Excitation functions and isotopic effects in (n,p) reactions for stable iron isotopes from reaction threshold to 20 MeV.

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Introduction

Structural materials are used to make the core and several other essential parts of a nuclear reactor. Stainless steel, Streicher [1] are the main off-core structural materials for thermal reactors and are essential materials for fast neutron reactors.

The excitation functions for (n,p) reactions from reaction threshold to 20 MeV on four stable isotopes viz; ^{54}Fe,^{56}Fe,^{57}Fe,and ^{58}Fe were calculated using Talys-1.2 nuclear model code. With a minimal effort on parameter fitting and only one free parameter called shell damping factor has been adjusted to get excellent agreement between the calculated and the experimental data. This is very importance to the validation of nuclear model approaches with increase predictive power. Measurement of excitation curves for the (n,p) reaction on chains of isotopes have revealed an interplay of the compound nucleus and the pre-equilibrium mechanisms.

Nuclear Models and Calculations

The nuclear model calculations performed includes the direct-interaction, pre-equilibrium and compound nucleus contributions. Much information regarding the choices of input parameters, nuclear models, level density parameters are described and explained in detail in the Talys user manual [2]. The Optical model potentials for neutron and proton used in the Talys-1.2 calculation is the global parameterizations of Koning and Delaroche [3]. In this work, we have chosen to study the global predictive power that reflects the state of knowledge of nuclear model parameters.

The energy dependent level density parameters by Ignatyuk [4] have been adopted which includes shell effects and is given by

$$a = a^{*}\left[1 + \left(\frac{\delta W}{U}\right)(1 - e^{-\gamma U})\right] \qquad (1)$$

where a^{*} is the asymptotic level density parameter, U is the excitation energy, δW is the shell correction energy. The liquid drop model mass is calculated using the formula by Myers and Swiatecki. γ is the shell damping factor given by ($\gamma = \gamma_0/A^{\frac{1}{3}}$) Mughabghab and Dunford. Here γ_0 is taken as free parameter. The asymptotic value a^{*} is given by the expression

$$a^{*} = \alpha A + \beta A^{2/3} \qquad (2)$$

Results and Discussion.

The excitation curve for ^{54}Fe(n,p)^{54}Mn is given in Fig. 1. The excitation curve for ^{56}Fe(n,p)^{56}Mn is shown in Fig. 2. All the parameters are calculated in a similar manner as done for the previous reaction except for the shell damping factor. The excitation curve for ^{57}Fe(n,p)^{57}Mn is give in Fig. 3. This is the only odd-A target which is studied here. The excitation curve for ^{58}Fe(n,p)^{58}Mn is given Fig. 4. Fig. 5. is a plot for cross-section versus atomic mass number for Iron isotopes at the projectile energy 14.7 MeV. Q –value versus the asymmetry parameter is given in Fig. 6

Referenfes

[1] Streicher, M. A., (1979). Stainless steels: past, present and future, in the Metallurgical Evolution of Stainless Steels, Pickering, F. B., Ed. Metals Society, London.

[2] Koning, A. J., et al. 2009. Talys Users manual, A Nuclear Reaction Program, User Manual. NRG-1755 ZG Petten, The Netherlands.

[3] Koning, A. J., Delaroche, J. P., 2003. Local and global optical models from 1 keV to 200 MeV. Nucl. Phys. A 713, 231-310.

[4] Ignatyuk, A. V., 1975. Phenomenological description of the energy dependence of the level density parameter, Sov. J. Nucl. Phys. 21, 255-257.

