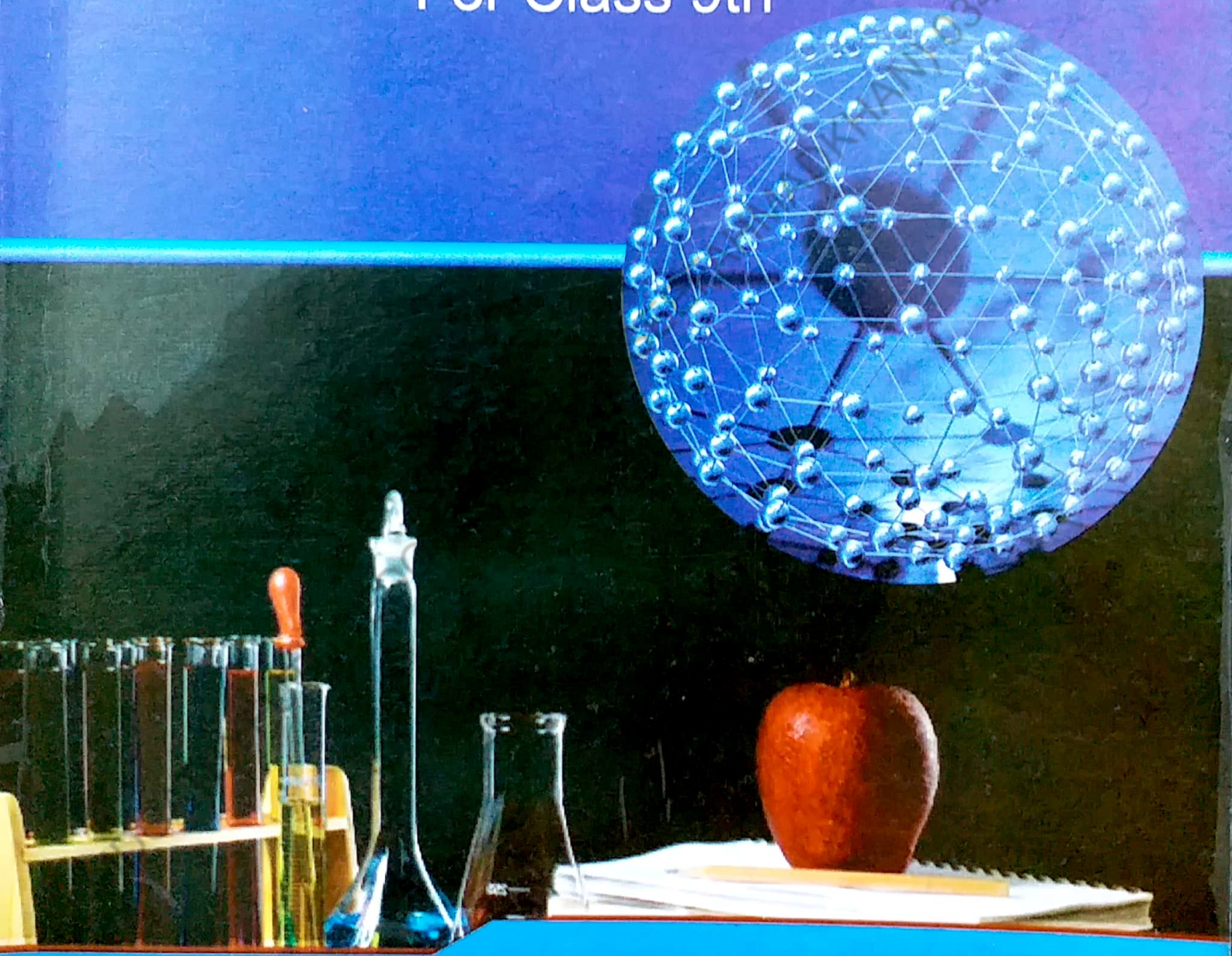
Chemistry

For Class 9th



Balochistan Textbook Board, Quetta.

بسم اللہ الرحمن الرحیم

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Chemistry 9

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Appeal,

Balochistan Textbook Board is a dedicated organization committed to undertake publication of quality textbooks in line with the curriculum. These books are the fruits of efforts by renowned educationists and experts. Despite our constant endeavours, chances of inadvertent mistakes cannot be ruled out, and there is always room for improvement. Therefore, we look forward to valuable suggestions to enhance the quality of the textbooks.

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Preface

With the beginning of new era, the need for reviewing and rewriting of syllabus was felt, so new curriculum for courses has been set by the Ministry of Education in 2006.

The new curriculum offers a radical shift from the traditional curriculum is based upon the multi text book system, creating the students being able to think independently, asking questions and looking for the answers at their own. The understanding of subject must be more developed in them rather than the traditional remembering procedures.

This chemistry '9' book is also the part of new curricula system, and has been written in very simple language, so the learner feel easy in understanding the basic concepts of chemistry, and cope with the challenging demands of the today's world.

Some of the main aims of this book are:

(i) Writing the chemistry in an easy and approachable manner so the students from the remote and backward areas feel easy to understand the important ideas, concepts of the subject.

(ii) An overview of the basic principles involved in the subject.

(iii) Knowledge of the practical approach in the subject, for this purpose many activities and interesting information have been introduced in the book.

(iv) Most of the topics also explain the role of chemistry tools in our society so the reader be able to understand the importance of the subject and its role for improving the life standard of us.

(v) There are also solved examples to guide the students how to cope with the problems on the topic.

(vi) Each chapter is accompanied with an exercise at the end to check the learning ability of the students.

As it is obvious that a text book can do nothing alone and the most important part of studies is the role of teachers and instructors , so the teachers are requested to apply the aims of this book in the light of the SLOs (Students learning outcomes) which are stated at the beginning of each chapter, that describes the time to be allotted to each chapter, tests and assignments of the chapter and the main areas that they should focus on.

At the end we are thankful to all those who helped us in writing this book, and made it possible for us to try to bring a change in the traditional education system.

We also appreciate for further suggestions from readers and educators to improve the quality of this text in future.

Thanking you all in anticipation.

