INTRODUCTION TO CHEMISTRY

Chapter One

Fundamentals of Chemistry

Unit Introduction

Many of you who do not plan to work as professional chemists may be surprised why studying chemistry is essential as you begin your college chemistry studies. You'll soon see that a fundamental knowledge of chemistry is helpful in various fields and professions. You'll also learn that having a solid understanding of chemistry enables you to make wise judgments regarding various matters that impact your life, your community, and the wider world (Sheldon, 2012). This text's main objective is to show the significance of chemistry in daily life plus our comprehension of the physical world, we live in and the biotic universe of which we are a fragment. This chapter has two main goals:

1. to introduce the scope, significance, and issues of contemporary chemistry; and
2. to provide some key terms and meanings you'll want to comprehend how chemists ponder and function (Daeneke et al., 2018).

> **Remember:**
>
> The fundamentals of chemistry is crucial for understanding the properties of matter, the behavior of elements and compounds, and the processes of chemical reactions.

Learning Objectives

At the end of this chapter, reader will be able to understand

1. The brief history of chemistry
2. The different branches of chemistry and their importance
3. The importance of different classification of matter
4. The concept of mixture and pure substances
5. The process of forming different simple things from chemicals

Key Terms

1. Physical Chemistry
2. Industrial Chemistry
3. Nuclear Chemistry
4. Oceanographers

5. Iridium
6. Carbon-Hydrogen Molecules
7. Radiotherapy
8. Volatility

1.1 Modern World Chemistry

The study of matter substances and transformations created by matter is called Chemistry. It is likely the scientific discipline with the widest range of connections to other academic disciplines. Geologists examine and categorize rock samples using chemical procedures to find new minerals or oil resources. Oceanographers use chemistry to observe ocean currents, approximate nutrient input into the ocean, and gauge the rate of nutrient exchange among ocean layers. While identifying materials for diversepractices, engineers consider the relationsamong the structures and the characteristics of the substances. To discover new subatomic particles, physicists benefit from various materials' characteristics. Astronomers use their chemical signature to compute a star's age and its distance. It allows them to deliver answers to fearsconcerning the origin of stars and the phase of the universe. Environmental sciences rely on chemistry to explain the causes and effects of air pollution, global warming, and ozone layer depletion (Stulz et al., 2011).

Biochemistry, using chemistry to investigate biological processes, is a key component of the sciences that concentrate on living things and their connections with the physical world. A live cell comprisesmany intricate molecules that perform thousands of different chemical processes, including those required for the cell to duplicate. Many chemical processes lead to biological spectaclessuch as sight, taste, smell, and movement. The interaction between the chemicals that enter our bodies and those that make up the body is the focus of fields like medicine, a study of pharmacy, nutrition, and toxicology. For instance, in the specialist field of sports medicine, understanding chemistry is necessary to comprehend why muscles hurt after activity and how extended exercise causes the euphoric sense known as "runner's high" (Eddy et al., 2014).

There are several instances of how chemistry is used in everyday life (Figure 1.1 "Chemistry in Routine Life"). When creating biologically acceptable grafts for joint alternates or developing highways, nuclear reactors, buildings, bridges, and that do not breakdown due to weakening structural components like steel and cement, engineers need to be aware of the biochemical properties of the substances (Pauling, 1951).

