

Radioactive Disintegration Series

When a radioactive element emits an α or β -particle a new element is formed. The element emitting α - or β -particle is called parent element and the new element formed is called daughter element. If the daughter element is radioactive, it again disintegrates by emitting α or β -particle forming a new element. Thus a daughter element becomes a parent element and a new element is formed. This process of disintegration goes on till the end product is a stable element (an isotope of lead or bismuth).

The series of spontaneous changes that take place starting from the parent element upto the formation of stable isotope is called radioactive series.

There are four radioactive series:

- (1) $4n$ series (Thorium series)
- (2) $(4n + 1)$ series (Neptunium series)
- (3) $(4n + 2)$ series (Uranium series)
- (4) $(4n + 3)$ series (Actinium series)

Series	Name of the Series	Starting Element	Stable and Product	Value of n for the starting element	Value of n for the stable end product
$4n$	Thorium series	Th — 232	Pb — 208	58	52
$4n + 1$	Neptunium series	Pu — 241	Bi — 209	59	52
$4n + 2$	Uranium series	U — 238	Pb — 206	59	51
$4n + 3$	Actinium series	U — 235	Pb — 207	58	51

Nuclear Transmutation

Nuclear transmutation is the change of one element into another.

Types of Nuclear Transmutation:

- (1) Natural Transmutation
- (2) Artificial Transmutation



(1) Natural Transmutation

The radioactive element emit α or β -particle and a new element is formed. This process is called natural transmutation. This process is spontaneous.

(2) Artificial Transmutation

The process of converting one element into the other by artificial means, i.e., by bombarding the atom with high speed (or high energy) particle such as proton, neutron or α -particle is called artificial transmutation.

The first nuclear transmutation was accomplished in 1917 by Rutherford, who bombarded ^{14}N nuclei with α -particles and found that ^{17}O was produced.

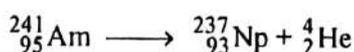
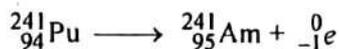


Synthesis of New Elements

Other nuclear transmutations can lead to the synthesis of entirely new elements never before seen on earth. Infact, all transuranium elements—Those elements with atomic number greater than 92 have been produced by bombardment reactions. Plutonium, for example, can be made by bombardment of uranium-238 with α -particles.



The plutonium-241 that results from uranium-238 bombardment is itself radioactive with half life of 14.4 days, decaying by β -emission to yield americium-241. Americium-241 is also radioactive, decaying by α -emission with a half life of 432 years.



Other Examples:

(a) Synthesis of Curium:



(b) Synthesis of Cf:



(c) Synthesis of ${}^{60}\text{Co}$:



Nuclear Reactions

When a bombarding particle (projectile) comes in close contact with the nucleus being hit, the incident particle and the target nucleus form a composite system and after a short while reaction takes place. Since in such a reaction nucleus of the target is changed into new nucleus, hence it is called a *nuclear reaction*. These reactions follow laws of conservation as given below:

(i) **Law of Conservation of mass and energy:** The total energy (rest energy and kinetic energy) of a particle before and after the reaction remains the same.

Since mass changes into energy ($E = mc^2$), hence during nuclear reactions, energy and mass are inter-convertible quantities inside

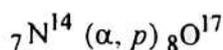
(ii) **Law of conservation of mass number:** The total number of nucleons (mass number) before and after the reaction is conserved.

(iii) **Law of conservation of atomic number:** The total charge (atomic number) before and after the reaction is conserved.

Such reactions are usually represented by the following notation (called **Bethe's notation**).

Target nucleus (bombarding particle i.e. *projectile*, particle emitted i.e., *ejectile*) product nucleus.

For Example:

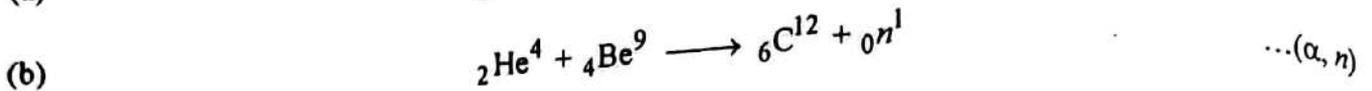
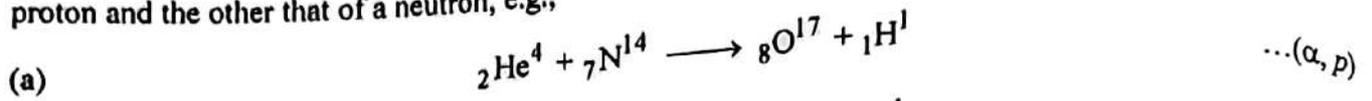


Similarly, $\text{Al}^{27} (\alpha, p) \text{Si}^{30}$ denotes that aluminium-27 is a target, α -particle is a projectile, proton is the ejectile (i.e., particle emitted) and silicon-30 is the product.



Different Types of Nuclear Reactions

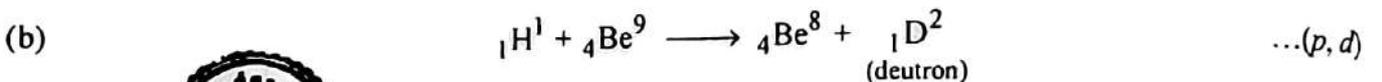
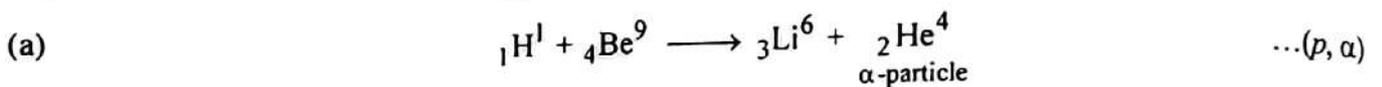
(i) **α -particle induced reactions:** Two types of reactions are observed, one involving the ejection of a proton and the other that of a neutron, e.g.,



(ii) **Neutron induced reaction:** Four types of reactions are observed. One example of each type is given below:



(iii) **Proton induced reaction:** Four types of disintegrations take place as follows:



(iv) **Deuterium induced reactions :** A few examples of this type are as follows:



A few examples of artificial disintegration by high energy γ -radiation have also been reported.
For example:



The reactions as given above are either **capture reactions** or **particle-particle reactions**. Capture reactions are those reactions in which the bombarding particle is absorbed by the nucleus and no massive particle is emitted except the product nucleus and γ -radiation e.g., (n, γ) and (p, γ) given above belong to this category. particle-particle reactions are those reactions in which in addition to product nucleus, a massive particle is also liberated. These are the most common types of nuclear reactions. Besides these, we also have **fission reactions, spallation reactions** and **fusion reactions**.