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Yield constants of external Bremsstrahlung excited by ^{90}Sr–^{90}Y, ^{147}Pm and ^{204}Tl in CdO and lead compounds

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ABSTRACT

Bremsstrahlung yield of ^{90}Sr–^{90}Y, ^{147}Pm and ^{204}Tl in CdO, PbF_2, $Pb(NO_3)_2$ and $PbCl_2$ has been measured using 3.8 cm × 3.8 cm NaI(Tl) crystal and is compared with Tseng and Pratt theory. The Z dependence of external Bremsstrahlung (EB) is also measured and compared with the theory. The Bremsstrahlung photon yield and energy yield constants (K' and K) are evaluated from the measured and theoretical yields. These values decrease with the increase in E_{max} of beta. The evaluated K' and K may be useful to calculate the photon yield and the energy yield, when these beta particles interact with the compounds of modified atomic number ranging from 42 to 73.

1. Introduction

External Bremsstrahlung (EB) is a continuous electromagnetic radiation emitted when an electron or a beta particle is deflected in the Coulomb field of the nucleus. The previous workers developed many theories [1–4] to explain the Bremsstrahlung process. An accurate theory has been developed by Tseng and Pratt [5]. Seltzer and Berger [6] extend the Tseng–Pratt theory to the field of atomic electron. Most of the EB works of beta have been carried out using only metal as a thick target but using compound as a thick target is lacking. Manjunatha and Rudraswamy [8,9] measured the external Bremsstrahlung spectra for a set of compounds and compared with the Tseng–Pratt theory. Markowicz and VanGriken [10] proposed a new expression for the prediction of the continuum intensity (I_k) to take into account the self-absorption of Bremsstrahlung for the accurate description of the Bremsstrahlung process:

$$I_k = \text{const}\frac{\Delta E}{E_\gamma} Z_{mod}(E_0 - E_\gamma)[1-f] \tag{1}$$

Here,

$$Z_{mod} = \frac{\sum_i^l (W_i Z_i^2/A_i)}{\sum_i^l (W_i Z_i/A_i)} \tag{2}$$

E_γ and E_0 are the emitted photon energy and incident electron energy, respectively. I_k represents the number of continuum photons with energy E_γ in a photon energy range ΔE_γ. A_i, W_i and Z_i are atomic weight, weight fraction and atomic number of the ith element in a compound. As seen from Eq. (1) the continuum intensity is a function of a modified atomic number (Z_{mod}). f is a function of E_0, E_γ and composition (for pure elements $f=0$). l denotes the number of elements in the compound. 'Const' in Eq. (1) refers constant. The new Markowicz formula derived in a more rigorous way gives theoretical results for composite samples, which are in better agreement with the experimental values of Vander Wood et al. [7] than those predicted by Kramer's law. Shivaramu [11] evaluated the atomic number (Z) for set of compounds for the Bremsstrahlung process from the measured yields. He reported that Z agrees fairly well with Z_{mod} than the mean atomic number.

The EB produced by beta particles stopping in thick targets has been discussed by Evans [12]. The expectation value of the total Bremsstrahlung energy that is produced by absorption of the entire β-ray spectrum in a material of atomic number Z will be proportional to

$$\int_1^{W_0} (W-1)^2 N(W) \mathrm{d}W$$

where $W=(E/0.51)+1$ and W_0 corresponds to the maximum energy E_0, in MeV, of the continuous β-ray spectrum. $N(W)\mathrm{d}W$ represents the probability that a given β-ray source will emit an electron with a total energy between W and $W+\mathrm{d}W$. The total number of β-rays emitted by this source is proportional to

$$\int_1^{W_0} N(W) \mathrm{d}W$$

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Consequently the average total energy yield (I) of the Bremsstrahlung per β-ray disintegration is

$$I = KZ(0.51)^2 \frac{\int_1^{W_0} (W-1)^2 N(W)\mathrm{d}W}{\int_1^{W_0} N(W)\mathrm{d}W} \tag{3}$$

where

$$E_{\mathrm{RMS}}^2 = (0.51)^2 \frac{\int_1^{W_0} (W-1)^2 N(W)\mathrm{d}W}{\int_1^{W_0} N(W)\mathrm{d}W}$$

$$I = KZE_{\mathrm{RMS}}^2 \tag{4}$$

This expression is derived on assumption that the basic cross-section depends on the square of the nuclear charge of the target material (Z^2). Energy yield (I) is the total Bremsstrahlung energy radiated per incident beta particle. The energy yield (I) of Bremsstrahlung for compounds can be expressed as

$$I = KZ_{\mathrm{mod}}E_{\mathrm{RMS}}^2(\mathrm{MeV/beta\ particle}) \tag{5}$$

where K is called the energy yield constant (in MeV^{-1}) and E_{RMS} is the root mean square energy of the beta particles (in MeV). Analogously one can write the EB photon number yield (N) as

$$N = K'Z_{\mathrm{mod}}E_{\mathrm{RMS}}(\mathrm{photons/beta\ particle}) \tag{6}$$

where K' is the photon number yield constant (in MeV^{-1}). The number of EB photons produced by electrons or beta particle while passing through a thick target enough to absorb them can be defined as photon yield (N) of the target. I depends on the cross-section for radiation as well as the average path length of the electron. The cross-section depends on Z^2 whereas the average path length depends on Z^{-1} [12]. So in Eqs. (3) and (4) we have Z instead of Z^2. Experiments suggest that the EB cross-sections are not strictly Z^2 dependent [13]. Hence we write Eqs. (5)

