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Parameters of Dosimetric Interest of Some Vanadium and Nickel Compounds

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Mass attenuation coefficients (μ_m), effective atomic numbers (Z_{eff}) and electron densities (N_{el}) of some vanadium compounds V_2O_3, VO_2, VF_3, VF_4, NH_4VO_3 and nickel compounds NiF_2, $NiCl_2$, $NiCl_2.6H_2O$, $Ni(ClO_4)_2.6H_2O$, $NiF_2.4H_2O$ have been computed over a wide energy region from 10 keV to 100 GeV. In all the parameters, a similar trend is observed. All the parameters initially possesses maximum values, which decreases very rapidly upto 100 keV, then becomes almost constant upto 3 MeV and with the further increase in the incident photon energy beyond 3 MeV, values of all the parameters also increase which may be due to dominance of different partial photon interaction process in different energy regions.

Key Words: Attenuation coefficient, Effective atomic number.

INTRODUCTION

Vanadium and nickel are both transition metals, which forms a large number of compounds due to their multiple valences and many of their compounds have been used in various technological applications such as in chemical industry, ceramic industry, act as catalyst, alloying agent, also used in fabrication of permanent magnets and electroplating.

The μ_m of a material describes the total reduction of the incident photon (X-ray/γ-ray) due to both absorption as well as scattering. Several researchers have contributed in providing μ_m data for a large number of compounds and mixtures theoretically[1,2] as well as experimentally. Z_{eff} is an energy dependent number assigned to compound/mixture similar to atomic number used for elements. Electron density describes the number of electrons being present per unit mass of the material for interaction with the photons. Z_{eff}[3] data is available for different amino acids and sugars[4], glasses[5], soils[6] and alloys[7] and N_{el} data is limited to few compounds[4,5] only.

In the present attempt, some parameters of dosimetric interest of vanadium and nickel compounds were computed *viz.*, μ_m, Z_{eff} and N_{el}. These are the basic parameters of the composite materials, which not only provides the better understanding of the interaction of gamma rays with the material but also very useful parameters to check the feasibility/optimum thickness of a given material to be used as shielding material.

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COMPUTATIONAL WORK

The mass attenuation coefficients μ_m values in the wide energy range of 10 keV to 100 GeV for the various constituents element and the selected compounds (V_2O_3, VO_2, VF_3, VF_4, NH_4VO_3, NiF_2, $NiCl_2$, $NiCl_2.6H_2O$, $Ni(ClO_4)_2.6H_2O$ and $NiF_2.4H_2O$) were obtained using WinXCom (XCom database[1]) computer software[2], which were further used by our computer program to compute molecular cross section (σ_m), atomic cross section (σ_a), electronic cross section (σ_e), effective atomic number (Z_{eff}) and effective electron number or density (N_{el}) of the chosen compound using the following relations:

$$\sigma_m = (\mu_m)_{compound} \frac{\sum_i n_i A_i}{N} \quad (1) \qquad \sigma_a = \frac{\sigma_m}{\sum_i n_i} \quad (2)$$

$$\sigma_e = \frac{1}{N} \sum_I \frac{f_i A_i}{Z_i} (\mu_m)_i \quad (3)$$

where N is the Avogadro's number, A_i and Z_i are atomic weights and atomic numbers of i^{th} element and f_i, n_i, $(\mu_m)_i$ are the fractional abundance, number of atoms and mass attenuation coefficient of i^{th} element present in a molecule of a compound respectively.

$$Z_{eff} = \frac{\sigma_a}{\sigma_e} \quad (4) \qquad N_{el} = \frac{(\mu_m)_{compound}}{\sigma_e} \quad (5)$$

RESULTS AND DISCUSSION

In Figs. 1 and 2, the variation of mass attenuation coefficients with incident photon energy for vanadium and nickel compounds has been shown. Almost similar trend is observed for both types of compounds. The variation of mass attenuation coefficient values with incident photon energy can be explained on the basis of dominance and Z-dependence of different partial photon interaction processes.

In the lower energy region (10 keV to few hundred keV), photoelectric absorption process is the dominant process whose cross-section depends on atomic number as Z^4 (low energy) or Z^5 (high energy) and inversely proportional to the incident photon energy as $E^{3.5}$ due to which there is a rapid decrease in the mass attenuation coefficient values. Further for the intermediate incident photon energy region (few hundred keV to few MeV), Compton scattering is the dominant process whose cross-section depends linearly with atomic number, hence the mass attenuation coefficient values becomes almost same in this energy region. However for high incident photon energy region (beyond few MeV), pair production becomes the dominant process, whose cross-section is related to atomic number as Z^2, so the mass attenuation coefficient values increase with the further increase in incident photon

energy. Finally it can be concluded that the variation of mass attenuation coefficient with the incident photon energy is due to the dominance and Z-dependence of different partial photon interaction processes.

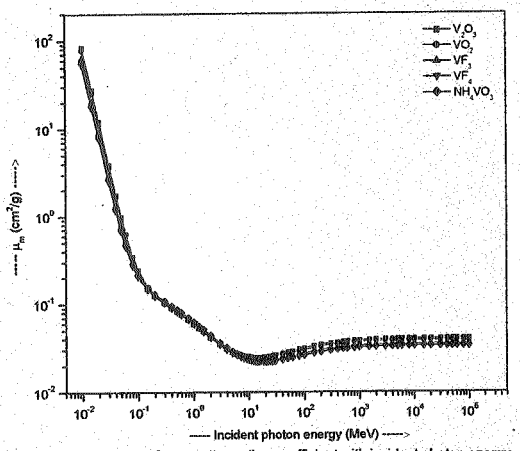

Fig. 1. The variaton of mass attenuation coefficient with incident photon energy for selected vanadium compounds.

