Part – 1
Nuclear physics

7th volume I
Unit-4 Atomic Structure

An atom is one and thousand times smaller than the thickest human hair. It has an average diameter of 0.0000000001m or 1×10^{-9} m. To understand atom's size with the familiar things we know, now let us find what is the size of pencil, red blood cell, virus and dust particle.

1×10^{-2} m 1×10^{-4} m 1×10^{-6} m
1×10^{-7} m 1×10^{-10} m

Now you could imagine how small an atom would be.

Evolution of idea of an atom

Many scientists have studied the structure of the atom and advanced their theories about it. The theories proposed by Dalton, Thomson and Rutherford are given below.

Dalton's atomic theory

John Dalton proposed the atomic theory in the year 1808. He proposed that matter consists of very small particles which he named atoms. An atom is smallest indivisible particle, it is speherical in shape. His theory does not propose anything about the positive and negative charges of an atom.

Hence , it was not able to explain many of the properties of substances.

Nanometer is the smallest unit used to measure small lengths. One metre is equal to 1×10^{-9} nm or one nanometer is equal to 1×10^{-9} m

In 1897 J.J Thomoson proposed a different theory. He compared an atom to a watermelon

His theory proposed that the atom has positively charged part like the red part of the watermelon and in it are embedded , like the seeds, negatively charged particles which he called electrons. According to this theory as the positive and negative charges are equal, the atom as a whole does not have any resultant charge.

Thomson's greatest contribution was to prove by experimentation the existence of the negatively charged particles or electrons in an atom. For this discovery, he was awarded the Nobel Prize in 1906. Although this theory explained why an atom is neutral , it was an incomplete theory in other ways.

Rutherford's theory

There were short comming in Thomson's theory, Earnest Rutherford gave a better understanding. Earnest Rutherford conducted an experiment. He bombarded a very thin layer of gold with positively charged alpha rays. He found that most of these rays which travel at a great velocity passed through the gold sheet without encountering any obstacles. A few are, however, turned back from the sheet.

Rutherford considered this remarkable and miraculous as if a bullet had turned back after colliding with tissue paper.

Based on this experiment, Rutherford proposed his famous theory. In his opinion, – 1. The fact that most alpha particles pass through the gold sheet means that the atom consists mainly of empty space. 2. The part from which the positively charged particles are turned back is positively charged but very small in size as compared to the empty space.

From these inferences, Rutherford presented his theory of the structure of atoms. For this theory, he was awarded the Nobel prize for chemistry.

Rutherford's theory proposes that

1. The nucleus at the centre of the atom has the positive charge. Most of the mass of the atom is concentrated in the nucleus.
2. The negatively charged electrons revolve around the nucleus in specific orbits.
3. In comparison with the size of the atom, the nucleus is very very small

You have around 7 billion atoms in your body, yet you replace about 98% of them every year!

The subatomic particles

The discoveries made during the twentieth century proved that atoms of all elements are made up of smaller components - electron, proton and neutron. An electron from hydrogen atom is no different from electron of a carbon atom. In the same manner, protons and neutrons of all elements also have same characteristics. These particles that make up the atom are called Subatomic Particles.

Proton (p)

The proton is the positively charged particle and its located in the nucleus. Its positive charge is of the same magnitude as that of the electron's negative charge.

Neutron (n)

Neutron is inside the nucleus. The neutron does not have any charge. Excepting hydrogen (protium), the nuclei of all atoms contain neutrons.

Electron (e)

This is a negatively charged particle. Electrons revolve around the nucleus of the atom in specific orbits. The mass of an electron is negligible as compared to that of a proton or neutron. Hence, the mass of an atom depends on the number of protons and neutrons in the nucleus.

Protons and Neutrons are the two types of particles in the nucleus of an atom. They are called nucleons. The total negative charge of all an electrons outside the nucleus is equal to the total positive charge in the nucleus. That makes the atom electrically neutral.

Atomic number and Mass number

If all elements are made up of same type of electrons, protons and neutrons how does a carbon atom differ from a iron atom? Further investigations led to the discovery that the number of the protons inside the nucleus of an atom determines what element it is. For Example if the nucleus has only one proton, then all such atoms are hydrogen atom. If there are eight protons then that atom is oxygen.

Is the structure of the atom the same as the structure of the solar system? Yes ! It is similar to the solar system. It has a core center called nucleus and it has paths called orbits around the nucleus.

Atomic number (z)

The number of electrons or protons in an atom is called the atomic number of that atom. It is represented by the letter Z. if we know the atomic number of an atom, we know the number of electrons or protons in it.

Look at the figures. The hydrogen nucleus has one proton around which revolves one electron. It means that its atomic number z=1.

In the helium atom there are two protons and two electrons in orbit around the nucleus, so the atomic number of helium is z=2.

Look at the atomic structure of oxygen shown in the figure. What is its atomic number?

Mass number (A) or Atomic mass :

We have seen that the mass of an atom is concentrated in its nucleus. From this, we can get the atomic mass number. mass number (A) is equal to the sum of the number of protons(p) and neutrons (n) in the nucleus.

Automic mass or mass number = Number of Protons + Number of Neutrons

$$A = p+n$$

A lithium atom contains 3 Protons and 4 neutrons . Its atomic mass number A = 3+4 = 7.

In a sodium atom, there are 11 Protons and 12 neutrons. Hence , its atomic mass number A = 11 + 12 = 23.

When writing the symbol of an element, its atomic number and atomic mass number are also written. For example, the symbols of hydrogen, carbon and oxygen are written as $_1H^1$, $_6C^{12}$, $_8O^{16}$ respectively.

Elements	Symbols	Number of proton, electron, neutron,
Carbon	$_6C^{12}$	**6p,6e,6n**
Beryllium	$_4Be^{12}$	4p,4e,5n
Nitrogen	$_7Be^{14}$	7p,7e,7n
Boron	$_5B^{11}$	5p,5e,6n

Isotopes: Atoms of the same element can have different number of neutrons. Such atoms will have same atomic number but different mass numbers. These atoms are called isotopes. For example Hydrogen has three isotopes --- Hydrogen (1H1), Deuterium (1H2), Tritium (1H3).

Isobars: Atoms that have the same mass number but different atomic numbers. for example Calcium – 40 and Argon - 40

Elements and their symbols with their atomic number and mass number.

Element	symbol	Atomic number	Protons (p)	Neutrons(n)	Mass number(p+n)
Hydrogen	H	1	1	0	1
Helium	He	2	2	2	4
Aluminium	Al	13	13	14	27
Oxygen	O	8	8	8	16
Sodium	Na	11	11	12	23

Valency

Imagine there are various people having different pattern of hands. Some have no hands and some have one, some two and others three. Few have four and no one has more than four. The person with four hands can hold hands of four others at a same time, while the one with no hands can never hold any hand. In this manner some atoms can hold one electron, some can hold two, some can hold three, some can hold four and some cannot hold any electron. This property is called valency.

WHAT MAKES ATOMS STICK TOGETHER?
Electrons carry a negative electric charge, and protons carry a positive charge. The attraction between them holds electrons in orbits.

This combining property of an atom is called as Valency. It is a measure of how many hydrogen atoms it can combine with. For example: oxygen can combine with two hydrogen atoms and create water molecule, the valency of oxygen atom is two. In case of chlorine, it can combine with only one hydrogen to create HCl (hydrochloric acid) here the valency of chlorine is one. Methane has one carbon atom combining with four hydrogen atoms to form carbon molecule is methane (CH4). Can you guess the valency of Carbon in methane? In ammonia molecule, Nitrogen combines with three hydrogen atoms. What is the valency of Nitrogen in ammonia?

Valency is defined as the combining capacity of an element. Atoms of different elements combine with each other to form molecules. Valency determines the number of atoms of an element that combines with atom or atoms of another type.

The element having valency one is called monovalent. For example: Hydrogen and Sodium. The elements having valency two are called divalent. For example: Oxygen and Beryllium. The elements having valency three are called trivalent. For example: Nitrogen and Aluminium. Some elements exhibits more than one valency. For example: Iron combines with oxygen to form two types ferrous oxide (exhibits valency 2) and ferric oxide (exhibits valency 3), however we will study about them later.

