RADIOACTIVITY

This is defined as the spontaneous disintegration of an element with the emission of particles such as Alpha particles, Beta rays and Gamma rays. Radioactivity was discovered by a scientist named Henri Becquerel.

TYPES OF RADIOACTIVITY

Artificial Radioactivity: This occurs in elements with stable nuclei. An element is said to have a stable nucleus if its neutron to proton ratio is approximately or equal to one.

For stable nucleus,

$$\frac{n}{p} \cong 1$$

This type of radioactivity is done through external bombardment of an element with (mainly) neutrons$\left({}_{0}^{1}n\right)$

Neutrons are used for artificial radioactivity they are massive yet neutral. Also, they are used in order to increase the neutron to proton ratio. Radioactivity occurs in elements without nuclear stability (i.e. elements which have their neutron to proton ratio much greater than one) in order for them to attain nuclear stability

Natural Radioactivity: This occurs in elements which naturally have nuclear instability (unstable nuclei). For such elements, their neutron to proton ratio is (much) greater than one. Examples include Uranium, Francium, and Radium etc.

Natural radioactivity occurs without any external aid or bombardment

RADIOACTIVE PARTICLES

These are the particles emitted during radioactive reactions. They are

Alpha particles: They are slowly deflected towards the negative plate of an electric field.

The slow deflection shows that it is massive. The direction of deflection shows that it is positive (since unlike charges attract). They have a very low penetrating power and can be stopped by a (thin) sheet of paper.

They have the highest ionizing effect on gases (they dissociate gas atoms into ions and electrons.

They have a mass of four units and a charge of two units therefore it is represented by the helium atom$\left({}_{2}^{4}He\right)$

Beta particles: They are strongly deflected towards the positive plate of an electric field. The strong deflection shows that they are light. The direction of deflection shows that they are negatively charged.
They have a higher penetrating power than alpha particles. They can be stopped by a thin aluminum foil. They have a lower ionizing effect on gases when compared to alpha particles.
They are streams are electrons and are represented by the sign of electrons $\left({}_{-1}^{0}e\right) \vee \left({}_{-1}^{0}\beta\right)$

Gamma Rays: They cannot be deflected by both electric and magnetic fields. They are electromagnetic in nature. They are neutral. They have the highest penetrating power amongst the three particles. They can be stopped by lead (blocks or jackets more often lead block)
They have the least ionizing effect on gases and they have no chemical symbol.

RADIOACTIVE DECAY

Alpha decay$\left(\alpha - decay\right)$: This is defined as the emission of alpha particles$\left({}_{2}^{4}He\right)$ from an element in a radioactive reaction. The mass number of the element reduces by four and its atomic number is reduced two and a new element is formed.

$${}_{Z}^{A}X \underset{\rightarrow}{\alpha - decay} {}_{Z-2}^{A-4}Y + {}_{2}^{4}He$$

Beta decay$\left(\beta - decay\right)$: This occurs when an element emits beta particles$\left({}_{-1}^{0}e\right)$. The mass number of the element remains unchanged while its atomic number is increased by one

$${}_{Z}^{A}X \underset{\rightarrow}{\beta - decay} {}_{Z+1}^{A}Y + {}_{-1}^{O}e$$

Gamma decay: This occurs when an element emits gamma rays. Both the mass number and the atomic number of the element remain unchanged but the element becomes more stable as a result of energy emission (or liberation).

