(NU3-9) Beta Absorption

Aim of experiment

Determination of the Range of Electrons (Beta Rays) and its average energy

Apparatus

GM tube counting station consists of GM counter – radioactive source Sr^{90}- source holder-stop watch, Pb thin sheets, source cabinet made of thick lead.

Theory of experiment

Unlike alpha radioactivity, which is common only to heavy nuclei, beta radioactivity can be encountered at all nucleus sizes. It consists of emission from the nucleus of light particles. When a neutron rich nucleus is unstable, it emits a negative beta particle (an electron) and an electron antineutrino (a particle without rest mass, similar to a quantum of light). When a proton rich nucleus is unstable, it emits a positive beta particle (called a positron, having the same mass as an electron but a positive electric charge) and an electron neutrino (also a mass-less particle). Sometimes the new nucleus (situated to the right in the periodic table for negative beta radioactivity and to the left for positive beta radioactivity) is in an excited energy state. De-excitation can be done through the emission of one or more gamma rays.

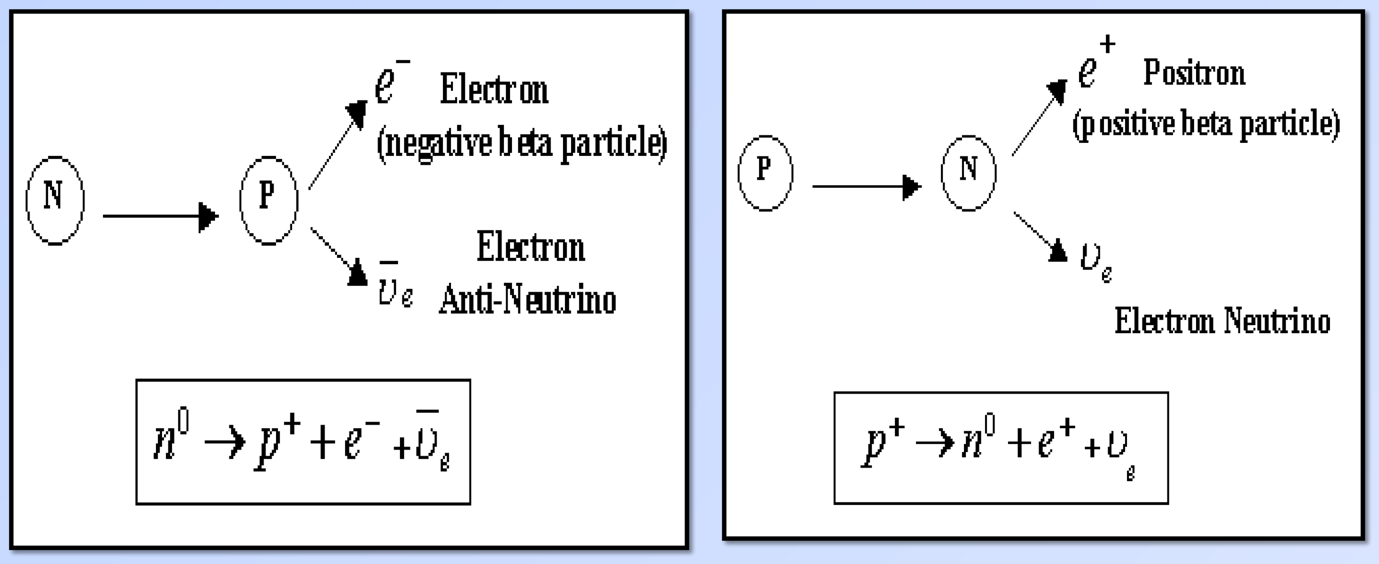

*Figure 1 A schematic diagram for n*eutron and proton disintegration

An example of negative beta radioactivity is the disintegration of P^{32}:

$P^{32} \longrightarrow S^{32}$ + electron + electron antineutrino + energy

An example of positive beta radioactivity is the disintegration of Na^{22} (89% of the cases of disintegration):

