# UNIT 20

# ....... Nuclear Physics ......

After studying this chapter students will be able to:

- describe a simple model for the atom to include protons, neutrons and electrons.
- determine the number of protons, neutrons and nucleons it contains for the specification of a nucleus in the form $_{Z}X^{A}$.
- explain that an element can exist in various isotopic forms each with a different number of neutrons.
- explain the use of mass spectrograph to demonstrate the existence of isotopes and to measure their relative abundance.
- define the terms unified mass scale, mass defect and calculate binding energy using Einstein's equation.
- illustrate graphically the variation of binding energy per nucleon with the mass number.
- explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.
- identify that some nuclei are unstable, give out radiation to get rid of excess energy and are said to be radioactive.
- describe that an element may change into another element when radioactivity occurs.
- identify the spontaneous and random nature of nuclear decay.
- describe the term half-life and solve problems using the equation $\lambda=0.693/T_{1/2}$.
- determine the release of energy from different nuclear reactions.

- explain that atomic number and mass number conserve in nuclear reactions.
- describe energy and mass conservation in simple reactions and in radioactive decay.
- describe the phenomena of nuclear fission and fusion.
- describe the fission chain reaction.
- describe the function of various components of a nuclear reactor.
- describe the interaction of nuclear radiation with matter.
- describe the use of Geiger Muller counter and solid state detectors to detect the radiations.
- describe the basic forces of nature.
- describe the key features and components of the standard model of matter including hadrons, leptons and quarks.

**For your information**

The goals of Nuclear Physics is to discover, explore, and understand all forms of nuclear matter .Every star shines because of the energy provided by nuclear reactions taking place inside it. It is also nuclear reactions that drive the spectacular stellar explosions seen as supernovas, which create nearly all of the chemical elements. A supernova is the explosion of a star. In an instant, a star with many times the mass of our Sun can detonate with the energy of a billion suns. And then within just a few hours or day, it dims down again.

## 20 .1 Atomic Nucleus

Let us begin by reviewing a few fundamental facts that are probably already familiar. The nucleus is made up neutrons and protons, two particles which are about 1840 times more massive than electrons. They are spoken of collectively as nucleons Fig 20.1(a).

The number of protons in a nucleus is just equal to its atomic number z, and the total number of nucleons A is the integer closest to its mass number; hence the number of neutrons is A –Z. Thus the nucleus of "$_{11}Na^{23}$, a sodium atom which has atomic number 11 and mass number 23, contains 11 protons and 12 neutrons.

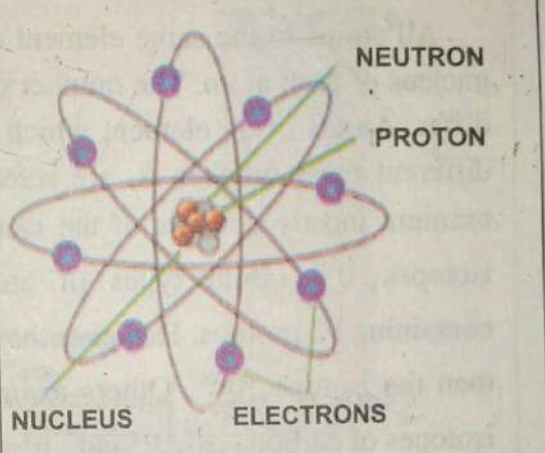

Figure 20.1(a): atomic nucleus

This is a relatively light nucleus; a typical heavy nucleus $_{92}U^{235}$, which is obviously contains 92 protons and 143 neutrons. The mass of the nucleus is very nearly equal to the mass of the atom; in kilograms it is the atomic weight divided by Avogadro's number, $6.03\times10^{26}$

A nuclide is a particular nucleus with a specified number of protons and neutrons. Any nuclide can be represented by its mass number A and atomic number z. For any element X its nuclide is written as $_{Z}X^{A}$. For example $_{1}H^{1}$ has $Z=1$ and A=1. $_{6}C^{12}$ has $Z=6$ and A=12.

The nucleus was first discovered in 1911 in experiment conducted by lord Rutherford and his students Geiger and Marsden on scattering of alpha particles by atom. He found that the scattering pattern could be explained of atoms consist of a small nucleus, deviation indicate that the nuclear size in of the order of $10^{-14}$ m. Since this is 10,000 times smaller than the diameter of atoms. The nucleus contains *Ze* charge, where *Z* is atomic number of the element and e is the charge quantum $1.60\times10^{-19}C$. The mass of nucleus is of the order of $10^{-27}kg$ . In nucleus, protons and neutrons are collectively called as nucleons.

## 20.2 Isotopes

All atoms of the same element contain the same number of protons in the nucleus of each atom. The number of neutrons in each atom of an element can differ. Atoms of an element which has the same atomic number Z, but have different mass number A, are referred to as isotopes. For example, natural uranium mostly consists of the isotopes $_{92}U^{238}$ and a small proportion of the isotopes $_{92}U^{235}$. Both types of atoms are uranium atoms, each nucleus containing 92 protons. However the isotope $_{92}U^{238}$ contains three more neutrons than the isotope $_{92}U^{235}$. Others examples are $_6C^{11}$; $_6C^{12}$; $_6C^{13}$; and $_6C^{14}$ are four isotopes of carbon, $_1H^1$; $_1H^2$ and $_1H^3$ are three isotopes of hydrogen etc.

Note that the number of electrons in an uncharged atom is equal to the number of protons in the nucleus. The chemical properties of an element are the same for all the isotopes of the element. This is because chemical reactions are determined by the electrons in an atom. Atoms of the same element undergoes the same chemical reactions because each atom has the same electron arrangement even if the atoms are different isotopes of the same elements.

## 20.3 Mass Spectrograph

It is a device with the help of which not only the isotopes of any element can be separated from one another but their masses can also be determined quite accurately. A mass spectrograph is based upon the principle that a beam of ions moving through electric and magnetic fields suffers a deflection that depends upon the charge and masses of the ions.

Hence ions of various masses are deflected differently. A spectrometer separates a mixture of ions into a spectrum of atoms having different masses.

A simple mass spectrograph is shown in (fig 20.1b). The atoms or molecules of the elements under investigation, in vapour form, are ionized in the ion source S. As a result of ionization, one electron is removed from the particles, leaving with a net positive charge +e. The positive ions, escaping the slit $S_1$ are accelerated through a potential difference $V$ applied between two slits $S_1$ and $S_2$ .

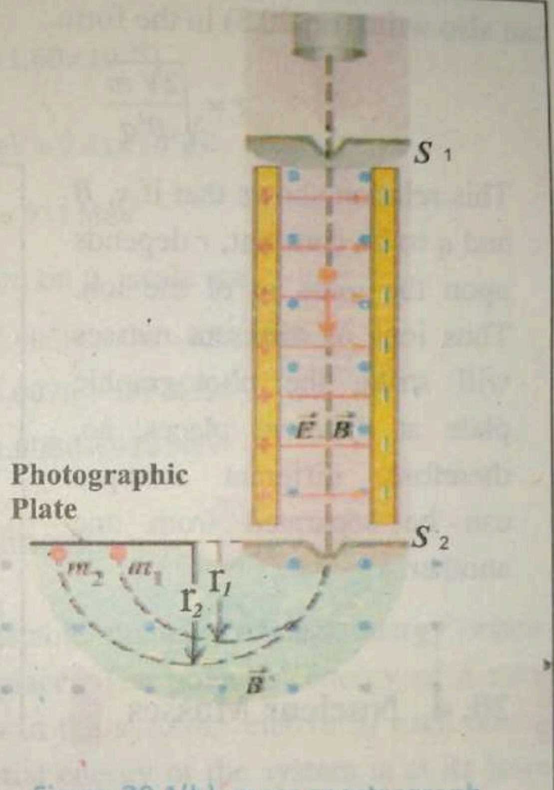

Figure 20.1(b): mass spectrograph

The ion passes through slit $S_2$ in the form of a narrow beam. The K.E of single charged ion at the slit $S_2$ will be given by

$$\frac{1}{2}mv^2 = Vq \qquad \text{...(20.1)}$$

The ions are then subjected to a perpendicular and uniform magnetic field B in a vacuum chamber, where they are deflected in semi-circular paths towards a detector. The detector records the number of ions arriving per second. The centripetal force applied by magnetic fields is given by

$$Bqv = \frac{mv^2}{r} \qquad \text{...(20.2)}$$

OR

$$m = \frac{B\,q\,r}{v}$$

Putting the value of v from Eq. 20.1, we get

$$m = \left(\frac{qr^2}{2V}\right)B^2 \qquad \text{...(20.3)}$$

We can therefore, compute the mass m of the ion if $r$, $B$, $q$ and $V$ are known. We can also write (Eq 20.3) in the form.

$$r = \sqrt{\frac{2Vm}{B^2q}} \qquad \text{...(20.4)}$$

This relation shows that if $v$, $B$ and $q$ to be constant, $r$ depends upon the mass m of the ion. Thus ions of different masses will strike the photographic plate at different places, so, therefore, different isotopes can be separated from one another.

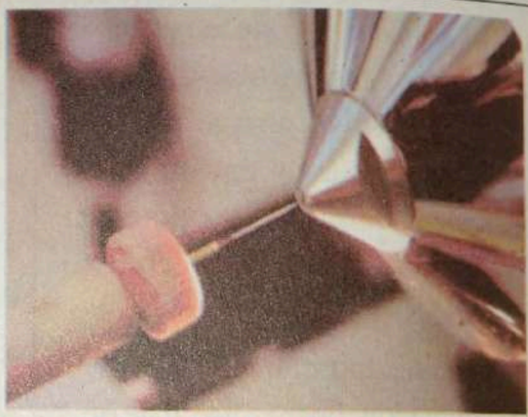

Figure 20.1 (c): Modern Mass Spectrometry instruments are used in the Drug Discovery and Development process.

## 20. 4 Nuclear Masses

It is known that a kilogram- mole of any element should contain Avogadro's number of atoms: $6.023\times10^{26}$ atoms/ kg mole. Thus the mass of an atom or a nucleus is of the order of $10^{-27}$ kg. Since it is a small number, therefore, atomic and nuclear masses are expressed in term of unified (U) mass scale. The unified mass scale is a scale based on assigning a mass exactly 12 to rest mass of an atom of $C^{12}$. On this scale one, mass unit, called an atomic mass unit or a.m.u., is equal to $\frac{1}{12}$ of the mass of the carbon atom $_6C^{12}$. All other masses are then measured in this unit by comparison. The relation of a.m.u. or u to the kilogram is found as follows:

$$\text{Mass of } 6.23\times10^{26} \text{ atoms of } c^{12} = 12\,\text{kg}$$

$$\text{Mass of 1 atom of } C^{12} = \frac{12}{6.023\times10^{26}}\,\text{kg} = 1.660\times10^{-27}\,\text{kg}$$

It is often convenient, in nuclear physics to express certain masses in energy unit. According to Einstein mass–energy equivalence relation.

$$E = mc^2$$

$$1u = (1.660\times10^{-27}\ kg)(3\times10^{8}\ ms^{-2})^2$$
$$= 1.49\times10^{-10}\ j$$

Since $1eV = 1.60\times10^{-19}\ j$

$$1u = \frac{1.49\times10^{-10}}{1.60\times10^{-19}}\ eV = 9.31\times10^{8}\ eV$$

$$1u = 931\times10^{6}\ eV = 931\ MeV$$

The masses of electron, proton and neutron on u –scale are

$$m_e = 9.109\times10^{-31}\ kg = 5.485\times10^{-4}\ u = 0.51\ MeV$$
$$m_p = 1.673\times10^{-27}\ kg = 1.007u = 937\ MeV$$
$$m_n = 1.675\times10^{-27}\ kg = 1.008u = 938\ MeV$$

## 20. 5 Mass defect and binding energy

Why should a large unstable nucleus release energy when it fissions or a radioactive change takes place? The potential energy of a system depends on the position of the particles in the system, relative to each other. A stable system is one in which the potential energy of the system is at its lowest. When an unstable system becomes more stable, it changes to a state of lower potential energy. The protons and the neutrons in a nucleus are held together by a strong attractive force that prevents the protons pushing away from one another. To separate the protons and neutrons from one another, work would need to be done on them to overcome the strong nuclear force. The work needed to separate a nucleus into separate neutrons and protons is referred to as the binding energy of the nucleus fig (20.2). The greater the binding energy of a nucleus, the greater the work that would be needed to separate the neutrons and the protons in the nucleus from each other.

The mass of a nucleus is less than the mass of the same number of separate neutrons and protons. For example, the mass of a helium nucleus which consists of two protons and two neutrons is 0.8% less than the mass of two protons and two neutrons separated from each other. This difference is called the mass defect of the nucleus and is due to the protons and neutrons binding together when the nucleus was formed. The binding energy of the nucleus can be calculated from the mass defect using Einstein's famous equation $E = mc^2$.

$$\text{Binding energy} = \text{mass defect} \times c^2 \qquad ...(20.5)$$

Nuclear masses are usually expressed in atomic mass unit (u).

