

Chapter 1

Some Basic Concepts of Chemistry

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BASIC CONCEPTS

Introduction

The pursuit of science can be seen as an ongoing human endeavor aimed at organizing knowledge to describe and comprehend the workings of nature. In our daily lives, we regularly encounter various substances found in nature and witness changes in them.

Examples of such changes are the transformation of milk into curd, the conversion of sugarcane juice into vinegar over an extended period, and the corrosion of iron, occurrences that are familiar in our day-to-day experiences.

For the sake of practicality, science is categorized into distinct disciplines, including but not limited to chemistry, physics, biology, and geology.

Chemistry, a specific branch of science, is devoted to the study of the preparation, properties, structure, and reactions of material substances. This discipline delves into the intricate details of how substances come into existence, their characteristics, the arrangement of their components, and the processes by which they undergo changes.

Importance Of Chemistry

Chemistry is the scientific exploration of the essence of matter, encompassing the study of various materials.

- Through an understanding of chemistry, we have the ability to convert matter into its most valuable and practical forms, positively impacting humanity.
- The examination of chemistry has substantially elevated the quality of our lives, influencing everything from our food and clothing to the medicines that maintain our well-being and the industries that provide employment opportunities for the human population. Chemistry stands as an indispensable aspect of human existence.

Chemistry has made significant contributions to various domains, including:

(1) Food Preservation:

Chemistry has enabled the development of techniques to enhance the shelf life and nutritional value of food.

Examples include canning, where processed food is stored in airtight containers, and the use of methods like refrigeration and chemical preservatives.

<ul style="list-style-type: none">➤ Atomic and Molecular Masses➤ Mole Concept and Molar Masses➤ Mole Concept and Number of Atoms/Molecules/Ions➤ Mole Concept and Volume of Ideal Gas at NTP/STP• Chemical Formulae<ul style="list-style-type: none">➤ Empirical and Molecular Formula➤ Balancing of Chemical Equations• Solution and Measurements Concentration<ul style="list-style-type: none">➤ Mass or Weight Percentage➤ Molality➤ Mole Fraction• Stoichiometry<ul style="list-style-type: none">➤ Stoichiometry and Stoichiometric Calculations➤ Limiting Reagent	<p>(2) Agriculture: Chemicals such as fertilizers, insecticides, and pesticides have significantly increased crop yields. Fertilizers provide essential nutrients to the soil, promoting plant growth, while insecticides protect crops from damage by pests.</p> <p>(3) Health and Medicines: Chemistry has played a crucial role in the development of medicines that cure various ailments, contributing to increased human longevity. Examples of medicines include antipyretics (against fever), analgesics (painkillers), and antacids (for heartburn).</p> <p>(4) Cosmetics: Chemistry contributes to the cosmetic industry, allowing individuals to present themselves confidently. Commonly used cosmetics include face powders, lipsticks, nail paints, perfumes, shampoos, and creams, with moisturizers helping retain skin moisture.</p> <p>(5) Clothing: Chemistry has advanced the clothing sector with the development of synthetic fibers like Nylon, Terylene, and Polyester. Synthetic fibers offer advantages such as durability, wrinkle resistance, quick drying, and ease of handling.</p> <p>(6) Industries: The mining and mineral industries play a crucial role not only in providing employment opportunities but also in the manufacturing of essential products such as cement, Plaster of Paris, dyes, and silicones.</p>
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These products contribute significantly to the construction of various structures, including homes and bridges, ensuring safety in diverse weather conditions and saving time.

In recent times, chemistry has effectively addressed environmental degradation issues. Successful efforts have been made to develop safer alternatives to environmentally harmful refrigerants like CFCs, which contribute to ozone depletion. However, significant environmental challenges persist, with the management of greenhouse gases such as methane and carbon dioxide being a major concern. Chemists continue to grapple with these issues, seeking innovative solutions.

The understanding of biochemical processes, the utilization of enzymes for large-scale chemical production, and the synthesis of novel materials present intellectual challenges for the future generation of chemists. In a developing country like India, there is a growing need for talented and creative chemists to tackle these challenges successfully. To excel in this field, individuals must grasp the fundamental concepts of chemistry, starting with a solid understanding of the concept of matter.

Development Of Chemistry

The field of chemistry, as we comprehend it today, has a relatively recent origin. It didn't emerge as a standalone discipline but rather evolved from the pursuit of two intriguing objectives:

- i. The quest for the Philosopher's Stone (Paras), which purportedly had the power to transmute base metals such as iron and copper into gold.
- ii. The search for the 'Elixir of Life,' a substance believed to grant immortality.

A notable figure in ancient Indian chemistry was Acharya Nagarjuna, a learned Buddhist from Nalanda University. His works, such as 'Taratantara' and 'Arogya Manjari,' detailed various chemical properties of different elements. Nalanda University, renowned globally for its chemistry school, witnessed significant contributions, including the discovery of mercury sulphide by Chakrapani and the invention of soap using mustard oil and alkalis.

