Atoms

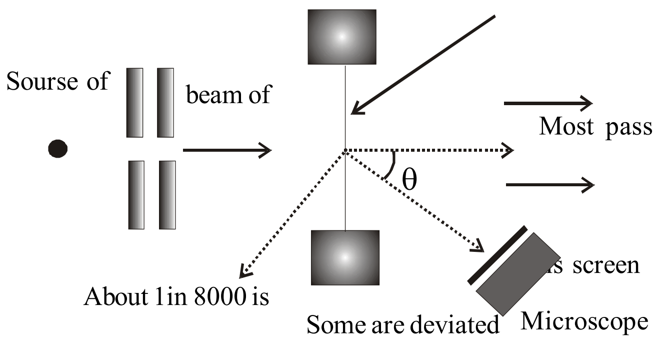
A theoretical explanation for the structure of atom is called an atom model. The first attempt to explain the structure of the atom was made by JJ Thomson. According to him, the atom consists of a cloud of +ve charges distributed uniformly in a sphere of diameter about 10^{-10}m. The electron are embedded in the cloud in such a manner that the electrostatic force of repulsion between them is exactly balanced by the force of attraction between the electrons and the +ve charges.

Rutherford's alpha particle scattering experiment or Geiger - Marsden experiment.

Rutherford and his associates Geiger and Marsedn studied the scattering of α particles (He nucleus) from a thin gold foil in order to determine the structure of the atom.

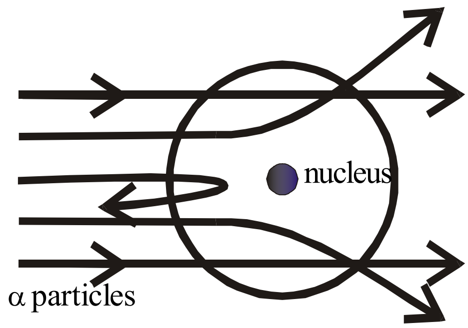
Experimental arrangement

α particles from a radioactive source $\left[{}_{83}Bi^{214}\right]$ placed in a lead cavity are collimated into a narrow beam with the help of a lead plate having a narrow slit. The narrow beam of α particles then fall on this gold foil. The scattered α particles are detected with the help of an α particle detector. The detector consists of a zinc sulphide screen. The scattered α particles on striking the screen produces bright flashes.



Observations:-

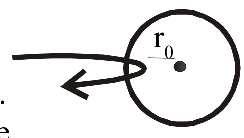
(i) Most of the α particles are found to pass through the gold foil without any appreciable deflection.
(ii) However, a number of α particles are found to undergo fairly large deflection.
(iii) A very small number of α particles are found to be deflected through large angles $(\approx 180^o)$



Explanations

* Since most of the α particles passed undeviated, the atom has a lot of empty space in it.
* Since the fast and heavy α particles could be deflected even through 180^0, the whole of the +ve charge and practically the entire mass (excluding electrons) of the atom was confined to an extremely small central core called "Nucleus".
* The nucleus is surrounded by 'electrons', i.e. they are spread over the remaining part of the atom leaving plenty of empty space.
* As atom is electrically neutral, total +ve charge is equal to the total -ve charge of the electrons in the atom.
* The electrons are not stationary. If they were at rest, they would be pulled into the nucleus due to the strong electrostatic force of attraction. They were revolving round the nucleus in circular orbits. The necessary centripetal force being provided to them by the electrostatic force of attraction between the electrons and the nucleus.

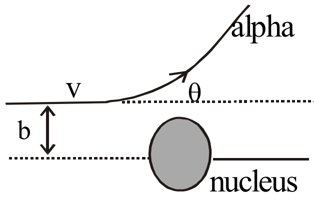
Distance of clossest approach (r_0)



An α particle travelling directly towards the nucleus (for head on collision) slows down as it approaches the nucleus due to the force of repulsion exerted by the nucleus. At a distance r_0 from the nucleus, the α particle becomes momentarily at rest (when the KE is completely converted into the PE of the system.) and then begins to retrace its path. This distance r_0 is called distance of closest approach. $\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_o}\frac{2e \times Ze}{r_0}$

Impact parameter (b)

It is defined as the perpendicular distance of the velocity vector of the α particle from the center of the nucleus, when the α particle is far away from the nucleus.



Drawbacks of Rutherford atom model.

1) According to electromagnetic theory, an accelerated electrical charge must radiate energy in the form of electromagnetic waves. If the accelerated electrons lose energy by radiation, the total energy of the electron continuously decreases an it must spiral down into the nucleus. Thus atom cannot be stable. But most of the atoms are stable.