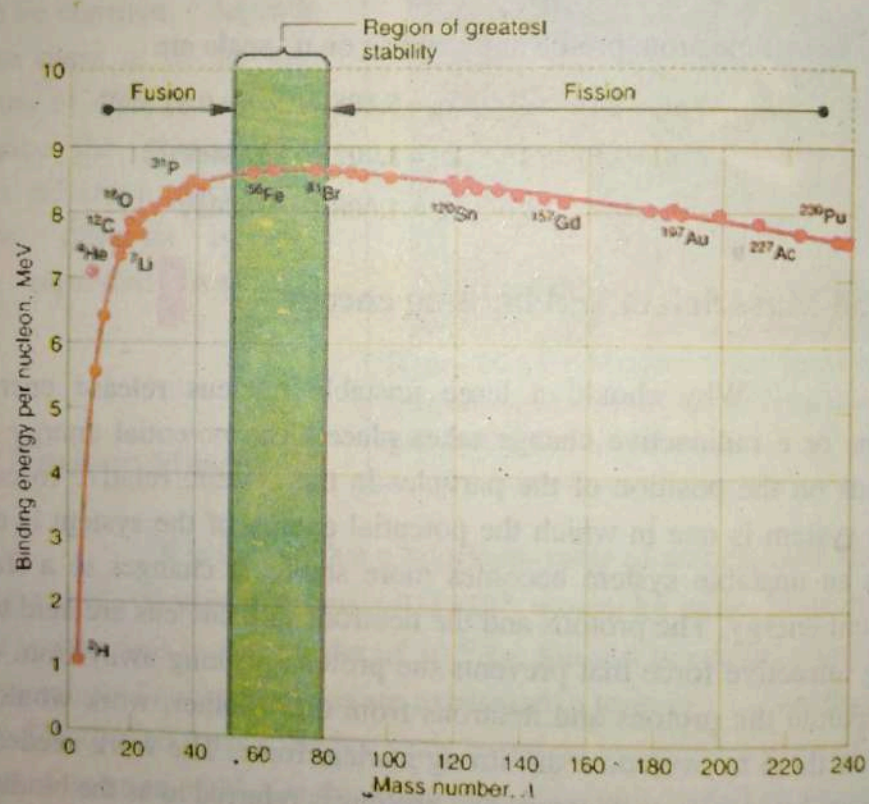


Figure 20.2 :binding energy curve

The binding energy per nucleon of a nucleus is the binding energy of a nucleus divided by the number of nucleons (i.e. protons and neutrons) in the nucleus.

This quantity is a measure of the stability of a nucleus. It can be easily calculated for any nucleus ${}_{Z}X^{A}$ of known mass M by following the steps below:

1. The mass defect (in atomic mass unit) of the nucleus,

$$\Delta m = Z\,m_p + (A-Z)m_n - M_{(A,Z)} \quad \ldots(20.6)$$

Or $\Delta m = Zm_p + Nm_n - M_{(A,Z)}$

Where $m_p$ is the mass of a proton and $m_N$ is the mass of a neutron.

2. The binding energy $E_b$ (in MeV) = 931 × Δm

3. The binding energy per nucleon = $\frac{E_b}{A}$ (Packing fraction)

*Note:* Z = The number of protons in the nucleus,

A = The number of neutrons and protons,

So A − Z is the number of neutrons in nucleus.

**Example 20.1**

The mass of a ${}_{92}U^{235}$ nucleus is 234.99333U. The mass of a proton = 1.00728 u and mass of a neutron = 1.00867u. Calculate the binding energy per nucleons of a ${}_{92}U^{235}$ nucleus.

**Solution:**

Z = 92, A = 235

The number of neutrons = A–Z = 143

mass defect = (92×1.00728) + (143 ×1.00867) – (234.99333 = 1.91624 U

Binding energy = 1.91624 ×931 = 1784 MeV

Binding energy per nucleon = $\frac{1784}{235}$ = 7.6 MeV/ A

A graph of binding energy per nucleon number A is shown in fig 20.2 Remember that greater the binding energy per nucleon of a nucleus is, the more stable the nucleus is. The graph shows that

1. The binding energy per nucleon increases as "A" increases to a maximum of about 1MeV per nucleon at about "A" = 50 to 60 then decreases gradually.

2. The most stable nuclei are about $A = 50$ to 60 since this is where the binding energy per nucleons is greatest.

3. The binding energy per nucleon is increasesd when nuclear fission of a uranium 235 nucleus occurs.

4. The binding energy per nucleons is increased when light nuclei are fused together.

When a $_{92}U^{235}$ nucleus undergoes fission, the two fragment nuclei each comprise about half the number of nucleons. Therefore the binding energy per nucleon increases from about 7.5 MeV per nucleon for $_{92}U^{235}$ to about 8.8 MeV per nucleon for the fragments.

Thus the binding energy per nucleon increases by about 1 MeV for every nucleon which means that the energy released from the fission of a single fissionable nucleus is about 200 MeV. The mass of a $_{92}U^{235}$ nucleus is about $4\times10^{-25}$ kg.

## 20. 6 Radioactivity

Radioactivity was discovered accidentally in Paris by Henry Becquerel in 1896 when he was conducting research into the effects of x–rays on uranium compounds. He had discovered that certain substances exposed to X – rays glow and continued to glow when the X–rays machine was switched off. He wanted to know if the reverse effect was possible, namely emission of x–rays after the substances had been exposed to strong sunlight. In readiness for a sunny day, he placed a wrapped photographic plate in a drawer with a small quantity of uranium compound on it. After

Figure 20.3 (a): nuclear radiations

several dull days, he decided to develop the plates, expecting to observe no more than a faint image of the compound.

He was therefore very surprised when he found a very strong image on plate. He realized that the uranium compound was emitting some form of radiation without having been exposed to sunlight. Further tests showed that the substance emits this radiation continuously even when stored in darkness for long period and that the radiation passes through glass but not through metal. The substance was described as "radioactive" because it did not need to be supplied with energy to make it emit radiations and was therefore emitting radiations actively.

Becquerel continued his research on X –rays and passed the investigation of radio activity on to his research student, Marie Curie. Within two years, Marie curie and her husband Pierre had discovered other substances which are radioactive, including two new elements, radium and polonium. Becquerel and the curies were awarded the noble prize in physics for their discoveries 1903.

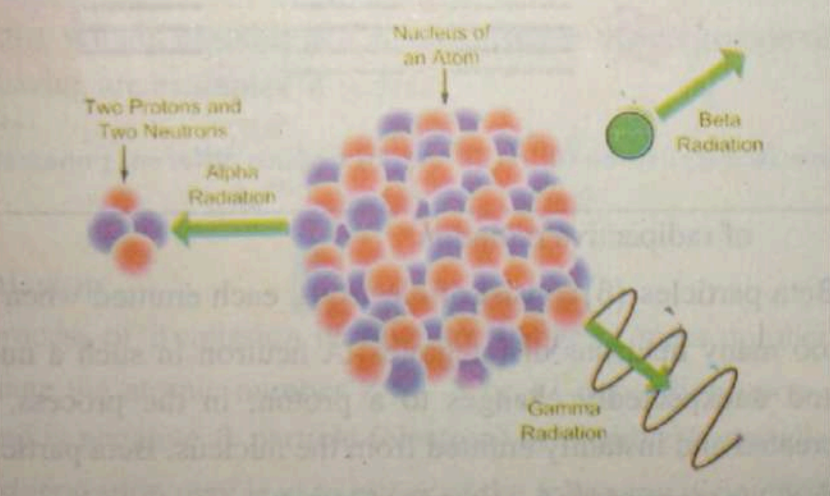


Figure 20.3 (b): nuclear radiations from radioactive element

*The phenomenon of the spontaneous disintegration of heavier elements Z > 82 in to lighter elements along with the emission of three types of radiations is called radioactivity.*

These three types of radiations are known as $\alpha-$particles, $\beta-$particles and $\gamma-$rays. The elements which possess this property, is called radioactive elements.

1. Alpha particle $\alpha$ consists of two protons and two neutrons i.e., these are positively charged helium nuclei. An $\alpha-$particle is emitted by a very large unstable nucleus. Alpha radiation.
   - a. Is easily stopped by cardboard or thin metal.
   - b. Has a range in air of no more than a few centimetres.
   - c. Ionizes air molecules much more strongly than the other two types of radioactive radiation.

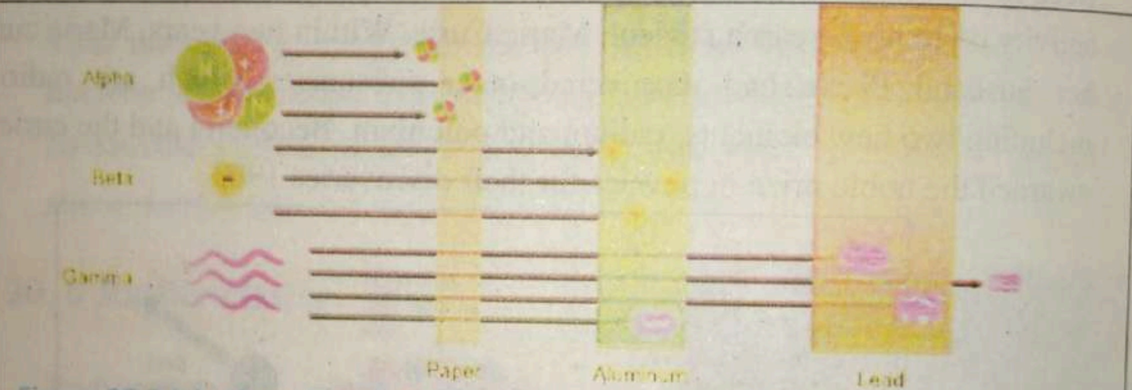

Figure 20.3 (c) : three forms of radiations with different penetration power

2. Beta particles $(\beta)$ consist of electrons, each emitted when a nucleus with too many neutrons disintegrates. A neutron in such a nucleus suddenly and unexpectedly changes to a proton; in the process, an electron is created and instantly emitted from the nucleus. Beta particles.
   - a. Is stopped by 5 –10 mm of metal.
   - b. Has a range in air of about 1m.
   - c. Ionizes air molecules less strongly than $\alpha-$particles.
3. Gamma radiation $(\gamma)$ consists of high energy photons. A photon is a packet of electromagnet waves. A gamma photon is emitted from a

nucleus with surplus energy after it has emitted an, $\alpha$ or a $\beta$-particle. Gamma radiations.

**a.** Is stopped only by several cm of lead.

**b.** Has an infinite range in air.

**c.** Ionizes air molecules very weakly.

## Alpha Emission

Whenever an atom $_{Z}X^{A}$ disintegrates by $\alpha$-emission, its atomic number reduces by 2 and the mass number reduces by 4 units. The disintegration reaction is, written as,

$$_{Z}X^{A} \longrightarrow {}_{Z-2}Y^{A-4} + {}_{2}He^{4} + Q$$

Q is the disintegration energy. Which is always positive, as the process is spontaneous. The decay product $_{Z-2}Y^{A-4}$ is called the daughter nucleus of the parent nucleus $_{Z}X^{A}$. The $\alpha$ particle is often written as $_{2}He^{4}$. The daughter nucleus may also remain unstable and undergo further disintegration till it attains stability. Following are examples of $\alpha$ decay.

$$_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4} + Q$$

$$_{88}Ra^{226} \longrightarrow {}_{86}Rn^{222} + {}_{2}He^{4} + Q$$

## Beta Emission

The process of $\beta$ emission involve no change in mass number $A$. It does, however, change the atomic number $Z$ by -1 or +1 depending upon whether the particle emitted is negative $\beta$ particle (electron) or positive $\beta$-particle (positron). Thus the $\beta$ disintegration may lead to either of the following disintegration.

$$_{Z}X^{A} \longrightarrow {}_{Z+1}X^{A} + {}_{-1}\beta^{\circ} + \text{antineutrino} + Q_{1}$$

$$_{Z}X^{A} \longrightarrow {}_{Z-1}X^{A} + {}_{+1}\beta^{\circ} + \text{neutrino} + Q_{1}$$

As an example of negative $\beta$ emission is the decay of thorium into protactinium:

$$_{90}Th^{234} \longrightarrow {}_{91}Pa^{234} + {}_{-1}\beta^{\circ} + \text{antineutrino} + Q_{1}$$

The prototype of $\beta$ decay is the decay of neutron itself. The neutron, in free space, is unstable, decaying to proton and electron with a half life of 12 minutes.

$$_{0}n^{1} \longrightarrow {}_{1}H^{1} + {}_{-1}\beta^{\circ} + \text{antineutrino}$$

The best known example of $\beta$ decay is from the naturally occurring isotope of $C^{14}$.

$$_{6}C^{14} \longrightarrow {}_{7}N^{14} + {}_{-1}\beta^{\circ} + \text{antineutrino}$$

As an example of a positron emitter is carbon 11, which decay by the reaction;

$$_{6}C^{11} \longrightarrow {}_{5}B^{11} + {}_{1}\beta^{\circ} + \text{neutrino}$$

### Gamma Emission

Most frequently the alpha or beta emission leaves the daughter nuclide in an exited state. Such a nuclide may go back to a more stable configuration and eventually to its ground state by emitting one or more $\gamma$-rays. Since $\gamma$-rays are massless photons, their emission will cause no change either in $A$ or $Z$ of the parent nuclide. The $\gamma$-decay process is written as follows.

$$_{Z}X^{A} \longrightarrow \left({}_{Z}X^{A}\right)^{*} \longrightarrow {}_{Z}X^{A} + \gamma$$

Where $\left({}_{Z}X^{A}\right)^{*}$ represents an excited state of the nucleus.

