12. NUCLEAR PHYSICS

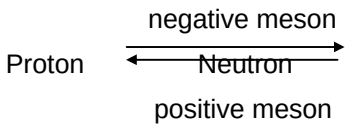
Synopsis:

1. **Composition of the nucleus :** Central part of the atom is called nucleus. It was first discovered by **Rutherford.**
2. The nucleus is spherical in shape and has a diameter of the order of 10^{-14} m.
3. The atomic nucleus is composed of elementary particles called protons and neutrons.
4. Protons has positive charge whose magnitude is equal to the charge of an electron but heavier than electron.
5. The neutron is electrically neutral and has a mass slightly greater than that of a proton.
6. Protons and neutrons are the building blocks of nucleus and are collectively called nucleons.
7. The number of protons in the nucleus is equal to the atomic number denoted by "Z". The number of neutrons is denoted by "N". The total number of neutrons and protons (nucleons) in the nucleus is called mass number (A) of the atom or nucleus i.e., A=Z+N.
8. A nucleus is symbolically represented by ${}_{Z}X^{A}$ in which X is the chemical symbol of the element. Eg. ${}_{7}N^{14}$ represents the nitrogen nucleus which contain 14 nucleons (7 protons and 7 neutrons)
9. Nuclides with same number of protons but different numbers of neutrons i.e. same atomic number Z, different neutron number N and different mass number A, are called isotopes.
10. Isotopes occupy same position in the periodic table and hence, they possess identical chemical properties and possess different nuclear properties.
11. ${}_{1}^{1}H$, ${}_{1}^{2}H$, ${}_{1}^{3}H$ are the isotopes of hydrogen atom.
12. ${}_{8}^{16}O$, ${}_{8}^{17}O$, ${}_{8}^{18}O$ are the isotopes of oxygen atom.
13. Nuclides with same number of neutrons N, but with different atomic number Z, and different mass number A are called isotones.
    ${}_{7}^{17}N$, ${}_{8}^{18}O$, ${}_{9}^{19}F$ are isotones.
14. Nuclides with same total number of nucleons A but differ in atomic number Z and also differ in neutron number N are called isobars.
    ${}_{6}^{14}C$, ${}_{7}^{14}N$ are isobars.
15. Nuclides having equal mass number A and atomic number Z but differing from one another in their nuclear energy states are called isomers.
16. ${}_{38}^{87}Sr^{m}$ is an isomer of ${}_{38}^{87}Sr^{g}$, where m denotes metastable state and g denotes ground state.
17. Nuclides having the same mass number A but with number of protons and neutrons interchanged are known as mirror nuclei ${}_{4}^{7}Be$ and ${}_{3}^{7}Li$.
18. **Nuclear size :** The distance of closest approach of α-particle to the nucleus was taken as a measure of nuclear radius which is approximately 10^{-15} m. The volume of the nucleus v is proportional to its mass number. If R is the radius of the nucleus then $R=R_0A^{1/3}$.
    where R_0 is constant its value is 1.1×10^{-15} m.
19. Nuclear distances are measured in units of fermi and 1 fermi=10^{-15} m.
20. The density of the nucleus is independent of mass number i.e. the density of nuclei of all atoms is same and is equal to 2.97×10^{17} kg m^{-3}.
21. The density of the nucleus is maximum at the centre and fall to zero, as we move rapidly outwards.

22. The nucleus does not have sharp boundaries.
23. The effective value of the radius of the nucleus is taken as the distance between its centre to the point where the density falls to half of its value at the centre.
24. **a.m.u :** The magnitude of the masses of the building blocks of an atom is expressed in atomic mass unit. It is defined as one twelfth of the mass of the carbon-12 atom.

    1 a.m.u=1.66054021x10^{-27} kg

    The energy equivalent of 1 amu=931.54 MeV.
25. Nuclear Force : It is the force of attraction between a proton and proton, proton and neutron and between a neutron and another neutron. It is a strong force. The relative strengths of gravitational, Coulomb's and nuclear forces among the nucleons are in the ratio $F_g:F_c:F_n=1:10^{36}:10^{38}$.
26. **Yukawa theory :** According to Yukawa, a new particle the meson which could have a positive or negative charge or may be neutral is exchanged between the nucleons, and the corresponding exchanging force is responsible for the binding of nucleons. Nuclear force is produced by a meson field. The rest mass of π charged mesons is about 273 times that of an electron. The exchange is represented as follows:

    Similarly, to explain the binding force between a neutron and another neutron, the existence of a neutral meson was proposed.

