Neutron Energy Spectra and Yields from the ^{60}Fe(n,γ) Reaction for Nuclear Astrophysics

B. Satheesh[1]*
[1] *Department of Physics, Mahatma Gandhi. Govt. Arts College, Chalakkara, New Mahe 673311, U.T. of Puducherry, INDIA*

Introduction

Knowledge of neutron physics quantities plays an important role in development of nuclear energy, national security and nuclear astrophysics applications. The usefulness of several recent evaluation works on cross section data as major sources of information is unquestionable. In this work, the reaction cross sections were evaluated using different nuclear reactions models and are tabulated. Also the present status of experimental data for neutron capture cross sections is still inadequate both in quality and quantity. Therefore, it is important to perform precise measurements of capture cross sections for this nuclide. In astrophysical studies, nucleosynthesis, isotopic abundance and other quantities of interest demand the knowledge of cross sections for some nuclide's in the stellar medium characteristic energy range.

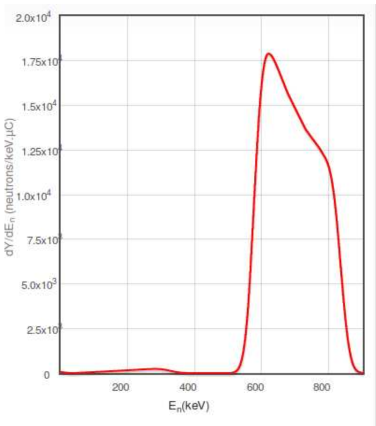

FIG. 1: Neutron flux energy spectrum from the ^{7}Li(p,n$_0$)^{7}Be reaction at $E_p = 2.25\pm0.02$ MeV obtained from the code EPEN

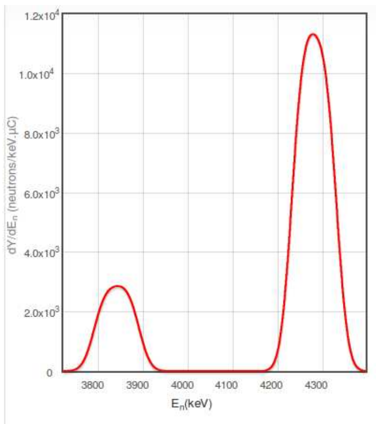

FIG. 2: Neutron flux energy spectrum (E) from the ^{7}Li(p,n$_0$)^{7}Be reaction at $E_p = 6.0\pm0.02$ MeV obtained from the code EPEN

Analysis and results

The production of ^{60}Fe in the slow neutron capture process (s - process) is hampered by the rather short - lived precursor ^{59}Fe ($t_{1/2}$ = 44.495 d), which acts as a branch point of the s - process path. Accordingly, high neutron densities are required to avoid that the reaction flow is bypasses ^{60}Fe via the decay of ^{59}Fe. Once ^{60}Fe is reached, it can also be destroyed by neutron capture or - on longer time scales - by β^-decay. High neutron densities are generally accompanied by very high temperatures, but the synthesis of ^{60}Fe requires an upper limit of about 2×10^9 K, because photo - disintegration reactions such as ^{60}Fe(γ,n) and ^{59}Fe(γ,n) start to dominate otherwise. There are two different astrophysical

*Electronic address: satheesh.b4@gmail.com

scenarios where ^{60}Fe can be produced: during the He - shell burning phase in low - mass thermally pulsing asymptotic giant branch (AGB) stars and during the convective C - shell burning in massive pre - supernova stars [1]. A crucial input for the production of ^{60}Fe in AGB stars and massive pre - supernova stars are the neutron capture cross sections at the respective stellar temperatures. So far, an activation measurement of the ^{60}Fe(n,γ)^{61}Fe cross section at neutron energies corresponding to a thermal energy of kT = 25 keV (typical for AGB stars) was performed at Forschungszentrum Karlsruhe, Germany. The Maxwellian averaged cross section (MACS) at kT = 30 keV was determined to (5.15±1.4) mb. The direct capture (DC) component of the cross section at this temperature constitutes an important information for the extrapolation towards the astrophysically interesting temperatures in massive stars around kT = 90 keV. In dealing with MACS measurements on unstable isotopes, the possibility for using sample sizes of a few μg or even less is particularly crucial, because these materials are hard to produce. Another important aspect in using small radioactive samples is that it allows one to keep the radiation hazards and the related backgrounds at a manageable level. Here, ^{60}Fe deserves special mentioning as the measurement of this MACS is complicated by the small (n,γ) cross section as well as by the difficulty in obtaining a suitable sample. Even if experimental cross section data are available, very often these data are not fully commensurable with the energy regime of the stellar situation. In such cases, cross sections obtained with theoretical models can be normalized to the available experimental data. If the uncertainty of the energy dependence of the calculated cross section is small, this method provides a safe extrapolation to the relevant stellar energies from the measured energies. This approach was applied to a number of isotopes, where the cross section has been determined only by activation in a quasi-stellar spectrum corresponding to k_B T = 25 keV. From the above motivation, I have evaluated the neutron capture cross sections on ^{60}Fe using EPEN [2] (Energy of Proton Energy of Neutron) nuclear reaction code and are tabulated. The Neutron flux energy spectrum from the ^{7}Li(p,n$_0$)^{7}Be reaction at E_p = 2.25±0.02 MeV and 6.0±0.02 MeV obtained from the code EPEN are shown in Fig. 1 and Fig. 2. Total cross section for the reaction and (n,γ) cross section are shown in the Fig. 3 and Fig. 4. The details will be presented.

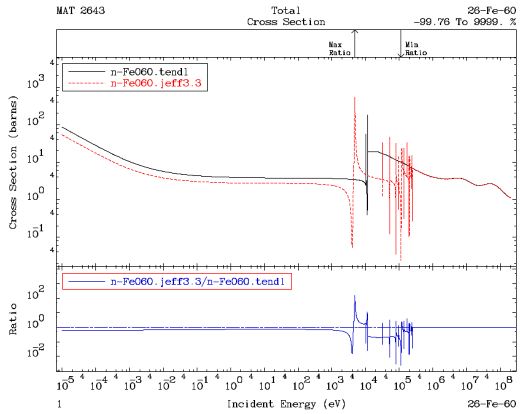

FIG. 3: Total cross section

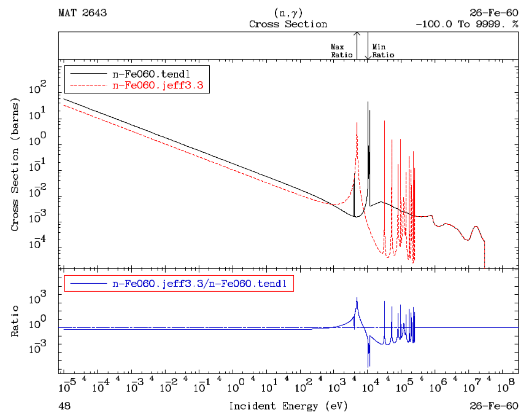

FIG. 4: (n,γ) cross section

References

[1] R Reifarth, C Lederer and F Kppeler, J. Phys. G: Nucl. Part. Phys.**41** 053101 (2014) (42pp).

[2] http://www.epen.nhergmzu.com/epen/.