Nuclear Chemistry. (Dr. S. S. Mahurkar)

Nuclear Chemistry is the branch of chemistry that deals with the study of the nucleus in an atom. & i.e. nuclear Particles, nuclear forces & nuclear reactions.

- Such reactions in which changes takes place inside the nucleus of the atom & they wholly depend on their structure, are called nuclear reactions.

(i) Nuclear Particles :- The most commonly known nuclear particles are Protons & neutrons. It is now known that neutron is not a stable particles. Inside the nucleus it may be stable for billions of years but when it comes outside the nucleus it has very short life (half-life = 12.8 minutes) after which it decomposes to a Proton & an electron.

Standard nuclear notation for an element shows the chemical symbol, the mass number & the atomic number of the isotopes.

$$^{A}_{Z}X \qquad A \rightarrow \text{mass No.}, \quad Z \rightarrow \text{At. No.}$$

(i) Fundamental Particles :- a) Stable (b) unstable

a) Stable fundamental Particles :-

1) Electron :- (e^{-} or $_{-1}e^{0}$ or β-Particle). It carries a unit negative charge. It was discovered by J.J. Thomson. The charge on an $\bar{e}$ is 4.8024×10^{-10} e.s.u. or 1.602×10^{-19} C. It's mass is 9.109×10^{-28} g or 9.109×10^{-31} kg. which is about 1837 times less than that of Proton.

ii) Proton ($_1H^1$) - The name of Proton was first proposed by Rutherford but it was already discovered by Goldstein. The mass of proton is 1.00872 amu. The charge is a unit +ve charge.

iii) Antiprotons :- In 1955, Segre & his associates at the university of california obtained the antiprotons. This particle having mass equal to that of proton but with -ve charge ($_{-1}H^1$)

iv) Positron :- / antielectron :- discovered by Anderson's in 1932. It has mass equal to that of an electron but with a unit +ve charge. They combine with electrons producing γ-rays. (e^+ or $_{+}e^0$)

v) Nutrino :- It has mass equal to that of an electron but having no charge. → $_0n^1$ (↓) . Neutron $_0n^1$ (↑)

(Half-spin)

$$_{+1}P^1 + _{-1}P^1 \longrightarrow _0n^1 (\uparrow) + _0n^1 (\downarrow)$$

Proton Antiproton neutron Antineutron

vi) Antineutrino - It is identical to the neutrino but of opposite spin.

Commonly used notations

α - $_2He^4$		P = $_1H^1$
$β^-$ - $_{-1}e^0$		d = $_1H^2$
$β^+$ - $_{+1}e^0$		
n = $_0n^1$		

b) Unstable Fundamental Particle :

i) Neutron (^1_0n) = It was discovered by Chadwick, Its mass is 1.0086 amu. It has no charge.

ii) Mesons :- They can be neutral or charged +vely or -vely. Mesons were discovered by H. Yukawa. μ-mesons with with mass 206 times that of an electron & charge which may be +ve or -ve.

μ, π, K } mesons

- π-mesons having mass ^270 times that of ēs & a charge which may be +ve or -ve. π-mesons decay into μ-mesons. π-mesons are usually called as (Pions)

- K-mesons having mass 970 times that of an ē & their charge may be zero, +ve or -ve.

iii) Hyperons :- Nuclear particles with mass larger than that of proton have also been obtained. These particles are called hyperons. The masses have been found to be about 2180, 2330 & 2580 times that of ē at rest. Some of these particles are electrically neutral while others are +vely or -vely charged.

Meson & Hyperons are very short-lived.

* Fundamental Particles :- Defn: one that does not change into anything else & is not derived from anything i.e. it exhibits an invariant behaviour throughout the course of time.

(1) Nuclear size :- size of the nucleus was obtained from Rutherford's experiments on scattering of alpha particles. more Accurate from expt on scattering of neutrons. This is given by eqn.

$$r = R_0 A^{1/3}$$

where r = radius of the nucleus of mass no. A.

R_0 = const. (1.5×10^{-15} m.)

