STRUCTURE OF ATOM

For a long time it was thought that the atoms are indivisible, so they do not have an inner structure. but We now know that atoms are divisible and they do have an inner structure. Atoms have smaller particles in them which are called subatomic particles.

Atoms are made up of three subatomic particles : electrons, protons and neutrons. Electron has negative charge, proton has positive charge, whereas neutron has no charge, it is neutral.

1. Protons and neutrons are present in a small nucleus at the centre of the atom. Almost the entire mass of the atom is in the nucleus because the electrons, which are outside the nucleus, have very, very small mass. Due to the presence of protons, nucleus has positive charge.

2. Electrons are outside the nucleus. The electrons in an atom revolve rapidly round the nucleus in fixed circular paths called energy levels or shells. Since an atom on the whole is electrically neutral (having no overall positive or negative charge), therefore, the number of electrons outside the nucleus is equal to the number of protons inside the nucleus.

3. Atoms of all the elements (except hydrogen) are made up of the three subatomic particles: electrons, protons and neutrons. Hydrogen atom is made up of only one electron and one proton. It does not contain any neutron.

4. The atoms of different elements differ in the number of electrons, protons and neutrons.

DISCOVERY OF ELECTRON

The existence of electrons in an atom was shown by J.J. Thomson in 1897.
Thomson passed electricity at high voltage through a gas at very low pressure taken in a discharge tube. Streams of minute particles were given out by the cathode (negative electrode). These streams of particles are called cathode rays.

Cathode rays consist of small, negatively charged particles called electrons. Since all the gases form cathode rays, it was concluded that all the atoms contain negatively charged particles called electrons.

Story// - Thomson explained the formation of cathode rays as follows. The gas taken in the discharge tube consists of atoms, and all the atoms contain electrons. When high electrical voltage is applied, the electrical energy pushes out some of the electrons from the atoms of the gas. These fast moving electrons form cathode rays. Thus, the formation of cathode rays shows that one of the subatomic particle present in all the atoms is the negatively charged 'electron'.

The electron is a negatively charged particle found in the atoms of all the elements.

Characteristics of an Electron

1. Mass of an Electron. The mass of an electron is about 1/1840 of the mass of hydrogen atom (which is the atom of lowest mass). Since the mass of a hydrogen atom is 1 u, we can say that the relative mass of an electron is 1/1840 u. The absolute mass of an electron is, however, 9×10^{-28} gram. The mass of an electron is so small that it is considered to be negligible. This is why the mass of electrons is ignored while calculating the atomic mass of an element.

2. Charge of an Electron. The absolute charge on an electron is 1.6×10^{-19} coulomb of negative charge. Now, 1.6×10^{-19} coulomb has been found to be the smallest negative charge carried by any particle. So, this is taken as the unit of negative charge. This means that an electron has 1 unit of negative charge. In other words, the relative charge of an electron is, –1 (minus one).

DISCOVERY OF PROTON

The formation of cathode rays has shown that all the atoms contain negatively charged particles called electrons. Now, an atom is electrically neutral, so it must contain some positively charged particles to balance the negative charge of electrons.

The existence of protons in the atoms was shown by E. Goldstein. When Goldstein passed electricity at high voltage through a gas at very low pressure taken in a discharge tube, streams of heavy particles were given out by the anode (positive electrode). These streams of particles are called anode rays. Anode rays consist of positively charged particles.
Hydrogen gas is the lightest gas and hydrogen atom is the lightest atom. So, the positive particles obtained from hydrogen gas are the lightest and have the smallest charge.

Story// - Goldstein explained the formation of protons as follows. Hydrogen gas consists of hydrogen atoms. When high electrical voltage is applied to hydrogen gas, the electrical energy removes the electrons from the hydrogen atoms. After the removal of negatively charged electron from a hydrogen atom, a positively charged particle called proton is formed. These fast moving protons form the anode rays.

The proton is a positively charged particle found in the atoms of all the elements. The protons are located in the nucleus of an atom.

Characteristics of a Proton

1. Mass of a Proton. The proton is actually a hydrogen atom which has lost its electron. Since the mass of an electron is very small, we can say that the mass of a proton is equal to the mass of a hydrogen atom. But the mass of a hydrogen atom is 1 u, therefore, the relative mass of a proton is 1 u. If, however, we compare the mass of a proton with that of an electron, then the mass of a proton is 1840 times that of an electron. The absolute mass of a proton is 1.6×10^{-24} gram.

2. Charge of a Proton. The charge of a proton is equal and opposite to the charge of an electron. So, the absolute charge of a proton is 1.6×10^{-19} coulomb of positive charge. Now, 1.6×10^{-19} coulomb has been found to be the smallest positive charge carried by any particle. So, this is taken as the unit of positive charge. This means that proton carries 1 unit positive charge. In other words, the relative charge of a proton is +1 (plus one).

The formation of cathode rays and anode rays on passing electricity through gases at very low pressure tells us that atom is not indivisible, it is made up of smaller particles.

DISCOVERY OF NEUTRON

After the discovery of protons and electrons, it was noticed that all the mass of an atom cannot be accounted for on the basis of only protons and electrons present in it. For example, a carbon atom contains 6 protons and 6 electrons.
Now, the mass of electrons is so small that it can be ignored. So, the atomic mass of carbon should be only 6 u, which is the mass of 6 protons. This, however, is wrong because the actual atomic mass of carbon is 12 u.

This problem was solved by the discovery of another subatomic particle by James Chadwick in 1932. This particle is called neutron. The neutron is a neutral particle found in the nucleus of an atom.

Note => the subatomic particle not present in a hydrogen atom is neutron.

Characteristics of a Neutron

1. Mass of a Neutron. The mass of a neutron is equal to the mass of a proton. In other words, the relative mass of a neutron is 1 u. The absolute mass of a neutron is 1.6×10^{-24} gram.

2. Charge of a Neutron. Neutron has no charge. It is electrically neutral. We are now in a position to explain why the atomic mass of carbon is 12 u. It is now known that a carbon atom contains 6 protons and 6 neutrons, each having a mass of 1 u. Now,

Atomic mass of carbon = Mass of 6 protons + Mass of 6 neutrons

$= 6 \times 1 + 6 \times 1$
$= 12$ u

STRUCTURE OF ATOM

Dalton's atomic theory suggested that atom was indivisible – which could not be broken down into smaller particles. But the discovery of subatomic particles such as electrons and protons inside the atom disproved this postulate of Dalton's atomic theory. The discovery of electrons and protons suggested that atoms are divisible and they do have an inner structure.

