extension of the shell model.

5. RADIOACTIVITY - DECAYS

Natural radioactivity was accidentally discovered by Becquerel in 1896, who found a photographic plate blackened by the proximity of a uranium compound. Radioactivity was investigated by Rutherford. He found the radiation consisted of two kinds namely the α- ray and the β-ray. Villard later discovered a third ray which he called the Gamma radiation.

A small amount of radioactive salt is placed at the bottom of a narrow hole drilled in a lead block. The rays escape from the lead block in a narrow pencil. The whole arrangement is enclosed in a box which can be evacuated. A magnetic field is applied at right angles to the beam of rays. The α-rays and β-rays are deflected, but the gamma rays are not deflected.

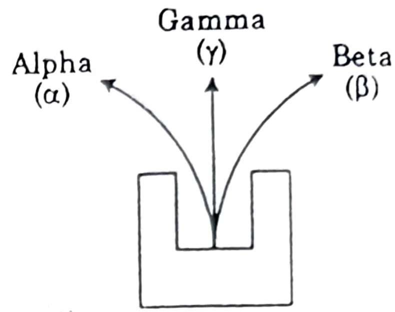

Fig. 15

The $\left[\frac{e}{m}\right]$ of the Beta rays was measured by Becquerel in 1900. The following year Kaufmann carried out a more precise measurement. These experiments showed that Beta rays were steams of electrons. Later Bucherer proved that the mass of the electron varied according to the formula $m = \frac{m_0}{\left[1 - \frac{v^2}{c^2}\right]^{1/2}}$

Rutherford and Robinson measured the $\frac{e}{m}$ for α-rays by deflections in electric and magnetic fields. The charge on the alpha particle was measured by Rutherford and Geiger as well as by Regener. The α - particle was found to have a mass four times the mass of the hydrogen atom and a positive charge equal to twice the charge on the electron.

This was confirmed by Rutherford and Royds.

Effect of Radioactive Decay

If an atom of charge Z and mass A emits an alpha particle, the following change occurs:

$Z \longrightarrow Z - 2$

$A \longrightarrow A - 4$

The emission of a beta particle from the nucleus raises the positive nuclear charge by unity while the mass remains unchanged.

$Z \longrightarrow Z + 1$

The unstable nucleus undergoes a spontaneous change in its charge, by the transformation of a neutron into a proton with the emission of an electron.

Decay Laws

The number of unstable nuclei remaining undecayed in a given sample decrea[ses] exponentially with time.

$$N = N_0 e^{-\lambda t}$$

where N_0 is the number of unstable nuclei present at an arbitrary instant of ti[me] $t = 0$. λ is called the decay constant which depends on the nuclide. ... (

The activity of a sample is the number of decays per unit time.

$$R = -\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$$

$$= \lambda N(t)$$ ... (

λdt represents the probability that a given nucleus will decay in time dt.

The decay of a nucleus is a random process, impossible to predict on the basis [of] the history of the nucleus. However a mean lifetime τ can be defined. If $v(t)\,dt$ is t[he] number disintegrating in the time interval between t and t + dt,

$$N_0\tau = \int_0^{\infty} t v(t) dt$$

$$v(t)\,dt = \lambda N(t)\,dt \text{ from } (14)$$

$$= \lambda N_0 e^{-\lambda t}\,dt$$

$$\therefore \tau = \frac{1}{\lambda}$$

Thus meanlife is the reciprocal of the decay constant.

If a certain unstable nucleus is present at a given instant, then the mean life time [sig]nifies how much longer we can statistically expect the nucleus to survive.

Half-life is the time that must elapse for the activity to fall to one-half of its present value.

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} = 0.693\tau$$

Branched decays

More than one decay process is possible for a given unstable nucleus in a give[n] state. For each process, we may define a **partial decay constant** $\lambda_1, \lambda_2, \ldots$. The tot[al] probability of decay per unit time is

$$\lambda = \lambda_1 + \lambda_2 + \ldots\ldots$$

Similarly,

$$\tau = \frac{1}{\lambda_1 + \lambda_2 + \ldots\ldots}$$

Unit of Activity $\left(R = -\frac{dN}{dt}\right)$ is 1 becquerel = 1 Bq. 1 Bq = 1 event/s. The activities [in] practice are so high that larger units are required.

$$1 \text{ MBq} = 10^6 \text{ Bq}$$

$$1 \text{ GBq} = 10^9 \text{ Bq}$$

$$1 \text{ curie} = 1 \text{ Ci} = 3.70 \times 10^{10} \text{ event/s} = 37 \text{ GBq}$$