Reading Material for
Medical Lab. Technician
(Elementary chemistry and chemical pathology)

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PREFACE

This book is for a two years post matric teaching program of Medical Laboratory Technicians (MLTs) for the students of Allied Health Sciences. The purpose of this reading material is to provide basic education to the paramedics about elements, compounds including other chemistry topics. This book also contains knowledge of chemical pathology which includes the normal and pathological aspects of the biochemistry, interpretation. The reading material attempts to cover almost all the basic theoretical knowledge required by students about routine chemistry and chemical pathology so that they can give better performance in their work at Pathology laboratory.

Elementary Chemistry and Chemical Pathology

Chapter one

Introduction to chemistry

Objective

After studying this chapter students will be able to demonstrate scientific understandings of the structure of matter and of its physical and chemical transformations. Students will be able to apply appropriate theories to predict chemical structure, reactivity, and physical properties.

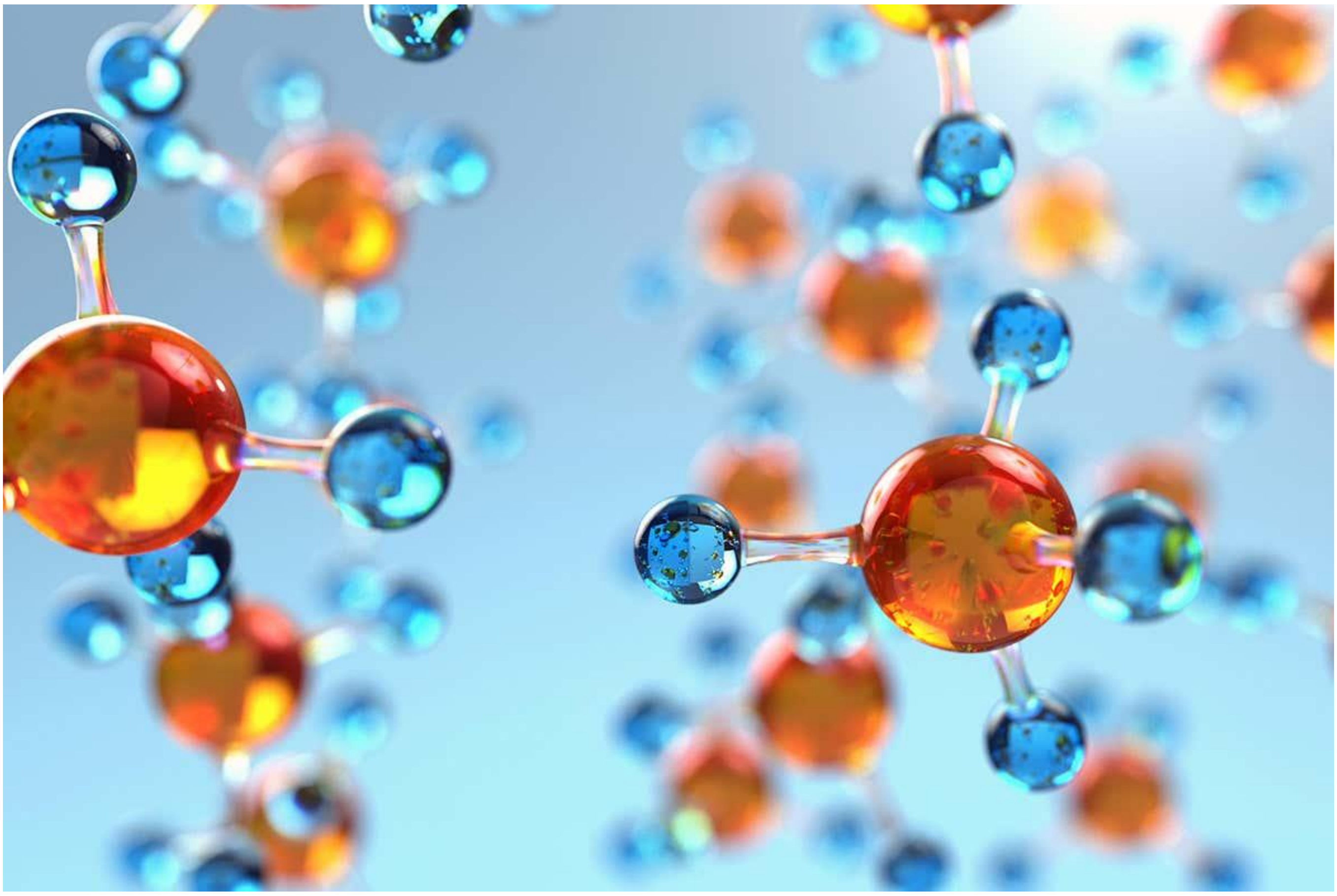
CHAPTER 1

INTRODUCTION TO CHEMISTRY

Chemistry deals with reality's most basic elements, from particles to atoms to molecules, chemistry is also known as the central science. Chemistry is also concerned with the utilization of natural substances and the creation of artificial ones. Cooking, fermentation, glass making, and metallurgy are all chemical processes that date from the beginnings of civilization. Today, vinyl, Teflon, liquid crystals, semiconductors, and superconductors represent the fruits of chemical technology. The 20th century saw dramatic advances in the comprehension of the marvelous and complex chemistry of living organisms, and a molecular interpretation of health and disease holds great promise. Modern chemistry, aided by increasingly sophisticated instruments, studies materials as small as single atoms and as large and complex as DNA (deoxyribonucleic acid), which contains millions of atoms. New substances can even be designed to bear desired characteristics and then synthesized. The rate at which chemical knowledge continues to accumulate is remarkable. Over time more than 8,000,000 different chemical substances, both natural and artificial, have been characterized and produced.

Chemistry**,** deals with the properties, composition, and structure of substances (defined as elements and compounds), the transformations they undergo, and the energy that is released or absorbed during these processes. Every substance, whether naturally occurring or artificially produced, consists of one or more species of atoms that have been identified as elements. Although these atoms, in turn, are composed of elementary particles, they are the basic building blocks of chemical substances; there is no quantity of oxygen, mercury, or gold, for example, smaller than an atom of that substance. Chemistry, therefore, is concerned not with the subatomic domain but with the properties of atoms and the laws governing their combinations and how the knowledge of these properties can be used to achieve specific purposes.

Sitting between biology and physics, the field of chemistry is sometimes called the central science. This branch of science deals with the most basic elements of reality, such as fundamental particles, or the complex world of living organisms, but the in-between world of atoms, molecules and chemical processes. Chemistry is the study of matter, analyzing its structure, properties and behavior to see what happens when they change in chemical reactions. As such, it can be considered a branch of physical science, alongside astronomy, physics and earth sciences including geology. An important area of chemistry is the understanding of atoms and what determines how they react. It turns out, reactivity is often largely mediated by the electrons that orbit atoms and the way these are exchanged and shared to create chemical bonds.



1.1, Branches of Chemistry

Chemistry has now split into many branches. For instance, analytical chemists might measure the traces of compounds in ancient pottery to discern what people were eating thousands of years ago.

1.1.1, Biochemistry is the study of the chemical processes that take place in living organisms, for instance in farming, and on the effect the resulting produce will have on our body’s metabolism. It examines the processes that occur in molecules and cells, the communications between cells and the relation of a cell's structure to its functions. Biochemistry has broad applications in medicine, particularly in studying the causes and cures of viruses, in nutrition and agriculture. Research in biochemistry may cover anything from basic cellular processes up to understanding disease to develop better treatments.

1.1.2, Organic chemistry, the study of compounds which contain carbon, connects up molecules in new ways to build and analyse an array of materials, from drugs to plastics to flexible electronics.

1.1.3, Inorganic chemistry: is the study of chemicals that are not primarily based on carbon. Inorganic chemicals are commonly found in rocks and minerals. One area of inorganic chemistry deals with the design and properties of materials involved in energy and information technology. Inorganic chemistry has many practical applications, including fertilizers production, surfactants and pigments. Inorganic chemistry is applied in the field of chemical and pharmaceutical production.

1.1.4, Physical chemistry involves looking at chemistry through the lens of physics to study changes in pressure, temperatures and rates of conversion, for example, as substances react.

1.1.5, Analytical chemistry: a branch of chemistry that uses chemical analysis to define types of matter and determine their quantities. There are qualitative and quantitative methods of chemical analysis. Qualitative methods look at the presence of different matters, whereas quantitative methods determine how much of a chemical exists within matter. There are many applications of analytical chemistry, including food and drug safety, environmental regulations, medical diagnosis, and forensic science.

Most of the materials that occur on Earth, such as wood, coal, minerals, or air, are mixtures of many different and distinct chemical substances. Each pure chemical substance (*e.g.,* oxygen, iron, or water) has a characteristic set of properties that gives it its chemical identity. Iron, for example, is a common silver-white metal that melts at 1,535° C, is very malleable, and readily combines with oxygen to form the common substances hematite and magnetite. The detection of iron in a mixture of metals, or in a compound such as magnetite, is a branch of analytical chemistry called qualitative analysis. Measurement of the actual amount of a certain substance in a compound or mixture is termed quantitative analysis. Quantitative analytic measurement determines that iron makes up 72.3 percent, by mass, of magnetite. Some very simple qualitative tests reveal the presence of specific chemical elements in very smaller amounts. The yellow color imparted to a flame by sodium. Such analytic tests have allowed chemists to identify the types and amounts of impurities in various substances and to determine the properties of very pure materials.

Sample Question; Define chemistry and name the branches of Chemistry?

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Chapter 2

Elements

Objective of the chapter,

After studying his chapter, the students will learn how the chemical elements are arranged on the Periodic Table. Students will be able to arrange the elements on the Periodic Table. Students will learn about some of the important chemical and physical properties of the elements.

Chemical element,

Any substance that cannot be decomposed into simpler substances by ordinary chemical processes. Elements are the fundamental materials of which all matter is composed.

At present there are 118 known chemical elements. About 20 percent of them do not exist in nature (or are present only in trace amounts) and are known only because they have been synthetically prepared in the laboratory. Of the known elements, 11 are gases under ordinary conditions, 2 are liquids (two more, cesium and gallium, melt at about or just above room temperature), and the rest are solids. Elements can combine with one another to form a wide variety of more complex substances called compounds. The number of possible compounds is almost infinite; perhaps a million are known, and more are being discovered every day. When two or more elements combine to form a compound, they lose their separate identities, and the product has characteristics quite different from those of the constituent elements. The gaseous elements hydrogen and oxygen, for example, with quite different properties, can combine to form the compound water, which has altogether different properties from either oxygen or hydrogen. Water clearly is not an element because it consists of, and actually can be decomposed chemically into, the two substances hydrogen and oxygen; these two substances, however, are elements because they cannot be decomposed into simpler substances by any known chemical process. Most samples of naturally occurring matter are physical mixtures of compounds (seawater), the most common of which is sodium chloride, or table salt.

Atoms of elemental substances are themselves complex structures composed of more fundamental particles called protons, neutrons, and electrons. Within an atom, a small nucleus, which contains both protons and neutrons, is surrounded by cloud, of electrons. The fundamental properties of these subatomic particles are their weight and electrical charge. Whereas protons carry a positive charge and electrons a negative one, neutrons are electrically neutral. The diameter of an atom (about 10^{-8} centimetre) is 10,000 times larger than that of its nucleus. Neutrons and protons, which are collectively called nucleons, have relative weights of approximately one atomic mass unit, whereas an electron is only about 1/2000 as heavy. Because neutrons and protons occur in the nucleus, virtually all of the mass of the atom is concentrated there. The number of protons in the nucleus is equivalent to the **atomic number** of the element. The total number of protons and neutrons is called the **mass number**. Because the atom itself is electrically neutral, the atomic number represents not only the number of protons, or positive charges, in the nucleus but also the number of electrons, or negative charges, in the extra nuclear region of the atom.

The chemical characteristics of elements are intimately related to the number and arrangement of electrons in their atoms. Thus, elements are completely distinguishable from each other by their atomic numbers. The realization that such is the case leads to another definition of an element, namely, a **substance**, all atoms of which have the same atomic number.

Not all the atoms present have the same atomic weight, even though they all have the same atomic number. Such a situation can occur only if the atoms have different numbers of neutrons in their nuclei. Such groups of atoms—with the same atomic number but with different relative weights—are called **isotopes**. The number of isotopic forms that a naturally occurring element possesses ranges from one (e.g., fluorine) to as many as ten (e.g., tin);

most of the elements have at least two isotopes. The atomic weight of an element is usually determined from large numbers of atoms containing the natural distribution of isotopes, and, therefore, it represents the average isotopic weight of the atoms constituting the sample.

2.1, Atom,

The basic building block of all matter and chemistry. Atoms can combine with other atoms to form molecules but cannot be divided into smaller parts by ordinary chemical processes.

Most of the atom is empty space. The rest consists of three basic types of subatomic particles: protons, neutrons, and electrons. The protons and neutrons form the atom's central nucleus. The ordinary hydrogen atom is an exception; it contains one proton but no neutrons. As their names suggest, protons have a positive electrical charge, while neutrons are electrically neutral—they carry no charge, the nucleus has a positive charge. Circling the nucleus is a cloud of electrons, which are negatively charged. Like opposite ends of a magnet that attract one another, the negative electrons are attracted to a positive force, which binds them to the nucleus. The nucleus is small and dense compared with the electrons, which are the lightest charged particles in nature. The electrons circle the nucleus in orbital paths called **shells**, each of which holds only a certain number of electrons.

An ordinary, neutral atom has an equal number of protons in the nucleus and electrons surrounding the nucleus. Thus the positive and negative charges are balanced. Some atoms, however, lose or gain electrons in chemical reactions or in collisions with other particles. Ordinary atoms that either gain or lose electrons are called ions. If a neutral atom loses an electron, it becomes a positive ion. If it gains an electron, it becomes a negative ion. These basic subatomic particles—protons, neutrons, and electrons—are themselves made up of smaller substances, such as quarks and leptons.

More than 90 types of atoms exist in nature, and each kind of atom forms a different chemical element. They are ranked in order of their atomic number (the total number of protons in its nucleus) in a chart called the periodic table. Accordingly, because an atom of iron has 26 protons in its nucleus, its atomic number is 26 and its ranking on the periodic table of chemical elements is 26. Because an ordinary atom has the same number of electrons as protons, an element's atomic number also tells how many electrons its atoms have, and it is the number and arrangement of the electrons in their orbiting shells that determines how one atom interacts with another. The key shell is the outermost one, called the valence shell. If this outermost shell is complete, or filled with the maximum number of electrons for that shell, the atom is stable, with little or no tendency to interact with other atoms. But atoms with incomplete outer shells seek to fill or to empty such shells by gaining or losing electrons or by sharing electrons with other atoms. This is the basis of an atom's chemical activity. Atoms that have the same number of electrons in the outer shell have similar chemical properties.

Electrons contribute only a tiny part to the mass of the atomic structure, however, they play an important role in the chemical reactions that create molecules. For most purposes, the atomic weight can be thought of as the number of protons plus the number of neutrons. Because the number of neutrons in an atom can vary, there can be several different atomic weights for most elements. Atoms having the same number of protons but different numbers of neutrons represent the same element and are known as **isotopes** of that element. An isotope for an element is specified by the sum of the number of protons and neutrons. For example, the following are two isotopes of the carbon atom:

- Carbon 12 is the most common, non-radioactive isotope of carbon.
- Carbon 14 is a less common, radioactive carbon isotope.

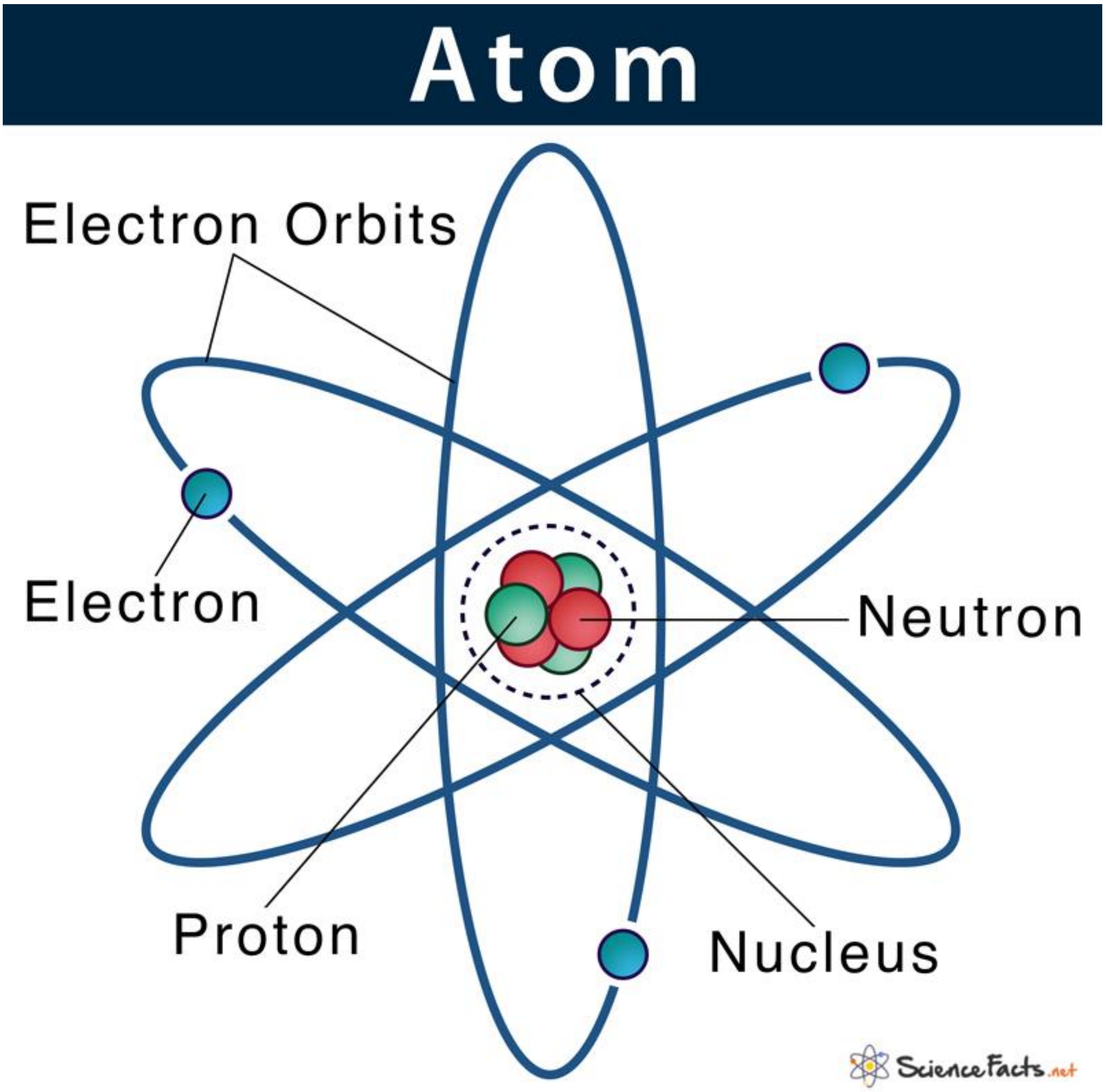


Figure: Structure of atom

2.2, Periodic Table of the Elements

The **Periodic table** of elements, simply called a Periodic Table, is a systematic arrangement of 118 known chemical elements. These chemical elements are organized in order of increasing atomic number, or the number of protons in an atom's nucleus, which typically corresponds with increasing atomic mass, from left to right and top to bottom. The **horizontal rows from left to right are called periods** while the **vertical columns from top to bottom are called groups** in a periodic table.

The periodic table is an essential aspect of Chemistry because it is an arrangement of all the known elements and therefore provides information about elements and their relation with one another to use reference. For example, properties of particular elements such as their mass, electron number, electron configuration, and their unique chemical properties. The 118 elements are arranged in 7 periods and 18 groups as shown below. Further, the elements are divided into different blocks.

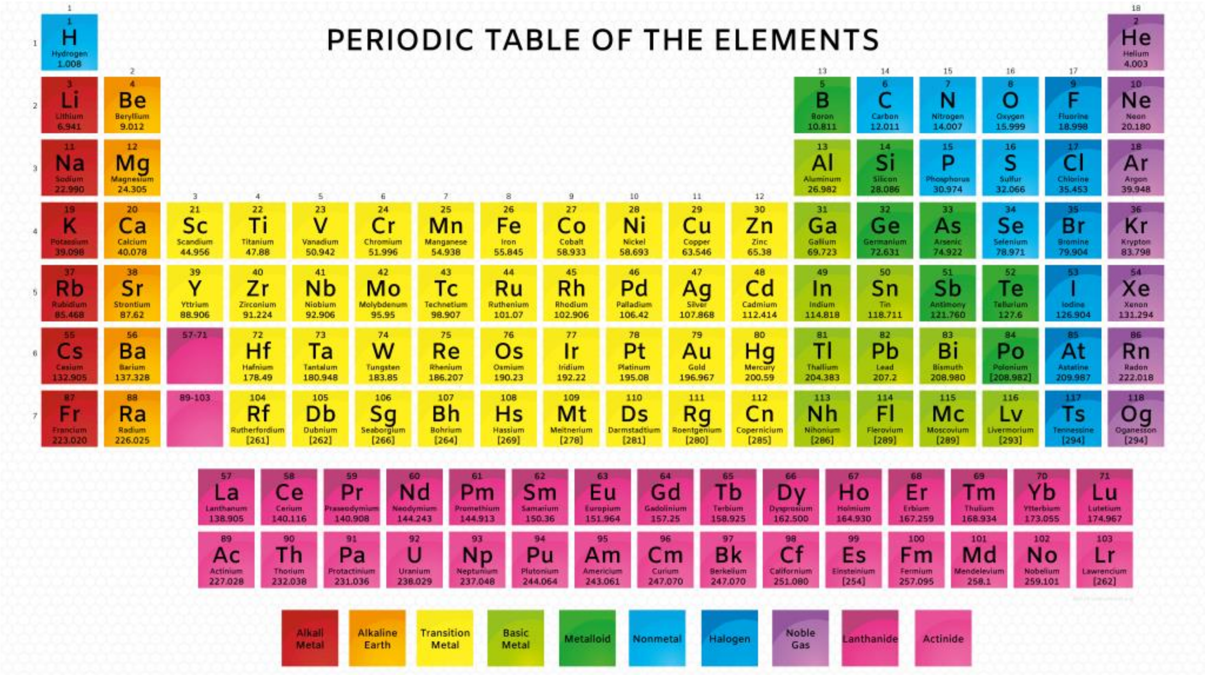
2.2.1 **s-block elements:** The first and the second group elements that have the last electron filled in the s-subshell are called s-block elements. The elements included in the s-block are Alkali metals and Alkaline Earth Metals.

2.2.2 **p-block elements:** The elements included in groups 13 to 17 are p-block elements. These elements have the last electron filled in their p-subshell. The elements included in this block from different groups are termed as Boron Family (Group 13), Carbon Family (Group 14), Nitrogen Family (Group 15), Oxygen Family (Group 16), and Fluorine Family (Group 17).

2.2.3 **d-block elements:** The elements present in groups 3 to 12 are d-block elements. These elements have the last electron filled in their d-subshell. d-block elements are also called transition elements as they have partially filled d-orbitals in their ground state.

2.2.4 **f-block elements:** These elements have the last electron filled in their f-subshell. Such elements are present in Lanthanides and Actinide groups.

Here is the table representing 118 elements of the periodic table. The elements listed are arranged according to the increasing order of atomic number and their respective atomic weight, symbols, density, and electronegativity.



2.3, Metal, any of a class of substances characterized by high electrical and thermal conductivity and high reflectivity of light. Metals are solids at room temperature (except for mercury), and are usually malleable (can be rolled into sheets) and ductile (can be drawn into wires). Metals are usually separated into the main group metals in Groups IA - VA and the transition metals in Groups IB - VIIIB. Approximately three-quarters of all known chemical elements are metals. The most abundant varieties in the Earth’s crustare aluminum, iron, calcium, sodium, potassium, and magnesium. The vast majority of metals are found in ores (mineral-bearing substances), but a few such as copper, gold, platinum, and silver frequently occur in the free state because they do not readily react with other elements.

Metals are usually crystalline solids. In most cases, they have a relatively simple crystal structure distinguished by a close packing of atoms and a high degree of symmetry. Typically, the atoms of metals contain less than half the full complement of electrons in their outermost shell. Because of this characteristic, metals tend not to form compounds with each other. They do, however, combine more readily with nonmetals (e.g., oxygen and sulfur), which generally have more than half the maximum number of valence electrons. Metals differ widely in their chemical reactivity. The most reactive include lithium, potassium, and radium, whereas those of low reactivity are gold, silver, palladium, and platinum.

The high electrical and thermal conductivities of the simple metals (i.e., the non-transition metals of the periodic table) are best explained by reference to the free-electron theory. According to this concept, the individual atoms in such metals have lost their valence electrons to the entire solid, and these free electrons that give rise to conductivity move as a group throughout the solid. In the case of the more complex metals (i.e., the transition elements), conductivities are better explained by the band theory, which takes into account not only the presence of free electrons but also their interaction with so-called *d* electrons.

The mechanical properties of metals, such as hardness, ability to resist repeated stressing, ductility, and malleability, are often attributed to defects or imperfections in their crystal structure. The absence of a layer of atoms in its densely packed structure, for example, enables a metal to deform plastically, and prevents it from being brittle.

2.4, The Non-Metals are a group of elements located on the right side of the periodic table (except for hydrogen, which is on the top left). These elements are distinctive in that they typically have low melting and boiling points, don't conduct heat or electricity very well, and tend to have high ionization energies and electronegativity values. They also don't have the shiny "metallic" appearance associated with the metals. While the metals are malleable and ductile, the nonmetals tend to form brittle solids. The nonmetals tend to gain electrons readily to fill their valence electrons shells, so their atoms often form negative-charged ions. There are 7 elements that belong to the nonmetals group:

Hydrogen (sometimes considered an alkali metal), Carbon, Nitrogen, Oxygen, Phosphorus, Sulfur, Selenium

Even though there are only 7 elements within the nonmetals group, two of these elements (hydrogen and helium) make up about 98% of the mass of the universe.**1**Nonmetals form more compounds than metals. Living organisms consist mainly of nonmetals.

2.5, MetalloidS, is a term used to describe a chemical element that forms a simple substance having properties intermediate between those of a typical metal and a typical nonmetal. The term is normally applied to a group of between six and nine elements (boron, silicon, germanium, arsenic, antimony, tellurium, bismuth, polonium, astatinefound near the center of the P-block or main block of the periodic table. There is no single property which can be used to unambiguously identify an element as a metalloid. Since most metalloids tend to display semiconducting properties, the class might reasonably be extended to also include gray silicon (which, unlike white silicon, is a semiconductor rather than a metal) and the graphite form of carbon (which, unlike the diamond form, is a semimetal rather than an insulator). Chemically, metalloids correspond to atoms having intermediate electronegativities and an ability to display a range of both positive and negative oxidation states in their compounds.

It can be noted that all seven of these elements can be found on the regular periodic table in a diagonal region of the p-block which extends from boron (which is placed on the upper left) to astatine (which is placed on the lower right). Some periodic tables have a dividing line between metals and nonmetals, and below this line, the metalloids can be found.

2.6, Named Families

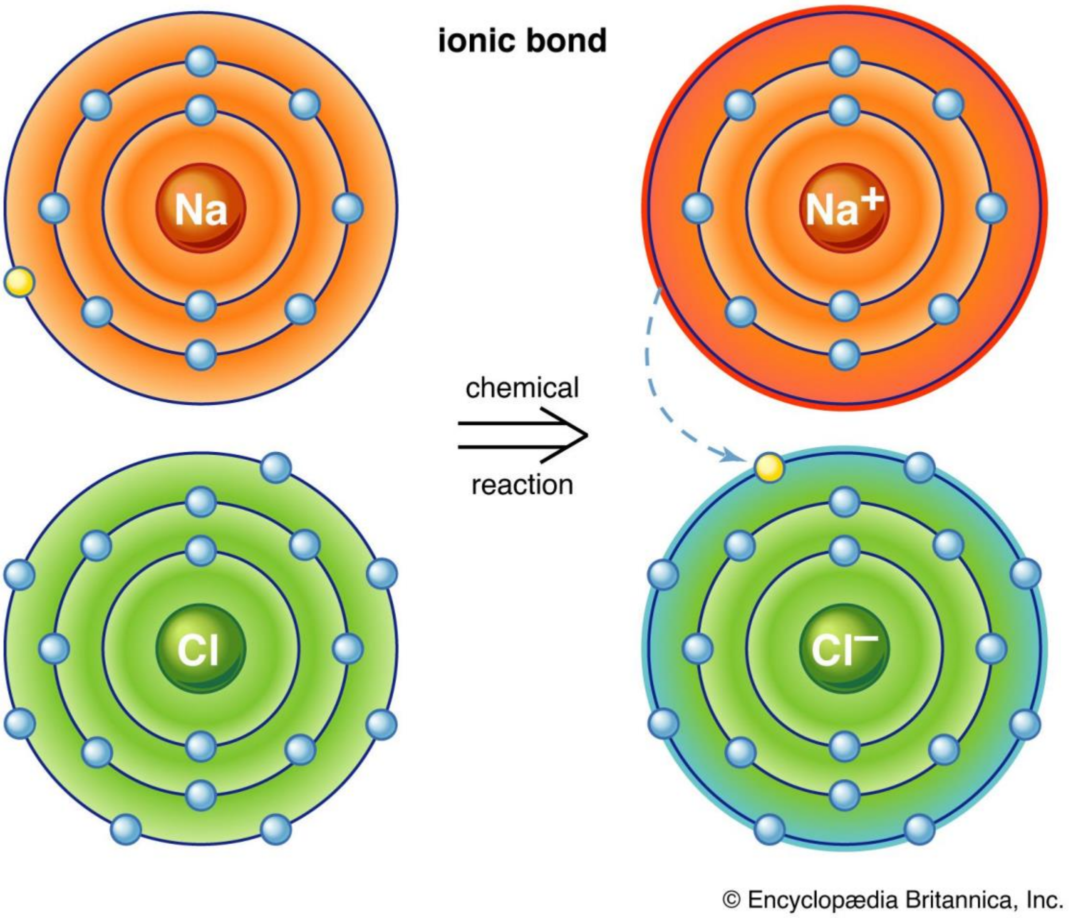
2.6.1, Alkali Metals Group IA, belong to the **s-block elements** occupying the left most side of the periodic table. Alkali metals readily lose electrons, making them count among the most reactive elements on earth. In general, **'alkali'** refers to the basic or alkaline nature of their metal hydroxides. The compounds are called alkali metals because when they react with water, they usually form alkalies which are nothing but strong bases that can easily neutralise acids. They occupy the first column of the periodic table. Alkali elements are Lithium(Li), Sodium(Na), Potassium (K), Rubidium (Ru), Cesium (Cs) and Francium (Fr), occupying successive periods from first to seven. Francium is a radioactive element with a very low half-life. However, the main reason why hydrogen (H) is not considered an alkali metal is that it is mostly found as a gas when the temperature and pressure are normal. Hydrogen can show properties or transform into an alkali metal when it is exposed to extremely high pressure.

