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Calculation of (n,α) reaction cross sections by using some Skyrme force parameters for Potassium (^{41}K) target nuclei

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Abstract. In this study, the (n,α) nuclear reaction cross section was calculated for ^{41}K target nuclei for neutron and proton density parameters using SKa, SKb, SLy5, and SLy6 Skyrme force. Theoretical cross section for the (n,α) nuclear reaction was obtained using a formula constituted by Tel et al. (2008). Results are compared with experimental data from EXFOR. The calculated results from formula was found in a close agreement with experimental data.

1 Introduction

Potassium (with a symbol K, Z=19) presents in some fruits and vegetables such as peach and melons etc. [1-3]. In recent years, Potassium has been used in different area like medicine and agriculture etc. [1-5]. Nowadays, nuclear reactions have been using different cross section formula similar to Tel et al. formula [6]. The Hartree-Fock-Skyrme-Method is used for studying the properties and structure of nuclei [7-12]. In addition, many properties of nuclei are calculated using this method such as proton (ρ_p) and neutron (ρ_n) densities. In this calculation, we investigated the proton (ρ_p) and neutron (ρ_n) densities for ^{41}K target nuclei using the Skyrme-Hartree-Fock [8, 10, 11] calculation method with the SKa, SKb, SLy5, and SLy6 force parameters [7, 13, 14]. From these calculations, the new proton and neutron densities were obtained. The theoretical results calculated for proton (ρ_p) and neutron (ρ_n) densities were used in the formula given by reference [6] for the (n,α) nuclear reaction cross section at incident neutron energy of 14-15 MeV [6].

2 Results and Discussion

In this study, we calculated the (n,α) theoretical nuclear reaction cross section for ^{41}K target nuclei. We used SKa, SKb, SLy5, and SLy6, Skyrme force parameters for calculations [7, 13, 14]. SKa, SKb, SLy5, and SLy6, Skyrme force parameters were given in Table 1 and Fig. 1-4. These parameters were then used in the Skyrme-Hartree-Fock Program (HAFOMN) [11, 15]. Cross section calculations were obtained for target nucleus with radius of 1.8 fm and then were compared with the semi-empirical results constituted by Tel et al. formula [6]. For the mass numbers between 37 and 239, this formula is given as follows [6];

$$\sigma_{(n,\alpha)} = 16.15(A^{1/3}+1)^2 e^{-33.01s} \qquad (1)$$

where A is mass number of atom, s is asymmetry parameter (S=(N-Z)/A).

Table 1. SKa, SKb, SLy5, and SLy6 Skyrme Force Parameters [7, 13, 14].

	SKa	SKb	SLy5	SLy6
t_0	-1602.78	-1602.78	-2484.88	-2479.50
t_1	570.88	570.88	483.13	462.18
t_2	-67.70	-67.70	-549.40	-448.61
t_3	8000	8000	13763	13673
t_4	125	125	126	122.00
x_0	-0.02	-0.02	0.778	0.825
x_1	0	-0.165	-0.328	-0.465
x_2	0	0	-1.00	-1
x_3	-0.286	-0.286	1.267	1.355
α	1/3	1/3	1/6	1/6

In earlier works, neutron and proton data for asymmetry parameter (S=(N-Z)/A) were used. But, for this study, we used in the formula developed by Tel et al. [6] proton and neutron density data for asymmetry parameter (S=(ρ_n-ρ_p)/(ρ_n+ρ_p)) [6,7,9]. Theoretical cross section values obtained with the cross section values ^{41}K(n,α)^{38}Cl results that are obtained using SKa, SKb, Sly5, and SLy6 parameters are given in Table 2 [7,13-14]. The neutron-number (N = 22) and neutron densities (ρ_n) are higher than proton-number (Z=19) and proton densities (ρ_p) because of Z=19 and N=22 for ^{41}K. The obtained value of the proton density (ρ_p) for ^{41}K target nuclei at the r = 1.8 fm have approximately been from 0.075 (for SKa and SLy5), 0.074 (for SKb), 0.079 (for SLy6) [7, 13, 14]. Moreover, value of the neutron density (ρ_n) for ^{41}K target nuclei at the r = 1.8 fm have

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approximately been from 0.081 (for SKa and SKb), 0.082 (for Sly5), 0.087 (for SLy6) and also obtained value of the asymmetry parameter for ^{41}K target nuclei at the 0.040 (for Ska), 0.043 (for SKb and SLy5), 0.044 (for Sly6) [7, 13, 14]. (see Figs. 1-4 and Table 2). Many experimental data were found from 1953 to 2017 for Potassium (for $^{41}K(n,\alpha)^{38}Cl$) [16]. Some experimental cross sections data were given in this study. For example; Garuska et al. found the cross section to be 30 ± 3 mb at 14.6 MeV neutron induced reactions [16, 17]. Filatenkov et al. found the cross section as to be 34.7 mb ± 1.6 mb at 14.1 ± 0.1 MeV neutron induced reactions [16-18]. Ercan et al. determined the experimental cross section as to be 36 ± 3 mb at 14.6 ± 0.1 MeV neutron induced reactions [16, 19]. Ikeda et al. found the cross sections to be 37.6 ± 2.8 mb at 13.97 MeV neutron induced reactions [16, 20]. Anders et al. found the cross section as to be 33 ± 1.3 mb at 14.7 ± 0.3 MeV neutron induced reactions [16, 21]. Bormann et al. found the cross section to be 12 ± 5 mb at 14.1 ± 0.05 MeV neutron induced reactions [16, 22]. Janczyszyn et al. found the cross section as to be 11 ± 2 mb at 14.0 MeV neutron induced reactions [16, 23].