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Contents

Chapter 1

INTRODUCTION OF CHEMISTRY

CONCEPTUAL LINKAGE

Before reading this chapter, the student must know the:

- Basics of Science.
- Divisions of Science
- Importance of Science

TIME ALLOCATION

Teaching periods	= 16
Assessment periods	= 03
Weightage	= 14%

LEARNING OUTCOMES

After reading this chapter, the Student will be able to:

- Identify and provide the examples of different branches of chemistry (Applying)
- Differentiate between branches of Chemistry (Understanding)
- Distinguish between matter and a substance. (Analyzing).
- Define ions, molecular ions, formula units and free radicals. (Remembering)
- Define atomic number, atomic mass, atomic mass unit. (Remembering)
- Differentiate among elements, compounds and mixtures. (Remembering)
- Define relative atomic mass based on C-12 scale. (Remembering)
- Differentiate between empirical and molecular formula.(Understanding)
- Distinguish between atoms and ions. (Analyzing)
- Differentiate between molecules and molecular ions. (Analyzing)
- Distinguish between ion and free radical. (Analyzing)
- Classify the chemical species from given examples.(Understanding)

- Identify the representative particles of elements and compounds.(Remembering).
- Relate gram atomic mass, gram molecular mass and gram formula mass to mole.(Applying)
- Describe how Avogadro's number is related to mole of any substance.(Understanding)
- Distinguish among the terms gram atomic mass, gram molecular mass and gram formula mass.(Analyzing)
- Change atomic mass, molecular mass and formula mass into gram atomic mass, gram molecular mass and gram formula mass.(Applying)

1.0 Introduction to Chemistry

Fig 1.0 Chemistry in action

The Science has been divided into many branches among which the chemistry is of key importance. In this field of Science, the matter, and to some extent energy, the two entities by which our universe is made up of are studied. But the main focus, here is of course upon the matter, and Chemistry deals with the structure of matter on both microscopic and macroscopic level, transformation in matter, in terms of chemical reaction, preparation of different new compounds, the use of these compounds and obviously, also the use of matter which exists already.

The chemistry is in action since the prehistoric era. Burning of wood, purifying the metals like gold for making ornaments, extracting ingredients for usage in drugs, all these involve chemical principles and are known far before our known history.

The chemistry plays very important role in our life. It has a direct application in every sphere of our life, whether concerned to our food we eat, our home we dwell, our cloths, our medicines, our entertaining materials, our educating books, all are direct result of chemistry, and chemistry is related with every discipline of our life. Without the applications of chemistry, the life will be same as of the prehistoric or even below than that, and knowledge and applications of chemistry are the basic constituent of our modern life.

So, all this shows that in order to maintain the living standards of humanity, and meet the new challenges of coming world, the chemistry is very essential to be studied in more depth and it is evident that the 21st century is the century of chemistry.

1.1 Branches of Chemistry

As already discussed that chemistry deals with a vast field of studies, so it has been divided into several branches to make it easier for study.

Here we discuss some of the important branches of chemistry.

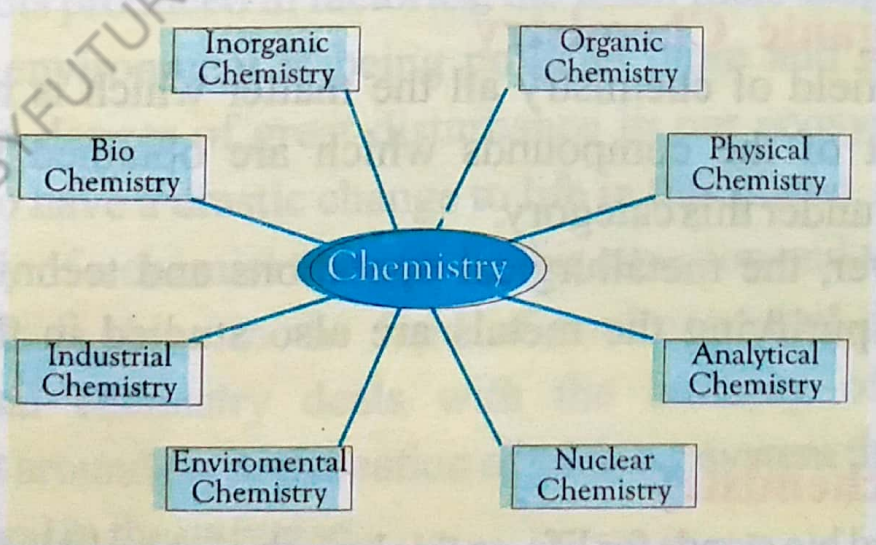


Fig. 1.1 Some branches of Chemistry

1.1.1 Physical Chemistry

This branch deals with the study of physical aspects of matter, such as the colour, melting and boiling points, density etc and all the factors which govern and relate with these characters.

The physical chemistry also deals with the study of atomic structure, role of energy in chemical and physical changes, and reaction kinetics.

Physical chemistry builds the hypothetical basis of structure elucidation of matter, enabling us to understand the basic nature of matter.

1.1.2 Organic Chemistry

The organic chemistry deals with the study of hydrocarbons and their derivatives. Hydrocarbons are the compounds that are composed of carbon and hydrogen e.g. methane, propane, butane, benzene, plastics etc.

Although in the organic chemistry we are primarily concerned with the Carbon and hydrogen elements, but due to the properties of Carbon element, the list of compounds formed are tremendously large, making the subject too heavy and complex. Millions of organic compounds have been in notice at now and each year new compounds are even added in this list.

1.1.3 Inorganic Chemistry

In this field of chemistry all the matter which is not organic is studied. Most of the compounds which are obtained from mineral sources come under this category.

Moreover, the metallurgical operations and techniques that are employed in purifying the metals are also studied in this branch of chemistry.

1.1.4 Biochemistry

The word bio stands for life, so this branch of chemistry deals with the

matter which is directly obtained from the living organisms. Thus it deals with the compounds like carbohydrates, proteins, lipids and others.

1.1.5 Industrial Chemistry

As the name indicates, the industrial chemistry is the chemistry of industries. All the materials produced by the industries are discussed here. This branch is important in the sense that all the matter produced in the laboratory must come in our life usage to make our life easier and comfortable, which is done by industries. e.g. the cement to make our homes, the fertilizers to grow up the amount of our food, the medicines to keep us healthy, the fabric industry to give us the cloths and almost all of the compounds which we use in our life is the result of research and comes in our reach by their production in the factories, which is dealt with the industrial chemistry.

1.1.6 Nuclear Chemistry

This branch of chemistry deals with the study of nucleus of an atom. This gives us the information for the production of energy from matter by nuclear reaction, weapons of mass destruction, transformation of elements, and preparation of nuclear medicines used in radiotherapy.

1.1.7 Environmental Chemistry

As the world is developing more and more and we are using the advanced tools produced in factories, the fossil fuels usage is increasing rapidly, the environment is being polluted more and more. This has increased the danger of great disturbance in our ecosystem, which is considered to have a drastic change to life in this planet, so it is also the responsibility of a chemist to improve this situation and to meet all such dangers. This is done in the field of environmental chemistry. The environmental chemistry deals with the building of life friendly environment around us, and creation of such ecosystem that is inevitable for our survival in the universe.

1.1.8 Analytical Chemistry

The basic aim of chemistry is the production and usage of compounds, which can be done only when the composition and structure of an existing compound is known, which is the main aim of analytical chemistry, which deals with the determination of structure and composition of matter i.e. in this branch of chemistry we analyze a chemical compound and determine the molecular formulae of the chemical compounds.

1.2 Basic Definitions

Before we proceed further, let us understand some of the key and basic terms used frequently in the chemistry.

1.2.1 Elements, Compounds and the Mixtures

The universe is made up of two basic entities, the matter and the energy. Chemistry deals with the matter, so we will focus on this exclusively.