When atoms of different elements combine with each other then molecules of compounds are formed. In these instances, it is necessary to know the valancies of those elements. For example:

1 2Na + Cl2 ---------- 2NaCl

Valency 1 + 1

Here, the valancies of both sodium and chlorine are 1.
Remember The valency of element Na is 1
The valency of element Cl is 1
Then, the molecular formula will be
Symbol of Elements Na Cl Molecular Formula
Radicals and ions 1 1 NaCl

2 Mg + Cl_2 ---------- Mg Cl_2

Element	**Symbol**	**Atomic Number**	**Mass Number**	**Valency**
Hydrogen	H	1	1	1
Carbon	C	6	12	4
Oxygen	O	8	16	2
Sodium	Na	11	23	1
Calcium	Ca	20	40	2

8th term II
Unit – 4 ATOMIC STRUCTURE

Introduction

Every substance in our surrounding is made up of unique elements. There are 118 elements identified worldwide so far. Out of these elements, 92 elements occur in the nature and the remaining elements are synthesised in the laboratories. Copper, Iron, Gold and Silver are some of the elements found in the nature. Elements like Technetium, Promethium, Neptunium and Plutonium are synthesised in the labaratories. Each element is made up of similar, minute particles called atoms. For example, the element gold is made up of similar atoms which determine its characteristics. The word atom is derived from the Greek word atomas. Tomas means smallest divisible particle and atomas means smallest indivisible particle. Ancient philosophers like Democritus have spoken about atoms. Even our Tamil poet Avvaiyar has mentioned about atoms in her poem while describing Thirukkural **(அணுவைத் துளைத்து ஏழ் கடலைப்புகட்டிக் குறுகத் தரித்த குறள்).**

But, none of them have scientific base. The first scientific theory about atom was given by John Dalton. Followed by him, J.J.Thomson and Rutherford have given their theory about atom. In this lesson, we will study how atomic theories evolved at different times. We will also study about valency, molecular formula, rules for naming chemical compounds and balancing chemical equations.

Dalton's Atomic Theory

John Dalton provided a basic theory about the nature of matter. He proposed a model of atom known as Dalton's atomic theory in 1808 based on his experiments. The main postulates of Dalton's atomic theory are:

- All the matters are made up of extremely small particles called atoms (Greek philosopher Democritus used the same name for the smallest indivisible particles).
- Atoms of the same element are identical in all respects (size, shape, mass and properties).
- Atoms of different elements have different sizes and masses and possess different properties.

- Atoms can neither be created nor be destroyed. i.e., atom is indestructible.
- Atoms of different elements may combine with each other in a fixed simple ratio to form molecules or compounds.
- An atom is the smallest particle of matter that takes part in a chemical reaction.

John Dalton, son of a poor weaver, began his career as a village school teacher at the age of 12. He became the principal of the school seven years later. In 1793, he moved to Manchester to teach Physics, Chemistry and Mathematics in a college. He proposed his atomic theory in 1803. He carefully recorded each day, the temperature, pressure and amount of rainfall from his youth till the end. He was a meticulous meteorologist.

Advantages of Dalton's Atomic Theory

- Dalton's theory explains most of the properties of gases and liquids.
- This explains the laws of chemical combination and the law of conservation of mass.
- This theory helps to recognize the molecular differences of elements and compounds.

Limitations of Dalton's Atomic Theory

- Atom is no longer considered as the smallest indivisible particle.
- Atoms of the same element have different masses (Isotopes).
- Atoms of the different elements may have same masses (Isobars).
- Substances made up of same kind of atoms may have different properties (Ex. Coal, Graphite and Diamond are made up of carbon atoms but they differ in their properties).

Fundamental Particles

In 1878, Sir William Crookes, while conducting an experiment using a discharge tube, found certain visible rays travelling between two metal electrodes. These rays are known as Crookes' Rays or Cathode Rays. The discharge tube used in the experiment is now referred as Crookes tube or more popularly as Cathode Ray Tube (CRT).

Cathode Ray Tube is a long glass tube filled with gas and sealed at both the ends. It consists of two metal plates (which act as electrodes) connected with high voltage. The electrode which is connected to the negative terminal of the battery is called the cathode (negative electrode). The electrode connected to the positive terminal is called the anode (positive electrode). There is a side tube which is connected to a pump. The pump is used to lower the pressure inside the discharge tube.

Electricity, when passes through air, removes the electrons from the gaseous atoms and produces ions. This is called electrical discharge.

Discovery of Electrons

When a high electric voltage of 10,000 volts or more is applied to the electrode of a discharge tube containing air or any gas at atmospheric pressure, no electricity flows through the air. However, when the high voltage of 10,000 volts is applied to the electrodes of discharge tube containing air or any gas at a very low pressure of about 0.001 mm of mercury, a greenish glow is observed on the walls of the discharge tube behind anode. This observations clearly show some invisible ray coming from the cathode. Hence, these rays are called cathode rays. Later, they were named as electrons.

The fact that air is a poor conductor of electricity is a blessing in disguise for us. Imagine what would happen if air had been a good conductor of electricity. All of us would have got electrocuted, when a minor spark was produced by accident.

Properties of Cathode rays

- Cathode rays travel in straight line from cathode towards anode.
- Cathode rays are made up of material particles which have mass and kinetic energy.
- Cathode rays are deflected by both electric and magnetic fields. They are negatively charged particles.
- The nature of the cathode rays does not depend on the nature of the gas filled inside the tube or the cathode used.

In television tube cathode rays are deflected by magnetic fields. A beam of cathode rays is directed toward a coated screen on the front of the tube, where by varying the magnet field generated by electromagnetic coils, the beam traces a luminescent image.

Discovery of Protons

The presence of positively charged particles in the atom has been precisely predicted by Goldstein based on the conception that the atom being electrically neutral in nature, should necessarily possess positively charged particles to balance the negatively charged electrons. Goldstein repeated the cathode ray experiment by using a perforated cathode. On applying a high voltage under low pressure, he observed a faint red glow on the wall behind the cathode. Since these rays originated from the anode, they were called anode rays or canal rays or positive rays. Anode rays were found as a stream of positively charged particles.

When invisible radiation falls on materials like zinc sulphide, they emit a visible light (or glow). These materials are called fluorescent materials.

Properties of Anode rays

- Anode rays travel in straight lines.
- Anode rays are made up of material particles.
- Anode rays are deflected by electric and magnetic fields. Since, they are deflected towards the negatively charged plate, they consist of positively charged particles.
- The properties of anode rays depend upon the nature of the gas taken inside in the discharge tube.
- The mass of the particle is the same as the atomic mass of the gas taken inside the discharge tube.

When hydrogen gas was taken in a discharge tube, the positively charged particles obtained from the hydrogen gas were called protons. Each of these protons are produced when one electron is removed from one hydrogen atom. Thus, a proton can be defined as an hydrogen ion (H+).

$H \rightarrow H^+ + e$

Discovery of Neutrons

At the time of J.J.Thomson, only two fundamental particles (proton and electron) were known. In the year 1932, James Chadwick discovered another fundamental particle, called neutron. But, the proper position of these particles in an atom was not clear till Rutherford described the structure of atom. You will study about Rutherford's atom model in your higher classes.

Properties of Neutrons

- Neutron is a neutral particle, that is, it carries no charge.
- It has mass equal to that of a proton, that is 1.6×10^{-24} grams.

Particle	Mass	Relative charge
Electron (e)	9.1×10^{-28} grams	–1
Proton (p)	1.6×10^{-24} grams	+1
Neutron (n)	1.6×10^{-24} grams	0

Thomson's Atom Model

J.J. Thomson, an English scientist, proposed the famous atom model in the year 1904, just after the discovery of electrons. Thomson proposed that the shape of an atom resembles a sphere having a radius of the order of 10-10 m. The positively charged particles are uniformly distributed with electrons arranged in such a manner that the atom is electrically neutral. Thomson's atom model was also called as the plum pudding model or the watermelon model. The embedded electrons resembled the seed of watermelon while the watermelon's red mass represented the positive charge distribution. The plum pudding atomic theory assumed that the mass of an atom is uniformly distributed all over the atom.

Limitations of Thomson's Atom model

Thomson's atom model could successfully explain the electrical neutrality of atom. However, it failed to explain the following.

1. Thomson's model failed to explain how the positively charged sphere is shielded from the negatively charged electrons without getting neutralised.
2. This theory explains only about the protons and electrons and failed to explain the presence of neutral particle neutron.

Valency

In order to understand valency of elements clearly, we need to learn a little about Rutherford's atom model here. According to Rutherford, an atom consists of subatomic particles namely, proton, electron and neutrons. Protons and neutrons are found at the centre of an atom, called nucleus. Electrons are revolving around the nucleus in a circular path, called orbits or shells. An atom has a number of orbits and each orbit has electrons. The electrons revolving in the outermost orbit are called valence electrons.

The arrangement of electrons in the orbits is known as electronic configuration. Atoms of all the elements will tend to have a stable electronic configuration, that is, they will tend to have either two electrons (known as duplet) or eight electrons (known as octet) in their outermost orbit. For example, helium has two electrons in the outermost orbit and so it is chemically inert. Similarly, neon is chemically inert because, it has eight electrons in the outermost orbit.

The valence electrons in an atom readily participate in a chemical reaction and so the chemical properties of an element are determined by these electrons. When molecules are formed, atoms combine together in a fixed proportion because each atom has different combining capacity. This combining capacity of an atom is called valency. Valency is defined as the number of electrons lost, gained or shared by an atom in a chemical combination so that it becomes chemically inert.