Chemistry in ancient India, often referred to as Ras Ayan Shastra, Ras Tantra, Ras Kriya, or Rashida, encompassed metallurgy, medicine, cosmetics manufacturing, glass production, and dye formulation. Excavations at Mohenjo-Daro and Harappa revealed advanced chemical processes, such as mass pottery production, glazing techniques, and the use of gypsum cement in construction.

The development of copper metallurgy, mentioned in Rigveda, and the production of salt from the sea, described in Kautilya's Artha Shastra, showcase the ancient Indians' proficiency in various chemical processes. The ancient Vedic literature aligns with modern scientific findings, mentioning the preparation of acids, oxides, and the use of various materials in scientific applications.

Notably, the Ajanta and Ellora cave paintings attest to the advanced scientific achievements in ancient India, while Varshini's Brihat Samhita, a sixth-century encyclopedia, reveals insights into materials prepared from plant extracts for construction purposes.

Ancient Indian knowledge also extends to textiles, with mentions of dye stuff like turmeric, madder, and lac in classical texts. Paper, ink, and the process of fermentation were well-known, as indicated by the accounts of Chinese travelers and the Vedas. The concept of atoms, proposed by Acharya Kanada around 2500 years before John Dalton, marked a significant philosophical speculation.

The Charaka Samhita, the oldest Ayurvedic epic, discusses the reduction of particle size of metals, akin to nanotechnology. However, the decline of alchemy and the advent of the western medicinal system led to a gradual decline in traditional techniques.

Modern chemistry gained momentum in India in the mid-nineteenth century, driven by the influx of European scientists. Chemistry, being the study of matter and its properties, composition, and changes, is often referred to as the science of atoms and molecules, emphasizing its foundational role in understanding the basic constituents of matter.

Nature of Matter

Everything presents in our surroundings qualifies as matter. It's essential to recognize that even air, which may seem intangible, is indeed a form of matter. Therefore, matter is defined as anything that occupies space and possesses mass.

Example of matter

include everyday items such as books, pens, pencils, water, air, and all living beings. The constituents of matter extend to the microscopic level, encompassing atomic particles, DNA, the air we breathe, and the diverse molecules within our bodies.

Understanding that matter is composed of particles, specifically atoms and molecules, is crucial. This section will delve into the nature of matter, examining its characteristics. The classification of matter is based on its physical state, and we can categorize it into three main types: solid, liquid, and gas.

States of Matter

Matter exhibits various physical properties, and its classification into distinct categories is based on these properties and the different states it can exist in; these categories are referred to as states of matter. Organic chemistry is the specialized discipline concerned with the study of the structure, composition, and chemical properties of organic compounds. Its primary focus lies in the comprehensive examination of carbon and its various compounds.

Biochemistry, on the other hand, is a branch of chemistry dedicated to investigating the chemical processes occurring in organisms and their connections. This field serves as a bridge between biology and chemistry, relying on laboratory-based research. By applying chemical knowledge and technology, biochemists can comprehensively understand and address biological challenges.

Analytical chemistry constitutes a distinct branch that utilizes instruments and analytical techniques to ascertain the structure, functionality, and properties of substances. This specialized field plays a crucial role in determining the characteristics of various materials through precise and systematic analytical methods.

Matter encompasses entities with mass and occupies a specific volume within space. Typically, matter is categorized into three distinct phases:

- **Solid:** Solid substances exhibit both a definite shape and maintain their volume in accordance with their shape. These entities have minimal freedom of movement. Examples include sugar, iron, gold, and wood.
- **Liquid:** Liquids take on the shape of their container and possess a fixed volume. They also exhibit the property of flow and can be poured.
Examples of liquids include water, milk, oil, mercury, and alcohol.
- **Gas:** Gaseous substances lack a definite volume and shape. Gases tend to completely fill the containers they are confined in.
Examples encompass hydrogen (H_2), oxygen (O_2), carbon dioxide (CO_2), and others.

The transitions between these three states of matter are achievable by altering temperature and pressure conditions. This interconvertibility is a fundamental aspect of the dynamic nature of matter.