THOMSON'S MODEL OF THE ATOM

When J.J. Thomson proposed his model of the atom in 1903, then only electrons and protons were known to be present in the atom.

1. An atom consists of a sphere (or ball) of positive charge with negatively charged electrons embedded in it.
2. The positive and negative charges in an atom are equal in magnitude, due to which an atom is electrically neutral. It has no overall positive or negative charge.

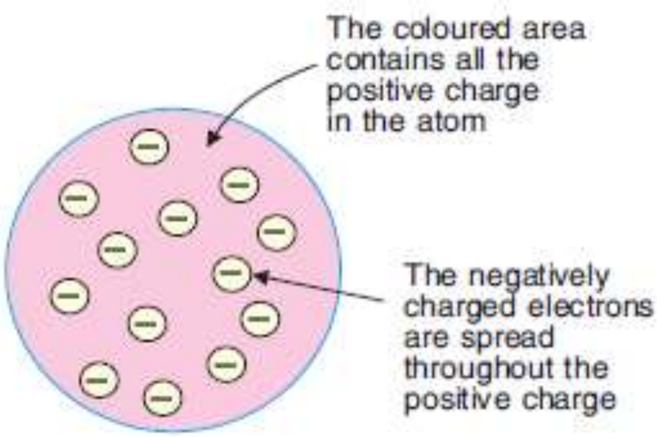


Figure 7. Thomson's model of the atom.

Thomson's model of atom to a watermelon. The red, edible part of watermelon represents the sphere of positive charge whereas the black seeds embedded in watermelon are like the electrons.

Rutherford's Experiment – Discovery of Nucleus

It was Rutherford's alpha particle scattering experiment which led to the discovery of a small positively charged nucleus in the atom containing all the protons and neutrons.

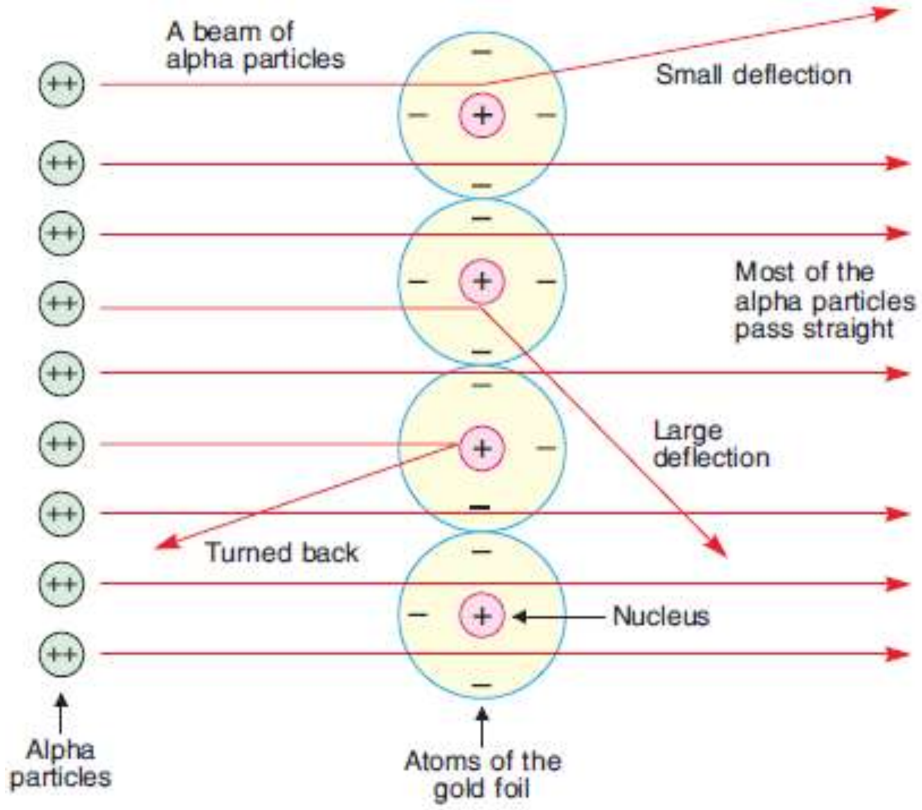


Figure 13. Scattering of alpha particles by the atoms of a gold foil.

When fast moving alpha particles are allowed to strike a very thin gold foil in vacuum, it is found that :

1. Most of the alpha particles pass straight through the gold foil without any deflection from their original path (see Figure 13).

2. A few alpha particles are deflected through small angles and a few are deflected through large angles.

3. A very few alpha particles completely rebound on hitting the gold foil and turn back on their path (just as a ball rebounds on hitting a hard wall).

Rutherford explained these observations in the following way :

Gold foil is made up of atoms. If the atoms were solid throughout their volume, then every alpha particle striking them should have changed its path and got deflected. Since most of the alpha particles pass straight through the gold foil without any deflection, it shows that there is a lot of empty space in the atom.

We know that similar charges repel each other. So, a positively charged body will repel another positively charged body.

1. The observation that some of the alpha particles are deflected through small and large angles shows that there is a 'centre of positive charge' in the atom which repels the positively charged alpha particles and deflects them from their original path.

2. This centre of positive charge in the atom is known as nucleus. Thus, the scattering of alpha particles by a thin gold foil shows the existence of a positively charged nucleus in the atom.

3. A very few of the alpha particles are turned back on their path. This fact cannot be explained only on the basis of repulsion due to positive charge of the nucleus. It can, however, be explained by assuming that the nucleus is very dense and hard.

Rutherford's alpha-particle scattering experiment shows the presence of a nucleus in the atom. It also gives the **following important information** about the nucleus of an atom :

(i) Nucleus of an atom is positively charged.

(ii) Nucleus of an atom is very dense and hard.

(iii) Nucleus of an atom is very small as compared to the size of the atom as a whole.

Nucleus

The nucleus is a small positively charged part at the centre of an atom. The nucleus contains all the protons and neutrons, therefore, almost the entire mass of an atom is concentrated in the nucleus.

The positive charge on the nucleus is due to the presence of protons in it. The number of protons in the nucleus determines the number of positive charges on the nucleus. The neutrons which are also present in the nucleus have no charge, they are neutral.

Protons and neutrons taken together are known as nucleons (because they are present in the nucleus). The volume of the nucleus of an atom is very small as compared to the volume of the extra nuclear part of the atom.