Types of Valency

As we saw earlier, an atom will either gain or lose electrons in order to attain the stable electronic configuration. In order to understand valency in a better way, it can be explained in two ways depending on whether an atom gains or losses electrons.

Atoms of all metals will have 1 to 3 electrons in their outermost orbit. By loosing these electrons they will have stable electronic configuration. So, they lose them to other atoms in a chemical reaction and become positively charged. Such atoms which donate electrons are said to have positive valency. For example, sodium atom (Atomic number: 11) has one electron in its outermost orbit and in order to have stability it loses one electron and becomes positively charged. Thus, sodium has positive valency.

All non-metals will have 4 to 7 electrons in the outermost orbit of their atoms. In order to attain stable electronic configuration, they need few electrons. They accept these electrons from other atoms in a chemical reaction and become negatively charged. These atoms which accept electrons are said to have negative valency. For example, chlorine atom (Atomic number: 17) has seven electrons in its outermost orbit. By gaining one electron it attains stable electronic configuration. Thus, chlorine has negative valency.

Valency with respect to atoms

Valency of an element is also determined with respect to other atoms. Generally, valency of an atom is determined with respect to hydrogen, oxygen and chlorine.

Valency with respect to Hydrogen

Since hydrogen atom loses one elctron in its outermost orbit, its valency is taken as one and it is selected as the standard. Valencies of the other elements are expressed in terms of hydrogen. Thus, valency of an element can also be defined as the number of hydrogen atoms which combine with one atom of it. In hydrogen chloride molecule, one hydrogen atom combines with one chlorine atom. Thus, the valency of chlorine is one. Similarly, in water molecule, two hydrogen atoms combine with one oxygen atom. So, valency of oxygen is two.

Since some of the elements do not combine with hydrogen, the valency of the element is also defined in terms of other elements like chlorine or oxygen. This is because almost all the elements combine with chlorine and oxygen.

Molecule	Element	Valency
Hydrogen chloride (HCl)	Chlorine	1
Water (H_2O)	Oxygen	2
Ammonia (NH_3)	Nitrogen	3
Methane (CH_4)	Carbon	4

Valency with respect to Chlorine

Since valency of chlorine is one, the number of chlorine atoms with which one atom of an element can combine is called valency. In sodium chloride (NaCl) molecule, one chlorine atom combines with one sodium atom. So, the valency of sodium is one. But, in magnesium chloride (MgCl2) valency of magnesium is two because it combines with two chlorine atoms.

Valency with respect to oxygen

In another way, valency can be defined as double the number of oxygen atoms with which one atom of an element can combine because valency of oxygen is two. For example, in magnesium oxide (MgO) valency of magnesium is two.

Variable Valency

Atoms of some elements combine with atoms of other elements and form more than one product. Thus, they are said to have different combining capacity. These atoms have more than one valency. Some cations exhibit more than one valency. For example, copper combines with oxygen and forms two products namely cuprous oxide (Cu_2O) and cupric oxide (CuO). In Cu_2O, valency of copper is one and in CuO valency of copper is two. For lower valency a suffix –ous is attached at the end of the name of the metal. For higher valency a suffix –ic is attached at the end of the name of the metal. Sometimes Roman numeral such as I, II, III, IV etc. indicated in parenthesis followed by the name of the metal can also be used.

Element	Cation	Names
Copper	Cu^{+}	Cuprous (or) Copper (I)
	Cu^{2+}	Cupric (or) Copper (II)
Iron	Fe^{2+}	Ferrous (or) Iron (II)
	Fe^{3+}	Ferric (or) Iron (III)
Mercury	Hg^{+}	Mercurous (or) Mercury (I)
	Hg^{2+}	Mercuric (or) Mercury (II)
Tin	Sn^{2+}	Stannous (or) Tin (II)
	Sn^{4+}	Stannic (or) Tin (IV)

Ions

In an atom, the number of protons is equal to the number of electrons and so the atom is electrically neutral. But, during chemical reactions unstable atoms try to attain stable electronic configuration (duplet or octet) either by gaining or losing one or more electrons. When an atom gains an electron it has more number of electrons and thus it carries negative charge. At the same time when an atom loses an electron it has more number of protons and thus it carries positive charge. These atoms which carry positive or negative charges are called ions. The number of electrons gained or lost by an atom is shown as a superscript to the right of its symbol. When an atom loses an electron, '+' sign is shown in the superscript and '–' sign is shown if an electron is gained by an atom. Some times, two or more atoms of different elements collectively lose or gain electrons to acquire positive or negative charge. Thus we can say, an atom or a group of atoms when they either lose or gain electrons, get converted into ions or radicals.

Types of Ions

Ions are classified into two types. They are: cations and anions.

Cations

If an atom loses one or more electrons during a chemical reaction, it will have more number of positive charge on it. These are called cations (or) positive radicals. Sodium atom loses one electron to attain stability and it becomes cation. Sodium ion is represented as Na^+.

Anions

If an atom gains one or more electrons during a chemical reaction, it will have more number of negative charge on it. These are called anions or negative radicals. Chlorine atom attains stable electronic configuration by gaining an electron. Thus, it becomes anion. Chlorine ion is represented as Cl^-.

Different valent ions

During a chemical reaction, an atom may gain or lose more than one electron. An ion or radical is classified as monovalent, divalent, trivalent or tetravalent when the number of charges over it is 1,2,3 or 4 respectively. Based on the charges carried by the ions, they will have different valencies.

Valency of Anions (negative radicals) and Cations (positive radicals)

The valency of an anion or cation is a number which expresses the number of hydrogen atoms or any other monovalent atoms (Na,K,Cl….) which combine with them to give an appropriate compound. For example, two hydrogen atoms combine with one sulphate ions (SO_4^{2-}) to form sulphuric acid (H^2SO^4). So, the valency of SO_4^{2-} is 2. One chlorine atom (Cl) combines with one ammonium ion

(NH_4^+) to form NH_4Cl. So, the valency of NH_4^+ is 1. Valencies of some anions and cations and their corresponding compounds are given below.

Compound	Name of the anion	Formula of anion	Valency of anion
HCl	Chloride	Cl^-	1
H_2SO_4	Sulphate	SO_4^{2-}	2
HNO_3	Nitrate	NO_3^-	1
H_2CO_3	Carbonate	CO_3^{2-}	2
H_3PO_4	Phosphate	PO_4^{3-}	3
H_2O	Oxide	O^{2-}	2
H_2S	Sulphide	S^{2-}	2
NaOH	hydroxide	OH^-	1

Compound	Name of cation	Formula of cation	Valency of cation
NaCl	Sodium	Na^+	1
KCl	Potassium	K^+	1
NH_4Cl	Ammonium	NH_4^+	1
$MgCl_2$	Magesium	Mg^{2+}	2
$CaCl_2$	Calcium	Ca^{2+}	2
$AlCl_3$	Aluminium	Al^{3+}	3

Chemical formula or Molecular formula

Chemical formula is the shorthand notation of a molecule of a substance (compound). It shows the actual number of atoms of each element present in a molecule of a substance. Certain steps are followed to write down the chemical formula of a substance. They are given below.

1. Write down the symbols of elements/ ions side by side so that the positive radical is on the left and the negative radical is on the right hand side.

2. Write the valencies of the two radicals above their symbols to the right in superscript (Signs '+' and '-' of the ions are omitted).
3. Reduce the valencies to simplest ratio if needed. Otherwise interchange the valencies of the elements/ions. Write these numbers as subscripts. However, '1' appearing on the superscript of the symbol is omitted.

❖ Thus, we arrive the chemical formula of the compound.
❖ Let us derive the chemical formula for calcium chloride.

1. Write the symbols of calcium and chlorine side by side. Ca Cl
2. Write the valencies of calcium and chlorine above their symbols to the right. Ca_2 Cl^1
3. Interchange the valencies of elements. Ca Cl^2

Thus the chemical formula for calcium chloride is $CaCl_2$

Naming chemical compounds

A chemical compound is a substance formed out of more than one element joined together by chemical bond. Such compounds have properties that are unique from that of the elements that formed them. While naming these compounds specific ways are followed. They are given below.

In naming a compound containing a metal and a non-metal, the name of the metal is written first and the name of the non-metal is written next after adding the suffix-ide to its name.

Examples:

- NaCl - Sodium chloride
- Ag Br - Silver bromide

In naming a compound containing a metal, a non-metal and oxygen, name of the metal is written first and name of the non-metal with oxygen is written next after adding the suffix- ate (for more atoms of oxygen) or –ite (for less atoms of oxygen) to its name.

Examples:

- Na_2 SO_4 - Sodium sulphate

- Na NO_2 - Sodium nitrite

In naming a compound containing two non-metals only, the prefix mono, di, tri, tetra, penta etc. is written before the name of non- metals.

