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The *f*-factor, neutron, gamma radiation and proton shielding competences of glasses with Pb or Pb/Bi heavy elements for nuclear protection applications

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ABSTRACT

In this article, proton, neutron, and gamma-ray shielding competences of six glasses with PbO or PbO/Bi_2O_3 heavy metal oxides namely as Glass 1 to Glass 6 have been investigated via WinXcom and EXABCal computer codes. The maximum values of μ_m were equal to 50.6, 53.06, 72.51, 80.67, 99.54, and 102.35 $cm^2\ g^{-1}$ at 0.015 MeV for Glass 1 to Glass 6, respectively. The μ_m of the glass's trend in ascending order for Glass 1 to Glass 6. Results of HVL and MFP of the glass's were trend in descending order for Glass 1 to Glass 6. The Z_{eff} of glasses varied from 14.49 (1.5 MeV) to 37.78 (0.1 MeV) and from 43.93 (2 MeV) to 65.62 (0.02 MeV) for Glass 1 and Glass 6, respectively. The *f*-factor of Glass 5 and Glass 6 was maximum for throughout the energy spectrum. The buildup factors are low and grow with the penetration depth rapidly up to the maximum depth of 40 mfp. The values of Σ_R were varied from 0.0947 to 0.1155 cm^{-1} for Glass1 to Glass 6, respectively. Glass 2 and Glass 6 are preferred fast neutron shield when compared with ordinary concrete, water, and graphite. Generally, the molar concentration of PbO or PbO + Bi_2O_3 improved the shielding capacity of the investigated glasses.

1. Introduction

Knowledge of ionizing radiation (IR) interaction parameters is of great value in quality assurance (QA) and control (QC) procedures in many peaceful applications of IR. A cardinal objective of these procedures is the use of radiation shields, coupled with dose measurement for the sole purpose of protecting man, the biota, and devices from the harmful effect of radiation. Without IR interacting parameters of materials, human tissues, and other systems that are adopted in all IR fields, QA and QC in nuclear industries would be impossible and radiation applications would be threatened [1]. This could lead to reduction in the quality of human lives. To this end, parameters describing interaction of different groups of media with IR of various energy and linear energy transfer have been obtained by different research groups [2–10].

Glasses and glass-ceramics form a group of material that have gained wide interest among others. Glass materials have been found to possess good attributes that make them preferred choices in radiation shielding applications compared with common radiation shields such as lead, depleted uranium, and concrete [2,3,11–14]. These attributes include (but not limited to): transparency, ease of production, and environmentally friendly (since they can be recycled). Furthermore, the fact that the chemical composition of glass can be modified (through doping and other easy chemical and physical processes). Accomplishing the appropriate shielding competence is a major factor that has precipitated much research on shielding parameters of different glass compositions [4,14–24].

Traditionally, lead is a very good radiation shield and has become very popular due to its low cost and high efficiency in terms of gamma radiation shielding. Lead has high atomic number and mass density, these two factors are required for an effective photon shield. However, its poisonous nature has continued to encourage researcher to find alternatives. One possible way of reducing the toxicity level of lead is to mix it with other materials. While the production and use of different types of glasses for radiation shielding has continued to grow. Addition of heavy metal oxides such as lead to glass matrix combines the excellent radiation shielding properties of heavy metals with other beautiful properties of glasses. The use of heavy elements (Pb, Bi, or Pb with Bi) in the glass composition has significantly recorded an improvement in its physical and radiation shielding characteristics. Several researchers have investigated the influence of different amounts and types of heavy metal oxides additives used in glass for gamma- and

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