Note - when Rutherford put forward his nuclear model of atom in 1911, even then only electrons and protons were known to be present in the atom. This is because neutron was discovered much later in 1932. So, the original model of an atom given by Rutherford contained only protons in the nucleus. Rutherford's model of the atom was improved later on by including neutrons in the nucleus.

RUTHERFORD'S MODEL OF THE ATOM

1. An atom consists of a positively charged, dense and very small nucleus containing all the protons and neutrons (protons have positive charge whereas neutrons have no charge). Almost the entire mass of an atom is concentrated in the nucleus.
2. The nucleus is surrounded by negatively charged electrons. The electrons are revolving round the nucleus in circular paths at very high speeds. The circular paths of the electrons are called orbits.
3. The electrostatic attraction between the positively charged nucleus and negatively charged electrons holds the atom together.
4. An atom is electrically neutral. This is because the number of protons and electrons in an atom is equal.
5. Most of the atom is empty space.

The simplest atom is that of hydrogen. It contains one proton and one electron.
The next simplest atom is that of helium. A helium atom consists of a small central nucleus containing 2 protons and 2 neutrons, and there are 2 electrons revolving around this nucleus (Figure 18). Since the helium atom contains an equal number of protons and electrons (2 each), therefore, it is electrically neutral.

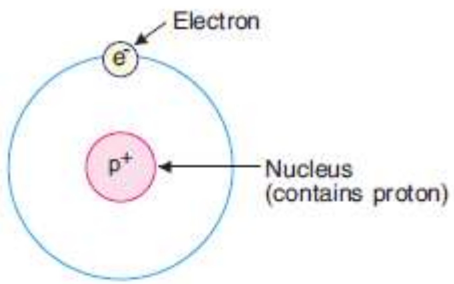


Figure 17. Structure of a hydrogen atom.
Here p^+ = proton
e^- = electron

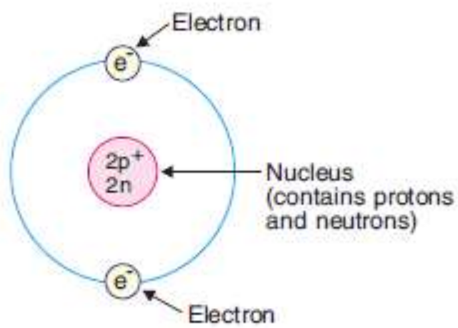


Figure 18. Structure of a helium atom.
p^+ = proton, n = neutron
e^- = electron

Drawback of Rutherford's Model of the Atom

A major drawback (or defect) of Rutherford's model of the atom is that it does not explain the stability of the atom.

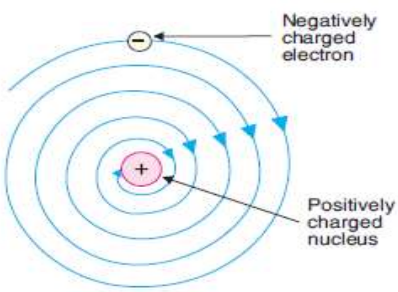


Figure 19. Diagram to show how an energy losing electron could fall into the nucleus.

Story// - According to the electromagnetic theory of physics, if a charged particle undergoes accelerated motion, then it must radiate energy (or lose energy) continuously. Now, if we apply this electromagnetic theory to the Rutherford's model of an atom, it will mean that the negatively charged electrons revolving around the nucleus with accelerated motion, will lose their energy continuously by radiation. Thus, the energy of revolving electrons will decrease gradually and their speed will also go on decreasing. The electrons will then be attracted more strongly by the oppositely charged nucleus due to which they will come more and more close to the nucleus. And ultimately the electrons should fall into the nucleus by taking a spiral path (as shown in Figure 19). This should make the atom very unstable and hence the atom should collapse.

Neils Bohr Explained the Stability of Atom

According to Neils Bohr :

1. The electrons could revolve around the nucleus in only ''certain orbits'' (or ''certain energy levels''),each orbit having a different radius. The electrons in each orbit have a characteristic amount of energy. The electrons which are in orbits close to the nucleus have low energy while those in orbits farther from the nucleus have higher energy.

2. When an electron is revolving in a particular orbit or particular energy level around the nucleus, the electron does not radiate energy (does not lose energy), even though it has accelerated motion around the nucleus. And since the electrons do not lose energy while revolving in certain permitted orbits, they do not fall into the nucleus, and hence the atom remains stable. Please note that the circular paths or orbits around the nucleus (where the movement of electrons takes place), are also known as ''energy levels'' or ''electron shells''.

BOHR'S MODEL OF THE ATOM

1. An atom is made up of three particles : electrons, protons and neutrons. Electrons have negative charge, protons have positive charge whereas neutrons have no charge, they are neutral.

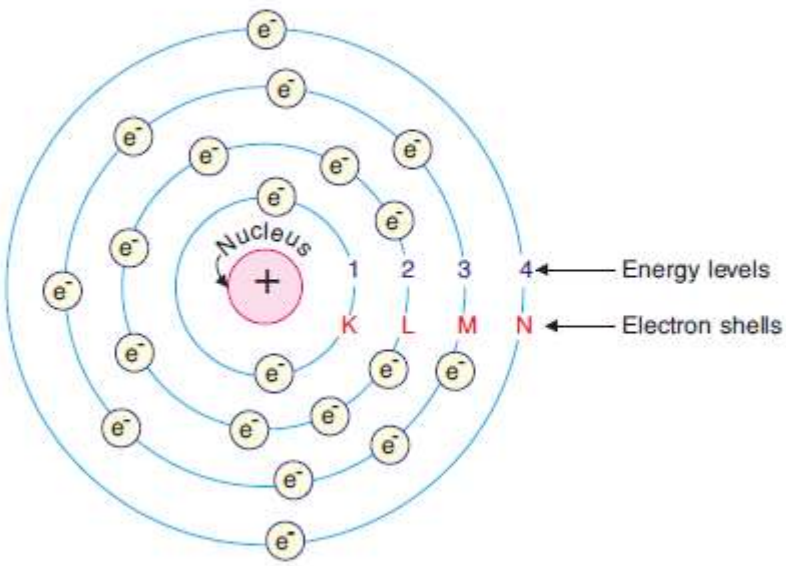
2. The protons and neutrons are located in a small nucleus at the centre of the atom. Due to the presence of protons, nucleus is positively charged.

3. The electrons revolve rapidly round the nucleus in fixed circular paths called energy levels or shells. The energy levels or shells are represented in two ways : either by the numbers 1, 2, 3, 4, 5 and 6 or by the letters K, L, M, N, O and P (see Figure 21). The energy levels are counted from the centre outwards.