Examples:

- SO_2 - Sulphur dioxide
- N_2O_5 - Dinitrogen pentoxide

Chemical Equation

A chemical equation is a short hand representation of a chemical reaction with the help of chemical symbols and formulae. Every chemical equation has two components: reactants and products. Reactants are the substances that take part in a chemical reaction and the products are the substances that are formed in a chemical reaction.

Steps in writing the skeleton equation

Before writing the balanced equation of a chemical reaction, skeletal equation is written. The following are the steps involved in writing the skeletal equation.

1. Write the symbols and formulae of each of the reactants on the left hand side (LHS) and join them by plus (+) sign.
2. Follow them by an arrow (→) which is interpreted as gives or forms.
3. Write on the right hand side (RHS) of arrow the symbols and formulae for each of the products.
4. The equation thus written is called as skeleton equation (unbalanced equation).
5. If the product is a gas it should be represented by upward arrow (↑) and if it is a precipitate it should be represented by downward arrow(↓).

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2\uparrow$$

Balancing chemical equation

According to law of conservation of mass, the total mass of all the atoms forming the reactants should be equal to that of all the atoms forming the products. This law will hold good only when the number of atoms of all types of elements on both sides is equal. A balanced chemical equation is one in which the total number of atoms of any element on the reactant side is equal to the total number of atoms of that element on the product side.

There are many methods of balancing a chemical equation. Trial and error method (direct inspection), fractional method and odd number-even number method are some of them. While balancing a chemical equation following points are to be borne in mind.

1. Initially the number of times an element occurs on both sides of the skeleton equation should be counted.
2. An element which occurs least number of times in reactant and product side must be balanced first. Then, elements occuring two times, elements occuring three times and so on in an increasing order must be balanced.
3. When two or more elements occur same number of times, the metallic element is balanced first in preference to non-metallic element. If more than one metal or non-metal is present then a metal or non-metal with higher atomic mass (refer periodic table to find the atomic mass) is balanced first.
4. The number of molecules of reactants and products are written as coefficient.
5. The formula should not be changed to make the elements equal.
6. Fractional method of balancing must be employed only for molecule of an element (O_2,H_2,O_3,P_4,⋯) not for compound (H_2O, NH_3,⋯)

Now let us balance the equation for the reaction of hydrogen and oxygen which gives water. Write the word equation and balance it.

1. Write the word equation. Hydrogen + Oxygen → Water
2. Write the skeleton equation. $H_2 + O_2 \rightarrow H_2O$
3. Select the element which is to be balanced first based on the number of times an element occurs on both sides of the skeleton equation.

Element	H	O
Number of times particular element occurs on both sides	2	2

4. In the above case, both elements occur one time each. Here, preference must be given to oxygen because it has higher atomic mass (refer periodic table).

5. To balance oxygen, put 2 before H2O on the right hand side (RHS).
   $H_2 + O_2 \rightarrow 2H_2O$
6. To balance hydrogen, put 2 near hydrogen (H2) on the left hand side (LHS).
   $2H_2 + O_2 \rightarrow 2H_2O$
   (H = 4 0 = 2) (H = 4 0 = 2)

Now, on both sides number of hydrogen atoms is four and oxygen atoms is two. Thus, the chemical equation is balanced.

Information conveyed by a balanced chemical equation

A balanced chemical equation gives us both qualitative and quantitative information. It gives us qualitative informations such as the names, symbols and formulae of the reactant molecules taking part in the reaction and those of the product molecules formed in the reaction. We also can get quantitative information like the number of molecules/ atoms of the reactants and products that are taking part in the reaction. However, a chemical equation does not convey the following.

1. Physical state of the reactants and the products.
2. Heat changes (heat liberated or heat absorbed) accompanying the chemical reaction.
3. Conditions such as temperature, pressure, catalyst etc., under which the reaction takes place.
4. Concentration (dilute or concentrated) of the reactants and products.
5. Speed of the reaction

Laws of chemical combinations

By studying quantitative measurements of many reactions, it was observed that the reactions taking place between various substances are governed by certain laws. They are called as the 'Laws of chemical combinations'. They are given below.

1. Law of conservation of mass
2. Law of constant proportion
3. Law of multiple proportions
4. Gay Lussac's law of gaseous volumes

In this lesson, we will study about the first two laws. You will study about Law of multiple proportions and Gay Lussac's Law of gaseous volumes in standard IX.

Law of conservation of mass

The law of conservation of mass which relates the mass of the reactants and products during the chemical change was stated by a French chemist Lavoisier in 1774. It states that during any chemical change, the total mass of the products is equal to the total mass of the reactants. In other words the law of conservation of mass means that mass can neither be created nor be destroyed during any chemical reaction. This law is also known as Law of indestructibility of mass.

Consider the formation of ammonia (Haber's process) from the reaction between nitrogen and hydrogen

$N_2 + 3H_2 \rightarrow 2NH_3$
$28_g \quad 6_g \quad 34_g$

During Haber's process the total mass of the reactant and the product are exactly same throughout the reaction.

Now, it is clear that mass is neither created not destroyed during physical or chemical change. Thus, law of conservation of mass is proved.

Law of constant proportions

Law of constant proportions was proposed by the scientist Joseph Proust in 1779. He states that in a pure chemical compound the elements are always present in definite proportions by mass. He observed all the compounds with two or more elements and noticed that each of such compounds had the same elements in same proportions, irrespective of where the compound came from or who prepared it. For example, water obtained from different sources like rain, well, sea, and river will always consist of the same two elements hydrogen and oxygen, in the ratio 1:8 by mass. Similarly, the mode of preparation of compounds may be different but their composition will never change. It will be in a fixed ratio. Hence, this law is also known as 'Law of definite proportions'.

9th std
Unit - 11 Atomic Structure

Introduction

Just as a small child wants to take a toy apart to find out what is inside, scientists have for long been curious about the internal structure of an atom. They wanted to find out what are the particles present inside an atom and how are these particles arranged in an atom. For explaining this many scientists proposed various atomic models.

We have learnt Dalton's atomic theory and J.J. Thomson's model in class VIII. Now we will learn about sub-atomic particles and the other atomic models to explain how these particles are arranged within an atom.

Discovery of Nucleus

In 1911, Lord Rutherford, a scientist from New Zealand, performed his famous experiment of bombarding a thin gold foil with very small positively charged particles called alpha(α) particles. He selected a gold foil because, he wanted as thin layer as possible and gold is the most malleable metal.

1. Most of the alpha particles passed straight through the foil.
2. Some alpha particles were slightly deflected from their straight path.
3. Very few alpha particles completely bounced back.

Later, Rutherford generalized these results of alpha particles scattering experiment and suggested a model of the atom that is known as Rutherford's Atomic model.

Rutherford's Atomic model

According to this model :

1. The atom contains large empty space.

2. There is a positively charged mass at the centre of the atom, known as nucleus. The size of the nucleus of an atom is very small compared to the size of an atom.
3. The electrons revolve around the nucleus in close circular paths called orbits.
4. An atom as a whole is electrically neutral, i.e., the number of protons and electrons in an atom are equal

Rutherford's model of atomic structure is similar to the structure of the solar system. Just as in the solar system, the Sun is at the centre and the planets revolve around it, similarly in an atom the nucleus contains the main mass and the electrons revolve around it in orbits or shells.

Limitations in Rutherford's model

According to Electromagnetic theory, a moving electron should accelerate and continuously lose energy. Due to the loss of energy, path of electron may reduce and finally the electron should fall into the nucleus. If it happens so, atom becomes unstable. But atoms are stable. Thus, Rutherford's model failed to explain the stability of an atom.

Bohr's model of an atom

In 1913, Neils Bohr, a Danish physicist, explained the causes of the stability of the atom in a different manner. The main postulates are:

1. In atoms, the electron revolve around the nucleus in stationary circular paths called orbits or shells or energy levels.
2. While revolving around the nucleus in an orbit, an electron neither loses nor gains energy.
3. An electron in a shell can move to a higher or lower energy shell by absorbing or releasing a fixed amount of energy.
4. The orbits or shells are represented by the letters K,L,M,N,… or the numbers, n= 1,2,3,4,….

The orbit closest to the nucleus is the K shell. It has the least amount of energy and the electrons present in it are called K electrons, and so on with the successive shells and their electrons. These orbits are associated with fixed amount of energy , so Bohr called them as energy level or energy shells.

Limitations of Bohr's model

One main limitation was that this model was applicable only to hydrogen and hydrogen like ions (example, He+, Li2+, Be3+, and so on). It could not be extended to multi electron nucleus.

Discovery of Neutrons

In 1932 James Chadwick observed when Beryllium was exposed to alpha particles, particles with about the same mass as protons were emitted.

Beryllium + alpha ray → carbon + neutron

These emitted particles carried no electrical charges. They were called as neutrons. It is denoted by **0*n*1**. The superscript 1 represents its mass and subscript 0 represents its electric charge.