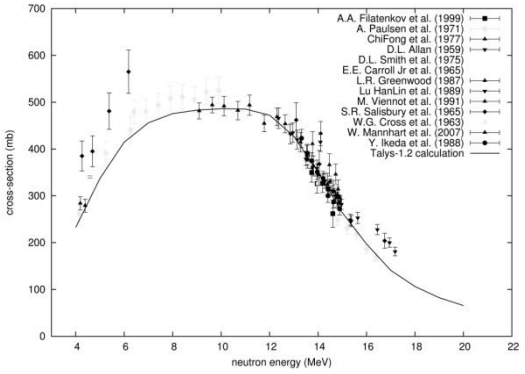

Fig. 1. Excitation curve for $^{54}Fe(n,p)^{54}Mn$

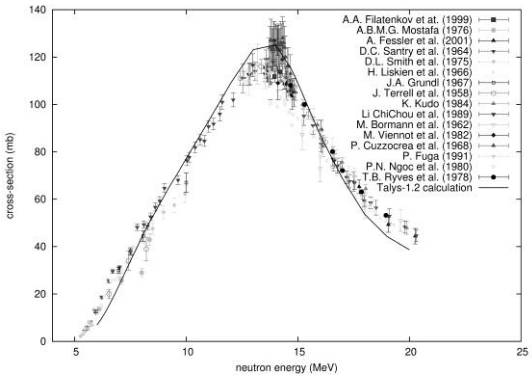

Fig. 2. Excitation curve for $^{56}Fe(n,p)^{56}Mn$

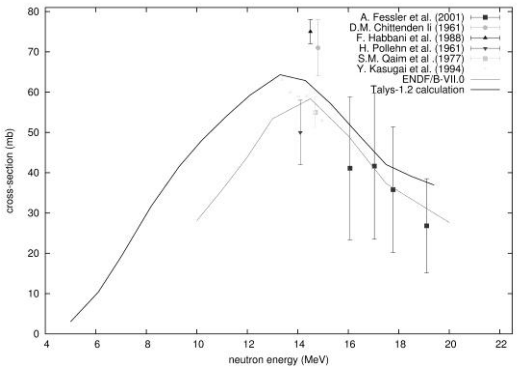

Fig. 3. Excitation curve for $^{57}Fe(n,p)^{57}Mn$

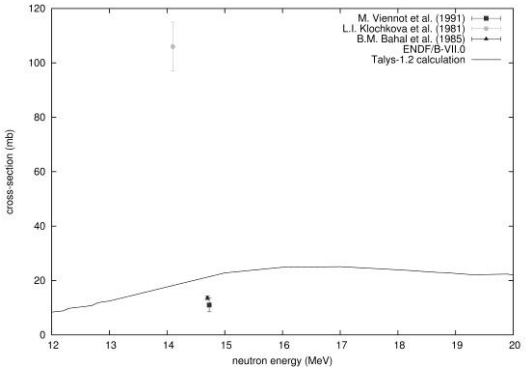

Fig. 4. Excitation curve for $^{58}Fe(n,p)^{58}Mn$

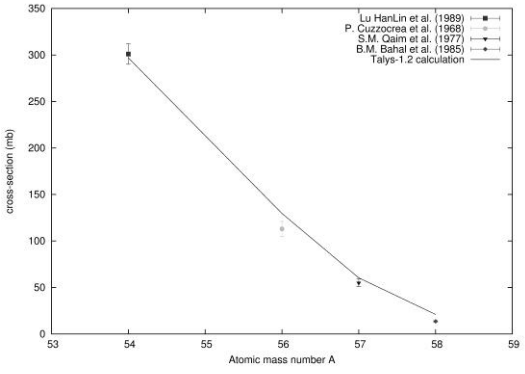

Fig. 5. Cross-section versus atomic mass number

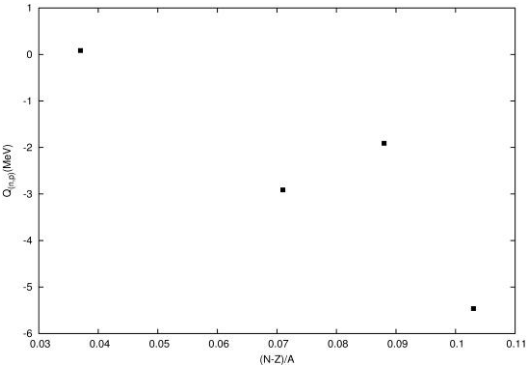

Fig. 6. Q value versus the asymmetry parameter