The matter is the substance that has mass. It is distributed all round us and this matter is classified into the two main categories, i.e. the pure substances and the mixtures. A pure substance is that which shows uniform properties every time, for example melting point and boiling point of such substances are always same, while in a mixture the quantity of constituents can vary, e.g. in the mixture of sugar syrup the amount of sugar can be less of greater. The pure substances are further divided in to two sub divisions i.e., the elements and the compounds, this classification is shown in the following flow diagram. These divisions will be discussed in the subsequent sections in detail.

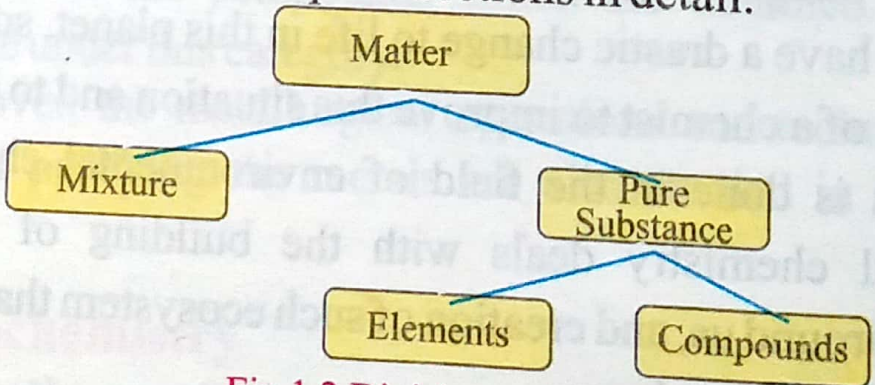


Fig 1.2 Divisions of matter

1.2.1.1 Elements and their Symbols

The element is defined as the sample of a pure substance in which all the atoms are alike.

For example, if we take a rod of iron metal, it consists of same type of atoms, so iron is an element, and on the other hand, a piece of wood consists of different types of atoms, so wood is not an element.

The elements found in all three stats of matter i.e., the gas (Nitrogen, Oxygen, Hydrogen etc.), liquid (Bromine and Mercury) and solid (Aluminum, Sodium, Copper etc.).

Different elements show different physical and chemical properties, for example, if we take the above described three gaseous elements i.e., is N_2, O_2 and H_2, all these have different boiling points and show different chemical products on reactions, such as:

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{2(l)}$$

$$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)}$$

In Chemistry, the atoms are identified by their atomic numbers, (The atomic numbers are discussed in detail in the section 1.2.2.1). So an element can be defined as the sample of pure substance that has all the atoms with same atomic numbers. (e.g. in the example of iron rod, all atoms have atomic number = 26). In our daily life we normally deal with the atoms in the form of elements, e.g. O_2, Au, Ag, Cu and many more. Usually we use a short name for an element called the Symbol. A symbol is chosen normally by taking the first letter, written as the capital letter of the English name of that element, e.g. 'H' is used for hydrogen, 'O' for oxygen, 'C' for carbon.

Here is a table (Table 1.1) showing symbols and English names of some of the common elements.

Name of Element	Symbol	Name of Element	Symbol
Hydrogen	H	Fluorine	F
Oxygen	O	Iodine	I
Nitrogen	N	Boron	B
Carbon	C	Sulphur	S

Table: 1.1: Some elements whose symbols are derived from their english names

Sometimes the first and second letter from the English name are used, e.g. 'He' for helium, 'Ca' for calcium. When two letters are used, the second letter must be written in small alphabets. Here are some examples of such elements (Table 1.2).

Name of Element	Symbol	Name of Element	Symbol
Lithium	Li	Neon	Ne
Beryllium	Be	Nickel	Ni
Aluminum	Al		

Table: 1.2: Symbols of some elements having first and second letters from English names

In some cases, first and any other letter is used, as described in the table 1.3.

Name of Element	Symbol	Name of Element	Symbol
Chlorine	Cl	Cadmium	Cd
Chromium	Cr	Magnesium	Mg

Table: 1.3: Symbols of some elements having first and a prominent letter from their English names

Some elements which are known from prehistoric era, are represented by the symbols of their Greek names, e.g. (see table 1.4).

English Name of Element	Greek/Latin Name of Element	Symbol
Gold	Aurum	Au
Silver	Argentum	Ag
Mercury	Hydrargyrum	Hg
Sodium	Natrium	Na
Copper	Cuprum	Cu

Table: 1.4: Symbols of some elements derived from their Greek/Latin names

So far 118 elements have been discovered of which 92 are found naturally while rest are synthesized artificially in laboratories, these elements found in both the free and in combined states.

Interesting To Know

In our solar system top 3 elements are:
H = 74%, He = 24%, and O = less than 2%

In the earth crust top 3 elements are:
O = 46.6%, Si = 27.7% and Al = 8%

In our atmosphere top 3 elements are:
N = 78%, O = 21% and Ar = 0.9%

In our body top 3 elements are:
O = 65%, C = 18% and H = 10%

1.2.1.2 The Compound

When different elements combine, they form a compound, thus generally a compound has two or more than two types of elements, example of such substances include water, table salt, glucose.

In a compound the proportion of elements is fixed and can not be changed, e.g. in H_2O the proportion of H atoms to O atom is 2:1, and this ratio is fixed otherwise the compound will be changed, for example in above example of hydrogen and oxygen, if the ratio between these two elements changes 2:2 the result is formation of H_2O_2 (hydrogen per oxide) which is totally different from H_2O (water). It is also notable that the formation of a compound is a chemical change and can not be easily reversed back to its constituent elements.

A compound which is formed of different type of elements shows properties quite different from the elements that form it, e.g., water which is a liquid is formed of two gases hydrogen and oxygen, the hydrogen burns while the oxygen helps in burning process, on the other hand the compound water extinguishes the burning objects.

A compound is represented by its short name called its formula or molecular formula. A formula shows all the elements present in the compound with the number of each type of atoms.

Formula	Name of Compound
CO_2	Carbon Dioxide
NaCl	Sodium Chloride
$C_{12}H_{22}O_{11}$	Sugar (Sucrose)
$C_6H_{12}O_6$	Glucose
$Na_2CO_3.10H_2O$	Sodium Carbonate
$NaHCO_3$	Sodium Bicarbonate
$CaCO_3$	Calcium Carbonate
SiO_2	Silicon Dioxide
$(C_6H_{10}O_5)_n$	Cellulose

Table:1.5: Some Compounds and their Formulae

A compound can be divided into two sub types, the ionic and the covalent. Ionic compounds consist of a large number of particles forming a huge crystal structure, while the covalent exists in the molecular form.

The mixture is a combination of two or more substances (Elements or compounds) in such a manner that each component shows its own characters, i.e. they are not combined chemically.

Fig 1.3 Fabric--A mixture of yarns

The common examples of such mixtures include sugar syrup, air and fabric woven of yarns combining various colors.

The mixtures do not have the uniform composition and properties, and the components of a mixture can easily be separated by simple

physical methods e.g. the sugar from the syrup can be separated simply by evaporating the water from the syrup.

