Nuclear Fission

The phenomena of the division of a heavy nucleus into two nearly equal parts is termed as Nuclear fission.

- The schematic eqn. for the fission process may be written as.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow (^{236}_{92}U) \rightarrow X + Y + \text{neutrons.}$$

Here X & Y are the fission fragment

Typically fission reaction are

(i) $^{235}_{92}U + ^{1}_{0}n \rightarrow (^{236}_{92}U) \rightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3^{1}_{0}n + Q$

(ii) $^{235}_{92}U + ^{1}_{0}n \rightarrow (^{236}_{92}U) \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n + Q$

Energy Released in Fission n.

- The Energy released in the fission process is so high that the two main fission products fly apart in opposite direction with great speeds as comformed.

by many cloud chamber photograph.

Actual kinetic energy of the separate particle is about 180 MeV. & the energy of the gamma radiation emitted in the process is about 20 MeV

The following calculation is given below.

Before fission:

$^{235}_{92}U$ = 235.0439 amu.

$^{1}_{0}n$ = 1.0087 amu.

Total = 336.0526 amu.

After fission:

$^{140}_{58}Ce$ = 139.9054 amu

$^{94}_{40}Zr$ = 93.9036 amu.

$2\,^{1}_{0}n$ = 2.0173 amu.

$6\beta^{-}$ = 0.0033 amu

Total = 235.8296 amu

Mass difference = (236.0526 − 235.8296) amu,

= 0.223 amu.

This represents a Q-value given by

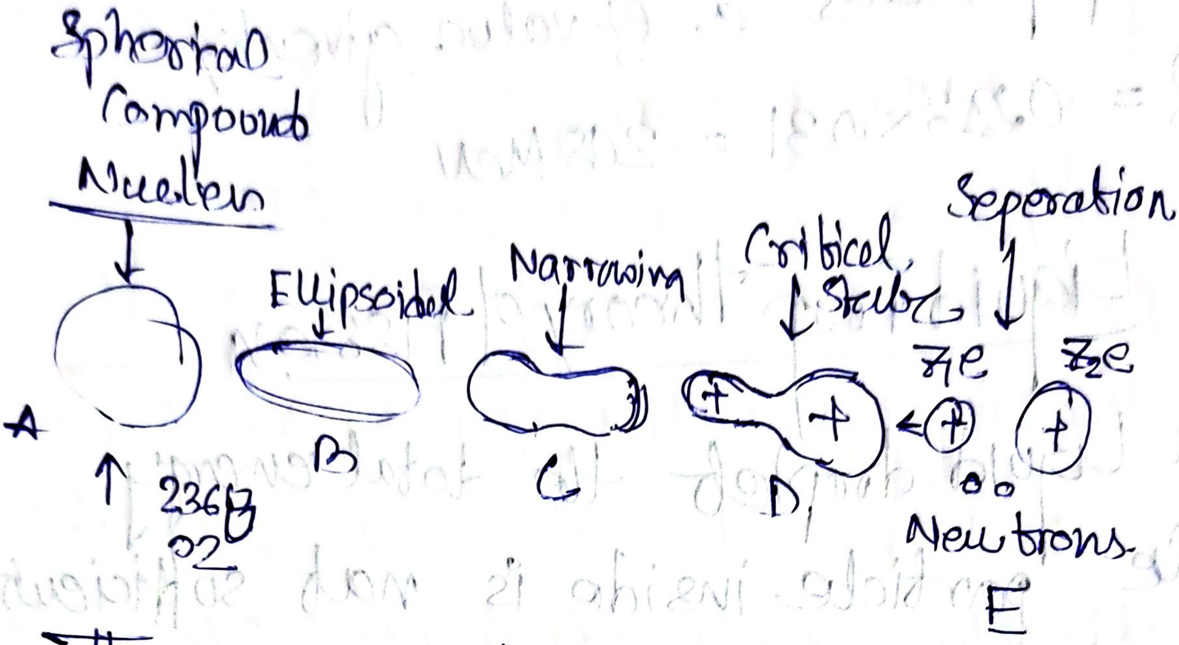
$$Q = 0.223 \times 931 = 208 \text{ MeV}.$$

Liquid Drop theory of Fission

In a liquid droplet the total energy of the particle inside is not sufficient enough to overcome the forces that hold the particle together in the form of droplet. But if some energy is added to the droplet so ~~as~~ as to set into vibration, it will alternately elongate & contract. If the amplitude of vibration be sufficiently large the droplet might devide itself into two more ~~of~~ or less equal parts.

~~The coulomb~~

According to Bohr's such a situation arises in the nucleus when bombarded with neutron & results in the fission.



