Stability of Nucleus:

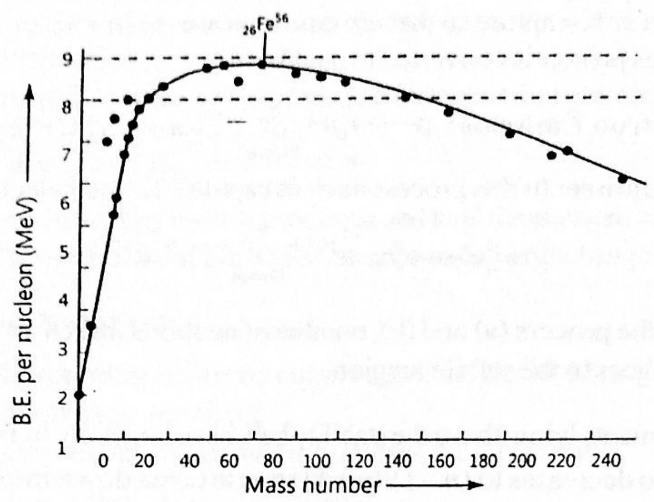
Stability of nucleus can be explained on the basis of following theories.

(1) Binding Energy and B.E. per Nucleon:

Binding energy of nucleus is the measure of stability of nucleus. The stability of nuclei of same mass number can be explained on the basis of binding energy but the stability of elements different mass number can not be explained on the basis of binding energy. The nuclei of same mass number having the larger binding energy are more stable. Binding energy increases with increase in mass number but for higher mass number, the rate of increase in binding energy becomes slow, because nuclei having higher number of nucleons have larger binding energy.

The stability of nuclei of different mass number and the same mass number can be explained on the bases of B.E. per nucleon $(\bar{B})$.

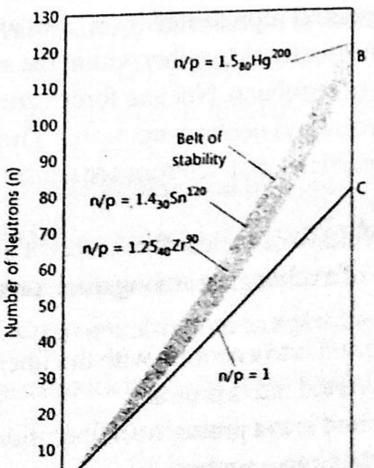
The nucleus with large B.E. per nucleon is more stable. When a graph is plotted b/w B.E. per nucleon and mass number of differnt nuclei, the following curve is obtained. This curve is called nuclear binding energy curve.



Except $^{4}_{2}He$, $^{12}_{6}C$ and $^{16}_{8}O$, all the elements lie on this curve. B.E. per nucleon of heavy elements is small, so these elements are radioactive. The heavy elements are disintegrated and after disintegration stable nuclei are formed because these stable nuclei have larger value of B.E. per nucleon.
The maximum B.E. per nucleon (8.7 MeV) is of iron so iron is found in nature in abundance.
Maximum stable nuclei have near about 8 MeV.

(2) Ratio of Neutrons and Protons (N/P Ratio):

The stability of nucleus can also be explained on the basis of *n/p* ratio. The nuclei of elements for which the value of *n/p* is in the range 1 to 1.52 are stable. The value of *n/p* for hydrogen $\left(^{1}_{1}H\right)$ is zero and this $^{1}_{1}H$ nucleus is stable because it has only one proton and no electron and no force of repulsion works in this nucleus. The most abundant stable isotopes of other elements upto $_{20}Ca$ (including $_{20}Ca$ also) usually have the same number of protons and neutrons ($^{4}_{2}He$, $^{12}_{6}C$, $^{28}_{14}Se$, etc for example) or have only one more neutron than proton ($^{11}_{5}B$, $^{19}_{9}F$ and $^{23}_{11}Na$, For example), i.e., these elements have value of $n/p \sim 1$. If number of neutrons is plotted against the number of protons, the following curve is obained which shown by dots. This curve is called nuclear stability belt. The nuclei with atomic number upto 20 have *n/p* ratio close to 1 i.e., plot is linear. With increase in atomic number, the graph becomes curved which slope increases grdually. The nuclei with *n/p* ratio lying above or below the stability belt are unstable. They undergo positron $\left(\beta^{+}\right)$ emission or K-capture or lose of a α or β-particles so that their *n/p* ratio falls within the stability belt.



1. The elements lying below the stability belt, have lesser number of neutrons. These elements decay by positron emission or K-capture so that *n/p* ratio increases to $(n+1)/(p-1)$ so as to go up into the stability belt. In these processes proton is converted to neutron.

(a) Positron Emission: ${}_{1}^{1}p \longrightarrow {}_{0}^{1}n + \underset{\text{Positron}}{{}_{+1}^{0}e}$; ${}_{7}^{13}Na \longrightarrow {}_{6}^{13}C + {}_{+1}^{0}e + v$; ${}_{15}^{30}P \longrightarrow {}_{14}^{30}Si + {}_{+1}^{0}e$

(b) K-capture: In this process nucleus captures K-shell electron.

$${}_{1}^{1}p + {}_{-1}^{0}e \longrightarrow {}_{0}^{1}n; \quad {}_{37}^{81}Rb + \underset{\text{Electron}}{{}_{-1}^{0}e} \longrightarrow {}_{36}^{81}Kr$$

In both the process (a) and (b), number of neutrons increases so *n/p* ratio also increases and the new element formed goes to the stability region.

2. The elements lying above the stability belt, have larger no. of neutrons. These elements emit β-particles so that *n/p* ratio decreases to $(n-1)/(p+1)$ so as to come down into the stability belt. In this process, one neutrons is converted to β-particle and proton.

$$\underset{\text{Neutron}}{{}_{0}^{1}n} \longrightarrow \underset{\text{Proton}}{{}_{1}^{1}p} + \underset{\beta\text{-particle}}{{}_{-1}^{0}e} + \underset{\text{Antinutrino}}{\bar{v}}$$

$${}_{1}^{3}H \longrightarrow {}_{2}^{3}He + {}_{-1}^{0}e$$

$${}_{6}^{14}C \longrightarrow {}_{7}^{14}N + {}_{-1}^{0}e$$

3. The elements having mass number larger than 209 and atomic number larger than 83, have *n/p* ratio greater than 1.5 and these elements are radio active.

For example: ${}_{92}^{238}U$, $n/p = \dfrac{146}{92} = 1.58$; ${}_{90}^{234}U$, $n/p = \dfrac{144}{90} = 1.6$

These elements emit α-particles and form a stable nucleus.
In this process number of protons and neutrons decreases equally and the *n/p* ratio also decreases.

$${}_{92}^{238}U \rightarrow {}_{90}^{234}Th + \underset{\alpha\text{-particle}}{{}_{2}^{4}He}$$

Note : There are several elements which have *n/p* ratio smaller than 1.5 and are radio active.

For example: ${}_{6}^{14}C$, $n/p = \dfrac{8}{6} = 1.33$; ${}_{15}^{30}P$, $n/p = \dfrac{15}{15} = 1$; ${}_{7}^{13}N$, $n/p = \dfrac{6}{7} = 0.86$