① **Nature of nuclear forces :-**

A peculiar type of force is believed to operate inside the nucleus which holds the nucleons together.

Features :- ① It can not be electrical or gravitational force as the electric force ~~(2)~~ bet^n two proton is repulsive & the binding of neutral neutrons can not be covered by electric forces. again their magnitudes is much weaker than estimated nuclear binding forces.

② This is a very short range force.

③ The binding energy would increase with increasing the no. of nucleon.

④ Nuclear force is charge independent & irrespective of their nature.

⑤ The magnitude of the force bet^n two nucleons depend on the direction of the spin of the nucleons.

So it is clear that nuclear force is quite complicated. π meson theory is accepted to explain Nuclear Binding ~~Forces~~ Forces.

Nuclear stability may be explained by rapid exchange of π meson bet^n two nearest nucleons irrespective of their nature. This sort of exchange of π-meson is very rapid & operates only bet^n two nearest neighbours. As a result of this nucleons are attracted overcoming their repulsive interaction.

Schematic Presentation :-

π meson → π^+ (π-positive), π^- (π-negative), π^0 (π-neutral)

$$P + n \longrightarrow (n + \pi^+) + n \longrightarrow n + (n + \pi^+) \longrightarrow n + p$$

(rapid interconversion of nucleons through the interchange of π-mesn)

p → proton
n → ~~nute~~ neutron } → nucleon.

② **Uses of radioisotope**

ⓐ Radiocarbon dating

ⓑ Age determination of archeological specimen.

ⓒ Agricultural & Laboratory purposes.

ⓓ Medicinal purposes. (**)

Use of radioisotopes in Medicinal purpose

1) Co^{60} → External radiation therapy for Cancer treatment.
2) Na^{24} → Along with Salt Solution, it is used to trace the flow of blood in the body.
3) I^{131} → Internal radiation therapy for treatment of Thyroid diseases.
4) P^{32} → Leucomia disease.
5) Radiowaves are used to stimulate sudden nuclei in the presence of extremely powerful magnetic field.

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(3) Artificial Radioactivity :-

Irene Curie & Frederic Joliot Curie showed that when Al-target was bombarded by α particle, the reacⁿ produced a radioactive P which is a positron emitter.

$${}_{13}Al^{27} + {}_{2}He^{4} \longrightarrow {}_{15}^{*}P^{30} + {}_{0}n^{1}$$

(* → Indicate the element is radioactive)

$${}_{15}^{*}P^{30} \longrightarrow {}_{14}Si^{30} + \underset{\text{positron}}{e^{0}_{+1}} + \nu$$

They showed that on withdrawing the source of α particle, neutron emission is stopped but positron emission is continued.

Schematic Presentation

$\boxed{{}_{13}Al^{27}}$ ← bombarded with α particle (which initiates radioactivity)

non radio active element

→ $\boxed{{}_{15}^{*}P^{30}}$ + ${}_0n^1$ (comes only from ${}_{13}^{27}Al + \alpha$, if they are absent no ${}_0n^1$ emission)

radioactive element → show release of radioactive radiation is started.

radioactive decay ↓

$\boxed{{}_{14}Si^{30}}$ + e^{0}_{+1} + ν

Nonradio active

e^{0}_{+1} → comes only from ${}_{15}^{*}P^{30}$ decay.

Conclusion

As product ${}_0^1n + {}_{+1}e^0 \Rightarrow {}_{13}^{27}Al + \alpha \longrightarrow {}_{15}^{*}P^{30} + {}_0n^1 \longrightarrow {}_{14}Si^{30} + {}_{+1}e^0 + \nu$

~~As product~~

chemically formation of a new element through radioactive decay

⇓

Artificial Radioactivity.

NUCLEAR SPALLATION :

When a target nucleus is bombarded with high energy particles like 400 MeV proton or 200 MeV deuterons ~~are these~~ then it ~~bara~~ breaks into several smaller nuclei with emission of a large no. of nucleons. Such reactions are called spallation reactions.

$$As^{75}_{33} + H^{2}_{1} \longrightarrow Mn^{56}_{25} + 9H^{1}_{1} + 12n^{1}_{0}$$

$$U^{238}_{92} + He^{4}_{2} \longrightarrow W^{187}_{74} + 20H^{1}_{1} + 35n^{1}_{0}.$$

Characteristic features :

1) Spallation may occur with light as well as heavy nuclei
2) In heavier nuclei, fission and spallation may occur at the same time.
3) In spallation only a single massive fragment is obtained.
4) The product fragment differs in mass by 10 to 20 units from the product.
5) The process is not a self-sustaining one.
6) A large no of nucleons are emitted.

FISSION VS SPALLATION :

1) Fission gives two products of comparable masses but spallation gives a single heavy product
2) Fission is a self sustaining process but spallation is not.
3) Fission occurs only for heavy elements but spallation occurs for both heavy ~~and~~ elements and for element of intermediate mass numbers.
4) ~~Effected~~ Ejected particles are more in a spallation reaction than in a fission reaction.
5) In fission the masses of the fragments are very much less than that of the target. But in spallation its masses differ by 10 to 20 units from the target

NUCLEAR FUSION :

This is a nuclear reaction where two or more light nuclei fuse together to give a heavier nuclei with liberation of tremendous amount of energy.

$$H_1^2 + H_1^3 \longrightarrow He_2^4 + n_0^1 + 17.6 \text{ MeV}.$$

$$4H_1^1 \longrightarrow He_2^4 + 2e_{+1}^0 + 2\nu_0^0 + 27 \text{ MeV}.$$

Characteristic features :

① The process has a very high activation energy. This is because the energy barrier for the collision of two positively charged cores is very high. The colliding nuclei must have enough kinetic energy to overcome this energy barrier. Therefore, this reaction occurs only at a very high temperature and called thermonuclear reaction.

