5. Inside the Atom

Can you recall? 1. What is meant by matter ? 2. What is an atom ?
3. What is the smallest unit of matter ?

We have seen that matter is made of molecules. Molecules are formed from atoms. Effectively an atom is the smallest unit of matter. An atom is the smallest particle of an element which retains its chemical identity in all the physical and chemical changes.

The table 5.1 shows names and formulae of some substances. Complete the table by putting tick marks in appropriate box to indicate the information of the smallest particle and the type of matter.

Name of substance	Formula	Smallest particle of the substance				Type of matter	
		is an atom	is a molecule	single type of atoms in the molecule	different types of atoms in the molecule	Element	Compound
Water	H_2O		✓		✓		✓
Oxygen	O_2		✓	✓		✓	
Helium	He	✓		✓		✓	
Hydrogen	H_2						
Ammonia	NH_3						
Nitrogen	N_2						
Methane	CH_4						
Argon	Ar						
Neon	Ne						
Chlorine	Cl_2						

5.1 Types of substances

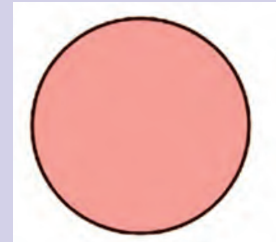
We have learnt in the earlier standard that the smallest particles of most of the substances are molecules. The molecules of a few substances contain only one atom. Molecules are formed by chemical of combination of atoms. From this we understand that the smallest particle of an element taking part in chemical combination is an atom. The concept of atom is more than 2500 years old. However, it was forgotten in the course of time. In the modern times, scientists on the basis of experiments explained the nature of atom as well as the internal structure of atom. It started with Dalton's atomic theory.

Do you know?

- Indian philosopher Kanad (6th century B.C.) stated that there is a limit to divide matter into small particles. The indivisible particles that constitute matter were named by Kanad Muni as 'Paramanu' (meaning the smallest particles). He also stated that 'Paramanu' is indistructible.
- Greek philosopher Democritus (5th century B.C.) stated that matter is made of small particles and these cannot be divide. The smallest particle of matter was name by Democritus as 'Atom'. (In Greek language 'Atomos' means the one which cannot be cut.)

Dalton's atomic theory : British scientist John Dalton put forth in 1803 A.D. his celebrated 'Atomic Theory'. According to this theory matter is made of atoms and atoms are indivisible and indestructible. All atom of an element are alike while different element have different atom with different mass.

John Dalton



Dalton's atomic model

5.2 Dalton's atomic model

Try this

1. Take a solid ball and a 'Bundi Laddu.' Press both these spheres with your palms. What did you find ?
2. Cut the solid ball with a sharp knife. What did you find?

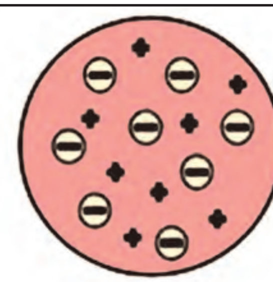
A 'Bundi Laddu' is found to have an internal structure. It is formed by sticking smaller particles, the 'Bundis' to each other. However, the solid ball, broadly speaking, does not have any internal structure. The atom, as described by Dalton, turns out to be a hard, solid sphere with no internal structure. According to Daltons atomic theory the mass is distributed uniformly in an atom. The scientist J.J. Thomson demonstrated experimentally that the negatively charged particles inside an atom have a mass 1800 times less than a hydrogen atom. Later these particles were named as electron. Common substances are usally electrically neutral. Obviously the molecules of substances and the atom which combine chemically to form molecules are electrically neutral.

How is an atom electrically neutral in spite of having negatively charged electrons in it ? Thomson overcame this difficulty by putting forth the plum pudding model of atomic structure.

Thomson's plum pudding model of atom

The plum pudding model of atom put forth by Thomson in the year 1904 is the first model of atomic structure. According to this model the positive charge is distributed throughout the atom and the negatively charged electron are embedded in it. The distributed positive charge is balanced by the negative charge on the electrons. Therefore the atom becomes electrically neutral.