4. There is a limit to the number of electrons which each energy level (or shell) can hold. For
example, the first energy level (or K shell) can hold a maximum of 2 electrons; second energy level (or L shell) can hold a maximum of 8 electrons; third energy level (or M shell) can hold a maximum of 18 electrons and fourth energy level (or N shell) can hold a maximum of 32 electrons.

5. Each energy level (or shell) is associated with a fixed amount of energy, the shell nearest to the nucleus having minimum energy and the shell farthest from the nucleus having the maximum energy.

6. There is no change in the energy of electrons as long as they keep revolving in the same energy level, and the atom remains stable.



------------------**End of Part – 1**-------------------

ATOMIC NUMBER

The number of protons in one atom of an element is known as atomic number of that element. **Atomic number of an element = Number of protons in one atom of element**
For example, one atom of sodium element has 11 protons in it, so the atomic number of sodium is 11.

Note - **1.** All the atoms of the same element have the same number of protons in their nuclei, and hence they have the same atomic number.
2. No two elements can have the same atomic number therefore atomic number can be used to identify an element.
3. the number of protons is equal to the number of electrons. (not applicable in ions)
Atomic number of an element = Number of electrons in one neutral atom
4. The atomic number of an element does not change during a chemical reaction, it remains the same.

the atomic number of an element tells us two things :
1. It tells us the number of protons in one atom of the element.
2. It tells us the number of electrons in one normal atom of the element.

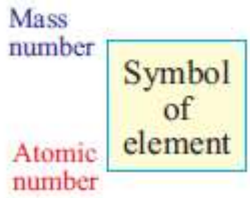
MASS NUMBER

The total number of protons and neutrons present in one atom of an element is known as its mass number. **Mass number = No. of protons + No. of neutrons**

The mass number of an element is denoted by the letter A.
For example, one atom of sodium element contains 11 protons and 12 neutrons, so the mass number of sodium is 11 + 12 = 23.

the total mass of protons and neutrons is called atomic mass, so :
Mass number = Atomic mass

Relationship Between Mass Number and Atomic Number
Mass number = No. of protons + No. of neutrons
Since the number of protons in an atom is equal to the atomic number of the element,
Mass number = Atomic number + No. of neutrons



Sample Problem 1. Calculate the atomic number of an element whose atomic nucleus has mass number 23 and neutron number 12. What is the symbol of the element?

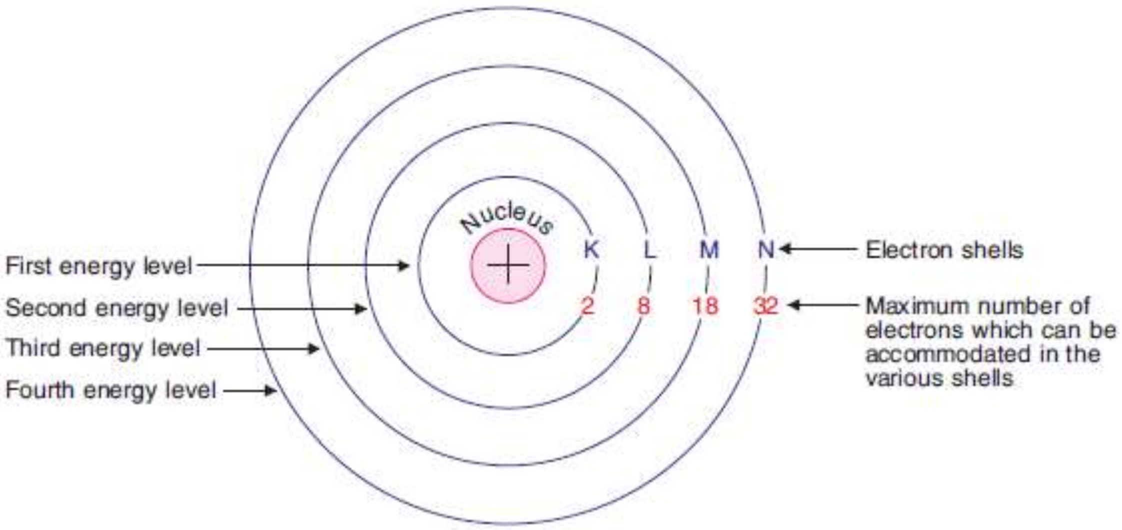
Sample Problem 2. The number of electrons in an atom is 8 and the number of protons is also 8. (a) What is the atomic number of the atom ? (b) What is the charge on the atom ?

Sample Problem 3. Helium atom has an atomic mass of 4 u and two protons in its nucleus. How many neutrons does it have ?

ARRANGEMENT OF ELECTRONS IN THE ATOMS

Electrons are negatively charged, so they form a cloud of negative charges outside the nucleus. In this cloud, the electrons are arranged according to their potential energy in different energy levels or shells. The energy levels of the electrons are denoted by the numbers 1, 2, 3, 4, 5 and 6 whereas shells are represented by the letters K, L, M, N, O and P.

1st energy level is K shell
2nd energy level is L shell
3rd energy level is M shell
4th energy level is N shell...



Electronic Configurations of Elements

The arrangement of electrons in the various shells (or energy levels) of an atom of the element is known as electronic configuration of the element.

In order to write down the electronic configuration of an element, we should know two things :

(i) We should know the number of electrons in one atom of the element.

(ii) We should know the maximum number of electrons that can be accommodated in different shells of the atom.

Note - the number of electrons in an atom of the element is equal to the atomic number of the element.

For example, if the atomic number of an element is 12, then its atom contains 12 electrons.

1. The maximum number of electrons which can be accommodated in any energy level of the atom is given by $2n^2$ (where n is the number of that energy level).

(i) For 1st energy level, n = 1

So, The maximum number of electrons in 1st energy level = $2n^2$

$= 2 \times (1)^2$

$= 2 \times 1$

$= 2$

(ii) For 2nd energy level, n = 2

So, The maximum number of electrons in 2nd energy level = $2n^2$

$= 2 \times (2)^2$

$= 2 \times 4$

$= 8$

(iii) For 3rd energy level, n = 3

So, The maximum number of electrons in 3rd energy level = $2n^2$

$= 2 \times (3)^2$

$= 2 \times 9$

$= 18$

(iv) For 4th energy level, n = 4

So, The maximum number of electrons in 4th energy level = $2n^2$

$= 2 \times (4)^2$

$= 2 \times 16$

$= 32$

Electron shell	Maximum capacity
K shell	2 electrons
L shell	8 electrons
M shell	18 electrons
N shell	32 electrons

2. The outermost shell of an atom cannot accommodate more than 8 electrons, even if it has the capacity to accommodate more electrons.