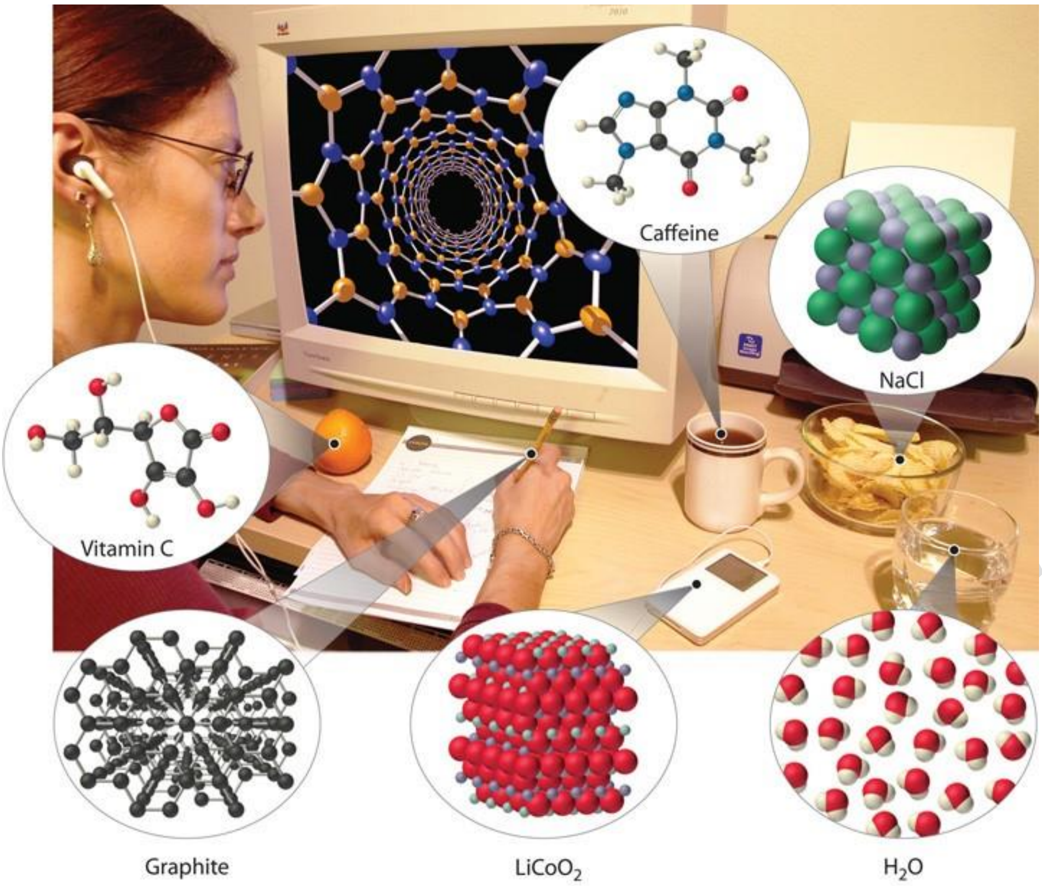

Figure 1.1. Illustration of chemistry in routine life (Source: Saylordotorg, Creative Commons License)

It would help if you weren't shocked to find at this time that chemistry played a crucial role in understanding the extinction of the dinosaurs, a significant event in Earth's history. Although dominating the planet other than 150 million years ago, geological proof indicates that the dinosaurs became extinct sharply about 66 million years ago. Any climatic shift, lethal virus or microbe may be any epidemic are unlike theories that give important evidence of their extinction (Zacharia, 2011).

Figure 1.2, shows "Sign for the Asteroid Influence That May Have Caused the Extinction of the Dinosaurs,", a tinny layer of sedimentary rock made 66 million ages ago that confined remarkably great absorptions of the rare metal iridium (Martinón-Torres, 2012).

This layer was formed when dinosaurs stopped showing up in the fossil record. Iridium is significantly more prevalent in comets and asteroids than in most rocks, where it is extremely rare and makes up only 0.0000001% of the Earth's crust. The Alvarezes proposed that a huge asteroid collision with Earth caused the demise of the dinosaurs since similar samples of rocks in countries like Italy and Denmark had high quantities of iridium. All 66 million-year-old sediment samples examined by chemists from various locations worldwide were found to have high quantities of iridium. The majority of the layers containing iridium also show minute cracks in small quartz grains that are indicative of high-intensity shockwave. These grains appear to have come from terrestrial boulders at the control site that was broken up on effect and sent into the high atmosphere afore settling out all over the planet (Quadri et al., 2022).

Figure 1.2. Image of asteroid that may have caused the extinction of the dinosaurs (Source: The conversation, Crrative Commons License)