2) If Rutherford's atom model is true, the electron can revolve in orbits of all possible radii and hence it should emit continuous energy spectrum. However, the atoms like hydrogen possess line spectrum. Rutherford failed to explain the existence of line spectrum.

Bohr atom model.

In order to account for the stability of the atom and the line spectra of hydrogen atom, Bohr introduced the concept of stationary orbits.

Postulates of Bohr atom model.

(i) Electrons revolve round the +vely charged nucleus in circular orbits.

(ii) The electrons which remain in a privileged path cannot radiate energy.

(iii) The orbital angular momentum of the electrons is an integral multiple of $\frac{h}{2\pi}$

i.e. $mvr = \frac{nh}{2\pi}$ ....(1) $\quad [n = 1,2,3,........\& \ h = \text{Planck's constant} = 6.62 \times 10^{-34} \text{J s}]$

(1) is known as **Bohr quantisation condition.**

(iv) Emission or absorption of energy takes place when an electron jumps from one orbit to another.

Note:- The energy is radiated when an electron jumps from higher to lower energy orbits; and the energy is absorbed when it jumps from lower to higher energy orbit.

If E_i and E_f are the energies of two orbits and ν is the frequency of radiation emitted or absorbed, then

$$h\nu = E_i - E_f \qquad \therefore \ \nu = \frac{E_i - E_f}{h}$$

This is known as **Bohr's frequency condition**.

Bohr's theory of hydrogen atom.

Radius of hydrogen atom.

In a hydrogen atom, an electron having charge - e revolves round the nucleus having charge +e in a circular orbit of radius r.

The force of attraction between the nucleus and the electron is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{e\,e}{r^2} = \frac{e^2}{4\pi\varepsilon_0 r^2} \ ....(1)$$

This force provides the centripetal force for the orbiting energy

i.e. $$\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r} \ ....(2)$$

$$mv^2 = \frac{e^2}{4\pi\varepsilon_0 r} \ ....(3)$$

According to Bohr's second postulate, $mvr = \frac{nh}{2\pi}$

$$\therefore\ v = \frac{nh}{2\pi m r} \ ....(4)$$

Substuting (4) in (2), $\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{m}{r}\left[\frac{nh}{2\pi m r}\right]^2$ i.e, $\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{m n^2 h^2}{r 4\pi^2 m^2 r^2}$

$$\therefore\ r = \frac{\varepsilon_0 n^2 h^2}{\pi e^2 m} \ ....(5) \quad \text{where} \quad n = 1,2,3.........$$

Bohr's radius

The radius of the innermost orbit (1st orbit) in hydrogen atom is called Bohr's radius.

If $n = 1$ in (5) $\quad r_0 = \frac{\varepsilon_0 h^2}{\pi m e^2} = 0.53 A^0$

Energy of electron in the Hydrogen atom.

The Kinetic Energy of revolving electron is $KE = \frac{1}{2} m v^2 \ ....(6)$

Substuting for mv^2 fom (3), $KE = \frac{e^2}{8\pi\varepsilon_0 r} \ ....(7)$

Potential Energy of electrons is $PE = -\frac{e^2}{4\pi\varepsilon_0 r} \ ....(8)$

Now total energy, TE = KE + PE

i.e. $E = \frac{e^2}{8\pi\varepsilon_0 r} + \frac{-e^2}{4\pi\varepsilon_0 r} \qquad \therefore\ E = \frac{-e^2}{8\pi\varepsilon_0 r} \ ....(9)$

Substuting for r from (5); Energy of electron in hydrogen orbit, $E = \frac{-me^4}{8\varepsilon_0^2 n^2 h^2} \ ....(10)$

Substuting the values of m, e, ε_0 and h then $E = \frac{-13.6}{n^2}$ eV

Energy levels

Ground state (E_1)

It is the lowest energy state in which the electron revolve in the orbit of smallest radius. For ground state, n = 1.

Energy of hydrogen atom, $E_1 = \frac{-13.6}{1} = -13.6$ eV

Excited states

When hydrogen atom receives energy, the electrons may raise to higher energy levels. Then atom is said to be in excited state.

First excited state: - Here n = 2. $E_2 = \frac{-13.6}{2^2} = -3.4$ eV

Second excited state: - n = 3. $E_3 = \frac{-13.6}{3^2} = -1.51$ eV

Energy difference between E_1 and E_2 of hydrogen atom, $\Delta E = E_2 - E_1 = -3.4 - -13.6 = +10.2$ eV.

So the energy required for the existance of an electron in hydrogen atom in its first excited state is 10.2 eV.

Ionisation energy.