$Na^{22} \longrightarrow Ne^{22}$ + positron + electron neutrino + energy

Because beta particles share their energy with an antineutrino or neutrino, the beta energy spectrum is continuous. The energy of the beta particle varies continuously between zero and a maximum value, which is specific to the beta emitting radionuclide. At the maximum particle energy, the antineutrino or neutrino, has zero kinetic energy. Because of this continuous spectrum, beta spectrometry is n … a s

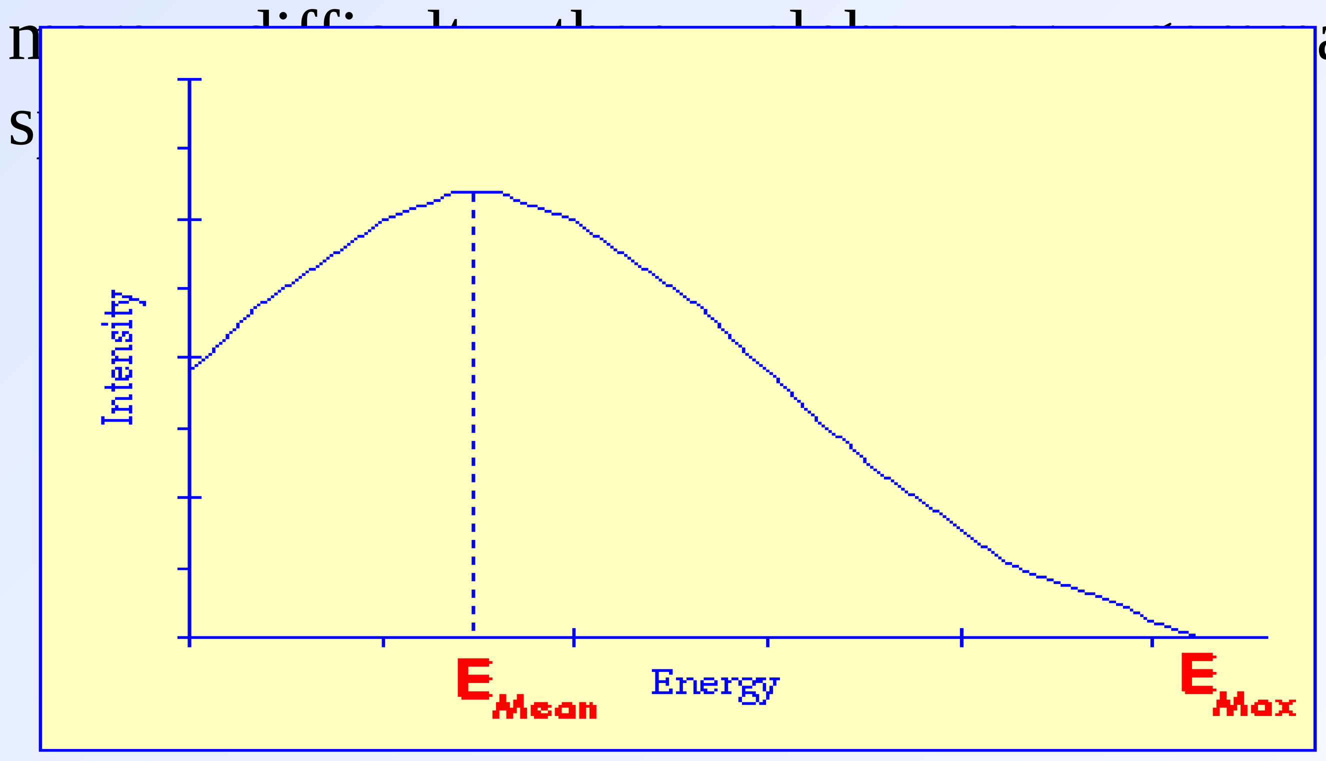

Figure 2. Intensity distributions as a function of beta energy

The path of beta-particles in matter is often described as being tortuous, since they tend to be scattered from atom to atom. A final and important point to note is that the energy of beta-particles is never found to be distinct in contrast to the alpha-particles above. The energies of the beta particles from a radioactive source forms a spectrum up to a maximum energy - see *figure 2*. Notice from the figure that a range of energies is present and features such as the mean energy, E_{mean}, or the maximum energy, E_{max}, are quoted.

