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External Bremsstrahlung produced by beta particles

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ABSTRACT

The external bremsstrahlung (EB) produced by beta particles having E_{max} 1.46 to 2.26 MeV in different thicknesses of Cu, Ag, Cd and Sn targets has been measured with NaI(Tl) scintillation spectrometer. The external bremsstrahlung intensity increases rapidly with target thickness, but increase intensity is not linear. This nonlinear increase of EB intensity is shown to follow an empirical relation of the type t exp ($-\Sigma_B t$), where t is the thickness of the target in mg cm-2 and Σ_B is a constant. Σ_B($cm^2 mg^{-1}$) is found to be a constant and independent of the atomic number of the target Σ_B and yield constant K is determined for ^{90}Sr-^{90}Y, ^{90}Y, ^{32}P and ^{89}Sr beta sources. The values of Σ_B are found to be constant and agree with each other 10 to 15% for these sources, showing that Σ_B is constant, independent of the atomic number of the target and maximum energy of beta particles.

Keywords: Beta, Effective atomic number, External Bremsstrahlung, NaI (Tl), Yield constant.

INTRODUCTION

External bremsstrahlung EB is a low probability electromagnetic radiation associated with the acceleration of charge particles produces by electron or beta particles and classified as internal and external bresstrahlung. External bremsstrahlung can be a thick target bremsstrahlung. For beta particle source requires an extremely thick targets because of continuous spectrum of energy from 0 to maximum energy (E_m).

Theory for relativistic electrons and for nonrelativistic incident electrons developed by (Bethe and Heitler, 1934; Sauter, 1934; Racah, 1934 and Sommerfeld, 1931), (Miller *et al.,* 1954), (Motz and Miller 1954, Motz 1955, Starfelt and Koch 1956, Motz and Placious 1958, Koch and Motz 1959, Fredricksen 1961 and Roy and Reed 1968) all these shows that the electron kinetic energy that are small compare to rest mass electron energy, the experimental results, show general agreement with Sommerfeld theory except for certain minor discrepancies, for electron kinetic energies that are of the some order of magnitude as the electron rest mass energy. The Born approximation theory underestimates the experimental results, and for electron kinetic energies that are large compared with electron rest mass energy result agree within 10%.

The EB is produced in the first few layers of thick target and the emitted photons have to pass through the rest of the target thickness. The EB intensity is affected by the slowing down of beta particles and also by the attenuation of the EB photons in the thickness of the target.

From integrated as well as differential EB measurements it has been shown (Mudhole and Umakantha, 1972 and Manjunatha, 2011) that for target thicknesses less than approximately 0-4 times the range R of beta particles. The increase with target intensity with target thickness follows an empirical relation of the type.

$$I = KZ^n\left(t/_{A}\right)e^{-\Sigma_B t} \qquad (1)$$

Where n is a exponent of Z, K is yield constant, Σ_B material constant, Z and A are atomic number and Atomic weight of the target and t is thickness of the target in mg cm^{-2}.

Rewriting equation (1) for conveyance

$$ln\left(\frac{IA}{t}\right) = \ln(KZ^n) - \sum\nolimits_B t \qquad (2)$$

The present investigation was to study the dependence of Σ_B on the E_{max} of beta particles by the integrated EB intensity as a function of the target thickness.

Experimental details

The experimental arrangement used to study is as shown in figure 1. The pure beta sources ^{90}Sr-^{90}Y (0.54 and 2.26 MeV), ^{90}Y (2.26 MeV), ^{32}P (1.71 MeV) and ^{89}Sr (1.49 MeV) of strength 50-100 µCi were used. The perspex stand and scintillation head was kept in Pb castle. The beta source was kept in perspex source holder and all sides of the beta source were covered by perspex to stop beta particles in all except the forward direction and thereby minimize extraneous EB production from the surrounding material. A 1.4 cm thick Perspex sheet was kept between the source and the detector so as to prevent beta particles form producing EB in the detector and the shielding material. The integrated and differential EB measurements are done using a NaI(Tl) 1.75″ ×2″ scintillation spectrometer to 16 k – multichannel.