## 20. 7 Spontaneous and Random Nuclear Decay

We know that radioactive elements disintegrates and emit $\alpha, \beta$ and $\gamma$ radiations. This process is called transmutation by spontaneous disintegration. In this process each of the nuclei of a radioactive sample has a probability of decay into a daughter nucleus. The per unit time probability of decay of all nuclei is the same and has a fixed value, characteristics of material. However, the decay probability of one nucleus is quite independent of that of another nucleus. So in the natural spontaneous disintegration of a radioactive material not all the atoms disintegrates at the same time. Contrary, different atoms decay at different times. The process of disintegration takes place randomly. When a nucleus disintegrates, nobody knows. However, it is observed that, on the average, the actual number of atoms, which decay at any instant, is proportional to the number of atoms present. As times goes on, some nuclei disintegrates and other survive. So the activity continues but with ever decreasing intensity.

## 20. 8 Half-life and rate of decay

The half –life of a radioactive isotope is the time taken for half the number of atoms of the isotope to disintegrate. Suppose 10000 atoms of a certain radioactive isotope "*X*" are present initially. The number of atoms decreases.

- From 10000 to 5000 after first half life, then
- From 5000 to 2500 second a further half life, then
- From 2500 to 1250 third a further half life, etc.

The amount of the radioactive isotope therefore decreases with time as shown in fig: 20.4 which is a half –life curve. Half –life values range from a fraction of a second to billions of years. For example, the half-life of polonium 212 is $3\times10^{-7}$ s and that of lead 204 is $1.4\times10^{7}$ years.

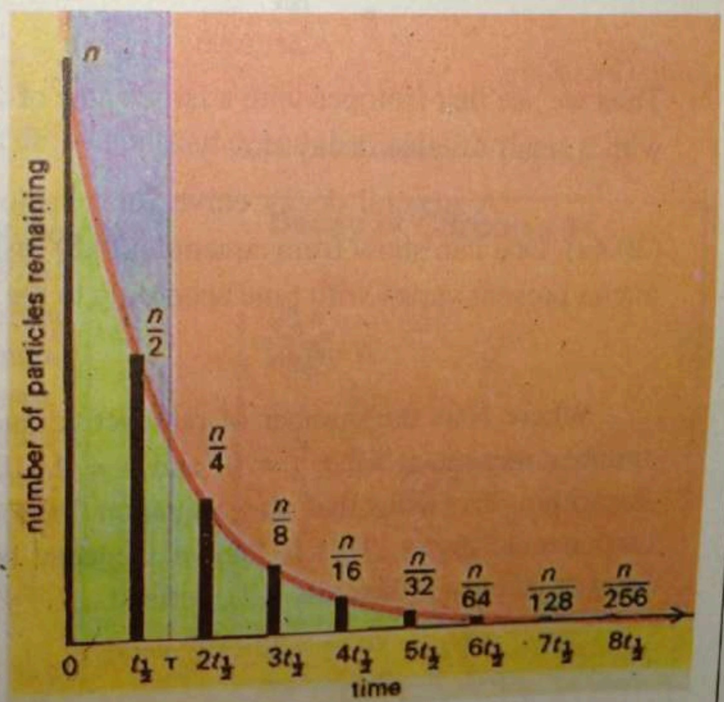


Figure 20.4 (a) :half –life curve

Radioactive disintegration is a random process.

For a large number of atoms of a given radioactive isotope, the proportion that disintegrate per second is constant. This follows because of the random nature of radioactive disintegration.

If a radioactive sample contains "N" radioactive nuclei at some instant, one finds that the number of nuclei $\Delta N$, that decay in a time $\Delta t$ is proportional to N.

$$\frac{\Delta N}{\Delta t} \propto -N$$

$$\frac{\Delta N}{\Delta t} = -\lambda N \qquad \cdots(20.7)$$

Where $\lambda$ is a constant of proportionality which depends on the nature of the element and is called decay constant and the negative sign signifies that $N$ decreases with time, that is, $\Delta N$ is negative. The value of $\lambda$ for any isotope determines the rate at which that isotope will decay.

The decay rate, or activity R, of a sample is defined as the number of decay per second. From equation 20.7 the decay rate is

$$R = -\frac{\Delta N}{\Delta t} = \lambda N \qquad \cdots(20.8)$$

Thus we see that isotopes with a large value of $\lambda$ decay at a rapid rate in those with a small $\lambda$ value decay slowly.

A general decay curve for a radioactive sample shown in figure (20.4a). One can show from equation (20.8) (using calculus) that the number of nuclei present varies with time according to the expression,

$$N = N_o e^{-\lambda t} \qquad \cdots(20.9)$$

Where N is the number of radioactive nuclei present at time $t$, $N_o$ is the number present at time. $t = 0$, and $e = 2.718$..... is the base of the natural logarithm. Processes that obey equation (20.9) are sometimes said to undergo exponential decay. This is known as decay law of radioactive element. The unit of activity is the curie (Ci), defined as

$$1\text{Ci} = 3.70 \times 10^{10} \text{ decay/s}.$$

This number of decay events per second was selected as the original activity unit because it is the approximate activity of 1g of radium. The S.I. unit of the activity is the Becquerel (Bq):

$$1\ \text{Bq} = 1 \text{ decay per second}$$

$$1\ \text{Ci} = 3.70\times10^{10}\text{Bq}$$

By substituting $N=\frac{1}{2}N_o$ and $T = T\frac{1}{2}$ in the equation (20.9), we find that

$$\frac{1}{2}N_o = N_o e^{-\lambda T\frac{1}{2}}$$

$$\frac{1}{2} = e^{-\lambda T\frac{1}{2}}$$

$$2 = e^{\lambda T\frac{1}{2}}$$

Take natural logarithm of both sides and note that lne =1. We find that

$$ln2 = \lambda T\tfrac{1}{2}$$

$$\Rightarrow T\tfrac{1}{2} = \frac{ln 2}{\lambda}$$

$$T\tfrac{1}{2} = \frac{0.693}{\lambda} \qquad \cdots (20.10)$$

This is the relation between the decay constant $\lambda$ and the half–life $T\frac{1}{2}$.

The half-life for radioactive isotope $C^{14}$ is 5730 years, it means in 5730 years the 10 g of carbon disintegrated to 5 g and 5 g remain in given sample. As the time passes, the amount of remaining substance decreases but never reached to zero.
The value of half- life is constant for each radioactive element and it is possible to characterize the element by using its half -life value.
The rate of radioactive decay is directly proportional to the stability of the isotope.

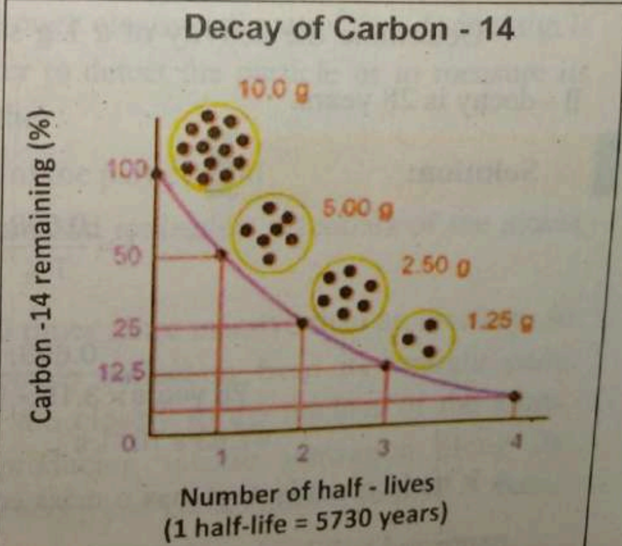


Figure 20.4 (b) : half –life curve

The half -life is a measurement of stability of radioactive elements. The half-life of $U^{238}$ is 4.5 x $10^9$ years. So $C^{14}$ is far less stable than $U^{238}$.

**Example: 20.2:**

The half life of radioactive nucleus $_{86}Ra^{226}$ is $1.6\times10^3$ years. Determine the decay constant.

**Solution:**

$$T_{\frac{1}{2}} = \frac{0.693}{\lambda}$$

$$\lambda = \frac{0.693}{T_{\frac{1}{2}}}$$

$$T_{\frac{1}{2}} = 1.6\times10^3 \text{ years} = (1.6\times10^3 \text{ years})(3.15\times10^7 \text{ s/year})$$

$$= 5.0\times10^{10} \text{ s}$$

Therefore,

$$\lambda = \frac{0.693}{5.0\times10^{10} \text{ s}} = 1.4\times10^{-11} \text{ s}^{-1}$$

**Example (20.3):**

Determine the activity of a 1 g sample of $_{38}Sr^{90}$ whose half –life against $\beta$–decay is 28 years.

**Solution:**

$$\lambda = \frac{0.693}{T_{\frac{1}{2}}}$$

$$= \frac{0.693}{28 \text{ years}\times3.15\times10^7 \text{ s/year}}$$

$$= 7.83\times10^{-10} \text{ s}^{-1}$$

A k mole of an isotope has a mass equal to the atomic weight of that isotope expressed in kilograms. Hence 1 g of $_{38}Sr^{90}$ contains.

$$\frac{10^{-3}kg}{90\ kg/kmole} = 1.11\times10^{-5}\ kmoles$$

One k mole of any isotope contains Avogadro's number of atoms, and so 1g of $^{90}_{38}Sr$ contains $1.11\times10^{-5}$ kmole $\times$ $6.025\times10^{26}$ atoms/ k mole = $6.69\times10^{21}$ atoms

Thus the activity of the sample is,

$$R = \lambda N$$
$$= 7.83\times10^{-10}\times6.69\times10^{21}\ s^{-1}$$
$$= 5.23\times10^{12}\ s^{-1}$$
$$= 141\ curies$$

## 20.9 Interaction of Radiation with Matter

### 1. Interaction of $\alpha$ – particles with matter

An $\alpha$ – particle travels a small distance in a medium before coming to rest. This distance is called the range of the particle. As the particle passes through a solid, liquid or gas, it loses energy due to excitation and ionization of atoms and molecules in the matter. The ionization may due to direct elastic collisions or through electrostatic attraction. Ionization is the main interaction with matter to detect the particle or to measure its energy. The range depends on the

**i.** Charge, mass and energy of the particle and

**ii.** The density of the medium and ionization potentials of the atoms of the medium.

Since $\alpha$ – particle is about 7000 times more massive than an electron, so it does not suffer any appreciable deflection from its straight path, provided it does not approach too closely to the nucleus of the atom. Thus $\alpha$ – particle continues producing intense ionization along its straight path till it loses all its energy and comes almost to rest. It, then, captures two electrons from the medium and become a neutral helium atom.

## 2 Interaction of beta -particles with matter

$\beta-$particles also lose energy by producing ionization. However, its ionizing ability is about 100 times less than that of $\alpha-$particles. As a result its range is about 100 times more than $\alpha-$particles. $\beta-$particles are more easily deflected by collisions than heavy $\alpha-$particles. Thus the path of $\beta-$particles in matter is not straight but shows much straggling or scattering. The range of $\beta-$particles is measured by the effective depth of penetration into the medium not by the length of erratic path. If the density of the material is more through which the particle moves, the shorter will be its range. $\alpha$ and $\beta-$particles both radiate energy as X-rays photons when they are slow down by the electric field of the charged particles in a solid material.

## 3 Interaction of gamma rays with matter

Photons of $\gamma-$rays, being uncharged, cause very little ionization. Photons are removed from a beam by either scattering or absorption in the medium. They interact with matter in three distinct ways, depending mainly on their energy.

i. At low energies (less than about 0.5 MeV), the dominant process removes photons from a beam is the photoelectric effect.

ii. At intermediate energies, the dominant process is Compton scattering.

iii. At higher energies (more than 1.02 MeV), the dominant process is pair production.

In air $\gamma-$rays intensity falls off as the inverse square of the distance from the source, in the same manner as light from a lamp. In solids, the intensity decreases exponentially with increasing depth of penetration into the material. The intensity $I_o$ of a beam after passing through a distance X in the medium is reduced to intensity $I$ given by the relation $I = I_0 e^{-\mu x}$, where, $\mu$ is the linear absorption coefficient of the medium. This co –efficient depends on the energy of the photon as well as on the properties of matter.

Charged particles $\alpha$ or $\beta$ and $\gamma$ – radiation produce fluorescence or glow on striking some substance like zinc sulphide, sodium iodide or barium platinocyanide coated screens.

"Fluorescence is the property of absorbing radiant energy of high frequency and reemitting energy of low frequency in the visible region of electromagnetic spectrum".

## 4 Interaction of neutrons with matter

Neutrons, being neutral particles, are extremely penetrating particles. To be stopped or slowed, a neutron must undergo a direct collision with a nucleus or some other particles that has mass comparable to that of neutron Materials such as water or plastic, which contain more low mass nuclei per unit volume are used to stop neutrons. Neutrons produce a little indirect ionization when they interact with materials containing H – atoms and knock out protons.

## 20.10 Radiation Detectors

Various devices have been developed for detecting radiations. They are used for a variety of purposes including medical diagnosis, radioactive dating measurement and the measurement of background radiations.

### Geiger –Muller Counter:

The Geiger –Muller counter (Fig 20.5) is perhaps the most common device used to detect radiations. It can be considered the prototype of all counters that make use of the ionization of a medium as the basic detection process. It consists of a cylindrical metal tube filled with gas at low pressure and a long wire along the axis of the tube. The wire is maintained at a high positive potential (about 1000V) with respect to the tube.