2.6.2, Alkaline earth metals are the elements that correspond to **group 2** of the modern periodic table. This group of elements includes beryllium, magnesium, calcium, strontium, barium, and radium**.** The elements of this group are quite similar in their physical and chemical properties. For example, all alkaline earth metals are silvery-white-coloured solids under standard conditions. They are also highly shiny and are quite reactive. Since the alkaline earth metals have a completely full s-orbital in their respective valence shells, they tend to readily lose two electrons to form cations with a charge of +2. Thus, the most common oxidation state exhibited by alkaline earth metals is +2.

The alkaline earths are the elements located in Group IIA of the periodic table. This is the second column of the table.

2.6.3, Halogens, any of the six nonmetallic elements that constitute Group 17 Group VIIA of the periodic table. The halogen elements are fluorine (F), chlorine (Cl), bromine (Br), iodine (I), astatine (At), and tennessine (Ts). They were given the name *halogen*, from the Greek roots *hal*- (“salt”) and -*gen* (“to produce”), because they all produce sodium salts of similar properties, of which sodium chloridetable salt, or halite is best known. Because of their great reactivity, the free halogen elements are not found in nature. In combined form, fluorine is the most abundant of the halogens in Earth’s crust. The percentages of the halogens in the igneous rocks of Earth’s crust are 0.06 fluorine, 0.031 chlorine, 0.00016 bromine, and 0.00003 iodine. Astatine and tennessine do not occur in nature, because they consist of only short-lived radioactive isotopes.

The halogen elements show great resemblances to one another in their general chemical behaviour and in the properties of their compounds with other elements. There is, however, a progressive change in properties from fluorine through chlorine, bromine, and iodine to astatine. Fluorine is the most reactive of the halogens. Chlorine is the best known of the halogen elements. The free element is widely used as a water-purification agent, and it is employed in a number of chemical processes. Table salt, sodium chloride, of course, is one of the most familiar chemical compounds. Fluorides are known chiefly for their addition to public water supplies to prevent tooth decay, but organic fluorides are also used as refrigerants and lubricants. Iodine is most familiar as an antiseptic, and bromine is used chiefly to prepare bromine compounds that are used in flame retardants and as general pesticides. In the past ethylene dibromide was extensively used as an additive in leaded gasoline.



2.6.4, Group VIIIA of the periodic table are the **noble gases** or **inert gases**: helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn). The name comes from the fact that these elements are virtually unreactive towards other elements or compounds. They are found in trace amounts in the atmosphere (in fact, 1% of the atmosphere is argon); helium is also found in natural gas deposits. In their elemental form at room temperature, the Group 8A elements are all colorless, odorless, monatomic gases. They traditionally have been labeled Group 0 in the periodic table because for decades after their discovery it was believed that they could not bond to other atoms; that is, that their atoms could not combine with those of other elements to form chemical compounds. Their electronic structures and the finding that some of them do indeed form compounds has led to the more appropriate designation, Group 18 (VIIIA).

Under standard conditions for temperature and pressure, all the noble gases exist in the gaseous phase. They are known to possess extremely low chemical reactivity (hence the name inert gas). This is because all the noble gases have stable electronic configurations. This is the reason why noble gases do not form molecules easily and are mostly found as mono-atomic gases.

2.7, Valence,

The property of an element that determines the number of other atoms with which an atom of the element can combine. The term is used to express both the power of combination of an element in general and the numerical value of the power of combination. Characteristic valences for the elements were measured in terms of the number of atoms of hydrogen with which an atom of the element can combine or that it can replace in a compound. It became evident, however, that the valences of many elements vary in different compounds.

Valence electrons are the ***s and p electrons in the outermost shell.*** The electrons present in the inner shell are core electrons. When we study and observe the atom of an element, we come across tiny subatomic particles called valence electrons. Valence electrons are all arranged in different orbitals or shells and are mostly negatively charged particles. Further, these electrons are ***responsible for interaction between atoms and the formation of chemical bonds.*** However, not all electrons are associated with the atom. Only the electrons present in the outermost shell can participate in the formation of a chemical bond or a molecule. Such type of electrons is called valence electrons.

2.8, Symbols

Each element has a name. Each element name is abbreviated as usually the first letter of the element's name, while the second letter is some other letter from the name. Some elements have symbols that derive from earlier, mostly Latin names, so the symbols may not contain any letters from the English name. Table lists the names and symbols of some of the most familiar elements.

Element Names and Symbols			
Aluminum	Al	magnesium	Mg
Argon	Ar	manganese	Mn
Arsenic	As	mercury	Hg*
Barium	Ba	Neon	Ne
Bismuth	Bi	Nickel	Ni
Boron	B	nitrogen	N
Bromine	Br	oxygen	O
Calcium	Ca	phosphorus	P
Carbon	C	platinum	Pt
Chlorine	Cl	potassium	K*
Chromium	Cr	Silicon	Si
Copper	Cu*	Silver	Ag*
Fluorine	F	Sodium	Na*
Gold	Au*	strontium	Sr
Helium	He	Sulfur	S
Hydrogen	H	Tin	Sn*
Iron	Fe	tungsten	W†

Iodine	I	uranium	U
Lead	Pb*	Zinc	Zn
Lithium	Li	zirconium	Zr
*The symbol comes from the Latin name of element.			
†The symbol for tungsten comes from its German name—*wolfram*.			

2.9, DESCRIPTION OF IMPORTANT ELEMENTS

most living matter consists primarily of the bulk elements: oxygen, carbon, hydrogen, nitrogen, and sulfur, the building blocks of the compounds. these five elements also constitute the bulk of our diet. six other elements, sodium, magnesium, potassium, calcium, chlorine, and phosphorus are often referred to as macrominerals because they provide essential ions in body fluids and form the major structural components of the body. in addition, phosphorus is a key constituent of both dna and rna: the genetic building blocks of living organisms. some of these important elements are listed below:

2.9.1, CARBON,

our body is made up of 18% carbon. sugar, proteins, vitamins, etc all are made up of carbon. apart from this carbon is used in medicinal industries for making drugs and medicines. carbon dioxide gas we release during respiration is used by plants for the process of photosynthesis.

2.9.2, HYDROGEN,

it is used in the synthesis of water which is essential for life. it is used in making fertilizers, ammonia, etc. other than this hydrogen is used as rocket fuel to create strong explosions.

2.9.3, OXYGEN

it is essential for respiration, circulation, and many more physiological processes. we cannot live without oxygen.

2.9.3, CHLORINE,

It is used as a disinfectant for water. industrial and sewage waste help in sanitization. it is used as a bleaching agent.

2.9.4, SULPHUR,

it is used in the synthesis of sulfuric acid and in making insecticides and fungicides.

2.9.5, CALCIUM,

makes strong bones and teeth. it is important for physiological processes like the movement of muscles, for nerves, carry signals from the brain to body parts. calcium carbonate is used in the cement industry in the synthesis of cement.

2.9.6, IRON

is an important element of blood and helps in the transportation of food and minerals apart from this iron is used in industries in anufacturing structural elements for building, machinery and tools, and many more.

2.9.7, PHOSPHORUS,

it is used in making matches, fertilizers, phosphorus bronze, detergents, and many more.

2.9.8, NITROGEN,

is an essential element in the synthesis of proteins, in medicine manufacturing, food packing, and preservation, etc,

2.9.9, SODIUM,

it helps in synthesis of many reagents in chemical industries (sodium hydroxide) naoh, sodium borohydrides (nabh4) etc. apart from this sodium salts are used in medicinal industries. the salt we consume in our food is nacl (sodium chloride).

other than these elements many other elements like magnesium, zinc, neon, and helium are also used in our daily life.

Sample Question; describe the definition of valence, metalloids, symbols and periodic table?

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Chapter 3

Compounds and Mixtures

Learning Objective of the chapter:

After studying this chapter students will be able to know what makes compounds different from elements. Students will be able to identify compounds by their names and properties.

3.1, Chemical compound,

any substance composed of identical molecule consisting of atoms of two or more chemical elements.

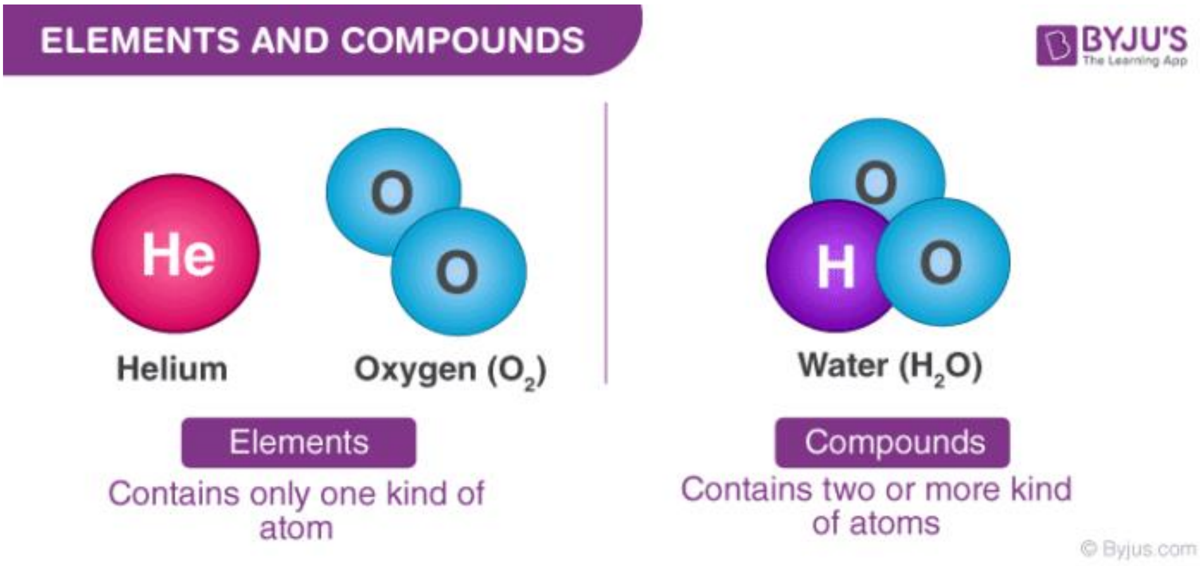
The fundamental principle of the science of chemistry is that the atoms of different elements can combine with one another to form chemical compounds. Methane, for example, which is formed from the elements carbon and hydrogen in the ratio four hydrogen atoms for each carbon atom, is known to contain distinct CH_4 molecules. The formula of a compound such as CH_4 indicates the types of atoms present.

Water, which is a chemical compound of hydrogen and oxygen in the ratio of two hydrogen atoms for every oxygen atom, contains H_2O molecules. Sodium chloride is a chemical compound formed from sodium (Na) and chlorine (Cl) in a 1:1 ratio. Although the formula for sodium chloride is NaCl. The substances mentioned above exemplify the two basic types of chemical compounds: molecular (covalent) and ionic. Methane and water are composed of molecules; that is, they are **molecular compounds**. Sodium chloride, on the other hand, contains ions; it is an **ionic compound**.

In fact, there are millions of chemical compounds known, and many more millions are possible. Most substances found in nature—such as wood, soil, and rocks—are mixtures of chemical compounds. These substances can be separated into their constituent compounds by physical methods, which are methods that do not change the way in which atoms are aggregated within the compounds. Compounds can be broken down into their constituent elements by chemical changes. A chemical change (that is, a chemical reaction) is one in which the organization of the atoms is altered. An example of a chemical reaction is the burning of methane in the presence of molecular oxygen (O_2) to form carbon dioxide (CO_2) and water.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Chemical compounds at ordinary temperatures and pressures, some are solids, some are liquids, and some are gases. The colours of the various compounds span those of the rainbow. Some compounds are highly toxic to humans, whereas others are essential for life. Substitution of only a single atom within a compound may be responsible for changing the colour, odour, or toxicity of a substance. Out of this great diversity, classification systems have been developed. An example is the classification of the compounds as **molecular or ionic**. Compounds are also classified as **organic or inorgani**c. Because of the great variety of ways that carbon can bond with itself and other elements, there are more than nine million organic compounds.



3.2, Mixtures

A mixture is a compound that is made up of two more chemical compounds or substances that do not combine together chemically. It is the physical combination of two or more substances that are able to retain their individual identities while they are mixed to form solutions, suspensions, or colloids. Physical means can be used to separate them. A solution of salt and water, a combination of sugar and water, various gases, air, and so on are examples. The different components of any combination do not unite through any chemical changes. As a result, the components retain their distinct characteristics. In addition, unlike in a compound, the components in a mixture do not combine chemically to produce new material. Instead, they just mix and maintain their original characteristics.

Properties of Mixtures,

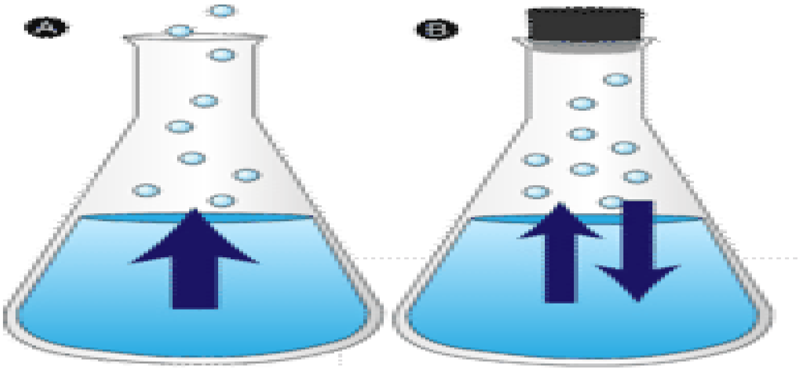
All the components or substances in a mixture retain their original physical properties.
The mixture can be separated into its components physically by using some techniques
Components in a mixture may or may not be in a fixed proportion and can vary in quantity.

Examples of Mixtures

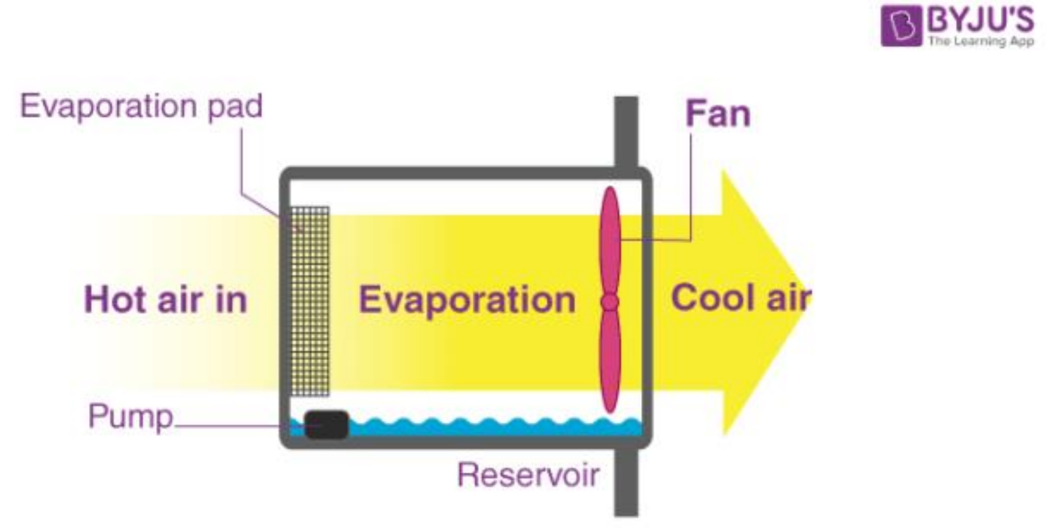
3.2.1 **Smog** is a mixture of Smoke and Fog.
3.2.2 **Cement** is a mixture of Sand, Water and Gravel.
3.2.3 **Sea Water** is a mixture of Water and Salt.
3.2.4 **Soil** is a mixture of Minerals, Air, Organic materials, Water, and Living Organisms.
3.2.5 **Blood** is a mixture of Plasma, White Blood Cells, Red Blood Cells, and Platelets.
3.2.6, Gasoline is a mixture of Hydrocarbons, Petroleum, and Fuel Additives.

3.3, Evaporation, a process by which an element or compound transitions from its liquid state to its gaseous state below the temperature at which it boils; in particular, the process by which liquid water enters the atmosphere as water vapour in the water cycle.

In order for a liquid molecule to escape into the gas state, the molecule must have enough kinetic energy to overcome the intermolecular attractive forces in the liquid. A given liquid sample will have molecules with a wide range of kinetic energies. Liquid molecules that have this certain threshold kinetic energy escape the surface and become vapor. As a result, the liquid molecules that remain now have lower kinetic energy. As evaporation occurs, the temperature of the remaining liquid decreases. On a hot day, the water molecules in perspiration absorb body heat and evaporate from the surface of your skin. The evaporation process leaves the remaining perspiration cooler, which in turn absorbs more heat from your body.



A given liquid will evaporate more quickly when it is heated. This is because the heating process results in a greater fraction of the liquid's molecules having the necessary kinetic energy to escape the surface of the liquid.



Schematic Representation of Working of an Air Cooler

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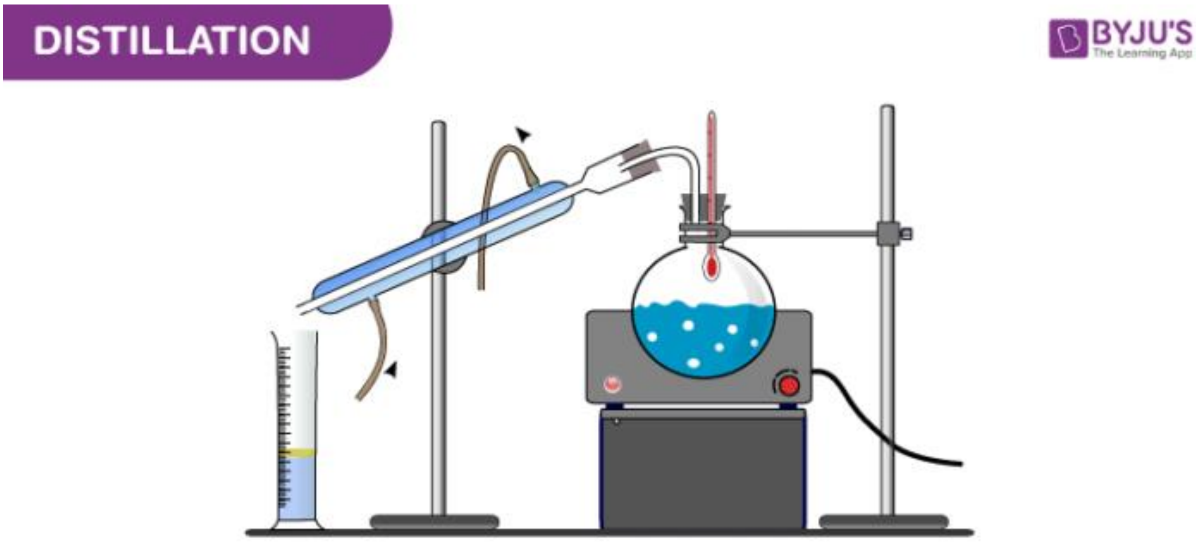
3.4, Distillation, involves the conversion of a liquid into vapour that is subsequently condensed back to liquid form. When steam from a kettle becomes deposited as drops of distilled water on a cold surface. Distillation is used to separate liquids from nonvolatile solids, as in the separation of gasoline, kerosene, and lubricating oil from crude oil. Other industrial applications include the processing of chemical products as formaldehyde and phenol and the desalination of seawater.

Distillation refers to the selective boiling and subsequent condensation of a component in a liquid mixture. It is a separation technique that can be used to either increase the concentration of a particular component in the mixture or to obtain pure components from the mixture. The process of distillation exploits the difference in the boiling points of the components in the liquid mixture by forcing one of them into a gaseous state. It is important to note that distillation is not a chemical reaction but it can be considered as a physical separation process.



Role of Raoult's Law and Dalton's Law

The temperature at which the vapor pressure of a liquid becomes equal to the pressure of the surrounding area is known as the **boiling point** of that liquid. At this temperature point, the liquid is converted into its vapor form via the formation of vapor bubbles at its bulk. For a mixture of liquids, the distillation process is dependent on Dalton's law and Raoult's law. As per **Raoult's law**, the partial pressure of a single liquid component in an ideal liquid mixture equals the product of the vapor pressure of the pure component and its mole fraction. According to **Dalton's law of partial pressures**, the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of all the constituent gases.

When a mixture of liquids is heated, the vapor pressure of the individual components increases, which in turn increases the total vapor pressure. Therefore, the mixture cannot have multiple boiling points at a given composition and pressure.

Types of Distillation

- Simple distillation

- Fractional distillation
- Steam distillation
- Vacuum distillation
- Air-sensitive vacuum distillation
- Short path distillation
- Zone distillation

3.5, Filtration, Filtration is technically defined as the process of separating suspended solid matter from a liquid, by causing the latter to pass through the pores of a membrane, called a filter. The process in which solid particles in a liquid or gaseous fluid are removed by the use of a filter medium that permits the fluid to pass through but retains the solid particles. Either the clarified fluid or the solid particles removed from the fluid may be the desired product. Other media, such as electricity, light, and sound, also can be filtered.

The basic requirements for filtration are: (1) a filter medium; (2) a fluid with suspended solids; (3) a driving force such as a pressure difference to cause fluid to flow; and (4) a mechanical device (the filter) that holds the filter medium, contains the fluid, and permits the application of force.

Filtration also plays a role in water treatment. The process of filtration can become a costly process when it comes to water treatment and water purification. But filters have enough advantages to be used as a mechanism of water treatment or purification.

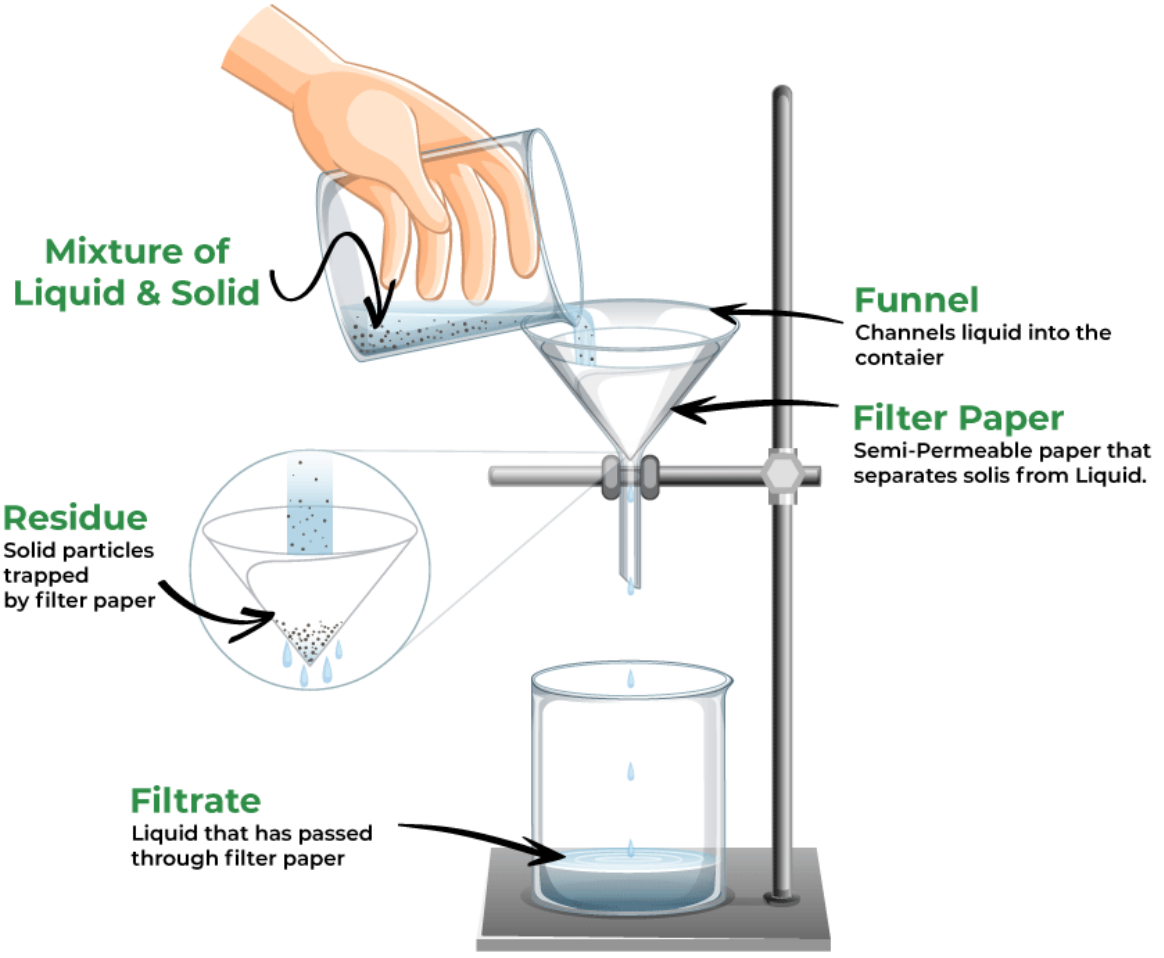
Filtration Methods

3.5.1, General Filtration: The most basic form of filtration is using gravity to filter a mixture. The mixture is poured from above onto a filter medium (e.g., filter paper) and gravity pulls the liquid down. The solid is left on the filter, while the liquid flows below it.

3.5.2, Vacuum Filtration: A Büchner flask and hose are used to create a vacuum to suck the fluid through the filter (usually with the aid of gravity). This greatly speeds the separation and can be used to dry the solid. A related technique uses a pump to form a pressure difference on both sides of the filter. Pump filters do not need to be vertical because gravity is not the source of the pressure difference on the sides of the filter.

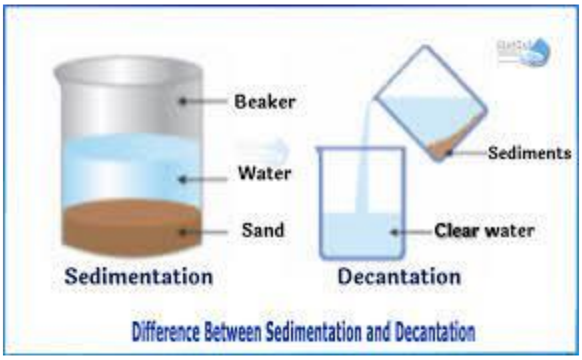
3.5.3, Cold Filtration: Cold filtration is used to quickly cool a solution, prompting the formation of small crystals. This is a method used when the solid is initially dissolved. A common method is to place the container with the solution in an ice bath prior to filtration.

3.5.4, Hot Filtration: In hot filtration, the solution, filter, and funnel are heated to minimize crystal formation during filtration. Stemless funnels are useful because there is less surface area for crystal growth. This method is used when crystals would clog the funnel or prevent crystallization of the second component in a mixture.



3.6, Sedimentation Process

Sedimentation is the process of allowing particles in suspension in water to settle out of the suspension under the effect of gravity. The particles that settle out from the suspension become sediment, and in water treatment is known as sludge. When a thick layer of sediment continues to settle, this is known as consolidation. When consolidation of sediment, or sludge, is assisted by mechanical means then this is known as thickening.Sedimentation is the process of separating small particles and sediments in water. This process happens naturally when water is still because gravity will pull the heavier sediments down to form a sludge layer. However, this action can be artificially stimulated in the water treatment process. This mechanical assistance is called thickening.



Uses of Sedimentation

Sedimentation also helps to determine the medical conditions of a person. Sedimentation rate of RBC’s is an example. The sedimentation rate is performed by measuring how long it takes red blood cells (RBCs) to settle in a test tube. As time passes, RBC’s start to separate from the other plasma contents, and they settle down at the bottom and serum will be formed above. The sedimentation rate or the ESR (erythrocyte sedimentation rate) is measured simply by recording how far the top of the Red Blood Cell layer has fallen (in millimetres) from the top of the serum layer in one hour.

