include flammability, toxicity, acidity, several types of reactivity, and heat of combustion.

A. Reactivity
Reactivity refers to the capacity of matter to interact with other substances chemically. Some substances are highly reactive, while others are very inert. For instance, potassium is highly reactive, even with water. A small piece of potassium, about the size of a pea, can react explosively when it comes into contact with a minimal amount of water.

B. Flammability
Flammability is the term used to describe the tendency of matter to ignite or burn. When matter burns, it undergoes a reaction with oxygen, resulting in the formation of different substances. Any material that can easily catch fire, such as wood, is considered flammable.

C. Toxicity
Toxicity is the measure of the potential harm that a chemical substance or a mixture of chemicals can cause to a living organism. Examples include asbestos, lead, mercury, and gasoline.

D. Acidity
The capacity of a substance to interact with an acid is a characteristic chemical property. Certain metals can form compounds when they react with various acids—the reaction between acids and bases results in water formation, which neutralizes the acid.

Composition of Matter

Matter can be categorized based on its chemical composition.

A. Pure Substance
Materials that are made up of only one kind of particle and have a fixed or constant structure. These substances maintain a consistent chemical composition, irrespective of their source. Pure substances are free of impurities or contaminants.

1. **Elements –** are pure substances that consist of only one type of atom. Elements cannot be broken down into simpler substances by ordinary chemical processes. Each element is characterized by the number of protons in the nuclei of their atoms, known as the atomic number.

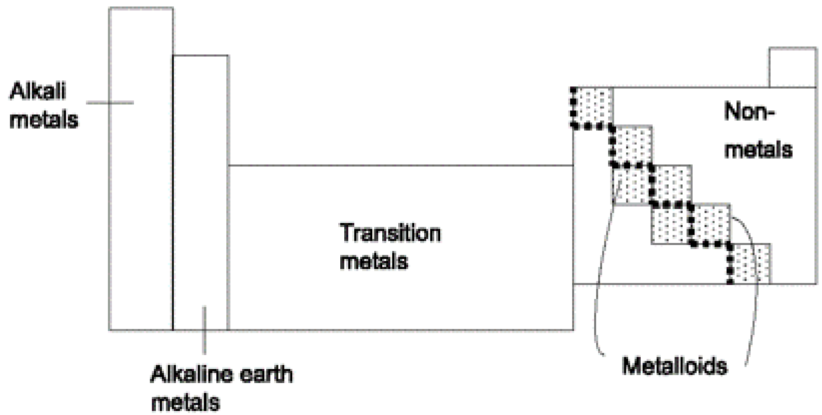


Figure 1. Metal Placement on the Periodic Table.

a. **Metals –** compose almost 80% of the elements in the table. The elements on the left side of the table are composed mostly of metals. Most metals are shiny and good conductors of electricity. Mercury is the only metallic element that is liquid at room temperature.
b. **Non-metals** – Most non-metals are gases or brittle solids. Bromine is the only non-metal that is liquid at room temperature.

2. **Compound –** pure substances of several different atoms in a fixed composition ratio. Water, as an example, has hydrogen and oxygen as atoms with a ratio of 2:1. Depending on the source, water can be contaminated, but the molecule separate from the contaminants would always contain the H_2O molecule. These substances can be separated into definite proportions through a chemical process.

B. **Mixture –** can be separated into two or more substances by physical means. A chemical reaction is not necessary to separate its composition. For example, sand and salt in salt water can be separated by filtering and evaporation.

1. **Homogeneous -** A homogeneous mixture, also called a solution, has only one phase but may have more than one component within the sample. A coffee drink is a good example. It is liquid, but within the solution is water, coffee, sugar, milk, or cream, which are undistinguishable by sight or texture.
2. **Heterogeneous –** A mixture with physically separate parts that can be distinguished from each other easily. It usually exists in separate phases. The classic example, fruit salad, represents a mixture since its components include distinct phases: solids for the diverse kinds of fruits distinct from each other and liquids for the milk and cream. Differences in appearance, texture, or size can separate the components of a solid mixture. A salt and pepper mixture is distinguishable because of the differences in color of the salt (white) and pepper (black or grey).