The histogram of accumulated spectra is the incident photon spectrum folded by a self attenuation of NaI(Tl) crystal also with background. Therefore EB spectrum should be suppressed to get corrected counts.

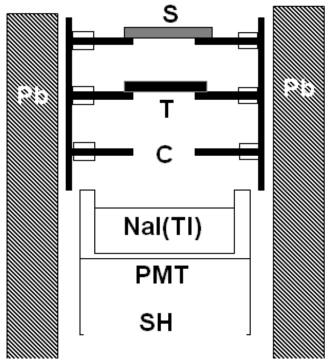

Fig. 1: Experimental setup S- source, T- target, Pb- lead castle, C- lead collimators. RESULTS AND DISCUSSION

The integrate EB intensity was measured for ^{90}Sr-^{90}Y, ^{90}Y, ^{32}P and ^{89}Sr beta sources using Cu, Ag, Cd and Sn targets.

Table 1. The least squares fit values of Σ_B(cm^2mg^{-1}) for ^{90}Sr-^{90}Y, ^{90}Y, ^{32}P and ^{89}Sr beta sources and for CU, Ag, Cd and Sn targets

Z	Target elements	^{89}Sr (E_0=1.46 MeV)	^{32}P (E_0=1.71MeV)	^{90}Y (E_0=2.26MeV)	^{90}Sr-^{90}Y (E_0=0.54, 2.26 MeV)
29	Cu	0.00254	0.00246	0.00239	0.00236
47	Ag	0.00266	0.00264	0.00260	0.00255
48	Cd	0.00287	0.00282	0.00280	0.00276
50	Sn	0.00293	0.00287	0.00282	0.00276

From equation (2) the plot of the values of *ln*(IA/t) as a function of target thickness is a linear after regression gives slope equal to Σ_B and intercept as *ln*(KZ^n). The values of Σ_B for elements at energies are tabulated in Table 1. Similarly the slope of plots of *ln*(KZ^n) versus *ln*(Z) gives slope equal to vales of index of z (n). The calculated values of n are shown in Table 2. The mass attenuation coefficient (μ/ρ) for low energy photons is mainly due to photoelectric and Compton effects and these processes are highly dependent on the atomic number of the absorber. However, Σ_B is found to be independent of the atomic number of the targets and Σ_B does not correspond to the μ/ρ. Thus, the non linearity in the increase of EB intensity with target thickness is not due to the attenuation of low energy Bremsstrahlung photons in the targets.

Table 2: The least squares fit values of n for ^{90}Sr-^{90}Y, ^{90}Y, ^{32}P and ^{89}Sr beta sources.

Energy (MeV)	*Ln*(KZ^n)				Index n
	Cu	Ag	Cd	Sn	
1.46	9.6504	10.5733	10.6292	10.9082	1.9204
1.71	9.6545	10.5721	10.6215	10.6865	1.9233
0.54-2.26	9.6398	10.5695	10.6200	10.6823	1.9264
2.26	9.6372	10.5657	10.6176	10.6782	1.9246

In figure 2 shows plots values of *ln*(Z) v/s *ln*(KZ^n) for all energies and it is seen that the values of index n is nearly equal to 2.