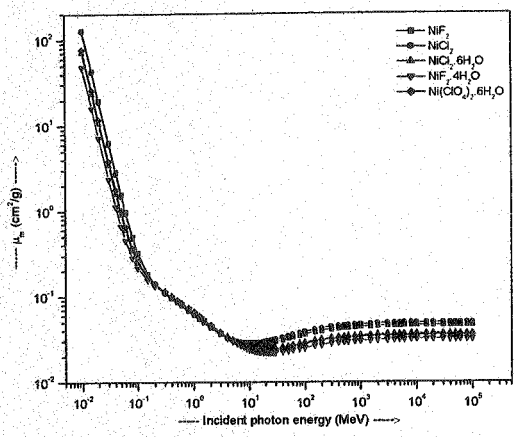

Fig. 2. The variation of mass attenuation coefficient with incident photon energy for selected nickel compounds.

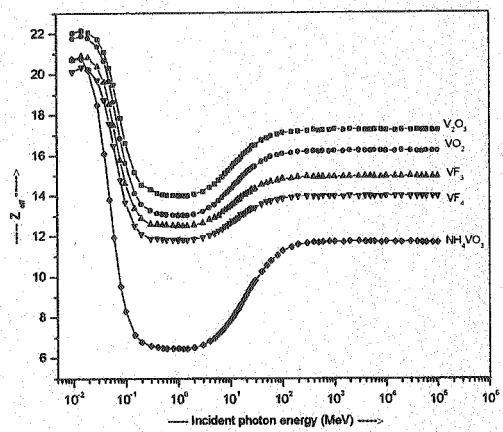

Fig. 3. The variation of effective atomic number with incident photon energy for some selected vanadium compounds.

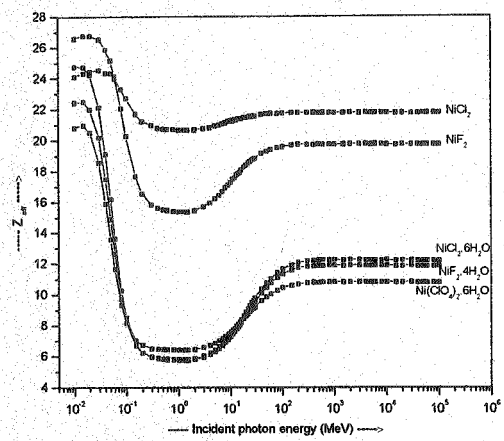

Fig. 4. The variation of effective atomic number with incident photon energy for some selected nickel compounds.

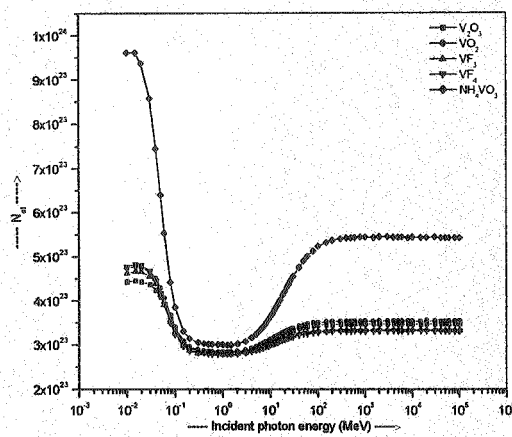

Fig. 5. The variation of electron density with incident photon energy for some selected vanadium compounds.

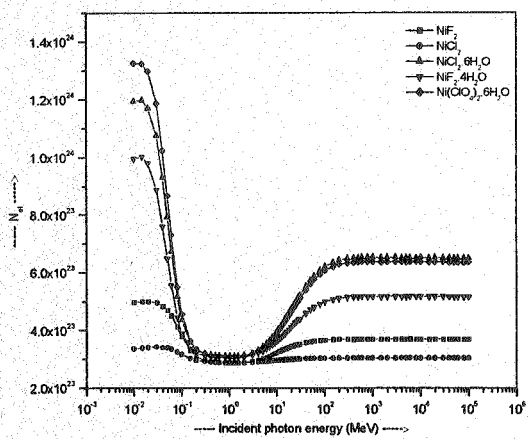

Fig. 6. The variation of electron density with incident photon energy for some selected nickel compounds.

The variation of effective atomic number with incident photon energy for selected vanadium and nickel compounds are shown in Figs. 3 and 4. Again the trend of variation of effective atomic number for both the materials is same, which is due to the same reason as explained above. Moreover some compounds which consists of more than three elements

(NH_4VO_3, $NiCl_2.6H_2O$, $Ni(ClO_4)_2.6H_2O$ and $NiF_2.4H_2O$) shows large variation in effective atomic numbers as compared to others which are simple and made up of only two elements (V_2O_3, VO_2, VF_3, VF_4, NiF_2, $NiCl_2$).

In Figs. 5 and 6, computed values of electron density for different vanadium and nickel compounds have been plotted against the incident photon energy. The variation of electron density with the incident photon energy shows a similar trend as observed in case of effective atomic number, which is obvious, as the effective atomic number is supposed to provide information regarding number of electrons/protons present in a compound in a similar way as atomic number provides information about the number of electrons/protons present in its neutral atom.

Moreover, it has also been observed that effective atomic number as well as electron densities for NH_4VO_3, $NiCl_2.6H_2O$, $Ni(ClO_4)_2.6H_2O$ and $NiF_2.4H_2O$ shows a large variation as compared to other materials, so it can be concluded here that complex materials (made up of three or more elements) have a large variation in their electron densities as compared to the simple compounds (made up of two elements only).

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