Effective atomic number Electron density and Kerma of gamma radiation for Lanthanide oxides

B. Rudraswamy[1*], R.S.Niranjan[1], N. Dhananjaya [1].
Department of Physics, Bangalore University, Bangalore 560 056, Karnataka, India.
*E-mail :rbasavanna2002@yahoo.com,niranjanrs1977@yahoo.com

Abstract

An attempt has been made to estimate the effective atomic number, electron density (0.001 to 10^5 MeV) and kerma (0.001 to 20 MeV) of gamma radiation for wide range of Lanthanide oxides using the theoretical values of the mass attenuation coefficient from XCOM and mass energy absorption coefficient (Hubbell and Seltzer). The Lanthanide oxides used in the present steady are Y_2O_3, Gd_2O_3, Nd_2O_3, Dy_2O_3, Eu_2O_3, Sm_2O_3 and La_2O_3.

Key words: effective atomic number; electron density; Kerma; Lanthanide oxides.

1. Introduction

Hubbell [1] developed XCOM for estimation of mass attenuation coefficient and photon interaction cross-section of any element, compound and mixture in the energy range from 1 keV to 100 GeV . XCOM was transformed to the Windows platform by Gerward et al. [2] and this Windows version is being called as WinXCom. Manohara etal.,[3] have estimated the effective atomic number and electron densities for l amino acid in the energy range 1 keV–100 GeV using WinXCom program.

Effective atomic number, electron density, kerma in the energy range between 0.001MeV to 10^5 MeV. In the present work, we have made an attempt to estimate theoretically effective atomic number, electron density and kerma of gamma radiation for Lanthanide oxides such as Y_2O_3, Gd_2O_3, Nd_2O_3, Dy_2O_3, Eu_2O_3, Sm_2O_3 and La_2O_3 in the energy range between 0.001MeV to 10^5 MeV. Important pre-requisites for the studies of radiation shielding design materials.

2. Estimation of parameters

2.1 Effective atomic number and electron density of the Lanthanide oxide:

The effective atomic number (Z_{eff}) and the electron density (N_e) have been estimated with the known mass attenuation coefficient , $\left(\frac{\mu}{\rho}\right)$, atomic cross section, σ_a and electronic cross section, σ_e of Lanthanide oxide used in the following expressions .

$$Z_{eff} = \frac{\sigma_a}{\sigma_e} \quad (1)$$

$$N_e = \frac{\left(\frac{\mu}{\rho}\right) Z_{eff}}{\sigma_a} \quad (2)$$

σ_a and σ_e have been estimated with the known σ_m , Σn_i , fi Z_i and A_i and N used in the following expressions

$$\sigma_a = \frac{\sigma_m}{\sum_i n_i} \quad (3)$$

$$\sigma_e = \frac{1}{N} \sum_i \left(\frac{f_i A_i}{Z_i}\right)\left(\frac{\mu}{\rho}\right)_i \quad (4)$$

Molecular cross section σ_m of the compound has been estimated with known $\left(\frac{\mu}{\rho}\right)$, $\Sigma n_i A_i$ and N

$$\sigma_m = \left(\frac{\mu}{\rho}\right) \frac{\sum_i n_i A_i}{N} \quad (5)$$

fi is the fractional abundance of the i^{th} element such that $f_1 + f_2 + f_3 + ... + f_i = 1$, Z_i and A_i are the atomic and mass numbers of i^{th} element respectively and Σn_i, is the total number of atoms of i^{th} element of the compound .

The theoretical $\left(\frac{\mu}{\rho}\right)$ has been estimated for the given energy and the compound with the following mixture rule

$$\left(\frac{\mu}{\rho}\right) = \sum_i \omega_i \left(\frac{\mu}{\rho}\right)_i \quad (6)$$

$\left(\frac{\mu}{\rho}\right)_i$ and w_i are the mass attenuation coefficient and weight fraction of the i^{th} element of the compound, whose values at various gamma energies has been obtained from XCOM data [1,2].