Water treatment plants use the method of sedimentation to filter out unwanted particles from unclean water. Filtering through several layers of sand and soil, allowing certain sizes of particles to pass through.

A separatory funnel is used to separate immiscible liquids. When two immiscible liquids are placed in a separator funnel, two layers are seen. The denser solvent will be the bottom layer. Most halogenated solvents are denser than water, most non halogenated solvents are less dense than water. If you are not sure which layer is which, add a drop of water and see which layer it joins.

3.7, Magnetic separation is a process used to separate materials based on their magnetic properties. Essentially, magnetic materials can be separated from non-magnetic materials by using a magnetic field. The application of a magnetic field in the separation process is initiated by using a magnet or an **electromagnet**, which produces a magnetic field in the desired separation region. Within this field, materials possessing magnetic properties are drawn towards the magnet's source. This attraction is often due to the material's magnetic orientations of its atoms synchronize with the external magnetic field. Conversely, non-magnetic materials remain unaffected by the magnet, allowing for their easy separation as they don't adhere to the magnet. Following the separation, magnetic and non-magnetic materials are gathered. This separation process can be conducted in both dry and wet environments. There are various devices designed for this purpose, such as:

3.7.1, Magnetic Drum Separator: Used for the automatic separation of magnetic particles from raw materials.

3.7.2, Magnetic Roll Separator: Uses strong rare-earth magnets for the purification of products.

3.7.3, Magnetic Pulley: Often installed at the end of conveyor belts to extract metal contaminants.

Sample Question; Describe the types of compounds and the procedure of filtration?

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Chapter 4

Units of Measurements

Objectives.

This chapter relates various units to appropriate quantities for measurement. It shows that compound units can be produced by multiplying and by dividing the units associated with quantities and understand that the product of a unit and a value is constant for a measurement.

Measurements and Units

Measurements provide the macroscopic information that is the basis of most of the hypotheses, theories, and laws that describe the behavior of matter and energy in both the macroscopic and microscopic domains of chemistry. Every measurement provides three kinds of information: a number (quantitative observation), a unit (describes how it was measured), and the degree of reliability (uncertainty of the measurement). While the number and unit are explicitly represented when a quantity is written, the uncertainty is an aspect of the measurement result. The number in the measurement can be represented in different ways, including decimal form and scientific notation. For example, the maximum takeoff weight of a Boeing 777-200ER airliner is 298,000 kilograms, which can also be written as 2.98×10^5 kg. The mass of the average mosquito is about 0.0000025 kilograms, which can be written as 2.5×10^{-6} kg.

4.1, Units, such as liters, pounds, and centimeters, are standards of comparison for measurements. When we buy a 2-liter bottle of a soft drink, we expect that the volume of the drink was measured, so it is two times larger than the volume that everyone agrees to be 1 liter. Without units, a number can be meaningless, confusing, or possibly life threatening. Suppose a doctor prescribes phenobarbital to control a patient’s seizures and states a dosage of “100” without specifying units. Not only will this be confusing to the medical professional giving the dose, but the consequences can be dire: 100 mg given three times per day can be effective as an anticonvulsant, but a single dose of 100 g is more than 10 times the lethal amount.

We usually report the results of scientific measurements in SI units, an updated version of the metric system, using the units listed in Table 1. Other units can be derived from these base units. The standards for these units are fixed by international agreement, and they are called the **International System of Units** or **SI Units** (from the French, *Le Système International d’Unités*).

Table: Base Units of the SI System

Property Measured	**Name of Unit**	**Symbol of Unit**
Length	Meter	M
mass	Kilogram	Kg
time	Second	S
temperature	Kelvin	K
electric current	Ampere	A
amount of substance	Mole	Mol
luminous intensity	Candela	Cd

Sometimes we use units that are fractions or multiples of a base unit. these fractions or multiples are always powers of 10. Fractional or multiple SI units are named using a prefix and the name of the base unit. For example, a length of 1000 meters is also called a kilometer because the prefix *kilo* means “one thousand,” which in scientific notation is 10^3 (1 kilometer = 1000 m = 10^3 m).

SI also provides a series of prefixes that can be attached to the units, creating units that are larger or smaller by powers of 10. Common prefixes and their multiplicative factors are listed in Table. The base unit *kilogram* is a combination of a prefix, kilo- meaning 1,000 ×, and a unit of mass, the gram.) Some prefixes create a multiple of the original unit: 1 kilogram equals 1,000 grams, and 1 megameter equals 1,000,000 meters. Other prefixes create a fraction of the original unit. Thus, 1-centimeter equals 1/100 of a meter, 1millimeter (ml) equals 1/1,000 of a meter, 1 microgram equals 1/1,000,000 of a gram, and so forth.

Table: Prefixes Used with SI Units

Prefix	**Abbreviation**	**Multiplicative Factor**	**Multiplicative Factor in Scientific Notation**
giga-	G	1,000,000,000 ×	10^9 ×
mega-	M	1,000,000 ×	10^6 ×
kilo-	K	1,000 ×	10^3 ×
deca-	D	10 ×	10^1 ×
deci-	D	1/10 ×	10^{-1} ×
centi-	C	1/100 ×	10^{-2} ×
milli-	M	1/1,000 ×	10^{-3} ×
micro-	µ*	1/1,000,000 ×	10^{-6} ×
nano-	N	1/1,000,000,000 ×	10^{-9} ×

*The letter µ is the Greek lowercase letter for *m* and is called “mu,” which is pronounced “myoo.”

4.2, SI Base Units

There are several SI units used in physics that are used to express the different quantities. The quantities can be classified into two groups i.e. ***base units*** and ***derived units.*** These are the fundamental units and are considered as the building blocks of the system. All the other units are derived from the SI Base units. One of the examples is that the SI unit of mass is ***kilogram.***

There are ***7 SI base units.*** The seven units along with their SI unit and symbol are given below:

4.2.1, Unit of length, meter (m): Meter is the SI unit of length and is defined by taking the fixed value of the speed of light in vacuum. It is expressed as $m.s^{-1}$. It is defined as the distance light in a vacuum travel in 1/299,792,458 of a second. A meter is about 3 inches longer than a yard. one meter is about 39.37 inches or 1.094 yards. Longer distances are often reported in kilometres (1 km = 1000 m = 10^3 m), whereas shorter distances can be reported in centimetres (1 cm = 0.01 m = 10^{-2} m) or millimetres (1 mm = 0.001 m= 10^{-3} m).

4.2.2, Unit of mass, kilogram (kg): Kilogram is the SI unit of mass and is defined by taking the fixed value of the Planck constant. It is expressed as $kg.m^2.s^{-1}$. A kilogram was originally defined as the mass of a liter of water (a cube of water with an edge length of exactly 0.1 meter). It is now defined by a certain cylinder of platinum-iridium alloy. Any object with the same mass as this cylinder is said to have a mass of 1 kilogram. One kilogram is about 2.2 pounds. The gram (g) is exactly equal to 1/1000 of the mass of the kilogram (10^{-3} kg).

4.2.3, Unit of time, second (s): Second is the SI unit of time and is defined by taking the fixed value of Cesium frequency. It is expressed as s^1. Small- and large-time intervals can be expressed with the appropriate prefixes; for example, 3 microseconds = 0.000003 s = 3×10^{-6} and 5 Mega seconds = 5,000,000 s = 5×10^6 s. Alternatively, hours, days, and years can be used.

4.2.4, Unit of electric current, ampere (A): Ampere is the SI unit of electric current and is defined by taking the fixed value of the elementary charge.

4.2.5, Unit of thermodynamic temperature, Kelvin (K): Kelvin is the SI unit of thermodynamic temperature and is defined by taking the fixed value of Boltzmann constant $k = 1.380649\times10^{-23}$. The degree Celsius (°C) is also allowed in the SI system, with both the word “degree” and the degree symbol used for Celsius measurements. Celsius degrees are the same magnitude as those of kelvin, but the two scales place their zeros in different places. Water freezes at 273.15 K (0 °C) and boils at 373.15 K (100 °C).

4.2.6, Unit of luminous intensity, candela (cd): Candela is the SI unit of luminous intensity and is defined by the fixed value of the luminous efficacy.

4.2.7, Unit of the amount of substance; mole (mol): Mole is the SI unit of the amount of substance and is defined by the fixed value of Avogadro constant N_A. One mole contains $6.02214076 \times 10^{23}$ elementary entities and is expressed as mol^{-1}.

4.3, Derived SI Units, SI derived units are units of measurement derived from the seven SI base units specified by the International System of Units (SI). They can be expressed as a product (or ratio) of one or more of the base units, possibly scaled by an appropriate power of exponentiation. The derived units are unlimited as they are formed by different operations on the base units. For derived units, the dimensions are expressed in terms of the dimensions of the base units. The derived units might also be expressed with the combination of base and derived units.

4.4, Volume

Volume is the measure of the amount of space occupied by an object. The standard SI unit of volume is defined by the base unit of length. The standard volume is a cubic meter (m^3), a cube with an edge length of exactly one meter. A more commonly used unit of volume is derived from the decimetre (0.1 m, or 10 cm). A cube with edge lengths of exactly one decimeter contains a volume of one cubic decimeter (dm^3). A liter (L) is the more common name for the cubic decimeter. One liter is about 1.06 quarts. A cubic centimeter (cm^3) is the volume of a cube with an edge length of exactly one centimeter. The abbreviation **cc** (for **c**ubic **c**entimeter) is often used by health professionals. A cubic centimeter is also called a milliliter (mL) and is 1/1000 of a liter.

4.5, The Celsius Scale

The Celsius scale of the metric system is named after Swedish astronomer Anders **Celsius** (1701-1744). The Celsius scale sets the freezing point and boiling point of water at 0^oC and 100^oC, respectively. The distance between those two points is divided into 100 equal intervals, each of which is one degree. Another term sometimes used for the Celsius scale is "centigrade" because there are 100 degrees between the freezing and boiling points of water on this scale. However, the preferred term is "Celsius".

4.6, The Kelvin Scale

It is based on molecular motion, with the temperature of 0K0K, also known as absolute zero, being the point where all molecular motion ceases. The freezing point of water on the Kelvin scale is 273.15K273.15K, while the boiling point is 373.15K373.15K. Notice that there is no "degree" used in the temperature designation.

Converting between Scales

The Kelvin is the same size as the Celsius degree, so measurements are easily converted from one to the other. The freezing point of water is 0°C = 273.15 K; the boiling point of water is 100°C = 373.15 K. The Kelvin and Celsius scales are related as follows:

$K = °C + 273.15$

$°C = 5 \div 9 \times (°F - 32)$

$°F = 9 \div 5 \times (°C) + 32$

There is only one temperature for which the numerical value is the same on both the Fahrenheit and Celsius scales: −40°C = −40°F.s

Each measurement has an amount, a unit for comparison, and an uncertainty. Measurements can be represented in either decimal or scientific notation Scientists primarily use the SI (International System) or metric systems. We use base SI units such as meters, seconds, and kilograms, as well as derived units, such as liters (for volume) and g/cm^3 (for density). In many cases, we find it convenient to use unit prefixes that yield fractional and multiple units, such as microseconds (10^{-6} seconds) and megahertz (10^6 hertz), respectively.

Sample Question; describe the units of measurements, Mass , Temperature?

What are SI units of Measurement?

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Chapter 5

Solutions

Objectives

This chapter will help students distinguish between heterogeneous and homogeneous mixtures, different solute and solvent combinations, compare the properties of suspensions and solutions. It helps in comparing the effects of temperature and pressure on solubility. the mass of solute and volume of solvent, and the concentration of a solution, and to determine the amount of solute in a given amount of solution.

5.1, Solutions

Solutions have two components; one is solvent and the other is solute. Aqueous solutions are those where the solvent is water. Sugar in water, carbon dioxide in water, etc. are examples. Non-aqueous solutions do not use water as a solvent. The component that dissolves the other component is called the solvent. The component dissolved in the solvent is called solute.

Generally solvent is present in a major proportion compared to the solute. The amount of solute is lesser than the solvent. The solute and solvent can be in any state of matter i.e. solid, liquid, or gas. Solutions that are in the liquid state consist of a solid, liquid, or gas dissolved in a liquid solvent. Alloys and air are examples of solid and gaseous solutions, respectively.

Examples

The following examples illustrate solvent and solute in some solutions.

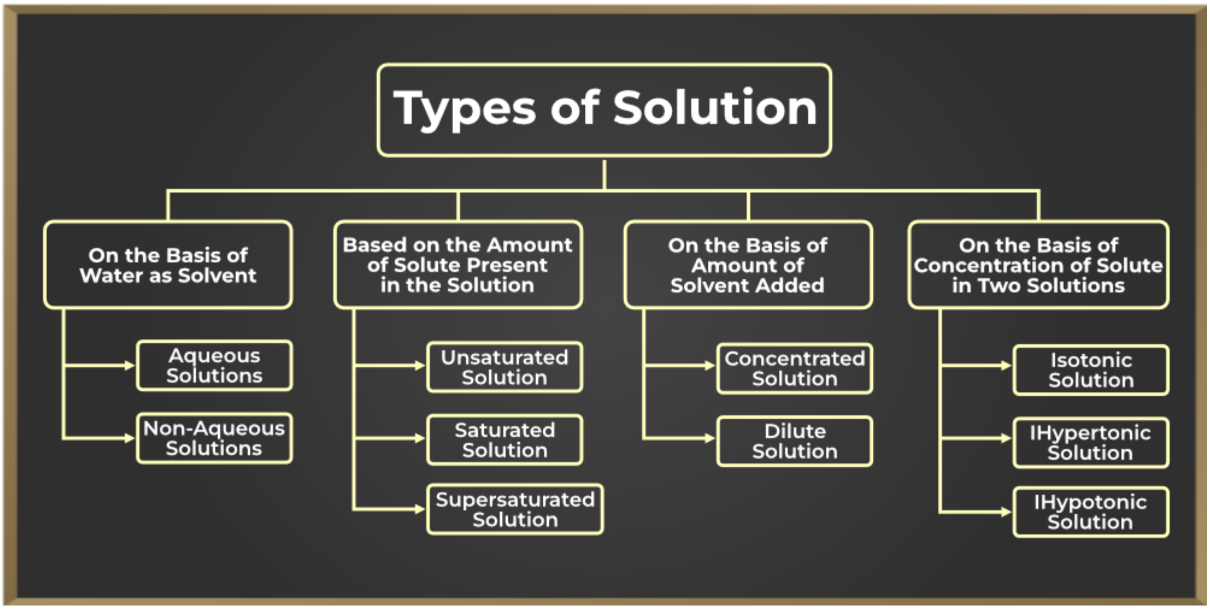
5.1.1 **Air** is a homogeneous mixture of gases. Here both the solvent and the solute are gases.

5.1.2 **Sugar syrup** is a solution where sugar is dissolved in water using heat. Here, water is the solvent and sugar is the solute.

5.1.3 **Tincture of iodine**, a mixture of iodine in alcohol. Iodine is the solute whereas alcohol is the solvent.

5.2, Types of Solution

Liquid solutions, such as sugar in water, are the most common kind, but some solutions are gases or solids.



Any state of matter (solid, liquid, or gas) can act both as a solute and as a solvent.

5.2.1, Aqueous Solutions; Aqueous Solutions contain water as the solvent. Different solutes can be dissolved in water to form such solutions, such as salt water, sugar water or carbon dioxide in water.

5.2.2 Non-Aqueous Solutions; Non-Aqueous Solutions do not contain water as the solvent. The solvent could be other liquids such as ether, petrol, carbon tetrachloride, etc. Some examples of non-aqueous solutions are sulphur in carbon disulphide, naphthalene in benzene, etc.

5.2.3 Saturated Solutions; A solvent can dissolve some particular types of solutes in it. The maximum amount of solute that can be dissolved in a solvent at a specified temperature can be termed a saturated solution. A solution cannot dissolve any more solute further upon reaching saturation. The undissolved substances remain at the bottom. The point at which the solute stops dissolving in the solvent is termed the saturation point.

5.2.4 Unsaturated Solutions; The amount of solute that is contained in lesser amounts than the maximum value, that is before the solution reaches the saturation level is called an unsaturated solution. No remaining substances leave at the bottom, that is, all the solute is dissolved in the solvent. An unsaturated solution is basically a chemical solution which has a solute concentration lesser than its corresponding equilibrium solubility.

5.2.5 Supersaturated Solutions; The amount of solute contained in the solution exceeds the maximum amount of solute. The solution has already reached and crossed the saturation point. The solute is dissolved into the solution forcefully by raising the temperature or pressure of the solution. The solute particles on further dissolve, crystal out in the bottom of the container by the method called crystallization.

5.2.6 Concentrated Solutions; A concentrated solution contains large quantities of solute in the given solvent to form a solution. Some examples of concentrated solutions are mango juice, brine solution or dark colour tea.

5.2.7 Dilute Solutions; A dilute solution contains small quantities of solute in the given large quantity of solvent to form a solution. Some examples of dilute solutions are salt solutions or light color tea.

5.2.8 Isotonic Solution; The solution contained in the beaker has a higher concentration of solute in it. As a result of this, the water emerges from the cell and into the solution contained in the beaker.

5.2.9 Hypertonic Solution; Hypertonic solutions contain the same concentration of solute in them. The water moves across the cell from the solution in the beaker in both directions.

5.2.10 Hypotonic Solution; There is a lower concentration of solute in the solution contained in the beaker. As a result, water goes into the cell which causes the cells to swell up and eventually burst.

5.3, Properties of Solutions

Properties of the solutions are as follows:

5.3.1 A solution is a homogeneous mixture.

5.3.2 The constituent particles of a solution are smaller than 10^{-9} metres in diameter.

5.3.3 Constituent particles of a solution cannot be seen by naked eyes.

5.3.4 Solutions do not scatter a beam of light passing through it. So, the path of the light beam is not visible in solutions.

5.3.5. Solute particles cannot be separated by filtration.

5.3.6 Solute or solvent particles do not settle down when left undisturbed.

5.3.7 Solutions are stable at a given temperature.

5.4, Solubility

The maximum amount of solute that can be dissolved in a known quantity of solvent at a certain temperature is called solubility. The factors affecting solubility vary on the state of the solute:

Liquids in Liquids
Solids in Liquids
Gases In Liquids

Factors Affecting Solubility:

The solubility of a substance depends on the physical and chemical properties of that substance. In addition to this, there are a few conditions which can manipulate it. Temperature, pressure and the type of bond and forces between the particles are few among them.

5.4.1 Temperature:

By changing the temperature, we can increase the soluble property of a solute. Generally, water dissolves solutes at 20° C or 100° C. Sparingly soluble solid or liquid substances can be dissolved completely by increasing the temperature. But in the case of gaseous substance, temperature inversely influences solubility i.e. as the temperature increases gases expand and escapes from their solvent.

5.4.2 Forces and Bonds:

The type of intermolecular forces and bonds vary among each molecule. The chances of solubility between two unlike substances are more challengeable than the like substances. For example, water is a polar solvent where a polar solute like ethanol is easily soluble.

5.4.3 Pressure:

Gaseous substances are much influenced than solids and liquids by pressure. When the partial pressure of gas increases, the chance of its solubility is also increased. A soda bottle is an example of where CO_2 is bottled under high pressure.

5.4.4 Solubility of Liquids in Liquids

Solubility is the new bond formation between the solute molecules and solvent molecules. In terms of quantity, solubility is the maximum concentration of solute that dissolves in a known concentration of solvent at a given temperature. Solutes are categorized into highly soluble, sparingly soluble or insoluble. If a concentration of 0.1 g or more of a solute can be dissolved in a 100ml solvent, it is said to be soluble. While a concentration below 0.1 g is dissolved in the solvent it is said to be sparingly soluble. Thus, it is said that solubility is a quantitative expression and is expressed by the unit gram/liter (g/l).

5.4.5 Solubility of Solids in Liquids

Let us understand the process by which a solid dissolves in a solvent. Once a solid solute is added to a solvent, the solute particles dissolve in the solvent and this process is known as dissolution. Solute particles in the solution collide with each other and some of these particles get separated out of the solution, this process is called crystallization.

A state of dynamic equilibrium is established between these two processes and at this point, the number of solute molecules entering the solution becomes equal to the number of particles leaving the solution. As a result, the concentration of the solute in the solution will remain constant at a given temperature and pressure.

5.4.6 Solubility of Gases In Liquids

The gas solubility in liquids is greatly affected by temperature and pressure as well as the nature of the solute and the solvent.

There are many gases that readily dissolve in water, while there are gases that do not dissolve in water under normal conditions. Oxygen is only sparingly soluble in water while HCl or ammonia readily dissolves in water. Henry’s Law gives a quantitative relation between pressure and gas solubility in a liquid. It states that:

The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution.

$P = K_H x$

Where, p = partial pressure of the gas

x = mole fraction of the gas solution

K_H = Henry’s law constant

5.5 Concentration of a Solution

The amount of solute in a given solution is called the concentration of a solution. The proportion of solute and solvent in solutions is not even. Depending upon the proportion of solute, a solution can be:

- *Diluted*
- *Concentrated*
- *Saturated*

$$\text{The concentration of solution} = \frac{\text{Amount of solute}}{\text{Amount of solution}}$$

5.5.1 Molarity (Molar Concentration):

Molarity (M) is defined as a number of moles of solute dissolved in one litre (or one cubic decimetre) of the solution. The unit of molarity is mol L^{-1} 0r mol dm^{-3} or M.

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres or } dm^3}$$

Number of moles of a substance can be found using the formula

$$\text{Number of moles} = \frac{\text{Given mass of a substance}}{\text{Molecular mass of the substance}}$$

Molarity changes with temperature because volume changes with temperature.

Molarity can be expressed as

- Decimolar = M/10 (0.1 M)
- Semimolar = M/2 (0.5 M)
- Pentimolar = M/5 (0.2 M)
- Centimolar = M/100 (0.01 M)
- milimolar = M/1000 (0.001 M).

5.5.2 Molality:

Molality (m) is defined as a number of moles of solute expressed in kg dissolved in one kg of solvent, Molality has no unit.

Molality is a better way of expressing concentration than molarity because there is no term of volume of solvent is involved. The volume of the solvent depends on the temperature of the solvent. Thus, there is no effect of the change of temperature on the molality.

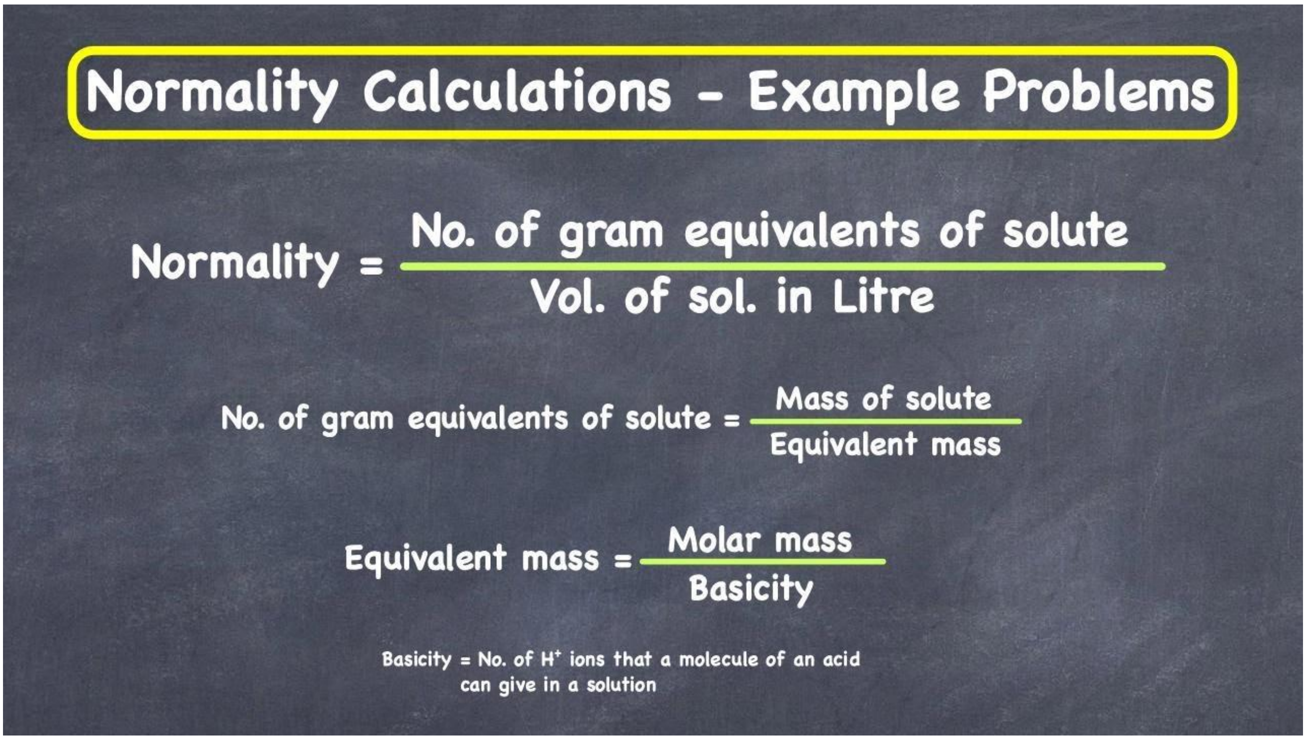
$$\text{Molality} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in Kg}}$$

Molality is related to solubility as

$$\text{Molality} = \frac{\text{Solubility} \times 10}{\text{Molecular mass of solute}}$$

5.5.3 Normality:

Normality (N) is defined as gram-equivalent of solute dissolved in one litre (or one cubic decimetre) of the solution, Unit of molarity is N.



Normality Calculations - Example Problems

$$\text{Normality} = \frac{\text{No. of gram equivalents of solute}}{\text{Vol. of sol. in Litre}}$$

$$\text{No. of gram equivalents of solute} = \frac{\text{Mass of solute}}{\text{Equivalent mass}}$$

$$\text{Equivalent mass} = \frac{\text{Molar mass}}{\text{Basicity}}$$

Basicity = No. of H^+ ions that a molecule of an acid can give in a solution

5.5.4 Formality:

Formality is the number of formula mass in gram present per litre of a solution.

If the formula mass of solute is equal to its molar mass, then the formality is equal to molarity. The formality of a solution depends on temperature. This concept is used in the case of ionic substances.

A mole of an ionic compound is called formole and its molarity is called formality. Thus, the formality of a solution may be defined as a number of moles of ionic solute present in one litre of the solution.

Sample Question; What are the types of a solution? Describe factors affecting solubility?

References;

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2 Vemula VR, Lagishetty V, Lingala S. Solubility enhancement techniques. *International Journal of Pharmaceutical Sciences Review and Research.* 2010;5(1):41–51.

3; Narinder Singh, Amar paul Singh, January 2021, International Journal of Pharmaceutical Chemistry and Analysis 7(4):166-171. Solubility: An overview

Chapter 6
Acids, Bases and Salts
Objectives

This chapter introduces students to tell the difference between an acid and a base. Students will learn to define and identify both types of substances and explain how they differ. They will also discover why this type of information is important to know.

Acids and bases are important to many chemical processes: maintaining a stable internal environment in the human body, baking a delicious cake, or determining whether a lake can support aquatic life. Reactions involving acids and bases can be described through the transfer of protons – single H^+ ions.

6.1 Acids

Acids are characterized by their ability to donate hydrogen ions (H+) when dissolved in water. An acid is a substance whose water solution tastes sour, turns blue litmus red and neutralizes bases. According to Liebig, acids are compounds which contain hydrogen that can be replaced by metals. Acids have pH of less than 7.

Acids react with bases to form salts and water. Acids can be found naturally in many foods and beverages, including citrus fruits, vinegar, and fermented products, and they are also used in various industrial processes.
Acids can be classified into two categories:

6.1.1 organic acids, which are derived from living organisms,

6.1.2 inorganic acids, which are derived from non-living sources.

6.2 Chemical *Properties of Acid*

Acid has various chemical properties few of the following chemical properties of acids include,

6.3 Reaction of acids with metals*:* *When an acid reacts with a metal, it produces hydrogen gas and the corresponding salt.*

Metal + Acid → Salt + Hydrogen

When hydrochloride acid combines with zinc metal, it produces hydrogen gas and zinc chloride.

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

When acids react with metal carbonates, they produce carbon dioxide gas and salts as well as water.

Metal carbonate + Acid → Salt + Carbon dioxide + Water

When hydrochloric acid combines with sodium carbonate, it produces carbon dioxide gas, sodium chloride, and water.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

Reaction of acid with hydrogen carbonates (bicarbonates): When acids react with metal hydrogen carbonates, they produce carbon dioxide gas, salt, and water.

Acid + Metal hydrogen carbonate → Salt + Carbon dioxide + Water

Sulfuric acid gives sodium sulfate, Carbon dioxide gas and water when it reacts with sodium bicarbonate.

$2NaHCO_3 + H_2SO_4 \rightarrow NaCl + CO_2 + H_2O$

6.4 Types of Acids

On the basis of thei Occurrence acid are subdivided into two categories

- Natural Acids
- Mineral Acids

Natural Acids;

Natural acids also known as organic acids, are acids derived from natural sources. For example, Methanoic acid ($HCOOH$), Acetic acid (CH_3COOH), Oxalic acid ($C_2H_2O_4$), etc.