    Pion or pi-meson (Yukawa particle) is responsible for the origin of nuclear forces. It has mean life time of 10^{-8} second.

    Nuclear forces are charge independent i.e., $n - p \approx p - p \approx n - n$.

    Nuclear forces are saturated forces i.e., a nucleon in the nucleus interacts only with its neighbours.

    Nuclear forces are strongly attractive and have short range upto 0.5×10^{-15} m.
27. **Properties of nuclear forces :**
    a) Nuclear forces are attractive forces between proton and neutron (p-n), proton and proton (p-p) and neutron and neutron (n-n).
    b) Nuclear forces are charge independent. It was found that nuclear force between two protons is the same as that between a proton and a neutron or between two neutrons.
    c) Nuclear forces are the strongest in nature.
    d) Nuclear forces are short range forces. Short range means, they are applicable with in the distances of the order of 10^{-15} m. At greater distances these forces are negligible.
    e) Nuclear forces are spin dependent. Forces between nucleons are strong when spins are parallel and weak when spins are anti-parallel.
    f) Nuclear forces are non-central forces which implies that they do not act along the line joining the two nucleons.
    g) Nuclear forces are saturated forces. It means that each nucleon attracts only those nucleons which are its immediate neighbours. It does not interact with all the nucleons.
    h) Nuclear forces are exchanged forces. The nuclear forces between the two nucleons is the result of the exchange of π mesons (π^0, π^+, π^-) between them.

28. **Mass defect and binding energy of a nucleus :**

a) The actual mass of a nucleus is always found to be less than the sum of the masses of the nucleons present in it. The mass difference is known as the "mass defect" and is denoted by Δ m.

b) $\Delta m = \left[Zm_p + (A-Z)m_n\right] - M$ where m_p and m_n are the masses of proton and neutron respectively and M is the actual mass of the nucleus.

c) The mass defect per nucleon of the nucleus is defined as "Packing fraction".

Packing fraction= $\frac{\text{mass defect}}{\text{Mass number}} = \frac{\Delta m}{A}$

d) Binding energy : The energy equivalent of the mass defect is the binding energy of the nucleus. Binding energy is also defined as the minimum energy required to split the nucleus into its constituent nucleons.

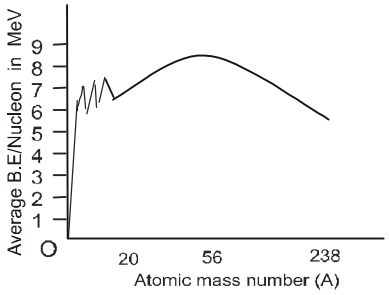
e) The ratio of binding energy of nucleus and the total number of nucleons in the nucleus is called the binding energy per nucleon. It is also called as "binding fraction" or average binding energy or specific binding energy.

Binding fraction= $\frac{\text{Binding energy of the nucleus}}{A}$

Binding energy of the nucleus= Δ m x 931.5 MeV

The graph of binding energy per nucleon as a function of mass number is shown in the figure.

The conclusions from the binding fraction verses mass number curve are



a) nuclei of the intermediate mass are most stable,

b) heavier nuclei and lighter nuclei are less stable,

c) a large amount of energy can be liberated if heavier nuclei can be split into lighter nuclei. (this is what happens when $_{92}U^{235}$ undergoes fission).

d) a large amount of energy can be liberated if lighter nuclei can be made to fuse to form heavier nuclei (this is what happens when hydrogen nuclei combine to form heavier nucleus $_2He^4$ in nuclear fusion).