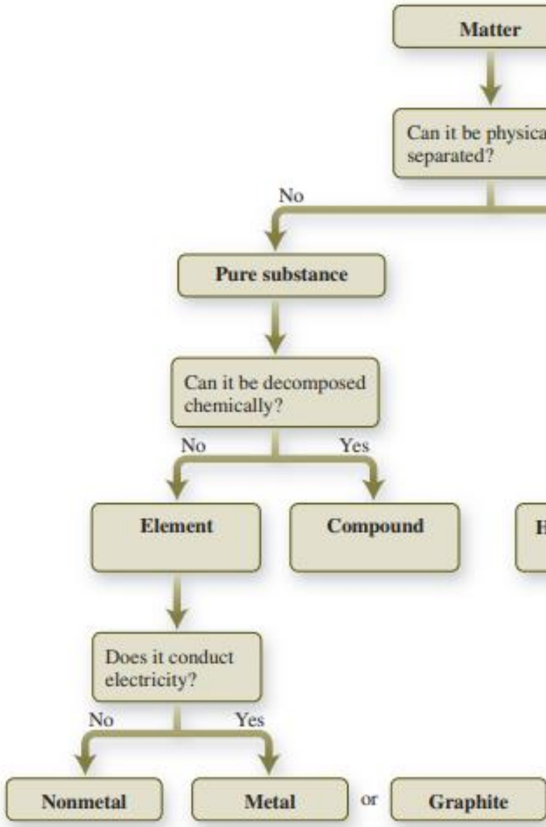
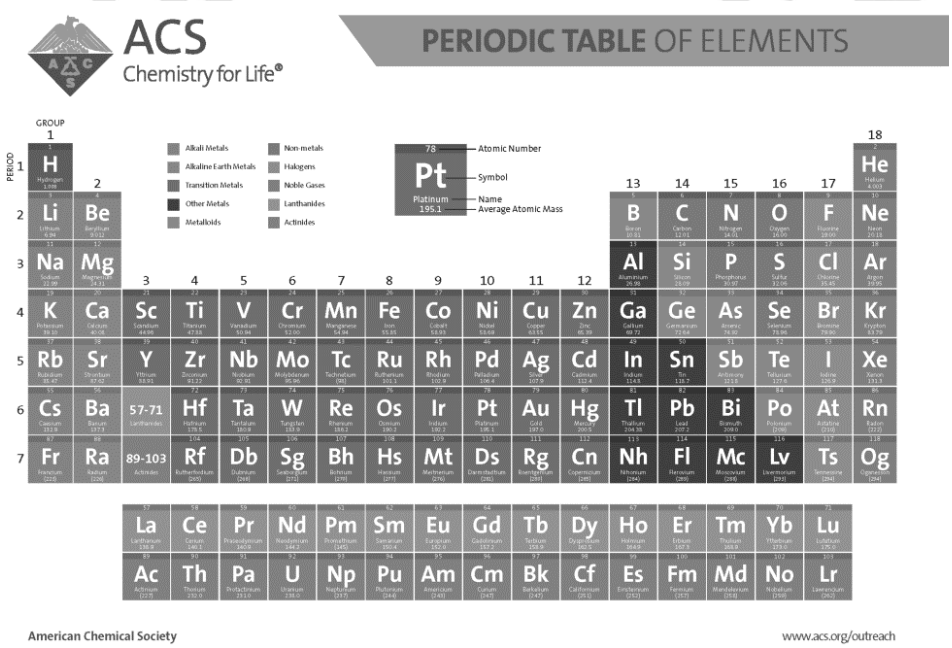


Figure 2. Classification of Matter (Bauer, 2024, pg.8)

Writing Chemical Formula (Millhollon & Langley, 2022)



Chemical nomenclature is the standardized system used to name chemical compounds. The table of elements encompasses all recognized chemical elements. As of the year 2024, there are 118 confirmed chemical elements. Every element on the table is denoted by its unique atomic symbol and possesses a distinct atomic number, equivalent to the count of protons in its atomic core.

Writing the full names of elements and compounds repeatedly would be time-consuming, especially when writing lengthy chemical formulas and chemical reactions. Thus, chemical symbols that represent the elements are used. The symbol for an element can be one letter as in carbon (C) and hydrogen (H), two letters as in calcium (Ca) or silicon (Si), or up to three (3) letters in the more recently discovered elements such as ununquadium (Uuq). When an element has more than one letter to its name, only the first letter is written in capital letters.

Rules of Writing Chemical Formula

The chemical formula of a compound is a symbolic representation of its composition. The combining capacity of an element is called valency. It can be used to figure out how an element's atoms will combine with those of other elements.