J.J. Thomson



Thomson's plum pudding model of atom

5.3 Thomson's plum pudding model of atom

Use your brain power

How will you think about atomic mass distribution according to Thomson's model? Whether this distribution is uniform or non uniform as per Dalton's atomic theory ?

Do you know?

Plum pudding or plum cake is sweetdish prepared during Christmas. In old times, this dish was made in Western countries by adding pieces of dried fruit called plum. These days, raisins or dates are used.

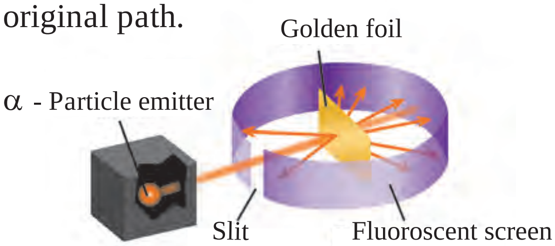
Can you tell?

1. If the striker flicked by you misses the coin that you aimed at, where would the striker go?
2. If the striker hits the coin, in which direction would it go? Straight forward to a side or in the reverse direction?

Rutherford's nuclear model of atom (1911)

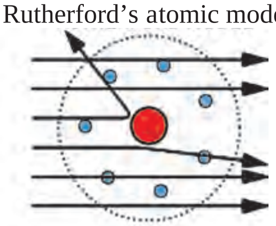
Rutherford studied the inside of atom by his celebrated scatterring experiment and put forth the nuclear model of atom in the year 1911.

Rutherford took a very thin gold foil (thickness : 10^{-4}mm) and bombarded it with positively charged α - particles emitted by a radioactive element. (fig. 5.4) He observed the path of α - particles by means of a fluorescent screen around the gold foil. It was expected that the α- particles would get reflected from the gold foil if the positively charged mass were evenly distributed inside the atoms. Unexpectedly, most of the α - particles went straight through the foil, a small number of α - particles get deflected from the original path through a small angle, a still smaller number of α- particles get deflected throught a larger angle and susprisingly one α - particle out of 20000 bounced back in the direction opposite to the original path.



5.4 Rutherford's scatterring experiment

The large number of the α - particles that went straight through the foil indicates that there was no obstacle in their path. It meant that there must be mainly an empty space inside the atoms in the solid gold foil. The small number of α - particles that get deflected through a small or a big angle must have faced an obstacle in their path. It meant that the positively charged and heavy part causing obstruction would be in the centre of the atom. From this Rutherford put forth a nuclear model for atom as follows :



5.5 Rutherford's Nuclear atomic model

1. There is a positively charged nucleus at centre of an atom. 2. Almost the entire mass of the atom is concentrated in the nucleus. 3. Negatively charged particles called electrons revolve around the nucleus. 4. The total negative charged on all the electron is equal to the positive charge on the nucleus. As the opposite charges are balanced the atom is electrically neutral. 5. There is an empty space between the revolving electron and the atomic nucleus.

Use your brain power

1. Which discovery did point out that an atom has internal structure?
2. What is the difference between the solid atom in Dalton's atomic theory and Thomson's atomic model?
3. Explain the difference between the distribution of positive charge in Thomson's atomic model and Rutherford's atomic model.
4. What is the point difference between the place of electron in the atomic models of Thomson and Rutherford?
5. What is the thing which is present in Rutherford's atomic model and not present in Dalton's and Thomson's atomic models?

An established law of physics an electrically charged body is revolving in a circular orbit, its energy decreases. According to this law the atom described in Rutherford's model turns out to be unstable. In reality, however all atom, except radioactive atom, are stable. This shortcoming of Rutherford's atomic model was removed by the atomic model put forth by Niels Bohr in the year 1913.

Bohr's stable orbit atomic model (1913)

In the year 1913 Danish scientist Niels Bohr explained the stability of atom by putting forth stable orbit atomic model. The important postulates of Bohr's atomic model are as follows.