Properties of Neutrons

1. This particle was not found to be deflected by any magnetic or electric field, proving that it is electrically neutral.
2. Its mass is equal to 1.676×10^{-24}g (1 amu).

In 1920 Rutherford predicted the presence of another particle in the nucleus as neutral. James Chadwick, the inventor of neutron was student of Rutherford

Characteristics of Fundamental particles

The atom is built up of a number of sub- atomic particles. The three sub-atomic particles of great importance in understanding the structure of an atom are electrons, protons and neutrons, the properties.

Particle	Symbol	Charge (electronic units)	mass (amu)	mass (grams)
Electron	$_{-1}e^0$	−1	1/1837	9.1×10^{-28}
Proton	$_1H^1$	+1	1	1.6×10^{-24}
Neutron	$_0n^1$	0	1	1.6×10^{-24}

There are two structural parts of an atom, the nucleus and the empty space in which there are imaginary paths called orbits.

Nucleus:

The protons and neutrons [collectively called **nucleons**]are found in the nucleus of an atom.

Orbits:

Orbit is defined as the path, by which electrons revolve around he nucleus.

Besides the fundamental particles like protons, electrons and neutrons some more particles are discovered in the nucleus of an atom. They include mesons, neutrino, antineutrino, positrons etc.

Atomic number and Mass number

Only hydrogen atoms have one proton in their nuclei. Only helium atoms have two protons. Indeed, only gold atoms have 79 protons. This shows that the number of protons in the nucleus of an atom decides which element it is. This very important number is known as the atomic number (proton number, given the symbol Z) of an atom.

Atomic number(Z) = Number of protons = Number of electrons

Protons alone do not make up all of the mass of an atom. The neutrons in the nucleus also contribute to the total mass. The mass of the electron can be regarded as so small that it can be ignored. As a proton and a neutron have the same mass, the mass of a particular atom depends on the total number of protons and neutrons present. This number is called the **mass number** (or nucleon number, given the symbol A) of an atom.

Mass number = Number of protons + Number of neutrons

For any element, the atomic numbers are shown as subscripts and mass number are shown as superscripts.

Here **7** is its atomic number and **14** is its mass number.

The difference between the mass number of an element and its atomic number gives the number of neutrons present in one atom of the element.

Number of neutrons (n) = Mass number (A) – Atomic number (z)

Atomic number is designated as Z why?
Z stands for Zahl, which means NUMBER in German.
Z can be called Atomzahl or atomic number
A is the symbol recommened in the ACS style guide instead of M (massenzahl in German).

Calculate the atomic number of an element whose mass number is 39 and number of neutrons is 20. Also find the name of the element.

Solution:

Mass Number = Atomic number + Number of neutrons
Atomic Number = Mass number – Number of neutrons
= 39 – 20
Atomic Number = 19
Element having atomic number 19 is Potassium (K)

Electronic configuration of atoms

You already know that electrons occupy different energy levels called orbits or shells. The distribution of electrons in different shells is called electronic configuration. This distribution of electrons is governed by certain rules or conditions, known as Bohr and Bury Rules of electronic configuration.

The maximum number of electrons that can be accommodated in a shell is equal to 2n2 where 'n' is the serial number of the shell from the nucleus.

Shell	Value of (n)	Maximum number of electrons ($2n^2$)
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$

Shells are filled in a **stepwise manner** in the increasing order of energy.

The outermost shell of an atom cannot have more than 8 electrons , even if it has capacity to accomodate more electrons. For example, electronic arrangement in calcium having 20 electrons is,

K L M N
2 8 8 2

What is the Electronic configuration of Aluminium?

Solution:

Electronic configuration of Aluminium atom: (Z = 13) **K shell = 2 , L shell = 8 and M shell = 3 electron**.

So its electronic configuration is 2, 8, 3

The forces between the protons and the neutrons in the nucleus are of special kind called Yukawa forces. This strong force is more powerful than gravity.

Geometric Representation of atomic structure of elements

Knowing the mass number and atomic number of an element we can represent atomic structure.

Example:

Geometric Representation of oxygen atom $_8^{16}O$
Mass number A = 16

Atomic number Z = 8
Number of neutrons = A − Z = 16 − 8 = 8
Number of protons = 8
Number of electron = 8
Electronic configuration = 2, 6

Atoms are so tiny their mass number cannot be expressed in grams but expressed in amu (atomic mass unit). New unit is U Size of an atom can be measured in nano metre (1 nm = 10^{-9} m)Even though atom is an invisible tiny particle now-a-days atoms can be viewed through SEM that is Scanning Electron Microscope.

Valence electrons

In the above example, we can see that there are six electrons in the outermost shell of oxygen atom. These six electrons are called as valence electrons.

The outermost shell of an atom is called valence shell and the electrons present in the valence shell are known as valence electrons. The chemical properties of elements are decided by these valence electrons, since they are the ones that take part in chemical reaction.

The elements with same number of electrons in the valence shell show similar properties and those with different number of valence electrons show different chemical properties. Elements, which have valence electrons 1 or 2 or 3 (except Hydrogen) are metals.

Elements with 4 to 7 electrons in their valence shell are non-metals.

Valency

Valency of an element is the combining capacity of the element with other elements and is equal to the number of electrons that take part in a chemical reaction. Valency of the elements having valence electrons 1, 2, 3, 4 is 1, 2, 3, 4 respectively.

Valency of an element with 5, 6 and 7 valence electrons is 3, 2 and 1 (8–valence electrons) respectively. Because 8 is the number of electrons required by an element to attain stable electronic configuration. Elements having completely filled outermost shell show Zero valency.

Find the valency of Magnesium and Sulphur

Solution:

Electronic configuration of magnesium is 2, 8, 2. So valency is 2.
Electronic configuration of sulphur is 2, 8, 6. So valency is 2 i.e.(8 – 6)

Isotopes

In nature a number a atoms of some elements have been identified, which have the same atomic number but different mass numbers. For example, take the case of hydrogen atom it has three atomic species.

On the basis of these examples, isotopes are defined as the atoms of the same elements having the same atomic number but different mass numbers. There are two types of isotopes those which are stable and those which are unstable. The isotopes which are unstable as a result of the extra neutrons in their nuclei are radio active and are called radio isotopes. For example, uranium –235
which is a source of nuclear reactors and cobalt-60 which is used in radiotherapy treatment are both radio isotopes.

Isobars

Let us consider two elements – calcium (atomic number 20), and argon (atomic number 18).

Different number of protons and electrons. But, the mass number of both these elements is 40. It follows that the total number of nucleons in both the atoms are the same. They are called isobars. Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars.

No of neutrons in boron = 11 – 5 = 6
No of neutrons in carbon = 12 – 6 = 6

The above pair of elements Boron and Carbon has the same number of neutrons but different number of protons and hence different atomic numbers. Atoms of different elements with different atomic numbers and different mass numbers, but with same number of neutrons are called isotones.

Laws of Chemical combination

In the seventeenth century, scientists had been trying to find out methods for converting one substance into another. During their studies of chemical changes, they made certain generalisations. These generalisations are known as laws of chemical combination. These are :

1. Law of conservation of mass
2. Law of constant proportions
3. Law of multiple proportions
4. Law of reciprocal proportions
5. Gay Lussac's law of gaseous volumes

Out of these five laws you have already learnt the first two laws in class VIII. Let us see the next three laws in detail in this chapter.

Law of multiple proportions

This law was proposed by John Dalton in 1804.

It states that, "When two elements A and B combine together to form more than one compound, then masses of A which separately combines with a fixed mass of B are in simple ratio".

To illustrate the law let us consider the following example.

Carbon combines with oxygen to form two different oxides, carbon monoxide(CO) and carbon dioxide (CO_2). The ratio of masses of oxygen in CO and CO_2 for fixed mass of carbon is 1: 2.

	Mass of carbon (g)	Mass of oxygen (g)	Ratio of O in CO to O in CO_2
CO	12	16	1:2
CO_2	12	32	

Let us take one more example, Sulphur combines with oxygen to form sulphur dioxide and sulphur trioxide. The ratio of masses of oxygen in SO_2 and SO_3 for fixed mass of Sulphur is 2:3.

Law of Reciprocal Proportions

The law of reciprocal proportions was proposed by Jeremias Ritcher in 1792.

It states that, "If two different elements combine separately with the same weight of a third element, the ratios of the masses in which they do so are either the same or a simple multiple of the mass ratio in which they combine."

Consider the three elements hydrogen, oxygen and water as shown below:

Here, hydrogen and oxygen combine separately with the same weight of carbon to form methane (CH_4) and carbon dioxide (CO_2).

Compounds	Combining elements		Combining weights	
CH_4	C	H	12	4
CO_2	C	O	12	32

Now, hydrogen and oxygen combine to form water (H_2O).

Gay Lussac's Law of Combining Volumes

According to Gay Lussac's Law, Whenever gases react together, the volumes of the reacting gases as well as the products bear a simple whole number ratio, provided all the volumes are measured under similar conditions of temperature and pressure.