29. **Natural Radioactivity :**

a) The nuclei of certain elements disintegrate spontaneously by emitting alpha (α), beta (β) and gamma (γ) rays. This phenomenon is called natural radioactivity

b) Natural radioactivity is displayed by heavy nuclei, beyond lead in the periodic table. There are also naturally radioactive light nuclei, such as potassium isotoper $^{40}_{19}K$, the carbon isotope $^{14}_{6}C$ and the rubidium isotope $^{87}_{37}Rb$.

i) **Alpha Radiation:**

a) When a nucleus disintegrates and radiates α-rays it is said to undergo α-decay.

b) When a nucleus emits an alpha particle its atomic number Z decreases by two units and its mass number A decreases by four units.

c) Both electric charge and nucleon number are conserved in the process of -decay.

d) The general form of -decay can be written as

$${}^{A}_{Z}P \rightarrow {}^{A-4}_{Z-2}D + {}^{4}_{2}He$$

Ex-1: $${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

e) A beam of -particles can be deflected by an electric field as well as magnetic field.

f) The speed of α -particles is of the order of 10^6 m/s.

g) α -particle produce intense ionisation of the medium through which they pass.

g) α -particles can penetrate small distances in matter and can be stopped after travelling a few mm in air. Due to large mass, the penetrating power of α -particles is lower than both β -rays and γ -rays.

i) α - particle produces scintillations when they strike fluorescent materials such as zinc sulphide.

j) α -particles affect photographic plate.

ii) Beta Radiation:

a) When a nucleus disintegrates and radiates -rays it is said to undergo β -decay.

b) β - particles are nothing but electrons. Hence when a nucleus emits a β particle, the atomic number of the nucleus increase by one unit, but the mass number does not change.

c) The general form of β -decay can be writen as ${}^{A}_{Z}P \rightarrow {}^{A}_{Z+1}D + {}^{0}_{-1}e$.

Ex : $${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$$

d) β - particles are deflected by electric as well as magnetic fields.

e) The speed of α -particle is of the order of 1/10th of the speed of light.

f) β -particles ionize the medium throguh which they pass. The ionising power is 1/100th of α -particles.

g) β -particles penetrate through matter. They travel a few centimeters in air. The penetrating power of β -particles is greater than that of α -rays but less than that of α -rays.

h) β -rays affect photographic plate.

iii) Gamma Radiation:

a) When a nucleus disintegrates and releases α -rays it is said to undergo γ -decay.

b) The emission of γ -rays from the nucleus does not alter either atomic number Z or mass number A.

c) The wavelengths of -rays is less than $1A^0$.

d) γ -rays are not deflected either by electric or magnetic fields because they do not posses any charge.

e) γ -rays travel with the speed of light.

f) The ionising power of the -radiations is small when ocmpared to α and β rays.

g) The penetrating power of -rays is the largest when comparted to α and β rays.

h) γ -rays also produce scintillations when they strike fluorescent material.

i) γ -rays affect photographic plates more than α and β particles.

30. **The radioactive decay law:**

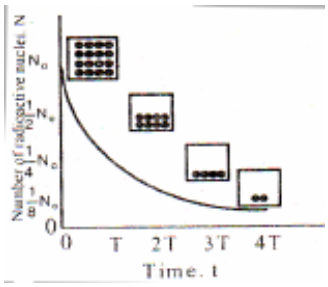
a) The radioactive decay is a random process such that the rate of disintegration is proportional to the number of nuclei (N) available for disintegration.

$$\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N$$

Where λ is decay constant

On solving $N = N_0 e^{-\lambda t}$

Where N_0 is the initial number of atoms.



This shows that the number of atoms of radioactive element decreases exponentially with time.

b) The number of disintegrations per second is called the activity of a radio active sample.

$$A = \lambda N = \lambda N_0 e^{-lt} = A_0 e^{-\lambda t}$$

c) $A = \lambda N \Rightarrow A = \frac{0.693}{t_{1/2}} N$

$$A = \frac{0.693}{t_{1/2}} \left(\frac{\text{Weight in grams}}{\text{mass number (A)}} \right) 0.693 \times 10^{23}$$

$$\therefore A \propto \frac{N}{t_{1/2}}$$

d) **The unit of activity :**

a) Units of activity are Curie and Rutherford.

b) 1 Curie = 3.7×10^{10} disintegrations/sec

c) 1 Rutherford = 10^6 disintegrations/sec

d) 1 Becqueral = 1 disintegration per sec

e) The activity of 1gm of material is defined as specific activity.

f) The decay constant of the end product of a radioactive series is infinity.

e) **Halflife ($t_{1/2}$)** : The time taken by the number of atoms to decrease from N_0 to N is

$$t = \frac{1}{\lambda} \log_c \frac{N_0}{N} \Rightarrow t = \frac{2.303}{\lambda} \log_{10} \frac{N_0}{N}$$

The half life ($t_{1/2}$) of a radio active nuclei is the time taken by the radio active element to disinatearate to half the initial number of atoms.