When a high energy particle or photon enters the tube through a thin window at one end, some of the atoms of the gas become ionized. The electrons removed from the atoms are attracted towards the wire, and in the process they ionize other atoms in their path. This results in an avalanche of electrons, which produces a current pulse at the output of the tube. After the pulse is amplified, it can be either used to trigger an electronic counter or delivered to a loudspeaker, which clicks each time a particle enters the detector.

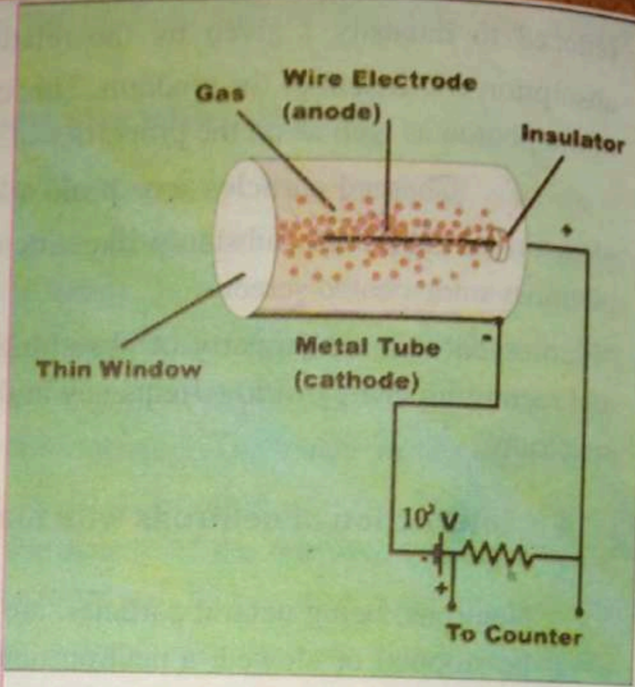

Figure 20.5 :G.M tube

## Solid State Detector:

A solid state detector or semi-conductor diode detector is essentially a reversed –biased P–N junction (Fig 20.6). A P–N junction diode is a device which passes current readily when forward –biased and impedes the flow of current when reversed –biased.

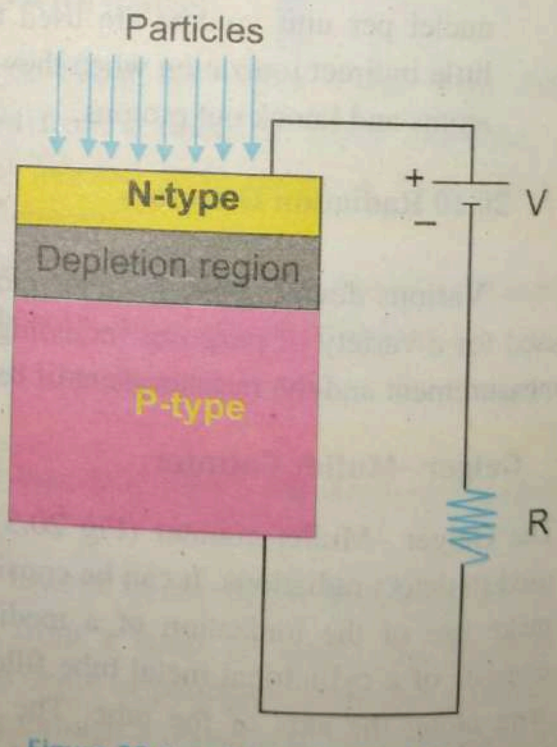

Figure 20.6: solid state detector

As an energetic particle passes through the junction, and electrons holes are simultaneously created. The internal electric field sweeps the electrons towards the side of the junction connected to positive side of the battery and the holes are swept toward the negative side. This creates a pulse of current that can be measured with any electronic counter. In a typical device, the duration of the pulse is about $10^{-7}$ s.

## 20.11 Nuclear Reactions

It is possible to change the structure of nuclei by bombarding them with energetic particles. Such collisions, which change the identity or properties of the target nuclei, are called nuclear reactions.

When a nucleus "*X*" is bombarded with some light particle "*a*", nuclear reaction take place, the product nucleus "*Y*" and a light particle "*b*" will be obtained. This will be represented by the equation.

$$X + a \longrightarrow Y + b$$

Rutherford was the first to observe nuclear reaction in 1919, using naturally occurring radioactive sources for the bombarding particles. He bombarded $\alpha$-particles on nitrogen. He observed that as result of this reaction, oxygen is obtained and a proton is emitted. That is

$$_7N^{14} + _2He^4 \longrightarrow _8O^{17} + _1H^1 + Q \qquad (20.11)$$

The energy equivalent of the difference between the rest masses of elements on the L.H.S and those on the R.H.S is called the nuclear reaction energy and is denoted by "*Q*". Basically, "*Q*" represents the energy absorbed or evolved in any reaction. If "*Q* " is negative, energy is absorbed in the reaction (endothermic reaction) and if "*Q*" is positive, energy is evolved in the reaction (exothermic reaction). If "*Q*" is negative, the energy required to complete the reaction is usually provided by the K.E of the incoming particle unlike the case of chemical reaction, where the energy is usually provided by heating.

## Conservation Laws in a Nuclear Reaction

In any nuclear reaction the following conservation laws must be obeyed. These laws form the guiding principles in determining which isotopes are formed during a nuclear reaction.

### Conservation of atomic and mass number

Before and after any nuclear reaction the number of protons and neutrons must remain the same because protons and neutrons can neither be created nor destroyed using equation (20 .11) , we have

The number of nucleons on the L.H.S. = The number of nucleons on the R.H.S.

Number of protons $= 7+2 = 8+1$

Number of neutrons $= 7+2 = 9+0$

Number of nucleons $= 18 = 18$

### Conservation of mass –energy

The conservation of number of nucleon does not imply the conservation of mass because the mass numbers differ from the atomic masses and the difference provides the binding energy to nucleons in the nucleus. Further, from Einstein's mass –energy relation it is known that the conservation of mass in no more a separate and independent principle but is a part of a more general principle of conservation of energy. Therefore, the principle of conservation of energy in mechanics is extended to the conservation of mass –energy in nuclear reactions. This will also include the energy difference due to changes of mass.

Based on the above conservation laws one can determined the (i) energy absorbed or liberated in any nuclear reaction and (ii) the product nucleus formed etc.

Let us calculate the reaction energy for the reaction given by equation (20.11). The rest mass of various particles on addition is

$${}_2He^4 = 4.00263u \qquad {}_8O^{17} = 16.999133u$$

$${}_7N^{14} = \frac{14.003074u +}{18.005677} \qquad {}_1H^1 = \frac{1.007825u +}{18.006958u}$$

Difference in rest masses before and after the reaction.

$$=18.005677-18.006958$$
$$=-0.001281\,u$$
$$Q=-0.001281\times 931$$
$$Q=-1.192\,MeV$$

Since "$Q$" is negative, the $\alpha$–particle must have K.E 1.192 MeV for this reaction to occur. If the particle has less energy, this transformation will not take place. Usually the $\alpha$–particles, i.e. more than 1.192 MeV, appears, as the K.E of product particles or nuclei.

## 20.12 Nuclear Fission

Knowing the fact that the emission of a $\beta^-$ particle increases the atomic number by one, Fermi and his co–workers (1934) attempted to produce the elements beyond uranium ($Z$=92) which at that time was the last element in the periodic table. They bombarded uranium with neutrons and found that $\beta$–particles with different half –lives were emitted. Therefore, they concluded that the elements with $Z>92$, i.e. the elements heavier than uranium, had been formed.

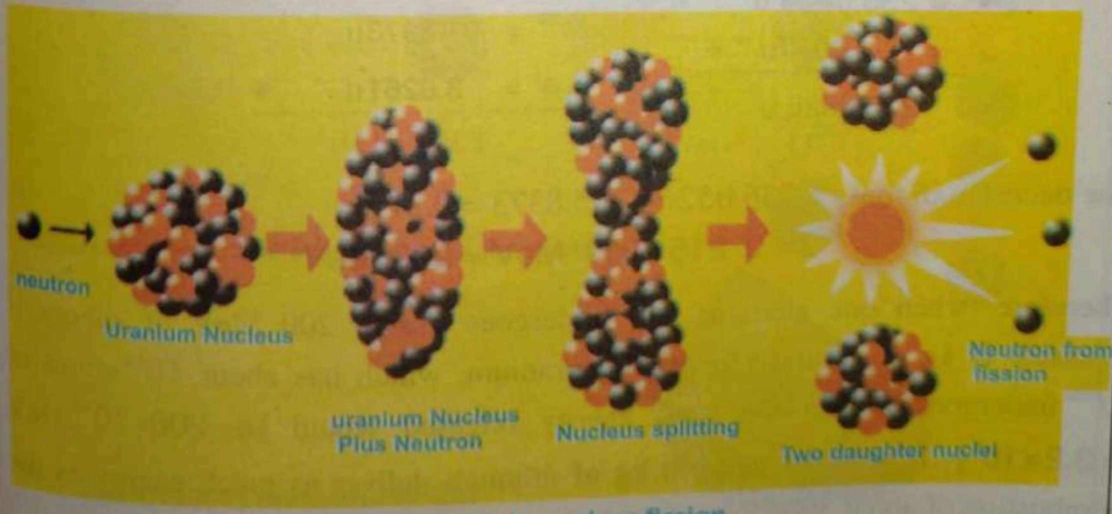


Figure 20.7 (a) : nuclear fission

Hahn and Strassmann made similar experiments in 1939. After the chemical analysis of the products they concluded that one of the product nuclei is barium and not a heavier element as predicted earlier. They concluded that the neutron bombardment can cause a uranium nucleus to break apart, producing two or more fragments of moderate and comparable size. This process was called nuclear fission. Further they found that reaction is much more pronounced with thermal neutron. Only $U^{235}$ undergoes this process of fission – though naturally occurring uranium has 99.3% of $U^{238}$ and 0.7% of $U^{235}$. We shall see that in this process there is a decrease in the mass of the system and hence energy is released. Since this process can be started automatically, it can be controlled and the energy liberated provides a good source of energy.

It was observed that when one thermal neutron strikes a uranium nuclei, three neutrons are emitted. In the reaction observed by Hahn that the product nuclei were ${}_{56}Ba^{141}$ and ${}_{36}Kr^{92}$. Therefore, the reaction can be written as

$${}_0n^1 + {}_{92}U^{235} \rightarrow {}_{92}\overset{*236}{U} \rightarrow {}_{36}Kr^{92} + {}_{56}Ba^{141} + 3{}_0n^1 + Q \qquad \cdots(20.12)$$

Where $Q$, is the energy of reaction which can be calculated from the value of rest masses of different nuclei. The calculation is given below

| Initial masses | Final masses |
|---|---|
| $U^{235} = 235.0439\ u$ | $Ba^{141} = 140.9139\ u$ |
| ${}_0n^1 = 1.0087u$ + | $Kr^{92} = 91.8973u$ |
| | $3{}_0n^1 = 3.0261\ u$ + |
| 236.0526 u | 235.8373 u |

The decrease in mass = 236.0526 – 235.8373 = 0.215 u

$$Q = 0\cdot215 \times 931\ \text{MeV} = 200\ \text{MeV}$$

Therefore, when one atom of $U^{235}$ undergoes fission 200 MeV of energy is released. If 1g of naturally occurring uranium, which has about $10^{19}$ atoms of $U^{235}$ undergoes fission the total energy released would be $200\times10^{19}$ MeV $= 3.2\times10^{8}$ j. It is found that 1.0 kg of uranium deliver as much energy as the combustion of about 3000 tons of coal.

## Fission Chain Reaction

As mentioned before when one uranium atom undergoes fission it releases 3 neutrons. If more than one of these neutrons is able to cause fission in the other $U^{235}$ nuclei, the number of neutrons will increase rapidly. Thus, a chain reaction can be set up (Fig 20.7(b). The fission would produce at an ever –increasing rate and in a very short time the whole of $U^{235}$ would be transformed with the release of a large amount of energy. If such a chain reaction is not controlled, the large energy can cause a violent explosion and destroy every thing that comes in its way.

This is the principle of the atom bomb. Further, if the amount of uranium is too small, the chain reaction can stop before it release the amount of energy required for explosion therefore, if the chain reaction is to start, it is necessary that the mass of uranium must be greater than some minimum mass called the critical mass or critical size.