Beta Particle Range

Low energy electrons (≤1 MeV) are removed from a beam of electrons mainly by scattering from atomic electrons in the absorbing material. At higher energies, the electrons lose energy through the Bremsstrahlung process. Whereas photons are generally annihilated when they interact with matter, electrons just lose energy until they essentially come to a stop, thereby leaving the beam. Hence it becomes useful to speak of the range of the electron, i.e., the thickness of absorber required to bring the electron to a stop. In beta decay, electrons are emitted with a spectrum of energies and so it becomes necessary to consider only the range of the most energetic electrons.

As charged particle transverses a material, the particle slows as it loses kinetic energy. The loss of energy by charged particles traveling through a material is broken into two components based on the mechanism of energy transfer either collisional or radiative energy loss. The total *stopping power* is

$$\frac{dE}{dx} = \left(\frac{dE}{dx}\right)_{col} + \left(\frac{dE}{dx}\right)_{rad}$$

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where $(dE/dx)_{col}$ is the electronic energy loss due to Coulomb interactions (*i.e.*, the ionization and excitation), and $(dE/dx)_{rad}$ is the nuclear energy loss (*e.g.*, due to emission of Bremsstrahlung or Cerenkov radiation, and nuclear interactions). *Excitation* raises an electron to a higher energy shell, whereas *ionization* completely removes the electron from the atom. Ionization creates an *ion pair*, which is the (now) free electron and the positively charged atom from which the electron was removed. The freed electron may possess sufficient kinetic energy to cause further ionization events (such energetic electrons are sometimes called delta rays).

The initial energy of β particle is finite. We find that in traversing matter it continuously loses energy producing ionizations and is finally stopped, thus charged particle radiations have a finite range. The range of β particle is dependent on the number of atoms the particle encounters when it travels through a medium. The best way to estimate the number of atoms in a medium is using the concept of mass per unit area. If the density of a material is given by ρ gcm^{-3}, then the mass per unit area of a sheet of thickness t is $\rho\, t$ gcm^{-2}. If we express the range in this form then we find that the formula for the range of β particles can be given in terms of the energies of the particles only. The maximum range, R_{max}, of a beta particle can be computed from an empirical formula given by Katz and Penfold:

$$E_\beta = 0.185\, R_{max}\, (g/cm^2) + 0.245$$

where E_β is the maximum beta energy in MeV. The ability to stop betas depends primarily on the number of electrons in the absorber (*i.e.*, the areal density, which is the number of electrons per cm^2). Hence, the range when expressed as a density thickness (g/cm^2) of the material gives a generic quantifier by which various absorbers can be compared.

Procedure

1. Set the high voltage to the value specified on the tube holder, 700 V.
2. Set the clock to preset the running time.
3. Set the time to 90 s. This preset time is not to be changed during the experiment.
4. Click Data collection. It will stop 90 s after it starts.
5. When counting ceases, record number of counts, which is N_{bg} in this case.
6. In order to obtain better statistics, set time at longer collection time.
7. Use the tweezers to place the Sr^{90} source in the plastic tray and slide the tray into the fourth slot from the top.
8. When counting ceases, record number of counts, which is N_0 in the case of no absorber.
9. Clear the data. Measure and record the thickness of the wide piece of Al that is provided and insert the sheet into slot 1 just below the detector and above the source. Collect data. Record the number of counts, which is the number of counts at first Al sheet thickness.
10. Repeat the process described in step 8 until all the sheets of Al such that no counts are recorded.

Results

N_{bg}= counts/ sec

Al Thickness, x (cm)	N(t) counts/s	N=N(t)- N_{bg} counts/s	Ln (N)

11. Plot the number of counts per second (on a ln scale as the ordinate) vs. absorber thickness (on a linear scale as the abscissa). From the intercept with the x-axis, determine the range of β -particle, x_{Range}, measured in cm^{-1}.
12. Determine the range in g/cm^2

    $R(g/m^2) = X_{Range}\ x\ \rho_{Al,}$

    where ρ_{Al} is the density of Aland then and calculate the average β-energy from the relation

$E_\beta = 0.185\, R_{max}\, (g/cm^2) + 0.245$

Compare the obtained result with that in nuclear data sheets for Sr^{90} source.

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