- The nuclear radius is very small of the order of 10^{-14} m. It is measured in fermi units f. ($f = 10^{-13}$ cm = 10^{-15} m).

e.g. 1) Estimate the radius of $^{27}_{13}Al$ nucleus:

Ans :- $A = 27$ ∴ $r = R_0 A^{1/3}$

$= 1.5 \times 10^{-15} \times (27)^{1/3}$

$= 4.5 \times 10^{-15}$ m $= 4.5 f$

2) $^{23}_{11}Na$ $r = 1.5 \times 10^{-15} \times (23$

(3) $^{63.5}_{29}Cu$

(4) $^{126.9}_{53}I$

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Classification of nuclides :-

1) Isotopes :-

Atoms of a given element which have same atomic number but different mass number are called isotopes.

Thus, isotopes have same number of protons & $\bar{e}$s but different number of neutrons.

e.g. i) $_1H^1$, $_1H^2$, $_1H^3$ ii) $_6C^{12}$, $_6C^{13}$, $_6C^{14}$

iii) $_8O^{16}$, $_8O^{17}$, $_8O^{18}$ iv) $_{17}Cl^{35}$, $_{17}Cl^{37}$

- Atomic weight of various elements are fractional because of the presence of isotope.

e.g. Chlorine has two naturally occuring isotopes, Cl^{35} (75%) & Cl^{37} (25%). So atomic weight of Cl can be calculated as.

$$Cl = \frac{35 \times 75 + 37 \times 25}{100} = 35.5 \text{ amu.}$$

2) Isobars :-

Isobars are the atoms with the same mass number but different atomic numbers. Thus isobars have different number of protons, neutrons & $\bar{e}$s but the sum of protons & neutrons is same.

e.g. i) $_{18}Ar^{40}$, $_{19}K^{40}$, $_{20}Ca^{40}$ ii) $_{52}Te^{130}$, $_{54}Xe^{130}$, $_{56}Ba^{130}$

iii) $_6C^{14}$, $_7N^{14}$; $_8O^{17}$ & $_9F^{17}$

3) Isotones :-

Isotones are the atoms with the same number of neutrons but different mass numbers.

e.g. i) $_{14}Si^{30}$, $_{15}P^{31}$, $_{16}S^{32}$

ii) $_{19}K^{39}$, $_{20}Ca^{40}$

4) Isomers (Nuclear isomers) :-

Nuclear isomers are the atoms with the same atomic number & same mass number but with different radioactive Properties.

They have same number of $\bar{e}$, Protons & neutrons.

e.g. Uranium X_2 - half life 6.7 hrs

Uranium Z - " 1.14 min.

5) Isosters :- molecules having same number of atoms & same number of electrons are called isosters.

e.g. i) CaO & MgS ii) F_2 & HCl iii) C_6H_5 & $B_3N_3H_6$

6) Isoelectronic species :-

Atoms, molecules & ions having the same number of $\bar{e}$s are called isoelectronic

e.g. i) C^{4-}, N^{3-}, O^{2-}, F^{-}, Ne, Na^{+} (10 $\bar{e}$ each)

ii) CO, CN^{-}, N_2 (14 $\bar{e}$ each).

	Z	A	P	n	n+P	n−P
isotopes	same	diff.	same	diff.	diff	diff.
Isobars	differ	same	diff	diff	same	diff
Isotones	different	diff	diff	same	diff	diff.

(6) Nuclear stability :-

The attractive forces amongst nucleons are known as nuclear forces which determine the stability of nucleus.

The stability of nucleus is influenced by three imp. factors that are
i) mass defect
ii) Binding energy
iii) Neutron - Proton ratio (N/p ratio) (N/Z)

a) **mass defect :-**

It has been found that the actual isotopic mass of an element is almost invariably less than the sum of the masses of protons, neutrons & $\bar{e}$s present in it.

→ The difference betn the expected mass (Theoretical / calculated) & the actual mass of an isotope is called mass defect (Δm)

Δm = expected mass − Actual mass

mass defect (Δm) $= [(A-Z)m_n + Zm_H] - M$ | $\Delta m = Z \cdot m_p + (A-Z)\, m_n - M(Z,A)$

where A = mass no., Z = atomic no.

m_n - mass of neutron (1.0086), m_H = mass of proton (1.0078)

M = Actual mass.

Greater the mass defect, greater is the stability of an atomic nucleus.

e.g.) 1) The mass defect for $^{40}_{20}Ca$ whose mass is 39.975 a.m.u.

$\Delta m = (20 \times 1.0078 + 20 \times 1.0086) - 39.975$

$= 40.3280 - 39.9750$

$= 0.3530$ a.m.u.

2) $^{4}_{2}H$ mass is = 4.00150 amu.