2.2 kerma relative to air

Mass-energy attenuation coefficient $\left(\frac{\mu_{en}}{\rho}\right)_{\mathbf{comp}}$ of Lanthanide oxide has been estimated with the known $\left(\frac{\mu}{\rho}\right)$ values used in the following expression as proposed by earlier worker [4]

$$\left(\frac{\mu_{en}}{\rho}\right)_{\mathbf{com\ p}} = \left(\frac{\mu}{\rho}\right) 102.497\times E^{(0.1052\ln E-1.49622)} \qquad (7)$$

E is the energy of the gamma source

Kerma , K of gamma radiation for the compound has been estimated with the known $(\mu_{en/\rho})_{comp}$ and $(\mu_{en/\rho})_{air}$ [1] values used in the following expression

$$K = \frac{\left(\mu_{en}/\rho\right)_{comp}}{\left(\mu_{en}/\rho\right)_{air}} \qquad (8)$$

3. Results and discussion:

Theoretical values of Z_{eff}, N_e (0.001 to 10^5 MeV) and K (0.001 to 20 MeV) of Lanthanide oxides are as shown in Figures 1, 2 and 3.

4. Conclusions:

The results obtained are useful to understand, how Z_{eff}, N_e and K change with energy for different Lanthanide oxides and in the design of shielding materials for gamma radiation.

References:

[1] WWW http://physics.nist.gov/xcom.html.

[2] L. Gerward, N. Guilbert, K. B. Jensen, H. Levring Rad Phys and Chem **71**(2004) 653.

[3] S. R. Manohara, S. M. Hanagodimath and L. Gerward PHYSICS IN MEDICINE AND BIOLOGY 53 (2008) N377–N386 .

[4] B. Rudraswamy, N. Dhananjaya, H. C. Manjunatha Nuclear Instruments and Methods in Physics Research A **619** (2010) 171.

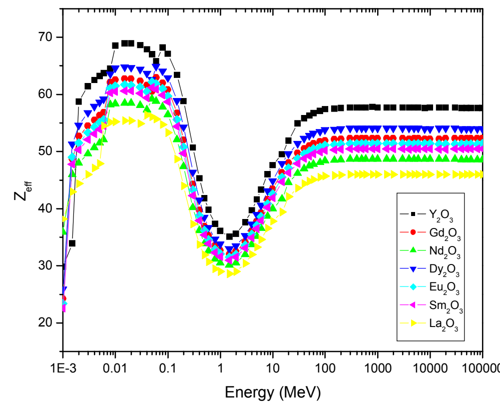

Fig. 1. Variation of Z_{eff} with gamma energy

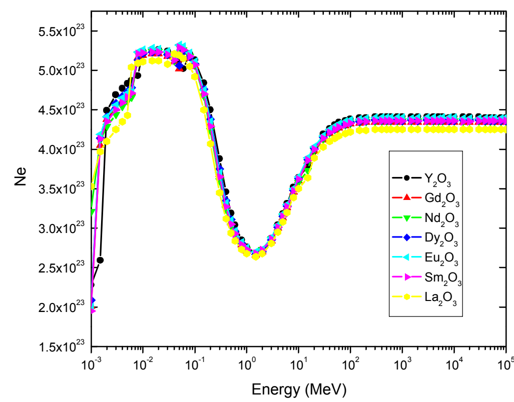

Fig. 2. Variation of N_e with gamma energy

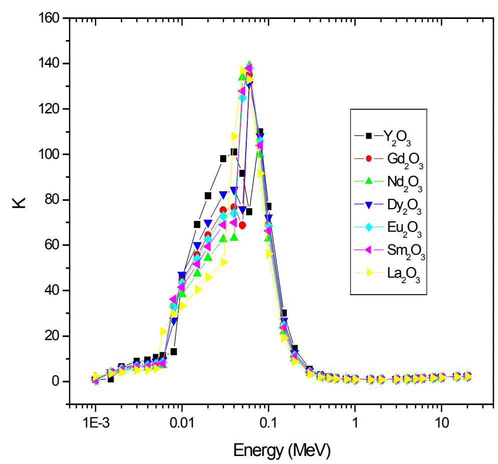

Fig. 3. Variation of K with gamma energy