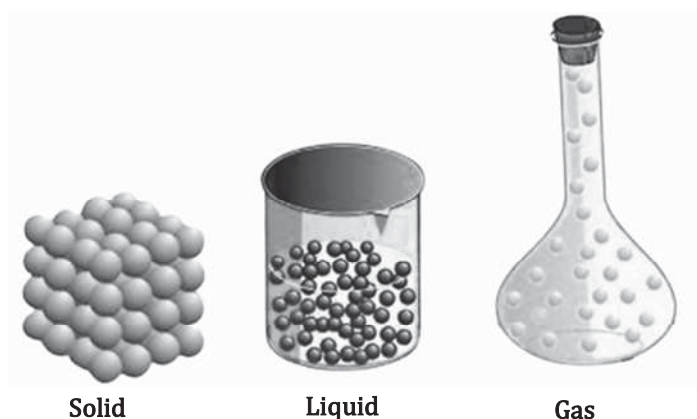
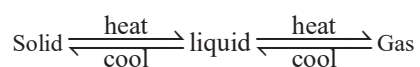
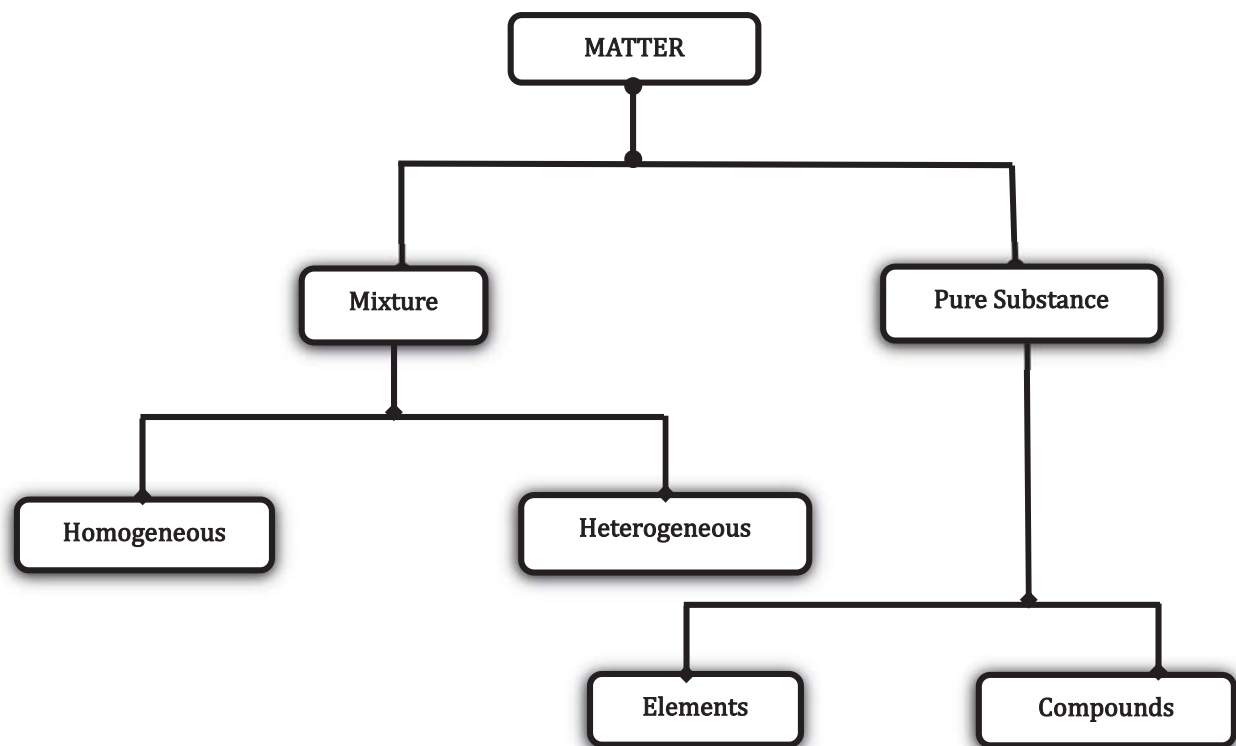


Fig: Arrangement of particles in solid, liquid and gaseous state

Classification of Matter at acroscopic Level



Matter can further be classified into following at bulk or macroscopic level:

- (a) Mixtures (b) Pure Substances

These can be further classified as shown below:

(a) **Mixtures:**

A mixture is a composition containing two or more substances in any proportion. It is fundamentally categorized into two types: Heterogeneous mixtures, where the components are visibly distinct, and Homogeneous mixtures, where the components are uniformly distributed.

The properties of a mixture are directly reflective of the properties of its individual components. Separation of a mixture can be achieved through straightforward physical methods.

It is 2 Types

- (i) Homogeneous mixture (ii) Hetrogeneous mixture

(i) **Homogeneous Mixture**

Two substances are combined to create a mixture in which a single uniform phase is present, meaning the composition of the substances is consistent throughout. Examples of such homogeneous mixtures include sugar solution and air.

Ex. Water + Salt, Water + Sugar, Water + alcohol,

(ii) **Heterogeneous Mixtures**

Two or more substances are combined, leading to a mixture with a non-uniform composition throughout. Examples of such mixtures include suspensions and combinations of two solids, such as a mixture of salt and sugar.