② This reaction is accompanied by liberation of a tremendous amount of energy. The BE/nucleon of the product is much higher than that of the reactant.

③ Once started, the energy released maintains the temperature and the reaction may continue in a self-sustaining process.

④ Energy in sun, stars etc. is believed to be continuous fusion process at very high temp.

⑤ Calculation of energy

$$4H_1^1 \longrightarrow He_2^4 + 2e_{+1}^0 + 2\nu.$$

$$\text{mass defect} = (4 \times 1.00728 \text{ amu}) - (4.0015 \text{ amu} + 2 \times 0.0005 \text{ amu})$$

$$= 0.0265 \text{ amu}$$

So energy released per He nucleus formed $= (0.0265 \times 931)$ MeV

$\simeq 27$ MeV.

⑥ Efficiency of fusion process is 0.38%

NUCLEAR FISSION:

The process of splitting up of a heavy nucleus into two roughly equal parts on bombardment is called nuclear fission. This is accompanied by liberation of some neutrons and enormous energy.

U^{235} nucleus on bombardment by a slow neutron splits into two lighter fragments of comparable size

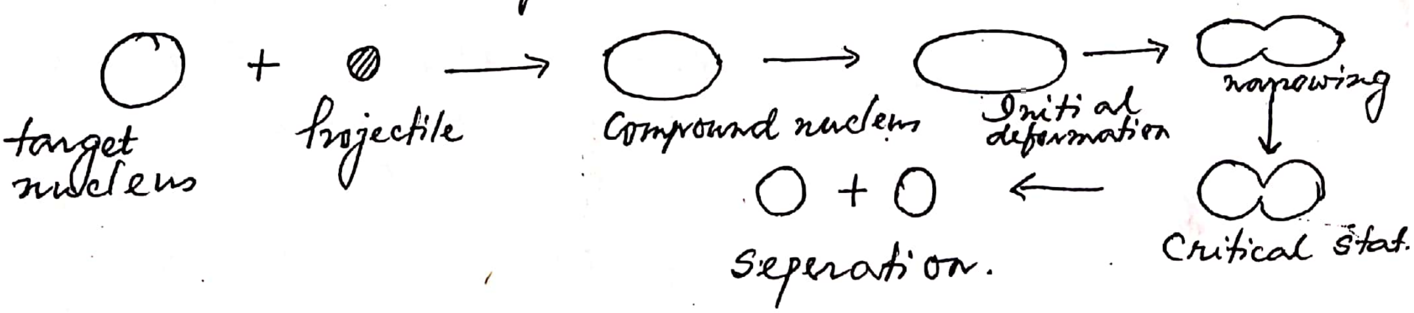
$$U^{235} + n_0^1 \longrightarrow Kr_{36}^{92} + Ba_{56}^{141} + 3n_0^1 + Q$$

$$[Q \approx 200\ MeV]$$

The difference in the masses of products and the reactants is converted into energy which is released.

Characteristic features of Nuclear Fission:

a) Mechanism: This can be well understood by liquid drop model. A liquid drop retains its spherical shape due to surface tension. On application of energy sufficient to counter the surface tension the liquid drop may be forced to move from a sphere to an ellipsoid, then to a dumbell and finally into two spheres. Similarly if sufficient energy is introduced into U^{235} by bombardment with neutron, then the compound nucleus might behave as a liquid drop. Under the influence of a distortion force this nucleus may ultimately break up into two nuclei of close mass numbers.



b) Fission fragments:

The products of fission belong to two groups — one having mass numbers 85 to 104 while the other has mass numbers 130 to 149.

SEPARATION OF ISOTOPES BY SZILARD – CHALMER'S PROCESS:

Sometimes, by selecting suitable nuclear reactions, the product isotopic ~~mass~~ nuclei can be easily seperated from the parent isotopic nuclei because of their diff. chemical states. In case of slow neutron reactions of the type (n, γ) type the product nucleus and the target nucleus have the same atomic no. and hence the same chemical properties. No chemical seperation is possible in such cases.

Interestingly, during the ejection of a γ-ray photon the product nucleus recoils and gets automatically dissociated from the parent molecule. Now the target nuclide and which remains bound to the molecule is in a diff. chemical state from the product nuclide. Thus they can be seperated by selecting some suitable reactions. This is the basis of Szilard-Chalmers' reaction to seperate the isotopes.

Example: $C_2H_5I^{127} + n^1 \rightarrow C_2H_5\overset{*}{I}^{128} \longrightarrow I^{128} + C_2H_5$

Here $C_2H_5I^{127}$ on being bombarded by slow neutrons in presence of H_2O produces I^{128} that readily passes into the aqueous phase while the non radioactive I^{127} isotope remains bound to the organic molecule. By using suitable org. substances the isotop- can be seperated.

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