3. Electrons in an atom do not occupy a new shell unless all the inner shells are completely filled with electrons

Sample Problem 1. Write the electronic configuration of an element X whose atomic number is 12.

Sample Problem 2. Write the distribution of electrons in a carbon atom. (Atomic number of carbon = 6)

Sample Problem 3. Write the electronic configuration of sodium atom (Atomic number of sodium = 11)

Sample Problem 4. What would be the electronic configuration of a positively charged sodium ion, Na+ ? What would be its atomic number ?

Sample Problem 5. Explain why, sodium ion, Na+, has completely filled K and L shells.

Sample Problem 6. If both K and L shells of an atom are full, what is the total number of electrons in the atom ?

Sample Problem 7. An element has 2 electrons in the M shell. What is the atomic number of the element ?

Electronic Configurations of First 20 Elements

Electronic Configurations of First Twenty Elements

Element	*Symbol*	*Atomic number*	*Electronic configuration (or Electron distribution)* K L M N
1. Hydrogen	H	1	1
2. Helium	He	2	2
3. Lithium	Li	3	2, 1
4. Beryllium	Be	4	2, 2
5. Boron	B	5	2, 3
6. Carbon	C	6	2, 4
7. Nitrogen	N	7	2, 5
8. Oxygen	O	8	2, 6
9. Fluorine	F	9	2, 7
10. Neon	Ne	10	2, 8
11. Sodium	Na	11	2, 8, 1
12. Magnesium	Mg	12	2, 8, 2
13. Aluminium	Al	13	2, 8, 3
14. Silicon	Si	14	2, 8, 4
15. Phosphorus	P	15	2, 8, 5
16. Sulphur	S	16	2, 8, 6
17. Chlorine	Cl	17	2, 8, 7
18. Argon	Ar	18	2, 8, 8
19. Potassium	K	19	2, 8, 8, 1
20. Calcium	Ca	20	2, 8, 8, 2

1. Fill in the blanks in the following statements :

(a) The number of protons in the nucleus of an atom is called its ....

(b) The total number of protons and neutrons in the nucleus of an atom is called its ....

(c) An atom has atomic mass number 23 and atomic number 11. The atom has .... electrons.

(d) An atom of an element has 11 protons, 11 electrons and 12 neutrons. The atomic mass of the atom is ....

(e) If the nucleus of an atom has atomic number 17, mass number 37 and there are 17 electrons outside the nucleus, the number of neutrons in it is ....

(f) Almost all the mass of an atom is concentrated in a small region of space called the ....

(g) Cathode rays are a beam of fast moving ....

(h) The anode rays obtained from hydrogen gas consist of particles called ....

(i) The maximum number of electrons that can be accommodated in L shell are ....

(j) The maximum number of electrons that can go into the M shell is ....
(k) The subatomic particle not present in a hydrogen atom is ....
(l) The electron has ....charge, the proton has .... charge, and the neutron has .... charge.

2. Fill in the following blanks :

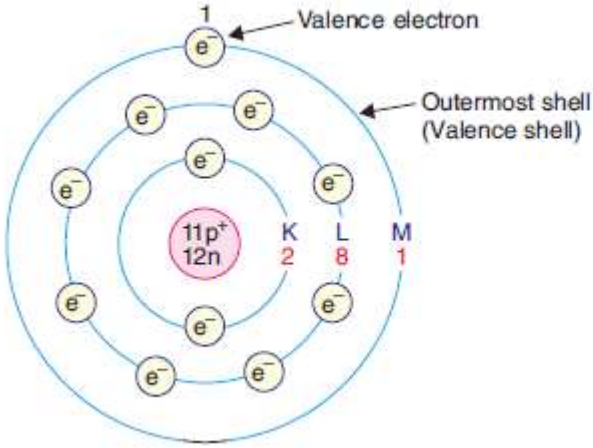
Atomic number	Mass number	Protons	Neutrons	Electrons	Symbol
10	22	....	....	....	....

3. Fill in the following blanks in respect of an atom of an element :

No. of protons	No. of neutrons	Mass number	Atomic number	No. of electrons	Symbol
11	12	....	....	....	....

VALENCE ELECTRONS (OR VALENCY ELECTRONS)

The electrons present in the outermost shell of an atom are known as valence electrons (or valency electrons) because they decide the valency (combining capacity) of the atom.
Note - (Why) Only the valence electrons of an atom take part in chemical reactions because they have more energy than all the inner electrons of the atom.



those electrons of an atom which take part in chemical reactions are called valence electrons. Valence electrons are located in the outermost shell of an atom.

(i) The elements Hydrogen, Lithium, Sodium and Potassium have 1 valence electron each in their atoms.
(ii) The elements Helium, Beryllium, Magnesium and Calcium have 2 valence electrons each in their atoms.
(iii) The elements Boron and Aluminium have 3 valence electrons each in their atoms.

(iv) The elements Carbon and Silicon have 4 valence electrons each in their atoms.
(v) The elements Nitrogen and Phosphorus have 5 valence electrons each in their atoms.
(vi) The elements Oxygen and Sulphur have 6 valence electrons each in their atoms.
(vii) The elements Fluorine and Chlorine have 7 valence electrons each in their atoms.
(viii) The elements Neon and Argon have 8 valence electrons each in their atoms.

Sample Problem. What is the number of valence electrons in the atom of an element X having atomic number 17 ? Name the valence shell of this atom.

Inertness of Noble Gases

Helium, Neon, Argon, Krypton, Xenon and Radon. They are known as noble gases or inert gases because they do not react with other elements to form compounds. We know that only the outermost electrons of an atom take part in a chemical reaction. Since the noble gases are chemically unreactive, we must conclude that the electron arrangements in their atoms are very stable which do not allow the outermost electrons to take part in chemical reactions.

Electronic Configurations of Noble Gases (or Inert Gases)

Noble gas (Inert gas)	*Symbol*	*Atomic number*	*Electronic configuration* K L M N O P	*Number of electrons in outermost shell (Valence shell)*
1. Helium	He	2	2	2
2. Neon	Ne	10	2, 8	8
3. Argon	Ar	18	2, 8, 8	8
4. Krypton	Kr	36	2, 8, 18, 8	8
5. Xenon	Xe	54	2, 8, 18, 18, 8	8
6. Radon	Rn	86	2, 8, 18, 32, 18, 8	8

Cause of Chemical Combination

Everything in this world wants to become more stable. For atoms, stability means having the electron arrangement of an inert gas. The atoms combine with one another to achieve the inert gas electron arrangement and become more stable.

