Determine Neutron Yield From Beryllium Compounds Bombarding With Alpha Particles

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Abstract: The chemical combination of Beryllium used in the (α,n) reaction as a target materials. wherefore, Beryllium has generally been the material of select when manufacturing a neutron source. Beryllium compounds has a significant impact on the scheme and manufacture of the ^{238}Cm-^{9}Be neutron source. In present work the Beryllium chemical combinations were considered as a producer of neutrons with different percentage of mass, and the neutron yields were likewise determined using the outcomes of the ASTAR calculations per unit incident charge. The neutron yields of Beryllium Oxide, Beryllium Carbide, Beryllium Hydride, Beryllium Hydroxide and Beryllium Nitride were calculated as 3.1006e-005, 3.0365e-005, 2.2866e-005, 2.0464e-005 and 3.0386e-005 respectively. The results show that the Beryllium Oxide is a suitable material to use in the ^{238}Cm-^{9}Be neutron source.

Index Terms: Neutron Yield, Neutron source, ASTAR, α – emitters, The ${}^{9}_{4}\mathrm{Be}\,(\alpha,\mathrm{n})\,{}^{12}_{6}\mathrm{C}$ reaction, Beryllium, Curium.

1 Introduction

Neutron source is a common expression indicating to a varied apparatuses that generate neutrons, Regardless of the technique used to generate the neutrons. according to variables involving the neutrons energy generated by the source, the neutrons rate from the source, the source measurements, the expense of possession and upkeep the source, and polity rules to the source, these apparatuses has a large utilization in a varied group of applications in physics fields, Medication and therapy, Engineering and construction, nuclear power and weapons, Drilling petroleum, Biological science, Chemistry, and other manufactures[1].

2 Theory of (α,n) Reaction

When alpha particles interact with any of several isotopes that has low atomic weight neutrons are emitted, these isotopes like Beryllium, Oxygen and Carbon isotopes [2]. One of (α) particle reactions with nucleus is the reaction that an α particle suffer fusion with a light nuclei to produce the compound nucleus and the compound nucleus declining to a ground level by emit a neutron [2]. The largest yield of neutrons is reached according to studies when beryllium is used in the (α,n) reaction as a target. so, Beryllium has generally been the material of select in the neutron sources [3]. The beginning of chain reaction is through blending a few of beryllium with Polonium, Radium or different $\boldsymbol{\alpha}$ -emitter. The release of $\boldsymbol{\alpha}$-particles is start by nuclear decay, $\boldsymbol{\alpha}$-particles from this decay is reason to release of neutrons from the Beryllium when Beryllium undergo to transmutation process to Carbon-12 [4]. This reaction is: ${}^{9}_{4}\mathrm{Be}\,(\alpha,\mathrm{n})\,{}^{12}_{6}\mathrm{C}$. for instance, $\boldsymbol{\alpha}$-Beryllium neutron source can be in prospect to generate about 30 neutrons per every one million α-particles [5]. In theory any nuclides over helium are apt to suffer the (α,n) reaction, but isotopes which suffer an exothermic process or has low threshold of energy for (α,n) reaction are considered only. In the best state of affairs the probability of an (α,n) reaction is completely small. For example bombarding Beryllium with an 8 MeV alpha particle, the (α,n) cross section in this case is about of 0.6 barns.

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Typically the cross section for (α,n) reaction depend on (increases) energy of α-particle [3]. When an alpha particle interact with a target nucleus, this make the compound nucleus is in an energetic level. A neutron will be released if added energy is enough to override the threshold energy conditions for the (α,n) reaction. Sometimes the particle will carry enough energy (predominantly kinetic energy) where compound nucleus will be in an excited state after the neutron is released. Neutron emission are differentiated by the energy state in which they leave the nucleus. These groups of neutrons are specified by n_0, n_1, n_2, etc. That correspond to the energy state of the nucleus [6].

2.1 (α,n) radioactive nuclides

α-particle emitting radionuclides or the so-called “emitters” or “source” are a basic part of (α,n) neutron sources. α-particles represent a normal decay process for many nuclei that has an atomic number bigger than lead element. Lanthanides are also apt to suffering α decay It is noted that all these nuclides generally have a long half-life and low decay energy. The decay energy of an isotope is inversely proportional to its half-life. So the isotopes that has very long half-lives and many lanthanides have low decay energies. In fact the prospect of an (α,n) reaction become greater with α-particle energy and the numbers of α emissions for isotope are inversely proportional to its half-life, the α-emitters that have a comparatively short half-life are considered a perfect emitters. It is worth mentioning, the isotopes that has too small a half-life will be too unpractical to generate and employ efficiently as an (α,n) neutron source. So, an acceptable half-life for α emitters, when we want to use it as a neutron source, should be in the range of 1 to 25 years [3]. Extra α emissions can also contribute to the neutron yield of a neutron source. The half-life of the instantaneous progeny nuclides is longer than that of the parent nuclides. so, these additional alpha emissions can commonly be ignored from neutron yield calculations [7].The (α,n) neutron yield and energy influx for a specific source arranging possibly be resolved using complex transport equations and resolved with *Monte Carlo Methods* [8].

