Natural Products Chemistry & Research 2022, Vol.10, Issue 4, 001-003 **Research Article**

Galena with B_4C High-Density Heavy Concrete for Shielding Nuclear Reactors

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Abstract

Shielding of a biological type belonging to a nuclear reactor is considered one of the main issues and the lower complexity and expense of these installations are of important interest. In this paper, Galena mineral and Boron Carbide (B_4C) were used to produce high-density heavy concrete. Galena minerals that are present in most regions of Iran were regarded to be applied in the concrete mix design. Boron Carbide (B_4C) is regarded as a ceramic material that is efficient in order to absorb thermal neutrons as a consequence of a wide neutron absorption cross-section. Neutron shielding characteristics of samples could explain the cross-section in matter and neutron capture. Neutron cross-section measurements of samples have been done by using a source of 14.1MeV neutrons. By using Geant 4 Monte Carlo code, cross-section and neutron capture of each sample could be calculated through it. As a consequence, the cross-section value of concrete can be raised by growing boron carbide (B_4C) concentration and lower neutron capture value of samples and boost the attributes of shielding.

Keywords: Galena • B4C • Neutron cross-section • Heavy concrete • Shielding

Introduction

Because of its cheaper, easier molded into compound shape, good structural and appropriate as neutron shielding materials in comparison to other shielding materials, concrete is considered a multi-user material and it is usually accustomed as a radiation shielding material [1]. investigated that frequently concretes are composites materials including aggregate, sand, water, and cement. The radiation shielding type belonging to a nuclear reactor is an expensive and very complex method [2]. have recognized that a nuclear reactor usually requires two shields one of which is a shield to guard the walls of the reactor against radiation harm and simultaneously, reflect neutrons back into the core; and the other, a biological shield that guards people and the environment. The biological type shield lowers the rank of Gamma radiation and neutrons to current dose limits. The biological shield is marked by many centimeters of very high-density concrete [3]. proposed that in nuclear-type reactors, neutron radiation is the main hard to shield and hydrogen is regarded as the major effective element in decelerating (thermalizing) neutrons over the whole energy spectrum. It is thought that the greatest hydrogen in concrete is normally shown in the model of water in which hydrated within cement curing and collects setting and free water streaming in the porousness of concrete explored that Boron is an important chemical component to be used in neutron absorption mechanisms [4]. It is important in shielding technology because of its flawless shielding characteristics have recognized that it is an effective absorber that can be used in neutron shielding materials [5]. There is various research carried out about radiation shielding by boron mixtures [6-10]. Concrete has many advantages and is a very effective material to be used in shielding reactors. The high the density of concrete, the higher the linear gamma and neutron attenuation properties in comparison to regular concrete explored that concrete is made up of Portland cement, sand aggregate, and water and is considered one of the main conventional materials used in the structure of commercial buildings [11]. Nowadays, normal concrete (density of about 2350 kg/m^3) is mostly advantageous to be applied in superficial and orthovoltage radiotherapy rooms [12].

Galena (PbS) is the basic lead mineral [13]. Galena also has cerussite ($PbCO_3$), plattenerite (PbO_2), and anglesite ($PbSO_4$) in its combination. Galena is a very condensed material and has a density equal to 7400-7600 kg/m^3, so it is nearly as dense as iron. The chemical combination and physical properties of Galena are summarized in table 1. In the nuclear-type reactor, a specific composition of Portland, cement, and sand was used to implement radiation shielding, while as Atsuhiko et al. (2004) confirm, boron carbide (B_4C) was doped with Portland cement to construct concrete as a thermal neutron absorber and lower radioactivity through thermal neutron.

The main goals of this paper are to reach to neutron cross-section through Geant4 Monte Carlo code for samples. A cross-section according B_4C percentage for Galena is shown in table 2.

Materials and Methods

Plant material

To start with, the materials included gravel, sand, cement, water, micro siliceous, and Boron Carbide powder. Galena minerals were applied

Table 1. Physical properties of the Galena used in this study.

Properties	Galena
Chemical composition	Lead Sulfide(PbS)
Molecular weight	239.26g
Lead content	86.59% Pb 13.40% S
B_2O_3 content	---
stiffness	2.5
Density (g/cm^3)	7.0-7.5
Color	Gray

Table 2. Cross-section, neutron capture, and density of concretes according to B_4C percentage and Galena.