Table 2 Theoretical cross section results for $^{41}K(n,\alpha)$ nuclear reactions for r=1.8 fm

SHF Parameters	Proton densities	Neutron densities	Asymmetry parameter	σ_{Theo} (mb)
SKa	0.075	0.081	0.040	10.08
SKb	0.074	0.081	0.043	9.086
SLy5	0.075	0.082	0.043	9.142
SLy6	0.079	0.087	0.044	9.046

We compared our data of target ^{41}K with literature data from EXFOR around 14-15 MeV [16, 18]. In this study, the obtained neutron and proton density results were depicted in Figs. 1-4. For neutron incident energy at 14.00 MeV, the experimental data is 11 ± 2 mb [23] and theoretically calculations are about 10.08 mb for SKa, 9.086 mb for SKb, 9.142 mb for SLy5, and 9.046 mb for SLy6 at r = 1.8 fm. These parameters were then used in the Skyrme-Hartree-Fock-program (HAFOMN) [7, 13-15]. Empirical results are found in compatible with theoretical data obtained in reference [6].

3 Conclusion

Many researchers have studied experimental and theoretical cross sections in recent years. In this study, (n,α) nuclear theoretical cross section reactions have been investigated for ^{41}K target nuclei incident neutron energy of 14-15 MeV. The attained data have also been contrasted on the existing some experimental values in EXFOR [16]. The attained theoretical and experimental results can be explained as follows;

In order to be calculate (n,α) reaction cross section, we used the formula developed by Tel et al. formula [6]. In Equation 1 developed by Tel et al. [6] can be used to calculate cross section with SKa, SKb, SLy5 and SLy6 Skyrme-force-parameters for ^{41}K target nuclei [7, 13-14]. The obtained results were compared with experimental result for 1.8 fm radius (see Figs. 1-4). In order to be calculate (n,α) different radius reaction cross section for ^{41}K target nuclei, we used Tel et al formula [6] and the we obtained theoretical cross section agreement with experimental results (see Figs. 1-4).

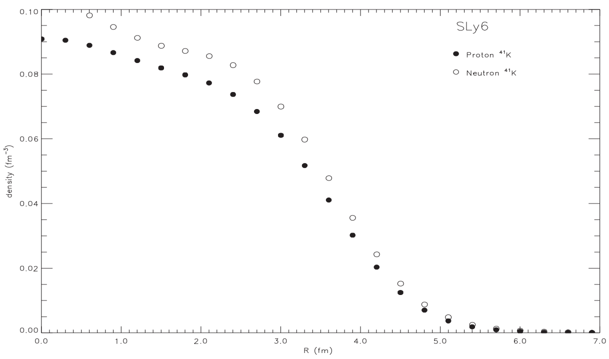

Fig. 1 $^{41}K(n,\alpha)^{38}Cl$ SLy6 proton and neutron density values.

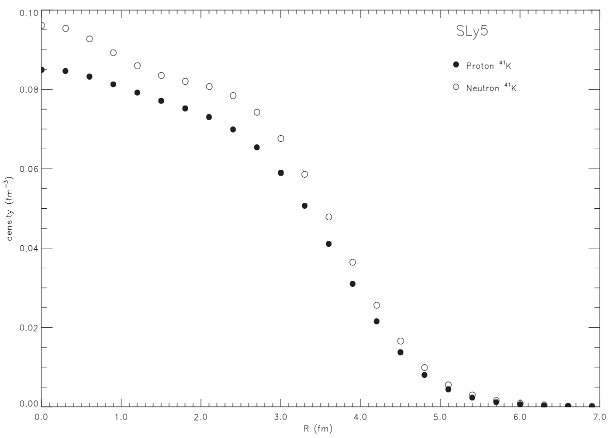

Fig. 2. $^{41}K(n,\alpha)^{38}Cl$ SLy5 proton and neutron density values

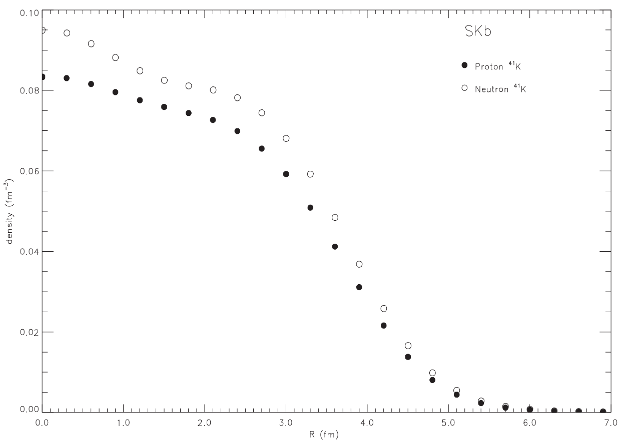

Fig. 3. $^{41}K\ (n,\alpha)^{38}Cl$ SKb proton and neutron density values

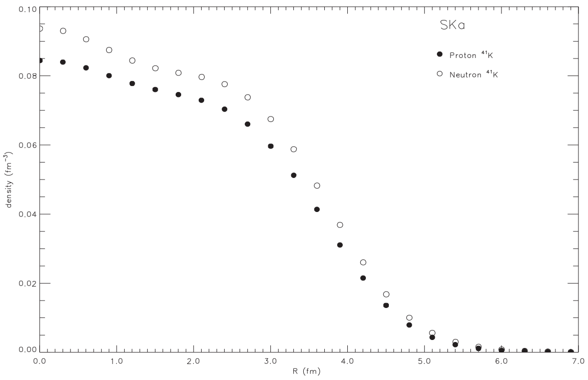

Fig. 4. $^{41}K(n,\alpha)^{38}Cl$ SKa proton and neutron density values

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