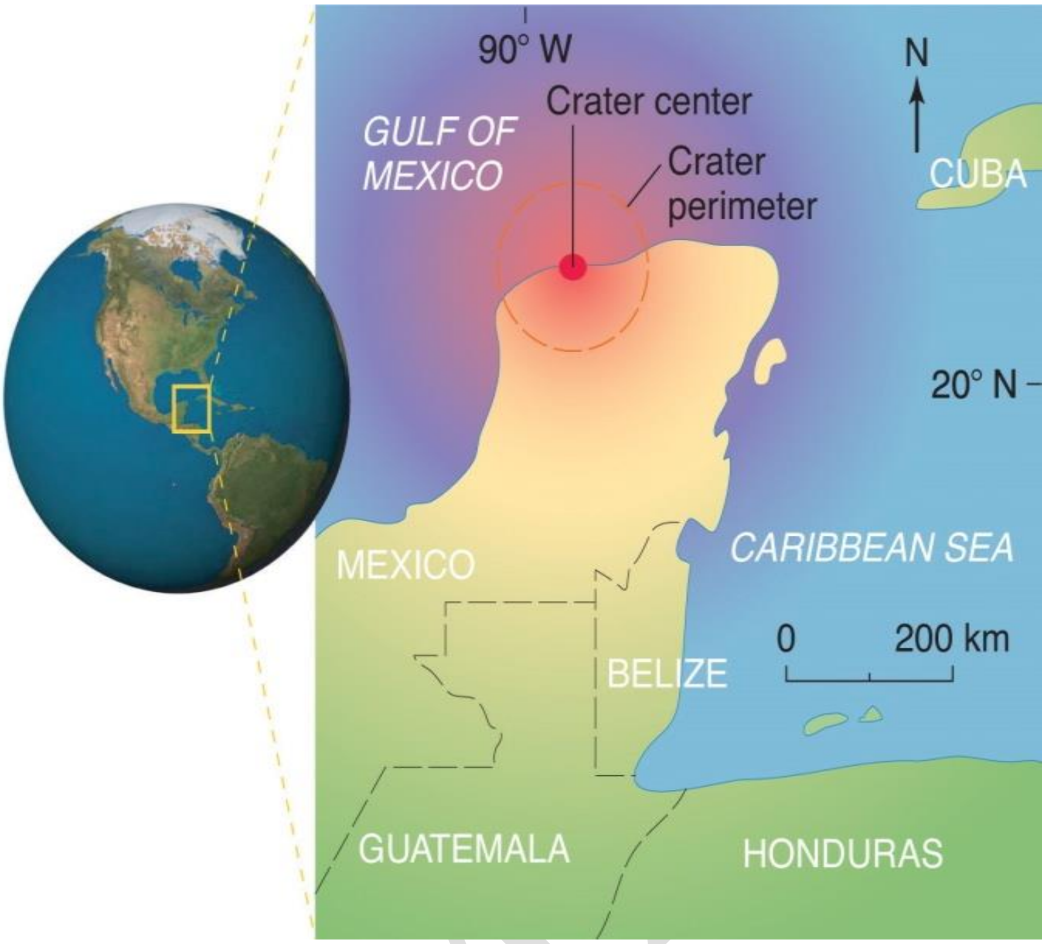

Figure 1.3. Schematic of Asterioid Impacr (Source: The conversation, Crrative Commons License)

One illustration of the use of chemistry to solve a significant scientific issue. We will also cover other chemical presentations and descriptions in this work, such as how astronomers measure the distance between galaxies and how fish may live in water that is below-freezing under polar ice sheets. Adding iodine to table salt, creating more potent medications to treat conditions like cancer, AIDS, and arthritis, and retooling the industrial sector to use chemicals like non-chlorine-containing refrigerants and propellants to protect the ozone layer are just a few examples of how chemistry impacts our daily lives (Larkins, 1995). The application of contemporary materials in engineering, current initiatives to address acid rain and climate change, and the knowledge that our bodies need trace amounts of some chemicals that are dangerous when consumed in large quantities. By the end of this text, you can deliberate these types of subjects intelligently, either as a establishing scientist who plans to devote your career researching such issues or as an well-versed bystander who can take part in public discussions that will undoubtedly take place as society wrestles with scientific issues (Gielen, 2008).

1.2 Brief History of Chemistry

We don't have any records of anyone trying to elucidate the chemical fluctuations they witnessed and exploited until the time of the ancient Greeks. Earth, fire, water and air were the only four fundamental elements that made up all natural objects at the time. After that, in the 4th century BC, 2 Greek philosophers, such as Leucippus and Democritus, proposed that matter was composed of fundamental, indivisible units known as atoms rather than being infinitely divided into smaller bits (Liu et al., 2022). However, these ancient philosophers lacked the equipment to put their theories to the test. As the ancient Greeks did not perform trials or apply the scientific method, it is improbable that they would have done so. They assumed that logical intellect alone could reveal the nature of the universe (Sevilla, 1999).

Alchemists made numerous advancements in chemistry during the following two millennia while engaging in a type of chemistry and theoretical philosophy throughout the Renaissance and Middle Ages. Their main objective was to use a technique they called transmutation to change certain elements into others (Ratner, 2013). Alchemists, in specific, sought a method of turning less expensive metals into gold. Alchemists in China, the Arab kingdoms, and mediaeval Europe made important assistances, including discovering elements like quick-silver (mercury) and creating several potent acids. However, many of the alchemists' didn't address chemistry analytically (Naik & Patil, 2015).

According to calculations made by scientists, a impact between Earth and a stony asteroid with a diameter of about 10 kilometres (6 miles) and moving at a speed of 25 kilometres/sec (roughly 56,000 miles per hour) would nearly instantly discharge energy equal to the eruption of around 100 million mega tons of TNT (trinitrotoluene) (Bezold et al., 2020). Its energy is greater than the whole amount of nuclear weapons in existence. Large tracts of forest would catch fire due to the energy unrestricted by such an impact. The dust produced as a result of the impact and the smoke from the fires would block daylight for years or months, killing the majority of organisms that depend on green plants and almost all of the green plants themselves. It might help to explain why roughly 70% of entire species—not just the dinosaurs—died off in the same period (Caley, 1927).

According to scientists, the impact would create a crater with a minimum diameter of 125 kilometres (78 miles). New satellite photographs from a Space Shuttle mission have proven that a massive asteroid or comet struck Earth's exterior at the northern tip of Yucatan in the Gulf of Mexico 65 million years ago, producing a crater that is partially submerged and 180 kilometres (112 miles) in diameter (Figure 1.3 "Asteroid Impact"). Hence, a different and intense explanation for the demise of the dinosaurs was produced by making simple chemical quantities of the amount of one component in rocks. Further, largely chemical data supports this explanation, which is still debatable (Garfield, 1985).

