EXPERIMENT

Determine the range of α, β, γ Particles by using G.M counter.

Theory

Natural radio-activity:-

Nuclear reactions which occur spontaneously are said to be an example of natural radio-activity. These are three naturally occuring radioactive series among the elements in the periodic table. These are known as the uniform series and uranium series the actinium series and thorium series, each named after the element at which the series start.

Artificial Radio-activity:-

Not all nuclear reactions are spontaneous. These reaction occur when stable isotopes are bombarded with particles such as neutron. This method of inducing a nuclear reaction to proceed is termed artificial radioactivity. This meant new nuclear reactions, which wouldn't have been viewed spontaneously could now be observed. Since 1940, a set of new elements with atomic numbers over 92 (the atomic number of naturally occuring element, Uranium) have been artificially made. These are called the transuranium elements.

Properties and Range of α-particles:-

(1) These are deflected by electric and magnetic fields and the direction of their deflection shows that they consist of postively charged particles. Each α-particle has a charge +2e.

(2) By measuring e/m, it is found that the α-ray consist of helium nuclei i.e $_2He^4$.

(3) They are shot out from the radioactive element with large velocities ranging from 1.4×10^9 to 1.7×10^9 cm per second. The velocity of the α-rays depend upon the elements from which they are ejected and for a given element it remains the same.

(4) They effect the photographic plate. The effect is very feeble.

(5) They produce flourescence in substances like zinic sulphide or barium platinocyanide on observing

the fluorescence through a low power microscope successive scientillations are seen which are produced by the impact of individual particle.

They produce intense ionization in the gas through which they pass.

Their power of ionization is 100 times greater than that of β-rays and 10,000 times greater than that of γ-rays.

Their power of penetration through layers of matter is very small.

They produce a heating effect. A quantity of radium always maintains itself at a temperature higher than that of the surrounding. The evolution of heat is due to the stoppage of α, β and γ-rays by the radioactive element.

When exposed to α-rays, the body suffers incurable burns.

When an α-particle is emitted from a radioactive substance, the charge number and mass number (A) both change. Since an α-particle has a charge +2e and mass number 4. This can be represented by the following equation.

$_ZX^A \longrightarrow \, _{Z-2}Y^{A-4} + \alpha\text{-particle}$

$_ZX^A \longrightarrow \, _{Z-2}Y^{A-4} + \, _2He^4$

In other words with a emission of α-particle, the element moves back two places in the Periodic table.

Properties of β-rays and their range:

(1) These are deflected by electric and magnetic field and the direction of their deflection indicate that they consist of negtively charged particles. Each β-particle has a charge of -1e.

(2) By measuring e/m, it is found that β-rays consist of fast moving electrons.

(3) They are shot out from radioactive substances with very high velocities ranging from 33% to 99% of the velocity of light.

(4) The velocity of all the β-particles given out by a substances is not the same.

(5) They effect the photographic plate and their effect is greater than that of α-particle.

(6) They produced fluorescence in barium platino-cynide, calcium tungston,

willemite etc.
They can ionize the gases but their ionizing power is much less than that of α-rays.
Their power of penetration through material layer is much more than that of α-rays. They can easily pass through 1cm of thick aluminium sheet.
When β-particle is emitted from a radioactive substance, the charge number (z) changes but there is no change in the mass number (A). (mass of electron is ~~freed~~ small). With the emission of a β-particle, one of the neutron in the nucleus is converted into proton as given by equation.

$$ {}_0N^1 = {}_1P^{1} + {}_{-1}e^0 $$

or

$$ {}_0N^1 = {}_1P^1 + {}_{-1}\beta^0 $$

Thus emission of β-particle can be represented by following equation

$$ {}_ZX^A \longrightarrow {}_{Z+1}Y^A + \beta\text{-Particle} + \vec{\nu} $$

or

$$ {}_ZX^A \longrightarrow {}_{Z+1}Y^A + {}_{-1}\beta^0 + \tilde{\nu} $$

In other words, the daughter element (Y) is ahead of parent element (X) by one place in the periodic table. $\bar{\nu}$ is called anti-neutrino which shares the energy.

Properties and Range of γ-rays:-

(1) These rays are not deflected by electric or magnetic fields, so they consist of chargeless particles.

(2) They are electromagnetic radiation in nature as the X-rays (Photons) and have very small wavelength.

(3) They are shot out from radioactive substances with the velocity of light 3×10^{10} cm per second.

(4) They effect the photographic plate and there effect is greater than that for β-rays.