Material	Cross-section(cm^{-1})	Neutron Capture	density (g/cm^3)
5% B_4C+95% PBS	0.2069627	20	7.6
10% B_4C+90PBS	0.2217395	18	7.092
15% B_4C+85% PBS	0.2368774	12	6.838
20% B_4C+80%PBS	0.249168	13	6.584
25% B_4C+75% PBS	0.2599995	14	6.33
30% B_4C+70% PBS	0.2691495	10	6.076
35% B_4C+65% PBS	0.2762899	4	5.822
40% B_4C+60% PBS	0.2821242	11	5.568
45% B_4C+55% PBS	0.2865148	9	5.314
50% B_4C+50% PBS	0.2892206	8	5.06
55% B_4C+45% PBS	0.2888801	5	4.806
60% B_4C+40% PBS	0.2882943	9	4.552
65% B_4C+35% PBS	0.2866266	5	4.298
70% B_4C+30% PBS	0.282944	4	4.044
75% B_4C+25% PBS	0.2773991	4	3.79
80% B_4C+20% PBS	0.2701028	1	3.536
85% B_4C+15% PBS	0.2607065	2	3.282
90% B_4C+10% PBS	0.2498469	2	3.028
95% B_4+C5% PBS	0.2373147	1	2.774

for the production of high-density concrete. Concrete must include a large amount of water in order to be used as a shield in nuclear reactors. Higher water content cause to be concrete more efficient than any regular concrete. In this paper, two types of concrete mixes were produced. First, regular concrete mixes were composed of gravel, sand, cement, water, and micro siliceous. Second, GaB$_4$C concrete Galena and B$_4$C were applied to completely replace the sand concrete mixture. In table 3, the concentration of Galena and Boron Carbide (B$_4$C) in concretes is exhibited. Cross-section according to neutron capture is shown in figure1 and cross-section according to density is shown in figure 2. By exposing to neutron source 241Am-Be (number of events processed 100000) radiation test was carried out.

Table 3. The concentration of Galena and Boron Carbide (B$_4$C) in concretes.

Material	Galena	Boron Carbide
1	95%	5%
2	90%	10%
3	85%	15%
4	80%	20%
5	75%	25%
6	70%	30%
7	65%	35%
8	60%	40%
9	55%	45%
10	50%	50%
11	45%	55%
12	40%	60%
13	35%	65%
14	30%	70%
15	25%	75%
16	20%	80%
17	15%	85%
18	10%	90%
19	5%	95%

Monte Carlo Simulation

The Geant4 program is considered a functional simulation tool for several applications in high-energy physics. The interaction and propagation of neutrons in the matter in shielding design with the Geant4 program can be simulated. It is yielded that cross-section and neutron capture could be obtained through Geant4 Monte Carlo code. In the first stage, we entered the atomic stoichiometric and densities of the sample. In the second stage, simulation was started for 100000 primary neutron particles.

Results and Discussion

The cross-section and neutron capture are regarded as effective elements in order to define the neutron shielding characteristics of the sample. Does not exist an easy scaling rule for neutron linear attenuation coefficient. But the cross-section is described and defined

Table 4. Shielding properties of Galena, Concrete, and Boron Carbide.

Material	Cross Section	Neutron Capture
PbS	0.188831501	16
Concrete	0.163818597	20
%100 B$_4$C	0.2251179	-

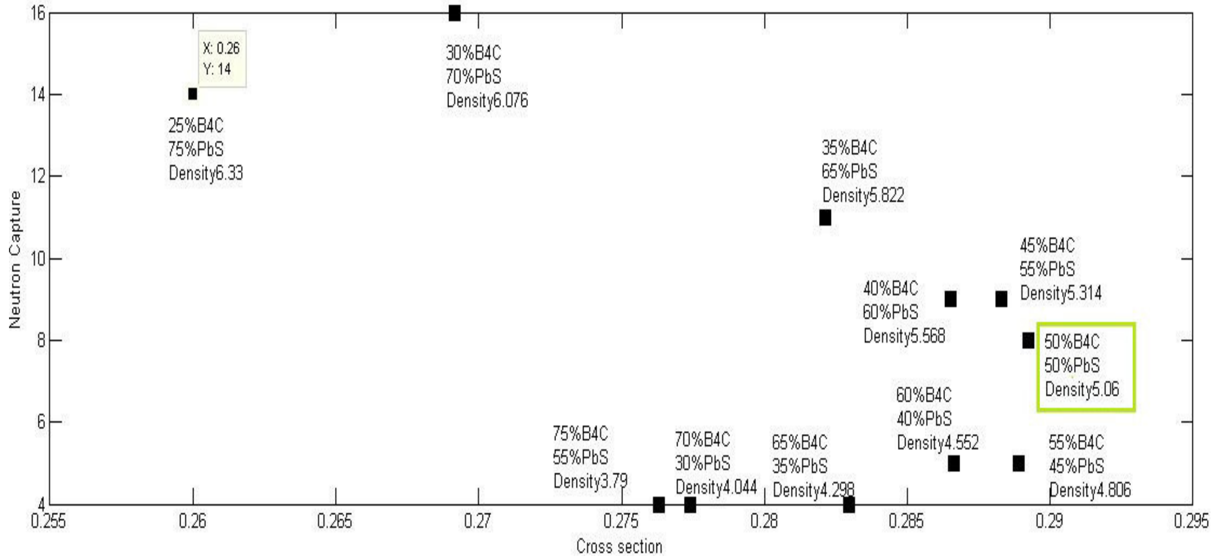

Figure 1. The measured value of Cross-section as a function of Neutron Capture.