$$t_{1/2} = \frac{2.303}{\lambda} \log_{10} (2) \Rightarrow t_{1/2} \frac{0.693}{\lambda}$$

After n half lives (i.e. $t = nt_{1/2}$)

$$\frac{N}{N_0} = \left(\frac{1}{2} \right)$$

f) $\left({}^{238}_{92}U \right)$ has a half -life of 4.47×10^9 years and $\left({}^{89}_{36}Kr \right)$ has a half-life of 3.16 minutes.

g) Mean life (τ) : - The mean life (or) average life of a radioactive substance is equal to the average time for which the nuclei of atoms of the radio active subsance exist.

h) The mean life of an atom of a radioactive nuclide is equal to the inverse of its decay constnat.

$$\tau = \frac{1}{\lambda}$$

$$\rightarrow \tau = 1.44\ t_{1/2}, \rightarrow t_{1/2} = 0.693\tau$$

i) Time required for disintegration of 75% (or) 3/4 of the radio active element is $2t_{1/2}$.

similarly

$t_{7/8}$ (or) $t_{87.5\%} = 3\ t_{1/2}$

$t_{15/16}$ (or) $t_{93.75\%} = 4\ t_{1/2}$

$$t_{90\%} = \frac{10}{3} t_{1/2}$$

$$t_{99\%} = \frac{20}{3} t_{1/2}$$

$$t_{99.9\%} = 10 t_{1/2}$$

$$t_{29.3\%} = \frac{1}{2} t_{1/2}$$

31. **Forces in the nucleus:**

There are four types of forces present in the nucleus.

a) Coulomb force b) Nuclear force

c) Tensor force d) Hard core repulsive force

A. Coulomb force:

1) It is the electrostatic force of repulsion between a proton and another proton.
2) These forces are responsible for instability of the nucleus.
3) As atomic number increases coulomb force increases and stability of the nucleus decreases.

Eg: $^{12}_{6}C$ is stable $^{235}_{92}U$ is unstable

B. Nuclear force:

1) The stability of nucleus is due to nuclear force.
2) The ratio of relative strengths of the gravitational, electrical and nuclear forces is $1:10^{36}:10^{38}$.

C. Tensor force

1) All nucleons have spin. So they behave as magnetic dipoles. There exists a force between two dipoles. This foce is called Tensor force.
2) Tensor force arises due to the rotation of nuclear dipoles.
3) It is an attractive force.
4) It prevails up to a distance 3 fm.

D. Hard core repulsive force:

1) If the distance between two nucleons becomes less than 0.5 fm there exists a force core repulsive forces.
2) They are strong repulsive force.
3) These forces keep the volume and density of the nucleus constant.

32. **Properties of nuclear forces :**

a) Nuclear forces are attractive forces between proton and neutron (p-n), proton and proton (p-p) and neutron and neutron (n-n).

b) Nuclear forces are charge independent. It was found that nuclear force between two protons is the same as that between a proton and a neutron or between two neutrons.

c) Nuclear forces are the strongest in nature.

d) Nuclear forces are short range forces. Short range means, they are applicable with in the distances of the order of 10^{-15} m. At greater distances these forces are negligible.

e) Nuclear forces are spin dependent. Forces between nucleons are strong when spins are parallel and weak when spins are anti-parallel.

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h) Nuclear forces are exchanged forces. The nuclear forces between the two nucleons is the result of the exchange of mesons (between them.

33. ARTIFICIAL TRANSMUTATION OF ELEMENTS

1. The conversion of one element into another by artificial means is called artificial means is called artificial transmutation of the element.

   Ex: ${}_7N^{14}_{(\text{stable})} + {}_2He^4 \rightarrow {}_8O^{17}_{(\text{stable})} + {}_1H^1_{(\text{proton})}$

2. It was discovered by Rutherford.
3. Artificial transmutation of elements was possible for elements with atomic number less than 20.

34. ARTIFICIAL RADIOACTIVITY OR INDUCED RADIOACTIVITY.

1. The phenomenon of converting a stable atom into a radio active atom by bombarding it with fast moving particles is called artificial or induced radioactivity.
2. It was discovered by Irene curie and Jolliot curie.
3. For example radioactive phosphorous is produced by bombarding aluminium with alpha particles from polonium.

