Validation study of surrogate reaction method for the determination of (n,xp) cross sections

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Introduction

Nuclear data related to neutron induced reactions is very important for future technologies [1–4]. Indirect approaches like the surrogate reaction method, the Trojan Horse method, Coulomb dissociation, asymptotic normalization coefficient, and Oslo and β-Oslo methods, are used for cross section determination whenever direct measurements can not be performed. Surrogate reaction method is one of the established procedure for determining (n,f), and(n,γ) cross sections. (n,xp) and (n,xα) cross sections for long-lived radionuclie for neutron energies around 14 MeV are of high importance, as these reactions contribute in the hydrogen and helium production in the structural materials of the nuclear reactors [5].

There have been some measurements of the (n,xp) cross sections using surrogate ratio method [5–7], which is one of the variants of the surrogate reaction technique. But these measurements have been performed for the (n,xp) cross section measurement of the radionuclides, for which no data from the direct measurements is available. Therefore a direct comparison between data from surrogate measurements and the direct measurement is not possible. In this study we have measured the ^{56}Fe(n,xp) cross sections using the surrogate ratio method for neutron energy around 14 MeV, and then compared the results with the available data and the evaluated data to validate the use of surrogate ratio method for (n,xp) cross sections. We have used ^{52}Cr(n,xp) cross sections as the reference for the ratio method.

Experimental details

The experiment was performed at the BARC-TIFR Pelletron Accelerator Facility in Mumbai. We have used ^{6}Li(^{55}Mn,α)^{57}Fe and ^{6}Li(^{51}V,α)^{53}Cr reactions as surrogate to populate the desired compound nuclei, ^{57}Fe and ^{53}Cr. Both compound nuclei were populated in the overlapping excitation energy region using continuous beam of ^{6}Li at E_{lab} = 25 MeV with beam current ≈25 nA. Self supporting targets of ^{55}Mn (abundance = 100%) and ^{51}V (abundance = 100%) of thickness ≈ 600 $\mu g/cm^{-2}$ were used. Two silicon surface barrier $\Delta E - E$ detector telescopes were placed at 20^0 and 30^0 in the forward direction for the detection of the the particle like fragment. The evaporated protons from the compound nucleus were detected using the two large area silicon strip detector telescopes, each having an angular opening of 16^0 were mounted at backward angles 125^0 and 155^0 respectively. The evaporated protons were detected in the coincidence with the particle like fragments in order to determine the probability of the decay through proton emission of the compound nucleus.

In Fig. 1, we have presented the excitation energy spectra of α-particles from the telescope detectors along with the coincidence spectra ($\alpha - p$) for both of the reactions. From these measurements the the desired cross sections can be determined by using the following

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equation.

$$\frac{\sigma^{^{56}Fe(n,xp)}(E_x)}{\sigma^{^{52}Cr(n,xp)}(E_x)} = \frac{\sigma_{CN}^{^{57}Fe}(E_x)P_{CN}^{^{57}Fe}(E_x)}{\sigma_{CN}^{^{53}Cr}(E_x)P_{CN}^{^{53}Cr}(E_x)} \quad (1)$$

Here σ_{CN} represents the compound nucleus formation cross sections for the desired reaction, and the $P_{CN}(E_x)$ represents the proton emission probability of the compound nucleus and can be calculated as

$$P_{CN}(E_x) = \frac{N_{\alpha-p}^{coincidence}}{N_{\alpha}^{single}} \quad (2)$$

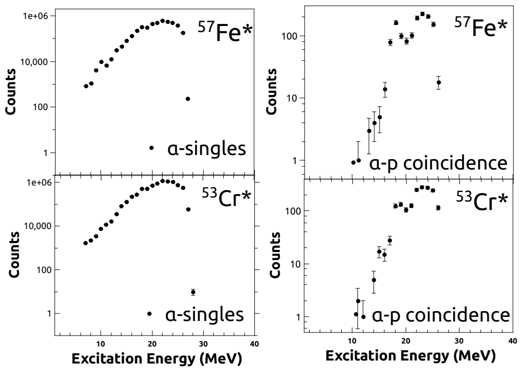

FIG. 1: Excitation energy spectra of coincidence and single particle from ^{57}Fe and ^{53}Cr populated in the two surrogate reactions.

Results and Discussion

The cross sections derived corresponding to excitation energies 19 to 22 MeV are presented in the Fig. 2. The cross section values for reference reaction ^{52}Cr(n,xp) were used from the JENDL data library. We have also presented the data from EXFOR and JENDL data library for the comparison along with the present measurements. It can be observed from Fig. 2 that the data derived in this study is consistent with the available data from EXFOR and evaluated data. Since proton decay probabilities depend on the spin of the compound nucleus, therefore Weiskopf Ewing approximation does not hold for the (n,p) reactions [8]. But from this study we observed that

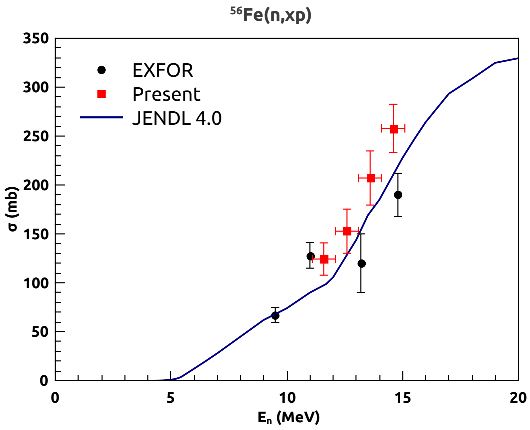

FIG. 2: ^{56}Fe(n,xp) cross sections measured in the present study with experimental data from EXFOR library and JENDL data.

surrogate ratio method overcomes the shortcomings of the absolute surrogate method and provide good results.

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