GEIGER - NUTTALL LAW :-

Geiger and Nuttall in 1911 discovered an important empirical relationship between the ranges of the α-particles and the disintegration constants of the naturally α-active substances emitting them. This is known as Geiger-Nuttall law, and is expressed as,

$$\log \lambda = A + B \log R \quad \text{——} \quad (1)$$

Where A and B are constants having different values for different radioactive substances. This law has proved to be useful in determining the disintegration constant λ of some of the products of disintegration, which cannot be easily determined. Although Geiger-Nuttall law is an approximated, it is used to check up the validity of any theory of α-decay. The plot of $\log \lambda$ against $\log R$, which is a straight line, the Geiger-Nuttall relation can be written as

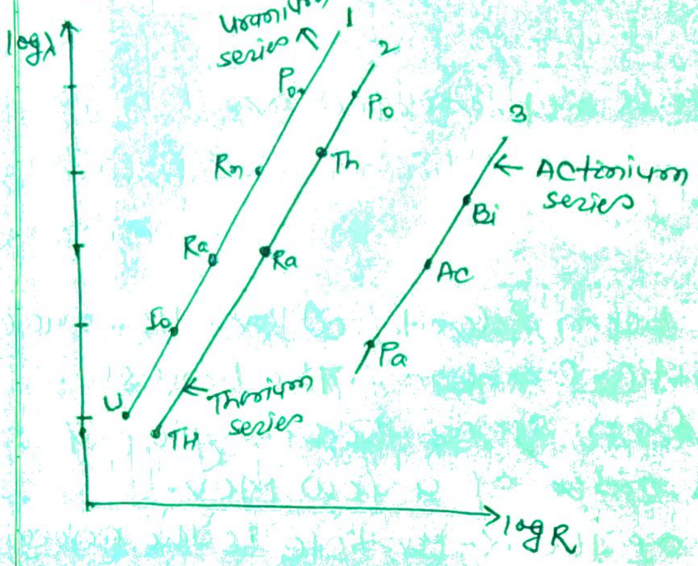
$$\log \lambda = C + D \log E \quad \text{——} \quad (2)$$

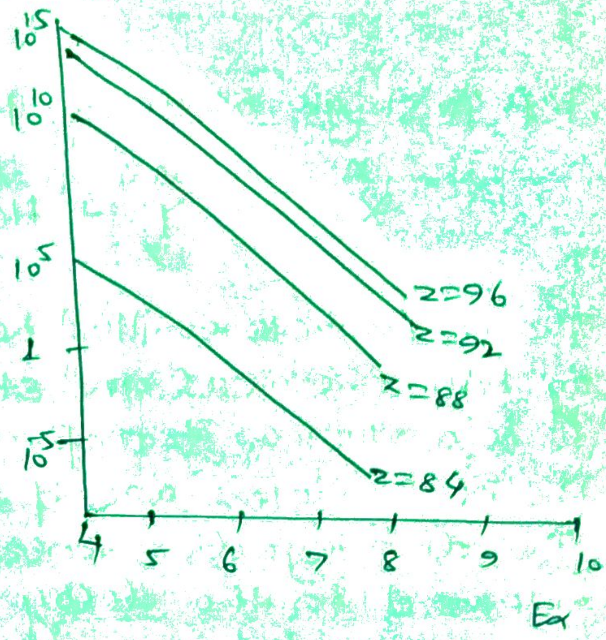
Where C and D are two other constants. The plot of $\log \lambda$ against $\log E$ is also a straight line.

<u>note</u>:- 1. since half-life $T = \frac{\log 2}{\lambda}$, Geiger-Nuttall law can be expressed by the variation of $\log \lambda$ with $\log R$ or $\log E$. The straight lines with negative slope will be obtained.

2. Geiger-Nuttall law was theoretically derived by Gamow to explain the quantum mechanical tunnelling.

3. The Geiger-Nuttall law is not very accurate. more accurate relation between λ and R has been derived later on.





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-: DISINTEGRATION ENERGY OF SPONTANEOUS α-DCAY :-

let a single α-decay process represented as

$$ {}^{A}X_{Z} \longrightarrow {}^{A-4}Y_{Z-2} + {}^{4}He_{2} + Q_\alpha $$

The α-particle emitted has been identified as He-nucleus by both chemical and statistical means. The process is a Nuclear transformation since the energies of the α-particles are of the order of a few Mev.

The disintegration energy of the α-particle is the energy released in the decay process and is given by

$$Q_\alpha = \left(M_X - M_\alpha - M_Y\right) c^2 \quad (1)$$

Whose M_α, M_Y and M_α are ~~represen~~ respectively the masses of the parent nucleus, daughter nucleus and the α-particle, c is the velocity of light in vacuum.

If the nucleus be at rest during decay and the residual nucleus recoil the velocity V_y, then from the conservation of momentum,

$$0 = M_\alpha v_\alpha - M_Y V_y \quad (2)$$

and $$Q_\alpha = \frac{1}{2} M_\alpha v_\alpha^2 + \frac{1}{2} M_Y v_y^2 \quad (3)$$

assuming v_α and v_y in the non-relativistic region

from eqn (2) & (3)

$$Q_\alpha = \frac{1}{2} M_\alpha v_\alpha^2 + \frac{1}{2} M_Y \left(\frac{M_\alpha v_\alpha^2}{M_Y}\right)$$

$$= \frac{1}{2} M_\alpha v_\alpha^2 \left(1 + \frac{M_\alpha}{M_Y}\right)$$

$$= T_\alpha \left(1 + \frac{M_\alpha}{M_Y}\right)$$

or, $$Q_\alpha = T_\alpha + \left(1 + \frac{M_\alpha}{M_Y}\right)^2 \quad \text{——— (4)}$$

It is quite reasonable to replace the ratio of masses by the ratio of mass number.

$$\therefore \frac{M_\alpha}{M_Y} = \frac{4}{A-4}$$

$$\therefore Q_\alpha = T_\alpha \frac{A}{A-4} \quad \text{——— (5)}$$

where 'A' is the mass no. of the parent nucleus.
If A is very large, $A-4 \simeq A$ and,

$$Q_\alpha = T_\alpha \frac{A}{A} \quad \text{or,} \quad \boxed{Q_\alpha = T_\alpha} \text{ — (6)}$$

This means for large nuclei, most of disintegration energy is carried away by the α-particle.