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"Research Note"

STUDY OF NEUTRON YIELD FOR THE $^{241}Am{-}^{9}Be$ SOURCE[*]

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Abstract – Beryllium chemical combination has a considerable effect on the design and fabrication of the $^{241}Am{-}^{9}Be$ neutron source. In this investigation the beryllium combinations were studied as a generator of neutrons with various mass percentage, and the neutron yields were also calculated using the results of the ALICE and SRIM codes calculations per unit incident charge. The neutron yields of Beryllium Hydride, Beryllium Carbide, Beryllium Hydroxide, Beryllium Oxide, Beryllium Acetate, Beryllium Acetylacetonate and Beryllium Sulfate were calculated as 4397.992×10^{-7}, 1511.184×10^{-7}, 976.609×10^{-7}, 595.299×10^{-7}, 336.163×10^{-7}, 169.62×10^{-7} and 149.053×10^{-7} respectively. Our calculations indicate that, the Beryllium Hydride is a proper material for use in the $^{241}Am{-}^{9}Be$ neutron source.

Keywords – Neutron, Beryllium, Americium, ALICE Code, SRIM Code, Neutron Yield

1. INTRODUCTION

In general, the (α,n) neutron sources contain an α-emitting radioisotope, with low mass nuclei as a target. As compared to other isotopes, the ^{9}Be is the most important target, because, it has the highest neutron yield. Due to many advantages of the (α,n) neutron source, such as their simplicity of installation, operation and low price compared to nuclear reactors, these neutron sources are used in activation analysis [1, 2, 3], calibration source [4], and industrial applications [5, 6]. The major problem of the (α,n) neutron sources is the yield. The $^{241}Am{-}^{9}Be$ source, with long half-life (432.7 yr) is used in many laboratories as a standard source [7]. Beryllium or Beryllium Oxide are usually employed in the $^{241}Am{-}^{9}Be$ neutron sources as a target, so other combinations of Beryllium have not yet been considered. In the present work, the neutron yield of other Beryllium combinations was determined.

2. DEFINITIONS AND PRELIMINARIES

In order to determine the neutron yield, the $^{9}Be(\alpha,n)^{12}C$ reaction cross section at various incident particle energy, and the stopping power, in terms of projectile energy have been calculated.

The Beryllium combinations cross section, of which the Beryllium nucleus is the only target to generate the neutron in them, were determined as Beryllium Hydroxide, Beryllium Hydride, Beryllium Carbide, Beryllium Oxide, Beryllium Acetate, Beryllium Acetylacetonate and Beryllium Sulfate by Alice code. The α-particles stopping power in terms of the incident energy in each combination of Beryllium was determined by SRIM code [8]. The neutron yield was determined as follows [9]:

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$$Neutron\ Yield = N\int_{0}^{E0}\frac{\sigma_{(E)}}{dE\ /\ dX}dE \qquad (1)$$

Where, "N" is the atomic number of target per unit volume, which is defined as follows:

$$N = w\rho N_A / A \qquad (2)$$

Where, "*w*" is the Beryllium abundant in the combination, "ρ" is the combination density, "A" is the Beryllium mass number," N_A" is the Avogadro's number, "$\sigma_{(E)}$" is the cross section," dE/dX" is the incident particle initial energy.

3. MAIN RESULTS

The excitation function of the $^{9}Be(\alpha,n)^{12}C$ reaction is shown in Fig. 1. As Fig. 1 shows, the maximum cross section of the $^{9}Be(\alpha,n)^{12}C$ reaction with 8 MeV Alpha particle energy is 1141.87 mb. As the α-particle energy of the $^{241}Am-^{9}Be$ source is equal to 5.48 MeV, so the cross section of the $^{9}Be(\alpha,n)^{12}C$ reaction in this source is 1109.61 mb.

The stopping power of α-particle in the various chemical compositions is different.