Mineral Acids

These are created from minerals. Inorganic acids, man-made acids, and synthetic acids are all examples of Mineral Acids. For example, Hydrochloric acid (HCl), Sulphuric acid (H_2SO_4), Nitric acid (HNO_3), Carbonic acid (H_2CO_3), Phosphoric acid (H_3PO_4), etc.

On the basis of Concentration

On the basis of Concentration, acids are categorized into two categories

- Strong Acids
- Weak Acids

Strong Acids

A strong Acid is an acid which completely ionizes in water and produces (H^+). For example, Hydrochloric acid (HCl), Sulphuric acid (H_2SO_4), Nitric acid (HNO_3) etc.

Weak Acids

A weak acid is partially ionized in water, creating a tiny amount of hydrogen ions (H^+). For example, Acetic acid (CH_3COOH), Carbonic acid (H_2CO_3) etc.

6.5 Bases

A compound that can neutralize an acid and produces salt and hydroxide(($OH^–$). Bases turn red litmus paper blue while the blue litmus paper stays blue. They taste bitter and also feel soapy to the touch. Aqueous solutions of the bases can conduct electricity. Some common examples are;

copper oxide, sodium hydroxide sodium bicarbonate (used in cooking, and household bleach).

6.6 Chemical Properties of Base

few of the following chemical properties of bases are,

6.6.1 Reaction of Base with Metals:

When bases react with metal, salt and hydrogen gas is produced.

Alkali + Metal → Salt + Hydrogen

When sodium hydroxide interacts with aluminium metal, sodium aluminate and hydrogen gas are generated.

$$2NaOH + 2Al + 2H_2O \rightarrow 2NaAlO_2 + 2H_2$$

6.6.2 Reaction of Non-Metallic Oxides with Base:

Salt and water are formed when non -metallic oxides react with a base.

Non-metallic oxide + Base → Salt + Water

When calcium hydroxide reacts with carbon dioxide calcium carbonate is formed along with water.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

6.6.3 Reaction of Bases with Ammonium Salts:

Ammonia is produced when alkalis react with ammonium salts.

Alkali + Ammonium salt → Salt + Water + Ammonia

When calcium hydroxide reacts with ammonium chloride, calcium chloride, water, and ammonia are produced.

$$Ca(OH)_2 + NH_4Cl \rightarrow CaCl_2 + H_2O + NH_3$$

6.7 Types of Bases

Acidity, concentration, and degree of ionization are three variables that can be used to classify bases.

Types of Bases Based on Acidity

The number of hydroxyl ions presents determines acidity in bases. Based on acidity, bases are classified into three categories:

- Monoacidic
- Diacidic
- Triacidic

6.7.1 Monoacidic bases are those that contain only one hydroxyl ion and interact with only one hydrogen ion. Mono-acidic bases include NaOH, KOH, and others.

6.7.2 Diacidic base is a base with two hydroxyl ions that interact with two hydrogen ions. Ca (OH)2, Mg (OH)2, and other di-acidic bases are examples.

6.7.3 Triacidic a type of base that comprises three hydroxyl ions and three hydrogen ions. And include Al (OH)3, Fe (OH)2, and others.

6.8 Types of Bases Based on their Concentration

Based on their concentration in an aqueous solution, bases are divided into two categories:

- Concentrated
- Diluted

Concentrated**:** The concentration of base is higher in the solution in their aqueous solution. Concentrated NaOH solution, for example.

Diluted**:** These types of bases have a lower concentration of base in their aqueous solution. For instance, dilute NaOH, dilute KOH, and so on.

6.9 Types of Bases Based on their Degree of Ionization

When bases are dissolved in water, it produces a certain quantity of hydroxyl ions. The degree of ionization distinguishes two types of bases.

- Strong Base
- Weak Base

Strong Base**:** A strong base is one that dissociates entirely or to a large extent in water. For example, NaOH, KOH, and strong bases.

Weak Base**:** A weak base is one that does not dissolve entirely or only dissociates to a very little level. For example, NH4OH, and others are weak bases.

6.10 Alkali

Bases that are easily dissolved in water are called Alkali, in other words, water soluble bases are called Alkali. For example, NaOH is an alkali as it dissolves in water forming Na+ and OH– ions.

The three most important modern concepts of acids and bases are**:**

Arrhenius Concept

According to this concept, Substances which produce H^+ ions when dissolved in water are called acids while those which ionize in water to produce $OH^–$ ions are called bases.

$HA \rightarrow H^+ + A^–$ (Acid)

$BOH \rightarrow B^+ + OH^–$ (Base)

Arrhenius proposed that reactions are acidic if they dissociate in aqueous solution to form hydrogen ions (H^+) and bases if they form hydroxide ($OH^–$) ions in aqueous solution.

Limitations of Arrhenius Concept

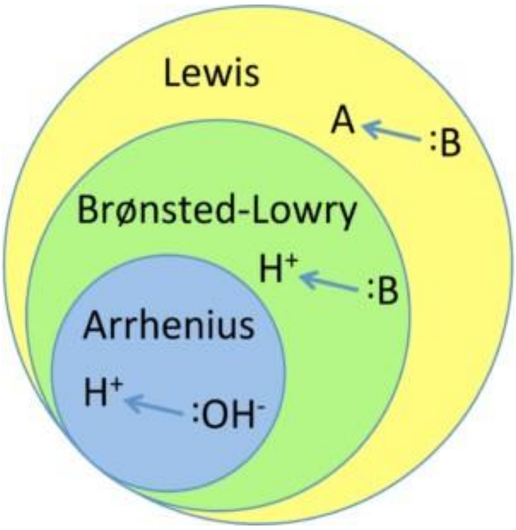
The presence of water is absolutely necessary for acids and bases. Dry HCl can’t act as an acid. HCl acts as an acid in water only and not in any other solvent.

The concept does not explain the acidic and basic character of substances in non-aqueous solvents.

The neutralization process is only possible for reactions which can occur in aqueous solutions, although reactions involving salt formation can occur in the absence of a solvent.

Bronsted-Lowry Concept

.According to them, an acid is defined as any hydrogen-containing material (molecule, anion or cation) which can donate a proton to other substance and a base is any substance (molecule, cation or anion) that can accept a proton from any other substance. Therefore, acids are proton donors whereas bases are proton acceptors.



Conjugate Acid-Base Pairs

Consider a reaction

$Acid_1 + Base_2 \rightarrow Acid_2 + Base_1$

$H_2O + HCl \Leftrightarrow H_3O^+ + Cl^–$

In this reaction, HCl donates a proton to H_2O and is, therefore an acid. Water, on the other hand, accepts a proton from HCl, and is, therefore, a base. In the reverse reaction, the H_3O^+ ions donate a proton to Cl– ion, hence H_3O^+, an ion is an acid. $Cl^–$ ion, because it accepts a proton from H3O+ ion, is a base.

Acid-base pairs in which the members of the reaction can be formed from each other by gaining or losing protons are called conjugate acid-base pairs.

Limitations of Bronsted Lowry Concept

- Bronsted Lowry could not explain the reaction occurring in non-protonic solvent like $COCl_3$, SO_2, N_2O_4, etc.
- It cannot explain the reactions between acidic oxides and the basic oxides which can easily take place in the absence of solvent as well e.g. (No proton transfer)
- Substances like BF_3, $AlCl_3$, etc, do not contain hydrogen which means they can’t donate a proton, still they behave as acids.

Lewis Concept

According to this theory bases donate pairs of electrons and acids accept pairs of electrons. Thus, it can be said that a Lewis acid is electron-pair acceptor. Oxidation-reduction reactions take place on a transfer of electrons from one atom to another, with a net change in the oxidation number of one or more atoms. There is no change in the oxidation numbers of any atoms. Either an electron is transferred from one atom to another, or the atoms come together to share a pair of electrons.

$Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O$ (Aluminium hydroxide is acting as a base)

$Al(OH)_3 + OH^- \rightarrow Al(OH)^{4-}$ (Aluminium hydroxide is acting as an acid)

When Aluminium hydroxide accepts protons, it acts as a base. When it accepts electrons, it acts as an acid. This theory also explains why non-metal oxides such as carbon dioxide dissolve in H_2O to form acids, such as carbonic acid H_2CO_3.

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

Limitations of Lewis Concept

Lewis's concept gave a generalized idea including all coordination reactions and compounds. This is not always true.
An idea about the relative strength of acids and bases is not provided by Lewis's concept.
Lewis's concept is not in line with the acid-base reaction concentration.

6.11 Salts

When an acid and a base react, they generate salts, which are ionic substances. Salts do not have an electrical charge. Apart from sodium chloride, other common salts are sodium nitrate, barium sulfate etc. Sodium chloride or common salt is a product of the reaction between the hydrochloric acid (acid) and sodium hydroxide (base). Solid sodium chloride is made of a cluster of positively charged sodium ions and negatively charged chloride ions held together by electrostatic forces.

Physical Properties of Salt
some of physical properties of salts are,

- The bulk of the salts are crystalline.
- Salts that are transparent or opaque are available.
- The salts are soluble in water.
- Salt solutions, in their molten state, also transmit electricity.
- The taste of salts can be salty, sour, sweet, bitter, or savoury.
- There is no odour to neutral salts.

- Because it contains ions, salt water is an excellent conductor of electricity.
- Electrostatic attraction holds the ions together, and a chemical bond is established between them.

Types of Salts

Some of the important categories of salts are given below

- Acidic Salts
- Basic or Alkali Salts
- Neutral Saltss
-

6.11.1 Acidic Salt

A class of salts that produce an acidic solution after being dissolved in a solvent. Its formation as a substance has a greater electrical conductivity than that of the pure solvent. An acidic solution formed by acid salt is made during partial neutralization of diprotic or polyprotic acids. A partial neutralisation of a diprotic or polyprotic acid produces an acidic salt. These salts contain H+ cations or strong cations in their aqueous solution. The ionizable H+ makes up the majority of the ions. Some examples of acidic salts are $NaHSO4$, $KH2PO4$ etc. These salts are formed by the neutralization of strong acids and weak bases.

Ammonium Chloride

Ammonium chloride is formed when hydrochloric acid (a strong acid) interacts with ammonium hydroxide (a weak base).

$NH4OH + HCl \rightarrow NH4Cl + H2O$

Ammonium Sulphate

Ammonium sulphate is formed when ammonium hydroxide (a weak base) reacts with sulphuric acid (a strong acid).

$2NH4OH + H2SO4 \rightarrow (NH4)2SO4 + 2H2O$

6.11.2 Basic or Alkali Salt

A basic salt is formed when a strong base reacts with a weak acid to partially neutralise it. When they are hydrolyzed, they decompose into a basic solution. This is because when a basic salt is hydrolyzed, it produces the conjugate base of a weak acid in the solution. e.g. Sodium Carbonate ($Na2CO3$), Sodium Acetate ($CH3COONa$).

Sodium Carbonate

Sodium carbonate is formed when sodium hydroxide (a strong base) reacts with carbonic acid (a weak acid)

$H2CO3 + 2$

$NaOH$ → $Na_2CO_3 + H_2O$

Sodium Acetate

Sodium acetate is formed when a strongly basic, sodium hydroxide (a strong base), reacts with acetic acid (a weak acid)

$CH_3COOH + NaOH$ → $CH_3COONa + H_2O$

6.11.3 Neutral Salts

Salts generated by the reaction of a strong acid with a strong base are neutral in nature. The pH of these salts is 7, which is considered neutral. Potassium Chloride, Sodium Chloride, and others are examples of neutral salts.

Sodium Chloride is formed when hydrochloric acid (a strong acid) mixes with sodium hydroxide (a strong base).
$NaOH + HCl$ → $NaCl + H_2O$

Salts can also be categorised into other categories which include,

- Mixed Salts
- Double Salt
-

6.11.4 Double Salt

Salts with more than one cation or anion are known as double salts. They're created by mixing two different salts that crystallised in the same ionic lattice. e.g. Potassium Sodium Tartrate ($KNaC_4H_4O_6.4H_2O$) also known as Rochelle salt.

6.11.5 Mixed Salts;

Salts which are produced by mixing two salts, which generally share a common cation or anion, are called mixed salts. e..g. Bleaching Powder $CaOCl_2$.

6.11.6 Formation of Acidic, Basic, and Neutral Salts

- When a strong acid reacts with a weak base, the base is unable to completely neutralize the acid. As a result acidic salt is formed.
- When a strong base is combined with a weak acid, the acid is unable to completely neutralize it. As a result a simple salt is formed.
- When an equal-strength acid and base react, they totally neutralise each other. A neutral salt is formed as a result of this process.

6.12 Strength of Acids and Base

The strength of an acid or a base is measured by the amount of H^+ ions or OH^- ions present in the aqueous solutions. Strong acids have a higher concentration of H+ ions per unit volume in their aqueous solution whereas weaker acids or bases have a lower concentration of H+ ions or OH^- per unit volume in their aqueous solutions.

An acid's strength is affected by the electronegativity of the conjugate base and the polarity of the acidic hydrogen. Strength refers to how readily the hydrogen cation (H^+) disassociates from the anion. Strong acids and bases dissociate entirely in aqueous solutions, whereas weak acids and bases dissociate partially into their conjugate ions. The strength of an acid or a base is measured by the amount of H+ ions or OH– ions present in their aqueous solution. The strength of Aicds and Bases can easily be measured using a pH scale.

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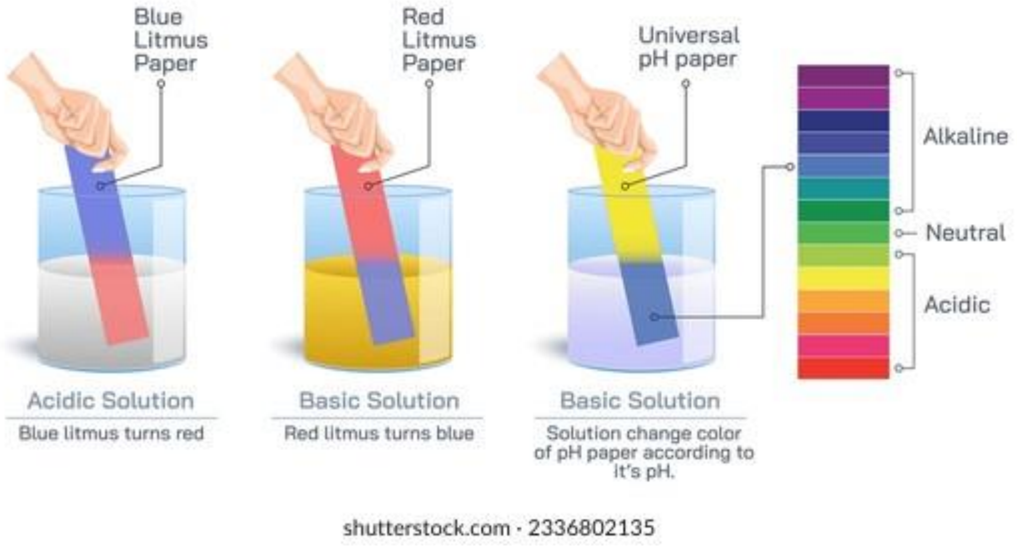
It is calculated using the formula,

$$pH = -\log[H+]$$

For an acid, pH ranges from 0 to 7 whereas for a base it ranges between 7 and 14. The lower the pH higher is the strength of the acid and the higher the pH higher the strength of the base.

6.13 Indicator

Indicators are chemical compounds which help to indicate the presence of an acid or a base in a chemical reaction. They possess different colors in acidic solutions and different colors in basic solutions. Indicators are made naturally by plants and animals or artificially. The image shows a litmus test of ids and bases.



Types of Indicators

Various types of indicators used are mentioned below,

- Natural Indicators**:** are derived from plants, animals or any living organism, examples, Red Cabbage, Litmus paper.
- Synthetic Indicators**:** these are made artificially in laboratories and factories are synthetic indicators, examples, are Phenopthelien, Methyl orange.
- Olfactory Indicators**:** Substances that have different smells in an acidic or basic medium are Olfactory Indicators, example onions, olives and others.

6.14 Titration

In titration, a solution of a known concentration, called a standard solution, is used to determine the concentration of another solution. For acid-base titrations, a standardized solution of base is slowly added to an acid of unknown concentration or the acid is added to the base. The acid-base reaction is a neutralization reaction, which forms a salt and water. When the moles of hydrogen ions in the acid are equal to the moles of hydroxyl ions added from the base, the solution reaches neutral pH.

To perform an acid-base titration, the standardized base is slowly added to a stirring flask of the unknown acid using a burette, which enables the measurement of volume and the dropwise addition of base. The pH of the solution is closely monitored throughout the titration using a pH indicator added to the acid. Typically, phenolphthalein is used as the solution remains colorless until it becomes basic, turning a light pink.

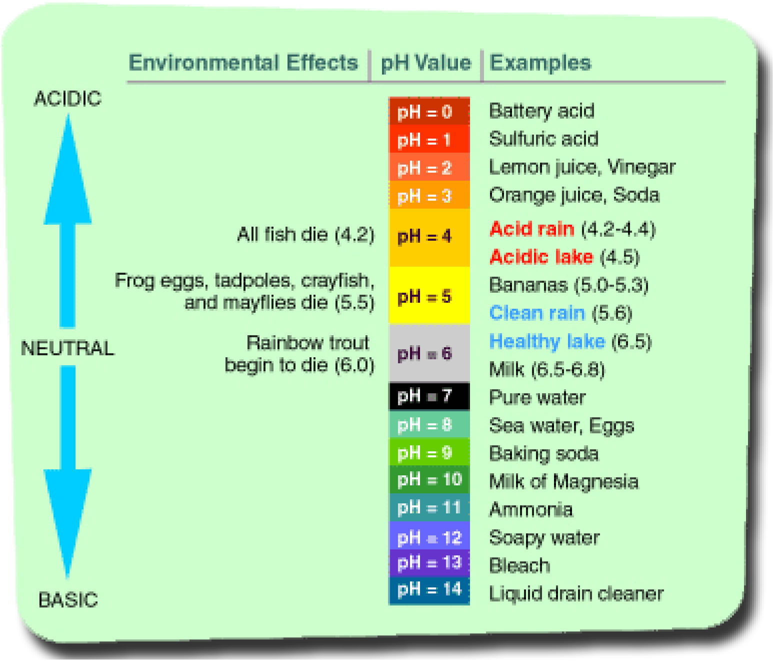
As the equivalence point is reached, (when the moles of hydrogen ions equal the moles of hydroxyl ions), the pH indicator temporarily changes color due to an excess of hydroxyl ions. When the flask is swirled, the pH indicator's acidic color returns. The titration is complete and has reached its endpoint when a tiny excess of hydroxyl ions changes the indicator permanently to its basic color.

The titration curve is a plot of the pH of a solution versus the volume of standardized base added. The equivalence point is located at the inflection point of the curve, and it is calculated as the second derivative of the titration curve.

If an acid is polyprotic, it will have multiple equivalence points, one for each hydrogen ion dissociation. The pH at the halfway point to the equivalence point for monoprotic acids, or between equivalence points in the case of polyprotic acids, is equal to the pK_a of the acid.

6.15 pH

pH is a measure of the amount of hydrogen ions in a solution and the degree of the acidity of the solution. The pH range runs from 0 to 14; aqueous solutions with a pH below 7 are acidic, and aqueous solutions with a pH above 7 are alkaline or basic. Solutions at pH 7 are considered neutral.



Environmental Effects	pH Value	Examples
	pH = 0	Battery acid
	pH = 1	Sulfuric acid
	pH = 2	Lemon juice, Vinegar
	pH = 3	Orange juice, Soda
All fish die (4.2)	pH = 4	Acid rain (4.2-4.4) Acidic lake (4.5)
Frog eggs, tadpoles, crayfish, and mayflies die (5.5)	pH = 5	Bananas (5.0-5.3) Clean rain (5.6)
Rainbow trout begin to die (6.0)	pH = 6	Healthy lake (6.5) Milk (6.5-6.8)
	pH = 7	Pure water
	pH = 8	Sea water, Eggs
	pH = 9	Baking soda
	pH = 10	Milk of Magnesia
	pH = 11	Ammonia
	pH = 12	Soapy water
	pH = 13	Bleach
	pH = 14	Liquid drain cleaner

The pH of a solution is equal to the negative log base ten of the concentration of hydrogen ions in solution.

$$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$$

Water interacts strongly with the hydrogen ion because its strong positive charge attracts the negative pole of surrounding water molecules. In fact, they interact so strongly that they form a covalent bond and the H_3O^+ cation, called hydronium. The above equation is rewritten to reflect this.

$$\mathrm{pH} = -\log_{10}[\mathrm{H_3O}^+]$$

For simplicity, we'll refer to the concentration of hydrogen ions instead of hydronium ions when discussing pH. The lower the pH value of a solution, the more hydrogen ions that are present, and the more acidic the solution. For example, the pH of 1 mM of sulfuric acid is 2.75, whereas the pH of 1 mM of hydrochloric is 3.01. The concentration of hydrogen ions in the sulfuric acid solution is calculated as $1 \times 10^{2.75}$, whereas the concentration of hydrogen ions in the hydrochloric acid solution is 1 × $10^{-3.01}$. Thus, there are more hydrogen ions present in sulfuric acid, and it is more acidic.

A^-. Higher K_a values represent stronger acids, whereas smaller K_a values represent weaker acids.

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

K_a is reported in the form of pK_a, which is the negative log base 10 of K_a. Lower pK_a values correspond to a stronger acid, whereas higher pK_a values correspond to a weaker acid.

$$pK_a = -\log_{10} K_a$$

Some acids dissociate only one hydrogen ion and therefore have one pK_a value. These acids are called **monoprotic**. However, some acids can dissociate more than one hydrogen ion and are called **polyprotic**.

pK_a can also be used to calculate the equilibrium pH of an acid-base reaction, as shown in the **Henderson-Hasselbalch equation.**

$$pH = pK_a + \log_{10} \frac{[A^-]}{[HA]}$$

The Henderson-Hasselbalch equation is used to calculate pH, when the concentrations of the conjugate base and the weak acid are known, or to calculate the pK_a if the pH and concentrations are known.

6.16 **Various chemical processes**

6.16.1 Filtration:

Filtration is a separation process that involves passing a mixture through a porous material (filter) to separate solid particles from a liquid.

Procedure:

An appropriate filter medium based on the size of particles to be separated is used.
Place the filter medium in a funnel and set it over a container to collect the filtrate.
Pour the mixture through the funnel. Allow the liquid to pass through the filter, leaving the solid particles on the filter. Wash the solid with a suitable solvent if necessary. Collect the filtrate in the container.
It is used to separate solid impurities from liquids in various laboratory and industrial processes.

6.16.2 Crystallization:

The transition of a substance from a liquid or gas phase to a solid crystalline form.

Procedure:

Dissolve the solute in a suitable solvent to form a saturated solution.

Heat the solution to dissolve as much solute as possible. Allow the solution to cool slowly or evaporate, encouraging the formation of crystals. If necessary, scratch the inside of the container to induce crystallization. Collect the crystals using filtration.

6.16.3 Decantation:

is a separation process where a liquid is poured off from a mixture, leaving the solid sediment behind.

Procedure: Allow the mixture to settle to allow the heavier solid particles to settle at the bottom.

Carefully pour off the clear liquid, leaving the solid sediment behind. If necessary, use a wash bottle to rinse the remaining solid with a suitable solvent.

Commonly used to separate suspended solids from liquids.

6.16.4 Precipitation:

Precipitation is the formation of a solid from a solution during a chemical reaction.

Procedure:

Mix two solutions containing the ions or compounds to be reacted. Observe the formation of a precipitate (insoluble solid). Allow the precipitate to settle or use filtration to separate it from the liquid. Wash the precipitate with a suitable solvent to remove impurities.

It is ued in qualitative and quantitative analysis to isolate specific ions or compounds.

6.16.5 Evaporation:

Evaporation is the process by which a liquid turns into a vapor or gas.

Procedure: Heat the liquid to increase its temperature. Allow the liquid to evaporate, leaving behind the solutes. If necessary, use a cover to prevent contamination. Collect the residue left after evaporation

Commonly used to concentrate solutions and separate solutes from liquids.

6.16.6 Titration:

Titration is a technique used to determine the concentration of a substance in a solution by reacting it with a solution of known concentration.

Procedure:

Use a burette to add a solution of known concentration (titrant) to the solution of unknown concentration (analyte). Continuously mix the solutions until the reaction is complete.

Note the volume of titrant used. Use stoichiometry to calculate the concentration of the analyte.

Widely used in analytical chemistry for quantitative analysis.

6.16.7 Sublimation:

Sublimation is the transition of a substance directly from a solid to a gas without passing through the liquid phase.

Procedure**:**

Substance is heated to induce sublimation. Collect the vapor on a cold surface to form the solid sublimate. Alternatively, collect the sublimate in a cold trap.

Used to purify substances and obtain them in a highly pure form.

6.16.8 Distillation:

It is a separation process that involves heating a liquid to create vapor and then cooling the vapor to create a liquid (condensate).

Procedure**:**

Lliquid mixture is heated to create vapor. Collect the vapor in a condenser to condense it back into liquid form. Collect the distillate in a separate container Utilization: Commonly used to separate components of a liquid mixture based on differences in boiling points.

6.16.9 Fractional Distillation:

Fractional distillation is a more precise form of distillation that separates a mixture into its individual components based on their boiling points.

Procedure

Heat the liquid mixture, and the vapor rises through a fractionating column.

The column provides multiple condensation and vaporization steps. Different components condense at different levels, allowing for separation.

It is sed in the separation of complex mixtures, such as in the petroleum industry.

6.16.10 Hydrolysis:

Hydrolysis is a chemical reaction in which water reacts with a compound to produce other compounds.

Procedure**:** Add water to the compound undergoing hydrolysis. Allow the chemical reaction to occur, breaking bonds in the compound. Observe the formation of new products. Adjust conditions such as temperature and concentration if needed.

Commonly used in the digestion of food and in various chemical processes in laboratories and industries.

6.16.11 Centrifugation:

It is a process that uses centrifugal force to separate particles from a suspension or solution.

Procedure**:** Place the sample in a centrifuge tube. Secure the tube in the centrifuge rotor. Spin the centrifuge at high speed. The denser particles move to the bottom of the tube, forming a pellet.

Used in laboratories for the separation of particles from liquids, such as in blood sample processing.

6.16.12 Oxidation and Reduction:

Oxidation involves the loss of electrons, while reduction involves the gain of electrons. Observe the transfer of electrons between the reactants. Balance the redox equation. Oxidation states of the elements before and after the reaction are noted.

Utilization**:** Redox reactions play a crucial role in various biological processes, industrial processes, and laboratory analyses.

6.16.13 Catalysis:

Catalysis is the acceleration or initiation of a chemical reaction by a substance (catalyst) that remains unchanged in the process.

Procedure**:** Introduce the catalyst into the reaction mixture. Observe the acceleration of the reaction.

Note that the catalyst remains unchanged after the reaction.

Widely used in industrial processes and laboratory reactions to increase reaction rates.

6.17 Types of Chemical Reactions:

Chemical reactions involve the transformation of one or more substances into new substances with different properties. Many chemical reactions can be classified as combination, decomposition, single-replacement, double-replacement, combustion, oxidation-reduction reactions, Acid-base reactions and precipitation reactions. Having a thorough understanding of these types of reactions will be useful for predicting the products of an unknown reaction. Understanding chemical reactions is crucial for analyzing biological samples, diagnosing diseases, and performing laboratory tests

6.17.1 Combination Reactions:

A combination reaction, also known as a synthesis reaction, is a reaction in which two or more substances combine to form a single new substance. Combination reactions can also be called synthesis reactions. The general form of a combination reaction is:

$$A+B \rightarrow AB$$

One combination reaction is two elements combining to form a compound. Solid sodium metal reacts with chlorine gas to produce solid sodium chloride.

$$2Na(s)+Cl2(g) \rightarrow 2NaCl(s)$$

Notice that to write and balance the equation correctly, it is important to remember the seven elements that exist in nature as diatomic molecules (H2, N2, O2, F2, Cl2, Br2, and I2). One sort of combination reaction that occurs frequently is the reaction of an element with oxygen to form an oxide. Metals and nonmetals both react readily with oxygen under most conditions. Magnesium reacts rapidly and dramatically when ignited, combining with oxygen from the air to produce a fine powder of magnesium oxide.

$$2Mg(s)+O2(g) \rightarrow 2MgO(s)$$

6.17.2 Decomposition Reactions:

A decomposition reaction is a reaction in which a compound breaks down into two or more simpler substances. The general form of a decomposition reaction is:

$$AB \rightarrow A+B$$

Most decomposition reactions require an input of energy in the form of heat, light, or electricity.

Binary compounds are compounds composed of just two elements. The simplest kind of decomposition reaction is when a binary compound decomposes into its elements. Mercury (II) oxide, a red solid, decomposes when heated to produce mercury and oxygen gas.

$2HgO(s) \rightarrow 2Hg(l)+O_2(g)$

A reaction is also considered to be a decomposition reaction even when one or more of the products is still a compound. A metal carbonate decomposes into a metal oxide and carbon dioxide gas. For example, calcium carbonate decomposes into calcium oxide and carbon dioxide.

$CaCO_3(s) \rightarrow CaO(s)+CO_2(g)$

Metal hydroxides decompose on heating to yield metal oxides and water. Sodium hydroxide decomposes to produce sodium oxide and water.

$$2NaOH(s) \rightarrow Na_2O(s)+H_2O(g)$$

6.17.3 Single- Replacement Reactions

A single-replacement reaction is a reaction in which one element replaces a similar element in a compound. The general form of a single-replacement (also called single displacement) reaction is:

$A+BC \rightarrow AC+B$

In this general reaction, element A is a metal and replaces element B, also a metal, in the compound. When the element that is doing the replacing is a nonmetal, it must replace another nonmetal in a compound, and the general equation becomes:

$Y+XZ \rightarrow XY+Z$

Y is a nonmetal and replaces the nonmetal Z in the compound with X.