Ex. Water + Sand, Water + Oil.

Note: Any distinct portion of matter that is uniform throughout in composition and properties is called a Phase.

(b) Pure substances

A substance that consists solely of one type of material is referred to as a pure substance. Pure substances cannot be divided into simpler components through physical methods, and they maintain a fixed composition. Examples of pure substances include copper, silver, gold, water, and glucose. Glucose, for instance, contains carbon, hydrogen, and oxygen in a predetermined ratio, and its particles possess a consistent composition. Consequently, similar to other pure substances, glucose maintains a fixed composition, and its constituent elements—carbon, hydrogen, and oxygen—cannot be separated through simple physical processes.

Ex.

Element	=	Na, Mg, Ca etc.
Compound	=	HCl, H ₂ O, CO ₂ , HNO ₃ etc.

It is 2 Types

(i) Element

(ii) Compound

Note: In the realm of chemistry, a substance with a consistent chemical composition and unchanging chemical properties is referred to as a pure substance. These substances cannot be divided into components through physical methods. Pure substances are further categorized as outlined below:

(i) Element

An element is characterized as a pure substance consisting of only one type of atom and is indivisible into simpler components. These elements are then categorized into three classes based on their physical and chemical properties, namely:

(1) Metals

(2) Non- metals and

(3) Metalloids.

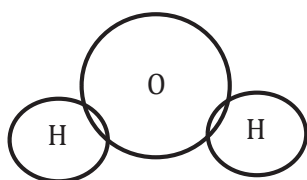
(ii) Compound

A compound is a pure substance composed of two or more elements blended in a specified mass ratio. Additionally, the characteristics of a compound are unique and differ from those of its individual elements. Importantly, the constituents of a compound cannot be isolated into simpler substances through physical methods; instead, chemical methods are required for separation.

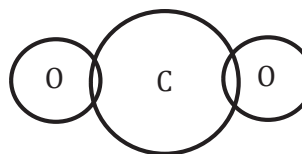
Ex. H₂O, HCl, CO₂, HNO₃ etc.

2: 16

1: 8 by wt.



Water molecule
(H₂O)



Carbon dioxide
Molecule (CO₂)

Fig: A depiction of molecules of water and carbon dioxide

Atom

An atom is the tiniest constituent of matter, capable of participating in chemical reactions, and it may or may not exist independently. The term "atom" itself carries the significance of being indivisible or not subject to division.

Dalton's Atomic Theory

The notion that matters consists of extremely small particles was initially proposed by both Indian and Greek philosophers. As early as 400 to 500 B.C., the Greek philosopher Democritus suggested that matter could not be endlessly divided into smaller parts, considering these ultimate particles as indivisible entities called atoms. The term "atom" is derived from the Greek word 'atoms,' signifying 'indivisible.' However, these early ideas were speculative rather than experimental.

The acknowledgment of the existence of atoms gained support from Boyle in his book 'The Skeptical Chemist' (1661) and from Newton in his works 'Principia' and 'Optics' (1704). Subsequently, John Dalton systematized these ideas into a comprehensive theory known as Dalton's Atomic Theory between 1803 and 1808, marking a significant milestone in the history of chemistry.

The main points of Dalton's atomic theory are:

- (i) Elements are composed of minute, indivisible, and indestructible particles known as atoms.
- (ii) Atoms within the same element are identical to each other, sharing the same mass and size.
- (iii) Atoms belonging to different elements exhibit distinct properties and possess varying masses and sizes.
- (iv) The formation of compounds occurs when atoms of different elements combine in simple numerical ratios, such as one-to-one, one-to-two, two-to-three, and so forth.
- (v) Atoms cannot be created, destroyed, or transformed into atoms of other elements.
- (vi) In a given compound, the relative numbers and types of atoms remain constant. While this theory effectively explained various laws of chemical combination, it has been substantially revised with the modern concept of the atom's structure. Nevertheless, the Daltonian atom still holds significance as the fundamental unit involved in chemical reactions.

The following are the modified views regarding Dalton's atomic theory:

- (i) The concept of the atom as indivisible has evolved, acknowledging it as a complex rather than a simple particle.
- (ii) Atoms within the same element may not uniformly possess the same mass; however, they share identical atomic numbers and exhibit similar chemical properties, a phenomenon discovered through the identification of isotopes.
- (iii) While atoms of different elements may have the same mass, they invariably possess distinct atomic numbers and differ in chemical properties, as evidenced by the discovery of isobars.
- (iv) The transformation of atoms from one element to another, known as artificial transmutation, challenges the notion of atoms being immutable.
- (v) In certain organic compounds, such as proteins, starch, cellulose, etc., the ratio in which atoms of different elements combine is not necessarily simple. Several compounds deviate from the law of constant proportions, leading to the classification of such substances as non-stoichiometric compounds.