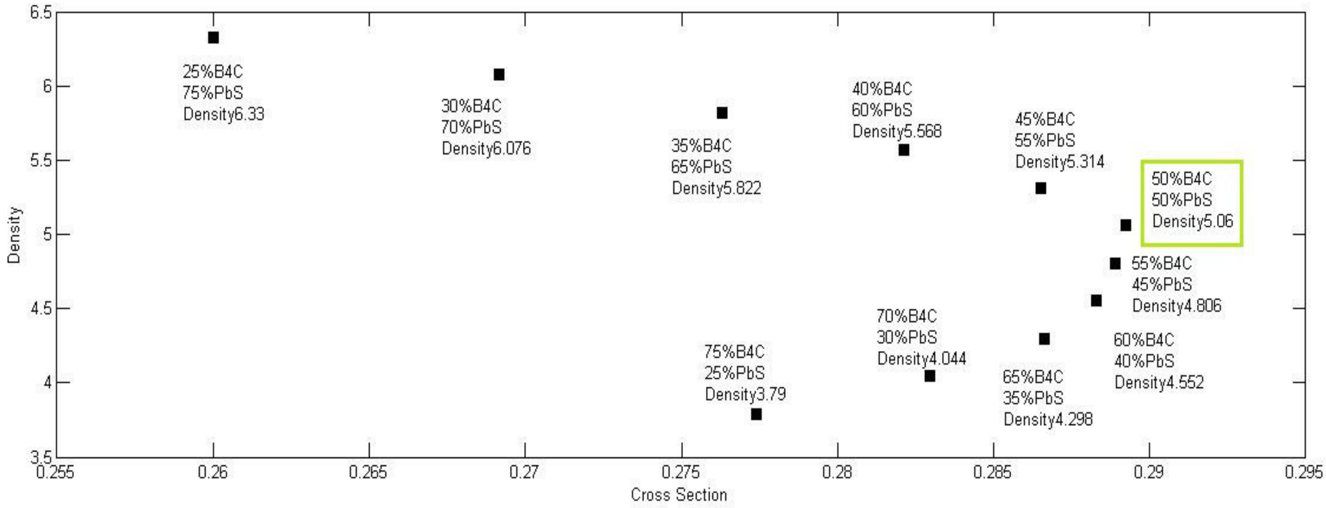

Figure 2. The measured value of cross-section as a function of Density.

by a neutron. Inverse length in units of the linear attenuation coefficient that is commonly pointed out by cm^{-1}. The microscopic range of neutron interaction describes the cross-section. Cross-section illustrates the effective cross-sectional region to neutrons displayed by each nucleus of attenuating materials. The units are normally the barn in which 1 barn is equivalent to 10-30 cm^{-2}

The neutron cross-section has been computed by a neutron detector. From Geant4 Monte Carlo code, we calculated the cross-section and neutron capture. The calculated contents of cross-section and neutron capture by using Geant4 Monte Carlo code are represented as a function of the percentage of the Boron Carbide (B_4C) in table 2 and Cross-section according to neutron capture is shown in figure 1.

As can be seen in table 2, as the cross-section increases, the percentage of Boron Carbide (B_4C) in the samples increases. It is seen successfully that the neutron cross-section is strongly dependent on the Boron Carbide (B_4C) intensity in the matter and as it can be seen in figure 1, 50% B4C + 50% Galena with a density of 5.06 has a high cross-section value and so it has high neutron shielding properties in comparison to other samples.

Furthermore, the calculated contents of cross-section and neutron. As demonstrated above, the Boron Carbide percentage is effective on neutron shielding capability of matter. Thus, as can be seen in table 2 and figure 2, because of the high cross-section, 50 % Galena + 50% Boron Carbide is a more effective shielding material. Also, cross-section, Neutron capture, and Density of Galena, Concrete, and Boron Carbide are listed in table 4.

As it could be inferred from table 2, we can say that neutron capture increases as the density increases, and also we can see in figure 2 that 50% B_4C + 50%Galena with a density of 5.06 has a high cross-section value and have a high neutron shielding properties in comparison to other samples.

Conclusion

We have explored in the present research, rapid neutron shielding capture by using Geant4 Monte Carlo code is represented as a function of the density in table2, and in fig.2, the cross-section is shown according to Density.

Characteristics of Galena (PbS), Boron Carbide (B_4C), different percentages of Galena with Boron Carbide samples by using experiment and simulation process in. The results of the present study do consider a new explanation of the cross-section of fast neutron through materials containing different percentages of Boron Carbide. Neutron cross-section and neutron capture are mainly in relation to the value of Boron Carbide in our samples. Because of the high cross-section and good neutron capture of our samples, 50% Galena + 50% Boron Carbide is a more acceptable shield than other samples. These materials can be very advantageous for building walls of nuclear energy centrals, as moderators for nuclear reactors, in nuclear medicine departments and nuclear research centers, etc., to keep safe harm from neutron particles.

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