Cross section of ^{22}Ne, ^{27}Al and ^{nat}Mg in proton induced reactions and the influence of the nuclear level density

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Introduction

Activation cross sections of proton induced nuclear reactions are of interest for the cognition on the excitation functions is needed for optimizing a radioisotope production, for the study of surface wear from metal surfaces by the thin layer activation, and for studies of the material behaviors by the charged particle irradiation. This process involves a selection of the projectile energy range that will maximize the yield of the product cross section for nuclear reaction and minimize that of the radioactive impurities. The nuclear reaction calculations based on standard nuclear reaction models can be helpful for determining the accuracy of various parameters of nuclear models and experimental measurements.

The radioisotope ^{22}Na is convenient for production of laboratory based slow β^+ beams, because of the long (2.6 year) half-life and the high (=90.6%) β^+ branching ratio [1] and recently is applied in the calibration of PET cameras. There are several routes for production of ^{22}Na, where these take into account the available accelerator, the production yield, the specific activity and the contamination level.

In this work, we have used five various statistical nuclear models in the TALYS-1.4 code [2] for the following reactions ^{27}Al(p,x)^{22}Na, ^{22}Ne(p,n)^{22}Na, ^{24,25,26,nat}Mg(p,x)^{22}Na and ^{23}Na(p,x)^{22}Na, in the energy range from threshold to 100 MeV and the results are compared with experimental values as reported in EXFOR[3] and results published in literature.

Nuclear Model Calculations

The nuclear level density is a fundamental ingredient for all the application of the statistical theories of nuclear reactions. In certain reactions the effect of five various statistical models has been explored. Calculations employ the Constant Temperature Model (CTM)[4, 5], the Back-Shifted Fermi-Gas Model (BFM)[5, 6], the Generalized Super-Fluid Model (GSM)[7] and two sets of microscopic level densities, one based on Hartree-Fock calculations (HFM)[8] and the other based on the combinatorial model (HFBM), the calculations make coherent use of nuclear structure properties determined within the deformed Skyrme-Hartree-Fock-Bogolyubov framework [9]. The constant temperature model is used at low excitation energies and the Fermi gas model with shell and energy dependent level density parameter a is used at high energies. The two models and the match procedure to obtain the matching excitation energy (E_x^{match}) between the models is given in details in Ref [10]. Our main aim is here to demonstrate the predictive power of different models calculations and this comparison may be considered as starting point for the future improvements in the theoretical models.

Result and Discussion

The excitation functions for the production of radio-isotope ^{22}Na by proton-induced reactions on ^{27}Al, ^{nat}Mg and ^{22}Ne for 1-100 MeV energy have been calculated using five different nuclear level density models in the optical model code TALYS-1.4. The calculated excitation functions based on five models along with the comparison with experimental data are shown in figures.1 to 4. From the fig. 1 we see that measured excitation function of ^{27}Al is well reproduced by the HFM, GSM and HFB model. However CTM and BFM lesser predicts the data, the discrepancy being negligible at low and high energies, while in the figures 2 and 3,

GSM reproduces the measured values diversely than other models in the fluctuations of cross-

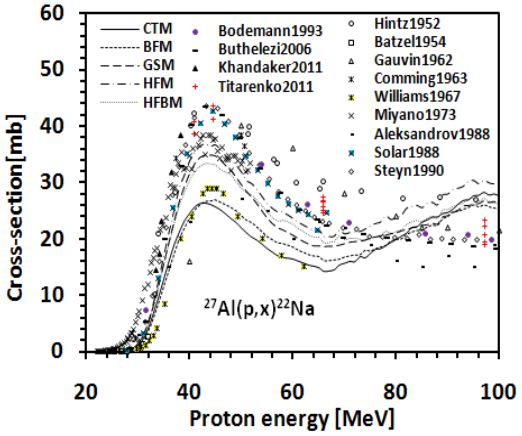

Fig.1 Excitation function of ^{27}Al(p,x)^{22}Na reaction

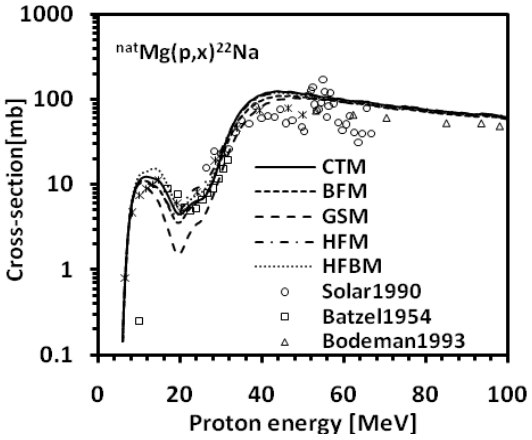

Fig.2 Excitation function of ^{nat}Mg(p,x)^{22}Na reaction

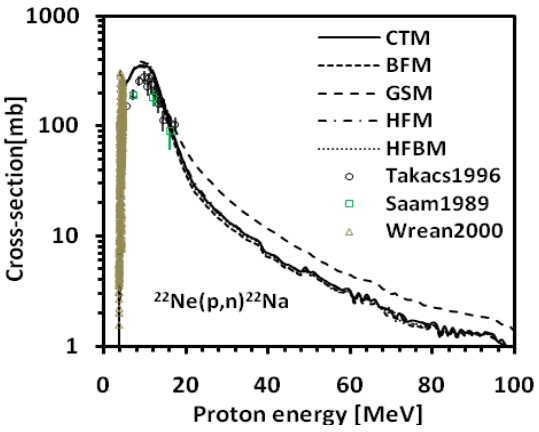

Fig.3 Excitation function of ^{22}Ne(p,n)^{22}Na reaction section. The Fig.4 shows the prediction of HFBM near the threshold energy for Wrean data. In this case, the data don't need to discuss the agreement. Finally it may be noted that none of these additional calculations resulted insignificant improvements, they help understanding of the remaining differences between calculations and measurement.

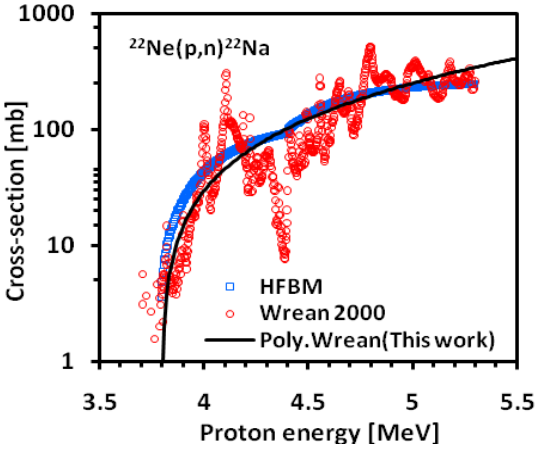

Fig.4 Excitation function of ^{22}Ne(p,n)^{22}Na reaction, from threshold to 5.3 MeV (Fig.3 expanded)

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