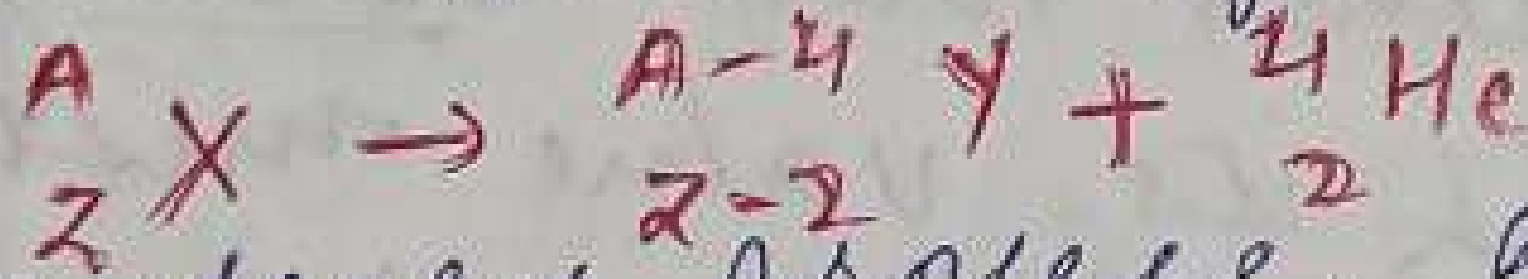


α -Decay

alpha decay is a type of radioactive decay in which an atomic nucleus emits an α particle (helium nucleus) & thereby decays into a different atomic nucleus, with a mass no. that is reduced by 4 & atomic no. reduced by 2. Alpha particle is identical to the nucleus of helium - 4 atoms which consist of 2 protons & 2 neutrons. It has a charge of $+2e$ & a mass of $4u$.

Alpha decay typically occurs in heaviest nuclides heavier than nickel (element 28), where the overall binding energy per nucleon is no longer a minimum & nuclides are therefore unstable towards spontaneous fission processes.



In alpha decay process, a parent atom ejects defined daughter nucleus leaving another defined product behind. α -particles have a E of 5 MeV (or $\approx 0.13\%$ of their total energy) & have speed of about 5% of speed of light.

The condⁿ for α -decay can be obtained by applying the principle of conservation of energy & linear momentum.

Let M_p , m_d & m_α be rest masses. Since, initially the parent nucleus remains at rest

before decay, its linear momentum is -

∴ dir^{ce} of ~~day~~ daughter & α -particle should be just opp. to conserve momentum.

Let T_i be total energy before decay & T_f be total energy after decay. Acc. to conservation of energy,

$$\therefore T_i = T_f$$
$$\Rightarrow m_p c^2 = m_d c^2 + U_d + m_\alpha c^2 + U_\alpha$$

where, U_d & U_α are nuclear energies of daughter & α -particle, given by

$$U_d = \frac{1}{2} m_d v_d^2$$

$$U_\alpha = \frac{1}{2} m_\alpha v_\alpha^2$$

∴ eqⁿ becomes

$$U_d + U_\alpha = (M_p - m_\alpha - m_d) c^2$$

This eqⁿ represents total disintegration energy or Q-value & its value must be +ve for spontaneous emission. Hence, the condⁿ for spontaneous α -decay is the rest mass of parent nucleus must be greater than the sum of masses of daughter & α -particle.

In order to calculate KE of α -particle, we use law of conservation of momentum & energy. From cons. of momentum, it is

$$m_d v_d = m_\alpha v_\alpha$$

as parent nucleus is at rest initially,

$$Q = U_d + U_\alpha = \frac{1}{2} m_d v_d^2 + \frac{1}{2} m_\alpha v_\alpha^2$$

$$\text{or } Q = \frac{1}{2} m_d \left(\frac{m_\alpha v_\alpha}{m_d} \right)^2 + \frac{1}{2} m_\alpha v_\alpha^2$$

$$= U_\alpha \left(\frac{m_\alpha}{m_d} + 1 \right)$$

$$\text{or } U = \frac{Q}{1 + (m_\alpha / m_d)}$$

$$\text{as } \frac{m_\alpha}{m_d} = \frac{4}{A-4}$$

$$\therefore \text{KE of } \alpha\text{-particle is } U_\alpha = \frac{A-4}{4} (Q)$$

From above eqⁿ, it is clear that α -particle carries most of the disintegration energy as A is very large. α -decay cannot be explained classically but by quantum mechanics.

It is presumed that parent nucleus before decay consists of daughter nucleus & α -particle. Acc. to quantum mechanics, α -particle exist in one of the discrete energy state of daughter nucleus & potential barrier ~~is~~ created by daughter nucleus restricts its motion.

Classically, α -particle does not have enough energy to climb the barrier but quantum mechanically there is some probability to penetrate the barrier. This effect is called tunnelling.

The probability of finding α -particle on one side of barrier is much less than to the other side of barrier & inside the barrier the probability decreases exponentially. This explains why α -particle emitters have long half-lives for low T .

Gamow Theory of α -decay

α -decay is explained quantum mechanically by Gamow & Condon in 1928.

Acc. to this theory, the postulates are: within the nucleus (of radius R), the potential is assumed to be simply a spherically symmetric ~~constant~~ constant-potential well

$$V(r) = -V \quad \text{for } 0 < r < R.$$

The effect of nuclear interaction is assumed to vanish outside the radius of nucleus $r > R$. Thus, the potential immediately outside & out to infinity is simply the spherically symmetric 'electrostatic' ~~low~~ Coulomb potential. Note that there is no intermediate