Magnesium is a more reactive metal than copper. When a strip of magnesium metal is placed in an aqueous solution of copper (II) nitrate, it replaces the copper. The products of the reaction are aqueous magnesium nitrate and solid copper metal.

$Mg(s)+Cu\ (NO_3)_2(aq) \rightarrow Mg\ (NO_3)_2(aq)+Cu(s)$

Many metals react easily with acids, and, when they do so, one of the products of the reaction is hydrogen gas. Zinc reacts with hydrochloric acid to produce aqueous zinc chloride and hydrogen (see figure below).

$$Zn(s)+2HCl(aq) \rightarrow ZnCl_2(aq)+H_2(g$$

6.17.4 Double-Replacement Reactions:

A reaction in which the positive and negative ions of two ionic compounds exchange places to form two new compounds. The general form of a double-replacement reaction is:

$$AB+CD\rightarrow AD+CB$$

In this reaction, A and C are positively-charged cations, while B and D are negatively charged anions. Double-replacement reactions generally occur between substances in aqueous solution. In order for a reaction to occur, one of the products is usually a solid precipitate, a gas, or a molecular compound such as water.

A precipitate forms in a double-replacement reaction when the cations from one of the reactants combine with the anions from the other reactant to form an insoluble ionic compound. When aqueous solutions of potassium iodide and lead (II) nitrate are mixed, the following reaction occurs.

$$2KI\,(aq)+Pb(NO3)2(aq)\rightarrow 2KNO3(aq)+PbI2(s)$$

6.17.5. Combustion Reactions

A combustion reaction is a reaction in which a substance reacts with oxygen gas, releasing energy in the form of light and heat. Combustion reactions must involve O2 as one reactant. The combustion of hydrogen gas produces water vapor.

$$2H2(g)+O2(g)+2H2O(g)$$

Notice that this reaction also qualifies as a combination reaction.

Many combustion reactions occur with a hydrocarbon, a compound made up solely of carbon and hydrogen. The products of the combustion of hydrocarbons are always carbon dioxide and water. Many hydrocarbons are used as fuel because their combustion releases very large amount of heat energy. Propane (C3H8) is a gaseous hydrocarbon that is commonly used as the fuel source in gas grills.

$$C3H8(g)+5O2(g)\rightarrow 3CO2(g)+4H2O(g)$$

6.17.6. Oxidation-Reduction Reactions

Commonly known as redox reactions, are reactions that involve the transfer of electrons from one species to another. The species that loses electrons is said to be oxidized, while the species that gains electrons is said to be reduced.

Redox reactions are all around us: the burning of fuels, the corrosion of metals, and even the processes of photosynthesis and cellular respiration involve oxidation and reduction. Some examples of common redox reactions are shown below.

$CH_4(g) + 2O_2 (g) = CO2(g) + 2H2O (g)$ (combustion of methane)

$2Cu(s) + O2 (g) = 2CuO(s)$ (oxidation of copper)

$6CO2\} (g) + 6H2O(l) = C6H12O6(s)+6O2 (g)$ (photosynthesis)

During a redox reaction, some species undergo **oxidation**, or the loss of electrons, while others undergo **reduction**, or the gain of electrons. For example, consider the reaction between iron and oxygen to form rust:

$4Fe (s) + 3O_2(g) = 2Fe2O3 (s)$ (rusting of iron)

In this reaction, neutral Fe loses electrons to form Fe^{3+} ions and neutral O^{2} gains electrons to form O^{2-} ions. In other words, iron is *oxidized* and oxygen is *reduced*. Importantly, oxidation and reduction don't occur only between metals and nonmetals.

6.17.7 Acid-Base Reactions

It involves the reaction between an acid and a base to form water and a salt. An acid -base reaction is a reaction when any acid reacts with any base, regardless of their strength. A neutralization reaction is a reaction when a strong acid reacts with an equally strong base or when a weak acid reacts with an equally weak base. The product of neutralization reactions is a neutral salt and water solution. The products of acid-base reactions vary in acidity and basicity.
An example of an acid-base neutralization reaction is the formation of table salt, sodium chloride, and water.

HCl + NaOH ----> H2O + NaCl

A strong acid (hydrochloric acid) and a strong base (sodium hydroxide) react quantitatively to form a neutral salt and water solution.

6.17.8 Precipitation Reactions:

Precipitation reactions are usually double displacement reactions involving the production of a solid form residue called the precipitate. These reactions also occur when two or more solutions with different salts are combined, resulting in the formation of insoluble salts that precipitate out of the solution.

$AgNO_3$(aqueous) + KCl(aqueous) ——AgCl(precipitate) + KNO_3(aqueous)

In the above reaction, a white precipitate called silver chloride or AgCl is formed which is in the solid-state. This solid silver chloride is insoluble in water. Precipitation reactions help in determining the presence of different ions present in a particular solution.

The other example of a precipitation reaction is the reaction between calcium chloride and potassium hydroxide, resulting in the formation of an insoluble salt called calcium hydroxide. The chemical equation for this reaction is below-

2KOH (aqueous) + $CaCl_2$(aqueous)—-Ca $(OH)_2$(aqueous) + 2KCl(aqueous)

Some more examples of chemical equations of on precipitation reaction are as below-

$AgNO_3$(aqueous) + NaCl(aqueous) —- AgCl↓ + $NaNO_3$ (aqueous)

Mg $(OH)_2$(s) + 2HCl (aqueous) ——— $MgCl_2$(aqueous) +2H_2 O

Sample Question? Name the types of chemical reactions? What are combination and decomposition reactions? What is titration?

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Chemical Pathology
chapter 7

Objectives

Chemical pathology is a medical specialty that involves the diagnosis, monitoring, and management of disease through the measurement of hormones and other molecules in body fluids. It includes the biochemical diagnosis of abnormal cell metabolites, electrolytes, proteins, and lipids.
Chemical pathology brings together science and medicine. By understanding the chemistry of bodily fluids and monitoring these, laboratory professionals can tell whether a patient's organs are working properly, diagnose diseases and recommend treatment. For example high glucose levels in blood may be a sign of diabetes.

Chemical pathology (or clinical biochemistry) involves monitoring bodily fluids like blood and urine to detect important changes in the body's chemistry. Pathologists in this area play a key role in diagnosing and monitoring patients with a wide variety of illnesses – from high cholesterol to rare genetic diseases.

7.1 Introduction of chemical pathology Definition and scope of chemical pathology

Chemical pathology (also known as clinical biochemistry) involves the biochemical investigation of bodily fluids such as blood, urine and cerebrospinal fluid. By discovering how and where the body's chemistry has changed, diseases can be diagnosed and monitored. Testing in this specialty utilizes chemical reactions to identify or quantify levels of chemical compounds in bodily fluids.

The Goals and Objectives of chemical pathology include:

A ; Providing relevant information and data on the biochemical basis of disease.

B ; Assisting the clinician in confirmation of or exclusion of a presumptive clinical diagnosis and monitor patients’ response to treatment.

7.2 Scope of chemical pathology

Chemical pathology brings together science and medicine. By understanding the chemistry of bodily fluids and monitoring these, laboratory professionals can tell whether a patient's organs are working properly, diagnose diseases and recommend treatment. For example, high glucose levels in blood may be a sign of diabetes.

7.3 Subjects to be taught

Medical Lab Technology, or MLT is an allied healthcare branch of science that deals with clinical laboratory investigations for the diagnosis of various diseases. It involves the analysis of blood samples, other body fluids, and tissues for the presence of foreign bodies and abnormalities.

Nearly 85 per cent of all medical decisions are based on the outcomes of these clinical investigation reports as no treatment is possible without the proper and accurate diagnosis.

7.4 A medical lab technician is a healthcare professional who performs chemical, hematological, immunologic, microscopic, and microbiological diagnostic analyses on body fluids such as blood, urine, sputum, stool, cerebrospinal fluid (CSF), peritoneal fluid, pericardial fluid, synovial fluid, as well as other specimens.

Medical Laboratory Scientists and medical lab technicians work in clinical laboratories at hospitals, reference laboratories, biotechnology laboratories, and non-clinical industrial labs.

7.5 Various Disciplines of Medical Laboratory Technology Courses

In the modern era of medical science, medical laboratories keep upgrading the existing diagnostic techniques and adopting new hi-tech technologies. With the involvement of special investigations and sophisticated computerized equipment, various disciplines of laboratories are growing day by day. Also, there are various disciplines wherein a laboratory technician discharges his/her duties namely.

- Pathology
- Pharmacology
- Microbiology
- Forensic Medicine
- Human Anatomy & Physiology
- Clinical Biochemistry
- Molecular Medicine
- Blood Bank & Immunohaematology

7.6 Roles and Responsibilities of a Medical Lab Technician

The roles and responsibilities of a Medical Lab Technician after completing a Laboratory Technician course would be the following-

- Collection of specimens like blood, urine, stool, sputum, semen, tissues, and body fluids for various biochemical, microbiological, pathological, blood banking, hematological investigations.
- Assisting to make an accurate diagnosis for proper treatment
- Early disease detection- they make cultures of body fluids and tissue samples to determine the presence of bacteria, viruses, fungi.
- Perform investigations for differential diagnosis
- Control the development of contagious diseases
- Perform complex protein and nucleic acid testing on human cell samples
- Collect, type, and cross match blood; prepare its components for transfusions
- Medical disaster management
- Maintenance of records and preparation of statistics
- Manufacturing vaccines and antisera like DPT, meningitis, anti-snake venom, Testing and certifying medicines.

7.7 Relationship with other branches of pathology

Clinical pathology is a branch of pathology that deals with the laboratory analysis of bodily fluids and tissues for the diagnosis and monitoring of diseases. It plays a crucial role in understanding the underlying mechanisms of diseases and in guiding patient care. Clinical pathology is closely related to other branches of pathology, and together they form a comprehensive approach to the study of diseases. Here's a detailed explanation of the relationship between clinical pathology and other branches of pathology:

7.7.1 Anatomic Pathology:

- Relationship**:** Clinical pathology and anatomic pathology are the two main branches of pathology. While clinical pathology focuses on laboratory analysis, anatomic pathology involves the examination of tissues, organs, and whole bodies through techniques like microscopy, gross examination, and molecular pathology.
- Interconnection**:** The findings from clinical pathology often complement the information obtained from anatomic pathology. For example, the results of blood tests may correlate with the histopathological findings of a biopsy, providing a more comprehensive understanding of a patient's condition.

7.7.2 Hematopathology:

Relationship**:** Hematopathology is a specialized branch that focuses on the study of blood cells and hematologic diseases. Clinical pathology includes the analysis of blood components, making it closely related to hematopathology.

Interconnection*:* Hematopathologists interpret blood smears, bone marrow aspirates, and other hematologic tests, working closely with clinical pathologists who provide data on complete blood counts (CBC), coagulation studies, and blood chemistry. Together, they contribute to the diagnosis and management of blood disorders.

7.7.3 Microbiology:

Relationship**:** Clinical microbiology deals with the identification and characterization of microorganisms causing infections. Clinical pathology often involves the analysis of body fluids for the presence of pathogens.

Interconnection**:** Clinical pathologists collaborate with microbiologists to identify infectious agents through techniques like cultures, molecular diagnostics, and serological tests. The results help guide appropriate antimicrobial therapy and infection control measures.

7.7.4 Chemical Pathology/Clinical Chemistry:

Relationship**:** Chemical pathology, also known as clinical chemistry, focuses on the analysis of body fluids to assess metabolic functions and diagnose diseases. It is a key component of clinical pathology.

Interconnection*:* Pathologists, especially those specialized in clinical chemistry, analyze blood and urine samples to assess electrolyte balance, organ function, and metabolic status. The results aid in the diagnosis and monitoring of various diseases, including diabetes, kidney disorders, and liver diseases.

7.7.5 Immunopathology:

Relationship*:* Immunopathology studies the immune system and its role in diseases. Clinical pathology involves the assessment of immune response through serological tests and other immunological assays.

Interconnection**:** Clinical pathologists collaborate with immunopathologists to understand the immune status of patients. For example, autoimmune diseases, allergies, and immunodeficiencies are conditions where both branches contribute to a comprehensive diagnosis.

7.7.8 Molecular Pathology:

Relationship**:** Molecular pathology involves the study of genetic and molecular alterations in diseases. Clinical pathology incorporates molecular techniques to identify genetic markers and mutations associated with various conditions.

Interconnection*:* Clinical pathologists, especially those involved in molecular pathology, use techniques like polymerase chain reaction (PCR), DNA sequencing, and gene expression analysis to detect genetic abnormalities. This information is crucial for personalized medicine and targeted therapies.

In summary, clinical pathology is an integral part of the broader field of pathology, and its close collaboration with other branches ensures a comprehensive and accurate approach to disease diagnosis, monitoring, and management. The synergy between these branches is essential for providing valuable insights into the nature and progression of various medical conditions.

7.8 Laboratory Equipment

Laboratory equipment refers to the many devices of equipment used in a laboratory to carry out specific tasks. These tools are meant for use by scientists, students, professors, and medical professionals. Some scientific lab equipment is used for weighing materials, mixing and creating solutions, and cleaning containers. Any experiment must be performed with care to prevent injury, to ensure safety and properly carry out an experiment, it is essential to understand the names and purposes of lab equipment.

7.8.1 Microscope

A microscope is a common laboratory instrument used to observe items that are too small to see with the human eye. A light microscope examines a small object by using lights and a set of magnifying lenses. An electron microscope uses electrons to magnify an image.

7.8.2 Test Tube:

A test tube is a lab vessel often used to carry and mix liquid chemicals. A test tube is shaped like a finger and has one open end. There are many various sizes of test tubes, but the common size is 18 x 150 mm.

7.8.3 Watch Glass:

A watch glass is a common kind of chemical lab tool. It is a concave piece of glass that's often used to store solids, evaporate liquids, and heat tiny amounts of a substance.

20 Common Laboratory Apparatus Names and Their Uses:

Common Laboratory Apparatus List

7.8.4 Crucible:

The crucible is a tiny container made of porcelain. It also includes a cover that is designed to keep smoke particles inside.

Volumetric Flasks:

Volumetric flasks are calibrated to retain certain amounts of liquid at specific temperatures. It is used in chemistry to make standard solutions and accurate dilutions. This flask comes in several sizes, and the capacity is generally specified. Depending on how many solutions are required a 50ml, 125ml, 250ml, 500ml, or 1000 ml volumetric flask.

7.8.4 Beakers:

Similar to test tubes, beakers are used to heat, mix, and store different types of materials. Beakers are cylindrical containers without rounded bottoms and have a spout and a flat base. They are also available in several sizes

7.8.5 Bunsen Burner:

This device is used for sterilizing and heating things. Natural gas or liquefied petroleum gas, such as methane, could be utilized.

7.8.6 Spatula:

A laboratory spatula is similar to a kitchen spatula, except it is considerably smaller. Spatulas are tiny, hand-held instruments for scooping and transferring solids. They can also be used to apply paste-like treatments. Most spatulas are used with various chemicals, typically resistant to heat and acid.

7.8.7 Magnifying Glass:

This specific piece of lab equipment creates a magnified image of an object. It is a convex lens covered with a handle-equipped frame.

7.8.8 Spring Balance:

A spring balance is also known as a newton- metre. The tension of a spring on the scale is used to calculate the object's weight. On one side, there is a spring, and on the other, there is a hook.

7.8.9. Dropper:

A dropper is also known as a Pasteur pipette. It is a small glass or plastic pipe with a rubber tip on one end. Its purpose is to give little volumes of liquids one drop at a time.

7.8.10 Measuring Cylinder:

This instrument is used to determine the volume of a liquid. It is calibrated, with each marker indicating the quantity of chemical used. This glassware is cylindrical and narrow, as the name indicates.

7.8.10 Thermometer:

Laboratory thermometers are almost identical in that they measure the temperature of substances and have a high level of accuracy.

7.8.11 Burette:

A chemical laboratory equipment used to dispense volumes of material. It is often used in titrations. The stopcock is located at the bottom of the long-graded tube. The burettes are 50ml, 25ml, and 10ml.

7.8.12 Balance:

Because certain experiments demand correct quantities of ingredients, solids are often weighed before use. A balance is a device that is used to consider materials. The most popular balance types are analytical and top loading balances.

7.8.13 Funnels:

Funnels are another essential kind of device. They are used to transfer chemicals into small-mouthed receptacles. Filter, thistle, and falling funnels are some of the various types, and each has a specific purpose. Büchner and Hirsch's funnels are excellent examples of organic chemistry laboratory gear.

7.8.14 Wash Bottle:

As squeeze container used to clean and rinse glassware. The majority of wash bottles are plastic, it may be filled with ethanol or deionised water.

7.8.15 Tongs:

Lab workers are always exposed to chemicals, heat, and other potentially harmful substances when working in a laboratory. Tongs are used to grab dangerous things and handle hot containers. Each sort of tong is intended for a particular purpose. Beaker, utility, and crucible tongs are common examples.

7.8.16 Ammeter:

This is a piece of equipment that is present in every physics lab. An ammeter is a tool to gauge how much electricity moves across a circuit.

7.8.17 Brushes for Test Tubes:

Test tubes, flasks, and beakers are cleaned using cleaning brushes. After usage, all equipment should be cleaned and safely stored.

7.9 Reagent

A laboratory reagent can be described as a substance used to measure, detect, or create other substances during a chemical reaction. A reagent is a compound or mixture added to a system to cause a chemical reaction. A reagent or compound can facilitate a reaction, and they are used in most widely used tests. This includes, pregnancy tests, blood glucose tests, and most COVID-19 test kits.

7.9.1 Grading of reagents grading system is used to show how pure a substance is. High grades are provided to the purest chemicals. As the level of impurities increases, the grades begin to get low. These impurities can be metal, water, or other chemicals. It is important to use specified grades; otherwise, errors can arise due to contamination from reagents themselves. Reagents are graded on the basis of their purity below

7.9.2 Technical Grade Chemicals: or Commercial Grade. It is used for low-grade applications like commercial or industrial purposes. Due to the presence of impurities, it isn’t utilized in drug, food, or medicinal purposes. It is also found it in qualitative testing.

7.9.3 Synthesis Grade Chemicals: The primary purpose of this involves organic synthesis and preparative tasks.

7.9.4 Lab Grade Chemicals: These are commonly called Laboratory Reagent (LR Grade chemicals), or Chemically Pure (CP). These are used in educational or teaching labs. Like technical grade, their purity isn’t sufficient to use them for any drug, food, or medicinal applications. However, they may be utilized in work that doesn’t require analytical reagents.

7.9.5 AR grade Chemicals: These are used for high precision work. In this, trace impurities are restricted to the lowest possible limits for high precision. Such reagents ares used mainly for analytical applications, research, and quality control. If such reagents meet the specifications of the American Chemical Society Committee on Analytical Reagents, it will be denoted as AR (ACS).

7.9.6 ACS Grade Chemicals: These reagents either meet or exceed all the standards stated by the American Chemical Society (ACS). Their purity levels are exceptionally high, and are used in drug, food, or medical applications because they have above 95% purity.

7.9.7 General Reagent (GR) – These are the reagent that meets or exceed AR grade specifications.

7.9.8 Extra Pure Grade Chemicals: These are suitable for laboratory accreditations and also work requiring compliance with pharmacopoeial standard requirements.

We can also classify the chemicals based on their applications. Let’s see a few examples.

7.9.8 Electronic Grade Chemicals: – these have very stringent limits for metallic impurities as required for use in electronic component industry as such as below ppt or ppb levels

7.9.9 HPLC Grade Chemicals: These include adequately pure ion-pair reagents, solvents, and buffers used as the mobile phase of High-Performance Liquid Chromatography (HPLC).
They meet strict UV absorbance specifications and are filtered for removal of sub-micron suspended solids. Plus, they can be available in different purification degrees as per the HPLC requirements. The only thing here is that the impurities in the reagent should not interfere with the HPLC analysis.

7.9.10 Spectroscopy Grade Chemicals: Various compounds are gained through organic synthesis. Nuclear magnetic resonance spectroscopy is the technique used for their structural analysis. This process requires spectroscopy grade that includes solvents of high purity, low residue on boiling, and having absorption blank in the wavelength region of interest.

There is also an HPLC/spectroscopy grade for common use in HPLC and spectroscopic applications. Spectroscopy grade salts consist of alkali metal salts having transparency in the IR region such as KBr, NaCl, CsI, etc.

7.9.11 Nano Grade – These meet ACS grade specifications. They are used for extraction and pre-concentration applications.

7.9.12 Residue Grade Solvents – These solvents suitable for pesticide residue analysis.

Conclusion

Precision is of utmost importance in laboratory testing. The choice of the right grade of reagent is essential for the application in hand, and it is also important to use reagents from the same source for high precision of results.

7.10 FLAME PHOTOMETER

Flame photometer is a technique used for quantitative elemental analysis. It is particularly useful in measuring alkali and alkaline earth metals, such as sodium, potassium, calcium, and lithium. By subjecting a sample to a flame, the energy provided excites the atoms or ions present, causing them to emit light at specific wavelengths. This emitted light is then measured and correlated to the concentration of the element in the sample.

Working Principle of a Flame Photometer

The flame photometry principle is based on measuring the intensity of the emitted light when a metal is introduced into the flame. The color of the wavelength and its intensity both reveal information about the elements present in the given sample and their relative concentrations, respectively. When alkali and alkali earth metal compounds are placed into the flame, they break down into atoms. These neutral atoms receive energy from thermal energy and are then stimulated to a higher energy level. However, they are not stable at greater energy levels. As a result, these atoms, which are unstable at greater levels, return to the ground state. When these atoms return to their ground state, they emit radiation of a specific wavelength, primarily in the visible range.

When a solution containing a significant amount of the metal is injected into the flame, the following events occur in fast succession:

Liquid sample → Formation of droplets → Fine residue → Formation of neutral atoms → Excitation of atoms by thermal energy → Emission of radiation of specific wavelength

The working principle of a flame photometer involves several essential steps:

7.10.1 Sample Introduction: The sample solution is introduced into the flame through the atomizer. The solution is typically aspirated or nebulized, ensuring a fine spray for efficient atomization.

7.10.2 Atomization and Desolvation: As the sample enters the flame, the solvent evaporates, leaving behind the dissolved elements in the form of atoms or ions. The high temperature of the flame further excites these atoms or ions.

7.10.3 Emission of Light: The excited atoms or ions in the flame emit light at specific wavelengths characteristic of the elements present in the sample.

7.10.4 Emission of Light: The excited atoms or ions in the flame emit light at specific wavelengths characteristic of the elements present in the sample.

7.10.5 Detection and Measurement: The detector captures the selected wavelength of light and converts it into an electrical signal. The signal processor then measures the intensity of the signal, which is proportional to the concentration of the element in the sample.

7.10.6 Quantitative Analysis: The measured signal is compared to calibration curves or standards to determine the concentration of the element in the sample solution. This allows for the quantitative analysis of the specific element of interest.

Basic Components of a Flame Photomete

Flame Source: The flame source provides the necessary heat to excite the atoms or ions in the sample. It is typically a propane or natural gas flame.

Atomizer: The atomizer is responsible for introducing the sample solution into the flame in a controlled manner. This can be achieved using a nebulizer or an aspirator.

Monochromator: The monochromator is an optical device that selects a specific wavelength of light emitted by the sample. It helps eliminate unwanted background radiation and enhances the accuracy of measurements.

Detector: The detector captures the selected wavelength of light and converts it into an electrical signal.

Signal Processor: The signal processor amplifies and processes the electrical signal from the detector, allowing for quantitative analysis.

Flame Photometer Applications

Flame photometry finds applications in various fields, including:

Clinical Chemistry: Measurement of electrolytes, such as sodium and potassium, in blood or urine samples.

Environmental Analysis: Determination of alkali metals in soil, water, and plant samples.

Pharmaceutical Analysis: Quantification of trace elements in pharmaceutical formulations.

Food and Beverage Industry: Analysis of mineral content in food and beverages for quality control purposes.

Geological Studies: Measurement of elements in geological samples for mineral exploration and research.

7.11 Weighing Balance:

A Beam balance (or Beam scale) is a device to measure weight or mass. These are also known as mass scales, weight scales, mass balance, weight balance, or simply scale, balance, or balance scale. The traditional scale consists of two plates. Principle**:**

The basis of the rapid and exact working method of our Weigh Cells is the Principle of Electro Magnetic Force Restoration (EMFR).

The weighing pan is attached to an electromagnetic coil, through which electric current is flowing. The coil floats in a magnetic field created by an amplifier. The amplifier maintains the right current to keep the lever balanced with the mass on the pan. As more weight is applied to the pan, the current is increased to maintain the level's position. The counteracting force that is created is measured and "translated" by various electronics to obtain a readable result. The resulting electrical current is then "translated" into a displayed number that is shown to the user.

Methods for Weighing

Two common methods are used to weigh a chemical are "weighing by difference" or "taring the balance".

7.11.1 Weighing by Difference

The mass of the chemical is calculated by subtracting the weight of an empty container from the total weight of the container and chemical. Place an empty container on the pan, close the draft shield doors and wait a few seconds for the display to read a constant mass. Record the mass of the empty container to three decimal places; do not round off. Remove the container from the pan, spoon the chemical into the container, and record the mass of both container and chemical. The mass of the chemical is the difference of the two recorded masses. Remember to handle the container with tongs or tissue; moisture from fingers can cause an error in the apparent mass.

7.11.2 Taring the Balance

The balance is set to ignore the mass of the container so the mass of the added chemical is measured directly. Place the empty container on the pan and close the draft shield. Wait a few seconds for the display to register a constant mass.

Press the bar so the display reads "0.000 g". The balance is now set to "ignore" the mass of the container (a process called "taring" the balance). Now if a chemical is added to the container, the balance displays only the mass of that chemical. When the container and chemical is removed from the pan a negative weight will be displayed. (This negative weight is the mass of the original empty container which the balance was instructed to ignore.) To erase this weight from memory, press the bar again. The display should read "0.000g".

Applications:

Used for weighing chemicals and other biological specimen precisely

7.12 pH Meter

A pH meter is a scientific instrument that measures the hydrogen-ion activity in water based solutions, indicating its acidity or alkalinity expressed as pH.

Principle

pH meter basically works on the fact that interface of two liquids produces an electric potential which can be measured. In other words, when a liquid inside an enclosure made of glass is placed inside a solution other than that liquid, there exists an electrochemical potential between the two liquids.

Components

It is basically an electrode consisting of 4 components:

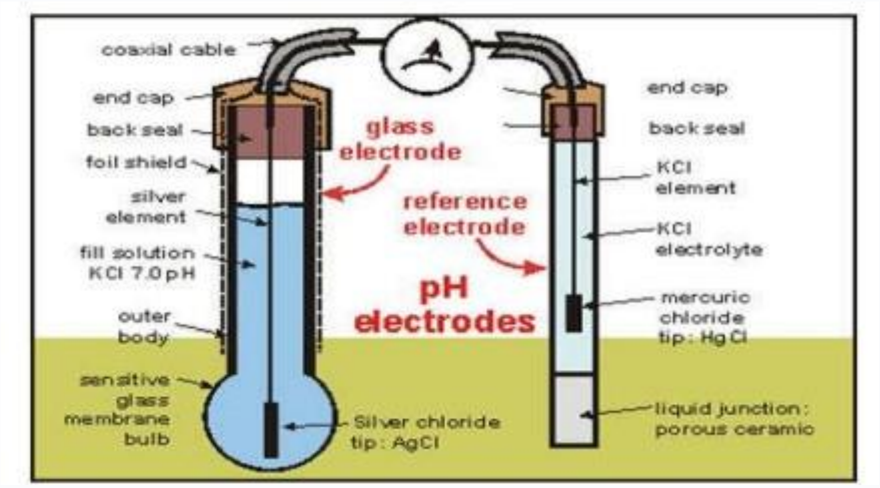
A measuring electrode:

It is a tube made up of glass and consists of a thin glass bulb welded to it, filled up with Potassium Chloride solution of known pH of 7. It also contains a block of silver chloride attached to a silver element. It generates the voltage used to measure pH of the unknown solution.

A Reference Electrode:
It is a glass tube consisting of potassium chloride solution in intimate contact with a mercury chloride block at the end of the potassium chloride. It is used to provide a stable zero voltage connection to the complete the whole circuit.

Preamplifier**:**
It is a signal conditioning device and converts the high impedance pH electrode signal to a low impedance signal. It strengthens and stabilizes the signal, making it less susceptible to electrical noise.

Transmitter or Analyzer: It is used to display the sensor's electrical signal and consists of a temperature sensor to compensate for the change in temperature.



Protocol & Working

The electrode is placed inside the beaker filled with a solution whose pH is to be measured. The glass bulb welded at the end of the measurement electrode consists of lithium ions doped to it which makes it act as an ion selective barrier and allows the hydrogen ions from the unknown solution to migrate through the barrier and interacts with the glass, developing an electrochemical potential related to the hydrogen ion concentration. The measurement electrode potential thus changes with the hydrogen ion concentration. On the other hand, the reference electrode potential doesn't change with the hydrogen ion concentration and provides a stable potential against which the measuring electrode is compared. It consists of a neutral solution which is allowed to exchange ions with the unknown solution through a porous separator, thus forming low resistance connection to complete the whole circuit. The potential difference between the two electrodes gives a direct measurement of the hydrogen ion concentration or pH of the system and is first pre amplified to strengthen it and then given to the voltmeter.