An atom can achieve the inert gas (or noble gas) **electron arrangement in three ways** :
(i) by losing one or more electrons (to another atom)
(ii) by gaining one or more electrons (from another atom)
(iii) by sharing one or more electrons (with another atom)

//important//

1. If an element has 1, 2 or 3 electrons in the outermost shell of its atom, then it loses these electrons to achieve the inert gas electron arrangement of eight valence electrons and forms positively charged ion or cation (It is not possible to add 7, 6 or 5 electrons to an atom due to energy considerations).

2. If an element has 5, 6 or 7 electrons in the outermost shell of its atom, then it gains (accepts) electrons to achieve the stable, inert gas configuration of eight valence electrons, and forms negatively charged ion called anion (It is not possible to remove 5, 6 or 7 electrons from an atom due to very high energy required).

3. If, however, an element has 4 electrons in the outermost shell of its atom, then it can neither lose 4 electrons nor gain 4 electrons due to energy considerations. An element having 4 electrons in the outermost shell of its atom can achieve the inert gas electron arrangement of eight valence electrons only by sharing its 4 outermost electrons with the 4 electrons of the other atoms.

VALENCY OF ELEMENTS

The capacity of an atom of an element to form chemical bonds is known as its valency. (the number of electrons transfer to mcomplete its octance is called valancy of element)

Types of Valency

There are two types of valency : Electrovalency and Covalency.

1. ELECTROVALENCY

the number of electrons lost or gained by one atom of an element to achieve the nearest inert gas electron configuration is known as its electrovalency. The elements which lose electrons form positive ions, so they have positive electrovalency. The elements which gain electrons form negative ions, so they have negative electrovalency.

for example -

(a) Valency of Sodium

The atomic number of sodium is 11, so its electronic configuration is 2, 8, 1. It has 1 electron in its outermost shell. Sodium atom can lose this electron to form a sodium ion, Na^+, having an inert gas electron arrangement of 2, 8. Since a sodium atom loses 1 electron to achieve the inert gas electron configuration, therefore, the valency of sodium is 1 (or 1+).

(b) Valency of Magnesium

The atomic number of magnesium is 12, and its electronic configuration is 2, 8, 2. It has 2 electrons in its valence shell. The magnesium atom can lose these two outermost electrons to form a magnesium ion, Mg^{2+}, having an inert gas electron configuration of 2,

8. Since one magnesium atom loses 2 electrons to achieve the inert gas electron configuration, therefore, the valency of magnesium is 2 (or 2+).

(c) Valency of Aluminium

The atomic number of aluminium is 13, so its electronic configuration is 2, 8, 3. It has 3 electrons in its outermost shell. The aluminium atom can lose these 3 electrons to form the aluminium ion, Al^{3+}, having an inert gas electron configuration of 2, 8. Since one atom of aluminium loses 3 electrons to achieve the inert gas electron configuration, so the valency of aluminium is 3 (or 3+).

(d) Valency of Chlorine

The atomic number of chlorine is 17, so its electronic configuration is 2, 8, 7. The chlorine atom has 7 electrons in its outermost shell and it needs 1 more electron to achieve the 8-electron configuration. So, the chlorine atom gains (accepts) 1 electron to form a chloride ion, Cl^{-}, having an inert gas electron arrangement of 2, 8, 8. Since one chlorine atom gains 1 electron to achieve the inert gas electron configuration, so the electrovalency of chlorine is 1 (or 1–).

(e) Valency of Oxygen

The atomic number of oxygen is 8, so its electronic configuration is 2, 6. The oxygen atom has 6 valence electrons, so it needs 2 more electrons to complete the 8-electron structure. The oxygen atom gains (accepts) 2 electrons to form an oxide ion, O^{2-}, having an inert gas electron arrangement of 2, 8. Since one atom of oxygen requires 2 electrons to achieve the nearest inert gas electron arrangement, so the electrovalency of oxygen is 2 (or 2–).

(f) Valency of Nitrogen

The atomic number of nitrogen is 7, so its electronic configuration is 2, 5. Nitrogen atom has 5 electrons in its outermost shell and it needs 3 more electrons to complete the 8-electron structure. Thus, the nitrogen atom gains 3 electrons to form a nitride ion, N^{3-}, having an inert gas electron configuration of 2, 8. Since one nitrogen atom needs 3 electrons to achieve the nearest inert gas electron arrangement, so the electrovalency of nitrogen is 3 (or 3 –).

2. COVALENCY

the number of electrons shared by one atom of an element to achieve the nearest inert gas electron configuration is known as its covalency.

(a) Covalency of Hydrogen

The atomic number of hydrogen is 1, so its electronic configuration is 1. A hydrogen atom has 1 electron in its outermost shell, which is K shell, so it needs 1 more electron to achieve the 2-electron inert gas electron arrangement of helium and become stable. Hydrogen atom gets this electron by sharing. Since one atom of hydrogen shares 1 electron to achieve the nearest inert gas electron configuration, therefore, the covalency (or just valency) of hydrogen is 1.

(b) Covalency of Chlorine

A chlorine atom has 7 electrons in its outermost shell, so it can share its 1 electron with one electron of another atom to achieve the 8-electron inert gas electron arrangement. Since one chlorine atom shares 1 electron to achieve the nearest inert gas electron arrangement, therefore, the covalency (or just valency) of chlorine is 1.

(c) Covalency of Oxygen

An oxygen atom has 6 valence electrons, so it can share its 2 electrons with two electrons of another atom to achieve the 8-electron inert gas electron arrangement and become stable. Since one oxygen atom shares 2 electrons to achieve the nearest inert gas electron arrangement, therefore, the covalency (or just valency) of oxygen is 2.

(d) Covalency of Nitrogen

A nitrogen atom has 5 valence electrons, so it can share its 3 electrons with three electrons of another atom to attain the 8-electron inert gas electron configuration. Since one nitrogen atom shares 3 electrons to achieve the nearest inert gas electronic configuration, therefore, the covalency (or just valency) of nitrogen is 3.