$\Delta m = (2 \times 1.0078 + 2 \times 1.0086) - 4.00150$

$= (2.0156 + 2.0173) - 4.0015$

$\Delta m \simeq 0.0303$

(3) $^{9}_{4}Be$ (mass = 9.012)

∴ $\Delta m = 0.065$ amu

(4) $^{7}_{3}Li$ (7.01653)

$\Delta m = 0.04216$.

b) i) Nuclear binding energy :

It is defined as the energy released in binding the nucleons together in the nucleus.

or

It is the amount of energy required to break the nucleus into its constituent nucleons.

Unit of B.E = MeV.

It is calculated by using formula

$$B.E. = 931 \times \Delta m \text{ MeV}.$$

The greater the mass defect, greater is the nuclear binding energy & hence greater is the stability of the nucleus.

ii) B.E. Per nucleon :-

It is define as the ratio of total B.E. of the nucleus to its mass number.

or

The average amount of energy required to isolate one nucleon from its nucleus.

$$B.E. \text{ Per nucleon} = \frac{\Delta m \times 931}{A} \text{ MeV}$$

Δm = mass defect ; A = mass number.

For practice e.g. calculate the Δm, B.E. & B.E. Per nucleon of $^{56}_{26}Fe$ having mass 55.9375 a.m.u.

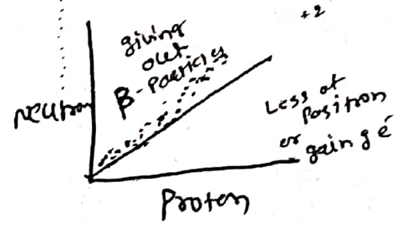
c) N/Z ratio :-

Nuclear stability is found to be related to the neutron to Proton (N/Z) ratio.

The N/Z ratios for stable nuclei vary betⁿ 1 to 1.6. The elements lying within the stability limit (1-1.6) constitute the stability belt or stability zone. However, the elements whose nuclei do not fall within the stability limit are said to be unstable.

The unstable nuclei, whose N/Z ratio is neither less than 1 or greater than 1.6 are radioactive & disintegrate giving out α, β or γ rays in their attempt to attain stability.

- Lighter nuclide upto ^{40}Ca have N/P ratio = 1.



④ odd & even no. of Protons & neutrons :-

or Nucleon Pairing :-

The nuclei $^{4}_{2}He$, $^{12}_{6}C$, $^{16}_{8}O$ & $^{24}_{12}Mg$ are very stable. The exception stability of these nuclei is attributed to the Presence of even number of neutrons & Protons. Nucleons, like the ē are assumed to paired. Just as, a Pair of ēs is more stable than an unpaired ē in electronic orbital, lly Paired nucleons are stable. complete pairing of all the Protons (Z) & all the neutrons (N) is Possible when a nucleus contains an even number of Protons & even number of neutrons. The complete pairing of like nucleons imparts extra stability to the nucleus.

e.g. $^{16}_{8}O$ is more stable than $^{17}_{8}O$ (in it one neutron remain unpaired)
(all nucleons are paired.)

(a) **Packing fraction :-** A measure of the loss or gain of total mass in a group of nucleons, when they are brought together to form an atomic nucleus

$$\Rightarrow \text{Packing fraction } (f) = \frac{\text{Actual isotopic mass} - \text{mass No.}}{\text{mass No.}} \times 10^4 = \frac{\Delta}{A}$$

Packing fraction & stability are related as

lower the packing fraction, greater is the stability of nuclei.

e.g. ① For ^{40}Ar (isotopic wt. of Ar is 39.96238)

Soln :

$$= \frac{39.96238 - 40}{40} \times 10^4$$

$$= -9.405$$

parts per 10000

② ^{35}Cl (34.98)

$$\therefore f = \frac{34.98 - 35}{35} = -0.00057 \times 10^4$$

$\therefore f$ of ^{35}Cl is -5.7

(b) **Magic No. :-** Nuclear shell model is a nuclear model in which protons & neutrons exist in levels, or shells, analogues to the shell structure that exist for $\bar{e}$ in an atom. The elements with even no. of P & n are more stable whereas elements with odd no. of P & n are less stable.

- This suggest that like $\bar{e}$, nucleon particles in the nucleus are paired. magnetic fields of the two paired P spinning in opposite direction cancel each other & develop attractive forces which are sufficient to stabilise the nucleus.