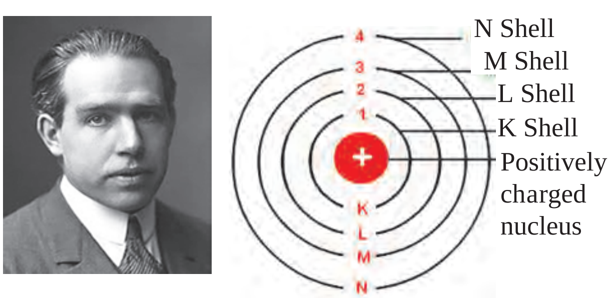
(i) The electrons revolving around the atomic nucleus lie in the concentric circular orbits at certain distance from the nucleus.

(ii) Energy of an electron is constant while it is in a particular orbit.

(iii) When an electron jumps from an inner orbit to an outer orbit it absorbs energy equal to the difference of its energy level and when it jumps from an outer orbit to an inner orbit it emits energy equal to the difference of its energy level.

Do you know?

When table salt (Sodium chloride) is thrown on LPG gas stove flame, immediatly yellow spark forms on that place. If sodium metal put in water, it burns to give yellow flame. On road sodium vapour lamp gives yellow colour light. From all above example, the electron of sodium absorb energy and goes to outermost shell and come back to inner shell by emitting energy. The difference of energy level of these two shells of sodium is fixed. This difference is similar to energy of yellow light. Therefore in above example same specific yellow light emitted.



5.6 Bohr's stable orbit atomic model

Some more atomic models were put forth after Bohr's atomic model. Atomic structure was studied at depth with the advent of a new branch of science called quantum mechanics. With all those some well accepted fundamental principles of atomic structure are as follows :

Atomic structure

An atom is formed from the nucleus and the extranuclear part. These contain three types of subatomic particles.

Nucleus

The atomic nucleus is positively charged. Almost entire mass of the atom is concentrated in the nucleus. The nucleus contains two types of subatomic particles together called nucleons. Protons and neutrons are the two types of nucleons.

Proton (p)

Proton is a positively charged subatomic particle in the atomic nucleus. The positive charge on the nucleus is due to the proton in it. A proton is represented by the symbol 'p'. Each proton carries a positive charge of +1e. ($1e = 1.6 \times 10^{-19}$ coulomb). When total positive charge on the nucleus is expressed in the unit 'e' , its magnitude is equal to the number of proton in the nucleus. The number of protons in the nucleus of an atom is the atomic number of that element and is denoted by the 'Z' mass of one proton is approximately 1u (1 Dalton)
($1u = 1.66 \times 10^{-27}$ Kg) (The mass of one hydrogen atom is also approximately 1 u.)

Neutron (n)

Neutron is an electrically neutral subatomic particle and is denoted by the symbol 'n'. The number of neutron in the nucleus is denoted by the symbol 'N'. Atomic nuclei of all the elements except hydrogen with atomic mass 1u, contain neutrons. The mass of a neutron is approximately 1 u, which is almost equal to that of a proton.

Extranuclear part

The extranuclear part in the atomic structure includes electrons revolving around the nucleus and the empty space in between the nucleus and the electron.

Electron (e^-)

Electron is a negatively charged subatomic particle and is denoted by the symbol 'e^-'. Each electron carries one unit of negative charge (-1e). Mass of an electron is 1800 times less than that of a hydrogen atom. Therefore the mass of an electron can be treated as negligible.

Electron in the extranuclear part revolve in the discrete orbits around the nucleus. The orbits being three dimensional in nature, a term 'shell' is used in stead of the term 'orbit'. The energy of an elctron is determined by the shell in which it is present.

The number of electron in the extranuclear part is equal to the number of proton in the nucleus (Z). Therefore electrical charges are balanced and the atom is electrically neutral.

Use your brain power

1. How many types of subatomic particles are found in atom?
2. Which subatomic particles are electrically charged?
3. Which subatomic particles are present in the nucleus?
4. Where are electrons revolving around the nucleus placed?

The mass of an electron being negligible, therefore the mass of an atom is mainly due to the protons and neutrons in its nucleus. The total number of protons and neutron in an atom is the atomic mass number of that element. The mass number is denoted by the symbol 'A'. The convention to denote atomic symbol, atomic number and mass number are together is shown as follows.