(e) Covalency of Carbon

The atomic number of carbon is 6, so its electronic configuration is 2, 4. Thus, a carbon atom has 4 valence electrons and it requires 4 more electrons to complete the 'octet'. It gets these electrons by sharing. So, a carbon atom shares its 4 electrons with the four electrons of other atoms to attain the 8-electron inert gas electron arrangement. Since one carbon atom shares its 4 electrons to attain the inert gas electron arrangement, therefore, the covalency (or just valency) of carbon is 4.

Problem 1. What valency will be shown by an element having atomic number 12 ?

Problem 2. What valency will be shown by an element having atomic number 15 ?

Problem 3. If Z = 3, what would be the valency of the element ? Also name the element.

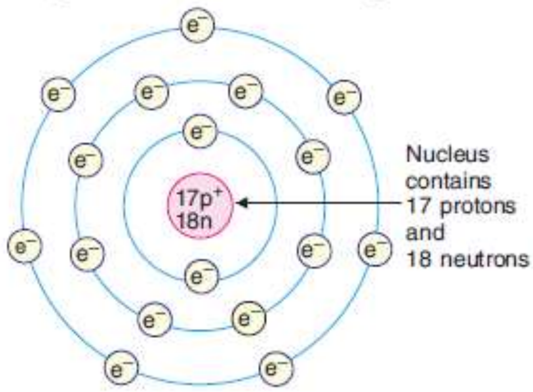
Problem 4. The number of valence electrons in a chloride ion, Cl–, are :
(a) 16 (b) 8 (c) 17 (d) 18

ISOTOPES

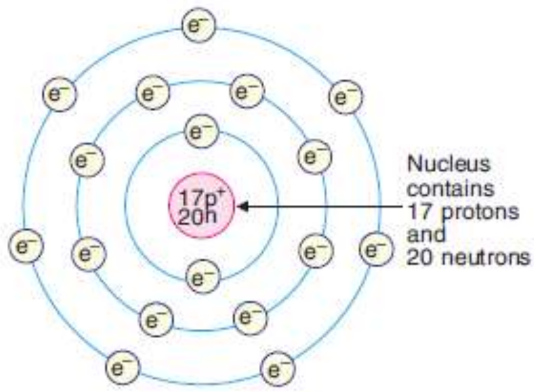
Isotopes are atoms of the same element having the same atomic number but different mass numbers. ('same atomic number' but 'different mass numbers'.)

Note - the isotopes of an element differ in the number of neutrons in their nuclei.

All the chlorine atoms contain 17 protons, so the atomic number of all the chlorine atoms is 17. Now, some chlorine atoms have 18 neutrons whereas other chlorine atoms contain 20 neutrons. Chlorine atoms can, therefore, have mass numbers of 17 + 18 = 35 or 17 + 20 = 37. Thus, chlorine has two isotopes of mass numbers 35 and 37 respectively.

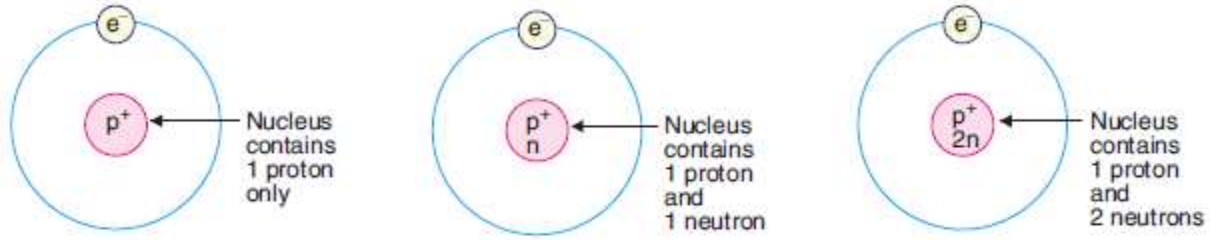


(i) Cl-35 isotope
(Mass number or Atomic mass = 35)



(ii) Cl-37 isotope
(Mass number or Atomic mass = 37)

1. Isotopes of Hydrogen. The hydrogen element has three isotopes having the same atomic number of 1 but different mass numbers of 1, 2 and 3 respectively
(i) Protium is the ordinary hydrogen isotope of mass number 1. Protium does not have a special symbol.
(ii) Deuterium is the heavy hydrogen isotope of mass number 2. The special symbol of deuterium is D.
(iii) Tritium is the very heavy hydrogen isotope of mass number 3. The special symbol of tritium is T.



(*i*) Ordinary hydrogen (or Protium) Atomic mass = 1 u

(*ii*) Heavy hydrogen (or Deuterium) Atomic mass = 2 u

(*iii*) Very heavy hydrogen (or Tritium) Atomic mass = 3 u

hydrogen element has three isotopes : protium, deuterium and tritium, having the same atomic number of 1 but different mass numbers of 1, 2 and 3 respectively.

2. Isotopes of Carbon. The carbon element has three isotopes having the same atomic number of 6 but different mass numbers of 12, 13 and 14.

3. Isotopes of Oxygen. The oxygen element has three isotopes : All the isotopes of oxygen have the same atomic number of 8 but they have different mass numbers of 16, 17 and 18 respectively.

4. Isotopes of Neon. All the isotopes of neon have the same atomic number of 10 but they have different mass numbers (or atomic masses) of 20, 21 and 22 respectively.

All the Isotopes of an Element Have Identical Chemical Properties

(Why?) - Since all the isotopes of an element have identical electronic configurations containing the same number of valence electrons, therefore, all the isotopes of an element show identical chemical properties.

The Physical Properties of the Isotopes of an Element are Different

Since the masses of the isotopes of an element are slightly different, therefore, the physical properties of the isotopes of an element are slightly different.

Reason for the Fractional Atomic Masses of Elements

The atomic masses of many elements are in fractions and not whole numbers. For example, the atomic mass of chlorine is 35.5 u whereas that of copper is 63.5 u. The fractional atomic masses of elements are due to the existence of their isotopes having different masses.

for example - natural chlorine consists of two types of atoms, one having a mass of 35 u and the other having a mass of 37 u in the proportion of 75% and 25% respectively. Thus, the average mass of a chlorine atom will be 75% of 35 and 25% of 37, which is 35.5 u.

(*i*) The chlorine isotope $^{35}_{17}Cl$ has a mass of 35 u and its abundance (proportion) in nature is 75%.

(*ii*) The chlorine isotope $^{37}_{17}Cl$ has a mass of 37 u and its abundance (proportion) in nature is 25%.