The Table 1.6 that shows some basic differences between compound and mixture.

Activity: 1.1

How can you separate the components of a mixture of table salt (NaCl) solution?
Try to separate these in the laboratory with the help of your teacher.

S/No	Compound	Mixture
i	They are pure substances.	They are impure.
ii	Compound is formed by chemical reaction of atoms/elements.	It is formed by the mixing of substances.
iii	Its properties are entirely different from the component substances by which it is made up of, e.g water is quite different from its building elements i.e. hydrogen and oxygen. $H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$	This shows the properties of its constituent.
iv	It cannot be converted back to its original constituents easily by physical methods.	A mixture can be easily converted back to its parent components by simple physical methods.
v	The constituents have fixed composition of the elements.	The constituents here do not have fixed composition.
vi	They show fixed melting and boiling points.	They do not show fixed melting and boiling points.

Table: 1.6: Some basic differences between compounds and mixtures

1.2.2 Atoms, the Building Blocks of Matter

The name atom has been derived from the Greek word "atomos" which means indivisible or which cannot be cutted further. This originated because scholars of ancient Greek believed all substances are made up of tiny indivisible particles which they named atomos.

In the modern era John Dalton proposed his atomic theory and named the basic constituent of matter as atoms.

Although atoms are the smallest unit of matter, and hence it is the building block of matter, but still they are not indivisible now. So, now a days atom is defined as the smallest unit of matter which takes part in chemical reactions and shows all properties of an element. e.g. if a piece of gold is divided into two fragments, each fragment will show the characters of gold, the gold is identified by its peculiar physical and chemical properties. When it is divided in more fragments again each fragment is the representative of chemical properties of gold, the division is continued until the last fragment achieved is called an atom.

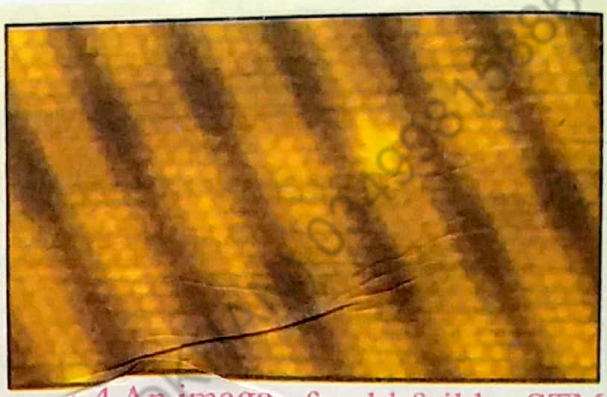


Fig 1.4 An image of gold foil by STM

Atoms are so small that they can't be seen by the naked eye or any traditional microscope, a recent technique called scanning tunneling microscopy (STM) have made atoms visible up to a little extent, An image of gold foil by STM is shown here in figure 1.4.

The atoms normally do not exist freely in nature, though some exceptions are there, e.g. all the members of group-18 in periodic table, called the noble gases exists as single atom, but their existing atoms are rendered as mono atomic molecules.

Although the atoms are invisible,

Interesting Information

The size of nucleus is very small as compared to volume of an atom and is about 10,000 time less than the size of an atom.

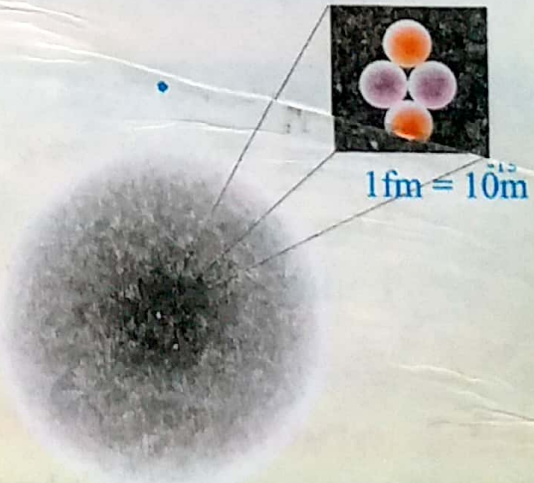


Fig 1.5
The modern view of an Atom

but by using special techniques and experiments, Scientists have created a picture of atom, that defines the atom as being buildup of more smaller particles, these particles are called electron, proton and neutron, of these three, the proton and the neutron lie in the center of atom, this center is termed as the nucleus of atom.

The electron revolves around the nucleus in definite areas called shell.

The electrons and the protons are charged particles and electron bears unit negative, while proton bears unit positive charge. The number of electrons and protons are equal in the atoms so the atom is electrically neutral. A simple picture of an atom described is thus given as in figure 1.5.

This picture 1.5 is showing the basic characteristics of the atom, the darker area represents the density of electron, and a comparison of the sizes of atom and nucleus of atom, note that an atom here has the size of 10^{-10} meters ($1A^{o}$) while the size of the nucleus is 10^{-15} meters (1fm).

The tiny center is the nucleus, and the cloudy area is the region of revolving electrons, the strength of clouds show the density of electron charge distribution.

1.2.2.1 Atomic Number and the Mass Number

In order to identify the atoms, each atom has been allotted a number, called **atomic number** (symbolized as **Z**). (This is same just like the students in a class are allotted the roll numbers to identify them easily). The atomic number is based upon the number of protons in the nucleus of the corresponding atom, e.g. H has 1 proton so its atomic number is also 1, the oxygen has 8 protons in its nucleus, so its atomic number is also 8. The concept of giving identity to atoms is of great importance, as nothing can be described about its properties unless it is identified separately.

The **mass number** (symbolized as **A**) is the total number of mass building particles in an atom, the mass building particles of atom are the neutrons and the protons. e.g. the 'N' has 7 protons and 7 neutrons so its mass number is '14', whereas, the 'C' has 6 protons and 6 neutrons, so its mass number is 12. The mass of an atom has great effect upon the physical and sometimes even the chemical properties of the atoms.

Table 1.7 shows the atomic number and mass number of some of the

Element	Number of Protons	Number of Neutrons	Atomic Number (Z)	Mass Number (A)
Hydrogen	1	0	1	1
Helium	2	2	2	4
Carbon	6	6	6	12
Nitrogen	7	7	7	14
Oxygen	8	8	8	16
Sodium	11	12	11	23
Calcium	20	20	20	40

Table 1.7: Some common elements with their atomic and mass numbers

The modern science has enabled us to increase or decrease the numb of particles in the nucleus and thus we can change the type of atoms.

Naturally there exist 90 different type of atoms while many have bee synthesized in the laboratories.

1.2.3 Relative Atomic mass and the Atomic mass unit

The relative atomic mass of an atom is its mass when compared wit the light isotope of carbon i.e. $C^{12.000000}$.

