# Nuclear Reaction

**Nuclear Reaction:** The reaction where nucleus of the atom is involved is called nuclear reaction. In a nuclear reaction a new element is formed. A nuclear reaction may occur spontaneously as in the phenomenon of natural radioactivity, or it may be brought about artificially.

**Artificial Transmutation of elements:** Conversion one element to another element through artificial nuclear reactions is called artificial transmutation of elements. Artificial nuclear reactions are brought about by bombardment of one element with neutron, proton, deuteron or alpha-particles. The element which is being bombarded is called the target and the particles by which bombardment occur is called projectile.

The first example of artificial transmutation was discovered by Rutherford (1929), where he bombarded pure nitrogen gas with high-energy alpha particle, producing an isotope of oxygen and high energy protons.

$$^{14}_{7}N + ^{4}_{2}He \rightarrow [^{18}_{9}F] \rightarrow ^{17}_{8}O + ^{1}_{1}H + Q \text{ (energy)}$$

Target Projectile Product Outgoing particle

It is $^{14}_{7}N$ (α,p) $^{17}_{8}O$ type nuclear reaction .

**Artificial radioactivity:** In an artificial transmutation reaction, if the product nucleus shows the radioactive property, then such type of radioactivity is known as artificial radioactivity. The artificial radioactivity was discovered by I. Curie and F. Joliot (1934) and the first discovered radioactive isotope is $^{30}_{15}P^{*}$. When $^{27}_{13}Al$ nucleus is bombarded with alpha particle of sufficient energy, then radioactive phosphorous is formed.

$$^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{15}P^{*} + ^{1}_{0}n \quad (\alpha,n)$$

$$^{30}_{15}P^{*} \rightarrow ^{30}_{14}Si + ^{0}_{+1}e$$

Type of nuclear reactions: According to use of projectile, the nuclear reaction may be classify into two categories:

**(I) Charged particle reaction**

Example: Charged Particle Reaction:

(a) Proton : (p,n), (p,α), (p,γ), (p,d)
(b) Deuteron: (d, p), (d,α), (d,γ), (d,n)
(c) Alpha particle: (α,n), (α,p),

**(II) Neutral particle reaction:**

**(i) Projectile Capture Reaction :** $^{12}_{6}C + {}^{1}_{1}H = {}^{14}_{6}C$

**(ii) Projectile Capture Particle Emission Reaction :** $^{12}_{7}N + {}^{1}_{0}n = {}^{14}_{6}C + {}^{1}_{1}H$

**(iii) Nuclear Fission Reaction:** $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + 200MeV$

**(iv) Nuclear Fusion Reaction:** $^{2}_{1}H + {}^{3}_{1}H = {}^{4}_{2}He + {}^{1}_{0}n$ **17.6 MeV**

**(v) Nuclear Spallation Reaction:** $^{75}_{33}As + {}^{2}_{1}H = {}^{56}_{25}Mn + 9\,{}^{1}_{1}H + 12\,{}^{1}_{0}n$

**Nuclear Fission Reaction:** When a heavy nucleus like $^{235}U$ is bombarded with a neutron of sufficient energy (slow neutron), it divides into two fragments of roughly equal parts and releases 2-3 neutrons and large amount of energy. This type of nuclear reaction is known as fission reaction. It is a self-sustaining chain reaction. The fission process occurs in nearly all nucleuses with mass number above 200 when bombarded with neutrons or other projectile of sufficient energy.

An example of typical fission reaction is as follows

$$^{235}_{92}U + {}^{1}_{0}n\,(slow) \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + 200\ MeV$$

**Nuclear Fusion Reaction**: When isotopes of very light nuclei like $^{2}_{1}H, {}^{3}_{1}H$ etc. are fused together to form a stable larger nucleus then, a tremendous amount of energy is released. This type of nuclear reaction is called nuclear fusion reaction. To initiate such a nuclear fusion reaction a high temperature ($10^6$ K) is required. So, a fission reaction is required to attain such a high temperature.

Typical fusion reaction takes place between the two heavy isotopes of hydrogen in which the helium nucleus is the product.

$$^{2}_{1}H + {}^{3}_{1}H = {}^{4}_{2}He + {}^{1}_{0}n + 17.6\ MeV$$

A nuclear fusion reaction is the source of the tremendous energy developed in the detonation of the so-called “hydrogen bomb”.

[ May be (i) $^{2}_{1}H + ^{2}_{1}H = ^{4}_{2}He + 24.9$ MeV (ii) $^{3}_{1}H + ^{1}_{1}H = ^{4}_{2}He + 20$ MeV (iii) $^{3}_{1}H + ^{3}_{1}H = ^{4}_{2}He + 2\ ^{1}_{0}n + 11$ MeV]

**Spallation Reaction:** High-Speed charge projectile with energies approximately 400 MeV may chip fragments from a heavy nucleus, leaving a smaller nucleus which can be identified. Usually the nucleus so produced has atomic number 10 to 20 units lower than the original nucleus. This type of nuclear reaction is known as nuclear spallation reaction.

A hypothetical spallation reaction may be indicated by the following equation:

(i) $_{29}Cu^{63} + ^{4}_{2}He$ (400 MeV) $\rightarrow$ $_{17}Cl^{37} + 14\ ^{1}H_{1} + 16\ _{0}n^{1}$

(ii) $_{92}U^{238} + ^{4}_{2}He \rightarrow ^{187}W_{74} + 20\ ^{1}H_{1} + 35\ _{0}n^{1}$

Spallation differs from ordinary nuclear reactions to the extent that in the ordinary type reaction the nucleus is rarely reduced in atomic number by more than 2. Spallation differs from fission in that the reaction is not self sustaining. More over the change in mass for a spallation reaction is not as great as that in fission.

Question:

1. Explain why nuclear fusion is consider to be a more potential source of energy than nuclear fission.
2. Differentiate the nuclear spallation reaction with Fission reaction and Fusion reaction.

Try to solve it , otherwise I will do it.