   ${}_{13}Al^{27}_{(\text{stable})} + {}_2He^4 \rightarrow {}_{15}P^{30}_{(\text{unstable})} + {}_0n^1_{(\text{neutron})}$

   Radiophosphorous is unstable and disintegrates producing a stable atom of silicon with a emission of position $\left({}_{+1}e^0\right)$.

   ${}_{15}P^{30} \rightarrow {}_{14}Si^{30} + {}_{+1}e^0$

35. Discovery of neutron :

1. The existence of neutron was first predicted by Rutherford and it was discovered by Chadwick.
2. Bethe and Becker bombarded α-particles on ${}_4Be^9$ (or Berryllium) and obtained penetrating radiations which do not have any charge. They thought it to be as γ-rays.
3. α-particles of energy 5 MeV emitted from polonium were used on Be target.
4. The first predicted reaction ${}^9_4Be + {}^4_2He \rightarrow \left[{}^{13}_6C\right] \rightarrow {}^{12}_6C + \gamma$.
5. Mr. Joliot and Madam Curie passed these radiations through a hydrogenous material such as paraffin, water, paper etc., and found energy discrepancy.
6. The energy of the same radiation was found to be having different values when incident on different hydrogenous substances. This led to the controversies about the energy of the γ-photon.
7. Chadwick solved the problem by identifying the radiations as streams of neutrons-neutral particles of mass almost equal to that of proton.

   ${}^9_4Be + {}^4_2He \rightarrow [{}^{13}_6C] \rightarrow {}^{12}_6C + {}_0n^1$.

36. Properties of Neutron:

1. Neutron is an uncharged particle and hence the electric and magnetic fields have no effect on it.
2. Being neutral particle, it possess very high penetrating power and has very low ionizing power.
3. It is stable inside the nucleus and unstable outside the nucleus. Its half-life period is 12 minutes and its average life is 1000 seconds.

   ${}^1_0n \rightarrow {}^1_1H + {}^0_{-1}e + \bar{\nu}$,

where $\bar{\nu}$ is called antineutrino.

4. The speed of the neutrons can be slowed down by passing them through heavy water, paraffin wax, graphite etc.
5. Slow neutrons (0.025 eV) are also known as thermal neutrons and they are efficient in causing nuclear reactions.

37. Artificial transmutation of elements :

a) When a nitrogen nucleus hit by an α-particle, disintegrates into oxygen nucleus and a proton ${}_1H^1$.

$${}_7N^{14} + {}_2He^4 \rightarrow {}_8O^{17} + {}_1H^1$$

This process of producing a new stable nucleus from other stable nucleus is called **artificial transmutation** of elements.

b) Artificial transmutation of elements is possible if atomic number of the element is less than 20.

c) When lighter atoms are bombarded with α-particles, atoms get radio active nature.

$${}_{13}Al^{27} + {}_2He^4 \rightarrow {}_{15}P^{30} + {}_0n^1$$

The half life period of the radioactive ${}_{15}P^{30}$ is 3.25 m and it decays in silicon and positron

$${}_{15}P^{30} \rightarrow {}_{14}Si^{30} + {}_{+1}e^0$$

d) Radio isotopes are not available in nature and produced by artificial means in nuclear reactors.

38. Nuclear Fission:

1. The process of splitting up of the nucleus of a heavy atom into two nuclei more or less of equal fragments when bombarded with neutron simultaneously releasing a large amount of energy is called nuclear fission.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow ({}^{236}_{92}U) \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + Q\ .$$

2. Where Q is energy released which is about 200 MeV.
3. This phenomenon was first observed by Strassmann and Hann. It was explained by Neils Bohr and J.A. Wheeler on the basis of liquid drop model of the nucleus. According to liquid drop model, the nucleus behaves like a liquid drop and owing to surface tension it tries to be perfectly spherical in shape. When a neutron is absorbed by the nucleus, a compound nucleus is formed and some excitation energy is imparted to the nucleus. This excitation energy tries to deform the nucleus where as the surface tension of the nucleus tries to keep the nucleus in spherical shape. Due to the struggle between the surface tension and the excitation energy, strong oscillations are set up inside the compound nucleus. These oscillations will distort the shape of the compound nucleus from spherical to ellipsoid.
4. If the excitation energy is sufficiently large, the ellipsoidal nucleus may attain the dumb bell shape. In this case the effect of nuclear attractive force is decreased because of the much increased surface area of the nucleus. Further the coulombic repulsive force drives the two portions of the dumb bell still farther and the nucleus undergoes fission, liberating two nuclei Ba and Kr and neutrons. These newly liberated neutrons are called prompt neutrons. In this process the products are not always the same, their atomic number varies from 34 to 58. Hence the number of prompt neutrons will also change with the mass number of the products. The products, emitted neutrons finally become stable. These occur within few seconds after the fission reaction. These are called delayed neutrons. They play an important role in controlling the nuclear chain reaction in a nuclear reactor.