3 Definitions and Theory

With a view to find the neutron yield for the ^{238}Cm-^{9}Be neutron source, the ^{9}Be(α,n)^{12}C reaction cross section at different incident particle energy, and the energy loss, in terms of projectile energy have been calculated. The cross section of Beryllium compounds, where the Beryllium nucleus is the only target to emit the neutron

were determined for Beryllium Oxide, Beryllium Carbide, Beryllium Hydride, Beryllium Hydroxide and Beryllium Nitride. The α-particles energy loss in terms of the incident energy in each compound of Beryllium was calculated by ASTAR [9]. The neutron yield was calculated through [10]:

$$\text{Neutron Yield} = \text{N} \int_0^{\text{E}} \frac{\sigma(\text{E})}{\text{dE}/\text{dx}}\ \text{dE} \ldots\ldots\ldots(1)$$

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

$$N = \omega\rho N_a/A \quad \ldots\ldots\ldots(2)$$

Where, ω 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, $\sigma(\text{E})$ the cross section, dE/dx the incident particle initial energy.

4 Results and Discussion

The maximum cross section of the ^{9}Be(α,n)^{12}C reaction with 5.380 MeV the α-particle energy is 557 mb as shown in The curve of the ^{9}Be(α,n)^{12}C reaction Fig.1 [11], the cross section of the ^{9}Be($\boldsymbol{\alpha}$,n)^{12}C reaction in this source is 532 mb because of the $\boldsymbol{\alpha}$-particle energy of the ^{238}Cm-^{9}Be source is equal to 5.800 MeV. The energy loss of $\boldsymbol{\alpha}$-particle in the different chemical compounds is unequal because of the atomic structure and density differences [11].

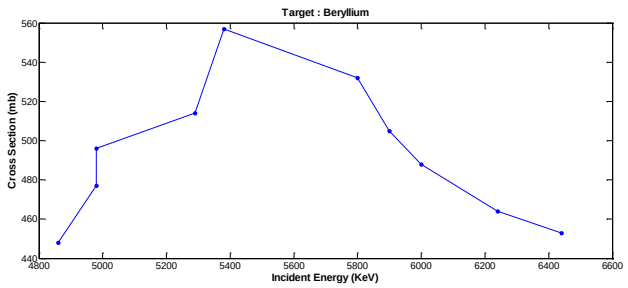

Fig.1. Cross section change for the reaction ^{9}Be(α,n)^{12}C with respect to incident particles energy.

The energy loss of α-particle were computed by ASTAR for each energy of projectile from zero to 5.800 MeV and the various chemical Beryllium combinations. The results of the ASTAR for different chemical combinations for incident α-particle energy of 5.800 MeV are tabulated in table (1). The neutron yield was calculated by taking the results of the energy loss table (1) and cross section (Fig.1).

TABLE 1
ASTAR RESULTS

Target	Energy loos	Density kg/m^3
BeO	200.6	3010
Be_2C	129.30	1900
BeH_2	58.74	650
$Be(OH)_2$	139.88	1920
Be_3N_2	184.29	2710

Alpha Particles Incident Energy is 5.48 MeV (Unit=MeV/mm)

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	Yield n/α
BeO	3.1006e-005
Be_2C	3.0365e-005
BeH_2	2.2866e-005
$Be(OH)_2$	2.8363e-005
Be_3N_2	3.0386e-005

We can see from table (2) that the Beryllium Oxide as a target, with the ^{238}Cm as aprojectile generator, has greatest neutron yield through the ^{9}Be($\boldsymbol{\alpha}$,n)^{12}C reaction and Beryllium hydride have the smallest neutron yield as compared to other combinations. The cross sections are same for the ^{9}Be($\boldsymbol{\alpha}$,n)^{12}C reaction with a Beryllium chemical combination as a target material for all combinations of Beryllium in this research , in a specific α-particle energy range. the results in table (2) indicate that the targets combination has important part in the neutron yield. In comparison with other chemical combinations the energy loss of α-particle in Beryllium hydride is small, while the mass percentage is more than other chemical combinations. Thus, the neutron yield of Beryllium hydride from equation (1) is small than others. In versus, Beryllium Oxide has a highest energy loss and greatest than other. Based on the chemical combinations properties and their neutron yield, Beryllium Oxide is an appropriate target for generating the neutrons by using ^{238}Cm-^{9}Be neutron source that has half-life 18.1 years [3] through the ^{9}Be(α,n)^{12}C reaction, which can be used in various fields like nuclear medicine research for diagnostics and therapy.

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