Chemical methods are used to find bone's period and artefacts and determine their provenance, archaeology and palaeontology (Barbara, 1996). While forensic scientists utilize chemical techniques to examine blood, fibres, and other suggestion as they scrutinize crimes, the law is not classicallysupposed of as a field related to chemistry. DNA matching—the process of matching biological models of inherited material to determine whether they might have originated from the similar person—has been utilized to resolve many eminent criminal cases and pardon innocent people who have been falsely charged or found guilty (Murray, 2011). One field of applied chemistry that is expanding quickly is forensics. Also, the field of patent law is growing quickly due to the industry's explosion of chemical and biological breakthroughs. Experts who can communicate complex chemical concepts to the general public through television, the Internet, print journalism, and standard literature are ultimately necessary for disseminating information in all domains where chemistry is relevant (Schwartz et al., 1994).

1.3 Branches Of Chemistry

We do reside in a chemically-based universe. Every living thing that depends on water, oxygen, or carbon dioxide to survive is an organism (Takacs, 2012).

Today, chemistry has an extensive range of applications in all life facets and works round-the-clock for humanity. Physical, organic, inorganic, biochemical, industrial, nuclear, environmental, and analytical chemistry is chemistry's primary branches (Sopková, 1992).

1.3.1 Physical Chemistry

Physical chemistry is the area of chemistry that examines the interaction between a substance's chemical makeup and physical characteristics and changes to those characteristics. This division focuses on the characteristics of matter, including atomic structure, molecule synthesis, thebehaviour of solids, liquids and gases, and the investigation of how heat and radiation affect matter (Cohn, 1925).

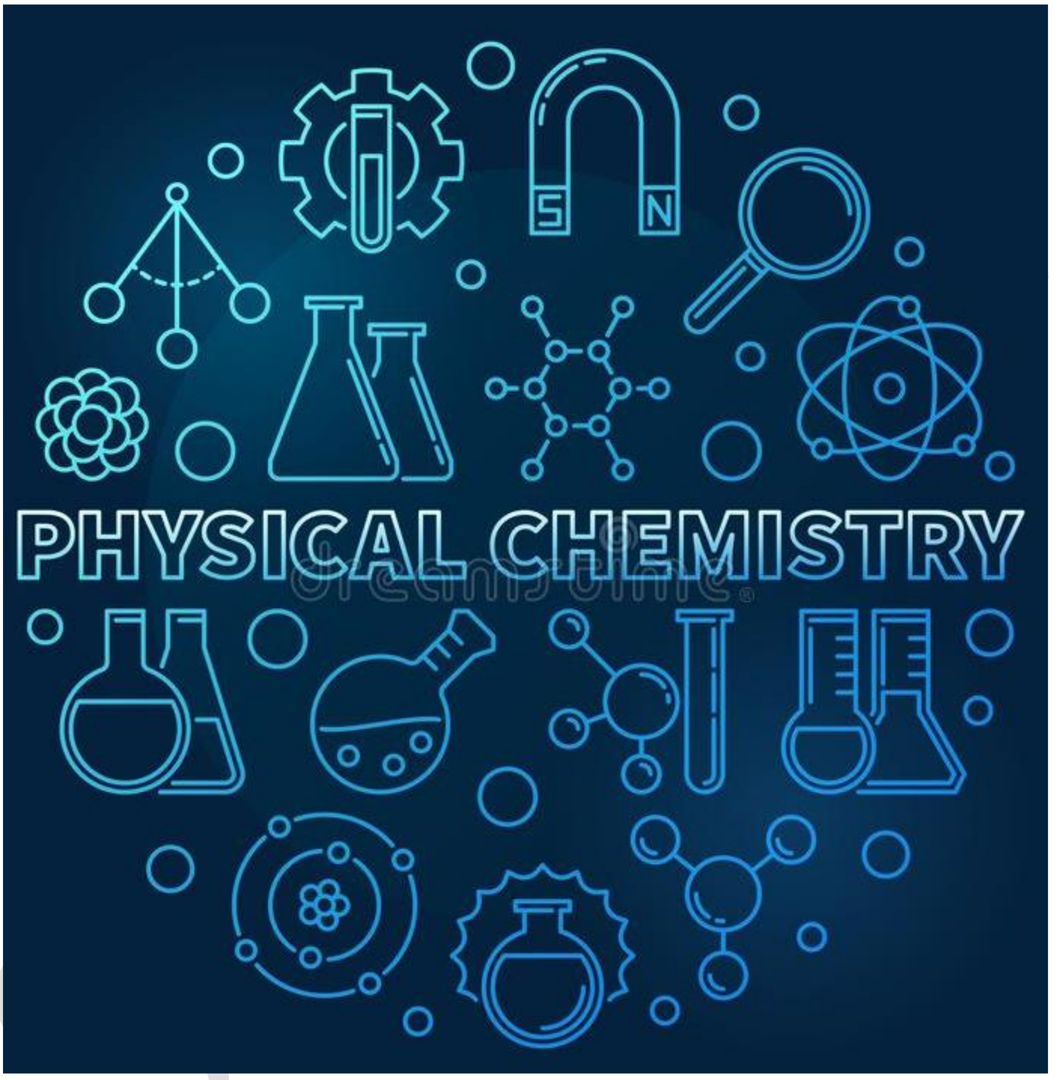

Figure 1.4. Illustration of physical chemistry (Source: Dreams time, Creative Commons License)