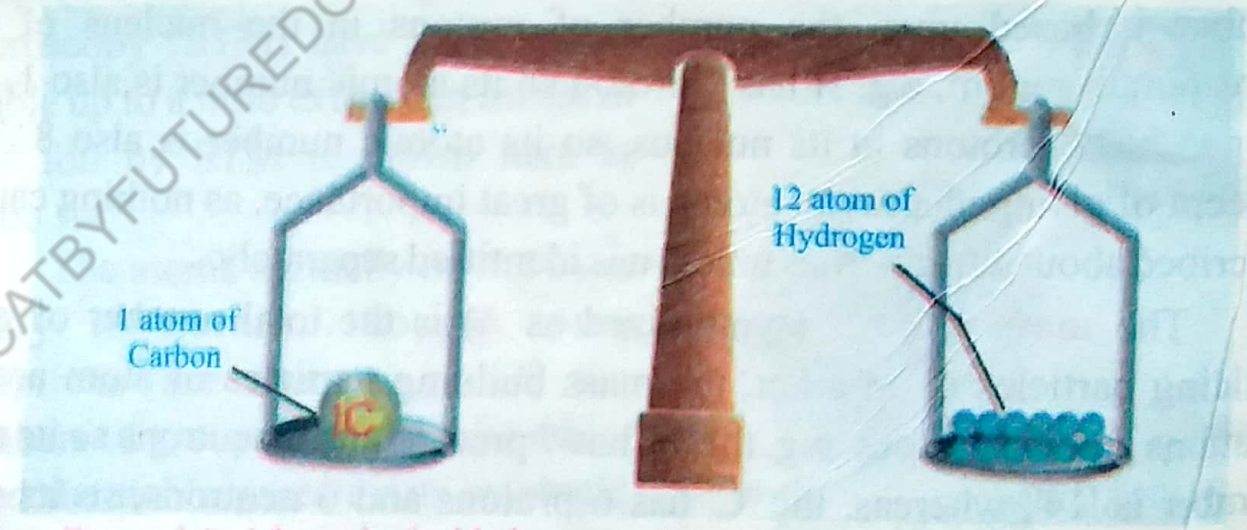


Figure 1.6: A hypothetical balance to show the concept of phenomenon of the comparing the mass of Hydrogen atoms with standard $C^{12.000000}$

The reason that relative unit is used rather than the absolute mass unit is that it is experimentally much easier and more precise to compare masses of

atoms and molecules than to measure their absolute masses. Masses are compared with a mass spectrometer. The atomic and molecular masses are measured in the unit of atomic mass unit (a.m.u), or sometimes as unified atomic mass unit, abbreviated as 'u'. It is defined to be one twelfth of the mass of an atom of the C^{12} nuclide. In kilograms it is written as:

$$1\ \text{a.m.u} = 1.6605402 \times 10^{-27}\ \text{kg}$$
$$1\ \text{a.m.u} = 1.6605402 \times 10^{-24}\ \text{grams}$$

In the periodic table, the atomic mass listed is the weighed average of all of the isotope masses for that element. In this weighed average, the weights are the percent abundance that each isotope occurs in nature. For example, if we analysed a lump of pure carbon from the planet Earth, it is observed that:

98.9 % of all carbon atoms are $C^{12.0000}$ atoms,

and

1.11 % of all carbon atoms are $C^{13.0039}$ atoms.

So the weighted average mass of carbon is:

$$\frac{(98.9 \times 12.000000) + (1.11 \times 13.0039)}{100} = 12.01\text{a.m.u}$$

In the same way, the natural abundance of $Cu^{62.93}$ is 69.09 % and for $Cu^{64.93}$ is 30.19 % respectively.

Thus the average atomic mass for copper is calculated as:

$$\frac{(69.09 \times 62.93) + (30.91 \times 64.93)}{100} = 63.55\text{a.m.u}$$

These average values of mass of respective elements are written in a periodic table along with the symbol of that element.

1.2.4 Empirical and the Molecular Formulae

The constitution of a compound can be represented in many ways, this representation is called formula of the respective compound. There formulas are written in different ways.

1.2.4.1 The Empirical Formula

The empirical formula represents the simple ratio of the atoms present in a compound, e.g. in glucose ($C_6H_{12}O_6$) the simplest ratio of atoms is 1:2:1

i.e. for each atom of Carbon there are two Hydrogen atoms and 1 Oxygen atom.

So the empirical formula of glucose is "CH_2O".

In water (H_2O) the simplest ratio of Hydrogen to Oxygen atoms is 2:1 so the empirical formula of water is "H_2O", remember this is also the molecular formula of water.

Activity: 1.2

What are the empirical formulae of following, Benzene (C_6H_6), Sucrose ($C_{12}H_{22}O_{11}$), Carbondioxide (CO_2), and Cellulose $(C_6H_{10}O_5)n$

1.2.4.2 The Molecular Formula

In Chemistry a short name is used to represent the constituents of a compound, this short name is called the formula of that specific compound, e.g. for water the formula is "H_2O".

In the table 1.8 some formulae of common compounds are written:

Name of Compound	Formula
Carbon dioxide	CO_2
Table salt (Sodium chloride)	NaCl
Sugar (Sucrose)	$C_{12}H_{22}O_{11}$
Glucose	$C_6H_{12}O_6$
Washing soda (Sodium carbonate)	$Na_2CO_3.10H_2O$
Baking soda (Sodium bicarbonate)	$NaHCO_3$
Lime stone (Calcium carbonate)	$CaCO_3$
Sand (Silicon dioxide)	SiO_2
Starch	$(C_6H_{10}O_5)n$

Table 1.8: Some common compounds with their formulae

As it is clear from the above table that a formula shows two basic information about that specific compound, i.e.

(i) The composition of the compound, stating types of the elements present in that compound.

(ii) The number of atoms of each element present in that compound.

Sometimes a compound consists of a large number of repeating unit called polymer e.g. Cellulose or Starch $(C_6H_{10}O_5)_n$

and Polyvinyl Chloride (P.V.C) $\left(-CH_2-\underset{\underset{Cl}{|}}{CH}-\right)_n$

Such enormously giant structures are called polymers.

1.2.4.3 The Formula Unit

Sometimes a molecule exists as a large entity of particles, for ease the simplest ratio of the formulae of such huge structures is written, this simplest ratio is termed as the unit of their formula or the formula unit, e.g Sodium chloride exists in such manner, and we write "NaCl" as its formula unit.

The NaCl consists of a large number of cations, The Na^+ ions, and the anions, Cl^-. Thus the NaCl exists as a large entity of crystal structure, in which the cations are surrounded by the anions and vice versa, this is shown here in the figure 1.7.