The value of the critical energy,

$$E_{crit} = 0.89 A^{2/3} - 0.02 \frac{Z(Z-1)}{A^{1/3}} \text{ MeV.}$$

* Critical Energy of U^{235}_{92}

$A = 235$, $Z = 92$

$$E_{crit} = 0.89(235)^{2/3} - 0.02\left(\frac{92(92-1)}{(235)^{1/3}}\right)$$

$= 33.9884486 - 27.0049621$

$= ~~33.8923681 - 27.1333402~~$

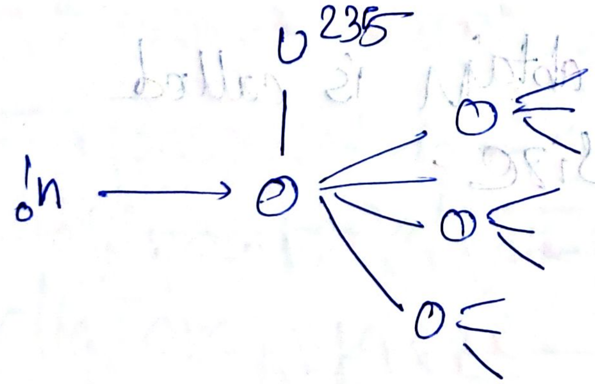
$= ~~6.7590270~~$ ~~MeV~~ $= 6.9834$

$\simeq$ ~~6.76~~ MeV.

$\simeq 6.9$ MeV.

Nuclear Chain Reaction

In each event of a fission reaction with heavie nuclie, the highly excited Nuclie, emit two of three prompt neutrons as correctly suggested by fermi, this fission producing neutrons interacts with neighbourie nuclie & produce intern fission in them. So that more neutrons are emitted the result is an avalanch like buildup a fission events. Such a fission reaction is called a Chain Reaction



Critical Mass

The important point in the possibility of achiving of chain reaction is the size of the core. the core is the space in which the chain reaction takes place. Reduction in the size of the core would increase, the number of the neutrons that escape beyond the core & would thus reduce the possibility of further development of chain Reaction.

The minimum size of the core at which a chain reaction can still be obtain is called the critical size.

Reproduction Factor

Let, at an instant there be N_0, ~~first~~ fast neutrons available to produce a fission a few of this may induce fission in capital U-238, so that the available neutrons increase in number by a factor μ & become $(N_0)\mu$. if Small "p" be the fraction slowed down then the available neutrons are $N_0\mu p$ of this again a fraction f may succeed in producing fission in U-235. Before being lost by diffusion. So the number U-235 is $N_0 \mu p f$. If at each fission U-235, e fast neutron are generated to restart the cycle. The total number of ~~electron~~ neutron after one cycle is

$$N = N_0 \mu p f e$$

$\frac{N}{N_0} = \epsilon f p \cdot e$ = Reproduction Factor = k

$$k = \frac{\text{Rate of neutron production}}{\text{Rate of neutron dissappearance}}$$

T/W Nucler Reaction

Nucler Fussion

If two Light nuclei combined or fused together to produce a relatively heavier nucleas, there would be a greater binding energy an conicequent decrease in nucler mass this type of nucler reaction is known as Nucler Fussion.

$$_1^1H + _1^1H \rightarrow _1^2H + _1^0e + \nu; \; Q = 0.42\,MeV$$

$$_1^2H + _1^2H \rightarrow _2^3He + _0^1n; \; Q = 3.3\,MeV$$

Proton-Proton Cycle

(a) $_1^1H + _1^1H \rightarrow _1^2H + _1^0e + \nu + 0.42\ MeV$

(b) $_1^2H + _1^1H \rightarrow _2^3He + \gamma + 5.5\ MeV$

(c) $_2^3He + _2^3He \rightarrow _2^4He + 2\,_1^1H + 12.8\ MeV$

Finally

$$4\,_1^1H \rightarrow _2^4He + 2\,_1^0e + 2\nu + 2\gamma$$

Carbon-Nitrogen Cycle

(a) $_1^1H + _6^{12}C \rightarrow _7^{13}N^* + \gamma + 1.95\ MeV$

(b) $_7^{13}N^* \xrightarrow{10.1\ min} _6^{13}C + _1^0e + \nu + 2.22\ MeV$

(c) $_1^1H + _6^{13}C \rightarrow _7^{14}N + \gamma + 7.54\ MeV$

(d) $_7^{14}N + _1^1H \rightarrow _8^{15}O^* + \gamma + 7.35\ MeV$

(e) $_8^{15}O^* \xrightarrow{2.05\ min} _7^{15}N + _1^0e + \nu + 2.7\ MeV$

(f) $_1^1H + _7^{15}N \rightarrow _6^{12}C + _2^4He + 4.96\ MeV$

The net result is:

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e + 2\nu + 3\gamma + 26.72\,MeV$$