This law may be illustrated by the following example.

It has been experimentally observed that two volumes of hydrogen reacts with one volume of oxygen to form two volumes of water.

The ratio of volume which gases bears is **2:1:2** which is a simple whole number ratio.

Quantum Numbers

When you specify the location of a building, you usually list which country it is in, which state and city it is in that country.

Just like we have four ways of defining the location of a building (country, state, city, and street address), we have four ways of defining the properties of an electron, i.e. four quantum numbers. Thus, the numbers which designate and distinguish various atomic orbitals and electrons present in an atom are called quantum numbers.

Quantum Number	Symbol	Information conveyed
Principal quantum number	n	Main energy level
Azimuthal quantum number	l	Sub shell/ shape of orbital
Magnetic quantum number	m	Orientation of orbitals
Spin quantum number	s	Spin of the electron

10th std
Unit – 6 NUCLEAR PHYSICS

INTRODUCTION

Humans are very much interested in knowing about atoms. Things around us are made up of atoms. A Greek Philosopher 'Democritus' in 400 BC believed that matter is made up of tiny indestructible units called atoms. Later, in 1803, John Dalton considered that elements consist of atoms, which are identical in nature. J J Thomson discovered cathode rays, known as electrons, experimentally and Goldstein discovered positive rays, which were named as protons by Rutherford. In 1932, James Chadwick discovered the charge less particles called neutrons. Presently, a large number of elementary particles like photon, meson, positron and nutrino have been discovered. In 1911, the British scientist, Ernest **Rutherford** explained that the mass of an atom is concentrated in its central part called **Nucleus**. You have already learnt about the atomic structure in the earlier classes.

RADIOACTIVITY
Discovery of radioactivity

In 1896, French physicist Henri Becquerel finished his research for the week and stored a certain amount of uranium compound away in a drawer for the week end. By chance, an unexposed photographic plate was also stored in the same drawer. After a week he returned and noticed that the film had been exposed to some radiation. He discovered that he could reproduce the effect whenever he placed uranium near a photographic film. Apparently, uranium radiated something that could affect a photographic plate. This phenomenon was called as Radioactivity. Uranium was identified to be a radioactive element.

Two years later, the Polish physicist Marie Curie and her husband Pierre Curie detected radioactivity in 'Pitchblende', a tiny black substance. They were not surprised at the radioactivity of pitchblende, which is known as an ore of uranium. Later, they discovered that the radiation was more intense from pure uranium. Also, it was found that the pitchblende had less concentration of uranium. They concluded that some other substance was present in pitchblende. After separating this new substance, they discovered that it had unknown chemical properties and it also emitted radiations spontaneously like uranium. They named this new substance as 'Radium'. The radioactive elements emit harmful radioactive radiations like alpha rays or beta rays or gamma rays.

Definition of radioactivity

The nucleus of some elements is unstable. Such nuclei undergo nuclear decay and get converted into more stable nuclei. During this nuclear reaction, these nuclei emit certain harmful radiations and elementary particles. The phenomenon of nuclear decay of certain elements with the emission of radiations like alpha, beta, and gamma rays is called 'radioactivity' and the elements, which undergo this phenomenon are called 'radioactive elements'.

Natural Radioactivity

The elements such as uranium and radium undergo radioactivity and emit the radiations on their own without any human intervention. This phenomenon of spontaneous emission of radiation from certain elements on their own is called 'natural radioactivity'.

The elements whose atomic number is more than 83 undergo spontaneous radioactivity. Eg: uranium, radium, etc. There are only two elements, which have been identified as radioactive substances with atomic number less than 83. They are technetium (Tc) with atomic number 43 and promethium (Pm) with atomic number 61.

There have been 29 radioactive substances discovered so far. Most of them are rare earth metals and transition metals.

Artificial Radioactivity (or) Induced Radioactivity

The phenomenon by which even light elements are made radioactive, by artificial or induced methods, is called 'artificial radioactivity' or 'man-made radioactivity'.

This kind of radioactivity was discovered by Irene Curie and F.Joliot in 1934. Artificial radioactivity is induced in certain lighter elements like boron, aluminium etc., by bombarding them with radiations such as 'alpha particles' emitted during the natural radioactivity of uranium. This also results in the emission of invisible radiations and elementary particles. During such a disintegration, the nucleus which undergoes disintegration is called 'parent nucleus' and that which is produced after the disintegration is called a 'daughter nucleus'. The particle, which is used to induce the artificial disintegration is termed as projectile and the particle which is produced after the disintegration is termed as ejected particle. When the projectile hits the parent nucleus, it is converted into an unstable nucleus, which in turn decays spontaneously emitting the daughter nucleus along with an ejected particle.

S.No.	Natural radioactivity	Artificial radioactivity
1.	Emission of radiation due to self disintegration of a nucleus.	Emission of radiation due to disintegration of a nucleus through induced process
2.	Alpha, beta and gamma radiations are emitted.	Mostly elementary particles such as neutron, positron, etc. are emitted.
3.	It is a spontaneous process.	It is an induced process
4.	Exhibited by elements with atomic number more than 83.	Exhibited by elements with atomic number less than 83.
5.	This cannot be controlled	This can be controlled.

Units of Radioactivity
Curie:

It is the traditional unit of radioactivity. It is defined as the quantity of a radioactive substance which undergoes 3.7 × 1010 disintegrations in one second. This is actually close to the activity of 1 g of radium 226.

1 curie = 3.7 × 1010 disintegrations per second.

Rutherford (Rd):

It is another unit of radioactivity. It is defined as the quantity of a radioactive substance, which produces 106 disintegrations in one second.

1 Rd = 106 disintegrations per second.

Becquerel (Bq) :

It is The SI unit of radioactivity is becquerel. It is defined as the quantity of one disintegration per second.

Roentgen (R):

It is The radiation exposure of γ and x-rays is measured by another unit called roentgen. One roentgen is defined as the quantity of radioactive substance which produces a charge of 2.58 × 10-4 coulomb in 1 kg of air under standard conditions of pressure, temperature and humidity.

ALPHA, BETA AND GAMMA RAYS

When a radioactive nucleus undergoes radioactivity, it emits harmful radiations. These radiations are usually comprised of any of the three types of particles. They are alpha(α), beta (β) and gamma(γ) rays.

Uranium, named after the planet Uranus, was discovered by Martin Klaproth, a German chemist in a mineral called pitchblende.

Properties of Alpha, Beta and Gamma rays

These three particles possess certain similarities and dissimilarities in their properties.

Radioactive displacement law

In 1913, Soddy and Fajan framed the displacement laws governing the daughter nucleus produced during an alpha and beta decay. They are stated below:

When a radioactive element emits an alpha particle, a daughter nucleus is formed whose mass number is less by 4 units and the atomic number is less by 2 units, than the mass number and atomic number of the parent nucleus.

When a radioactive element emits a beta particle, a daughter nucleus is formed whose mass number is the same and the atomic number is more by 1 unit, than the atomic number of the parent nucleus.

Alpha decay

A nuclear reaction in which an unstable parent nucleus emits an alpha particle and forms a stable daughter nucleus, is called 'alpha decay'.

E.g.: Decay of uranium (U^{238}) to thorium (Th^{234}) with the emission of an alpha particle.

$$_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4} \ (\alpha \text{ - decay})$$

In α - decay, the parent nucleus emits an α particle and so it is clear that for the daughter nucleus, the mass number decreases by four and the atomic number decreases.

Beta decay

A nuclear reaction, in which an unstable parent nucleus emits a beta particle and forms a stable daughter nucleus, is called 'beta decay'.

E.g.: Beta decay of phosphorous.

$$_{15}P^{32} \rightarrow {}_{16}S^{32} + {}_{-1}e^{0} \ (\beta \text{ - decay})$$

In β - decay there is no change in the mass number of the daughter nucleus but the atomic number increases by one.

Note:

In a nuclear reaction, the element formed as the product nucleus is identified by the atomic number of the resulting nucleus and not by its mass number.

Properties	α rays	β rays	γ rays
What are they?	Helium nucleus ($_2He^4$) consisting of two protons and two neutrons.	They are electrons ($_{-1}e^0$), basic elementary particle in all atoms.	They are electromagnetic waves consisting of photons.
Charge	Positively charged particles. Charge of each alpha particle = +2e	Negatively charged particles. Charge of each beta particle = −e	Neutral particles. Charge of each gamma particle = zero
Ionising power	100 time greater than β rays and 10,000 times greater than γ rays	Comparatively low	Very less ionization power
Penetrating power	Low penetrating power (even stopped by a thick paper)	Penetrating power is greater than that of α rays. They can penetrate through a thin metal foil.	They have a very high penetrating power greater than that of β rays. They can penetrate through thick metal blocks.
Effect of electric and magnetic field	Deflected by both the fields. (in accordance with Fleming's left hand rule)	Deflected by both the fields; but the direction of deflection is opposite to that for alpha rays. (in accordance with Fleming's left hand rule)	They are not deflected by both the fields.
Speed	Their speed ranges from 1/10 to 1/20 times the speed of light.	Their speed can go up to 9/10 times the speed of light.	They travel with the speed of light.