$^{A}_{Z}$symbol. For example, the conventional symbol $^{12}_{6}C$ means that the atomic number, that is, the proton number of carbon is 6 and the mass number of carbon is 12. From this it is also learnt that the nucleus of carbon contain (12-6) i.e. 6 neutrons.

Use your brain power

1. The symbol used for oxygen is 'O'. There are 8 protons and 8 neutrons in its nucleus. From this determine the atomic number (Z) and mass number (A) of oxygen and arrange these in a conventional symbol.
2. Atomic number of carbon is 6. How many electrons are there in a carbon atom ?
3. A sodium atom contains 11 electrons. What is the atomic number of sodium ?
4. The atomic number and mass number of magnesium are 12 and 24 respectively. How will you show this by the convention symbol ?
5. The atomic number and mass number of calcium are 20 and 40 respectively. Deduce the number of neutron present in the calcium nucleus.

Distribution of electron : As per Bohr's atomic model, electrons revolve in stable shells. These shells have a definite energy. The shell nearest to the nucleus is called the first shell. The next shell is called the second shell. A symbol 'n' is used for the ordinal number of a shell. The shells are referred to by the symbols K, L, M, N,.... corresponding to the ordinal numbers n = 1, 2, 3, 4, ... The maximum number of electron a shell can contain is obtained by the formula '$2n^2$'. As the magnitude of 'n' increases, the energy of an electron in that shell increases.

Complete the table

Shell		Electron capacity of the shell	
Symbol	n	Formula : $2n^2$	Number of Electrons
K	1	$2 \times (1)^2$	
L			
M			
N			

Write the maximum number of electron in a shell using the above table. K Shell : ..., L Shell : ..., M Shell :..., N Shell :...

Can you tell?

1. There is a similarity in the atomic structure and solar system. The planets revolve around the sun due to the gravitational force. Which force might be acting in the atomic structure ?
2. Positively charged proton are together in the nucleus. What might be, one of the function of the neutrons in the nucleus ?

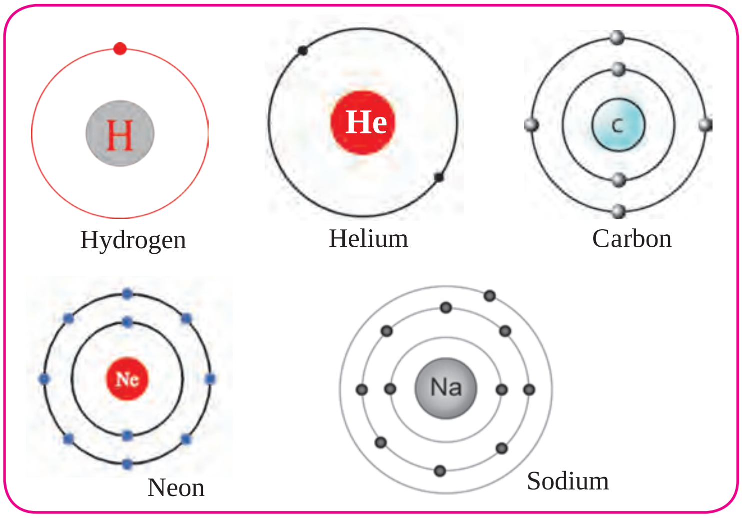
Electronic configuration of elements : We have seen that 2, 8, 18, 32.... electrons can be accommodated in the shells K, L, M, N .... respectively. This is the maximum capacity of that shells. The electrons in an atom are distributed in the shells according to their maximum capacity. The shellwise distribution of the electron in an atom of an element is called the electronic configuration of that element. Each electron has a definite energy as per the shell in which it is present. Energy of an electron in the first shell (K shell) is the lowest. Energy of electron in the subsequent shells goes on increasing with the ordinal number of the shell. The electronic configuration of an element is such that the energy of all the electrons together is the maximum possible. Electrons get a place in the shells in accordance with the maximum capacity of the electron shell in an atom and the increasing order of energy. Let us now look at the electronic configuration of atom of some elements. (Table 5.7). The rows 1 to 3 are filled in this table. Accordingly you have to fill the rest of the table.