It is the minimum energy required to produce a free electron from the ground state of an atom. {i.e. from $n=1$ to $n=\infty$.} So the ionisation energy of hydrogen atom is $E_\infty - E_1 = 0 - -13.6 = \underline{13.6\ eV}$.

Spectral series of Hydrogen atom.

When the electrons in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a spectral line. The wavelength of the spectral line depends upon th energy associated with the two energy levels between which the transition takes place. The spectral lines form a number of spectral series. The wavelength of a spectral line in a spectral series is given by the formula $\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$;

where R_H = Rydberg constant = $1.097 \times 10^7\ m^{-1}$, n_1 and n_2 are integers.

1. Lyman Series:- It is the series in which the spectral line correspond to the transition of electrons from some higher energy state to the lower energy state corresponding to $n_1 = 1$.

The wavelength of the spectral lines in Lyman series is given by $\frac{1}{\lambda} = R_H\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$; where $n_2 = 2,3,4,......$

These spectral lines are in the **uv region**.

2. Balmer Series:- Here the spectral lines corresponds to the transition of electrons from some higher energy states to the lower energy state of $n_1 = 2$. $\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right)$; where $n_2 = 3,4,5..................$

These spectral lines lie in the **visible region.**

3. Paschen Series: - $n_1 = 3$, $n_2 = 4,5,6,....................$ $\frac{1}{\lambda} = R_H\left(\frac{1}{3^2} - \frac{1}{n_2^2}\right)$ It lie in the **IR region**.

4. Brackett Series:- $n_1 = 4$, $n_2 = 5,6,7,$ .... $\frac{1}{\lambda} = R_H\left(\frac{1}{4^2} - \frac{1}{n_2^2}\right)$ It lie in the **IR region**.

5. :Pfund Series:- $\frac{1}{\lambda} = R_H\left(\frac{1}{5^2} - \frac{1}{n_2^2}\right)$ $n_2 = 6,7,8,$ .... It lie in the IR region.

Energy level diagram of Hydrogen atom.

We know the energy of Hydrogen atom, $E_n = \frac{-13.6}{n^2}\ eV$.

For $n = 1$, $E_1 = -13.6$ eV (Ground State)

$n = 2$, $E_2 = -\frac{13.6}{2^2} = -3.4\,eV$. (I[st] excited state)

$n = 3$, $E_3 = -\frac{13.6}{9} = -1.15\,eV$. (II[nd] excited state)

$$n=4,\quad E_4 = -\frac{13.6}{16} = -0.85\,eV. \text{ (III}^{rd}\text{ excited state)}$$

$$n=5,\quad E_5 = -\frac{13.6}{25} = -0.54\,eV.$$

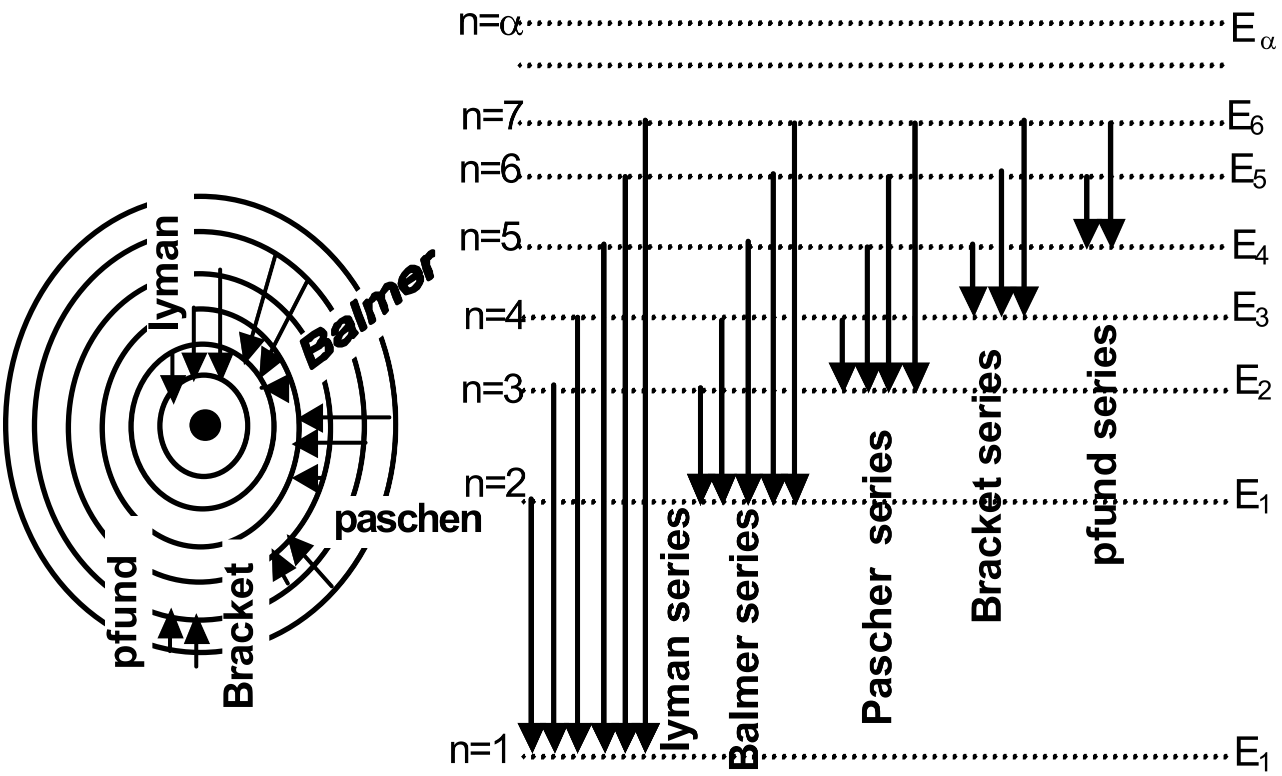
....