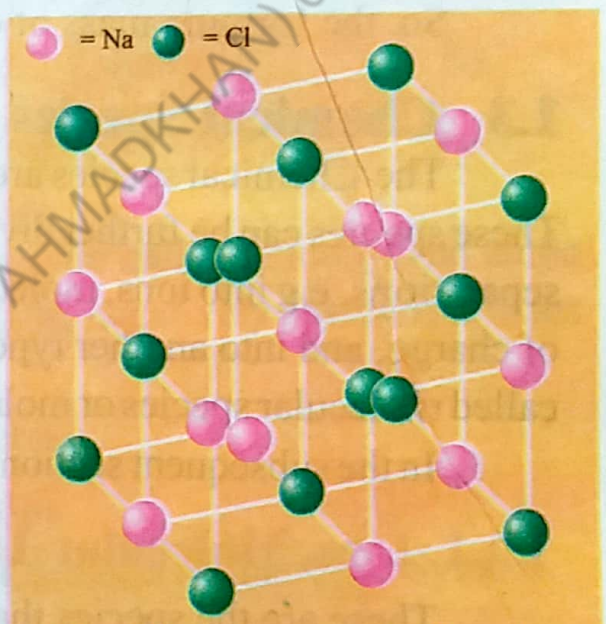


Fig.1.7: Arrangement of ions in Sodium Chloride

The simplest ratio of ions here is 1:1, so its formula unit is NaCl, in the same manner the ratio of ions in calcium bromide is 1:2, so the formula unit of Calcium bromide is $CaBr_2$.

1.2.5 The Molecular Mass and the Formula Mass

Molecular mass of a compound is the total mass of all the atoms present in that particular molecule. This is also known as the molar mass and is calculated easily by taking sum of masses of all the atoms present, e.g. for the molar mass of water,

H_2O

$H = 1 \times 2 = 2$

$O = 16 \times 1 = 16$

Sum of these two is $2 + 16 = 18$

So, the molar mass of water is 18 a.m.u.

The formula mass is also calculated in the same manner, e.g. the formula mass of Calcium nitrate, $Ca(NO_3)_2$ is:

$Ca(NO_3)_2$

$Ca = 40 \times 1 = 40$

$N = 14 \times 2 = 28$

$O = 16 \times 6 = 96$

Sum of these three is

$40 + 28 + 96 = 164$

So, the formula mass of calcium nitrate, $Ca(NO_3)_2$ is 164 a.m.u.

Activity: 1.3

Calculate the mass of following compounds,

NaCl, CO_2, Glucose ($C_6H_{12}O_6$), and $Al(OH)_3$

1.3 Chemical Species

The Chemical species are the building blocks of chemical compounds, These species can be further divided into different types on the basis of charge separations, e.g into ions, molecular ions and free radicals that bear some sort of charge, and into another types of stability which do not have such charge, called molecular species or molecules.

In the subsequent section we explain each of these types in detail.

1.3.1 Ions, Molecular Ions & Free Radicals

These are the species that bear some sort of charges on them:

1.3.1.1 Ions

An ion is an atom or group of atoms that has lost or gained one or more electrons.

The simplest ions are the proton (a hydrogen ion, ${}_1H^+$, positive charge), and alpha particle (helium ion, ${}_2^4He^{2+}$, consisting of two protons and two neutrons). The ions are of two types by the charges, negatively charged ions are called anions, and the positively charged are called cations, these names come from the fact that the negatively charged ions move towards the anode in the process of electrolysis, while the positively charged ions move towards the cathode so named cations. The table 1.9 shows some common monatomic cations.

Common Cations			
Common Name	Symbol	Common Name	Symbol
Aluminum	Al^{3+}	Nickel	Ni^{2+}
Calcium	Ca^{2+}	Magnesium	Mg^{2+}
Chromium (II) (Chromous)	Cr^{2+}	Chromium(III) (Chromic)	Cr^{3+}
Copper(I) (Cuprous)	Cu^{+}	Copper(II) (Cupric)	Cu^{2+}
Lead(II) (Plumbous)	Pb^{2+}	Lead (IV) (Plumbic)	Pb^{4+}
Silver (Argentum)	Ag^{+}	Potassium (Kalium)	K^{+}
Hydrogen	H^{+}	Sodium (Natrium)	Na^{+}
Iron (II) (Ferrous)	Fe^{2+}	Iron (III) or Ferric	Fe^{3+}

Table: 1.9 List of Common Cation

The ions that have the negative charge are called anions, (The name comes from the fact that in an electrolytic cell the negatively charged particles moves towards the anode, so anion—anode)

The table 1.10 lists some important anions:

Common anions			
Common Name	Symbol	Common Name	Symbol
Bromide	Br^{-}	Iodide	I^{-}
Chloride	Cl^{-}	Nitride	N^{3-}
Fluoride	F^{-}	Oxide	O^{2-}
Hydride	H^{-}	Sulphide	S^{2-}

Table 1.10: Some Important Anions

Although the existence of ions independently is hard due to their greater instability, but there are molecules that have combination of both positive and negative ions in a manner that both types neutralize and as a whole the compound is electrically neutral, as described above in the case of NaCl.

1.3.1.2 Molecular Ions

An ion consisting of multiple atoms is called a polyatomic ion, or molecular ion, e.g. NH_4^+ ion.

The molecular ions also may be of two types, the cations and the anions. Following tables show some common molecular cations (Table 1.11) and molecular anions (Table 1.12).

Polyatomic or Molecular Cations	
Ammonium	NH_4^+
Hydronium	H_3O^+
Nitronium	NO_2^+

Table: 1.11: Some Polyatomic Cations

Molecular anions	
Carbonate	CO_3^{2-}
Bicarbonate / Hydrogen Carbonate	HCO_3^-
Dichromate	$Cr_2O_7^{2-}$
Nitrate	NO_3^-
Phosphate	PO_4^{3-}
Hydrogen Phosphate	HPO_4^{2-}
Sulphate	SO_4^{2-}

Table: 1.12: Some Polyatomic Anions

Naming Ionic Compounds

The names of ionic compounds are written by listing the name of the positive ion first, followed by the name of the negative ion e.g.

$NaCl$ Sodium chloride

$(NH_4)_2SO_4$ Ammonium sulfate

$NaHCO_3$ Sodium Bicarbonate / Sodium Hydrogen Carbonate

$KClO_3$ Potassium chlorate

1.3.1.3 Free Radicals or Radicals

The radicals or free radicals are atomic or molecular species with unpaired electrons.

Due to these unpaired electrons the radicals are highly reactive, and are produced only during the course of a chemical reation for a very short time e.g. the chlorine radical is formed by the dissociatin of chlorine molecule by light energy and is readily react with the neighboring species.

$$Cl_{2(g)} \xrightarrow{UV} 2\dot{C}_{(g)}$$

The electron of the free radical is written b a dot upon the symbol of

free radical, as shown above in the radical of Cl. Radicals play an important role in combustion, atmospheric chemistry, polymerization, plasma chemistry, biochemistry and many other chemical processes, including human physiology. For example, superoxide and nitric oxide regulate many biological processes, such as controlling vascular tone.

The upper atmosphere of earth contains radicals which are formed there by the action of UV radiations that is coming from sun and thus the energy of this highly injurious UV radiation is blocked.

1.3.2 Molecular Species

A molecule is the smallest stable form of matter and is composed of generally two or more atoms. The constituting atoms may be same or different from each other, e.g O_2 is a molecule having both of its atoms same while the CO_2 is a molecule having different types of atom. Table 1.7 shows some molecules and their formulae.

