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 atom 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. $^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$

In alpha decay process, a parent atom ejects defined daughter nucleus leaving another defined product behind. α-particles have a E of 5MeV (or ≈ 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 0
∴ dirⁿ of ~~dag~~ daughter & α-parti
should be just opp. to conserve momen

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

$$\therefore \quad T_i = T_f$$

$$\Rightarrow \quad M_p c^2 = m_d c^2 + U_d + m_\alpha c^2 + U_\alpha$$

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

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

This eqⁿ represents total <u>disintigration energy</u> 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 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,

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

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

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

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

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

∴ KE of α-particle is

$$\boxed{U_\alpha = \frac{A-4}{4} (Q)}$$

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 ~~can~~ 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 side of barrier is much less than to in other side of barrier & inside the the probability lees exponentially. This explain why α - particle emitters have long half lives for low T.

Gamow Theory of α- decay

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

Acc. to this theory, the postulates are

Within the nucleus (of rad R), the potent assumed to be simply a spherically symm constant potential well

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

The effect of nuclear interaction is ass to vanish outside the radius of nucleus r > R. Thus, the potential immediately side & out to infinity is simply the sphe ly symmetric electrostatic coulomb ntial.

note that there is no intermed

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