U = EpH – Eref

EpH – Voltage potential of measurement electrode

Eref – Voltage potential of reference electrode

It is mostly used in food & drinks, drugs, mining, water treatment plants, and other manufacturing. Major end-users are food science, pharmaceuticals & biotechnology, environmental research & pollution centre, and others.

7.13 Centrifugation

Centrifugation is a technique of separating substances which involves the application of centrifugal force. The particles are separated from a solution according to their size, shape, density, viscosity of the medium and rotor speed.

Principle:

- In a solution, particles whose density is higher than that of the solvent sink (sediment), and particles that are lighter than it float to the top.
- A centrifuge is a piece of equipment that puts an object in rotation around a fixed axis (spins it in a circle), applying a potentially strong force perpendicular to the axis of spin (outward).
- The centrifuge works using the sedimentation principle, where the centripetal acceleration causes denser substances and particles to move outward in the radial direction.
- At the same time, objects that are less dense are displaced and move to the center.
- In a laboratory centrifuge that uses sample tubes, the radial acceleration causes denser particles to settle to the bottom of the tube, while low- density substances rise to the top.

Protocol for working:

Place the centrifuge on a firm, level surface**.** Because of the high speeds at which the centrifuge spins, it needs to be housed on a solid, flat surface. Find a level table or counter that is secure and can properly support the weight of the centrifuge.

Choose the proper rotor to use at the speed you need. The rotor is the piece that spins a sample. Some rotors have arms which can attach smaller buckets to, while other rotors are one piece place the tubes directly into it. Rotors are designated for specific tubes and speeds. Use a rotor that fits the tubes of samples and is within the limit of speed needed. If the samples are in the wrong type of tube, it may be needed to transfer them to the proper type before spinning.

Load the tubes opposite each other in the centrifuge. If spinning only 1 sample, there is a need to make a balance tube to load directly opposite the sample tube. If spinning more than 2 tubes, only the ones directly opposite each other have to be equal in mass.

Enter the centrifugation speed. Centrifugation speed is often given in rotations per minute (rpm), or how many times the rotor completes a full rotation in one minute. Speed can also be given in relative centrifugal force (RCF) or the G-force on the rotor. Modern day centrifuges are digital and have settings for both. The speed at which samples is spun, dependends upon what you are spinning. Do some online research if you aren't sure what speed to use.

Keep a safe distance while the centrifuge is running. Bumping or moving the centrifuge during use can cause an imbalance and lead to injury. Larger centrifuges can spin at very high speeds and are extremely dangerous if they become unbalanced.

Turn off the centrifuge if it is wobbling. After starting the centrifuge, stay close until it gets up to full speed in case it needs to be turned off. When a centrifuge is not balance it may shake or wobble. This can damage the equipment and can also lead to injury in severe cases.

Open the lid only after the rotor has completely stopped. Many modern centrifuges have a lock on them that will not unlock until the rotor has come to a stop. Older centrifuges may not have this feature so make sure the rotor is no longer moving before opening the lid. Do not touch the rotors while they are moving. Keep power cords away from the ground to avoid trip hazards that could move the centrifuge.

Remove the tubes carefully after the centrifuge has completely stopped spinning. Tubes should be removed gently so that the separated suspensions do not mix again. It should be observed if any of the samples have leaked or tubes broken. If a spill occurs, clean the rotor and buckets immediately.

Sample Question. Define Chemical Pathology, and describe the parts of a flame Photometer.

References;

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Chapter 8

Carbohydrates, lipids, proteins, enzymes and vitamins Carbohydrates

Objectives

The objective of this subject is to provide biochemical facts and the principles to understand the metabolism of nutrient molecules like proteins, lipids, enzymes etc. in physiological and pathological conditions. It also emphasizes on the genetic organization of the genome and hetero & auto-catalytic functions of DNA.

Introduction

Carbohydrates are defined as biomolecules containing a group of naturally occurring carbonyl compounds (aldehydes or ketones) and several hydroxyl groups. It consists of carbon (C), hydrogen (H), and oxygen (O) atoms, usually with a hydrogen-oxygen atom ratio of 2:1 (as in water). The general formula $C_x(H_2O)_y$ is commonly used to represent many carbohydrates, which means “watered carbon. Carbohydrates can also be defined as “optically active polyhydroxy aldehydes or polyhydroxy ketones or substances which give these on hydrolysis.”

Carbohydrates are probably the most abundant and widespread organic substances in nature, and they are essential constituents of all living things. Carbohydrates are formed by green plants from carbon dioxide and water during the process of photosynthesis. Carbohydrates serve as energy sources and as essential structural components in organisms; in addition, part of the structure of nucleic acids, which contain genetic information, consists of carbohydrate.

8.1 Sources of Carbohydrates

- Many fruits contain simple sugars in the form of fructose.
- All dairy products include galactose.
- Lactose may be found in large quantities in milk and other dairy products.
- Maltose may be found in a variety of foods, including cereal, beer, potatoes, processed cheese, and pasta.
- Sucrose is derived from sugar and honey, both of which include trace quantities of vitamins and minerals.

Carbohydrates in healthy food consist of both animal and plant sources which include:

- Corn
- Potatoes
- Milk Products
- Fresh Fruits
- Vegetables

Some of the most common carbohydrates that we come across in our daily lives are in the form of sugars. These sugars can be in the form of Glucose, Sucrose, Fructose, Cellulose, Maltose etc

8.2 sClassification of Carbohydrates

The main classification of carbohydrate is done on the basis of hydrolysis. This classification is as follow:

8.2.1 Monosaccharides: These are the simplest form of carbohydrate that cannot be hydrolyzed any further. They have the general formula of $(CH_2O)_n$. Some common examples are glucose, Ribose etc.

8.2.2 Oligosaccharides: Carbohydrates that on hydrolysis yield two to ten smaller units or monosaccharides are oligosaccharides. They are a large category and further divides into various subcategories. Three examples of oligosaccharides are raffinose, fructooligosaccharides and galactooligosaccharides. Raffinose and fructooligosaccharides are plant-derived oligosaccharides. Galactooligosaccharides are dairy-derived oligosaccharides.

8.2.3 Disaccharides: A further classification of oligosaccharides, these give two units of the same or different monosaccharides on hydrolysis. For example, sucrose on hydrolysis gives one molecule of glucose and fructose each. Whereas maltose on hydrolysis gives two molecules of only glucose,

8.2.4 Trisaccharides: Carbohydrates that on hydrolysis gives three molecules of monosaccharides, whether same or different. An example is Raffinose.

8.2.5 Tetrasaccharides: And as the name suggests this carbohydrate on hydrolysis give four molecules of monosaccharides. Stachyose is an example.

8.2.6 Polysaccharides: The final category of carbohydrates. These give a large number of monosaccharides when they undergo hydrolysis, These carbohydrates are not sweet in taste and are also known as non-sugars. Some common examples are starch, glycogen.

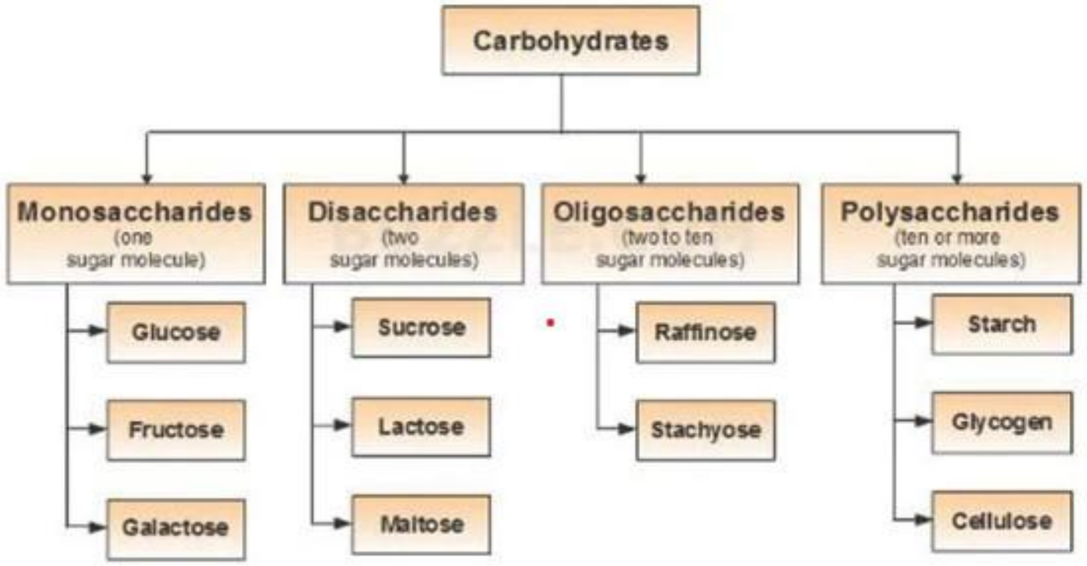


Figure: Classification summary and examples of carbohydrates.

8.3 Metabolism

During digestion, carbohydrates are broken down into simple, soluble sugars that can be transported across the intestinal wall into the circulatory system to be transported throughout the body. Carbohydrate digestion begins in the mouth with the action of **salivary amylase** on starches and ends with monosaccharides being absorbed across the epithelium of the small intestine. Once the absorbed monosaccharides are transported to the tissues, the process of **cellular respiration** begins Carbohydrate metabolism is the series of biochemical processes responsible for the formation, breakdown and interconversion of carbohydrates in living orgsanism. Carbohydrate metabolism is a fundamental biochemical process that ensures a constant supply of energy to living cells.

8.4 Carbohydrate metabolism pathways:

Metabolism of carbohydrates occurs in the following pathways listed below.

8.4.1 **Glycolysis**: This is otherwise called the Embden-Meyerhof pathway. This involves the conversion of glucose to pyruvate and lactate.

8.4.2 **Citric acid cycle**: This is also referred to as the Krebs cycle or tricarboxylic acid cycle. In this process, acetyl CoA is oxidized to CO.

8.4.3 **Gluconeogenesis**: Gluconeogenesis is the process that allows the body to form glucose from non-hexose precursors, particularly glycerol, lactate, pyruvate, propionate, and glucogenic amino acids. Gluconeogenesis essentially reverses glycolysis.

8.4.4 **Glycogenesis**: In this pathway, glycogen is produced from glucose.

8.4.5 **Glycogenolysis**: It is the process of glycogen breakdown.

8.4.6 **Hexose monophosphate shunt**: It can also be called a pentose phosphate pathway or direct oxidative pathway. It is an alternative pathway for the tricoaboxylic acid cycle (TCA cycle) and glycolysis.

8.4.7 **Uronic acid pathway**: It is an alternative oxidative pathway for glucose that involves the conversion of glucuronic acid to glucose. Through a series of enzymatic processes known as the uronic acid pathway, certain carbohydrates like galactose and glucose are transformed into matching uronic acid derivatives. Uronic acids are important constituents of glycosaminoglycans (GAGs), proteoglycans, and other physiologically relevant compounds.

8.4.8 **Galactose metabolism**: It involves the production of lactose and the conversion of glucose to galactose.

8.4.9 **Fructose metabolism**: It involves the oxidation of fructose.

8.4.10 Amino sugar and mucopolysaccharide metabolism: It involves the synthesis of mucopolysaccharides and glycoproteins.

Glycogen metabolism**:**

The inactive form of glucose is called glycogen. It is stored in the muscles and liver for use when needed. Two common pathways involved in glycogen metabolism are:

Glycogenesis

Glycogenolysis

8.5 Organs involved in carbohydrate metabolism:

Metabolism of carbohydrates occurs in different organs and parts of the body. Specific organs in carbohydrate metabolism biochemistry are:

Liver: The liver is the central organ that performs metabolism. Glycolysis, HMP shunt and glycogenesis occur at a higher rate. Decreased gluconeogenesis pathway.

Adipose tissue: It is the storehouse of energy. Glucose absorption is higher at this site. Glycolysis and hexose monophosphate shunt occur commonly.

Skeletal muscle: Glucose assimilation is higher and glycogen production is increased.

Brain: Glucose acts as an energy provider for the brain. 120g of carbohydrates, generally glucose, is consumed by the brain per day.

8.6 Importance of carbohydrate metabolism:

The metabolism of carbohydrates plays a major role in directing the functions of our body. Some of them are:

They serve as an important storehouse of energy.

They precede the function of other biomolecules.

They serve as the basis of cellular constituents.

It directs the function of different organs.

It stimulates enzyme activity.

Carbohydrate metabolism aids hormonal secretions.

It plays a major role in the structural development of the body.

They ensure development and growth.

It helps in brain functions.

8.7 Cell respiration

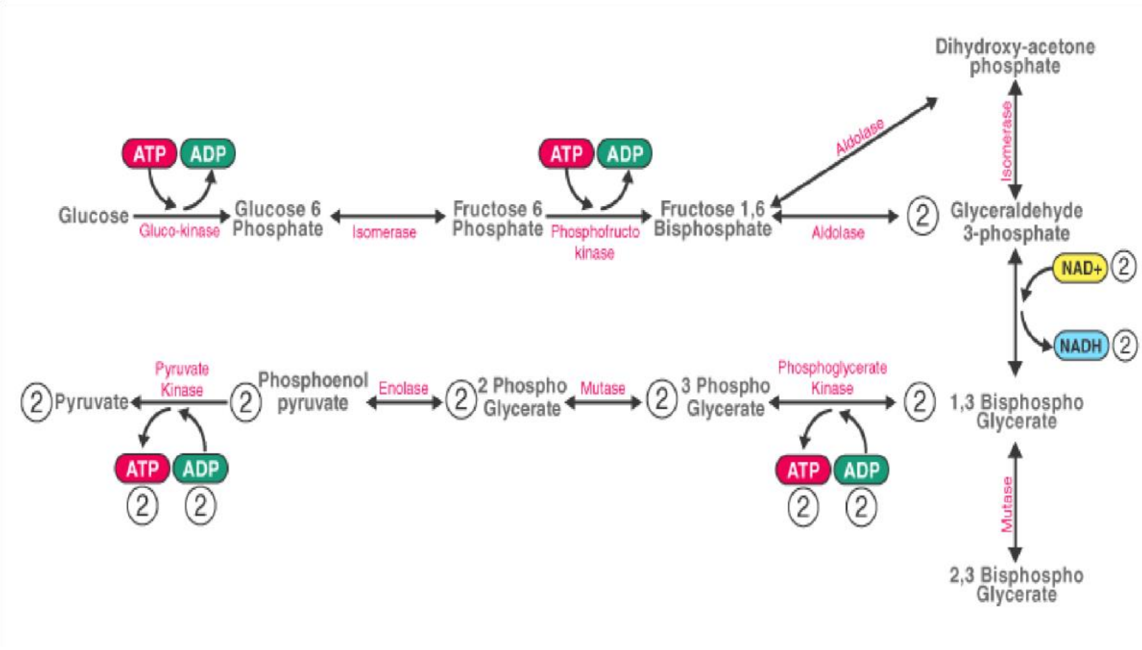
Cellular respiration is a catabolic reaction taking place in the cells. It is a biochemical process by which nutrients are broken down to release energy, which gets stored in the form of ATP and waste products are released. In aerobic respiration, oxygen is required.

Cellular respiration is a four-stage process. In the process, glucose is oxidized to carbon dioxide and oxygen is reduced to water. The energy released in the process is stored in the form of ATPs. 36 to 38 ATPs are formed from each glucose molecule.

The four stages are:

Glycolysis**:** In glycolysis, partial oxidation of glucose occurs, yielding two pyruvic acid molecules.

The glycolysis pathway occurs in the following stages:



Glycolysis pathway

Stage 1

- A phosphate group is added to glucose in the cell cytoplasm, by the action of enzyme hexokinase.
- In this, a phosphate group is transferred from ATP to glucose forming glucose,6 -phosphate.

Stage 2

Glucose-6-phosphate is isomerised into fructose,6-phosphate by the enzyme phosphoglucomutase.

Stage 3

The other ATP molecule transfers a phosphate group to fructose 6-phosphate and converts it into fructose 1,6-bisphosphate by the action of the enzyme phosphofructokinase.

Stage 4

The enzyme aldolase converts fructose 1,6-bisphosphate into glyceraldehyde 3 phosphate and dihydroxyacetone phosphate, which are isomers of each other.

Stage 5

Triose-phosphate isomerase converts dihydroxyacetone phosphate into glyceraldehyde 3-phosphate, the substrate in the successive step of glycolysis.

Stage 6

This step includes two reactions:

- The enzyme glyceraldehyde 3-phosphate dehydrogenase transfers 1 hydrogen molecule from glyceraldehyde phosphate to nicotinamide adenine dinucleotide to form NADH + H^+.
- Glyceraldehyde 3-phosphate dehydrogenase adds a phosphate to the oxidized glyceraldehyde phosphate to form 1,3-bisphosphoglycerate.

Stage 7

Phosphate is transferred from 1,3-bisphosphoglycerate to ADP to form ATP with the help of phosphoglycerokinase. Thus, two molecules of phosphoglycerate and ATP are obtained at the end of this reaction.

Stage 8

The phosphoglycerate molecules' phosphate is relocated from the third to the second carbon to yield two molecules of 2-phosphoglycerate by the enzyme phosphoglyceromutase.

Stage 9

The enzyme enolase removes a water molecule from 2-phosphoglycerate to form phosphoenolpyruvate.

Stage 10

A phosphate from phosphoenolpyruvate is transferred to ADP to form pyruvate and ATP by the action of pyruvate kinase. Two molecules of pyruvate and ATP are obtained as the end products.

Key Points of Glycolysis

- It is the process in which a glucose molecule is broken down into two molecules of pyruvate.
- The process takes place in the cytoplasm of plant and animal cells.
- Six enzymes are involved in the process.

The end products of the reaction include 2 pyruvate, 2 ATP and 2 NADH molecules. Cell Biology Partial oxidation of a glucose molecule to form 2 molecules of pyruvate. This process takes place in the cytosol.

Formation of Acetyl CoA:

Pyruvate formed in glycolysis enters the mitochondrial matrix. It undergoes oxidative decarboxylation to form two molecules of Acetyl CoA. The reaction is catalyzed by the pyruvate dehydrogenase enzyme.

$$2Pyruvate + 2NAD^{+} + 2CoA \xrightarrow{\text{Pyruvate dehydrogenase}} 2AcetylCoA + 2NADH + CO_2$$

Krebs cycle (TCA cycle or Citric Acid Cycle):

It is the common pathway for complete oxidation of carbohydrates, proteins and lipids as they are metabolized to acetyl coenzyme A or other intermediates of the cycle. The Acetyl CoA produced enters the Tricarboxylic acid cycle or Citric acid cycle. Glucose is fully oxidized in this process. The acetyl CoA combines with 4-carbon compound oxaloacetate to form 6C citrate. In this process, 2 molecules of CO_2 are released and oxaloacetate is recycled. Energy is stored in ATP and other high energy compounds like NADH and $FADH_2$.

Electron Transport System and Oxidative Phosphorylation: ATP is generated when electrons are transferred from the energy-rich molecules like NADH and $FADH_2$, produced in glycolysis, citric acid cycle and fatty acid oxidation to molecular O_2 by a series of electron carriers. O_2 is reduced to H_2O. It takes place in the inner membrane of mitochondria.

Krebs Cycle Steps

It is an eight-step process. Krebs cycle or TCA cycle takes place in the matrix of mitochondria under aerobic condition.

Step 1: The first step is the condensation of acetyl CoA with 4-carbon compound oxaloacetate to form 6C citrate, coenzyme A is released. The reaction is catalyzed by *citrate synthase*.

Step 2: Citrate is converted to its isomer, isocitrate. The enzyme *aconitase* catalyses this reaction.

Step 3: Isocitrate undergoes dehydrogenation and decarboxylation to form 5C ketoglutarate. A molecular form of CO_2 is released. *Isocitrate dehydrogenase* catalyzes the reaction. It is an NAD^+ dependent enzyme. NAD^+ is converted to NADH.

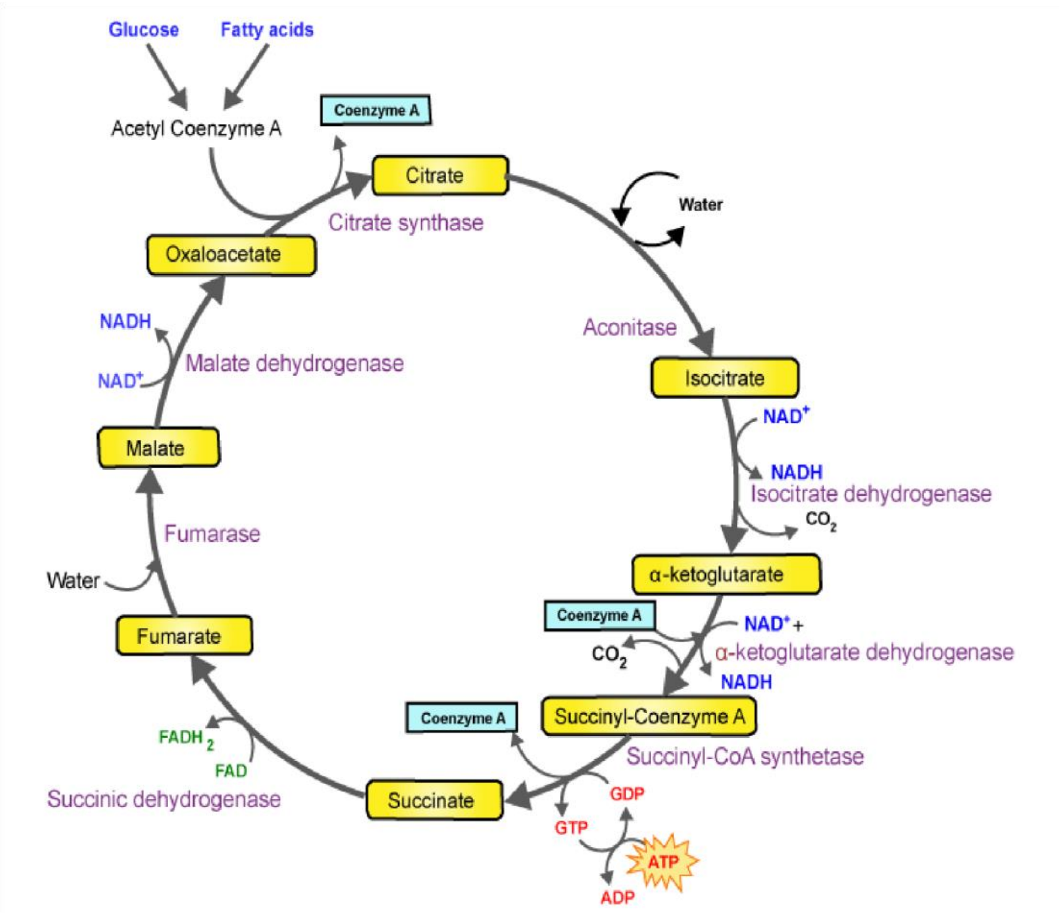
Step 4: -ketoglutarate undergoes oxidative decarboxylation to form succinyl CoA, a 4C compound. The reaction is catalyzed by the *-ketoglutarate dehydrogenase* enzyme complex. One molecule of CO_2 is released and NAD^+ is converted to NADH.

Step 5: Succinyl CoA forms succinate. The enzyme *succinyl CoA synthetase* catalyses the reaction. This is coupled with substrate-level phosphorylation of GDP to get GTP. GTP transfers its phosphate to ADP forming ATP.

Step 6: Succinate is oxidised by the enzyme *succinate dehydrogenase* to fumarate. In the process, FAD is converted to $FADH_2$.

Step 7: Fumarate gets converted to malate by the addition of one H_2O. The enzyme catalysing this reaction is *fumarase*.

Step 8: Malate is dehydrogenated to form oxaloacetate, which combines with another molecule of acetyl CoA and starts the new cycle. Hydrogens removed, get transferred to NAD^+ forming NADH. *Malate dehydrogenase* catalyses the reaction.



Kreb cycle or TCA cycle

Krebs cycle occurs in the mitochondrial matrix

Krebs cycle reactants: Acetyl CoA, which is produced from the end product of glycolysis, i.e. pyruvate and it condenses with 4 carbon oxaloacetate, which is generated back in the Krebs cycle

Krebs cycle products

Each citric acid cycle forms the following products:

- 2 molecules of CO_2 are released. Removal of CO_2 or decarboxylation of citric acid takes place at two places:
  1. In the conversion of isocitrate (6C) to -ketoglutarate (5C)
  2. In the conversion of -ketoglutarate (5C) to succinyl CoA (4C)
- One ATP is produced in the conversion of succinyl CoA to succinate.

- Three NAD^+ are reduced to NADH and 1 FAD^+ is converted to $FADH_2$ in the following reactions:
  1. Isocitrate to -ketoglutarate → NADH
  2. -ketoglutarate to succinyl CoA → NADH
  3. Succinate to fumarate → $FADH_2$
  4. Malate to Oxaloacetate → NADH

Note that 2 molecules of Acetyl CoA are produced from oxidative decarboxylation of 2 pyruvates so two cycles are required per glucose molecule.

To complete oxidation of a glucose molecule, Krebs cycle yields four CO_2, six NADH, two $FADH_2$ and two ATPs.

Each molecule of NADH can form 2-3 ATPs and each $FADH_2$ gives 2 ATPs on oxidation in the electron transport chain.

8.8 Lipids

Lipids are defined as heterogeneous groups of organic molecules soluble in non-polar solvents. Structurally, they are esters or amides of fatty acids. This class includes a range of molecules, such as fats, oils, hormones, and certain components of membranes. These molecules are either non-soluble or are poorly soluble in water.

Lipids are fatty compounds that perform a variety of functions in body. They're part of cell membranes. They help with moving and storing energy, absorbing vitamins and making hormones. Having too much of some lipids is harmful.

8.9 Sources of Lipids

Unsaturated fat is generally considered to be healthier because it contains fewer calories than an equivalent amount of saturated fat. Additionally, high consumption of saturated fats is linked to an increased risk of cardiovascular disease. Some examples of foods with high concentrations of saturated fats include butter, cheese, lard, and some fatty meats. Foods with higher concentrations of unsaturated fats include nuts, avocado, and vegetable oils such as canola oil and olive oil.

8.10 Classification of lipids

Lipids can be classified in four ways, depending on:

- chemical composition,
- fatty acids,
- requirements,

Lipids based on chemical composition are divided into three categories:

8.10.1 simple lipids

It includes esters of fatty acids and glycerol that are also termed neutral fats or triglycerides. They make up 98-99% of food and body fats and oil. Its three classes are fatty acids, triglycerides, and waxes.

Fatty acids

Fatty acids are the simplest form of lipids. They are a long chain of hydrocarbons (4 to 36 carbons long) with one carboxyl group. These molecules serve as constituents in a large number of complex lipids. In biological systems, fatty acids contain an even number of carbon atoms. Fatty acids are amphipathic, having both polar and nonpolar ends.AAA

Triacylglycerol

Triacylglycerols (or triglycerides) are tri-esters of fatty acids and glycerol. They are nonpolar and hydrophobic in nature. They do not possess any charge and are termed neutral lipids.

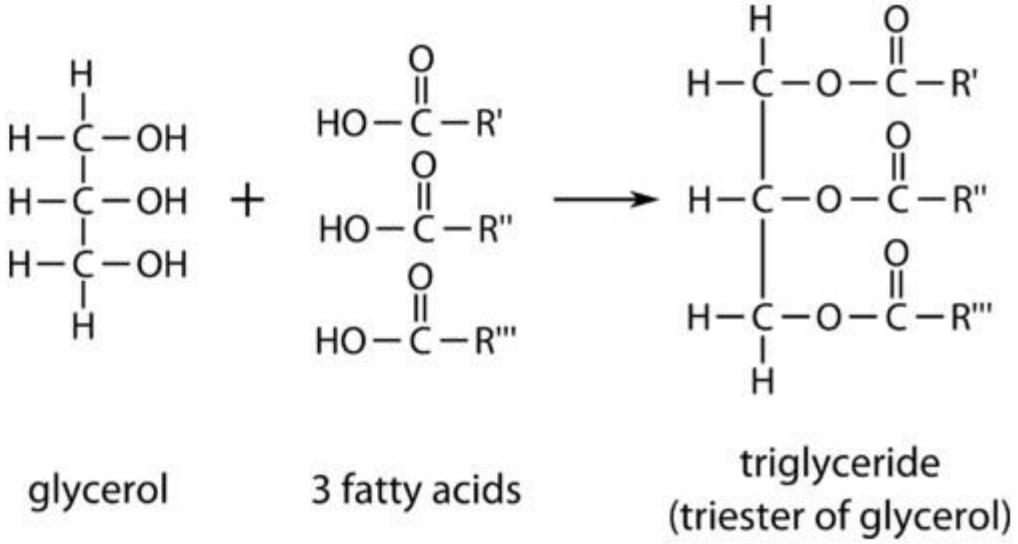


Image: Formation of triglyceride structure.

Waxes

Waxes are esters of long-chain fatty acids and long-chain alcohol. They are solid at room temperature and completely water-insoluble. They are formed by the esterification of long-chain fatty acids and monohydroxy alcohol of higher molecular weight.