Atom	Symbol	Electron number in the atom	Distribution of electrons				Electronic configuration in the numerical form
			Shell symbol (maximum capacity)				
			K (2)	L (8)	M (18)	N (32)	
Hydrogen	H	1	1				1
Helium	He	2	2				2
Lithium	Li	3	2	1			2, 1
Carbon	C	6					
Nitrogen	N	7					
Oxygen	O	8					
Fluorine	F	9					
Neon	Ne	10					
Sodium	Na	11					
Chlorine	Cl	17					
Argon	Ar	18					
Bromine	Br	35					

5.7 electronic configuration of some elements

The electronic configuration in the numerical form contains numbers separated by commas. Here the numbers indicate the electron number in the shells with increasing order of energy for example the electronic configuration of sodium is 2, 8, 1. It means that the total 11 electrons in sodium are distributed as 2 in the shell ‘K’, 8 in the shell ‘L’, and 1 in the shell ‘M’. The electronic configuration of an atom can also be represented by shell diagram as shown in fig 5.8

Valency and electronic configuaration : We have seen in the last chapter that valency means the number of chemical bonds formed by an atom. We also saw that generally the valency of an element remain constant in its compounds.



5.8 Skeleton of Electronic configuration

Can you recall?

Use the following molecular formulae to determine the valencies of H, Cl, O, S, N, C, Br, I, Na

Molecular formulae - H_2, HCl, H_2O, H_2S, NH_3, CH_4 HBr, HI, NaH .

Use your brain power

1. What are the symbols used for the shells which accommodate the electrons in various atoms?
2. What is the symbol and ordinal number of the inner most shell ?
3. Write symbol of electron distribution in shell of fluorine atom?
4. Which is the outermost shell of fluorine atom ?
5. Which is the outermost shell of sodium atom ?
6. Which is the outermost shell of hydrogen atom ?

The concepts regarding valency of an element chemical bonds in compounds get clarified from the electronic configuration. Atom forms chemical bonds by using electron of its outermost shell. Valency of an atom is determined by the configuration of its outermost shell. Therefore the outermost shell is called valence shell. Also, the electrons in the outermost shell are called **valence electrons.**

It can be seen that the valency of an atom is related to the number of valence electrons in that atom. Let us first look at the elements helium and neon. Atoms of both these gaseous element do not combine with any other atom. These elements are chemically inert. It means that their valency is 'Zero'.

Helium atom contains two electrons which are accommodated in the first shell 'K'.

(See the table 5.7) Helium has only one 'K' shell that contains electron and the same is also the outermost shell. The electron capacity ($2n^2$) of 'K' shell is 'two'. This indicates that the outermost shell of helium is completely filled. It is said that helium has an electron duplet. The electronic configuration of the inert gas neon contain two shell 'K' and 'L'. 'L' is valence shell of neon. The electron capacity of 'L' shell is 'eight' and the table 5.7 shows that the valence shell of neon is completely filled. It is said that neon has an electron octet. Argon is an inert gas having electron in the shells 'K', 'L' and 'M'. The electron capacity of the 'M' shell is $2 \times 3^2 = 18$. However in argon there are only 8 electron in the valence shell 'M'. (See table 5.7) It means that there are eight electron in the valence shell of inert gases, that is an electron octet. From this it is understood that the valency is 'Zero' when electron octet (or duplet) is complete.

The electronic configurations of elements other than inert gases (table 5.7) show that they do not have electron octet or their electron octet are incomplete. Regarding hydrogen, it can be said that its electron duplet is incomplete.

Atom of all the elements except inert gases have tendency to combine with other atoms, meaning that they have a non zero valency. You have seen from the formulae of the molecules formed by combination with hydrogen (for example H_2, HCl) that valency of hydrogen is 'one'. The electronic configuration of hydrogen shows that there is 'one' electron less than the complete duplet state.

This number 'one' matches with the valency of hydrogen which is also 'one'. Moreover it is learnt that the electronic configuration of sodium (2, 8, 1) has 'one' electron in the valence shell and the valency of sodium is also 'one' as seen from the molecular formulae NaCl, NaH, etc. It means that there is some relation between the valency of an element and the number of electron in its valence shell.