$$n=\infty,\quad E_\infty = -\frac{13.6}{\infty^2} = 0.$$

As n increases, the energy associated with a state becomes less negative and approaches closer and closer to the maximum value zero corresponding to $n=\infty$. For large values of n, the energy values are so close to each other that they form an energy continuum. At $n=\infty$, the electron no longer remain bound to the nucleus i.e., it becomes a *free electron*.

A fig. showing the energy levels of hydrogen atom and various spectral lines emitted by it is called energy level diagram of hydrogen. **{It is given below}**

Note: An electron can have any total energy above E = 0 eV. In such situations, the electron is free. Thus there is a continuum of energy starts above E = 0 eV.



Energy level diagram of H atom

NUCLEI

Composition of Nucleus.

A nucleus is made up of elementary particles called neutrons and protons.

Proton: The nucleus of lightest atom (isotope) of hydrogen is called proton. Mass of proton, $m_p = 1.67 \times 10^{-27}$ kg. Charge of proton is + 1.6×10^{-19}C. It is stable.

Discovery of Neutron

Neutron was discovered by James Chadwick in 1932. He produced neutrons by bombarding Beryllium with α particles.

$_4Be^9 + {_2He^4} \rightarrow {_6C^{12}} + {_0n^1} + E$; where E is the energy released during reaction. $_0n^1$ is neutron.

It has no charge and has mass nearly the same as that of proton.

Neutron Properties.

* Neutron is chargeless particle of mass 1.67 x 10^{-27} kg..
* It is stable inside nucleus but it is unstable in its free state.
* The unstable neutron decays into a proton, an electron and an antineutrino. ${}_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0 + \bar{\nu}$ ($\bar{\nu}$ is antineutrino. It is an elementary particle of matter.)
* The neutrons can be slowed down by passing them through heavy water, graphite etc. This is due to the elastic scattering of neutrons.
* Neutron produces intense biological effects.

Representation of Nuclide

Nucleids are represented by notation ${}^A_ZX$, where X is the chemical symbol of species, Z = atomic number = number of protons or electrons. N = Neutron Number, A = Mass number = Z + N (Total number of protons and neutrons).

Isotopes: The atoms of an element which have the same atomic number but different mass number are called isotopes. That is number of protons and electrons are same but number of neutrons are different. They occupy the same position in the periodic table and hence same chemical properties, but different nuclear properties.

Eg:(1) ${}_8O^{16}, {}_8O^{17}, {}_8O^{18}$ (2) ${}_{17}Cl^{35}$ & ${}_{17}Cl^{37}$ (3) ${}_1H^1, {}_1H^2, {}_1H^3$

Isobars: Isobars are atoms of different element which has the same mass number A but different atomic number Z.

Eg: (1) ${}_{11}Na^{22}$ & ${}_{10}Ne^{22}$ (2) ${}_{20}Ca^{40}$ & ${}_{18}Ar^{40}$

They occupy different places in the periodic table.

Isotones: They are nuclides containing the same number of neutrons (A - Z). Eg: ${}_{17}Cl^{37}$ & ${}_{19}K^{39}$

Size of the nucleus.

The α particle scattering experiment conducted by Geiger and Marsden gave an idea about the size of the nucleus.

The radius of the nucleus is related to mass number (A) by the equation

$$R = R_0 A^{\frac{1}{3}} \; ; \text{ where } R_0 = 1.2 \times 10^{-15} \text{ m.}$$

The volume of the nucleus (the shape of nucleus is assumed to be spherical) is proportional to A.