1.3.2 Organic Chemistry

The study of covalent carbon-hydrogen molecules (hydrocarbons) and their end product is known as organic chemistry. Both naturally occurring and synthetic organic molecules are created in laboratories. These artificial and naturally occurring chemicals' assemblies and characteristics are resolute by organic chemists. The petroleum, petrochemical, and pharmaceutical industries are included in the scope of this branch (Mathey, 2003).

1.3.3 Inorganic Chemistry

Except for carbon-hydrogen molecules (hydrocarbons) and their derivatives, all elements and their compounds are studied in inorganic chemistry (Mjos & Orvig, 2014). Every area of the chemical industry uses it, including glass, metallurgy (the withdrawl of metals from ores), ceramics and cement (Orvig & Abrams, 1999).

1.3.4 Biochemistry

We research the content, structure, and chemical processes of the compounds found in living things in this area of chemistry. It covers every chemical process in living things, including creating and metabolizing macromolecules like sugars, proteins, and lipids (Ferry, 1992). As researchers looked at how living organisms get their energy from food or how essential biological fluctuations happens in sickness, a new field called biochemistry was born. The domains of medicine, food science, and agriculture are just a few examples of where biochemistry is used (Shapiro & Weis, 2009).

1.3.5 Industrial Chemistry

Industrial chemistry refers to the area of chemistry that studies the mass production of chemical substances (Elvers, 1991). It produces fundamental chemicals for instance oxygen, ammonia, chlorine, caustic soda, sulphuric acid, and nitric acid. Several other sectors, that produce paint, paper, textiles, agricultural products, soap, fertilizers, and chemicals, rely on these compounds as their primary raw material (Hofstein & Kesner, 2006).

1.3.6 Nuclear Chemistry

Radioactivity, nuclear processes, and characteristics are covered within the area of nuclear chemistry (Tekin & Nakiboglu, 2006). Applying atomic energy in daily life is this branch's principal area of interest. It also investigates the chemical reactions from radiation absorption within living things, including plants, animals, and other materials. It has numerous uses in producing electrical power through nuclear reactors, food preservation, medical treatment (radiotherapy), and other fields (Vértes et al., 2003).

Tip: Always handle radioactive materials with proper care and follow safety protocols to minimize the risk of exposure.

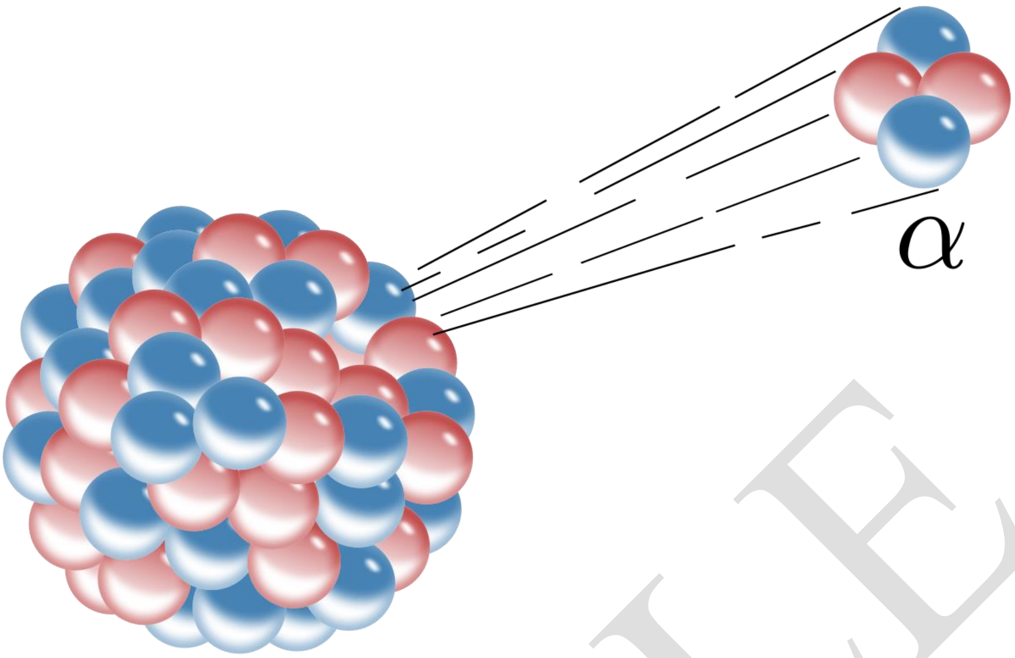

Figure 1.5. Schematic of nuclear chemistry (Source: Clough, Creative Commons License)

1.3.7 Environmental Chemistry

It is the area of chemistry where we research the elements of the surroundings and how human activity affects them. Biology, geology, ecology, soil, and water are all related to environmental chemistry (Nowack, 2003). Knowledge of the chemical processes occurring in the environment is essential for environmental upgrading and pollution prevention (Rücker & Kümmerer, 2015).