Use your brain power

The following table (5.9) shows molecular formulae of compounds formed by some elements. Write the valency of the respective element obtained from them and also their electronic configuration and the number of their valence electrons in the empty spaces.

Sr. No.	Symbol of element	Molecular formula of compound	Valency of the element	Electronic configuration of the element	Number of valence electrons x	8 - x (For x ≥ 4)
1	H	HCl	1	1	1	--------
2	Cl	HCl	1	2, 8, 7	7	8-7 = 1
3	Ne	No compound	0			
4	F	HF				
5	Na	NaH				
6	Mg	$MgCl_2$				
7	C	CH_4				
8	Al	$AlCl_3$				

5.9 Relationship between valency and electronic configuration

Use your brain power

In table 5.9 column you have written identified valency from its molecular formulae.

1. When the number of the valence electrons in an element 'x' is 4 or less than 4, does 'x' match with the valency of that element ?
2. When the number of the valence electrons in an element 'x' is 4 or more than 4, does '(8-x)' match with the valency of that element? How many electrons are used to complete the octet ?

From this you will learn that there is a general relationship between the valency of an element and its electronic configuration as shown below.

Always remember

''Valency of an element is same as the number of its valence electrons if this number is four or less than four. On the other hand, when an element has four or more valence electrons, the number of electron by which the octet is short of completion is the valency of that element.

Use your brain power

1. What is meant by the atomic number (Z) of an element ?
2. Atomic numbers (Z) of some elements are given here.
   Write down the number of electron present in the outermost shell of each of them.

Element	H	C	Na	Cl	N
Z	1	6	11	17	7
Number of electrons in the outermost shell					

3. The number of electrons of some elements is given here. By using it write the electronic configuration, number of valence electron and valency of the respective elements.

Element	Li	C	Mg	O
Number of electrons	3	6	12	8
Electronic configuration				
Number of valence electrons				
Valency				

4. Why are the atomic numbers and atomic mass numbers always in whole numbers ?
5. Sulphur contains 16 proton and 16 neutrons. What would be its atomic number and mass number?

Isotopes : The atomic number is a fundamental property of an element and its chemical identity. Some elements in nature have atoms with same atomic number but different mass number. Such atom of the same element having different mass number are called isotopes. For example, carbon has three isotopes, namely, C - 12, C - 13, C - 14. The mass number of isotopes is also represented by another method as ^{12}C , ^{13}C and ^{14}C. The isotopes have same proton number but different neutron number.

Isotope	Mass number A	Proton number (Atomic number) Z	Neutron number n = A - Z
^{12}C	12	6	6
^{13}C	13	6	7
^{14}C	14	6	8

Collect information

Hydrogen has three isotopes. They have separate names hydrogen, deuterium and tritium. Find out their mass numbers. Collect the information about what is heavy water from internet.

Complete the table

Isotopes	Proton number	Neutron number
$^{1}_{1}H$	……………	……………
……………	1	1
……………	1	2
$^{35}_{17}Cl$	……………	……………
$^{37}_{17}Cl$	……………	……………

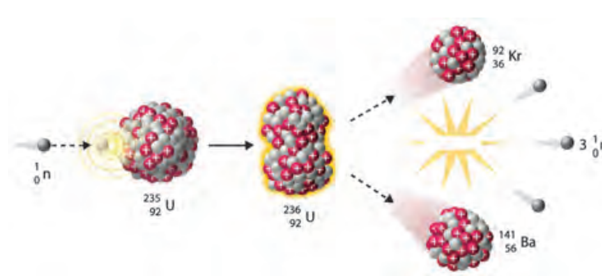
Uses of isotopes : Isotopes of some elements are radioactive. They are used in various fields such as industry, agriculture, medicine, research field.

1. Uranium - 235 is used for nuclear fission and production of electricity.
2. Some radioactive isotopes like Cobalt - 60 are used in the medical treatment of fatal diseases like cancer.
3. Iodine -131 is used in the treatment of goiter, disease of thyroid gland.
4. The radioactive isotopes are used for detection of cracks (leakage) in the underground pipes. eg. Sodium -24.
5. Radioactive isotopes are used for food preservation from microbes.
6. The radioactive isotope C-14 is used for determining the age of archeological objects.