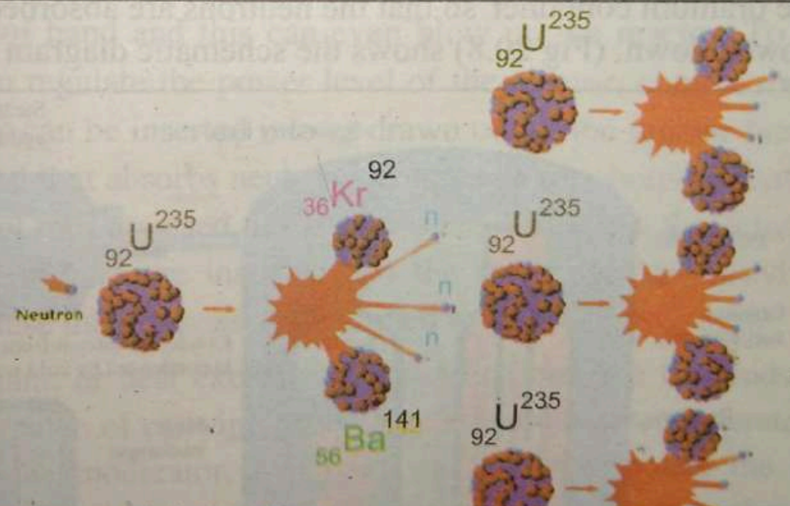


Figure 20.7 (b) : nuclear fission chain reaction

figure20.7( c) uranium ore rock

## 20. 13 Nuclear Reactors

The large amount of energy released in nuclear fission can be used for many useful purposes if the reaction is carried out under controlled conditions. A nuclear reactor is a device in which the fission chain reaction is a controlled one and the energy released can be used for any of the several purposes to produce power, to supply neutrons, to prepare radioisotopes, etc. The first reactor was installed and operated by Fermi and his co-workers in 1942 in the USA. In reactors, small pieces of uranium are spread throughout a material, called moderator, capable of slowing down the neutrons to thermal energies, so that they can cause fission in other nuclei. When a thermal neutron strikes a uranium atom, it starts the fission process which results in the splitting of the uranium atom and the production of more fast neutrons. These fast neutrons strike the materials and lose their K.E in repeated collision with the nuclei of the material and get thermalized. These thermalized neutrons strike another piece of uranium and again cause fission. Thus, a chain reaction is set up. Whenever this chain reaction is to be stopped, some material which is a strong absorber of neutrons is inserted in the uranium container so that the neutrons are absorbed and the rate of reaction is slowed down. (Fig 20.8) shows the schematic diagram of a nuclear reactor.

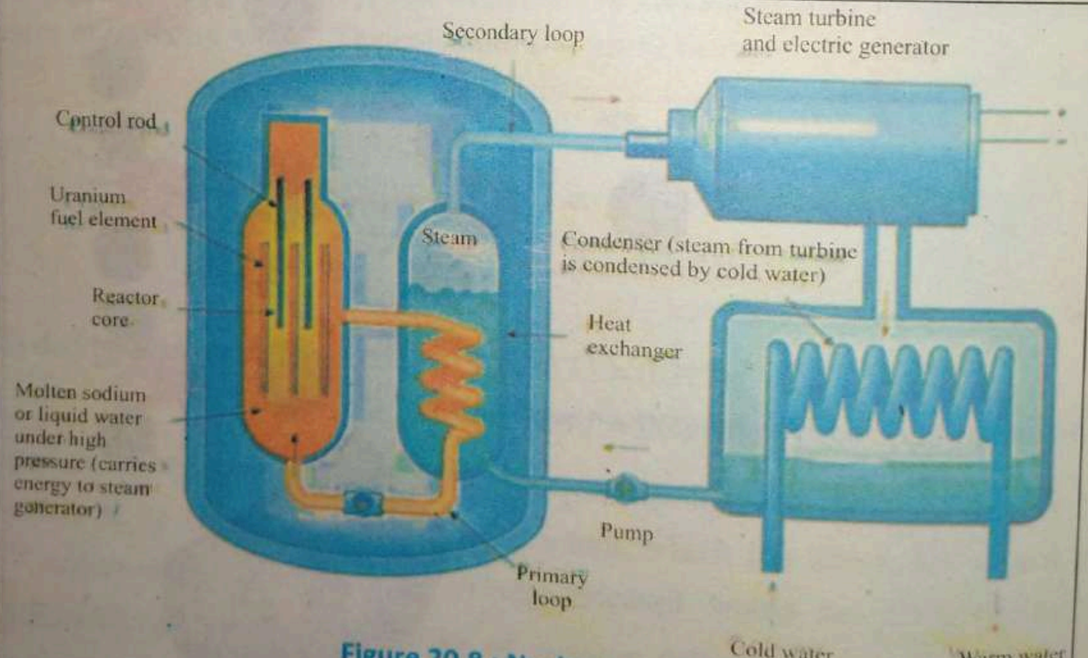


Figure 20.8 : Nuclear reactor

Basically, it consists of five parts (i) a core of nuclear fuel, (ii) a moderator for slowing down neutrons, (iii) control rods, (iv) coolant or heat exchanger for removing heat in the core, and (v) radiation shielding.

Nuclear fuel is a material that can be fissioned by thermal neutrons. It can be either one or all of the following isotopes. $U^{233}, U^{235}$ and $Pu^{239}$. We shall see that when natural uranium is used, plutonium is produced in the nuclear reactor. Usually the fuel is put in different aluminium cans in cylindrical rods placed some distance apart. The fuel cans are separated by the moderator. As mentioned earlier, the moderator is used to slow down the fast neutrons produced in the fission process when thermal neutrons strike the nuclear fuel. The fast neutrons have many collisions with the materials and come out with thermal energies to strike another fuel can. The material of moderator (i) should be light, and (ii) should not absorb neutrons. Usually, graphite and heavy water (water containing deuterium instead of hydrogen) are used as moderators.

Sometimes the chain reaction, once started, can liberate an enormous amount of energy and can go out of hand and this can even blow up the reactor. To avoid such an accident, and to regulate the power level of the reactor, control rods are used. These control rods can be inserted into or drawn out of the reactor fuel core and consists of a material that absorbs neutrons, e. g. cadmium, boron or hafnium usually, cadmium control rods are used. If these rods are drawn out, the activity of neutrons increases and if they are inserted into the fuel core, the activity of neutrons decreases because the neutrons are absorbed by the rods.

The coolant, or heat exchanger, is used to cool the fuel rods and the moderator, and is capable of carrying away large amount of heat generated in the fission process. If the moderator, fuel rods, etc. are not cooled, the heat generated can melt them. The heat carried by the coolant produces steam that can run a turbine, which in turn can run an electric generator as shown in (fig 20.8).

The last part of the nuclear reactor is the shielding. Since the neutrons and the fragments in a reactor undergo radioactive decay and produce radiations which are harmful to life, there must be some shielding device to absorb those radiations. For this purpose a concrete wall which in a few feet thick is used.

## 20.13.1 Types of Reactors

There are two main types of nuclear reactors. These are:

(i) Thermal reactor (ii) Fast reactors.

I. **Thermal reactors** :The thermal reactors are called "thermal" because the neutron must be slowed down to "thermal energies" to produce further fission. They use natural uranium or slightly enriched uranium as fuel. Enriched uranium contains a greater percentage of $U^{235}$ than natural uranium does. There are several designs of thermal reactors. Pressurized water reactor (PWR), are most widely used reactors in the world. In this type of reactor, the water is prevented from boiling, being kept under high pressure. This hot water is used to boil another circuit of water which produces steam for turbine rotation of electricity generators.

ii. **Fast reactor** :Fast reactor are designed to make use of $_{92}U^{238}$ which is about 99% content of natural uranium. Each $_{92}U^{238}$ nucleus absorbed a fast neutron and change into $_{94}P_u^{239}$.

$$_{92}U^{238} + {}_0n^1 \rightarrow {}_{93}N_p^{239} + {}_{-1}\beta^0$$

$$_{93}N_p^{234} \rightarrow {}_{94}P_u^{239} + {}_{-1}\beta^0$$

Plutonium can be fissioned by fast neutrons, hence, moderator is not needed in fast reactors. The core of fast reactors consists of a mixture of plutonium and uranium dioxide. Surrounded by a blanket of $U^{238}$ Neutrons that escape from the core interact with $U^{238}$ in the blanket, producing there by $_{94}P_u^{239}$. Thus more plutonium fuel is bred in this way and natural uranium is used more effectively.

## 20.14 Nuclear Fusion

Figure 20.2 shows that the binding energy for light nuclei (those having a mass number of less than 20) is much smaller than the binding energy for heavier nuclei. This suggests a possible process that is the reverse of fission.

**For your Information**

Experimental research reactor called tokamaks used for fusion.

*When two light nuclei combine to form a heavier nucleus, the process is called nuclear fusion.*

Because the mass of the final nucleus is less than the rest masses of the original nuclei, there is a loss of mass accompanied by a release of energy. It is important to recognize that although fusion power plant have not get been developed, a great world –wide effort is under way to harness the energy from fusion reactions in the laboratory. The basic exothermic reaction in stars, including our own sun – and hence the source of nearly all of the energy in the universe – is the fusion of hydrogen nuclei into helium nucleus. This can take place under stellar conditions in two different series of processes. In one of them, the proton –proton cycle, direct collisions of protons result in the formation of heavier nuclei whose collision in turn yield helium nuclei. The other, the carbon cycle, in a series of steps in which carbon nuclei absorbed a succession of protons until they ultimately disgorge alpha particles to become carbon nuclei once more.

The initial reaction in the proton – proton cycle is

$${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + \overset{+}{e} + \nu$$

Where, $e^+$ is called positron and "ν" is neutrino. A deuteron may then combine with a proton to from a ${}_2He^3$ nucleus:

$${}_1H^1 + {}_1H^2 \longrightarrow {}_2He^3 + \gamma$$

Finally two ${}_2He^3$ nuclei react to produce a ${}_2He^4$ nucleus plus two protons:

$${}_2He^3 + {}_2He^3 \rightarrow {}_2He^4 + {}_1H^1 + {}_1H^1$$

The total energy evolved is $(\Delta m)c^2$, where $\Delta m$ is the difference

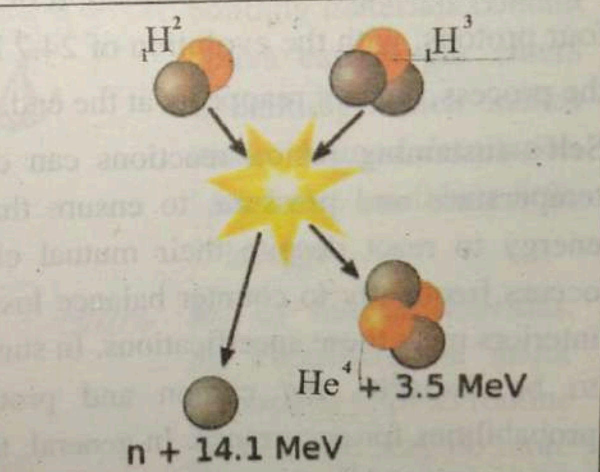

Figure 20.9 (a) : fusion reaction

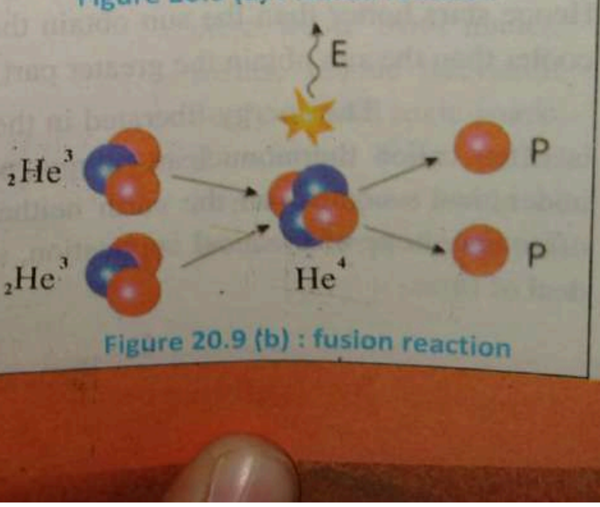

Figure 20.9 (b) : fusion reaction

between the mass of four protons and the mass of an alpha particles plus two positrons; it turn out to be 24.7 MeV.

The carbon cycle proceeds in the following way.

$$_1H^1 +_6 C^{12} \rightarrow_7 N^{13}$$

$$_7N^{13} \rightarrow_6 C^{13} + e^+ + \nu$$

$$_1H^1 + _6C^{13} \longrightarrow _7N^{14} + \gamma$$

$$_1H^1 + _7N^{14} \longrightarrow _8O^{15} + \gamma$$

$$_8O^{15} \longrightarrow _7N^{15} + e^+ + \nu$$

$$_1H^1 + _7N^{15} \longrightarrow _6C^{12} + _2He^4$$

The net result again is the formation of an alpha particle and two positrons from four protons, with the evolution of 24.7 MeV; the initial $_6C^{12}$ acts as a catalyst for the process, since it reappears at the end.

Self –sustaining fusion reactions can occur only under conditions of extreme temperature and pressure, to ensure that the participating nuclei have enough energy to react despite their mutual electrostatic repulsion and that reactions occurs frequently to counter balance losses of energy to the surrounding. Stellar interiors meet these specifications. In sun, whose interior temperature is estimated to be $2\times10^6$K, the carbon and proton –proton cycles have about equal probabilities for occurrence. In general, the carbon cycle is more efficient at high temperature, while the proton –proton cycle is more efficient at low temperature. Hence stars hotter than the sun obtain their energy the former cycle, while those cooler than the sun obtain the greater part of their energy from the latter cycle.

The energy liberated in the fusion of light nuclei into heavier ones is often called thermonuclear energy, particularly when the fusion take place under man's control on the earth neither the proton –proton nor carbon cycle offers any hope of practical application, since their several steps required a great deal of time.

