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LETTER TO THE EDITOR

Absorption of beta particles in matter

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Abstract. The fraction f_A of the incident beta particles from a pure beta source that are completely absorbed in a foil of thickness t is measured with an end-window GM counter for ^{32}P, ^{91}Y and ^{89}Sr beta sources using different thicknesses of Cu, Ag, Sn and Pb targets. The variation of f_A as a function of foil thickness is shown to follow an empirical relation of the type $t\exp(-\Sigma_A t)$, where Σ_A is a constant. The values of Σ_A agree with each other within 15–20% for all these sources and the targets used.

It is well known that when electrons pass through matter they interact with the atoms of the matter in bulk and undergo changes in energy and direction in each collision leading to the processes of slowing down, diffusion and absorption. Rossi (1952), Bethe and Ashkin (1953), Evans (1955), Birkoff (1958), and Roy and Reed (1968) have reviewed the different types of interactions that contribute to these processes. The most predominant interactions of low energy electrons with matter are elastic nuclear (Coulomb) scattering, inelastic scattering and radiative collisions.

Using a ^{90}Sr–^{90}Y pure beta source it has been shown (Mudhole 1973a) that the variation of the fraction f_A of the incident beta particles that are absorbed within a foil of thickness t, over a limited range of thicknesses, follows an empirical relation of the type

$$f_A = Kt\exp(-\Sigma_A t) \qquad (1)$$

where t is the thickness of the foil in milligrammes per square centimetre, K and Σ_A are constants. Σ_A was found to be constant and independent of the atomic number of the foil. The experiment was repeated using ^{32}P, ^{91}Y and ^{89}Sr beta sources to study the dependence of Σ_A on the end-point energies of the beta spectra.

The fraction of the incident beta particles that are absorbed within the foil was measured using an end-window GM counter having a 2·54 cm diameter window. The thickness of the GM counter window is 2 mg cm^{-2}. The foils used are 2·54 cm square in size and completely cover the window of the GM counter. The point beta sources ^{32}P, ^{91}Y and ^{89}Sr, of strength about 0·01 μCi, were prepared at this laboratory by slowly evaporating the known aliquots of the solution on aluminized mylar sheets of areal density 1 mg cm^{-2} and 2·54 cm in diameter. The sources were sealed with another mylar sheet.

The fraction of the incident beta particles that are absorbed within a foil of thickness t is determined as follows. The number of beta particles transmitted in all directions was measured in the GM counter by placing first the foil and then the source on the window of the counter. Next, the number of beta particles that are back-reflected in all directions was determined by keeping the source first and then the foil on the window of the counter. From these two numbers the fraction f_A of the incident beta particles that are absorbed within the foil of thickness t, was determined. Here we have assumed that the solid angle subtended by the effective window area of the counter at the point source is 2π. The dead space of the detector near the window is very small and further Brownell (1952) has shown experimentally that the electrons transmitted through a foil as well as back-reflected from a foil have an angular distribution which predominates only in the direction normal to the surface of the foil. So this assumption is fairly valid. The fraction f_A is determined for various thicknesses of t, up to $0{\cdot}4R$, where R is the range of beta particles of maximum energy.

The fraction f_A of the number of incident beta particles absorbed was determined as a function of foil thickness for ^{32}P, ^{91}Y and ^{89}Sr beta sources using Cu, Ag, Sn and Pb targets. In figure 1 we have plotted experimentally determined values of log (f_A/t) as a

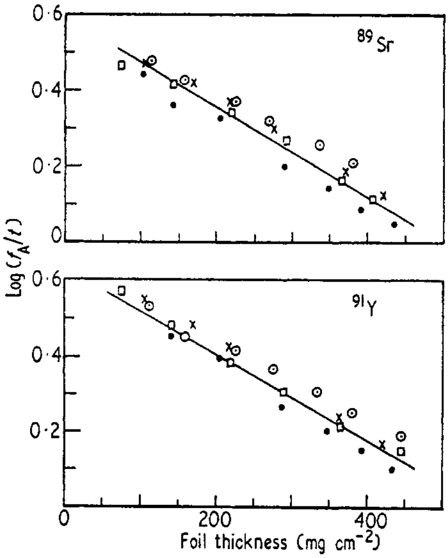

Figure 1. Logarithm of the fraction of the incident beta particles which are absorbed within the foil per mg cm^{-2} of the target as a function of the foil thickness for ^{89}Sr and ^{91}Y beta sources. ○ Cu; × Ag; □ Sn; ● Pb.

function of foil thickness for Cu, Ag, Sn and Pb targets and for ^{89}Sr and ^{91}Y beta sources. Similar curves have been obtained for ^{32}P also. In figure 1 the full lines are the least-squares fit straight lines. We see that the fraction of the incident beta particles absorbed in different thicknesses of various targets follows the empirical relation given in equation (1).

Table 1. The least-squares fit values of Σ_A (cm^2 mg^{-1}) for ^{32}P, ^{91}Y and ^{89}Sr beta sources and for Cu, Ag, Sn and Pb targets

Z	Target element	^{32}P (E_0 = 1·71 MeV)	^{91}Y (E_0 = 1·53 MeV)	^{89}Sr (E_0 = 1·46 MeV)
29	Cu	0·00188	0·00232	0·00230
47	Ag	0·00227	0·00249	0·00264
50	Sn	0·00196	0·00258	0·00263
82	Pb	0·00193	0·00239	0·00273

In table 1 the least-squares fit values of Σ_A are listed for ^{32}P, ^{91}Y and ^{89}Sr beta sources and for Cu, Ag, Sn and Pb targets. From column 3 it is obvious that for a given beta source Σ_A is constant and independent of the atomic number of the target. Columns 4 and 5 correspond to ^{91}Y and ^{89}Sr beta sources. From table 1 it is obvious that the values of Σ_A agree with each other within 15–20% for all the beta sources and Cu, Ag, Sn and Pb targets.

It has been shown (Mudhole 1973) that the variation of the external bremsstrahlung intensity as a function of the target thickness also follows an empirical relation of the form given in equation (1). It is interesting to compare the values of Σ_A with the values of Σ_B relevant to external bremsstrahlung. The values of Σ_A and Σ_B agree with each other within 25–30% showing that the nonlinear increase of external bremsstrahlung intensity as a function of foil thickness is governed by the same factors as the absorption of beta particles in foils. Monte Carlo calculations are in progress to check this contention.

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