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$$

$\therefore \underline{\underline{V \propto A}}$ The density of the nucleus is constant. It is independent of A and its value is 2.3 x 10^{17} kg/m^3.

Atomic mass unit (amu)

The mass of an atom is extremely small. So it is inconvenient to represent it in kilogram. Hence a very small unit amu is adopted.

amu is defined as $\frac{1}{12}^{th}$ *the mass of carbon - 12 atom*. So 1 amu = 1.66 x 10^{-27} kg.

Mass energy

According to Einstein, mass is considered as a source of energy. The mass m can be converted into energy. The mass m can be converted into energy according to relation, $E = mc^2$. where c = 3 x 10^8 m/s, the velocity of light. This is **mass energy equivalence** relation.

Mass defect and nuclear binding energy.

Mass defect: It is found that the mass of a stable nucleus is always less than the total mass of the constituent nucleons (neutron and proton).

The difference between the sum of the masses of the nucleons constituting a nucleus and the rest mass of the nucleus is known as mass defect. It is denoted by Δm.

Consider an atom $_ZX^A$. Nucleons of this atom contains Z protons and (A - Z) neutrons. Therefore mass of the constituting nucleons = $Z m_P + (A - Z) m_N$. {where m_P = mass of proton, m_N = mass of neutron}

If M is the mass of nucleons of $_ZX^A$, then mass defect, $\Delta m = [Z m_P + (A - Z) m_N] - M$.

Binding energy (E_b): When a nucleus is formed from the free nucleons, the decrease in mass of the nucleons is released as equivalent energy (in accordance with Einstein's mass energy relation). The energy equivalent to mass defect is used in binding the nucleons and is called binding energy of the nucleus. In order to break the nucleus or to completely separate the nucleons from each other, an equal amount of work has to be done.

The binding energy of a nucleus is defined as the energy equivalent to the mass defect. If Δm *is the mass defect of a nucleus, then according to Einsteins mass energy relation, binding energy of the nucleus,* $E_b = \Delta m c^2$.

Binding Energy per nucleon {E_{bn}}

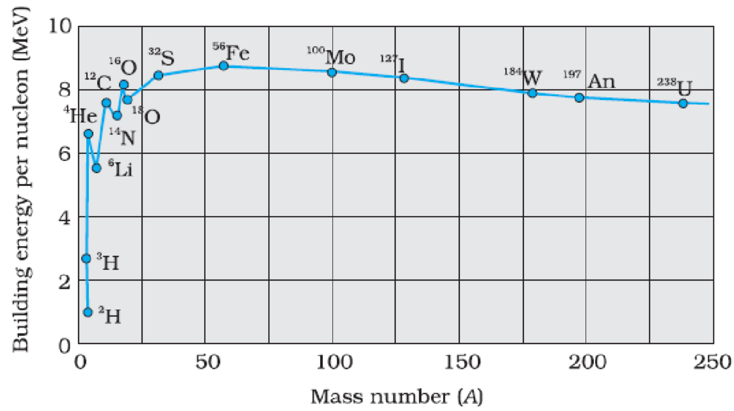
It is the average energy required to extract one nucleon from the nucleus. It is obtained by dividing the binding energy of the nucleus by the number of nucleons it contains (mass number).

$$\text{binding energy/ nucleon, } E_{bn} = \frac{\text{binding energy}}{A}.$$

The higher value of binding energy / nucleon indicates comparatively greater stability of the nucleus.

Binding energy curve.

It is the graph which shows the relation between the binding energy per nucleon, E_{bn} and the mass number A.



Main features of the graph.

(i) E_{bn} is almost constant for nuclei where massnumber ranges as $30 < A < 170$. The maximumvalue of E_{bn} is 8.75 MeV for ^{56}Fe and it is 7.7 MeV for ^{238}U.

(ii) There appear narrow spikes in the curve which shows extra stability.

(iii) E_{bn} is low for lighter nuclei and also for heavier nuclei.

Note: Lighter nuclei like $_1^2H$, $_1^3H$ etc have low E_{bn}. So it combine to form a heavier nuclei of high E_{bn} releasing energy. i.e. it undergoes nuclear fission. Heavier nuclei like ^{238}U have low E_{bn}. So it split up into nuclei of high E_{bn} releasing energy. i.e. it undergoes fission.