29. **Chain Reaction :** A chain reaction is a self propagating process in which a number of neutrons multiply rapidly during fission till the whole fissionable material is disintegrated.
30. Neutron multiplication factor K and conditions required for sustained chain reaction :

In the fission of uranium nuclei, on an average 2.5 neutrons are emitted per fission. The neutrons produced in a fission event are fast neutrons and are referred to as “neutrons of first generation”. There is

certain probability for some neutrons to escape without participating in further fission process. Therefore all emitted neutrons are not available for further fissions. The basic conditions for self sustained chain reaction is that at least one neutron should be available. The requirements are given below.

a) Fast neutrons should be changed into slow neutrons by passing through moderators.

b) At least one thermal neutron should be available to initiate the fission reaction.

c) The state of the chain reaction depends on the neutron multiplication factor 'K' which is defined as

$$K = \frac{\text{number of neutrons in present generation}}{\text{number of neutrons in the previous generation}}$$

when K<1, the number of neutrons in successive generations decreases and the chain reaction cannot continue. This state is called 'sub-critical state'.

If K=1, the chain reaction will proceed at a steady rate and this state is called 'critical state'.

If K>1, the number of neutrons increases and the reaction is said to be 'supercritical'.

31. **Critical mass :** If the mass of uranium is too small, the neutron may escape without participating further fission. To start the fission reaction mass of material should be more than the critical mass or critical size.

32. **Principal and working of a nuclear reactor :**

The device giving large amount of nuclear energy through fission process at a controlled rate is called a nuclear reactor or atomic pile. The first nuclear reactor was put into operation in Chicago (USA) in 1942 by Fermi. In the nuclear reactor the first fission reaction results in the production of fast neutrons. If fast moving neutrons are allowed to pass through moderator they become thermal neutrons. Subsequently these thermal neutrons are utilized for further fission reactions to produce a large amount of energy.

33. **Essential features of a nuclear reactor :**

i) **Nuclear Fuel:** The fissionable material used in the reactor is called nuclear fuel.

ii) The uranium isotopes $_{92}U^{235}$ and $_{92}U^{238}$, plutonium $_{94}Pu^{236}$ and thorium $_{90}Th^{232}$ are commonly used as fuels in the reactors. The rods of these fuels are tightly sealed in aluminium cylinders.

iii) **Moderators :** The purpose of the moderator is to slow down the fast moving neutrons produced as a result of nuclear fission. Some of the suitable materials used as moderators are heavy water, beryllium, carbon in the form of pure graphite, hydrocarbon plastics etc.

iv) **Control rods :** These are the materials used in the nuclear reactors that can absorb the neutrons and control the nuclear chain reaction. Cadmium or boron rods are generally used for this purpose. When the control rods are completely inserted into the carbon blocks, they absorb neutrons to such an extent that the chain reaction completely comes to halt.

v) **Safety rods:** These are used to reduce the neutrons rate to less than one abruptly to stop the chain reaction whenever required.

vi) **Protective Shielding :** To prevent the spreading of the radioactive effect to the space around the nuclear reactor, lead blocks, concrete walls of thickness 10 m are used.

vii) **Coolant :** The material used to absorb the heat generated in the reactor is called coolant. Commonly used coolants are light water, heavy water and sodium gas.

The coolant releases the heat energy to water and is thus converted into steam, which is used to run the turbines. These turbines in turn generate the power.