1.3.8 Analytical Chemistry

The area of chemistry called analytical chemistry deals with the separation and dissection of a sample to determine its constituent parts. Beforea qualitative and quantitative examination, the separation is done (Armenta et al., 2008). The identification of a drug is provided via qualitative analysis. Quantitative analysis, on the other side, quantifies the quantity of each component in the sample. Thus, several analysis methods and tools are researched in this branch. This branch's focus includes food, water, environmental, and clinical analysis (Tobiszewski et al., 2010).

1.4 Classification of Matter

Chemists examine the chemical, physical, and structural characteristics of chemical and physical substances (Hart, 1986). All objects that occupy space and have mass are thought to be composed of matter. There are peanuts, people, postage stamps, gold, and iridium, among other things. The matter is smogbed, smoked, and gassed. Yet, the matter is neither energy, light, or music, and neither are thoughts nor feelings (Ozdilek & Ozkan, 2009).

The mass of a object is gained by the amount of substance it comprises. It is significant to remember that weight, which is a force produced by the pull of gravity that an object experiences, is not the same as an object's mass. Mass is a ultimate property of an object that is not linked to location. The force that is required to alter the direction or speed of an object is perfectly related to the mass of the item, per physical rules (Chiu et al., 2016).

Yet, the weight of a particular object is dependant upon its positioning. Given that the gravitational force of Moon is almost one-sixth that of Earth's, an astronaut with a mass of 95 kg would weigh only 35 pounds on the Moon as opposed to about 210 pounds on Earth (Piccaluga et al., 2011). For practical reasons, weight and mass are regularly employed interchangeably in laboratories. It is considered that the gravitational pull of gravity is the same, 2.2 lb (a weight) equals 1.0 kg (a mass), everywhere on the globe's surface (Stains & Talanquer, 2007).

Under normal circumstances, matter exists in three different forms: gases, liquids, and solids. Solids are frequently rigid and possess consistent volumes and forms. For example, rocks are solids. Liquids, on the other hand, flow to conform to the shape of their containers regardless of having constant contents, such as a beverage in a can (McGill, 1996). For instance, the air in a car tyre has neither a known volume nor a specific shape; instead, gases expand to fill their containers. Temperature and pressure virtually do not affect the volume of liquids and solids but have an effect on gases. Matter commonly switches from one state to another through a process called physical shift. For instance, water can be either heated or chilled to produce steam, a gas. Yet, the chemical composition of a matter is unaffected by such changes in condition (Kim et al., 2008).

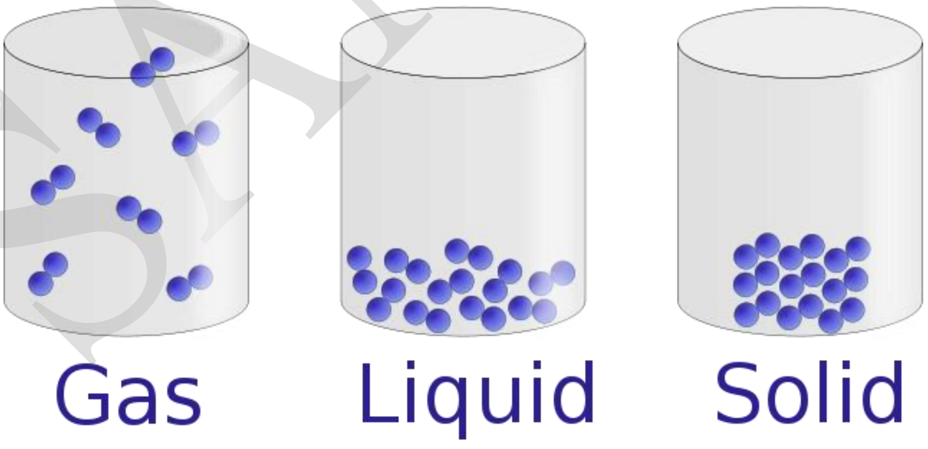

Figure 1.6. Picture of states of matter (Soure: free school, Creative Commons License)

Did You Know?

Solids make up about 25% of the known matter in the universe, while gases make up about 75%. Liquids make up a very small percentage of the known matter.