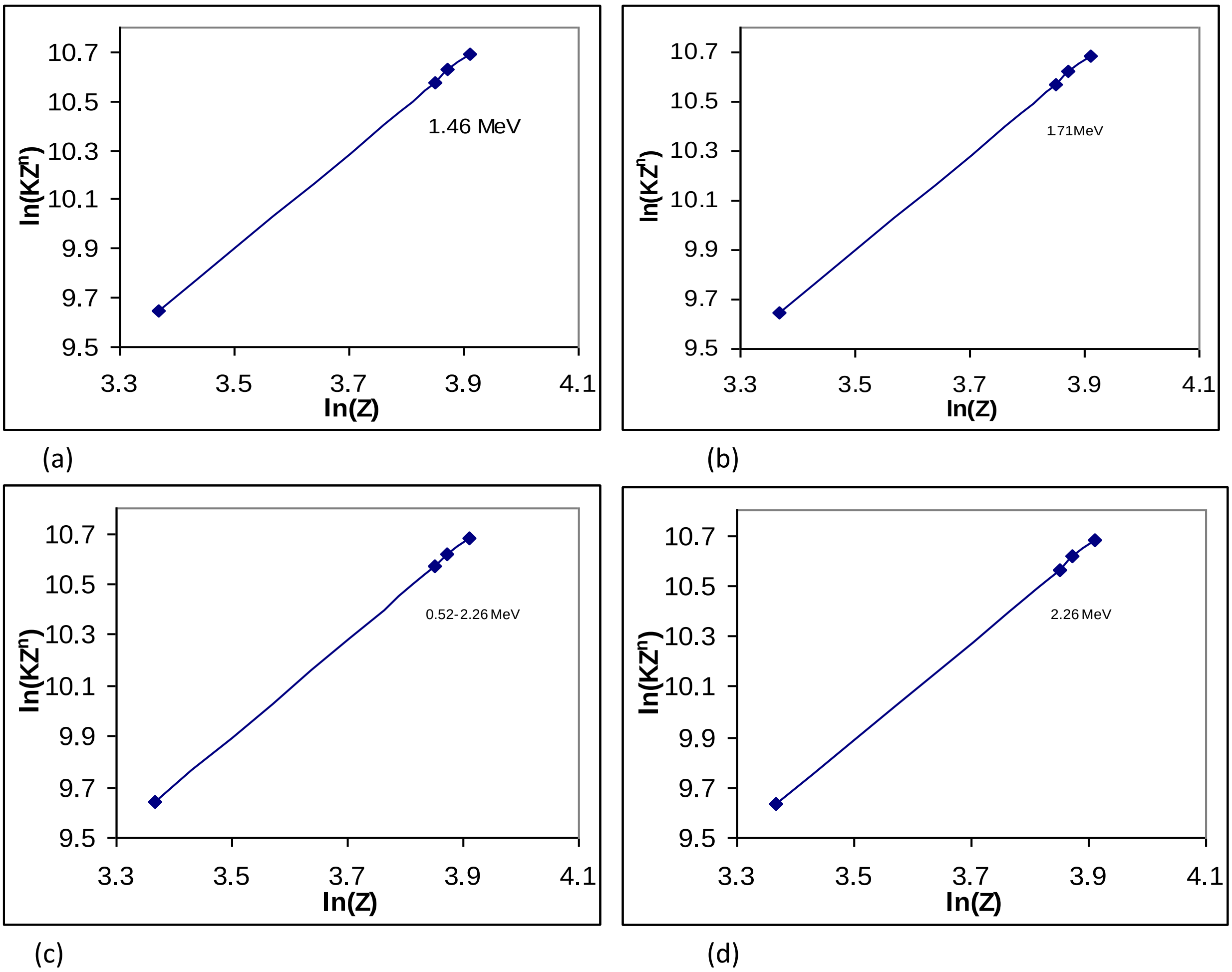

Fig. 2. The plots of ln(z) v/s ln(KZ^n) for energies (a) 1.46 MeV, (b) 1.71 MeV, (c) 0.54-2.26 MeV, (d) 2.26 MeV.

The μ/ρ of beta particles is nearly independent of the atomic weight of the absorber rising slightly with increasing Z and is uniquely determined by the end-point energy of the beta spectrum. However, Σ_B found to be independent of atomic number of the target and also the end-point energy of the beta spectra.

Therefore, the nonlinearity in the increase of EB intensity may be due to the slowing down of beta particles within the target. In the process of diffusion and slowing down, beta particles lose a small fraction of their energy and undergo small deflections in each collision. Most of the incident electrons lose their energy through excitation of the atoms. Using nuclear emulsion techniques, (Dudle 1951) has shown that in slowing down of beta particles the shape of the energy spectrum remains nearly constant as the characteristic of the input spectrum and that the angular distribution pattern of beta rays remains substantially constant throughout the process of slowing down. Therefore, the exact interpretation of Σ_B is possible only if one determines the spectrum of beta particles at each point in the target by using Monte Carlo calculation.

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