34. **Radio-isotopes (Uses):**

i) Radio-isotopes are produced in nuclear reactor.

ii) Isotopes are used to test wear and tear of engine parts like piston rings, gears, ball bearings and helps in deciding the efficiency of lubricants.

iii) Radio-iodine ($_{53}I^{131}$) has half life of 8 days is used in determining functioning of thyroid gland, information about the size and location of brain tumour.

iv) Restriction in blood circulation can be detected using radio sodium.

v) Leukemia disease is treated by radiation from radio-isotopes of phosphorus.

vi) To find the age of ancient objects found in excavations, manuscripts etc., the technique of radio-carbon dating is used.

vii) Radio-isotopes are used to test the metal castings and weldings.

35. **Radiation hazards:**

i) Damage to the intestinal mucosa, impairment of the production of the blood corpuscles, damage to the system of producing antibodies which are important in the defence against infections, damage to the lens of the eye, production of cancers including leukemia etc.

ii) The radiation damage to human beings is due to (i) intake of radioactive materials and (ii) exposure to radiation.

iii) Radio-iodine is extremely dangerous as it is concentrated in the thyroid gland, a very sensitive organ.

iv) Irradiation of the body with small dose of γ -rays or X-rays increases the body temperature.

v) Radiation causes genetic mutation.

vi) Radon inhaled is injurious to lungs.

vii) Because of small penetrating power of α -radiation into our bodies, its damage is the least. The main external hazard is posed by γ -rays and neutrons.

viii) To prevent radiation hazards, rules have been worked out by International Commission of Radiation Protection (ICRP).

ix) Tolerance doses which are permissible for individuals when exposed professionally.

36. Nuclear Fusion:

1. The process of the formation of a single stable nucleus by fusing two or more lighter nuclei is called nuclear fusion.
   $_1^2H + {}_1^2H \rightarrow {}_2^4He + 24\,MeV$.
2. If the energy released per nucleon in fusion is considered, then it is much higher in a fusion reaction than in the fission reaction, which is almost 7 times.
3. To carry out the fusion of two nuclei temperature nearly equal to 10^7 K is required. Once the fusion takes place the energy released can maintain the minimum required temperature for further and the fusion continues. Nuclear fusion reaction is also termed as thermo nuclear reaction. The secret behind the production of energy of the sun and the stars is nothing but the thermo nuclear reactions (Nuclear fusion).
4. Hydrogen bomb is based on the principle of nuclear fusion.

37. Energy of the Sun and the Stars:

Scientists proposed two types of cyclic processes for sources of energy in the sun and stars. The first one is known as carbon-nitrogen cycle and the second one is proton-proton cycle.

1. Carbon-Nitrogen Cycle: Bethe (1938) proposed a set of reactions taking place in the central part of the sun and stars in which carbon and nitrogen act as catalysts.

$$_1^1H + {}_6^{12}C \rightarrow {}_7^{13}N + Q_1$$

$$_7^{13}N \rightarrow {}_6^{13}C + {}_1^0e$$

$$_1^1H + {}_6^{13}C \rightarrow {}_7^{14}N + Q_2$$

$$_1^1H + {}_7^{14}N \rightarrow {}_8^{15}O + Q_3$$

$^{15}_{8}O \rightarrow {}^{15}_{7}N + {}^{0}_{1}e + Q_4$

$^{1}_{1}H + {}^{15}_{7}N \rightarrow {}^{12}_{6}C + {}^{4}_{2}He$

All the above reactions are added to give the following net nuclear reaction.

$4^{1}_{1}H \rightarrow {}^{4}_{2}He + 2^{0}_{1}e + Q$

The above set of six reactions is called carbon-nitrogen cycle. In this process the four protons are fused to form 2 positrons and helium nuclei releasing 26.72 MeV of energy.

2. Proton-Proton Cycle : Recent experiments show that the carbon-nitrogen cycle comes at a rather late stage in the life of the stars. Scientists proposed another nuclear fusion cycle process which takes place comparatively at low temperatures than carbon-nitrogen cycle and gives the same amount of energy as shown below.

$^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + {}^{0}_{1}e + Q_1$

$^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + Q_2$

$^{1}_{1}H + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + {}^{0}_{1}e + Q_3$

on adding $4^{1}_{1}H \rightarrow {}^{4}_{2}He + 2^{0}_{1}e + Q$

Energy released in this cycle is 24.6 MeV.

1. At the interior of sun, the temperature is of the order of $2x10^6$ K at which both of the above mentioned processes are equally probable. Stars having temperature more than that of sun obtain their energy from carbon-nitrogen cycle and the stars at low temperature follow proton-proton cycle in energy emission.
2. Positron is the anti-particle of electron and was first discovered by Anderson, although theoretically its existence was predicted by Dirac.

