Further investigations proved that an $\alpha-$ particle has a mass 4 amu and charge +2e. In other words, $\alpha-$ particles are helium nuclei. The charge and mass of a $\beta-$ particle are the same as those of an electron. Thus $\beta-$ particles are electrons. The $\gamma-$rays are electromagnetic waves of very high frequencies, i.e. very small wavelengths.
When $\alpha-$ particle is emmited by nucleus of radioactive substance an atom, its atomic number decreases by 2 and mass number decreases by 4.
When $\beta-$ particles is emited by nucleus of radioactive substance atomic number increases by 1 but mass number remains same.

The decaying nucleus is called the ***parent nucleus*** while the nucleus produced after the decay is called the ***daughter nucleus.*** The process is called ***radioactive decay*** or ***radioactivity*** and was discovered by Becquerel (1852-1908) in 1876. Radioactive decays occur because the parent nuclei are unstable and get converted to more stable daughter nuclei by the emission of some particles. These decays are of three types as described below.

Alpha Decay:

In this type of decay, the parent nucleus emits an alpha particle which is the nucleus of helium atom. The parent nucleus thus loses two protons and two neutrons. The decay can be expressed as

$$_Z^AX \rightarrow _{Z-2}^{A-4}Y + \alpha$$

X is the parent nucleus and Y is the daughter nucleus. All nuclei with A > 210 undergo alpha decay. The reason is that these nuclei have a large number of protons. The electrostatic repulsion between them is very large and the attractive nuclear forces between the nucleons are not able to cope with it. This makes the nucleus unstable and it tries to reduce the number of its protons by ejecting them in the form of alpha particles. An example of this is the alpha decay of bismuth which is the parent nucleus with A = 212 and 2 = 83. The daughter nucleus has A= 208 and 2 = 81, which is thallium. The reaction is

$$_{83}^{212}Bi \rightarrow _{81}^{208}T1 + \alpha$$

The total mass of the products of an alpha decay is always less than the mass of the parent atom. The excess mass appears as the kinetic energy of the products. The difference in the energy equivalent of the mass of the parent atom and that of the sum of masses of the products is called the Q-value, Q of the decay and is equal to the kinetic energy of the products. We can write,

$$Q = \left[m_X - m_Y - m_{He}\right]C^2$$

m_X, m_Y and M_{He} being the massses of the parent atom, the daughter atom and the helium atom. Note that we have used atomic masses to calculate the Q factor.

Beta Decay:

In this type of decay the nucleus emits an electron produced by converting a neutron in the nucleus into a proton. Thus, the basic process which takes place inside the parent nucleus is

$$n \rightarrow p + e^- + \text{antineutrino}$$

Neutrino and antineutrino are particles have very little mass and no charge. During beta decay, the number of nucleons i.e., the mass number of the nucleus remains unchanged. The daughter nucleus has one less neutron and one extra proton. Thus, Z increases by one and Ndecreases by one, A remaining constant. The decay can be written as,

$${}_{Z}^{A}X \rightarrow {}_{Z+1}^{A}Y + e^{-} + \text{antineutrino}$$

An example is

$${}_{27}^{60}Co \rightarrow {}_{28}^{60}Ni + e^{-} + \text{antineutrino}$$

There is another type of beta decay called the ***beta plus decay*** in which a proton gets converted to a neutron by emitting a positron and a neutrino. A positron is a particle with the same properties as an electron except that its charge is positive. It is known as the antiparticle of electron. This decay can be written as,

$$\text{p} \rightarrow \text{n} + \text{e}^{+} + \text{neutrino}$$

The mass number remains unchanged during the decay but Z increases by one and N decreases by one. The decay can be written as

$${}_{Z}^{A}X \rightarrow {}_{Z+1}^{A}Y + e^{+} + \text{neutrino}$$

An example is

$${}_{11}^{22}Na \rightarrow {}_{12}^{22}Ne + e^{+} + \text{neutrino}$$

Gamma Decay:

In this type of decay, gamma rays are emitted by the parent nucleus. As we know, gamma ray is a high energy photon. The daughter nucleus is same as the parent nucleus as no other particle is emitted, but it has less energy as some energy goes out in the form of the emitted gamma ray. We have seen that the electrons in an atom are arranged in different energy levels (orbits) and an electron from a higher orbit can make a transition to the lower orbit emitting a photon in the process. The situation in a nucleus is similar. The nucleons occupy energy levels with different energies. A nucleon can make a transition from a higher energy level to a lower energy level, emitting a photon in the process. The difference between atomic and nuclear energy levels is in their energies and energy separations. Energies and the differences in the energies of different levels in an atom are of the order of a few eVs, while those in the case of a nucleus are of the order of a few keV to a few MeV. Therefore, whereas the radiations emitted by atoms are in the ultraviolet to radio region, the radiations emitted by nuclei are in the range of gamma rays.

Units for measuring masses of atoms and sab atomic particles

A: Kg

m_e - $9.109383 \times 10^{-31} kg$

m_p - $1.672623 \times 10^{-27} kg$

m_n- $1.674927 \times 10^{-27} kg$

B : Amu Atomic mass unit (u)

$1u = 1.6605402 \times 10^{-27} kg$

m_e - 0.00055 u
m_p - 1.007825 u
m_n - 1.008665 u

C : $E = mc^2$ 1 u = 931.5 Mev/c^2
m = E / c^2
Mass in terms of energy equivalent

m_e - 0.511 MeV / c^2

m_p - 938.28 MeV / c^2

m_n - 939.57 MeV / c^2

Example : Calculate mass defect and binding energy of ${}_{27}CO^{59}$ which has a nucleus of mass *58.933 u (amu)*

Given m_p = 1.0078 u m_n = 1.0087 u

${}_{27}CO^{59} \rightarrow {}_Z X^A$ Z = 27 (proton)

A - Z - 59 - 27 = 32 (Neutron)

mass defet $\Delta m = 27 \times 1.0078 + 32 \times 1.0087 - 58.933u$

$\Delta m = [27.2106 + 32.2784] - 58.933$

$\Delta m = 59.487 - 58.933$

$\Delta m = 0.556u(amu)$ 1u = 931 MeV/c^2

BE = 517.914 MeV

Example : Calculate radius and density of Ge nucleus given that its mass to be approximately 69.924 u.

$R_x = RoA^{1/3}$

$R_{Ge} = Ro(70)^{1/3}$

$R_{Ge} = 1.2 \times 10^{-15} \times 4.12$

$R_{Ge} = 4.944 \times 10^{-15} m$

$$e = \frac{3m}{4\pi (R_{Ge})^3}$$

$$e = \frac{3 \times 69.924 \times 1.66 \times 10^{-27}}{4 \times 3.142 \times 4.944^3}$$ $1u = 1.66 \times 10^{-27}$ kg

$e = 2.29 \times 10^{17} kg / m^3$