Gamma decay

In a γ - decay, only the energy level of the nucleus changes. The atomic number and mass number of the radioactive nucleus remain the same.

NUCLEAR FISSION

Definition

In 1939, German Scientist Otto Hahn and F.Strassman discovered that when a uranium nucleus is bombarded with a neutron, it breaks up into two smaller nuclei of comparable mass along with the emission of a few neutrons and energy. This process of breaking (splitting) up of a heavier nucleus into two smaller nuclei with the release of a large amount of energy and a few neutrons is called 'nuclear fission'.

E.g.: Nuclear fission of a uranium nucleus (U^{235})

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + Q \text{ (energy)}$$

The average energy released in each fission process is about 3.2×10^{-11} J.

Fissionable materials

A fissionable material is a radioactive element, which undergoes fission in a sustained manner when it absorbs a neutron. It is also termed as 'fissile material'.

E.g.: U^{235}, plutonium (Pu^{239} and Pu^{241})

All isotopes of uranium do not undergo nuclear fission when they absorb a neutron. For example, natural uranium consists of 99.28 % of $_{92}U^{238}$ and 0.72 % of $_{92}U^{235}$. Of these two, U^{238} does not undergo fission where as U^{235} undergoes fission. Hence, U^{235} is a fissionable material and U^{238} is non- fissionable.

There are some radioactive elements, which can be converted into fissionable material. They are called as fertile materials.

E.g.: Uranium-238, Thorium-232, Plutonium-240.

Chain Reaction

A uranium nucleus (U-235) when bombarded with a neutron undergoes fission producing three neutrons. These three neutrons in turn can cause fission in three other uranium nuclei present in the sample, thus producing nine neutrons. These nine neutrons in turn may produce twenty seven neutrons and so on. This is known as 'chain reaction'. A chain reaction is a self- propagating process in which the number of neutrons goes on multiplying rapidly almost in a geometrical progression.

Two kinds of chain reactions are possible. They are:

1. controlled chain reaction and
2. uncontrolled chain reaction.

Controlled chain reaction

In the controlled chain reaction the number of neutrons released is maintained to be one. This is achieved by absorbing the extra neutrons with a neutron absorber leaving only one neutron to produce further fission. Thus, the reaction is sustained in a controlled manner. The energy released due to a controlled chain reaction can be utilized for constructive purposes. Controlled chain reaction is used in a nuclear reactor to produce energy in a sustained and controlled manner.

Uncontrolled chain reaction

In the uncontrolled chain reaction the number of neutrons multiplies indefinitely and causes fission in a large amount of the fissile material. This results in the release of a huge amount of energy within a fraction of a second. This kind of chain reaction is used in the atom bomb to produce an explosion.

Critical Mass

During a nuclear fission process, about 2 to 3 neutrons are released. But, all these neutrons may not be available to produce further fission. Some of them may escape from the system, which is termed as 'leakage of neutrons' and some may be absorbed by the non-fissionable materials present in the system. These two factors lead to the loss of neutrons. To sustain the chain reaction, the rate of production of neutrons due to nuclear fission must be more than the rate of its loss. This can be achieved only when the size (i.e., mass) of the fissionable material is equal to a certain optimum value. This is known as 'critical mass'.

The minimum mass of a fissile material necessary to sustain the chain reaction is called 'critical mass (mc)'. It depends on the nature, density and the size of the fissile material.

If the mass of the fissile material is less than the critical mass, it is termed as 'subcritical'. If the mass of the fissile material is more than the critical mass, it is termed as 'supercritical'.

Atom bomb

The atom bomb is based on the principle of uncontrolled chain reaction. In an uncontrolled chain reaction, the number of neutrons and the number of fission reactions multiply almost in a geometrical progression. This releases a huge amount of energy in a very small time interval and leads to an explosion.

Structure:

An atom bomb consists of a piece of fissile material whose mass is subcritical. This piece has a cylindrical void. It has a cylindrical fissile material which can fit into this void and its mass is also subcritical. When the bomb has to be exploded, this cylinder is injected into the void using a conventional explosive. Now, the two pieces of fissile material join to form the supercritical mass, which leads to an explosion.

During this explosion tremendous amount of energy in the form of heat, light and radiation is released. A region of very high temperature and pressure is formed in a fraction of a second along with the emission of hazardous radiation like γ rays, which adversely affect the living creatures. This type of atom bombs were exploded in 1945 at Hiroshima and Nagasaki in Japan during the World War II.

Electron Volt (eV) is the unit used in nuclear physics to measure the energy of small particles. It is nothing but the energy of one electron when it is accelerated us 1eV = 1.602×10^{-19} joule. ing an electric potential of one volt. 1 million electron volt = 1 MeV = 10^6 eV (mega electron volt) The energy released in a nuclear fission process is about 200 MeV.

NUCLEAR FUSION

You have learnt that energy can be produced when a heavy nucleus is split up into two smaller nuclei. Similarly, energy can be produced when two lighter nuclei combine to form a heavier nucleus. This phenomenon is known as nuclear fusion.

Definition

The process in which two lighter nuclei combine to form a heavier nucleus is termed as 'nuclear fusion'.

E.g.: $_1H^2 + {_1H^2}\ {_2He^4}$ + Q (Energy)

Here, $_1H^2$ represents an isotope of hydrogen known as 'deuterium'. The average energy released in each fusion reaction is about 3.84×10^{-12} J.

The mass of the daughter nucleus formed during a nuclear reaction (fission and fusion) is lesser than the sum of the masses of the two parent nuclei. This difference in mass is called mass defect. This mass is converted into energy, according to the mass-energy equivalence. This concept of mass-energy equivalence was proposed by Einstein in 1905. It stated that mass can be converted into energy and vice versa. The relation between mass and energy proposed by Einstein is $\mathbf{E = mc^2}$ where c is the velocity of light in vacuum and is equal to 3×10^8 ms^{-1}.

The nuclear bomb that was dropped in Hiroshima during World War II was called as 'Little boy'. It was a gun-type bomb which used a uranium core. The bomb, which was subsequently dropped over Nagasaki was called as 'Fat man'. It was an explosion type bomb, which used a plutonium core.

Conditions necessary for nuclear fusion

Earth's atmosphere contains a small trace of hydrogen. If nuclear fusion is a spontaneous process at normal temperature and pressure, then a number of fusion processes would happen in the atmosphere which may lead to explosions. But, we do not encounter any such explosions.

The answer is that nuclear fusion can take place only under certain conditions.

Nuclear fusion is possible only at an extremly high temperature of the order of 10^7 to 10^9 K and a high pressure to push the hydrogen nuclei closer to fuse with each other. Hence, it is named as 'Thermonuclear reaction'.

Nuclear fusion is the combination of two lighter nuclei. The charge of both nuclei is positive. According to electrostatic theory, when they come closer they tend to repel each other. This repulsive force will be overcome by the kinetic energy of the nuclei at higher temperature of the order of 10^7 to 10^9 K.

Stellar Energy

The stars like our Sun emit a large amount of energy in the form of light and heat. This energy is termed as the stellar energy. Where does this high energy come from? All stars contain a large amount of hydrogen. The surface temperature of the stars is very high which is sufficient to induce fusion of the hydrogen nuclei.

Fusion reaction that takes place in the cores of the Sun and other stars results in an enormous amount of energy, which is called as 'stellar energy. Thus, nuclear fusion or thermonuclear reaction is the source of light and heat energy in the Sun and other stars.

Hydrogen Bomb

Hydrogen bomb is based on the principle of nuclear fusion. A hydrogen bomb is always designed to have an inbuilt atom bomb which creates the high temperature and pressure required for fusion when it explodes. Then, fusion takes place in the hydrogen core and leads to the release of a very large amount of energy in an uncontrolled manner. The energy released in a hydrogen bomb (or fusion bomb) is much higher than that released in an atom bomb (or fission bomb).

S.No.	NUCLEAR FISSION	NUCLEAR FUSION
1	The process of breaking up (splitting) of a heavy nucleus into two smaller nuclei is called '**nuclear fission**'.	Nuclear fusion is the combination of two lighter nuclei to form a heavier nucleus.
2	Can be performed at room temperature.	Extremely high temperature and pressure is needed.
3	Alpha, beta and gamma radiations are emitted.	Alpha rays, positrons, and neutrinos are emitted.
4	Fission leads to emission of gamma radiation. This triggers the mutation in the human gene and causes genetic transform diseases.	Only light and heat energy is emitted.