HALF LIFE

This is defined as the time taken for an element to decay or disintegrate to half its (original) mass. The half of an element is a function of nuclear stability.
For example, if 16g is the total mass of an atom and its half-life is 3 days, it means that in every three days half its original mass will be disintegrated.
That means, the first three days the mass of the substance will become half its original (making it 8g). In the next three days, it will reduce to half its new original (half of 8g making it 4g). In the next three days, it becomes 2g and in the next three days it becomes 1g and so on.

$$number\ of\ half-lives\ covered=\frac{time\ given \vee time\ covered}{half-life}$$

$$n=\frac{T}{t}$$

$$Remaining\ fraction\left(after\ decay\right)=\frac{1}{2^{number\ of\ half-lives}}$$

$$f_r=\frac{1}{2^n}$$

$$Decayed\ fraction=1-Remaining\ fraction$$

$$f_d=1-f_r$$

$$f_d=1-\frac{1}{2^n}$$

$$Remaining\ mass\ of\ the\ element\left(after\ decay\right)=\frac{Original\ total\ mass}{2^{number\ of\ half-lives}}$$

$$m_r=\frac{M}{2^n}$$

$$m_r=M\left(\frac{1}{2^n}\right)$$

But

$$f_r=\frac{1}{2^n}$$

$$m_r=M\left(f_r\right)$$

$$decayed\ mass=total\ mass-remaining\ mass$$

$$m_d=M-m_r$$

$$m_r=\frac{M}{2^n}$$

$$m_d = M - \frac{M}{2^n}$$

$$m_d = M\left(1 - \frac{1}{2^n}\right)$$

$$f_d = 1 - \frac{1}{2^n}$$

$$m_d = M(f_d)$$

LAWS OF RADIOACTIVITY

Atoms of all radioactive elements are undergoing spontaneous disintegration i.e. they are constantly breaking and forming fresh radioactive products with the emission of alpha, beta and gamma rays.

The rate of breaking is not affected by external factors (like temperature, pressure or chemical combination etc.) but depends entirely on the rate of change

LAW OF CHANGE

The law of change states that the number of atoms breaking per second at any instance is proportional to the number of atoms present. In other words, the quantity of a radioactive element which disintegrates in a unit time is directly proportional to the amount of radioactive element present. Mathematically,

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

Also,

$$m = M e^{-\lambda t}$$

At half-life,

$$n = \frac{N}{2}$$

And

$$t = t_{\frac{1}{2}}$$

$$\frac{N}{2} = N e^{-\lambda t_{\frac{1}{2}}}$$

$$\frac{N}{2} \div N = e^{-\lambda t_{\frac{1}{2}}}$$

$$\frac{1}{2} = e^{-\lambda t_{\frac{1}{2}}}$$

Adding In to both sides,

$$\left(\frac{1}{2}\right)=\left(e^{-\lambda t_{\frac{1}{2}}}\right)$$

$$-0.693=-\lambda t_{\frac{1}{2}}$$

$$0.693=\lambda t_{\frac{1}{2}}$$

$$t_{\frac{1}{2}}=\frac{0.693}{\lambda}$$

Here, λ is called the decay constant

Average life period (l) of a radioactive element is the reciprocal of its decay constant.

$$l=\frac{1}{\lambda}$$

$$t_{\frac{1}{2}}=0.693\times\frac{1}{\lambda}$$

$$t_{\frac{1}{2}}=0.693\,l$$

<u>APPLICATIONS OF RADIOACTIVE RADIATION</u>

1. Many radiation sources such as cobalt-60 have been used for industrial radiography i.e. for investigating the interior of metallic acid for detecting any defects
2. Radioactive nuclei have been used to compact sources of heat energy
3. Radioactive nuclei emitting alpha and beta particles have been used for the production of electric power by thermo-electric conversion
4. Chemical changes initiated by radiation from radioactive substances is the basis of a newly developed subject called radiation chemistry
5. Nuclear radiation like gamma rays have been utilized for the preservation of food
6. Gamma radiations from cobalt-60 are used in hospitals for the sterilization of materials.
7. Population of insects which causes considerable damage to both plant and crop and livestock can be controlled by eradicating the main members of these insects so that they become sterile

8. Radiation mutation in plants have been practiced to produce new varieties of these plants
9. Self-luminous plants for use in instrument have been made by adding a natural alpha emitting radioactive substance to phosphorus.
10. The ionization produced by beta particles has been widely used for the diminution of static electricity which constitutes a serious fire and explosion hazard in the paper industry.