## 20.15 Radiation Exposure

When a Geiger tube is used in any experiment, it records radiation even when a radioactive source is no-where near it. This is caused by radiation called background radiation. It is partly due to cosmic radiation which comes to us from outer space and partly from naturally occurring radioactive substance in the Earth's crust. The cosmic radiation consists of high energy charged particles and electromagnetic radiation. The atmosphere acts as a shield to absorb some of these radiation as well as ultraviolet rays. In recent past, the depletion of ozone layer in upper atmosphere has been detected which particularly filter ultraviolet rays reaching us. This may result in increased eye and skin diseases. The depletion of ozone layer is suspected to be caused due to excessive release of some chemicals in the atmosphere such as chlorofluorocarbons (CFC) used in refrigeration, aerosol spray and plastic foam industry. Its use is now being replaced by environmentally friendly chemicals. Many building materials contain small amounts of radioactive isotopes, (radon) radioactive carbon gas enters buildings from the ground. It gets trapped inside the building which makes radiation levels much higher from radon inside than outside. A good ventilation can reduce radon level inside the building. All types of food also contain a little radioactive substance. The most common are $k^{40}$ and $C^{14}$ isotopes.

Some radiation in environment is added by human activities. Medical practices, mostly diagnostic x –rays probably contribute the major portion to it. It is an unfortunate fact that many x –rays exposures such as routine chest x –rays and dental x –ray are made for no strong reason and may do more harm than good. Even x –rays exposure should have a definite justification that outweighs the risk. The other source include radioactive waste from nuclear facilities, hospital, research and industrial establishments, colour television, luminous watches and to tobacco leaves. A smoker not only inhales toxic smoke but also hazardous radiation. Low level background radiation from natural sources is normally considered to be harmless. However, higher levels of exposure are certainly damaging. We cannot avoid unnecessary exposure to any kind of ionizing radiation.

## 20. 16 Biological Effects of Radiation

Excessive exposure to radiation can cause damage to living tissues, cells, or organism. The degree and kind of damage caused to a particular part of the body depend upon the type, energy and dose of radiation received. There is no lower limit below which radiation damage does not occur. A number of small doses received over long period of time may lead to fatal consequences,

Radiation damage to living organism is primarily due to ionization effects in the cells. The cells is the basic unit of life. Its normal metabolic function may be disrupted as a result of interaction with the ionizing radiation. Excessive radiation does may cause death of individual cells, or produce chromosome abnormalities or genetic mutation.

The biological effects are generally of two types. Somatic and genetic. Somatic effects affect an individual directly.. Skin burns, loss of hair, drop in the white blood cells and induction of cancer are example of somatic effects. The genetic effects may become apparent after a long time. The reason is that radiation can alter chemistry of the genes and may cause mutations. Even very low radiation doses reaching the reproductive organ of the body are potentially dangerous. Genetic effects may be passed on the future generations.

## 20. 17 Biological and Medical uses of Radiation

Although, all the isotopes of an element chemically behaves identically, but every isotopes emits radiation due to which it is easy to identify an isotope. It is this characteristic due to which the isotopes are being used in different fields of our life.

### Biological Use

The chemical changes going on in an animal or a plant are very complex. The tracer method has been applied to study these changes. For example, the process of photosynthesis and the incorporation of carbon atoms in the $CO_2$ into giant and complex protein or carbohydrate molecules have been investigated by tracer techniques. Similarly information concerning the complex process of metabolism is obtained by means of radioisotope tracers. The distribution of various elements, such as hydrogen, sodium, iodine, phosphorous, strontium, irons etc; in the body can be obtained by tracer technique. Genetic mutations are engineered by intense radioactively.

## Radiation Therapy

High energy radiations penetrate deep into the body and can be used for intentional selective destruction of tissues, such as cancerous tumor. Radioisotopes of $Co^{60}$ which emit $\beta$-particle and high -energy $\gamma$-rays is employed for the treatment of various types of cancers some radioisotopes are taken internally where they are selectively absorbed by certain organs and thus concentrate the radiation where it is most needed.

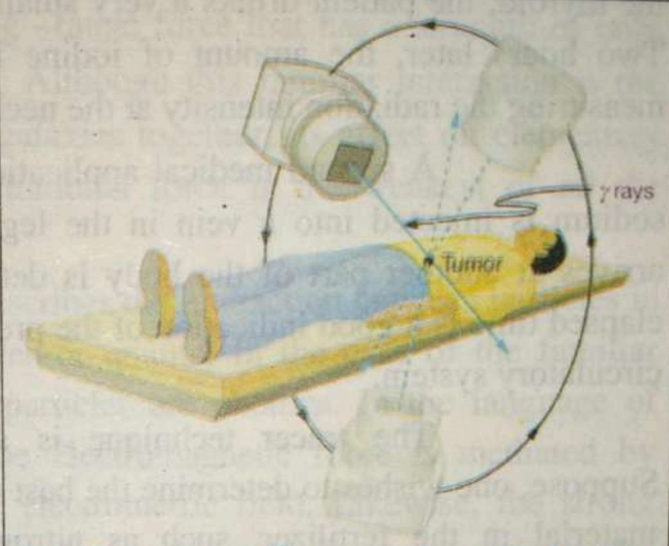

Fig 20. 10 :the $Co^{60}$ source of $\gamma$-radiation is rotated around the patient.

For example, cancerous thyroid is treated with $I^{131}$ radioisotope. Sometimes pellets or capsules of radioisotopes are planted close to the tumor and can be removed after treatment.

## Medical Diagnostics

Hydrogen and sodium atoms are distributed uniformly throughout the body where iodine tends to concentrate in thyroids, phosphorous and strontium in bones and cobalt in liver. They can serve as tracer when injected or other wise given to patients. Radiation detectors may ascertain the passage of tracer through the body and their concentration in diseased tissues. The pattern of distribution of the radioactive tracers in a body can give a clue about normality or abnormality of the specific parts of the body.

## Tracing Techniques

Radioactive particles can be used to trace chemicals participating in various reactions one of the most valuable uses of radioactive tracers is in medicine. For example, $I^{131}$ is an artificially produced isotope of iodine. Iodine, which is a necessary nutrient for our bodies, is obtained largely through the intake of iodized salt and seafood. The thyroid gland plays a major role in the distribution of iodine throughout the body in order to evaluate the performance of the thyroid; the patient drinks a very small amount of radioactive sodium iodide. Two hours later, the amount of iodine in the thyroid gland is determine by measuring the radiation intensity at the neck area.

A second medical application is that a salt containing radioactive sodium is injected into a vein in the leg. The time at which the radioisotope arrives at another part of the body is detected with the radiation counter. The elapsed time is a good indication of the presence or absence of constriction in the circulatory system.

The tracer technique is also useful in agricultural research. Suppose, one wishes to determine the best method of fertilizing a plant. A certain material in the fertilizer, such as nitrogen, can be tagged with one of its radioactive isotopes. The fertilizer is then sprayed on one group of plants, sprinkled on the ground for second group, and raked into soil for a third. A Geiger counter is then used to track the nitrogen through the three types of plants.

## 20 .18 Basic Forces of Nature

The key to understand the properties of elementary particles is to be able to describe the forces between them. All particles in nature are subjected to four fundamental forces. Strong, electromagnetic, weak, and gravitational.

The strong force is very short –ranged and is responsible for the binding of neutrons and protons into nuclei. This force represents the "glue" that hold the nucleons together and is the strongest of all the fundamental forces. The strong force is very short –ranged and is negligible for separation greater than $10^{-14}$m.

The electromagnetic force, which is about $10^{-2}$ times the strength of the strong force, is responsible for the binding of atoms and molecules. It is a long –range force that decreases in strength as the inverse square of the separation between interacting particles.

The weak force is a short –range nuclear force that tends to produce instability in certain nuclei. It is responsible for most radioactive decay processes such as beta decay, and its strength is only about $10^{-9}$ time that of the strong force. Scientists now believe that the weak and electromagnetic forces are two manifestations of a single force called the electro weak force.

Finally, the gravitational force is a long –range force that has a strength of only about $10^{-38}$ times that of strong force. Although this familiar interaction is the force that holds the plants, stars, and galaxies together, its effect on elementary particles is negligible. Thus the gravitational force is the weakest of all the fundamental forces.

In modern physics, one often describes the interaction between particles in terms of the exchange of field particles or quanta. In the case of the familiar electromagnetic interaction, the field particles are photons. In the language of modern physics, one can say that the electromagnetic force is mediated by photons, which are the quanta of the electrometric field. Likewise, the strong force mediated by field particle called gluons, the weak force is mediated by particles called the w and z bosons, and the gravitational force is mediated by quanta of the gravitational field called gravitons.

## 20.19 Building Blocks of Matter

The word "atom" is from Greek word atomos, which mean indivisible. At one time atoms were thought to be the indivisible constituents of matter, that is, they were regarded to be elementary particles. Discoveries in the early part of the $20^{th}$ century revealed that the atom is not elementary, but has as its constituents protons, neutrons and electrons. Up until the 1960s, physicists were bewildered by the large number and variety of elementary particles being discovered. In the last two decades, physicists have made tremendous advance in our knowledge of the structure of matter by recognizing that all particles with the exception of electrons, photons, and a few related particles are made of smaller particles called quarks. Thus, protons and neutrons, for example, are not truly elementary particles but are system of tightly bound quarks.

## Classification of particles

### Hadrons

Particles that interact through the strong force are called hadrons. There are two class of hadrons, known as mesons and baryons. Mesons has mass between the mass of the electron and the mass of proton. All mesons are known to be decay finally into electrons, positrons, neutrinos, and photons. The pion is the lightest of known mesons.

Baryons, which are the second class of hadrons, have mass equal to or greater than proton mass. Protons and neutrons are included in the baryon family, as are many other particles with the exception of the proton all baryons decay in such a way that the end products include a proton.

### Leptons

Leptons are a group of particles that participate in the weak interaction. Include in this group are electrons, muons, and neutrinos, which are all less massive than the lightest hadron. Since lepton has no internal structure, they appear to be truly elementary particles scientists believe that there are only six leptons.

### Quarks

According to quark theory initiated by M. Gell – Mann and G. Zweig, the quarks are proposed as the basic building blocks of the mesons and baryons. The quark model is based on the following assumptions.

1. There are six different types of quark, the up quark, the down quark, the strange quark, the charmed quark, the bottom quark and the top quark referred to as u, d, s, c, b and t.
2. For every type of quark, there is a corresponding antiquark.
3. Quarks combine in threes to form particles like the protons and the neutrons. Antiquarks also combine in threes to form antiparticles like the antiproton and the antineutron.
4. A meson consists of a quark and an antiquark.

In term of the charge of the electron, the *u*, *c* and *t* quarks each carry a charge of $+\frac{2}{3}e$ and the other three quarks carry a charge of $-\frac{1}{3}e$. An antiquark carries an equal and opposite charge to its corresponding quark. The symbol for antiquark is the same as for a quark but with a bar over the top. For example, $\bar{d}$ represents the symbol for a down antiquark.

Thus

- A proton is composed of two up quarks and a down quark.
- A neutron consists of an up quark and two down quarks, as shown in fig 20.11.

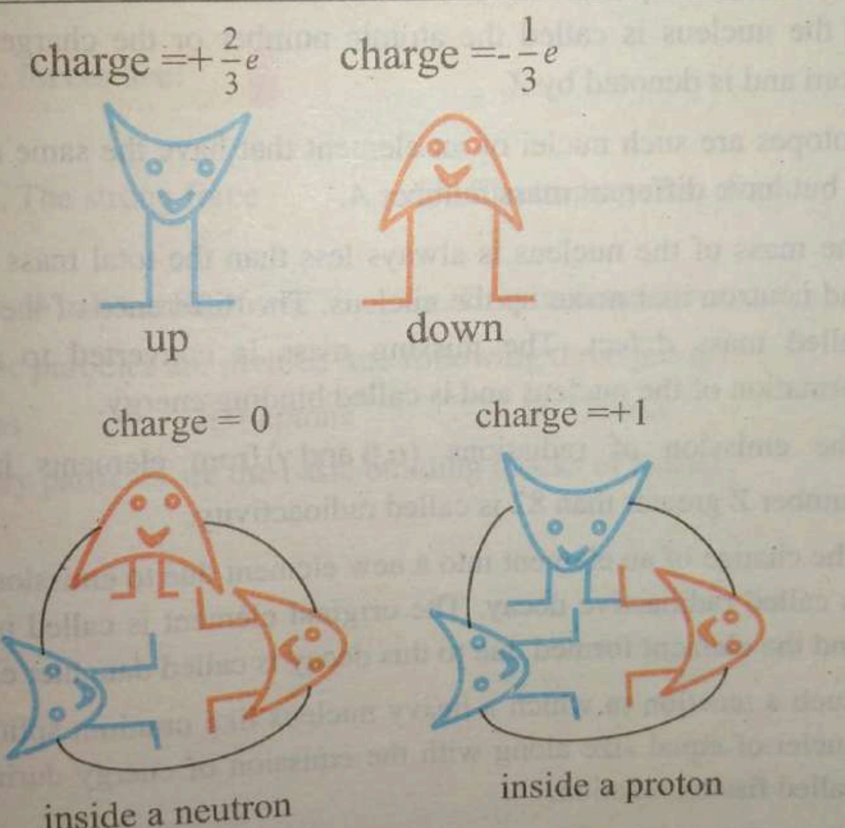


Figure 20.11: up and down quarks illustration

## Key points

- The combined number of all the protons and neutrons is known as mass number and is denoted by $A$.
- The protons and neutrons present in the nucleus are called nucleons.
- The number of neutrons present in a nucleus is called its neutrons number and is denoted by $N$.
- The number of protons inside a nucleus or the number of electrons outside of the nucleus is called the atomic number or the charge number of an atom and is denoted by $Z$.
- Isotopes are such nuclei of an element that have the same charge number $Z$, but have different mass number $A$.
- The mass of the nucleus is always less than the total mass of the protons and neutron that make up the nucleus. The difference of the two masses is called mass defect. The missing mass is converted to energy in the formation of the nucleus and is called binding energy.
- The emission of radiations $(\alpha, \beta \text{ and } \gamma)$ from elements having charge number $Z$ greater than 82 is called radioactivity.
- The change of an element into a new element due to emission of radiations is called radioactive decay. The original element is called parent element and the element formed due to this decay is called daughter element.
- Such a reaction in which a heavy nucleus like uranium splits up into two nuclei of equal size along with the emission of energy during reaction is called fission reaction.
- Half –life of a radioactive element is that period in which half of the atoms of the parent element decay into daughter element.
- Such a nuclear reaction in which two light nuclei merge to form a heavy nucleus along with the emission of energy is called fusion reaction.