1.5 Mixtures and Pure Substances

A material with a consistent chemical makeup and distinguishing characteristics is known as a pure substance. Let's say, oxygen is a pure chemical that has no color, is odourless at 25°C. There are very rare pure chemicals in matter samples; the majority are a mixtures of two or more pure substances in varying quantities while the constituent substances maintain their identity. Mixtures exist in tap water, air, blue cheese, milk, dirt, and bread. A substance is homogenous if its constituent parts exist in the same state, lack discernible borders, and exhibit uniform properties (Sanger, 2000). The air we and the tap water are examples of homogenous mixes. A homogeneous mixture is also referred to as a solution. As a result, the air is a mixture of oxygen, CO_2, water vapour, N2 , and other gases, while water contains trace amounts of many other compounds. However, the precise compositions of air and water vary depending on their sources and places of origin; for instance, the arrangement of the tap water in Buffalo, New York, differs from that of the tap water in Boise, Idaho. Solutions can be either solid or liquid, although most are liquid. The grey material that some dentists still use to fill cavities in teeth is a complex solution in solid stat and contains 50% mercury and 50% powder primarily composed of tin, copper, and silver with trace levels of mercury. Alloys are often referred to be solid mixtures of two or more metals (Li et al., 2014).

A material is considered heterogeneous if its composition is not uniform for example, blue cheese, chocolate chip biscuit dough, and dirt. On closer inspection, mixtures that seem homogeneous are frequently shown to be heterogeneous. For instance, milk looks homogeneous, but when studied under a microscope, it is revealed to be made up of microscopic globules of protein and fat scattered in water (Beegle et al., 1974). In most cases, separating the components in heterogeneous mixes is easy. Filtration, which involves putting a mixture from a barrier like a filter with holes that are minor than the solid elements in the mixture, is a simple method for separating solid-liquid mixtures like tea leaves in tea. Theoretically, microscopic examination and sorting can separate mixtures of two or more substances, for example salt and sugar. Most of the time, however, more difficult procedures are required, such as panning to separate gold nuggets from river pebbles. Solids are first detached from the river water through filtration and then are disjointed by examination. If gold is found to be present in rock, chemical techniques are used to separate it (Lötgering-Lin et al., 2018).

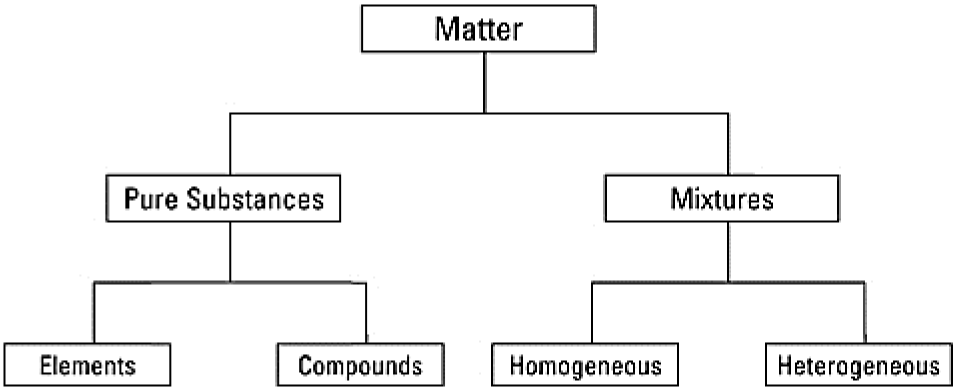

Figure 1.7. Illustration of types if pure substances and mixture (Source: Dummies, Creative Commons License)

Physical procedures based on alterations in some physical properties, such as variances in their boiling temperatures, can take apart homogeneous mixtures into their constituent elements. Distillation and crystallization are 2 of these separating techniques. Volatility is the measure of how quickly a substance turns into a gas at a specific temperature. Volatility differences of different substances are used in distillation. A straightforward distillation device for separating a mixture of materials where at least one of those materials is a liquid. The most flammable substance boils first and then condenses to a liquid in the condenser, which takes it into the receiving flask. For instance, when water and salt are mixed and distilled, pure water (the more volatile component), gathers in the reception flask and the salt stays in the distillation flask (Spiske, & Gaube, 1987).