8.10.2 Compound Lipids

The complex or co pound lipids contain some other organic molecules in addition to fatty acids and glycerols. They include phospholipids, glycolipids, and lipoproteins.

phospholipids

Phospholipids consist of four components: fatty acids, glycerol or sphingosine, phosphate, and alcohol attached to phosphate. It includes phosphoglycerides, ether glycerophospholipids, and sphingophospholipids. These molecules are amphipathic in nature (a chemical compound containing both polar or water-soluble and nonpolar or not water-soluble portions in its structure. It may also relate to a chemical compound having both hydrophobic and hydrophilic regions.

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Glycolipids

Glycolipids contain a carbohydrate group (attached through a glycosidic bond) in combination with glycerol and fatty acids. It’s the third major class of membrane lipids.

Lipoproteins

Lipoproteins are particles made of protein and fats (lipids). They carry cholesterol through bloodstream to blood cells. The two main groups of lipoproteins are called HDL (high-density lipoprotein) or "good" cholesterol and LDL (low-density lipoprotein) or "bad" cholesterol.

Lipoproteins soluble in the blood are categorized into four groups based on their densities:

- Chylomicrons
- Very Low-Density Lipoproteins (VLDL)
- Low-Density Lipoproteins (LDL)
- High-Density Lipoproteins (HDL)

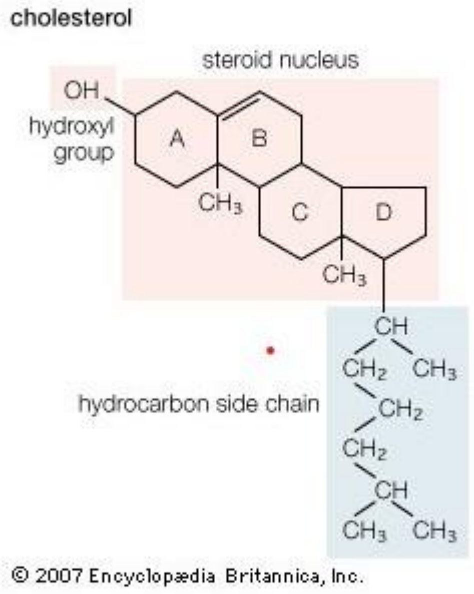
The lipoproteins have a core containing neutral lipids, triacylglycerols and cholesterol esters. The core is coated with a single layer of phospholipids, embedded with apolipoproteins and cholesterol.

Derived lipids

Derived lipids are released during hydrolysis of simple and compound lipids. They include steroids and some fatty acids.

8.10.3 Steroids

Steroids consist of four fused rings called steroid nucleus. They are complex derivatives of triterpenes. One example is cholesterol which is an essential component in animal cell membranes. It’s stored in cells as fatty acid esters and act as precursors for the biosynthesis of steroid hormones and bile salts.



The structure of Cholesterol

8.11 Classification Based on Fatty Acids

Lipids are divided into two categories based on the type of fatty acids present in them: saturated and unsaturated fatty acids.

8.12 Classification Based on Requirements by the Human Body

Lipids on the basis of requirements are divided into two groups: essential and nonessential fatty acids

1. Essential Fatty Acids

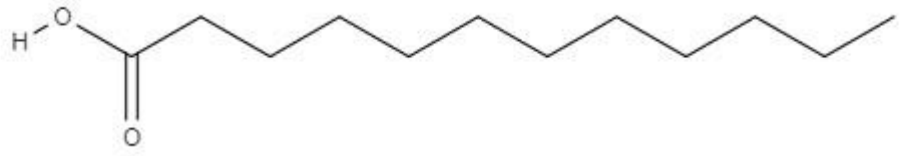
Fatty acids that cannot be produced or synthesized in our bodies are called essential fatty acids. These fatty acids need to be taken through a diet to fulfill the body’s requirement for different metabolic functions. It includes linoleic acid, linolenic acid, and arachidonic acid.

2.Non-essential Fatty Acids

Non-essential fatty acids include those lipids that are synthesized by our body. They are not needed to be taken through any outside food source. It includes palmitic acid, oleic acid, and butyric acid.

8.13 Fat metabolism

Most fat that is consumed is consumed in the form of triglycerides. A triglyceride consists of a glycerol backbone with three fatty acids attached. The enzyme lipase is excreted in the mouth, stomach, and small intestines, which breaks off fatty acids from the glycerol backbone. The small intestine micelles can absorb the fatty acids and monoglycerides (the glycerol with only one fatty acid attached). The fatty acid chains are just hydrocarbon chains with a carboxylic acid at the beginning. The carbon chains can be cut into small, two-carbon chains using beta oxidation. These two-carbon chains are converted into acetyl- CoA, which can then enter the citric acid cycle with pyruvate in step 1.



The fatty acid lauric acid can be broken into individual two carbon groups to be used in the citric acid cycle.

Saturated fatty acids can go directly into this process to create energy. Unsaturated fatty acids, such as omega-3 and omega-6 fatty acids, need to first undergo oxidation before entering this pathway.

8.14 Importance of Lipids

Fats and lipids are important because they serve as energy source, as well as a storage for energy in the form of fat cells. They also have a major cellular function as structural components in cell membranes. These membranes in association with carbohydrates and proteins regulate the flow of water, ions, and other molecules into and out of the cells. Hormone steroids and prostaglandins are chemical messengers between body tissues. Vitamins A, D, E, and K are lipid soluble and regulate critical biological processes; other lipids add in vitamin absorption and transportation. Lipids act as a shock absorber to protect vital organs and insulate the body from temperature extremes.

8.15 Proteins

Proteins are very large molecules composed of basic units called amino acids. Proteins contain carbon, hydrogen, oxygen, nitrogen, and sulphur. Protein molecules are formed by one or more twisted and folded strands of amino acids. Proteins are highly complex molecules that are actively involved in the most basic and important aspects of life.

Proteins are highly complex substance that are present in all living organisms. Proteins are of great nutritional value and are directly involved in the chemical processes essential for life. The term *protein*, is derived from the Greek word prōteios, meaning “holding first place.” Proteins are species-specific; that is, the proteins of one species differ from those of another species. They are also organ-specific; for instance, within a single organism, muscle proteins differ from those of the brain and liver.

Sources

Milk, milk products, eggs, beans and most legumes, grains, nuts, seeds and vegetables are the source of proteins

8.16 Classification of Proteins

Protein molecules are large, complex molecules formed by one or more twisted and folded strands of amino acids. Each amino acid is connected to the next amino acid by covalent bonds

8.16.1 Primary (first level) – Protein structure is a sequence of amino acids in a chain.

8.16.2 Secondary (secondary level) – Protein structure is formed by folding and twisting of the amino acid chain.

8.16.3 Tertiary (third level) – Protein structure is formed when the twists and folds of the secondary structure fold again to form a larger three-D structure.

8.16.4 Quaternary (fourth level) – Protein structure is a protein consisting of more than one folded amino acid chain.

Proteins can bond with other organic compounds and form “mixed” molecules. For example, glycoproteins embedded in cell membranes are proteins with sugars attached. Lipoproteins are lipid-protein combinations.

8.17 Protein Metabolism

The main sources of amino acids for the human body are the proteins in our diet, the non-essential amino acids synthesized by the liver plus the amino acids that come from the body protein, which are being constantly degraded and resynthesized.

Protein digestion begins in the stomach, where the action of gastric juice hydrolyzes about 10% of the peptide bonds. Gastric juice is a mixture of water (more than 99%), inorganic ions, hydrochloric acid, and various enzymes and other proteins. The pain of a gastric ulcer is at least partially due to irritation of the ulcerated tissue by acidic gastric juice.

The hydrochloric acid (HCl) in gastric juice is secreted by glands in the stomach lining. The pH of freshly secreted gastric juice is about 1.0, but the contents of the stomach may raise the pH to between 1.5 and 2.5. HCl helps to **denature food proteins**; that is, it unfolds the protein molecules to expose their chains to more efficient enzyme action. The principal digestive component of gastric juice is pepsinogen, an inactive enzyme produced in cells located in the stomach wall. When food enters the stomach after a period of fasting, pepsinogen is converted to its active form—pepsin—in a series of steps initiated by the drop in pH. Pepsin catalyzes the hydrolysis of peptide linkages within protein molecules. It has a fairly broad specificity but acts preferentially on linkages involving the aromatic amino acids tryptophan, tyrosine, and phenylalanine, as well as methionine and leucine. Protein digestion is completed in the small intestine.

Amino Acids pool

Once the proteins in the diet have been hydrolyzed, the free amino acids join the nonessential amino acid synthesized in the liver and the amino acids recycled from the body's own proteins, constituting the **amino acid pool** now available for metabolic processes. Most of the amino acid pool is used for the synthesis of protein and other nitrogen-containing compounds such as DNA bases, neurotransmitters, hormones, etc. Under certain metabolic situations, amino acids can also be used as a source of energy by the body. It is worth mentioning that the human body cannot store amino acids. If the amino acids in the amino acid pool are not used for biological processes, they are degraded and the nitrogen excreted in the urine as urea. Once the protein has been hydrolyzed and amino acids recycled, these amino acids are added to the amino acid pool for further utilization.

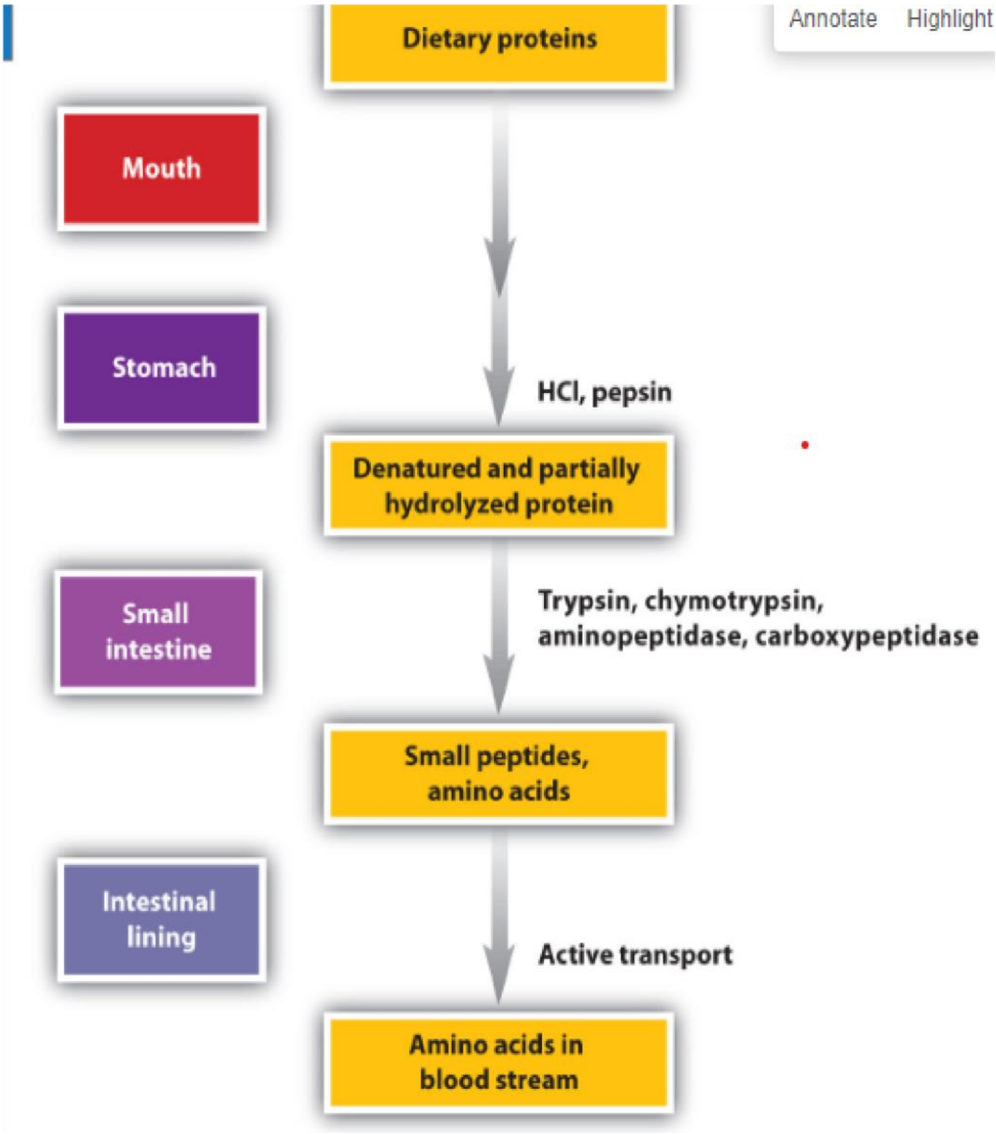


Figure. *The principal events and Sites of Protein Digestion*

8.18 Complete and Incomplete Proteins

Amino acids are classified into two groups namely: essential amino acids and nonessential amino acids

ESSENTIAL AMINO ACIDS

- Essential amino acids cannot be made by the body. As a result, they must come from food.
- The 9 essential amino acids are: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

NONESSENTIAL AMINO ACIDS

Nonessential means that our bodies produce an amino acid, even if we do not get it from the food we eat. Nonessential amino acids include: alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine.

Based on this classification of amino acids, proteins can also be classified as either complete or incomplete.

Complete proteins provide adequate amounts of all nine essential amino acids. Animal proteins such as meat, fish, milk, and eggs are good examples of complete proteins.

Incomplete proteins do not contain adequate amounts of one or more of the essential amino acids. For example, if a protein doesn't provide enough of the essential amino acid leucine it would be considered incomplete. Leucine would be referred to as the limiting amino acid, because there is not enough of it for the protein to be complete. Most plant foods are incomplete proteins, with a few exceptions such as soy.

Importance of proteins

Proteins are essential biomolecules that are critical to life and to perform various activities. Some of the important biological roles of proteins are:

> Many proteins act as catalysts that enhance the rate of chemical reactions in various metabolic pathways.
>
> The fibrous proteins are a component of various tissues holding the skeletal elements together like collagen, which is a structural unit of connective tissues.
>
> The nucleoproteins serve as carriers of genetic characters and hence govern the inheritance of traits.
>
> Proteins also perform transport functions that regulate the transport of many compounds in and out of the cells and accumulate inside at much higher concentrations than expected from diffusion alone.
>
> Various protein hormones regulate the growth of plants and animals, besides controlling many other physiological functions.

Blood plasma has multiple soluble proteins that can be used for the treatment of shock produced by severe injuries and operations.

Interferons are regulatory glycoproteins produced by many eukaryotic cells in response to virus infection, endotoxins, antigenic stimuli, and many parasitic organisms.

Peptides from humans called defensins are antibiotic in nature.

8.19 Enzymes

The majority of enzymes are proteins with catalytic capabilities crucial to perform different processes. Metabolic processes and other chemical reactions in the cell are carried out by a set of enzymes that are necessary to sustain life**.** Enzymes can be defined as, biological polymers that catalyze biochemical reactions. The macromolecular components of all enzymes consist of protein, except in the class of RNA catalysts called ribozymes. The word ribozyme is derived from the ribonucleic acid enzyme. Many ribozymes are molecules of ribonucleic acid, which catalyze reactions in one of their own bonds or among other RNAs.

Enzymes are found in all tissues and fluids of the body. Catalysis of all reactions taking place in metabolic pathways is carried out by intracellular enzymes. The biological processes that occur within all living organisms are chemical reactions, and most are regulated by enzymes. Without enzymes, many of these reactions would not take place at a perceptible rate. Enzymes catalyze all aspects of cell metabolism. This includes the digestion of food, in which large nutrient molecules (such as proteins, carbohydrates, and fats) are broken down into smaller molecules; the conservation and transformation of chemical energy; and the construction of cellular macromolecules from smaller precursors. Many inherited human diseases, such as albinism and phenylketonuria, result from a deficiency of a particular enzyme.

Enzymes also have valuable industrial and medical applications. The leavening of bread, curdling of cheese. Enzymes have assumed an increasing importance in industrial processes that involve organic chemical reactions. The uses of enzymes in medicine include killing disease-causing microorganisms, promoting wound healing, and diagnosing certain diseases.

8.19.1 Enzymes Classification

According to the International Union of Biochemists (I U B), enzymes are divided into six functional classes and are classified based on the type of reaction in which they are used to catalyze. The six kinds of enzymes are hydrolases, oxidoreductases, lyases, transferases, ligases and isomerases.

Listed below is the classification of enzymes discussed in detail.

Types	**Biochemical Property**
Oxidoreductases	The enzyme Oxidoreductase catalyzes the oxidation reaction where the electrons tend to travel from one form of a molecule to the other.
Transferases	The Transferases enzymes help in the transportation of the functional group among acceptors and donor molecules.
Hydrolases	Hydrolases are hydrolytic enzymes, which catalyze the hydrolysis reaction by adding water to cleave the bond and hydrolyze it.
Lyases	Adds water, carbon dioxide or ammonia across double bonds or eliminate these to create double bonds.
Isomerases	The Isomerases enzymes catalyze the structural shifts present in a molecule, thus causing the change in the shape of the molecule.
Ligases	The Ligases enzymes are known to charge the catalysis of a ligation process.

Importance of Enzymes

Enzymes serve as catalysts for biochemical reactions inside cells. Enzymes thus play an important role in controlling cellular metabolism. Enzymes play an increasingly important role in medicine. The enzyme thrombin is used to promote the healing of wounds. Other enzymes are used to diagnose certain kinds of disease, to cause the remission of some forms of leukemia—a disease of the blood-forming organs—and to counteract unfavorable reactions in people who are allergic to penicillin. The enzyme lysozyme, which destroys cell walls, is used to kill bacteria. Enzymes have also been investigated for their potential to prevent tooth decay and to serve as anticoagulants in the treatment of thrombosis, a disease characterized by the formation of a clot, or plug, in a blood vessel.

Enzymes may eventually be used to control enzyme deficiencies and abnormalities resulting from diseases.

It might also be noted in passing that enzymes are used in industrial processes involving the preparation of certain chemical compounds and the tanning of leather. They also are valuable in analytical procedures involving the detection of very small quantities of specific substances. Enzymes are necessary in various food-related industries, including cheese making and the baking of bread. Enzymes also may be used to clean clothes. For some industrial uses of enzymes.

A large protein enzyme molecule is composed of one or more amino acid chains called polypeptide chains. The amino acid sequence determines the characteristic folding patterns of the protein's structure, which is essential to enzyme specificity. If the enzyme is subjected to changes, such as fluctuations in temperature or pH, the protein structure may lose its integrity (denature) and its enzymatic ability. Denaturation is sometimes, but not always, reversible.

Bound to some enzymes is an additional chemical component called a cofactor, which is a direct participant in the catalytic event and thus is required for enzymatic activity. A cofactor may be either a coenzyme—an organic molecule, such as a vitamin—or an inorganic metal ion; some enzymes require both. A cofactor may be either tightly or loosely bound to the enzyme. If tightly connected, the cofactor is referred to as a prosthetic group.

8.20 Vitamins

Vitamins are heterogeneous group of organic molecules that are needed in small quantities for normal growth, reproduction, and homeostasis, but that the human body is unable to synthesize in adequate amounts. **Vitamins** are organic substances that are generally classified as either fat soluble or water soluble. Fat-soluble vitamins (vitamin A, vitamin D, vitamin E, and vitamin K) dissolve in fat and tend to accumulate in the body. Water-soluble vitamins (vitamin C and the B-complex vitamins, such as vitamin B6, vitamin B12, and folate) must dissolve in water before they can be absorbed by the body, and therefore cannot be stored. Any water-soluble vitamins unused by the body is primarily lost through urine.

Classification of Vitamins

Vitamins are classified according to their solubility.

Fat soluble Vitamins

- Fat-soluble vitamins are stored in the body's liver, fatty tissue, and muscles. The four fat-soluble vitamins are vitamins A, D, E, and K. These vitamins are absorbed more easily by the body in the presence of dietary fat.

Water-soluble vitamins

Water-soluble vitamins are not stored in the body. The nine water-soluble vitamins are vitamin C and all the B vitamins. Any leftover or excess amounts of these leave the body through the urine. They have to be consumed on a regular basis to prevent shortages or deficiencies in the body. The exception to this is vitamin B12, which can be stored in the liver for many years.

Sources of fat-soluble vitamins

Fish, meat, dairy products, cheeses, eggs, liver, carrots, spinach, red and yellow peppers, sweet potatoes, leafy greens, and pumpkin.

Sources of water-soluble vitamins

Whole grains, meats, fish, yeast, nuts, liver, eggs, yogurt, milk fruits and some vegetables.

Importance of vitamins

These vitamins are essential for a fully functioning metabolism. The main function of the B vitamins is to help body metabolize carbohydrates, proteins, and fats, and to use the stored energy in food. Thiamine (B-1), for example, helps the body cells convert carbohydrates into energy source and reduces nerve, gastrointestinal, and heart diseases. Riboflavin (B2), contributes to better digestive health, helps in iron absorption and helps in the development and growth of the fetus. Vitamin A (betacarotene) are eessential for vision, the immune system, and reproduction. Also essential for the growth and building of body tissues and for the formation of skin and bones. It also helps reduce the risk of cancer and promotes healthy skin and hair. Vitamin C is a powerful antioxidant that destroy free radicals, which damage cell membrane. Vitamin C aids in iron absorption, particularly non- haem iron.

Vitamins have diverse biochemical functions. Vitamin A acts as a regulator of cell and tissue growth and differentiation. Vitamin D provides a hormone-like function, regulating mineral metabolism for bones and other organs. The B complex vitamins function as enzyme cofactors (coenzymes) or the precursors for them. Vitamins C and E function as antioxidants. Both deficient and excess intake of a vitamin can potentially cause clinically significant illness, although excess intake of water-soluble vitamins is less likely to do so.

Vitamin**s** are necessary in small quantities for normal health and growth in higher forms of animal life. Vitamins are distinct in several ways from other biologically important compounds such as proteins, carbohydrates, and lipids. Although these latter substances also are indispensable for proper bodily functions, almost all of them can be synthesized by animals in adequate quantities. Vitamins, on the other hand, generally cannot be synthesized in amounts sufficient to meet bodily needs and therefore must be obtained from the diet or from some synthetic source. For this reason, vitamins are called essential nutrients. Vitamins also differ from the other biological compounds in that relatively small quantities are needed to complete their functions. In general functions are of a catalytic or regulatory nature, facilitating or controlling vital chemical reactions in the body’s cells. If a vitamin is absent from the diet or is not properly absorbed by the body, a specific deficiency disease may develop.

Sample Question; What are enzymes, classify the enzymes and the functions of the enzymes?

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Gregory Thompson MD & Kathleen Romito MD & Rhonda O'Brien MS, RD, CDE O'Connor PhD, RD, Current as of: March 1, 2023, Carbohydrates, Proteins, Fats, and Blood Sugar

Chapter 9

Blood Chemistry Metabolism

Objectives

Blood chemistry studies give important information about how well a person's kidneys, liver, and other organs are working. An abnormal amount of a substance in the blood can be a sign of disease or side effect of treatment.

Biochemistry combines biology and chemistry to study living matter. It powers scientific and medical discovery in fields such as pharmaceuticals, forensics and nutrition. With biochemistry, students will study chemical reactions at a molecular level.

Introduction

Metabolism is the chemical reactions in the body's cells that change food into energy. Specific proteins in the body control the chemical reactions of metabolism. Thousands of metabolic reactions happen at the same time, all regulated by the body to keep cells healthy and working. After taking food digestive system uses enzymes to:

Break proteins down into amino acids.

Turn fats into fatty acids.

Turn carbohydrates into simple sugars (for example, glucose).

The body can use sugar, amino acids, and fatty acids as energy sources when needed. These compounds are absorbed into the blood, which carries them to the cells.

After they enter the cells, other enzymes act to speed up or regulate the chemical reactions involved with "metabolizing" these compounds. During these processes, the energy from these compounds can be released for use by the body or being stored in body tissues, especially the liver, muscles, and body fat.

Metabolism is a balancing act involving two kinds of activities that go on at the same time:

building up body tissues and energy stores (called anabolism) breaking down body tissues and energy stores to get more fuel for body functions (called catabolism)

Anabolism or constructive metabolism, is all about building and storing. It supports the growth of new cells, the maintenance of body tissues, and the storage of energy for future use. In anabolism, small molecules change into larger, more complex molecules of carbohydrates, protein, and fat.

Catabolism, or destructive metabolism, is the process that produces the energy needed for all activity in the cells. Cells break down large molecules (mostly carbs and fats) to release energy. This provides fuel for anabolism, heats the body, and enables the muscles to contract and the body to move.

As complex chemical units break down into more simple substances, the body releases the waste products through the skin, kidneys, lungs, and intestines.

9.1 Regulators of Metabolism

Several hormones of the endocrine system help control the rate and direction of metabolism. Thyroxine, a hormone made and released by the thyroid gland, plays a key role in determining how fast or slow the chemical reactions of metabolism go in a person's body.

Another gland, the pancreas, secretes hormones that help determine whether the body's main metabolic activity at any one time are anabolic or catabolic. For example, more anabolic activity usually happens after eating a meal. That's because eating increases the blood's level of glucose — the body's most important fuel. The pancreas senses this increased glucose level and releases the hormone insulin, which signals cells to increase their anabolic activities.

Metabolism is a complicated chemical process. So, it's not surprising that many people think of it in its simplest sense: as something that influences how easily our bodies gain or lose weight. That's where calories come in.

A calorie is a unit that measures how much energy a particular food provides to the body.

A chocolate bar has more calories than an apple, so it provides the body with more energy — and sometimes that can be too much of a good thing. Just as a car stores gas in the gas tank until it is needed to fuel the engine, the body stores calories — primarily as fat. If you overfill a car's gas tank, it spills over onto the pavement. Likewise, if a person eats too many calories, they "spill over" in the form of excess body fat.

The number of calories someone burns in a day is affected by how much that person exercises, the amount of fat and muscle in his or her body, and the person's basal metabolic rate (BMR).

BMR is a measure of the rate at which a person's body "burns" energy, in the form of calories, while at rest.

The BMR can play a role in a person's tendency to gain weight. For example, someone with a low BMR (who therefore burns fewer calories while at rest or sleeping) will tend to gain more pounds of body fat over time than a similar-sized person with an average BMR who eats the same amount of food and gets the same amount of exercise.

BMR can be affected by a person's genes and by some health problems. It's also influenced by body composition — people with more muscle and less fat generally have higher BMRs. But people can change their BMR in certain ways. For example, a person who exercises more not only burns more calories, but becomes more physically fit, which increases his or her BMR.

9.2 Blood test for Metabolism

The comprehensive metabolic panel (CMP) is a group of blood test that gives doctors information about the body's fluid balance, levels of electrolytes like sodium and potassium, and how well the kidneys and liver are working.

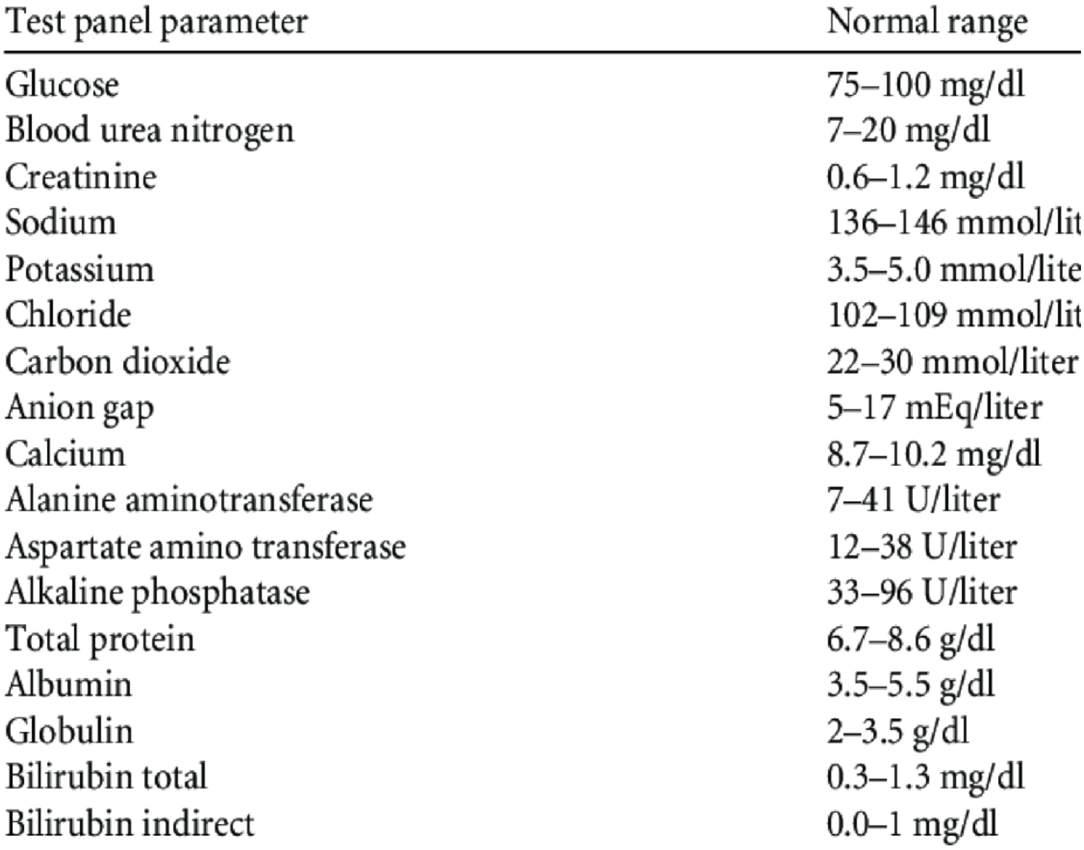
A comprehensive metabolic panel (CMP) is a routine blood test that measures 14 different substances in a sample of your blood. It provides important information about your metabolism (how your body uses food and energy) and the balance of certain chemicals in your body.