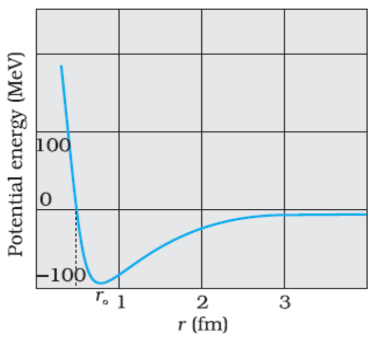
Nuclear force

It is the force between nucleons. The features of nuclear force are:

* It is the strongest force in nature. * It is short ranged. Each nucleon has its influence on its immediate neighbors only. So nuclear force is saturated. * The nuclear force is charge independent. i.e. nuclear force between proton - proton, neutron - proton and proton - neutron are the same.

Variation of potential energy with distance of separation between nucleons.

The PE of a pari of nucleons as a function of their separations is shown in fig:-.At a particular distance r_0 PE is minimum. The force is attractive when $r > r_0$ and is repulsive when $r < r_0$. The value of r_0 is about 0.8 x 10^{-15}m.



Radioactivity

The spontaneous transformation of an element into another with the emission of some particular or electromagnetic radiation is called natural radioactivity. The substances capable of emitting radiations are called radio active substances. Natural radioactivity was first discovered by Henri Becquerel. In radioactive decay, unstable nucleus undergoes decay into stable one. Decay are of three types. (i) α decay, (ii) β decay, (iii) γ decay.

(i) **α decay** : - It is the phenomena of emission of alpha particles from the nucleus. In α decay, mass number of parent nucleus is reduced by 4 units and atomic number is reduced by 2 units.

$${}_Z^AX \rightarrow {}_{Z-2}Y^{A-4} + {}_2He^4 \qquad {}_2He^4 \text{ is the } \alpha \text{ particle.}$$

Eg: $\quad {}_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_2He^4$

(ii) **Beta decay**:- There are two types of β decay - β^+ decay and β^- decay.

(a) **β^+ decay** :- In β^+ decay atomic number is reduced by 1 unit but mass number remains unchanged.

$${}_ZX^A \rightarrow {}_{Z-1}Y^A + e^+ + \nu \;\; ; \text{where } e^+ = \beta^+ \text{ ray and } \nu = \text{ neutrino}.$$

In β^+ decay, positron and neutrino are emitted. During this decay a proton is converted into neutrino, positron (β^+ ray) and neutrino. $\{p \rightarrow n + e^+ + \nu\}$.

Eg:- $\quad {}_{11}N^{22} \rightarrow {}_{10}Ne^{22} + e^+ + \nu$.

(b) **β^- decay** :- In β^- decay, atomic number is increased by 1 unit but mass number doesn't change.

$${}_ZX^A \rightarrow {}_{Z+1}Y^A + e^{-1} + \bar{\nu} \;\; ; \text{where } e^{-1} = \beta^- \text{ ray and } \bar{\nu} = \text{ antineutrino}.$$

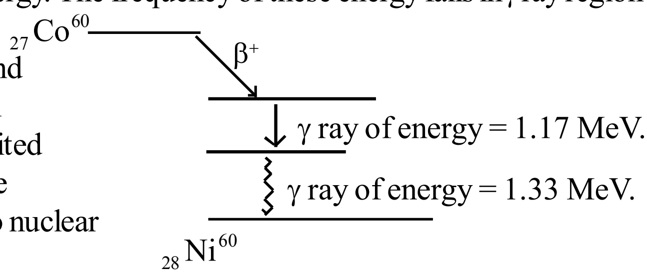
Here a neutron converts into proton, emitting electron and antineurtino. $\{n \rightarrow p + e^- + \bar{\nu}\}$

Eg:- $\quad {}_{15}P^{32} \rightarrow {}_{16}S^{32} + e^- + \bar{\nu}$.

(iii) **γ decay**:- We know that in an atom electrons revolve in different energy levels and there is a transition of electrons between these atomic energy levels and due to this transition, there is the emission of spectral lines.

Similar energy states called nuclear energy levels exist inside the nucleus. The transition between two nuclear energy levels also result in the emission of energy. The frequency of these energy falls in γ ray region of electromagnetic spectrum.

During radioactive decay, the emission of alpha and beta particles usually leaves the residual nucleus in an excited state, which is found to go to some other excited state or ground state by the emission of γ rays, whose energy equal to difference of energy between the two nuclear energy levels.



Eg:- ${}_{27}Co^{60}$ disintegrates into ${}_{28}Ni^{60}$ by β^+ decay along with the emission of two γ rays.

Properties of alpha, beta and gamma rays.

$ Properties of α particles.

1) α particles have a charge of +2e and a mass four times that of hydrogen atom.
2) Thy affect photographic plates.
3) They are deflected by electric and magnetic fields.
4) They have high ionising power.
5) They can penetrate very thin metal foils.
6) They can produce fluorescence and phosphorescence.

$ Properties of β particles.