Further, it is found that nuclei with certain number of protons or neutrons are more stable. These no. are called magic no.

magic no. of P = 2, 8, 20, 28, 50, 82, 114,

magic no of n = 2, 8, 20, 28, 50, 82, 126, 184, 196

nuclei such as $^{4}_{2}He$, $^{16}_{8}O$, $^{40}_{20}Ca$, $^{208}_{82}Pb$ are most stable.

e.g. 1) Calculate B.E. per nucleon of oxygen atom $^{16}_{8}O$ which has mass of 15.994910 a.m.u.

Soln:

oxygen atom contains 8-protons, 8-neutrons & 8-electrons.

∴ mass of 8 neutrons = 8 × 1.0086 = 8.0688

mass of 8 protons = 8 × 1.0072 = 8.0576

mass of 8 $\bar{e}$'s = 8 × 0.00054 = 0.00432

∴ Total calculated mass, M' = 16.13072

Actual mass of oxygen atom M = 15.99491 a.m.u.

∴ mass defect $\Delta m = M' - M$

= 16.13072 − 15.99491

= 0.1370148 amu.

$M' = Zm_p + Zm_e + (A-Z)m_n$

But, 1 amu = 931 MeV.

∴ B.E. of the nucleus = 931 × 0.137014

= 127.62 MeV.

∴ B.E. per nucleon = $\frac{127.62}{16}$ = 7.976 MeV.

2) Calculate B.E/A in Helium atom $^{4}_{2}He$ which has a mass of 4.00260 a.m.u.

Soln:

$\Delta m = (2 \times 1.0078 + 2 \times 1.0086) - 4.00260$

$= (2.0156 + 2.0172) - 4.00260$

$\Delta m = 4.0328 - 4.00260 \Rightarrow 0.0302$

∴ B.E = 931 × Δm ⇒ 931 × 0.0302

⇒ 28.1162

B.E/nucleon = $\frac{28.1162}{4}$ = 7.02905 MeV

1 MeV = 1.602×10^{-13} J

3) calculate Packing Fraction, mass defect & energy released in the formation of argon atom $^{40}_{18}Ar$. Isotopic mass of Ar = 39.96238 amu.

Soln:-

i) Packing Fraction = $\frac{\text{Isotopic mass} - \text{mass No.}}{\text{mass No.}} \times 10^4$

$= \frac{39.96238 - 40}{40} \times 10^4 \Rightarrow -9.4025$

ii) mass defect $\Delta m = [(A-Z)m_n + Zm_H] - M$

$= [22 \times 1.008665 + 18 \times 1.007825] - 39.96238$

$= [22.19063 + 18.14085] - 39.96238$

$= 40.33148 - 39.96238$

$= 0.3691$ a.m.u.

iii) Energy released in the formn of Argon

B.E. = 931 × 0.3691

B.E. = 343.816 meV.

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4) calculate the B.E. of $^{238}_{92}U$. mass of U = 238.125 amu

Home work →

Radioactivity

- The Phenomenon of spontaneously & contineausly emitting active radiations is called radioactivity & the substance emitting such radiations is called as radioactive.
- All the heavy elements from Bi & few lightee elements Possess radioactive Propeeties.

① Radioactive Rays :-

In 1905, Rutherferd analysed that the radiations from a radioactive substance are composed of three imp. rays. 1) α - rays 2) β - rays 3) γ - rays.

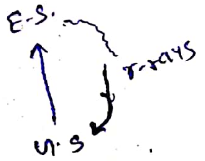
1) α - rays :-

- These rays consist of material Particles of mass four each & carrying two +ve charges.
- They are the helium nuclei, $_2^4He$.
- They have least Penetrating Power & they are easily absorbed by thin sheets of metal foil.
- α - Particles have the high velocity about 1/10 of the velocity of light.
- They have greatest (highest) ionising Power.
- They have limited range in air.
- They Produce luminacity in ZnS due to high Kinetic eneegy.
- α Particles are quite large & move slowly with less or no Penetrating Poweer.
- A sheet of the Papee or even the outee layee of skin might good enough to stop the α - Paeticles.

2) β-rays :-

- These rays consist of -vely charge particles identical with $\bar{e}$.
- They have a unit -ve charge & negligible mass ($^{0}_{-1}e$).
- The penetrating power is more than α-rays. (100 times than α)
- It possesses very high velocity comparable to that of light.
- They have weak ionising power.