Glucose, Calcium, serum electrolytes, proteins, enzymes ALT, AST, ALP, Bilirubin , Blood Urea Creatinine.

9.3 Normal values OR reference ranges of Blood tests

A reference range is a set of numbers that are the high and low ends of the range of results that are considered to be normal. The ranges are based on the test results from large groups of healthy people. A test may have different reference ranges for different groups of people. Reference values are the values expected for a healthy person. They are sometimes called “normal” values. By comparing test results with reference values, health care provider can see if any of test results fall outside the range of expected values. A patient's test values should be interpreted based on the reference value.

Table: reference ranges of chemical parameters,



Test panel parameter	Normal range
Glucose	75–100 mg/dl
Blood urea nitrogen	7–20 mg/dl
Creatinine	0.6–1.2 mg/dl
Sodium	136–146 mmol/lit
Potassium	3.5–5.0 mmol/lite
Chloride	102–109 mmol/lit
Carbon dioxide	22–30 mmol/liter
Anion gap	5–17 mEq/liter
Calcium	8.7–10.2 mg/dl
Alanine aminotransferase	7–41 U/liter
Aspartate amino transferase	12–38 U/liter
Alkaline phosphatase	33–96 U/liter
Total protein	6.7–8.6 g/dl
Albumin	3.5–5.5 g/dl
Globulin	2–3.5 g/dl
Bilirubin total	0.3–1.3 mg/dl
Bilirubin indirect	0.0–1 mg/dl

Interpretation of results of blood chemistry parameters

9.3.1 Sugar

A blood glucose test is used to find out if blood sugar levels are in a healthy range. It is often used to help diagnose and monitor diabetes. It is a main source of energy. A hormone called insulin helps move glucose from bloodstream into cells.

Too much or too little glucose in the blood can be a sign of a serious medical condition. High blood glucose levels (hyperglycaemia) may be a sign of diabetes mellitus, a disorder that can cause serious, long-term health conditions.

High blood sugar may also be caused by other conditions that can affect insulin or glucose levels in your blood, such as problems with pancreas or adrenal glands.

Low blood glucose levels (hypoglycaemia) are common among people with type 1 diabetes and people with type 2 diabetes who take certain diabetes medicines. Certain conditions, such as liver disease, may cause low levels of blood glucose in people without diabetes, but this is uncommon. Without treatment, severe low blood sugar can lead to major health problems, including seizures and brain damage.

9.3.2 Cholesterol Levels

A cholesterol test is a blood test that measures the amount of cholesterol and certain fats in blood. Cholesterol is a waxy, fat-like substance that's found in blood and every cell of the body. Some cholesterol is needed to keep cells and organs healthy. There are two main types of cholesterol: low-density lipoprotein (LDL), or "bad" cholesterol, and high-density lipoprotein (HDL), or "good" cholesterol.

Too much LDL cholesterol in blood increases risk for coronary artery disease (CAD) and other heart diseases. High LDL levels can cause the buildup of a sticky substance called plaque in the arteries. Over time, plaque can narrow the arteries or fully block them. When this happens, parts of body don't get enough blood:

- If the blood flow to the heart is blocked, it can cause a **heart attack.**
- If the blood flow to the brain is blocked, it can cause a **stroke.**
- If the blood flow to the arms or legs is blocked, it can cause peripheral artery disease.

Other names for a cholesterol test: Lipid profile, Lipid panel.

9.3.3 Urea

Accumulation of high levels of urea in blood leads to dangerous medical condition called uremia. Uremia is a symptom of kidney failure. When the kidneys cannot filter waste properly, it can enter the bloodstream. Uremia is a medical emergency that requires urgent treatment. People with uremia may need to be hospitalized. It is not possible to treat uremia at home.

9.3.4 Uric acid

Uric acid is a chemical created when the body breaks down substances called purines. A high level of uric acid in the blood is called hyperuricemia. Hyperuricemia causes uric acid to clump together in sharp crystals. These crystals can settle in joints and cause gout, a very painful form of arthritis. They can also build up in kidneys and form kidney stones. Greater than normal levels of uric acid (hyperuricemia) may be due to: Acidosis, Alcohol (ethanol) consumption, Chemotherapy-related side effects, dehydration, diabetic ketoacidosis, excessive exercise.

9.3.5 Bilirubin Blood Test

Bilirubin is a yellowish substance made during your body's normal process of breaking down from old red blood cells. Bilirubin is found in bile,a fluid which liver makes that helps to digest food. If liver is damaged, bilirubin can leak out of liver and into blood. When too much bilirubin gets into the bloodstream, it can cause jaundice, a condition that causes skin and eyes to turn yellow. Signs of jaundice, along with a bilirubin blood test, can help health care provider find out liver diseases. High bilirubin levels may mean liver isn't working right. Other things may cause higher than normal bilirubin levels, such as certain medicines and foods or strenuous exercise.

9.3.6 Alkaline Phosphatase (ALP)

An alkaline phosphatase (ALP) test measures the amount of ALP. ALP is an enzyme found in many parts of the body. Each part of the body produces a different type of ALP. Most ALP is found in liver, bones, kidneys, and digestive system.

Abnormal levels of ALP in blood may be a sign of a wide range of health conditions, including liver disease, bone disorders, and chronic kidney disease. But an alkaline phosphatase test alone can't identify the source of ALP in blood, so other tests are usually needed to make a diagnosis.

9.3.7 Serum Acid Phosphatase (AP)

Traditionally, the serum prostatic acid phosphatase has been thought to originate in the prostatic cancer cell and has been used to stage the disease. Until recently, elevated serum values have been accepted as an indication of extra prostatic disease, and were thought to rule out lesions confined to the prostate. Total acid phosphatase (AP) activity may be useful when evaluating for prostate cancer, Paget's disease, hyperparathyroidism with skeletal involvement, and Gaucher's disease since elevations in AP activity occur in these conditions.

9.3.8 Creatinine

This test measures creatinine levels in a sample of blood and /or urine. Creatinine is a normal waste product in body. It's made when muscles and some of the muscle tissue breaks down.

Normally, kidneys filter creatinine from blood and remove it from your body in urine. If there is a problem with kidneys, creatinine can build up in blood and less may be released in urine. High blood creatinine level may be a sign of Kidney disease or injury, including infection, poor blood flow to the kidneys, a blockage in the urinary system, or kidney failure. High level of creatinine can be due to condition that affects kidneys, such as heart failure or diabetes.

High blood creatinine levels don't always due to kidney problem. They may be caused by dehydration, muscle disorders and injuries, muscular dystrophy, intense exercise, or a diet high in meat. Certain health problems in pregnancy can also cause increases in creatinine.

Low levels of creatinine may be a sign of malnutrition or a condition that causes muscles to get smaller, such as a long illness, a nerve disorder, or muscle loss from aging. Serious liver disease can also lead to low levels. Low levels of blood creatinine aren't common.

9.3.9 Total Protein

Proteins are important building blocks of all cells and tissues. Proteins are necessary for body’s growth, development, and health. Blood contains albumin and globulin. Albumin proteins keep fluid from leaking out of blood vessels. Globulin proteins play an important role in immune system or defense system of the body. Elevated total protein may indicate inflammation or infections, such as viral hepatitis B or C, or HIV, bone marrow disorders, such as multiple myeloma or Waldenstrom’s disease. Low total protein may indicate bleeding, liver disorder, kidney disorder, such as a nephrotic disorder or glomerulonephritis, malnutrition

9.3.10 Serum Glutamic-Pyruvic Transaminase or ALT (Alanine aminotransferase)

It is an enzyme found mostly in the liver. An ALT test measures the amount of ALT in the blood. When liver cells are damaged, they release ALT into the bloodstream. High levels of ALT in blood may be a sign of a liver injury or disease. Some types of liver disease cause high ALT levels before symptoms of the disease. So, an ALT blood test may help diagnose certain liver diseases early. In general, high levels of ALT may be a sign of liver damage from hepatitis, infection, cirrhosis, liver cancer, or other liver diseases. The damage may also be from a lack of blood flow to the liver or certain medicines or poisons.

9.3.11 serum glutamic oxaloacetic transaminase test or AST Test

AST (aspartate aminotransferase) is an enzyme that is found mostly in the liver, but it's also in muscles and other organs in your body. When cells that contain AST are damaged, they release the AST into blood. An AST blood test measures the amount of AST in blood. The test is commonly used to help diagnose liver damage or disease.

High levels of AST in the blood may be a sign of hepatitis, cirrhosis, mononucleosis, or other liver diseases. High AST levels may also be a sign of heart problems or pancreatitis.

9.3.12 Thymol turbidity test

Thymol turbidity, laboratory test for the nonspecific measurement of globulins, a group of blood proteins that appear in abnormally high concentrations in association with a wide variety of diseased states, notably those affecting the liver. With this test it should be possible to distinguish between hepatitis, obstructive jaundice and hepatic cancer.

Sample Question; Define hyper and hypoglycemia, what is a hormone and its funtions?

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Chapter 10

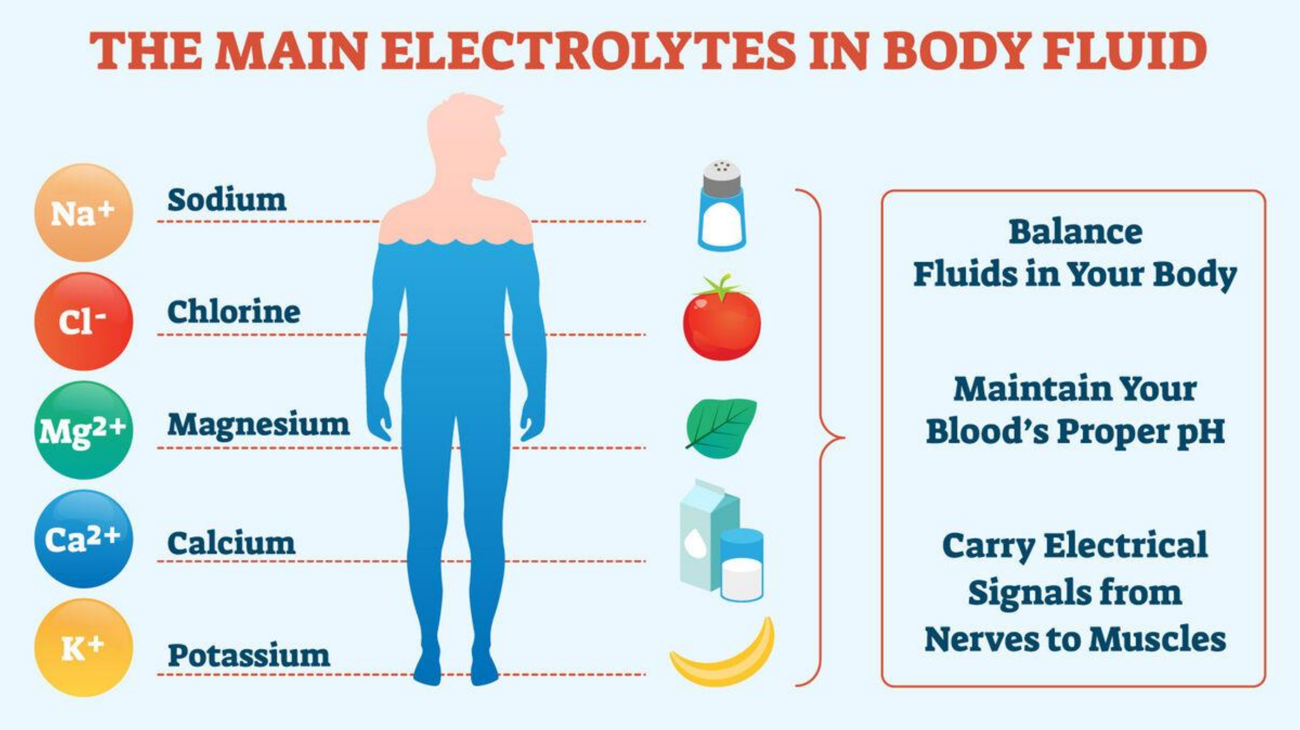
Electrolytes and water

Objectives

After studying this chapter students will be able to understand basic concepts in water and electrolyte metabolism. Students will learn about fluid and electrolyte balance which refers to a balance of intracellular volume (ICV) and extracellular volume. (ECV) and distribution of electrolytes.

10.1 Important Electrolytes in the human body

Electrolytes are minerals that have an electric charge when dissolved in water or body fluids, including blood. The electric charge can be positive or negative. Electrolytes are present in blood, urine, tissues, and other body fluids. Electrolytes come from food and fluids. In nutrition, the term refers to essential minerals in blood, sweat, and urine. When these minerals dissolve in a fluid, they form electrolytes — positive or negative ions in metabolic processes. These electrolytes are required for various bodily processes, including proper nerve and muscle function, maintaining acid-base balance and keeping individuals hydrated.



Electrolytes are important because they help:

Balance the amount of water in the body
Balance the body's acid/base (pH) level
Move nutrients into cells
Move wastes out of cells
Support muscle and nerve function
Keep heart rate and rhythm steady
Keep blood pressure stable
Keep bones and teeth healthy

10.2 Significant electrolytes in the body

The main electrolytes include

- Bicarbonate helps maintain the acid and base balance (pH). It also plays an important role in moving carbon dioxide through the bloodstream.
- Calcium is most often associated with healthy bones and teeth, although it also plays an important role in blood clotting, helping muscles to contract, and regulating normal heart rhythms and nerve functions.

- Chloride, also helps control the amount of fluid in the body. In addition, it helps maintain healthy blood volume and blood pressure.
- Magnesium, which helps muscles, nerves, and heart work properly. It also helps control blood pressure and blood glucose (blood sugar).
- Phosphate, which works together with calcium to build strong bones and teeth.
- Potassium, helps cells, heart, and muscles work properly.
- Sodium, helps control the amount of fluid in the body. It also helps nerves and muscles work properly.

These electrolytes are obtained from foods and fluids.

10.3 Electrolyte imbalance

These electrolytes can be imbalanced, leading to high or low levels. High or low levels of electrolytes disrupt normal bodily functions and can lead to life threatening complications.

The names of the different types of electrolyte imbalances are

Electrolyte	Too low	Too high
Bicarbonate	Acidosis	Alkalosis
Calcium	Hypocalcemia	Hypercalcemia

Electrolyte	Too low	Too high
Chloride	Hypochloremia	Hyperchloremia
Magnesium	Hypomagnesemia	Hypermagnesemia
Phosphate	Hypophosphatemia	Hyperphosphatemia
Potassium	Hypokalemia	Hyperkalemia
Sodium	Hyponatremia	Hypernatremia

10.3.1Sodium

Sodium, an osmotically active cation, is one of the essential electrolytes in the extracellular fluid. It is responsible for maintaining the extracellular fluid volume and regulating the membrane potential of cells. Sodium is exchanged along with potassium across cell membranes as part of active transport.

Sodium regulation occurs in the kidneys. The proximal tubule is where the majority of sodium reabsorption takes place. In the distal convoluted tubule, sodium undergoes reabsorption. Sodium transport occurs via sodium-chloride symporters, controlled by the hormone aldosterone.

Among the electrolyte disorders, hyponatremia is the most frequent. Hyponatremia is diagnosed when the serum sodium level is less than 135 mmol/l. Hyponatremia has neurological manifestations. Patients may present with headaches, confusion, nausea, and delirium. Hypernatremia occurs when serum sodium levels are greater than 145 mmol/l. Symptoms of hypernatremia include tachypnea, sleeping difficulty, and restlessness. Rapid sodium corrections can have severe consequences like cerebral edema.

10.3.2 Potassium

Potassium is a mineral that is essential for all of the body's functions. It is responsible for many crucial roles in the body, including:

- Maintaining normal blood pressure.
- Transmitting nerve signals between organs.
- Controlling muscle contractions.
- Ensuring optimal water balance within the system.
- Balancing pH in the body between acidity and alkalinity.

Potassium is mainly an intracellular ion. The sodium-potassium adenosine triphosphatase pump is primarily responsible for regulating the homeostasis between sodium and potassium, which pumps out sodium in exchange for potassium, which moves into the cells. In the kidneys, the filtration of potassium takes place at the glomerulus. Potassium reabsorption occurs at the proximal convoluted tubule and thick ascending loop of Henle. Potassium secretion occurs at the distal convoluted tubule. Aldosterone increases potassium secretion. Potassium channels and potassium-chloride cotransporters at the apical tubular membrane also secrete potassium Potassium derangements may result in cardiac arrhythmias. Hypokalemia occurs when serum potassium levels are under 3.6 mmol/l. The features of hypokalemia include weakness, fatigue, and muscle twitching. Hypokalemic paralysis is generalized body weakness that can be either familial or sporadic. Hyperkalemia occurs when the serum potassium levels are above 5.5 mmol/l, which can result in arrhythmias. Muscle cramps, muscle weakness, rhabdomyolysis, and myoglobinuria may be presenting signs and symptoms of hyperkalemia.

10.3.3 Calcium

Calcium has a significant physiological role in the body. It is involved in skeletal mineralization, contraction of muscles, the transmission of nerve impulses, blood clotting, and secretion of hormones. The diet is the predominant source of calcium. Calcium is a predominately extracellular cation. Calcium absorption in the intestine is primarily controlled by the hormonally active form of vitamin D, which is 1,25dihydroxy vitamin D3. Parathyroid hormone also regulates calcium secretion in the distal tubule of the kidneys. Calcitonin acts on bone cells to decrease calcium levels in the blood.

Hypocalcemia diagnosis requires checking the serum albumin level to correct for total calcium. Hypocalcemia is diagnosed when the corrected serum total calcium levels are less than 8.8 mg/dl, as in vitamin D deficiency or hypoparathyroidism. Checking serum calcium levels is a recommended test in post-thyroidectomy patients. Hypercalcemia is when corrected serum total calcium levels exceed 10.7 mg/dL, as seen with primary hyperparathyroidism. Humoral hypercalcemia presents in malignancy, primarily due to PTHrP secretion.

10.3.4 Iron (Fe)

Iron is a vital trace element for humans, as it plays a crucial role in oxygen transport, oxidative metabolism, cellular proliferation, and many catalytic reactions. To be beneficial, the amount of iron in the human body needs to be maintained within the ideal range. Iron metabolism is one of the most complex processes involving many organs and tissues, the interaction of which is critical for iron homeostasis. No active mechanism for iron excretion exists. Therefore, the amount of iron absorbed by the intestine is tightly controlled to balance the daily losses.

The two most common iron states are the divalent ferrous (Fe^{2+}) and the trivalent ferric (Fe^{3+}). Within the human body, iron is required as a cofactor for many hemoproteins and non-haem iron-containing proteins. Hemoproteins include hemoglobin and myoglobin that are responsible for oxygen binding and transport, catalase and peroxidase enzymes, which take part in oxygen metabolism, and cytochromes, which are involved in electron transport and mitochondrial respiration. Non-haem iron containing proteins also have crucial functions, as these are used in DNA synthesis, cell proliferation and differentiation, gene regulation, drug metabolism, and steroid synthesis.

The liver has an important storing and regulatory function. Through the production of the hormone hepcidin, it controls the release of iron from enterocytes and macrophages into the circulation. Therefore, this permits the fine regulation and the maintenance of plasma iron concentrations within physiological levels.

10.3.5 Distribution of body fluids

The fluids of the body are primarily composed of water, which in turn contains a multitude of substances. One such group of substances includes electrolytes such as sodium, potassium, magnesium, phosphate, chloride, etc. Another group includes metabolites, such as oxygen, carbon dioxide, glucose, urea, etc. A third important group of substances contained within the water of our body, which includes proteins, most of which are vital for our existence. Examples of proteins include coagulation factors, immunoglobulins, albumin, and various hormones.

For the average 70 kg man, 60% of the total body weight is comprised of water, equaling 42L. The body's fluid separates into two main compartments: Intracellular fluid volume (ICFV) and extracellular fluid volume (ECFV).

- Of the 42L of water found in the body, two-thirds of it is within the intracellular fluid (ICF) space, which equates to 28L.
- The extracellular fluid volume ECFV is present in two spaces: The interstitial fluid volume (ISFV) and the plasma volume (PV). One-third of the total body water is the ECFV, which is equivalent to 14L. Out of the extracellular fluid volume, 75% or 10.5L of the volume is present in the interstitial space, and 25% of that water is in the plasma, which is equivalent to 3.5L

Intracellular and extracellular fluids are separated into compartments by semipermeable membranes, and the transport of fluid and ions is maintained by channels in the cell membrane. Each compartment contains different concentrations of ions and osmolar molecules. The relative charge and osmolarity are maintained rigorously by the transport of water and substances between compartments. Hypernatremia, hyponatremia, and oedema are the clinical conditions arising from disturbances in the maintenance of osmolarity of the body fluid compartments.

10.4 Dehydration and oedema

Fluid regularly leaks into body tissues from the blood. The lymphatic system is a network of tubes throughout the body that drains this fluid (called lymph) from tissues and empties it back into the bloodstream. Fluid retention (oedema) occurs when the fluid isn’t removed from the tissues.

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The 2 broad categories of fluid retention include:

- generalised oedema – when swelling occurs throughout the body

- localised oedema – when particular parts of the body are affected.

The wide range of causes includes the body’s reaction to hot weather, a high salt intake, and the hormones associated with the menstrual cycle. However, it is symptomatic of serious medical conditions such as heart, kidney or liver disease. Edema, which occurs when the body retains too much fluid, commonly causes swelling and pain in the face, arms, legs, hands and feet.

Dehydration occurs when the body loses more water than it takes in. Vomiting, diarrhea, the use of drugs that increase urine excretion (diuretics), profuse sweating (for example, during heat waves, particularly with prolonged exertion), and decreased water intake can lead to dehydration.

The body is constantly losing water through breathing, sweating, and urinating. If water or fluid intake is not enough to replace this water loss, the condition is called dehydration.

Dehydration is particularly common among older people because their thirst center may not function as well as that in younger people. Therefore, some older people may not recognize that they are becoming dehydrated. Certain disorders such as diabetes mellitus, diabetes insipidus, and Addison disease can increase the excretion of urine and thereby lead to dehydration.
Dehydration in infants and children is also common because the amount of fluid lost during diarrhea or vomiting may represent a larger proportion of their body fluids than in older children and adults.

Symptoms of mild to moderate dehydration include,

- Thirst

- Reduced sweating
- Reduced skin elasticity
- Reduced urine production
- Dry mouth

In severe dehydration, the sensation of thirst may actually decrease and blood pressure can fall, causing light-headedness or fainting, particularly upon standing (a condition called orthostatic hypotension). If dehydration continues, shock and severe damage to internal organs, such as the kidneys, liver, and brain, occur. Brain cells are particularly susceptible to more severe levels of dehydration. Consequently, confusion is one of the best indicators that dehydration has become severe. Very severe dehydration can le

Sample Question; describe the distribution of water in the body?

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Chapter 11

Significance of qualitative analysis of urine

Objectives

Urine is used to detect and manage a wide range of disorders, such as urinary tract infections, kidney disease and diabetes. A urinalysis involves checking the appearance, concentration and content of urine. It will help students find problems that need treatment, including infections or kidney problems.

10.5 Significance of qualitative analysis of urine for, calcium, creatinine, urea, sugar, albumin and chloride

10.5.1 Significance of Analysis urinary Calcium

A calcium in urine test measures the amount of calcium in urine. If urine calcium levels are too high or too low, it may be a sign of kidney disease, kidney stones, bone disease, a parathyroid gland disorder, or other conditions.

The bulk of calcium ions (Ca++) discharged by body is excreted in the stool. However, there is small quantity of calcium that is normally excreted in urine. But it may increase depending up on the quantity of dietary calcium ingested. The 24-hour test is most often ordered to determine the function of the parathyroid gland, which maintains a balance between calcium and phosphorous by means of parathyroid hormone. Hyperparathyrpidism is a generalized disorder of calcium, phosphate and bone that results from increased secretion of parathyroid hormones and an increased excretion of urinary calcium. In hypoparathyrodism the urinary calcium is decreased. Some Interfering factors such as high sodium and magnesium intake, high milk intake and some drugs results in false positive test. Similarly, increased dietary phosphates, Alkaline urine and, Some drugs results in false negative test

10.5.2 Significance of analysis of urinary creatinine

Creatinine also a non-protein nitrogenous (NPN) waste product is produced from the breakdown of creatine and phosphocreatine and can also serve as an indicator of renal function. Creatine is synthesized in the liver, pancreas, and kidneys from the transamination of the amino acids arginine, glycine, and methionine. Creatine then circulates throughout the body and is converted to phosphocreatine by the process of phosphorylation in the skeletal muscle and brain. The majority of the creatinine is produced in the muscle. As a result, the concentration of plasma creatinine is influenced by the patient’s muscle mass. Compared to BUN, creatinine is less affected by diet and more suitable as an indicator of renal function.

The measurement of creatinine concentrations in plasma and urine samples illustrates the filtration capacity of the glomerulus, also known as the glomerular filtration rate (GFR.) Creatinine is produced endogenously within the body and is freely filtered by the glomerulus. These characteristics make creatinine a useful endogenous marker for creatinine clearance. If the GFR is decreased, as is in renal disease, creatinine clearance via the renal system is compromised. The reduced GFR will then lead to an increase in plasma creatinine concentration. The measurement of plasma alone should not be used to assess renal function. Plasma creatinine levels may not be affected until significant renal damage has occurred. In addition, a plasma creatinine level that is within normal reference range does not equate to a normal functioning renal system.

10.5.3 Significance of analysis of urinary urea

Urea is a product of protein metabolism. Amino acids derived from the breakdown of protein are deaminated to produce ammonia. Ammonia is then converted to urea via liver enzymes. Therefore, the concentration of urea is dependent on protein intake, the body's capacity to catabolize protein, and adequate excretion of urea by the renal system.

The body's dependency on the renal system to excrete urea makes it a useful analyte to evaluate renal function.

10.5.4 Significance of analysis of urine Sugar

Glucose, a monosaccharide, is the principal sugar in blood, serving the tissues as a major metabolic fuel. It is mainly the end- product of carbohydrate digestion, which provides energy for life process. The absence or lower production of insulin resulted in diabetes mellitus, which is characterized by an elevated blood glucose 39 levels (hyperglycemia) and accompanying glycosuria and may be accompanied by changes in fat metabolism. Glucose is the sugar most commonly found in the urine. Normally, urine does not contain a sufficient amount of sugar to react with any of the popular enzyme or reducing tests. When sugar appears in the urine, it shows the abnormality caused by disease diabetes mellitus. Hence urine sugar tests are extremely useful in monitoring the treatment of diabetes.

The presence of detectable amount of glucose in the urine is known as glycosuria. Normally almost all the glucose, which passes from the blood into the glomerular filtrate, is reabsorbed back into the circulation by the kidney tubules (proximal convoluted tubules). Usually less than 15 - 20 mg/dl (0.8 mmol) is excreted in the urine. But this amount cannot be detected by the routine laboratory tests. The term glycosuria is usually used to describe the presence of more than the normal amount (15- 20 mg /dl) of glucose in the urine. The occurrence of glucose in the urine is not normal if more than 15 - 20 mg/dl. The blood glucose concentration normally lies between 65 and 110 mg/dl. After a meal it may increase to 120 - 160 mg/dl. If the blood glucose concentration becomes too high (usually greater than 170 - 180 mg/dl), the excess glucose will not be reabsorbed into the blood and glucose start appearing in urine. The lowest blood glucose concentration that will result in glycosuria is termed as the renal threshold. The most common condition in which the renal threshold for glucose exceeds is diabetes mellitus.

10.5.5 Significance of urinary Albumin analysis

Albumin is a protein that is present in the blood. When the kidneys are working properly, only tiny amounts of albumin pass from the bloodstream into the urine. In kidney failure (the last stage of a slow process of decline in kidney function) large amounts of protein leak into the urine. A long time before this amount of damage, small changes in the kidney allow very small, but abnormal amounts of albumin to leak through, often as a result of having diabetes. Too little albumin is present to be detected by the usual simple urine test strip (sometimes called a protein dipstick). This is termed microalbuminuria because of the low but significant concentration of albumin in the urine, not because it is a smaller type of the protein. Microalbuminuria is usually simply called albuminuria.

An early morning or random sample of urine will be collected in which albumin and creatinine will be measured. The results are expressed as an albumin/creatinine ratio or ACR for short. A moderately increased ACR indicates an early phase of developing kidney disease. Very high values show that kidney disease is present in a more severe form. Very low values generally indicate that kidney function is normal if other tests of kidney function, e.g. the glomerular filtration rate, also show no abnormality.

10.5.6 Urine Chloride

Measuring levels of chloride ions in urine is sometimes useful in investigating an abnormally high or low level of chloride in the blood. The urine chloride assay is never requested on its own; it is always accompanied by the sodium assay. Changes in urine chloride levels usually reflect changes in urine sodium levels, except in the case of acid-base equilibrium disorder. Urine chloride levels are expressed in millimoles per day (mmol/d) for a 24-hour urine collection and millimoles per litre (mmol/L) for an isolated urination.

High levels of urine chloride may indicate dehydration, fasting, adrenal gland failure (Addison’s disease) or increased dietary salt intake. A high urine level of chloide may indicate dehydration, fasting, adrenal gland failure (Addison's disease) or increased dietary salt intake.

Sample question; Describe five of the anlytes measured in urine?

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