This means that the isotope of mass 35 u will contribute 75 per cent to the average atomic mass of chlorine whereas the isotope of mass 37 u will contribute 25 per cent to the average atomic mass of chlorine. So,

$$\text{Average atomic mass of chlorine} = 35 \times \frac{75}{100} + 37 \times \frac{25}{100}$$

$$= \frac{2625}{100} + \frac{925}{100}$$

$$= 26.25 + 9.25$$

$$= 35.5 \text{ u}$$

Thus, the average atomic mass of chlorine is 35.5 u.

Sample Problem 1.

Sample Problem 2.

Sample Problem 3. Bromine occurs in nature mainly in the form of two isotopes $^{79}_{35}Br$ and $^{81}_{35}Br$. If the abundance of $^{79}_{35}Br$ isotope is 49.7% and that of $^{81}_{35}Br$ isotope is 50.3%, calculate the average atomic mass of bromine. **(NCERT Book Question)**

Solution. We know that upper digit in the symbol of an isotope represents its mass (which is the same as its mass number). Now :

(*i*) The mass of $^{79}_{35}Br$ isotope is 79 u and its abundance is 49.7%.

(*ii*) The mass of $^{81}_{35}Br$ isotope is 81 u and its abundance is 50.3%.

$$\text{So, Average atomic mass of bromine} = 79 \times \frac{49.7}{100} + 81 \times \frac{50.3}{100}$$

$$= \frac{3926.3}{100} + \frac{4074.3}{100}$$

$$= 39.263 + 40.743$$
$$= 80.006$$
$$= 80 \text{ u}$$

Thus, the average atomic mass of bromine is 80 u.

Sample Problem 4. A sample of an element X contains two isotopes $^{16}_{8}X$ and $^{18}_{8}X$. If the average atomic mass of this sample of the element be 16.2 u, calculate the percentage of the two isotopes in this sample. **(NCERT Book Question)**

Solution. In order to solve this problem, we will have to suppose that the percentage of one of the isotopes in the sample is x, so that the percentage of the other isotope in the sample will be $(100 - x)$. Now :

(*i*) The mass of $^{16}_{8}X$ isotope is 16 u. Suppose its percentage in the sample is x %.

(*ii*) The mass of $^{18}_{8}X$ isotope is 18 u. Its percentage in the sample will be $(100 - x)$ %.

So, Average atomic mass of X $= 16 \times \frac{x}{100} + 18 \times \frac{(100-x)}{100}$

But the average atomic mass of X has been given to be 16.2 u. Therefore,

$$16.2 = 16 \times \frac{x}{100} + 18 \times \frac{(100-x)}{100}$$

or $$16.2 = \frac{16x + 1800 - 18x}{100}$$

or $$16.2 \times 100 = 1800 - 2x$$

or $$2x = 1800 - 1620$$

or $$2x = 180$$

And $$x = \frac{180}{2}$$

or $$x = 90$$

Thus, the percentage of the isotope $^{16}_{8}X$ in the sample is 90%. The percentage of the other isotope $^{18}_{8}X$ in the sample will be 100 – 90 = 10%.

RADIOACTIVE ISOTOPES

There are two types of isotopes : those which are stable and those which are unstable. The isotopes which are unstable (due to the presence of extra neutrons in their nuclei) and emit various types of radiations, are called radioactive isotopes (or just radioisotopes). The radiations (such as alpha particles, beta particles and gamma rays) are emitted by the unstable nuclei of the radioactive isotopes. Some of the common radioactive isotopes are : Carbon-14, Arsenic-74, Sodium-24, Iodine-131, Cobalt-60 and Uranium- 235. The high energy radiations emitted by radioactive isotopes are harmful to human beings. So, radioactive isotopes have to be used very, very carefully by taking suitable precautions and at proper concentrations to avoid damage.

Applications of Radioactive Isotopes

Radioactive isotopes are widely used in medicine to diagnose, study and treat various ailments. They are also used in power plants and in industry. Some of the important applications (or uses) of radioactive isotopes are given below.

1. Radioactive isotopes are used as a fuel in nuclear reactors of nuclear power plants for generating electricity. Uranium-235 isotope is used as a fuel in the reactors of nuclear power plants for generating electricity.

//Extra// This is done as follows : When uranium-235 atoms are bombarded with slow moving neutrons, the heavy uranium nuclei break up to form two smaller nuclei and a tremendous amount of heat energy is produced. This heat energy is used to boil water in big boilers to form steam. The high pressure steam turns the turbines. The turbines run the generators to produce electricity. The process in which big uranium-235 nuclei are broken into smaller nuclei to obtain energy is called nuclear fission.The radioactive isotopes such as uranium-235 and plutonium-239 are also used for making atom bombs (or nuclear bombs).

2. Radioactive isotopes are used as 'tracers' in medicine to detect the presence of tumors and blood clots, etc., in the human body. A small amount of the low activity radioactive compound (called tracer) is either injected into the body of a person or given orally. This radioactive compound moves through the body and accumulates in the area of tumor, blood clot, etc. The exact position of the accumulated radioactive tracer can be found with the help of a device called Geiger counter. This gives the exact position of the tumor or blood clot and is of great help to the doctors for deciding further treatment. Arsenic-74 tracer is used to detect the presence of tumors and sodium-24 tracer is used to detect the presence of blood clots.

3. Radioactive isotopes are used in the treatment of cancer.
Cobalt-60 radioisotope is used to cure cancer. When the high energy gamma radiations emitted by cobalt-60 radioisotopes are directed at the cancerous tumor in the human body, the cancerous cells get burnt. The treatment of cancer by using radioactive radiations is called radiotherapy.

4. Radioactive isotopes are used to determine the activity of thyroid gland which helps in the treatment of diseases like goitre. Doctors use iodine-131 radioisotope as a tracer to find how and at what rate the thyroid gland in our body takes up iodine (which is essential for making thyroxine hormone). This helps in the treatment of diseases like goitre.

5. Radioactive isotopes are used in industry to detect the leakage in underground oil pipelines, gas pipelines and water pipes.

ISOBARS

Isobars are the atoms of different elements having different atomic numbers but the same mass number (or same atomic mass).

Isobar	Protons	Neutrons	Mass number
Ar	18	22	18 + 22 = 40
Ca	20	20	20 + 20 = 40

Sample Problem 1. Which two of the following atomic species are isotopes of each other and which two are isobars ?

$^{231}_{90}Z$, $^{230}_{91}Z$, $^{230}_{88}Z$, $^{233}_{90}Z$

Sample Problem 2. Write the electronic configurations of any one pair of (a) isotopes, and (b) isobars.

------------------**End of Part – 2**-------------------