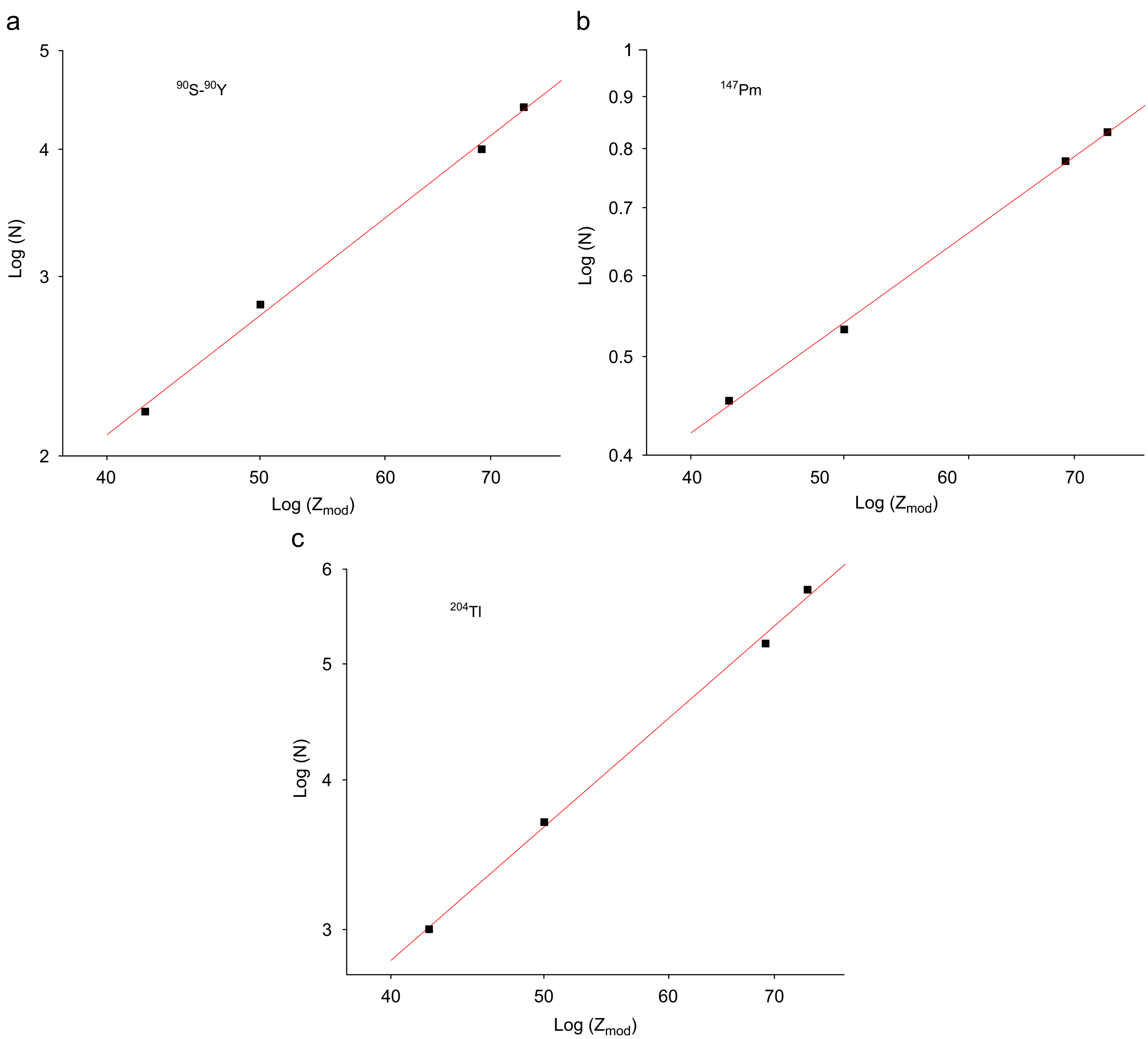

Fig. 1. Measured Bremsstrahlung photon yield (N) plotted against the modified atomic number (Z_{mod}) for beta particles of (a) ^{90}Sr–^{90}Y, (b) ^{147}Pm and (c) ^{204}Tl.