Double-differential cross-section of $^{56}Fe(n, \alpha)^{53}Cr$ reaction at 14 MeV neutrons

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Introduction

An accurate data of double – differential cross-section of neutron-induced charged particle emission (DDXc) is particularly in demand for the development of a fusion reactor. This development has just entered a new phase with the construction of the International Thermonuclear Experimental Reactor (ITER) [1] using deuterium-tritium plasma. One of the problems normally faced in the design of fusion reactors is the generation of helium gas through (n,α), (n, n'α) and (n, αn') reactions. These reactions are induced on bombardment of fast neutrons on the first wall, structural and blanket components of the reactor leading to the formation of helium gas in the reactor wall at different locations. In addition to the production of helium, the other processes such as atomic displacements and transmutations, etc., can produce micro structural defects in the material. Here, DDXc data will play an important role in estimating the nuclear heating and damage of candidate materials of the reactor irradiated with 14 MeV neutrons from D(T, n) α reaction. It is also quite important for estimating various physical quantities, such as primary knock-on atom (PKA) spectra, gas production per atom (GPA) and displacement per atom (DPA). Furthermore, the study of DDX is important as a basic study because the contributions of the direct and the pre-equilibrium processes as well as that of statistical compound nucleus process, in the emission of alpha particles can be estimated for a given (n, α) reaction [2]. In a typical fusion reactor few thousand tons of stainless steel will be used for different critical components of a fusion reactor. Iron is the main constituent of stainless steel. ^{56}Fe is the most abundant isotope among the four stable iron isotopes [^{54}Fe(5.845%), ^{56}Fe (91.745%), ^{57}Fe (2.119%), ^{58}Fe(0.282%)] in its natural form. A literature available in IAEA-EXFOR [3] database indicates that there is no DDX measurement for $^{56}Fe(n, \alpha)^{53}Cr$ reaction at 14 MeV. In view of this, the double differential cross-section (DDX) for the emission of alpha particles from $^{56}Fe(n,\alpha)^{53}Cr$ has been calculated using nuclear reaction modular code TALYS-1.4 [4] at 14 MeV neutron energy.

Nuclear Model Calculations

Nuclear level density, pre-equilibrium emission and optical model potential play an important role in determining the neutron induced reaction cross-sections. The nuclear model calculations for $^{56}Fe(n,\alpha)^{53}Cr$ is performed using nuclear reaction modular code TALYS-1.4 **.** The optical model parameters for neutron and proton have been obtained by a global potential proposed by Koning and Delaroche in TALYS-1.4. Similarly, the folding approach of Watanbe has used for alpha particles. TALYS - 1.4 uses the Hauser-Feshbach statistical model with width fluctuation corrections and estimates the direct and pre-equilibrium contributions. In TALYS-1.4 calculations, the two-component exciton model developed by Kalbach has been used for the calculation of pre-equilibrium contribution. The differential cross-section ($d\sigma/dE$) and double differential cross-section ($d^2\sigma/dEd\Omega$) for the emission of alpha particles from $^{56}Fe(n, \alpha)^{53}Cr$ reaction at 14 MeV neutrons have been calculated using above mentioned parameters and models, and are plotted in Figs. 1 and 2 respectively. The calculated energy distribution of the emitted alpha particles has been compared with available experimental data of Grimes et al [5] as shown in Fig.1. It can be seen from the Fig. 1 that theoretically calculated results using Talys 1.4 follow the trend with the experimentally measured data by Grimes et al. Further, the variation in the double differential cross-section (DDX) with the angle of emission of alpha particles from ^{56}Fe indicates that the emission of the alpha particles is very close to the isotropic distribution as shown in Fig.2.

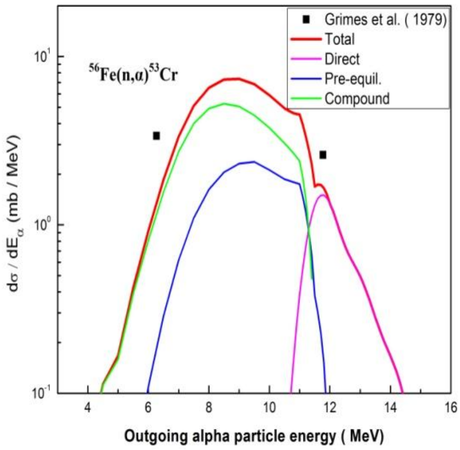

Fig. 1 The theoretical differential energy spectra of emitted α-particles from ^{56}Fe(n,α)^{53}Cr reaction at 14 MeV neutrons.

Conclusions

Theoretically calculated double differential cross-sections (DDX) for the emission of alpha particles from ^{56}Fe(n,α)^{53}Cr reaction at 14 MeV shows that the alpha particles below and around the most probable energies are emitted predominantly through the compound nucleus formation whereas the higher energy alpha particles are emitted through the pre-equilibrium or the direct reaction. It is planned to measure DDX for the emission of alpha particles from ^{56}Fe(n,α)^{53}Cr reaction using 14 MeV neutron generator facility at, IPR.

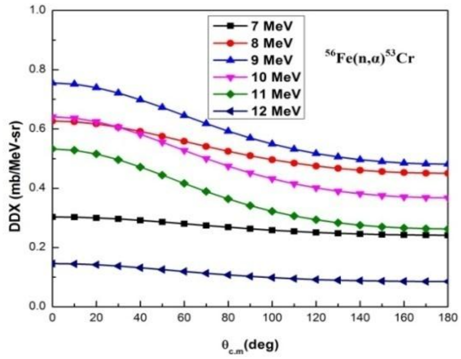

Fig. 2 Theoretical variations in the double differential cross-sections (DDX) with angle of emission for 7, 8, 9, 10, 11 and 12 MeV alpha particles emitted through ^{56}Fe(n,α)^{53}Cr reaction at 14 MeV neutrons.

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