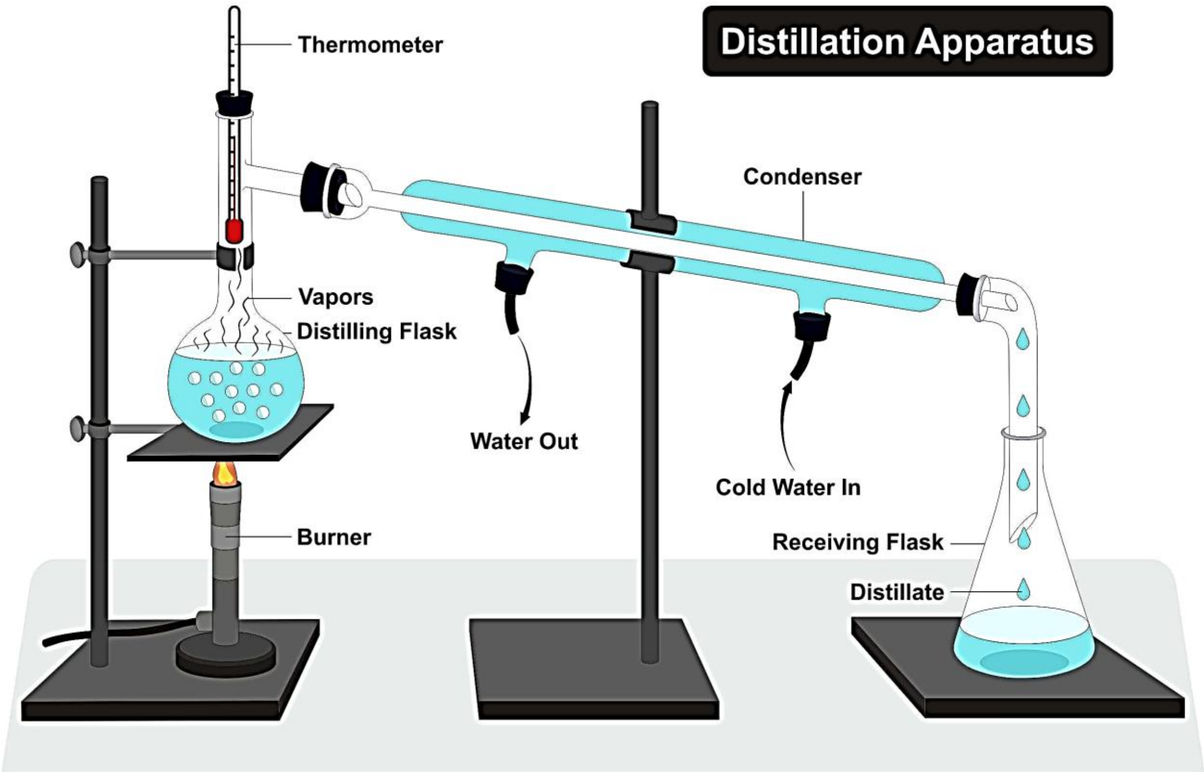

Figure 1.8. Diagram of equipement of distillation of table salt solution in water (Source: Shalom Education, Creative Commons License)

Distillation of a Table Salt Solution in Water is shown in fiure 1.8. In the distilling flask, the salt-water solution is heated until it boils. The more volatile component (water) is added to the resulting vapour, which then shrinks to a liquid in the cold condenser and gets together in the flask getting it (Sparrow et al., 1986).

Distillation equipment is more complex when separating combinations of two or more liquids with dissimilar boiling points. One such process is the transformation of crude petroleum into more refined forms of fuel such as jet fuel, gasoline, kerosene, diesel, and lubricating oil (in the estimated order of declining volatility). Distillation of alcoholic beverages like brandy and whisky is another instance of this. Solubility, or how abundant of a solid substance can be dissolved in a certain volume of liquid, is one of the factors that crystallization uses to separate compounds. Since most chemicals are more soluble at higher temperatures, it is possible to dissolve a combination of two or more substances at a high temperature and then gradually cool the solution. The solvent liquid could also be evaporated if desired. It is common for the substance that is least likely to remain dissolved to crystallize first, and this crystallization can be filtered out of the remaining solution (Masson et al., 1929).

Figure 1.9. Image of sodium acetate crystallization (Source: Science photo, Creative Commons License)

Figure 1.9 Sodium acetate crystallization from an aqueous sodium acetate solution at high concentration. When a small "seed" crystal is added to the flask, white crystals develop and quickly grow to fill the entire flask.

Compounds and elements can be extracted from most mixtures. Like the white, crystalline sodium chloride, a compoundcomprises two or more elements and typically has different chemical and physical properties than the elements themselves. In contrast, an element, like the grey, metallic sodium, can be broken down into simpler ones through chemical changes. Rare cases apart, the chemical makeup of a given substance remains constant throughout time and across different environments, meaning that its elemental composition (the elements present and their relative abundances) remains unchanged. A chemical change is a transformation in the chemical makeup of a substance. A chemical change, a chemical reaction, take place when two or more elements combine to form a new substance. In this case, sodium and chlorine combine to form sodium chloride. Just 118 elements are known at the moment. However, millions of chemical compounds have been produced from these 118. On the periodic table, all of the notorious elements are laid forth (Li & Firoozabadi, 2009).

Electrolysis can split water molecules into their parts, hydrogen and oxygen. Hydrogen and oxygen are two chemical components that combine to form water.

Compounds are often dismantled back into their constituent parts via a reductive chemical process. By use of electrolysis, for instance, the complex water can be split into its constituent elements, hydrogen and oxygen. A compound is broken down into its parts using electrical energy in electrolysis. Pure aluminium, a chemical element, is extracted from aluminium ores, a complex mixture of chemicals, using a process quite similar to that described above. Pure aluminium production is the most expensive due to the high cost of electricity needed for the electrolysis process. Hence, recycling aluminium is not only the responsible thing to do for the environment, but it also saves money (Yang, 1975).