3) γ-rays :- - These are electrically neutral rays having negligible mass & charge equal to zero.



- γ-rays are emitted only due to the deexcitation
- They have very high penetrating power & can penetrate even quite thick layers of lead. (1000 times of α, 10 time of β)
- They have very feeble ionising power.
- They have high energy & short wave-length.

Property	α-rays	β-rays	γ-Rays
Nature	+vely charged helium nucleus	-vely charged / +ve charge.	neutral rays
mass	4 times the mass of H (6.64×10^{-27} kg)	$\frac{1}{1837}$ of H-atom (9.1×10^{-31} kg)	Negligible zero
Charge	+2 unites (He^{+2})	-1	zero
velocity	$\frac{1}{10}$ of that of light	Almost same as that of light	same as that of light
petrating power	Less (few cm in air)	High (few mm of metal)	very high. (Thick or many cm of Pb metal)
Initial K. energy	very high	~~High~~ (~~moderate~~) moderate/Low	low (NIL)
ionising power	very high	High (moderately)	low
	It gets affected by electric as well as magnetic field.	It could get affected by both electric & magnetic fields	It is not affected by any magnetic or electric fields

* Group displacement law :-

(Fanjan rule)

When an α-particle is emitted by a nuclide of an element, the atomic number of the product decreases by two units & hence the product gets displaced by two places to the left of the parent atom in the periodic table & mass number is decrease by 4.

e.g. $^{214}_{84}Po \xrightarrow{-\alpha} \ ^{210}_{82}Pb$

(VI group) (IV group)

(2) $^{238}_{92}U \xrightarrow{\alpha} \ ^{234}_{90}Th$

- lly, when β-particles is emitted by nuclide of an element the atomic number increases by one unit. & displace the product by one place to the right of the parent element.

e.g. $^{214}_{84}Po \xrightarrow{-\beta} \ ^{214}_{85}At$

(VI) (VII group)

(2) $^{212}_{82}Pb \longrightarrow \ ^{212}_{83}Bi$

- isobars are formed by emission of β-particles. & Isotopes are formed by an α-change followed by two-β-changes in succession

e.g. $^{226}_{88}Ra \xrightarrow{-\alpha} \ ^{222}_{86}Rn \xrightarrow{-\beta} \ ^{222}_{87}Fr \xrightarrow{-\beta} \ ^{222}_{88}Ra$

isobars ($^{222}_{86}Rn$ and $^{222}_{87}Fr$)

Isotopes ($^{226}_{88}Ra$ and $^{222}_{88}Ra$)

Parent nucleus ⟶ daughter

Q. Calculate the no. of α, β particles emitted when $_{92}U^{238} \longrightarrow \ _{82}Pb^{206}$

⊙ **Nuclear Fission :-** (O. Hahn & F. Strassmann) (1934-38)

The Process of splitting up of nuclei of heavy atom into two nuclei of comparable masses is called nuclear fission.

e.g. $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{143}_{54}Xe + ^{90}_{38}Sr + 3\,^{1}_{0}n + 200\ MeV$

- Nuclear Fission is generally accompanied by emission of one or more neutrons. The nuclei with mass number over 200 when bombarded with subatomic Particles like neutrons or other particles with sufficient energy show fission Process.

- Thermal neutrons are effective to carry out fission of $^{2??}_{90}Th$, [illegible], $^{233}_{92}U$, $^{235}_{92}U$, $^{242}_{93}Np$ while fast neutrons Produce fission in $^{232}_{90}Th$, $^{231}_{93}Pa$, $^{242}_{94}Pu$

- There is invariably mass defect during Fission i.e. total mass of Products of fission is less than the total mass of the neutron & the ^{235}U atom. The loss in mass appears in the form of energy. according to Einstein's mass-energy relation. $E = mc^2$.