1) It is an electron
2) They are deflected by electric and magnetic fields.

3) They can affect photographic plates.
4) They can produce fluorescence and phosphorescence.
5) The have low ionisation power.

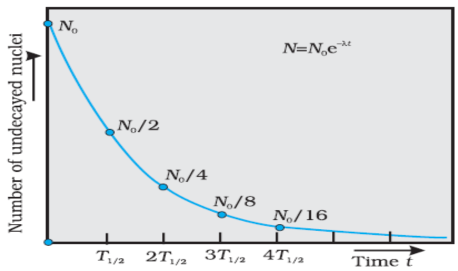
$ Properties of γ rays.
1) They are electromagnetic waves.
2) They have the speed of light.
3) They have high penetrating power.
4) They can affect photographic plates.
5) They can produce fluorescence and phosphorescence.
6) They have very low ionising power.
7) They are not deflected by electric and magnetic fields.

Laws of radioactive decay

According to law of radioactive decay, the number of nuclei undergoing decay per unit time (or rate of decay) is proportional to number of nuclei in the sample at that time.

$\frac{dN}{dt} \propto N$ i.e. $\frac{dN}{dt} = -\lambda N$; where λ is **decay constant or disintegration constant**. The -ve sign indicates that number of nuclei is decreasing with time.

The solutions to the above differential equations is $N_{(t)} = N_{(0)} e^{-\lambda t}$. This equation shows that number of nuclei is decreasing exponentially with time as shown.



Derivation of equation $N_{(t)} = N_{(0)} e^{-\lambda t}$.

According to radioactive decay,

$$\frac{dN}{dt} = -\lambda N(t)$$

$$\frac{dN}{dt} = -\lambda dt$$

$$\int \frac{dN}{N} = \int -\lambda\, dt$$

$\log_e^N = -\lambda t + C$ ....(1) ; where C is the constant of integration.

If t = 0, N = N_0 - initial value. So $\log_e^{N_0} = 0 + C$

i.e. $C = \log_e^{N_0}$

Substituting in (1), $\log_e^N = -\lambda t + \log_e^{N_0}$

$$\log_e^{\frac{N}{N_0}} = -\lambda t$$

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

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

The decay rate (K)

It is the number of nuclei disintegrated per unit time and is denoted by R.

$$R = -\frac{dN}{dt}$$

Differentiating the equation $N = N_0 e^{-\lambda t}$ we get $\frac{dN}{dt} = -N_0 \lambda e^{-\lambda t}$

$$-\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$$ i.e. $R = R_0 e^{-\lambda t}$;where $R_0 = \lambda N_0$. decay rate at t = 0.

Half life ($T_{1/2}$)

It is the time taken by radio nuclide to reduce to half of its initial value.

Half life period, $T_{1/2} = \frac{0.693}{\lambda}$.

To derive the relation $T_{1/2} = \frac{0.693}{\lambda}$

If $T_{1/2}$ is the half life period, then $N = \frac{N_0}{2}$.

Substitute in $N = N_0 e^{-\lambda t}$

$$\frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}}$$

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

i.e. $$2 = e^{\lambda T_{1/2}}$$

$$\log_e^2 = \lambda T_{1/2}$$

$$T_{1/2} = \frac{\log_e^2}{\lambda} \quad \text{Or} \quad T_{1/2} = \frac{0.693}{\lambda}$$

Mean life (τ) : It is defined as the ratio of total lifetime of all the radioactive atoms to the total number of atoms in it.

Relation between τ and $T_{1/2}$

$$T_{1/2} = 0.693\tau$$

Unit of radioactivity: SI unit of radioactivity is **becquerel (Bq)**. The traditional unit of activity is **curie**.
1 curie = 3.7 x 10^{10} Bq.

Nuclear Energy.

In the nuclear reaction like fission, fusion etc, huge quantity of energy of the order of MeV is released.

Nuclear fission.

In nuclear fission, a heavier nuclei splits into lighter ones releasing huge energy.

The fission reaction of ${}_{92}U^{235}$ may be represented as

$${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{92}U^{236} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{141} + 3\,{}_0n^1 + Q$$