On the basis of its composition molecules are classified into different sub types. These types are:

(a) **Monoatomic Molecules:** Although the molecule is generally considered of being formed by the combination of two or more atoms, but even a molecule could be composed of a single atom, this is because the main difference between the molecule an atom arises from its stability, molecules are the species which are stable, so even a single atom which is stable could be considered as the molecule, important examples of such monoatomic molecules include the He, Ar, Ne and other noble gases.

(b) **Diatomic molecules:** When a molecule consists of two atoms it is called diatomic molecule, for example H_2, O_2, HCl, CO etc.

(c) **Polyatomic molecules:** These are the molecules that are composed of more than two atoms, like $C_6H_{12}O_6$, HNO_3, $CuSO_4.5H_2O$ etc.

In addition to this the molecule may also be classified as **homo atomic molecules** (homo-similar) e.g. O_3, S_8, which are composed of same type of atoms and **heteroatomic molecules** (hetero-different) e.g. NH_3, HNO_3, H_2SO_4 etc, which are composed of different types of atoms.

1.4 Mole and the Avogadro's Number

1.4.1 The Mole (mol)

In Chemistry we often make reactions by combining two or more reactants, and for this we must have to take the reactants in correct amount, otherwise the product(s) may not be formed. (this is very similar to the behavior that in making a good tea one have, to take all the ingredients in correct amount). But in actual we are unable to count and take atoms of reacting substances in desired quantities.

So, to solve this, we use the concept of mole, which states the ratios of given substances in much easier way in the units of grams, and this makes it very easy and perfectly practical to measure the amounts of reactant(s) or product(s).

According to this concept the atomic mass or in case of molecules the molecular mass is taken in the unit of grams instead of atomic mass unit and hence it becomes easy to measure these using ordinary instruments (balances).

Thus the atomic mass or molecular mass expressed in terms of grams is called 1 mole of that substance, (or sometimes it is also called gram atom or gram molecule or gram formula mass), as shown in figure 1.8.

Here are some examples that elaborates this concept,

'H' has '1' atomic mass so 1g of it is one mole. 'O' has '16'a.m.u atomic mass so its 16g = 1 mole

'H_2' has '2' atomic mass so 2g of its is one mole. 'O_2' has '32'a.m.u atomic mass so its 32g = 1 mole H_2O has 18a.m.u molecular mass and its 18g = 1 mole

And

36 g of water = 2 moles

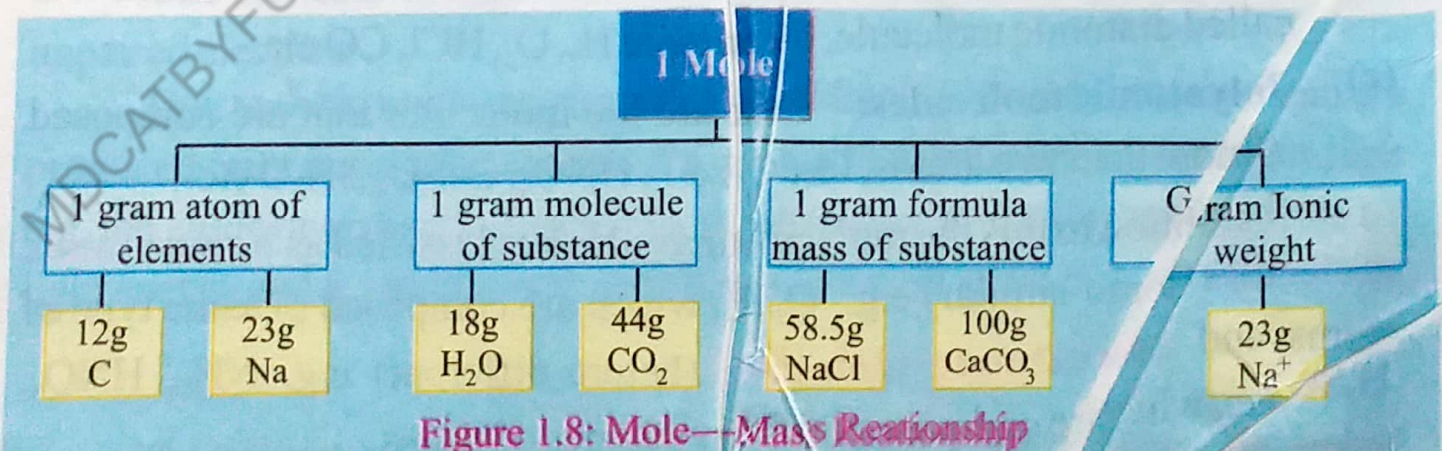


Figure 1.8: Mole—Mass Reationship

A simple relation that is used to interconvert the mole—mass relation, which given by:

$$\text{Mole} = \frac{\text{Given Mass}}{\text{Atomic / Molecular Mass / Mass Formula / Ionic Mass}}$$

The concept of mole is really very helpful for the Chemists and is applied widely.

Example: **Calculate number of moles in 250g of glucose.**

Solution: As the moles of glucose can easily be determined by using the formula:

$$\text{Mole} = \frac{\text{Given Mass}}{\text{Atomic or Molecular Mass}}$$

The molecular mass of glucose can be calculated by the help of its molecular formula, which is $C_6H_{12}O_6$.

Here,

C $= 6 \times 12.01 = 72.06$

H $= 12 \times 1.0076 = 12.0912$

O $= 6 \times 16.00 = 96$

Total mass $= 72.06 + 12.0912 + 96 = 180.15$

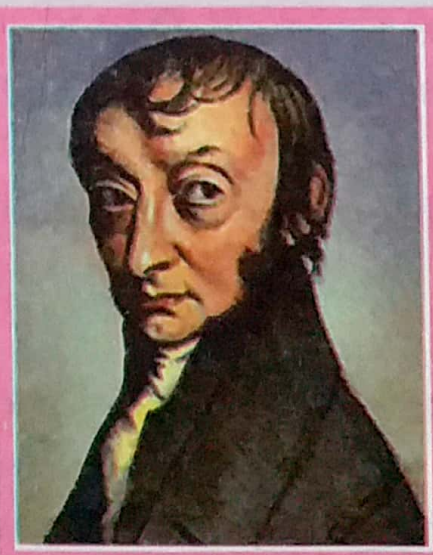
By inserting the values in the above formula, we get

$$\text{Mole} = \frac{250}{180.15} = 1.39 \text{ moles}$$

1.4.2 Avogadro's Number (N_A)

Avogadro practically found that one mole of any substance contains 6.02×10^{23} particles (atoms/ molecules) i.e 1 mole of 'O' has 6.02×10^{23} atoms and 1 mole of H_2O has 6.02×10^{23} molecules. This number is called Avogadro's Number.

This is to be remembered that in atomic species the Avogadro's Number represents



Amedeo Avogadro
(Italian Scientist)
1776 — 1856

number of atoms, e.g., Helium (He) gas which has atomic mass '4', 4gm helium will have 6.02×10^{23} atoms.