Sun fuses about 620 million metric tons of hydrogen each second and radiates about 3.8×10^{26} joule of energy per second. When this energy is radiated towards the Earth, it decreases in its intensity. When it reaches the Earth its value is about 1.4 kilo joule per unit area in unit time.

USES OF RADIOACTIVITY

Many radio isotopes can be obtained from radioactivity. These radio isotopes have found wide variety of applications in the fields of medicine, agriculture, industry and archeological research.

Agriculture

The radio isotope of phosphorous (P-32) helps to increase the productivity of crops. The radiations from the radio isotopes can be used to kill the insects and parasites and prevent the wastage of agricultural products. Certain perishable cereals exposed to radiations remain fresh beyond their normal life, enhancing the storage time. Very small doses of radiation prevent sprouting and spoilage of onions, potatoes and gram.

Medicine

Medical applications of radio isotopes can be divided into two parts:

1. Diagnosis
2. Therapy

Radio isotopes are used as tracers to diagnose the nature of circulatory disorders of blood, defects of bone metabolism, to locate tumors, etc. Some of the radio isotopes which are used as tracers are: hydrogen, carbon, nitrogen, sulphur, etc.

- Radio sodium (Na^{24}) is used for the effective functioning of heart.
- Radio – Iodine (I^{131}) is used to cure goiter.
- Radio-iron is (Fe^{59}) is used to diagnose anaemia and also to provide treatment for the same.
- Radio phosphorous (P^{32}) is used in the treatment of skin diseases.

- Radio cobalt (Co^{60}) and radio-gold (Au^{198}) are used in the treatment of skin cancer. Radiations are used to sterilize the surgical devices as they can kill the germs and microbes.

Industries

In industries, radioactive isotopes are used as tracers to detect any manufacturing defects such as cracks and leaks. Packaging faults can also be identified through radio activity. Gauges, which have radioactive sources are used in many industries to check the level of gases, liquids and solids.

- An isotope of californium (Cf^{252}) is used in the airlines to detect the explosives in the luggage.
- An isotope of Americium (Am^{241}) is used in many industries as a smoke detector.

Archeological research

Using the technique of radio carbon dating, the age of the Earth, fossils, old paintings and monuments can be determined. In radio carbon dating, the existing amount of radio carbon is determined and this gives an estimate about the age of these things.

SAFETY MEASURES

In day to day life, you do receive some natural radiation from the Sun. The radioactive elements present in the soil and rocks, the house hold appliances like television, microwave ovens, cell phones and the X-rays used in hospitals. These radiations do not produce any severe effects as they are very low in intensity.

The second source of radiation exposure is man-made. These are due to nuclear reactors and during the testing of the nuclear devices in the atmosphere or in the ground.

Improper and careless handling of radioactive materials release harmful radiations in our environment. These radiations are very harmful to the human body. A person who is exposed to radiations very closely or for a longer duration, is at a greater health risk and can be affected genetically.

How old is our mother Earth? Any guess?? It is nearly 4.54 × 109 years (around 45 Crore 40 lakh years). Wow!!

Permitted range

The International Commission on Radiological Protection (ICRP) has recommended certain maximum permissible exposure limits to radiation that is believed to be safe without producing any appreciable injury to a person. Safe limit of overall exposure to radiation is given as 20 milli sievert per year. In terms of roentgen, the safe limit of receiving the radiation is about 100 mR per week. If the exposure is 100 R, it may cause fatal diseases like leukemia (death of red blood corpuscle in the blood) or cancer. When the body is exposed to about 600 R, it leads to death.

Dosimeter is a device used to detect the levels of exposure to an ionizing radiation. It is frequently used in the environments where exposure to radiation may occur such as nuclear power plants and medical imaging facilities. Pocket dosimeter is used to provide the wearer with an immediate reading of his/her exposure to X-rays and γ rays.

Preventive measures

1. Radioactive materials should be kept in a thick walled lead container.
2. Lead coated aprons and lead gloves should be used while working with hazardous radioactive materials.
3. You should avoid eating while handling radioactive materials.
4. The radioactive materials should be handled only by tongs or by a remote control device.
5. Dosimeters should be worn by the users to check the level of radiation.

NUCLEAR REACTOR

A Nuclear reactor is a device in which the nuclear fission reaction takes place in a self-sustained and controlled manner to produce electricity. The first nuclear reactor was built in 1942 at Chicago, USA.

Types of nuclear reactors

Breeder reactor, fast breeder reactor, pressurized water reactor, pressurized heavy water reactor, boiling water reactor, water-cooled reactor, gas-cooled reactor, fusion reactor and thermal reactor are some types of nuclear reactors, which are used in different places world-wide.

Components of a nuclear reactors

The essential components of a nuclear reactor are (i) fuel, (ii) moderator, (iii) control rod, (iv) coolant and (v) protection wall.

Fuel:

A fissile material is used as the fuel. The commonly used fuel material is uranium.

Moderator:

A moderator is used to slow down the high energy neutrons to provide slow neutrons. Graphite and heavy water are the commonly used moderators.

Control rod:

Control rods are used to control the number of neutrons in order to have sustained chain reaction. Mostly boron or cadmium rods are used as control rods. They absorb the neutrons.

Coolant:

A coolant is used to remove the heat produced in the reactor core, to produce steam. This steam is used to run a turbine in order to produce electricity. Water, air and helium are some of the coolants.

Protection wall:

A thick concrete lead wall is built around the nuclear reactor in order to prevent the harmful radiations from escaping into the environment.

Uses of a nuclear reactor

1. Nuclear reactors are widely used in power generation.
2. They are also used to produce radio isotopes, which are used in a variety of applications.
3. Some reactors help us to do research in the field of nuclear physics.
4. Breeder reactors are used to convert non-fissionable materials into fissionable materials.

Nuclear power plants in India

Indian Atomic Energy Commission (AEC) was established in August 1948 by the Department of Indian Scientific Research committee at Bombay (now Mumbai) in Maharashtra. It is the nodal agency for all the research done in the field of atomic energy. Dr. Homi Jahangir Bhaba was the first chairman of Indian Atomic Energy Commission. Now, it is known as Bhaba Atomic Research Centre (BARC).

Nuclear power is the fifth largest source of power in India. Tarapur Atomic Power Station is India's first nuclear power station. Now, there are a total of seven power stations, one each in Maharashtra, Rajasthan, Gujarat, Uttar Pradesh and two in Tamilnadu. In Tamilnadu, we have nuclear power stations in Kalpakkam and Kudankulam. Apsara was the first nuclear reactor built in India and Asia. Now, there are 22 nuclear reactors which are operating in India. Some other operating reactors are

- Cirus
- Dhuruva
- Purnima

Identify A, B, C, and D from the following nuclear reactions.

$$_{13}Al^{27} + A \rightarrow {}_{15}P^{30} + B$$

$$_{12}Mg^{24} + B \rightarrow {}_{11}Na^{24} + C$$

$$_{92}U_{238} + B \rightarrow {}_{93}Np^{239} + D$$

Solution:

$$_{13}Al^{27} + {}_{2}He^{4} \rightarrow {}_{15}P^{30} + {}_{0}n^{1}$$
$$_{12}Mg^{24} + {}_{0}n^{1} \rightarrow {}_{11}Na^{24} + {}_{1}H^{1}$$
$$_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{93}Np^{239} + {}_{-1}e^{0}$$

A is alpha particle, B is neutron, C is proton, and D is electron

A radon specimen emits radiation of 3.7×10^{3} GBq per second. Convert this disintegration in terms of curie. (one curie = 3.7×10^{10} disintegration per second)

1 Bq = one disintegration per second one curie = 3.7×10^{10} Bq

$$1\ \text{Bq} = \frac{1}{3.7 \times 10^{10}}\ \text{curie}$$

$$\therefore\ 3.7 \times 10^{3}\ \text{G Bq} = 3.7 \times 10^{3} \times 10^{9} \times \frac{1}{3.7 \times 10^{10}}$$
$$= 100\ \text{curie}$$

$_{92}U^{235}$ experiences one α - decay and one β - decay. Find number of neutrons in the final daughter nucleus that is formed.

Solution:

Let X and Y be the resulting nucleus after the emission of the alpha and beta particles respectively.

$$_{92}U^{235} \xrightarrow{\alpha\ \text{decay}} {}_{90}X^{231} + {}_{2}He^{4}$$
$$_{90}X^{231} \xrightarrow{\beta\ \text{decay}} {}_{91}Y^{231} + {}_{-1}e^{0}$$

Number of neutrons = Mass number – Atomic number = 231 – 91 = 140

Calculate the amount of energy released when a radioactive substance undergoes fusion and results in a mass defect of 2 kg.

Solution:

Mass defect in the reaction (m) = 2 kg

Velocity of light (c) = 3×10^8 m s^{-1}

By Einstein's equation, Energy released $E = mc^2$

So $E = 2 \times (3 \times 10^8)^2 = 1.8 \times 10^{17}$J