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow \left(^{236}_{92}U\right) \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$$

Excited atom

- The energy released in one fission reach is different from the energy released in another fission reach. The number of neutrons released also varies from one fission reach to another. But, on an average, approximately 200 MeV energy & 2.5 neutrons are released in the fission of an atom of $^{235}_{92}U$.

fission Heat

③ Nuclear Fuels:-

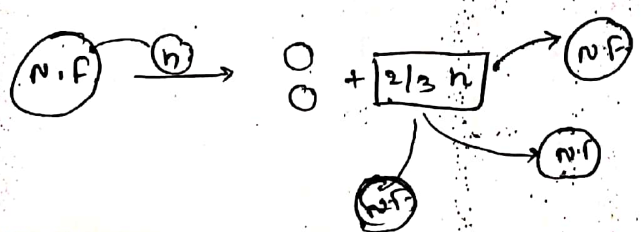
Nuclear Fuels is a substance that is used in nuclear power stations to produce heat to power turbines. Heat is created when nuclear fuel undergoes nuclear fission

- most nuclear fuels contain heavy fissile elements that are capable of nuclear fission, such as Uranium - 235 or Plutonium - 239. when the unstable nuclei of these atoms are hit by a slow-moving neutron, they split, creating two daughter nuclei & two to three more neutrons. These neutrons then go on to split more nuclei. This creates a self - sustaining chain reach that is controlled in a nuclear reactor, or uncontrolled in nuclear weapon.

⇒ The Processes involved in mining, refining, purifying, using & disposing of nuclear fuel are collectively known as the nuclear fuel cycle.

Nuclear Fuel has the highest energy density of all fuel sources.

e.g. → The neutrons that are released by the splitting of U^{235} are absorbed more readily by U^{238} than by other U^{235} nuclei. However, when the neutrons are slowed down by moderator, they are readily absorbed by U^{235}, so it is possible to sustain a chain reaction with low fractional abudance of the isotope. Heavy water, light water & graphite are the most commonly used moderators.



Chain Reach] Controlled in nuclear reactor.

fissionable 0.7% non-fissionable 235 U 99.3%

Plutonium Bomb:-

The ordinary uranium contains only of about 0.7% of ^{235}U which is fissionable. At the same time it is extremely difficult to isolate ^{235}U from the other non-fissionable isotopes present in ordinary uranium. It was found that plutonium which does not occur in nature but which can be prepared from the more abundant (99.3%) isotope ^{238}U, undergoes fission readily like ^{235}U.

The prepar^n of plutonium from uranium involves the following steps

$$^{238}_{92}U + ^{1}_{0}n \xrightarrow[\text{by neutron}]{\text{Bombardent}} ^{239}_{92}U \text{ (Excited nucleus)}$$

$$^{239}_{92}U \xrightarrow{-\beta} ^{239}_{93}Np + ^{0}_{-1}e$$

$$^{239}_{93}Np \xrightarrow{-\beta} ^{239}_{94}Pu + ^{0}_{-1}e$$

mushroom cloud
18 km
named as Fat man
18 km
Nagasaki 6 Aug 1945
(2 lac dead)

Plutonium being chemically different from uranium, can be separated easily. It has $t_{1/2}$ close to 24,000 years.

The discovery of plutonium solved the problems of release of nuclear energy through nuclear fission.

It is estimated that the energy released by a gram of plutonium is equal to that released by about 30 tons of T.N.T. This forms the basis of the manufacture of plutonium bomb.

[1 gm produce 8.68×10^{7} KJ]

Nuclear fusion

A reaction in which two lighter nuclei combine to form a heavier nucleus accompanied by release of energy is called nuclear Fusion.

e.g. $$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n + 17.6 \text{ meV}$$

When the two nuclei to be fused are brought together, they experience a very large coulombic repulsion. Thus, the fusion can occur only by making one nucleus collide with another highly energetically, that is, the K.E. of each nucleus should be kept very high so as to overcome the repulsive ~~coulo~~ coulombic potential energy barrier betn them. This requires a very high temperature, of the order of millions of degrees.

- A nuclear Fusion reacn is highly exoergic. Nuclear fusion reacn are called as thermonuclear reactions.
- Fusion reactions are more energetic than fission reacn. The fusion of 1gm of deuterium would result in the energy equivalent to that of 65 tonnes of TNT.

(6) Hydrogen Bomb :-

The nuclear fusion is the basic Principle involved in the Preparation of hydrogen bomb. Thus temp. required for fusion In this bomb is initially Produced by a nuclear Fission.

A hydrogen bomb consist of an arrangement of nuclear fission in the centre. It is surrounded by a mixture of deuterium ($^{2}_{1}H$) & lithium-6 isotope ($^{6}_{3}Li$). The nuclear fission Provides heat & neutrons.