38. Pair production :

A γ-ray can disintigrate in to positron and an electron.

$\gamma \rightarrow e^+ + e^-$

The minimum energy of γ-ray to produce pair is 1.02 MeV.

39. Pair annihilation : An electron and positron have the same mass and spin. However, they have the opposite charge. They annihilate each other, with the emission of 2 photons, when they come into contact. This is represented by the equation.

$e^- + e^+ = 2\gamma$

The two photons move in opposite direction.

40. ELEMENTARY PARTICLES :

Fundamental particles are building blocks of matter.

Initially the fundamental particles are classified based on their rest mass energy into four groups.

i) **Baryons** (Bary → Heavy) : They are particles with rest mass energy greater than 938 MeV (rest mass energy of proton). Eg. Proton, neutron

ii) **Mesons** (Meso → medium) : They are particles with rest mass energy lies between 130 MeV to 500 MeV. Eg. π-mesons

iii) **Leptons** (Lepto → light) : They are particles with rest mass energy lying between 130 MeV to 0 MeV. Eg. Electron, neutrino.

iv) **Photon** : The photon is a quantum of electromagnetic radiation with zero rest mass and spin of 1 unit. The photon is its own antiparticles.

41. Antiparticle : It was found that for every elementary particle, there exists an associated antiparticle. These anti-particles are designated by the same symbol as that elementary particle, but with a bar over

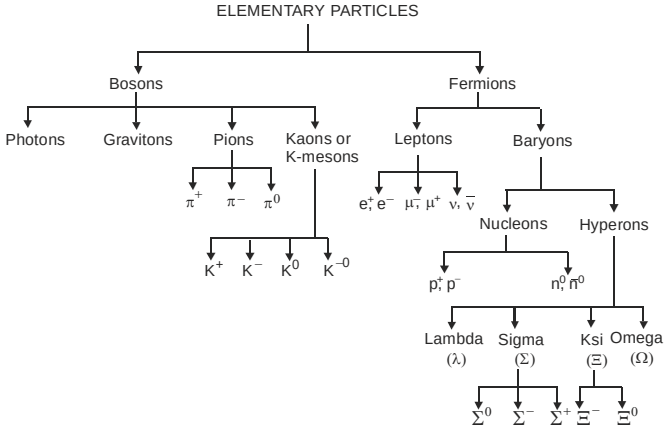
it. Antiparticle have the same mass and spin as that of the particle but with opposite electromagnetic properties such as charge and magnetic moment.

42. Classification of elementary particles based on spin:

1. Elementary particles are broadly classified into two categories viz., 1) Bosons and 2) Fermions depending upon their spin values. The most important difference between these two classes of particles is that the total number of bosons is not conserved whereas total number of fermions is conserved in the universe.

2. **Bosons** : Bosons are the particles with intrinsic angular momentum equal to an integral multiple of $h/2\pi$ and obey Bose-Einstein statistics. The members of the boson family include not only material particles but also photons (quanta). Pions or π-mesons (π^+, π and π^0) and kaons or K-mesons (K^+, K^-, K^0 and $\overrightarrow{K^0}$) are the examples of Bosons K-mesons are heavier than π-mesons. The photon has zero rest mass and a spin of unity and is called massless boson. A graviton is also a massless boson having spin of two units.

3. **Fermions** : Fermions are those particles having half integral spins and obey Fermy-Dirac statistics. Fermions are again sub-divided into two groups depending upon their masses. The lighter fermions are called Leptons and the heavier ones are called Baryons.



43. The leptons are the particles of weak interactions. The leptons include electrons, muons, neutrinos and their anti-particles. The baryons include protons, neutrons and their anti particles and also hyperons. Hyperons are un-stable and heavier particles. These include lambda (λ), sigma ($\Sigma^0, \Sigma^+, \Sigma^-$), omega ($\Omega$) and Ksi ($\Xi^-, \Xi^0$).

Baryons and mesons are jointly called 'hadrons' and are the particles of strong interaction. Elementary particles are also classified based on stability, type of interaction between them and masses.

Spins of the particles :

Particle	Spin
Electron	1/2
Proton	1/2
Neutron	1/2
Neutrino	1/2
Photon	1
Graviton	2
π^+, π^-, π^0	0