In case of molecular species this Avogadro's Number represents number of molecules e.g., 32g of oxygen (O_2) will have 6.02×10^{23} molecules.

Example:

Calculate total number of atoms in 1.0 g of water.

Solution

As 1 mole of water has 6.02×10^{23} molecules = 18g

1 mole of H_2O = 18g = 6.02×10^{23} molecules

80, 18g of H_2O has 6.02×10^{23} molecules and $6.02 \times 10^{23} \times 3$ atoms(as one molecule of H_2O has 3 atoms)

And 1g of H_2O will have:

$$\frac{6.02 \times 10^{23} \times 3 \text{ atoms}}{18\text{g } H_2O} \times 1\text{g } H_2O$$

$= 1.0033 \times 10^{23}$ atoms

Activity: 1.4

Calculate the number of atoms in 100g of CO_2, and Glucose ($C_6H_{12}O_6$).

SUMMARY OF THE CHAPTER

- **Chemistry** is the basic branch of Science that deals with the study of matter.
- The important **branches of Chemistry** are Physical Chemistry, Organic chemistry, Inorganic Chemistry, Biochemistry, Industrial Chemistry, Nuclear Chemistry, Environmental Chemistry, and Analytical Chemistry.
- The **Element** is a sample of pure substance that has all atoms with same atomic number.
- A **Compound** is a sample of pure substance that has two or more than two types of elements.
- A **mixture** is not a pure substance and is consists of by mixing two or more than two pure substances, the quantities of the components of a mixture could be changed.
- Atomic number is the identity number of an atom or element. It is equal to the number of protons found in the nucleus of atom.
- The sum of number of protons and neutrons in an atom is the **Atomic mass number**.
- **Relative atomic mass** is the mass of an atom or molecule which is obtained by comparing the mass of an atom or molecule with the standard $C^{12.0000}$.
- The atoms are very small and their mass is measured in a very small unit called **atomic mass unit (a.m.u)**, in grams it is equal to:

$$1 \text{ a.m.u} = 1.6\times10^{-24}\text{g}$$

- Empirical formula is the formula which shows the simplest ratio of atoms in a molecule.
- **Molecular formula** is the formula of a chemical compound and it shows the exact number and type of atoms present in that compound.
- **Molecular mass** is the sum of masses of all atoms in a molecule.
- **Ions** are the charged atoms. Ions are **anions** when they bear negative charge, and **cations** when they have positive charge.

- Radicals or free radicals are the species (atoms or group of atoms) that have an unpaired electron.
- The molecules are said to be **monoatomic** when they are composed of single atom, **diatomic** when they are composed of two atoms and **polyatomic** when they are formed by more than two atoms.
- The molecules are **homoatomic** if they are composed of same type of atoms and **Heteroatomic** when they are formed by different types of atoms.
- When atomic or molecular masses are represented in terms of grams, mass obtained is termed as **1 mole**.
- The number of particles in one mole is called **Avogadro's number** (N_A), this number is equal to $\mathbf{6.0225 \times 10^{23}}$.

EXERCISE

Q.1: Fill in the blanks.

i) Physical chemistry deals with ..... of matter.

ii) The branch of chemistry in which the nucleus of atom in studied is called ..... chemistry.

iii) A sample of pure substance having all atoms ..... is called an element.

iv) For the mass comparison of atoms, the standard atom chosen is .....

v) The number 6.0225×10^{23} is called ..... .

vi) ..... moles of water constitute 36g.

vii) The process of formation of ions is called ..... .

viii) The Atomic mass unit is expressed by the symbol ..... .

ix) The molecular formula shows ..... number of atoms.

x) Glucose is ..... type of molecule.

Q.2: Tick the correct answer from the given list.

i) The smallest component of an element that still retains properties of the element is called

(a) electron (b) proton (c) neutron (d) atom

ii) The atom is a Greek word meaning
(a) indivisible (b) small particle
(c) which enter in reactions (d) basic particle

iii) The branch of chemistry which deals with the determination of molecular formula is called
(a) Nuclear chemistry (b) organic chemistry
(c) Analytical chemistry (d) Industrial chemistry

iv) Empirical formula shows the
(a) ratio of atoms (b) ratio of molecules
(c) exact number of atoms (d) exact number of molecules

v) Molecular mass is calculated by
(a) Counting number of atoms of C^{12}
(b) Taking sum of the masses of atoms in the molecule
(c) By taking the sum of protons and neutrons number
(d) None of above

vi) The value of a.m.u in grams is
(a) 1.6×10^{23} (b) 1.6×10^{27}
(c) 1.6×10^{-23} (d) 1.6×10^{-24}

vii) The atoms can exists freely in nature
(a) Always (b) never
(c) some exist and some do not (d) none of these is true

viii) The formula unit is used for the
(a) ionic substances (b) molecular substances
(c) Mixture (d) none of these

ix) The gram atomic or molecular mass is called
(a) one mole (b) two moles
(c) three moles (d) 4 moles

x. The concept of Avogadro's number is used to calculate the
(a) number of atoms (b) number of molecules
(c) number of ions (d) all of these

Q3. Answer the following questions in short.

i) Why understanding of chemistry is important to us?

ii) Give a short note on classification of matter.
iii) What is meant by the term Atomic Number?
iv) How will you differentiate between the Atomic mass number and the Relative atomic mass?
v) Distinguish among atoms and ions with examples.
vi) Explain with an example how the molecular mass is calculated.
vii) What are the different types of matter found in nature?
viii) What is the mole?
ix) What is meant by a.m.u?
x) Describe with example how simple inorganic compounds are named.

Q4. Answer the following questions with reasoning.

i) How Avogadro's Number and the mole are related with each other?
ii) Comment that concepts of vital for chemists.
iii) Distinguish between ion and the free radical?
iv) What is the difference between empirical formula and the formula unit?
v) Why C^{12} is taken as the standard for calculating atomic or molecular masses?

Q5: Nicotine a deadly poison which is found in tobacco has the formula $C_{10}H_{14}N_2$. An average cigarette contains 1mg of nicotine. What will be the number of molecules in this quantity?.

Q6: Calculate the molar mass of following,

(a) K_2SO_4 (b) $MnCl_2$ (c) $Al(OH)_3$
(d) $Fe(NO)_3$ (e) $CuSO_4.5H_2O$

Q7: Write down the molecular formula of following compounds.

(a) Ferrous sulphate (b) Ferric sulphate
(c) Copper(II) sulphide (d) copper(I) sulphite
(e) Ammonium bicarbonate

Q8: What are the mass and mole of sulphur in 50g of sulphuric acid?

Q9: . Define Chemistry? How Chemistry effects our life?

Q10: Why the Science is divided into various branches? Discuss the ing of

branching of chemistry in detail?

Q11: What is the difference between the Element, mixture and the compound?

Q12: What do you understand by the term symbol of an element? Explain various rules for assigning symbols to an element?

Q13: What is the molecular formula of a compound? How the formulae are written?

Q14: Discuss the concept of mole in chemistry? How it is related with the Avogadro's number?