The neutrons are used in converting lithium isotope into tritium (^3_1H) & the heat liberated is used for the fusion betn ^2_1H & ^3_1H to start. The fusion reactions are then accompanied by the liberation of a large amount of energy. The reach taking place in a hydrogen bomb is represented as follows.

⇒ Fission (in the centre) ⟶ Heat + neutrons

$$^6_3Li + ^1_0n \xrightarrow{Fission} ^3_1H + ^4_2He + 4.78\ mev.$$

Tritium

$$^2_1H + ^3_1H \xrightarrow{Fusion} ^4_2He + ^1_0n + 17.6\ mev.$$

Deuterium Tritium

$$^2_1H + ^2_1H \longrightarrow ^3_2He + ^1_0n + 3.3\ mev$$

$$^3_1H + ^3_1H \longrightarrow ^4_2He + 2\,^1_0n + 11\ mev.$$

The heat & K.E. released in Fusion destroy the place where such a bomb is exploded. A hydrogen bomb is far more powerful than an atom bomb due to rapid release of tremendous amount of energy

Nuclear Fusion in the sun's atmosphere:-

The energy of the sun is supposed to arise from the fusion of nuclei of hydrogen present in the atmosphere of the sun to give helium by following thermonuclear fusion reaction

i) $^{1}_{1}H + ^{1}_{1}H \longrightarrow ^{2}_{1}H + ^{0}_{+1}e +$ Energy

Deuteron Positron

ii) $^{2}_{1}H + ^{1}_{1}H \longrightarrow ^{3}_{2}He +$ Energy

iii) $^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + 2\,^{1}_{1}H +$ Energy.

The total 6 hydrogen nuclei are used in all stages.

The first two process occur twice to obtain the nuclei of the isotope $^{3}_{2}He$. For stage (iii).

The overall reac^n is written as

$$4\,^{1}_{1}H \longrightarrow ^{4}_{2}He + 2\,^{0}_{+1}e$$

Positron

It is noted that the conversion of hydrogen into helium, which is the source of solar energy, is so slow even at such a high temperature as that of the sun that it take several million years for the conversion of 1 gm of hydrogen into helium. The reason why the sun is capable of producing energy at a high rate lies in its enormous size.

* Applications of Radioisotopes:

* In Medicine:

- Radio isotope of iodine ($^{131}_{53}I$) ($t_{1/2} = 8$ days) is given to a patient with thyroid disorders. It decays with β-emission. Detection of β-rays gives information regarding functioning of the thyroid gland.

- Radio isotope of $^{131}_{53}I$ used to detect brain tumor and also used to determine the efficiency of blood circulations.

- Phosphate containing radioactive isotope of phosphorus ($^{34}P^{*}$) is administered to patients suffering from bone fracture to check if phosphorus is being absorbed by the bone or not.

- In surgery, for example, in order to find out if blood is circulating to a wound or not, a radioactive isotope is injected into the body and after a suitable time the blood from the wound is examined for its radioactivity.

* In Agriculture:

- calcium phosphate containing radioactive phosphorus is generally used to trace the uptake of phosphorus by plants.

* In Industry:

- In research and process control: The flow of petroleum through underground pipeline is followed by mixing antimony-124 as tracer element with it.
- As a catalyst: Manufacture of C_2H_5Br from ethylene & HBr is catalysed by γ-rays from ^{60}Co.

• ^{60}Co finds use in the quality control of castings, welded piped and fabricated machine parts.

* **Carbon dating:**

The isotope $^{14}_{6}C$ is radioactive. The atmospheric carbon-dioxide is a mixture of $^{14}CO_2$ and $^{12}CO_2$ present in a fixed ratio. Plants absorbs CO_2 from the atmosphere and prepare wood. As long as the plant is alive the ratio of $^{14}_{6}C/^{12}_{6}C$ atoms in wood is the same as in the atmosphere. When the tree is cut, its cycle stops. and the ratio of $^{14}_{6}C/^{12}_{6}C$ begins to diminish as the $^{14}_{6}C$ atom are constantly disintegrating. Determination of the above ratio gives an idea about the age of the wood sample, i.e., the length of time which elapsed after the death of the living plant.

* **Radio therapy:**

^{60}Co emits high energy γ-rays. These are used for testing deep-seated cancer growth. Radio isotope of phosphorus is being used for treatment of leukemia and that of radio iodine for treatment of hyper thyroidism.