(5) They produce fluoresence in barium platino cyanide, etc.

(6) They ionize the gas through which they pass but their ionizing power is very small.

(7) They have very high power of penetration and can pass easily through 30cm thickness of iron.

They are diffracted by crystals just like X-rays.

When a nucleas emits γ-rays, neither its Charge number nor its mass no changes. The emission of γ-rays from a nucleas can be represented by the equation.

$$_{Z}X^{A*} \longrightarrow {_{Z}X^{A}} + \gamma\text{-ray}$$

$_{Z}X^{A*}$ represents an excited nucleus $_{Z}X^{A}$ the nucleas in the ground state.

DETECTORS

The interaction of alpha, beta and gamma radiations with matter produce positively charged ions and electrons. Radiation detector are devices that measure this ionization and produce an observe output. The commonly used detectors are

(1) Geiger counter
(2) Solid State X-ray and gamma-ray detectors.
(3) Low energy Charged particle detectors
(4) Neutron detectors.
(5) High energy Charged Particles detectors.
(6) Radiation detectors
(7) Neutrino detectors

GEIGER MULLER COUNTER

Construction:

Geiger Muller is a well known radiation detector. the discharge in the tube result from the ionization produced by the incident radiation. It consists of a stiff central wire acting as an anode in hollow metal cylinder acting as a cathode filled with a suitable mixture of gas at about 0.1 atm pressure. one end of the tube has a thin mica window to allow the entry of α or β particles and other end is sealed by non-conducting material & carries the conducting pins for the two electrodes. A high potential difference, (about 400V for Neon-Bromine filled tubes) but slightly less than that necessary to produce discharge through the gas is maintained between the electrodes.

WORKING:

When radiations enters the tube, ionization is produced. the free electrons are attracted towards the positively charges central wire As they are

accelerated towards the wire by strong electric field, they collide with other molecules of the gas and knock out more electrons which in turn do the same and produce a flow of electrons that move towards the central wire. This make a short pulse of electric current to pass through an external resistor. It is amplified and registered electronically. The counter, which also provide the power is called a scaler.
The flow of electrons produced by the entry of an ionizing particle is counted as a single pulso of approximately of the same size whatever the energy or path of the particle may be. It cannot, thus discriminate between the energies of the incident particle as output pulses are same. The entire electron pulse takes less than 1μs.

Dead time:

However, positive ions, being very massive than the electrons, take several hundred times as long to reach the outer cathode. During this time, called the dead time ($\sim 10^{-4}s$) of the counter, further incoming particles cannot be counted.

Quenching:

When positive ions strike the cathode, secondary electrons are emitted from the surface. These electrons would be accelerated to give further spurious counts. This is prevented by mixing a small amount of quenching gas with the principal gas.

The quenching gas must have an ionization potential lower than that of inert or principal gas. Thus, ions of quenching gas reach the cathode before principal gas ions following neutralization, the excess energy of the quenching molecules is dissipated in dissociation of molecules rather than in the release of electrons from the cathode.

Example

When bromine gas is added to neon gas in GM tube. The bromine molecules absorb energy from the ions or secondary electrons and dissociate into bromine atoms. The atoms then readily recombine into molecules again for the next pulse. The gas quenching is called self quenching. Although all commercial Geiger tubes are self quenched, it is common practice to use quenching in addition. For this purpose a large neglive voltage is applied to the anode immediately after recording output pulse. This reduces the electronic field below the critical value for ionization by collision. The negtive voltage remains until all positive ions are collected at cathode thus preventing secondary pulses.

Uses:

Geiger counter can be used to determine the range or penetration power of ionizing particles. The reduction in the count rate by inserting metal plates of varying thickness between the sources and the tube helps to estimate the penetration power of the incident radiation. Geiger counter is not suitable for fast counting. It is because its relatively long dead time of the order of more than a millisecond which limits the counting rate to a few hundred counts per second. If particles are incident on the tube at faster rate, not all of them will be counted since some will arrive during the dead time. Solid

State detectors are fast enough, more efficient and accurate

Disadvantages:

1) They cannot differentiale which type of radiation is being detected
They cannot be used to determine the exact energy of detected radiation
They have low efficiency.

Advantages:

They are inexpensive.
They are durable and easily portable.
They can detect all types of radiation.

Procedure:

Set the apparatus according to the diagram Put α-source in GM tube Take some metal plates of different thickness Take some metal plates of different thickness and Put them one by one above the Source. For each plate take number of Counts