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Research Article

Effective Atomic Numbers of Glass Samples

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Abstract:

Effective atomic numbers are a term used to understand the interaction of a compound or material with radiation. In particular, this term is often used for materials with complex structures that can be expressed by a single fixed atomic number. If different elements in a material are present in different concentrations, the effective atomic number of the material can be calculated by considering the contribution of each element. This is a useful method to better understand the response of the material to radiation or the effect of radiation within the material. In particular, when radiation passes through or acts on the material, the effective atomic number plays an important role in determining factors such as the material's radiation exposure properties, absorption or scattering. Effective atomic numbers are used in radiation interaction analyses in various fields such as materials science, medicine, geophysics and industry. This concept is used to express in a simpler way the radiation properties of compounds in which different elements are combined. In this study, the effective atomic numbers of magnesium borosilicate glasses were investigated. Such studies are important in the field of materials science and glass technology because the chemical constituents of glass and their interactions play a decisive role in the properties of glass. Magnesium borosilicate glasses are often used in industrial applications. The properties of these glasses depend on the amount of elements they contain and their chemical structure. Effective atomic numbers can be used to understand the specific properties of a material. By determining the effective atomic numbers of the elements contained in the glass, this study aims to provide an important basis for understanding the properties of the material, such as radiation exposure, electrical properties or optical properties.

1. Introduction

The ionizing radiation have been applied in various different fields such as agriculture, industry, scientific research medicine etc. On the other hand during this applications radiation may cause severe damage to humans and the environment if they are not handled with required care and in safe ways [1-8]

In the parallel of technological development, the radiation has been started to be used in different applications and this requires protection from hazardous effect of radiation. Due to negative effect of lead and lead based materials which have been used conventionally, alternative non-conventional materials is one of the most critical concerns in nuclear shielding technologies [9-11]

There are some known criteria such as high density and high atomic number (Z), in addition to low cost and availability in the selection of shielding materials [12-17]. The lead is the most used material to protect from X-rays and γ-rays in the past but due to its toxicity, heaviness, rigidity, and poor portability character, researchers focused on the radiation protection topic to find new alternative materials for radiation shielding. Thus there are many different types materials such as glasses and composites that can be the best replacement of the conventional material have recently been studied either experimentally or simulation code [18-36].

On the other hand there are still many open questions and more studies are required on this fields. Thus this work is an attempt to employ the glass to develop an alternative and environmentally friendly material for gamma-radiation protection applications.

Among those materials for use in radiological protection purposes, due to its ability to be shaped into specimens of varied thicknesses in a number of shapes the glasses have important place [37-43].
To evaluate the radiation shielding properties of new glass types, the linear attenuation coefficient (LAC), mean free path (mfp), Half value length (HVL), effective atomic number (Z_{eff}) and effective electron density (N_{eff}) are investigated. These parameters can be obtained in experimental studies, but in many cases it is not possible to conduct experimental research due to the lack of sufficient resources, including the lack of radioactive sources. In this study, the effects of effective atomic number, one of the radiation defense mechanisms of Magnesium Borosilicate Glasses, were investigated. The analyzing of glass compositions was tested as protective materials against gamma-radiation by using PhX/PSD software.

2. Material and Methods

The knowledge of Z_{eff} and N_{eff} are important parameters to test shielding properties of glasses used in medical hospitals. As the weights of the atomic numbers may vary with the different gamma ray interaction processes and the different gamma ray energy range they pre- dominate, the pureness materials cannot be represented by a single atomic number uniquely across the whole gamma ray energy region. Thus the number which describes the multi element materials in terms of equivalent elements is called effective atomic number (Z_{eff}). This number varies with the gamma ray energy. The effective electron density (N_{eff}) is expressed as the number of electrons per unit mass of a multi element material. These both parameters are used to understand the gamma ray interaction with the target material well [44].
The effective atomic number of a material composed of several elements cannot be expressed by a single number and for each of the different processes by which gamma-rays can interact with matter, the various atomic numbers in the material have to be weighted differently. This number for compounds and mixtures is named as the‘‘effective atomic number’’ and it varies with the energy [45].
The effective atomic numbers were determined by the ratio of total atomic cross section and the total electronic cross section,

$$Z_{eff} = \frac{\sum N_i Z_i \sigma_{T,EL}}{\sum_i N_i \sigma_{T,EL}} \quad (1)$$

where N_i is the total number of atoms, Z_i total atomic number and $\sigma_{T,EL}$ is the total electronic cross section [46].

The effective atomic number (Z_{eff}) can be obtained using atomic (σ_a) and the electronic (σ_e) cross-sections as given in equation [10],

$$Z_{eff} = \frac{\sigma_a}{\sigma_e} \quad (2)$$

[45].

3. Results and Discussions

In the present study the shielding parameters of effective atomic numbers for magnesium borosilicate glasses have been calculated using Phy-X/PSD software [47].

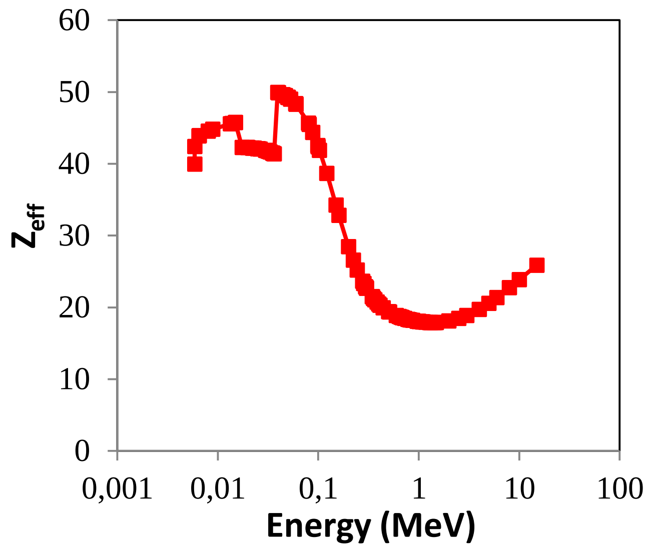

Figure 1. *The Z_{eff} for glass as a function of gamma energies*

In order to obtain effective atomic number and effective electron density, the atomic and electron cross section is needed. These parameters have been calculated as a function of gamma ray energies and displayed in Figure 1. The Z_{eff} of the tested glass sample as a function of gamma ray energies is graphed in Fig. 1. The figure shows that the Z_{eff} values increase with increasing energy in glass system. It can be seen from this figüre that at low energy Z_{eff} is higher and it is not stable while it decreased at higher energy (above 0.1 MeV). It is also clearly seen from this figure that the Z_{eff} stay constant until 1 MeV and slightly increased after 1 MeV.

4. Conclusions

This study is about the radiation shielding properties of magnesium borosilicate glasses samples. The variation of the effective atomic number (Z_{eff}) parameter in the glass sample was investigated. This investigation was done by obtaining some parameters. The parameters were calculated using

Phy-X software. The main objective of this study is to investigate the effectiveness of magnesium borosilicate glasses as a radiation shielding material. Effective atomic number is obtained for glass sample and the results discussed. It was found that effective atomic number is depends on gamma ray energies. According to the result obtained, magnesium borosilicate glasses have a clear positive effect on the radiation shielding properties of glasses. The work presented in this paper has been important data in this field.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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