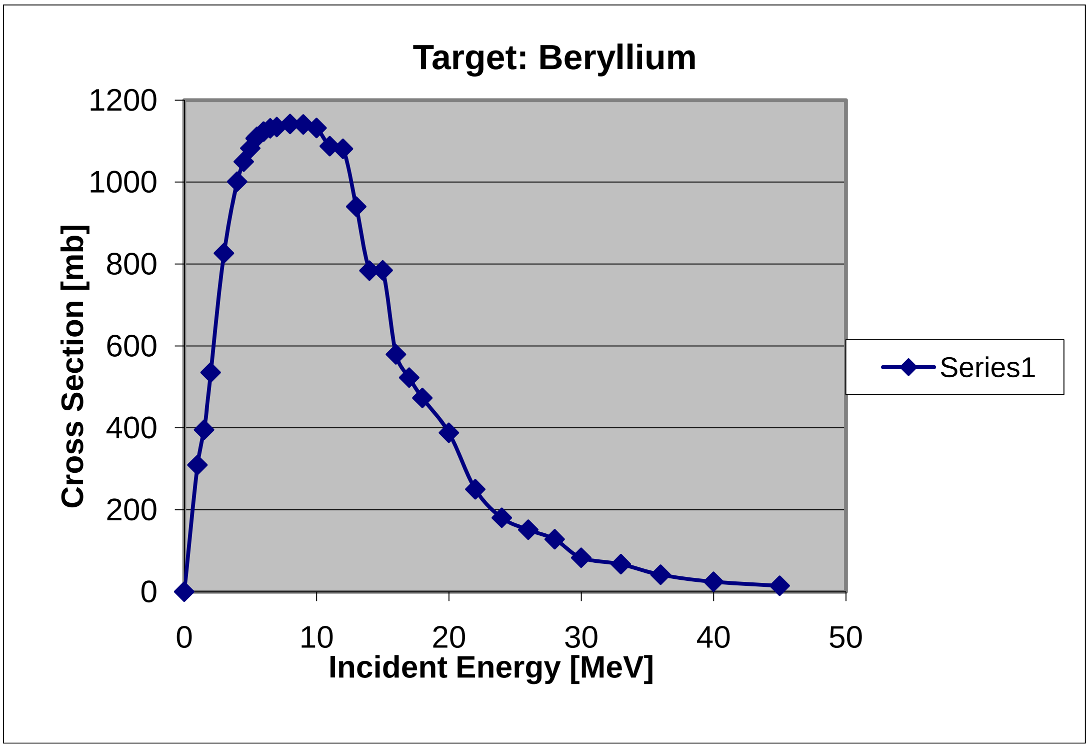

Fig. 1. Cross section variation of $^{9}Be(\alpha,n)^{12}C$ in terms of incident energy

The stopping power of α-particle for each energy of projectile from zero to 5.48 MeV and the various chemical Beryllium combinations, were computed by SRIM code. The results of the SRIM code, for different chemical combinations for incident α-particle energy of 5.48 MeV is tabulated in Table 1. The neutron yield was calculated from the results of the stopping power (Table 1) and cross section (Fig. 1) calculations.

Table 1. SRIM code results, alpha particles incident energy is 5.48 MeV (stopping unit=MeV/mm)

Target	**dE/dx Elec.**	**dE/dx Nuclear**	**Projected Range**
$Be_4O(C_2H_3O_2)_6$	9.02E+01	6.20E-02	40.11 um
$Be(C_5H_7O_2)_2$	8.86E+01	6.22E-02	40.42 um
Be_2C	1.38E+02	8.25E-02	26.36 um
BeH_2	6.31E+01	4.64E-02	55.81 um
$Be(OH)_2$	7.41E+01	5.12E-02	49.18 um
BeO	2.11E+02	1.34E-01	17.49 um
$BeSO_4.4H_2O$	1.26E+02	9.02E-02	28.85 um

The neutron yields for various chemical compositions were calculated using equation (1) and tabulated in Table 2.

Table 2. Neutron yield measurements for Beryllium chemical combinations

Target	**Stopping power) MeV/mm(**	**Computed neutron yield**
Beryllium Acetate	9.03E+01	336.163×10^{-7}
Beryllium Acetylacetonate	8.87E+01	169.62×10^{-7}
Beryllium Carbide	1.38E+02	1511.184×10^{-7}
Beryllium Hydride	6.31E+01	4397.992×10^{-7}
Beryllium Hydroxide	7.42E+01	976.609×10^{-7}
Beryllium Oxide	2.11E+02	595.299×10^{-7}
Beryllium Sulfate	1.26E+02	149.053×10^{-7}

The results of Table 2 indicate that the Beryllium Hydride as a target, along with the ^{241}Am as a projectile generator, has greatest neutron yield, through the $^{9}Be(\alpha,n)^{12}C$ reaction and Beryllium sulfate have the smallest neutron yield as compared to other combinations. The cross sections of the $^{9}Be(\alpha,n)^{12}C$ reaction with a chemical combination of Beryllium as a target for all combinations of Beryllium are almost the same, in a certain projectile energy range. As the results in Table 2 indicate, the targets combination plays a significant role in the neutron yield. As compared to other chemical combinations the stopping power of α-particle in Beryllium hydride is very small, while the mass percentage is more than other chemical combinations. Therefore, according to equation (1) the neutron yield of Beryllium hydride is more than others. According to the chemical combinations characteristic and their neutron yield, Beryllium hydride is a suitable target for generating the neutron through, the $^{9}Be(\alpha,n)^{12}C$ reaction, which can be used in nuclear medicine research for diagnostics and therapy.

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