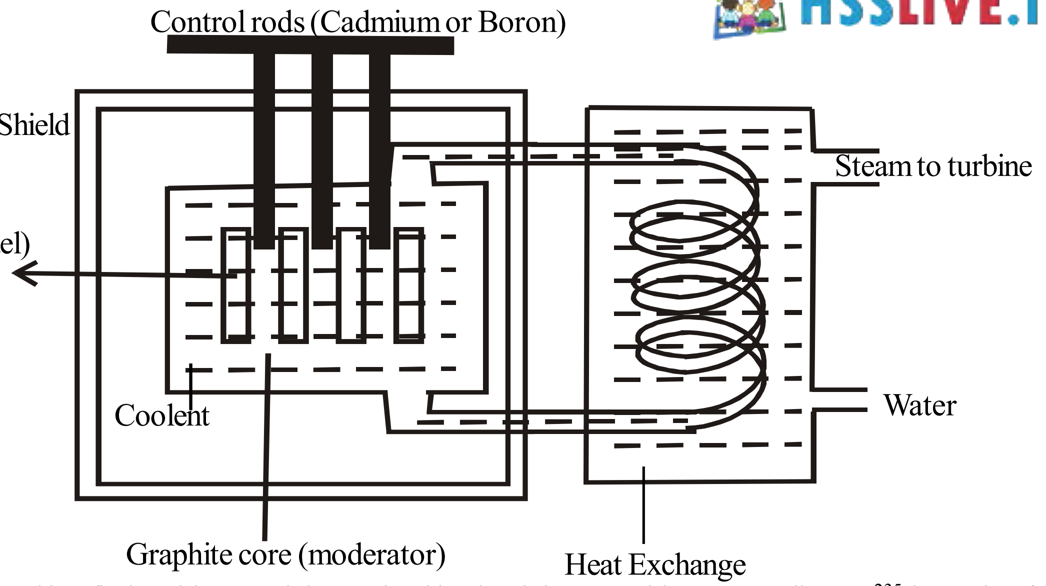
The energy Q released was estimated to be 200 MeV/fission and is equal to the difference in masses of the nuclei
before and after the fission.

Chain reaction: - The nuclear fission of U^{238} release extra neutrons. These extra neutrons may bombard with the neighboring Uranium atoms and make it to undergo nuclear fission, which in turn produce more neutrons. This process continues like a chain. This was first suggested by **Enrico Fermi**.

Nuclear reactor.

The nuclear reactor is a device in which nuclear fission can be carried out through a sustained and a controlled chain reaction.

A nuclear reactor consists of thick block of carbon surrounded by thick absorbing walls of concrete. The different parts of the reactor are: -



Nuclear fuel :- Fuel is a fissionable material contained in aluminium cyanides. Generally $_{92}U^{235}$ is used as fuel.

Moderator: The material used to slow down the fast moving neutrons produced as a result of nuclear fission is called moderator. The commonly used moderators are graphite, water or heavy water.

Control rods: - These are cadmium or boron rods inserted into the carbon block. They can absorb neutrons and control chain reaction.

Coolant: - The coolant absorbs heat generated during the chain reaction. It releases the heat energy to water and water is thus converted into super heated steam, which is used to run the turbines of generators. Liquid sodium or heavy water may be used as coolant.

Shield:- The reactor is surrounded by 10 m thick concrete wall to prevent the spreading of harmful radiations.

Uses: (i) In power generation. (ii) To produce radioactive isotopes for their use in medical science, industry , agriculture etc. (iii) To produce neutron beams of very high intensity. (iv) To convert non - fissionable material into fissionable material. {production reactor or breeder reactors}

Eg: - $_{92}U^{238}$ is a non fissionable material. It is converted into fissionable plutonium {$_{94}Pu^{239}$ } using a breeder reactor.

Nuclear fusion

In nuclear fusion, lighter nuclei combine to form heavier nuclei releasing energy. It is a thermonuclear reaction. It occurs at high temperature of the order of 10^7 K. At high temperature, particles get enough kinetic energy to overcome Coulomb repulsion. Thermonuclear fusion is the source of energy in stars. The fusion inside sun involves burning of hydrogen into Helium. $_1H^2 + {_1H^2} \rightarrow {_2He^4} + Q$. Here the energy released is of the order of 24 MeV.

In future, we expect to build up fusion reactor to generate power. For this to happen, the nuclear fuel must be kept at a temperature of 10^8 K. At this temperature, fuel exists in plasma state. The problem is that no container can stand such a high temperature. Several countries around the world including India are developing techniques to solve this problem.

Solved Problem: It is estimated that the energy released in an atom bomb explosion has been 7.6×10^{13}J. If each fission releases an energy of 200MeV, calculate the number of atoms fissioned.

200 MeV $= 200 \times 10^6 \times 1.6 \times 10^{-19}$J

No. of fission x Energy released in one fission = total energy released

i.e, $n \times 200 \times 10^{6} \times 1.6 \times 10^{-19} = 7.6 \times 10^{13}$

$$n = \frac{7.6 \times 10^{13}}{200 \times 10^{6} \times 1.6 \times 10^{-19}} = 2.375 \times 10^{-24} \text{ fission.}$$