- The strength of the radiation source is indicated by its activity measured in Becquerel. One Becquerel (Bq) is one disintegration per second. A larger unit is curie (ci) which equals $3.7\times10^{10}$ disintegration per second.
- The effect of radiation on a body absorbing it relates to a quantity called absorbed dose D defined as the energy E absorbed from ionizing radiation per unit mass m of the absorbing body.
- **The basic forces are:**

  i. The strong force  ii. Electromagnetic force

  iii. Weak nuclear force  iv. Gravitational force.
- Subatomic particles are divided into following three groups:

  i. Hadrons  ii. Leptons  iii. Quarks

  elementary particles are the basic building blocks of matter.

# Exercise ?

## Multiple choice questions:

Each of the following questions is followed by four answers. Select the correct answer in each case.

1. The binding energy for nucleus A is 7.7 MeV and that for nucleus B is 7.8 MeV. Which nucleus has the larger mass?

   a. Nucleus A b. Nucleus B

   c. Less than nucleus A d. None of these

2. How many neutrons are there in the nuclide $Zn^{66}$ ?

   a. 22 b. 30

   c. 36 d. 66

3. Mass equivalent of 931 MeV energy is

   a. $6.02\times10^{-23}$kg b. $1.766\times10^{-27}$kg

   c. $2.67\times10^{-27}$kg d. $6.02\times10^{-27}$kg

4. The energy equivalent of 1 kg of matter is about.

   a. $10^{-15}$ J b. 1 J c. $10^{-12}$ J d. $10^{17}$ J

5. The radioactive nuclide ${}_{86}Ra^{228}$ decays by a series of emissions of three alpha particles and one beta particle. The nuclide $X$ finally formed is.

   a. ${}_{84}^{220}X$ b. ${}_{86}^{222}X$

   c. ${}_{83}^{216}X$ d. ${}_{88}^{215}X$

6. A radioactive substance has a half life of four months. 3 –fourth of the substance will decay in.

a. 6 months b. 8 months

c. 12 months d. 16 months

7. Gamma radiations are emitted due to.

a. De-excitation of atom b. De–excitation of nucleus

c. Excitation of atom d. Excitation of nucleus

8. Unit of decay constant $\lambda$ is,

a. ms b. $m^{-1}$

c. m d. $s^{-1}$

9. Which of the following basic forces is able to provide an attraction between two neutrons.

a. Electrostatic and nuclear b. Electrostatic and gravitational

c. Gravitational and strong nuclear d. Only nuclear force

10. Bottom quark carries charge.

a. $\frac{2}{3}e$ b. $\frac{-2}{3}e$

c. $\frac{+1}{3}e$ d. $\frac{-1}{3}e$

## Conceptual Questions

1. Why does the alpha particle not make physical contact with nucleus, when an alpha particle in headed directly toward the nucleus of an atom.
2. Why do heavier elements require more neutrons in order to maintain stability?
3. An alpha particle has twice the charge of a beta particle. Why does the former defl[illegible] than the later when passing between electrically charged [illegible] they both have the same speed.

4. Element X has several isotopes. What do these isotopes have in common? How do they differ?
5. How many protons are there in the nucleus $_{86}Rn^{222}$ ? How many neutrons? How many electrons are there in the neutral atom?
6. $Ra^{226}$ has half –life of 1600 years.
   a. What fraction remains after 4800 years?
   b. How many half –lives does it have in 9600 years?
7. Radium has a half –life of about 1600 years. If the universe was formed five billion or more year ago, why is there any radium left now?
8. Nuclear power plants use nuclear fission reactions to generate steam to run steam –turbine generator. How does the nuclear reaction produce heat?
9. What factors make a fusion reaction difficult to achieve?
10. Discuss the similarities and differences between fission and fusion.
11. In what ways is time constant *CR* similar to and different from (a) radioactive decay constant, $\lambda$ (b) radioactive half-life?
12. What happen to atomic number of a nucleus that emits γ-rays photons?
13. What happen to its mass?
14. Explain why neutron activated nuclides tend to decay by $\beta^-$ rather than $\beta^+$.
15. Why are large nuclei unstable?
16. What happen to the atomic number and mass number of a nucleus that (a) emits an electron? (b) undergoes electron capture? (c) emits an α-particle?
17. How many α-decay occur in the decay of thorium $_{90}Th^{298}$ into $_{82}Pb^{212}$ ?
18. What is colour force?

## Comprehensive Questions:

1. What is meant by natural radioactivity? How are the natural radioactive radiations classified into three types?
2. Explain the principle, construction, working and necessary mathematical theory of a mass spectrometer.

3. What are isotopes? Explain with examples.
4. Explain the term mass defect and binding energy related to a nucleus.
5. Define and explain the half –life of a radioactive element?
6. Define and explain nuclear reactions.
7. Write a comprehensive note on nuclear fission.
8. What is a nuclear reactor? Give the principle, construction, working and uses of a typical nuclear reactor.
9. What is meant by nuclear fusion? Discuss how can energy be released in the fusion process? Illustrate with examples.
10. What is a radiation detector? Explain the principle and working of GM counter and solid state detector.
11. Discuss the technique and use of radio isotopes in the different fields of human activities.
12. Write a comprehensive note on hadrons, leptons and quarks.
13. What are harmful effects of radiations? What measures can be adopted to safeguard us from the nuclear hazards.
14. Explain tracer technique in agricultural research.
15. Name the four fundamental interaction and the particles that mediate each interaction.
16. Discuss the differences between hadrons and leptons.

## Numerical Problems:

1. Find the mass defect and binding energy for helium nucleus?

[0.03038 a·m·u, 28.3 Mev]

2. A certain radioactive isotope has half life of 8 hours. A solution containing 500 million atoms of this isotope is prepared. How many atoms of this isotope have not disintegrated after

a. 8 hours b. 24 hours [250 million, 62.5 million]

3. Write the nuclear equations for the beta decay of

(a) $_{82}Pb^{210}$ b. $_{83}Bi^{210}$ c. $_{90}Th^{234}$ d. $_{93}N_p^{239}$

4. Calculate the total energy released if 1 kg of $U^{235}$ undergoes fission? Taking the disintegration energy per event to be $Q = 208\ MeV$.

$[5.32 \times 10^{26}\ MeV]$

5. Find the energy released in the following fission reaction.

$$_0n^1 + _{92}U^{235} \rightarrow _{36}Kr^{92} + _{56}Ba^{141} + 3_0n^1 + Q$$

[174 MeV]

6. Find the energy released in the fusion reaction. $_1H^2 + _1H^3 \rightarrow _2He^4 + _0n^1$

[17.6 MeV]

7. Complete the following nuclear reactions.

$$_7N^{14} + _2He^4 \rightarrow _1H^1 + ?$$

$$_5B^{11} + _1H^1 \rightarrow _6C^{11} + ?$$

$$_3Li^6 + ? \rightarrow _4Be^7 + _0n^1 \quad (_8O^{17}, _0n^1, _1H^2)$$

8. $_3Li^6$ is bombarded by deutrons. The reaction gives two $\alpha$-particles along with release of energy equal to 22. 3 MeV. Knowing masses of deuteron and $\alpha$-particles determine mass of lithium isotope of $_3Li^6$.

[6.017U]

9. Find the energy released when $\beta$-decay changes $_{90}Th^{234}$ into $_{91}Pa^{234}$. Mass of $_{90}Th^{234}$ = 234. 0436u and $_{91}Pa^{234}$ = 234.042762u.

[0.279 MeV]

10. Find out the K.E to which a proton must be accelerated to induce the following nuclear reaction. $Li^7(p,n)Be^7$.

[1.67 MeV]

3. Write the nuclear equations for the beta decay of

(a) ${}_{82}^{210}Pb$ b. ${}_{83}^{210}Bi$ c. ${}_{90}^{234}Th$ d. ${}_{93}^{239}N_p$

4. Calculate the total energy released if 1 kg of $U^{235}$ undergoes fission? Taking the disintegration energy per event to be $Q = 208\text{ MeV}$.

[$5.32\times10^{26}$ MeV]

5. Find the energy released in the following fission reaction.

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

[174 MeV]

6. Find the energy released in the fusion reaction. ${}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}He^{4} + {}_{0}^{1}n$

[17.6 MeV]

7. Complete the following nuclear reactions.

$${}_{7}^{14}N + {}_{2}He^{4} \rightarrow {}_{1}H^{1} + ?$$

$${}_{5}^{11}B + {}_{1}H^{1} \rightarrow {}_{6}^{11}C + ?$$

$${}_{3}^{6}Li + ? \rightarrow {}_{4}^{7}Be + {}_{0}^{1}n \quad ({}_{8}O^{17}, {}_{0}n^{1}, {}_{1}H^{2})$$

8. ${}_{3}^{6}Li$ is bombarded by deutrons. The reaction gives two $\alpha$-particles along with release of energy equal to 22. 3 MeV. Knowing masses of deuteron and $\alpha$-particles determine mass of lithium isotope of ${}_{3}^{6}Li$.

[6.017U]

9. Find the energy released when $\beta$-decay changes ${}_{90}^{234}Th$ into ${}_{91}^{234}Pa$. Mass of ${}_{90}^{234}Th = 234.0436\text{u}$ and ${}_{91}^{234}Pa = 234.042762\text{u}$.

[0.279 MeV]

10. Find out the K.E to which a proton must be accelerated to induce the following nuclear reaction. $Li^{7}(p,n)Be^{7}$.

[1.67 MeV]

## Glossary

**Atria:** The **heart** is divided into four chambers that are connected by heart **valves**. The upper two heart chambers are called atria.
**Alternating Current:** Voltage forces electrons to flow in one direction and then quickly alternate to the opposite direction.
**Ammeter** A device to measure amperes (current).
**Ampere** Unit of current.
**Alternator**: A device that changes mechanical energy into an alternating current electrical energy, an AC generator.
**Cerebrospinal fluid (CSF)**: a clear colorless bodily fluid found in the brain and spine.
**Conductor** A material that permits a very free exchange/movement of electrons from one atom to another.
**Conventional Flow** This theory states that electrons flow from positive (+) to negative (-).
**Current** The flow of electrons in the same direction from atom to atom.
**Direct Current** Voltage forces the electrons to flow continuously in one direction.
**Dysfunction:** abnormality in the function of an organ or part.
**Dynamoelectric machine**: A dynamo or generator
**Disgorge**: taken out from the throat what has been eaten.
**Dynamo:** From the Greek word dynamis, which means power
**Dynamoelectric**: Relating to the conversion by induction of mechanical energy into electrical energy or vice versa
**Extra-terrestrial sources**
Sources that are existing or originating outside the limits of the earth.
**Electromagnets** Do not retain their magnetism after a magnetizing force is removed.
**Electromagnetic Induction:** The creation of voltage in a conductor from movement of the conductor or the magnetic field.
**Electron Flow:** This theory states that electrons flow from negative (-) to positive (+).
**Frequency** The number of cycles in one second of alternating current. Expressed in hertz (Hz). For example, 60 Hz is 60 cycles in one second.
**Generator**: A device that changes mechanical energy into electrical energy. Although the terms AC and DC generator are in common usage, a generator is normally considered to be a device that provides DC current.
**Insulators** Materials that don't readily give up electrons, thereby restricting the flow of current.
**Peak inverse voltage (PIV)**
The maximum voltage $V_m$ the diode can withstand during the negative half cycle (reverse bias) is known as peak inverse voltage (PIV).
**Myelin:**(Life Sciences & Allied Applications / Anatomy) a white tissue forming an insulating sheath (**myelin sheath**) around certain nerve fibres. Damage to the myelin sheath causes neurological disease, as in multiple sclerosis.
**Motor**:From the Latin word motus, one that imparts motion, prime mover. A device that changes electrical energy into mechanical energy.