Nuclear Reactor : Nuclear reactor is a machine that generates electricity on large scale by using atomic energy (See fig. 5.10). In a nuclear reactor, the nuclear energy in atom is released by bringing about nuclear reactions on the nuclear fuel. Let us understand a nuclear reaction with example of a nuclear fuel, namely, Uranium - 235. On bombardment with slow speed of neutrons, the nucleus of the isotope Uranium - 235 undergoes nuclear fission to form nuclei of two different elements Krypton - 92 and Barium - 141 and 2 to 3 neutrons. On decreasing the speed these neutrons bring about fission of more U-235 nuclei. In this way a chain reaction of nuclear fission takes place. (See the figure 5.11) A large amount of nuclear energy is released during a chain reaction of fission. The chain reaction is kept under control to prevent the probable explosion.

To control the chain reaction in the nuclear reactor it is necessary to decrease the speed and number of neutrons. For this purpose the following provision is made in a nuclear reactor.

5.10 Nucleur reactor: Bhabha Atomic Research centre, Mumbai



5.11 Uranium - 235 Disintegration

1. Moderator : Graphite or heavy water is used as moderator for reducing the speed of neutrons.

2. Controller : To reduce the number of neutron by absorbing them rods of boron, cadmium, beryllium etc. are used as controller.

The heat produced in the fission process is taken out by using water as coolent. Water is transformed into steam. By means of this steam, turbines are driven and electricity is generated.

In India, total twenty two nuclear reactors in eight places are functioning. 'Apsara' at Bhabha Atomic Research Centre in Mumbai is the first nuclear reactor in India which went critical on 4th August 1956. India has large reseves of the element Thorium -232. Therefore Indian scientists have developed a future plan for nuclear reactors based on production of the isotope U - 233 from Th - 232.

Use of ICT :

Collect detailed working information of atomic reactor from www.youtube.com and show video in the class.

Exercises

1. Answer the following.

a. What is the difference in the atomic models of Thomson and Rutherford?

b. What is meant by valency of an element? What is the relationship between the number of valence electron and valency?

c. What is meant by atomic mass number ? Explain how the atomic number and mass number of carbon are 6 and 12 respectively.

d. What is meant by subatomic particle ? Give brief information of three subatomic particles with reference to electrical charge, mass and location.

2. Give scientific reasons.

a. All the mass of an atom is concentrated in the nucleus.

b. Atom is electrically neutral.

c. Atomic mass number is a whole number.

d. Atoms are stable though negatively charged electron are revolving within it.

3. Define the following terms

a. Atom b. Isotope c. Atomic number d. Atomic mass number e. Moderator in nuclear reactor

4. Draw a neat labelled diagram.

a. Ruthrford's scattering experiment

b. Thomson's atomic model

c. Diagramatic sketch of electronic configuration of Magnesium (Atomic number 12)

d. Diagramatic sketch of electronic configuration of Argon (Atomic number 18)

5. Fill in the blanks.

a. Electron, proton, neutron are the types of .... in an atom.

b. An electron carries a .... charge.

c. The electron shell .... is nearest to the nucleus.

d. The electronic configuration of magnesium is 2, 8, 2. From this it is understood that the valence shell of Magnesium is ....

e. The valency of hydrogen is 'one' as per the molecular formula H_2O. Therefore valency of 'Fe' turns out to be .... as per the formula Fe_2O_3.

6. Match the pairs.

Group 'A'	Group 'B'
a. Proton	i. Negatively charged
b. Electron	ii. Neutral
c. Neutron	iii. Positively Charged

7. Deduce from the datum provided.

Datum	To deduce
${}^{23}_{11}Na$	Neutron number
${}^{14}_{6}C$	Mass number
${}^{37}_{17}Cl$	Proton number

Project :

Explain the atomic models using the material such as old C.D., balloon, thread, marbles, etc .

JUJ2HN