The valency of elements usually depends on their atomic number. Examples: Na(+1), Mg(+2), Al(+3), Cl(-1). These ionic charges can also be written as superscripts, such as Na^+. K^+, Ag^+, Cu^+, Mg^{2+}, Ca^{2+}, Zn^{2+}, Fe^{2+}. Cu^{2+}, Al^{3+}, Fe^{3+}, Cl^-, Br^-, I-, O^{2-}, S^{2-}, N^{3-}.

A polyatomic ion, also known as a molecular ion, is a group of two or more atoms that are covalently bonded and act as a single unit, carrying a net charge that is not zero. The hydroxide ion (OH-) is a polyatomic ion consisting of one oxygen atom and one hydrogen atom. Bonded together, they carry a net charge of -1. Some examples of polyatomic ions are ammonium (NH_4^+), nitrate (NO_3^-), hydrogen carbonate (HCO_3^-), sulphite (SO_3^{2-}), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}).

1. The valency or charges of the ions must balance.
   Example: H+ and Cl- forms HCL (neutral). H+ and O^{2+} forms H_2O
2. When a compound is composed of a metal and a nonmetal, the name of the metal is written first.
   Example: NaCl: Na+, sodium is a metal while Cl-, chlorine is a nonmetal
3. Compounds formed with polyatomic ions use brackets to enclose the formula and write the number of ions outside the bracket.
   Examples: Ammonium Sulphate is $(NH_4)_2SO_4$, which is from 2 polyatomic ion NH_4^+ and a sulphate.
4. For binary compounds, a crossover method is used.
   Example: H^+ and S^{2-} forms H_2S. Notice that the valency of 2- from the second element becomes the subscript of the first.

Symbol	Charge	Compound
Mg	2+	$Mg^{(2+)}$ $Cl^{(-)}$
Cl	-1	$Mg_{(-1)}Cl_{(2+)} = MgCl_2$

Table 3 Writing Formula for Magnesium Chloride

5. When the formula contains a polyatomic ion, brackets are used.

Symbol	Charge	Compound
Ca	2+	$Ca^{(2+)}$ $(OH)^{(-)}$
OH	-1	$Ca_{(-1)}OH_{(2+)} = Ca(OH)_2$

Table 4 Writing formula for compounds with polyatomic ion

Methods of Separating Mixtures (BYJUS, 2023)

Some of the common methods of separation are described below:

1. **Handpicking**
   This technique entails manually selecting and separating undesirable materials from desirable ones. The substances that have been separated could be impurities meant for disposal, or it could be that both separated substances have their uses. Examples: Sorting out ripe yellow mangoes from green ones.
2. **Threshing**
   This technique separates attached components from a stem or stalk by hitting, pounding, or trashing. For example, dried wheat grains are detached from the stalks and dropped onto the ground by thrashing the dried stalks to dislodge the dried grains.
3. **Sieving**
   This process is used to separate mixtures composed of substances of varying sizes. The mixture is sifted through the holes of a sieve. All the smaller particles easily pass through while the sieve holds back the larger components.
4. **Evaporation**
   A method to separate mixtures, typically a solution composed of a solvent and a soluble solid. In this process, the solution is heated until the organic solvent vaporizes, transforming into a gas and predominantly leaving the solid residue behind.
5. **Distillation**
   A method wherein mixtures with two or more liquid components are vaporized, condensed, and subsequently separated. The mixture undergoes heating, causing the more volatile component to evaporate first. This vapor then travels through a condenser, which is collected in a liquid form.
6. **Filtration**
   This method extracts the solid particles from the liquid. It is the most frequently used method to separate a liquid from an insoluble solid. Different filtering mediums, such as filter paper or other substances, are typically used. Example: separating a mixture of sand and water
7. **Sedimentation**
   Sedimentation is a procedure where denser contaminants descend to the bottom of the vessel containing the mixture, usually present in a liquid like water. This process requires a certain amount of time to complete.
8. **Funneling**

A separating funnel is primarily used to divide two non-mixing liquids. The process leverages the differing densities of the particles in the mixture. This technique can easily separate liquids like oil and water.

9. **Magnetic Separation**
   Powerful magnets are typically employed to isolate magnetic components in the mixture. When a substance in the mixture possesses magnetic properties, this method proves to be quite effective.

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