**Muon**
A negatively charged subatomic particle, with the same charge as an electron. It is about 200 times as massive as an electron.
**Ohm** Unit of resistance.
**Ohm's Law** Current is directly proportional to voltage and inversely proportional to resistance.
**Out of step**: out of step mean that the two waveforms are not synchronized.
**Parallel Circuits** Loads are connected across the power line to form branches.
**Permanent Magnets:** Retain their magnetism after a magnetizing force is removed.
**Resistance** The restriction to the flow of electrons.
**Right-Hand Rule** A current carrying conductor held in right hand will indicate the direction of lines of flux. **ELECTRICITY**
**RMS Value:** Root Mean Square Current is also referred to as effective current and is the square root of the average of all the instantaneous currents (current at any point on a sine wave) squared.
**Series Circuit** All loads in the circuit are connected one after the other.
**Single-Phase:** A continuous single alternating current cycle.
**Spectrum** : spectrum means set of freqtuencies absorbed or emitted by a substance.
**Terrestrial sources**
Sources that are existing or originating inside the limits of the earth.
**Three-Phase** A continuous series of three overlapping AC cycles offset by 120 degrees.
**Transformer** A device used to raise (step up) or lower (step down) a voltage level.
**Ventricle** - a chamber of the heart that receives blood from an atrium and pumps it to the arteries. Or the heart is divided into four chambers that are connected by heart valves. The lower two chambers of the heart are called ventricles.
**Volt** Unit of force applied to a conductor to free electrons, to cause electrical current flow.
**Voltage** The force applied to a conductor to free electrons, causing electrical current to flow.
**Voltage Drop** Voltage value as measured across each resistor or load.
**Voltmeter** A device to measure voltage.
**Waveform:** The shape of the curve obtained by plotting the instantaneous values of voltage or current as ordinate against time as abscissa is called its waveform or wave shape.
**Watt** The basic unit of power, indicating the amount of work accomplished when one volt causes one ampere to pass through a circuit.

## References


1. A Textbook of Electrical Technology By R K Rajput
2. University Physics With Modern Physics, 12/E By Hugh D. Young
3. The Pearson Guide to Objective Physics for Medical Entrance By Dudeja Ravi Raj http://books.google.com.pk/books?id=KOHkl-C9mQ8C&pg=PA248&lpg=PA248&dq=Eddy+current+is+produced+when++(a)%09a+metal+is+kept+in+varying+magnetic+field+%09+(b)%09a+metal+is+kept+in+steady+magnetic+field++(c)%09a+circular+coil+is+placed+in+a+steady+magnetic+field++(d)%09a+current+is+passed+through+a+circular+coil.&source=bl&ots=IR-7lGqvxf&sig=6GPd_uhhgBLsH-

y7mq8dJZaVMNE&hl=en&sa=X&ei=AxDAUanuLMPRtAa95IG4DA&ved=0CCgQ6AEwAA#v=onepage&q=Eddy%20current%20is%20produced%20when%20%20(a)%09a%20metal%20is%20kept%20in%20varying%20magnetic%20field%20%09%20(b)%09a%20metal%20is%20kept%20in%20steady%20magnetic%20field%20%20(c)%09a%20circular%20coil%20is%20r'aced%20in%20a%20steady%20magnetic%20field%20%20(d)%09a%20current%20is%20passed%20through%20a%20circular%20coil.&f=false

4. Electricity and magnetism By Josef F Becker
5. All New Electronics Self Teaching Guide (Self- learning guid) by Harry Kybett
6. Electrical and Electronic Principles and Technology by John Bird BSc (Hons) Starting Electronics
7. by Keith Brindley
8. Fundamental Electrical and Electronic Principles by C R Robertson
9. General Physics (calculus based) Class Notes Dr. Rakesh Kapoor
10. Objective Electrical Technology By V. K. Mehta, Rohit Mehta
11. Principles of Physics By P.V. Naik
12. Textbook of engineering physics (electric dipole) By Mehta
13. **http://books.google.com.pk/books?id=D4nrQDzq1jkC&pg=PA291&lpg=PA291&dq=explain-magnets+are+often+fitted+to+the+doors+of+refrigerators+and+cupboards&source=bl&ots=sI95nc8B8a&sig=-2s5NcpqZDYjw-VxnTuTyqNsdt0&hl=en&sa=X&ei=GhMSUsrTAYqK4ASilYHQAQ&ved=0CEEQ6AEwAw#v=onepage&q=explain%20that%20magnets%20are%20often%20fitted%20to%20the%20doors%20of%20refrigerators%20and%20cupboards&f=false**
14. Physics for class 12 by Dr. Tahir Hussain
15. Physics for class 12 by Dr. Muhammad ali khattak
16. Physics for class 12 by Bajaj
17. Physics principles and problems by murphy and Smoot
18. College physics by Fredrick J. Bueche and Eugene Hecat
19. College physics by Mcg raw Hill
20. College physics by Serway and Faughan
21. Applied physics by Beiser
22. Physics for class 12 by Punjab textbook board Lahore
23. Physics by Rowell and Herbert
24. Physics by Resnick Haliday, and Krane
25. Nelson physics by Alan storen and Ray Martin
26. Applied physics by Sears, Zeeman Sky and Young
27. Textbook of engineering physics By M.N. avadhanulu and P.G. Kshirsagar
28. Basics of Electrical Engineering By S Sharma
29. College physics by William and flora
30. Physics Handbook by Bryan mark
31. Grob'S Basic Electronics 10E By Schultz https://www.boundless.com/physics/induction-circuits-and-electrical-technologies/ac-circuits/inductance/
32. https://www.4everproxy.com/secure.php?u=g8nqVL2Gy5IGM6iodEgaNOIstGJ0RyXt%2FWY%3D&b=5

33.
http://www.physics.byu.edu/faculty/rees/220/book/Lesson12.pdf
34.
http://physics.ucsd.edu/neurophysics/courses/physics_1b/SerwayCP7_Ch21.pdf
35.
http://ebook.electronicdesign.com/Impedance-Matching/
36.
http://electronicdesign.com/communications/back-basics-impedance-matching-part-1
37.
http://www.nobelprize.org/educational/medicine/ecg/ecg-readmore.html
38.
39. Physics Now! Peter D Riley
40. Cambridge! GCSE Physics Malcolm Bradley & C. Sunley
41. Science Foundation Physics Bryam Milner
42. Physics Matters Nick England
43. Co-Ordinated Science Physics (Oxford)Stephen Pople
44. IGCSE Physics Tom Duncan & Heater Kennett
45. Science & Technology physics 9th Lakhmir Singh & Manjit Kaur
46. Core C.B.S.E Science & Technology Physics 9th V.K. Sally Dr. R. Goel
47. G.C.S.E Physics K. Foulds
48. Physics Expression N- Level Low Kia Keat
49. Check Point Physics Peter D. Riley
50. Science Scope Physics Brian Arnold
51. Coordinated Science Physics Mary Jones, Geoff Jones Phillip Marchington
52. 1st step to Physics Semin Agdin
53. Physics (O-Level) Charles Chaw, Leong See Cherg Chow Siew Foong
54. http://www.sfsciencecenter.org/sites/all/themes/bluemasters/pdf/heart.pdf

# LIST OF PRACTICAL FOR CLASS 12

## Standard experiments

1. Determine time constant by charging and discharging a capacitor through a resistor.
2. Determine resistance of wire by slide Wire Bridge.
3. Determine resistance of voltmeter by drawing graph between R and I/V.
4. Determine resistance of voltmeter by discharging a capacitor through it.
5. Analyse the variation of resistance of thermistor with temperature.
6. Determine internal resistance of a cell using potentiometer.
7. Determine emf of a cell using potentiometer.
8. Determine the emf and internal resistance of a cell by plotting V against I graph.
9. Investigate the relationship between current passing through a tungsten filament lamp and the potential applied across it.
10. Convert a galvanometer into voltmeter of range 0 – 3 V.
11. Determine the relation between current and capacitance when different capacitors are used in AC circuit using different series and parallel combinations of capacitors.

12. Determine the impedance of a RL circuit at 50Hz and hence find inductance.
13. Determine the impedance of a RC circuit at 50Hz and hence find capacitance.
14. Determine Young's modulus of the material of a given wire using Searle's apparatus.
15. Draw characteristics of semiconductor diode and calculate forward and reverse current resistances.
16. Study the half and full wave rectification by semiconductor diodes by displaying on CRO
17. Study of the variation of electric current with intensity of light using a photocell.
18. Determine Planck's constant using internal potential barrier of different light emitting diodes.
19. Observe the line spectrum of mercury with diffraction grating and spectrometer to determine the wavelength of several different lines, and hence, draw a conclusion about the width of visible spectrum.
20. Using a set of at least 100 dice, simulate the radioactive decay of nuclei and measure the simulated half life of the nuclei.
21. Draw the characteristics curve of a Geiger Muller tube.
22. Determine the amount of background radiation in your surrounding and identify their possible sources.
23. Set up a G.M. point tube and show the detection of alpha particles with the help of CRO and determine the count rate using scaler unit.

**Note:**

1. At least 20 standard practical alongwith exercises are required to be performed during the course of studies of class 12.
2. Use of centimetre graph paper be made compulsory.

Some Important Values

Charge of electron is **1.6022 x $10^{-19}$ Coulomb.**
**Mass of electron:** Mass of electron is **0.000548597 a.m.u.** or **9.1 x $10^{-31}$ kg.**
**Symbol of electron:** Electron is represented by **"e".**

Charge of proton is **1.6022 x $10^{-19}$ coulomb.**
**Mass of proton:** Mass of proton is **1.0072766 a.m.u.** or **1.6726 x $10^{-27}$ kg.**
**Comparative mass**: Proton is **1837** times heavier than an electron.

**Mass of neutron:** . Mass of neutron is **1.0086654 a.m.u.** or **1.6749 x $10^{-27}$ kg.**
**Compartive mass:** Neutron is **1842** times heavier than an electron.

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مومن تو آپس میں بھائی بھائی ہیں۔
پس اپنے دو بھائیوں میں صلح کرادیا کرو
اور اللہ سے ڈرتے رہو تاکہ تم پر رحم
کیا جائے۔

(سورۃ الحجرات:۱۰)

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کھاؤ جو ہم نے تم کو دی ہیں۔

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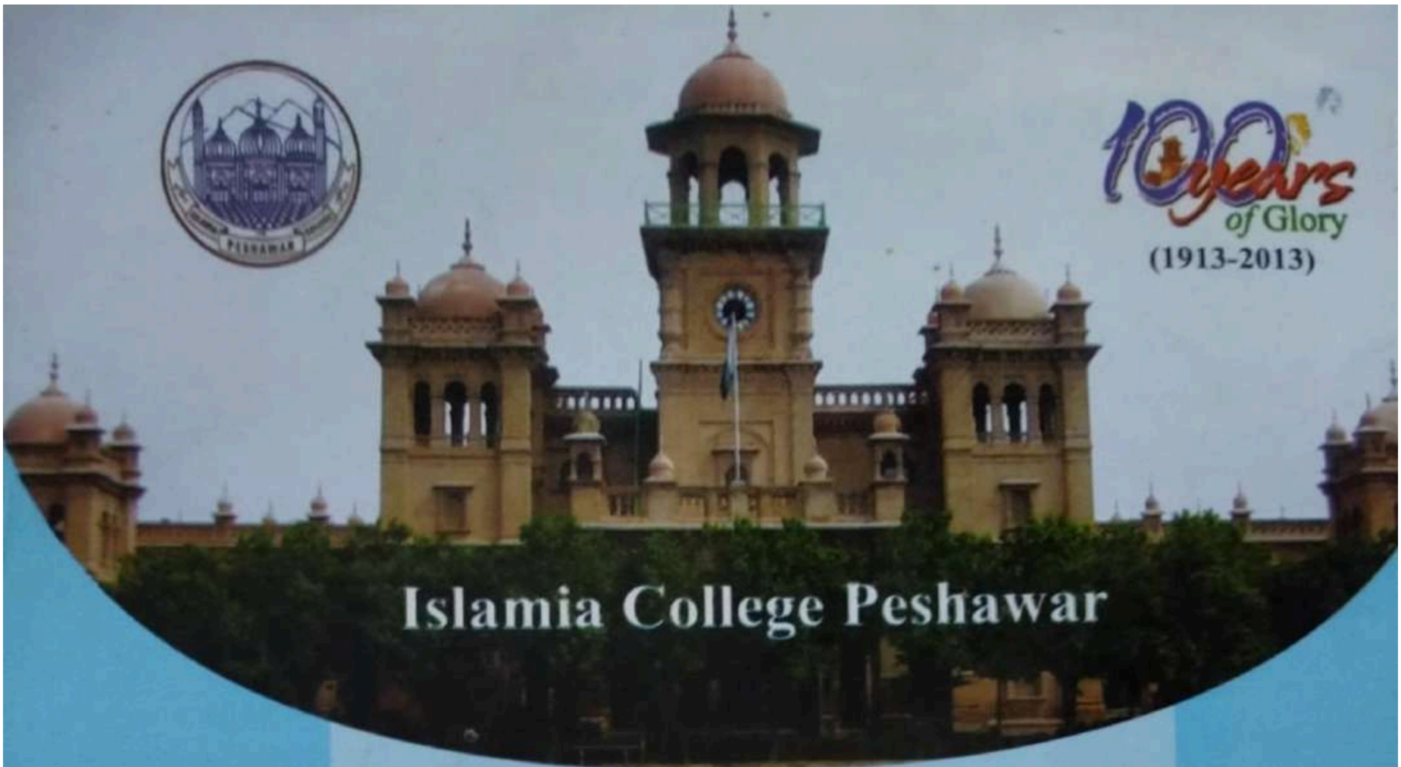


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