# Effect of pre-equilibrium emission on (n,α ) reactions of Br isotopes

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## Introduction:

Excitation function of (n,α) reactions around 14 MeV are of considerable importance from the view point of fusion and advanced fission reactor technology. The cross-sections of bromine isotopes induced by 14 MeV neutrons had been measured by many laboratories , but the existing data were discrepant. Recently, L. Zhao et al. [1] measured these cross-sections with good accuracy by making use of HPGe detectors. No theoretical calculations were performed by them to validate their experimental values. The theoretical understanding of nuclear reactions have been developed to the extent that with appropriate parameterization, nuclear models can be used for consistency checks of experimental data. EMPIRE-3.0 [2], a recent and versatile nuclear reaction model code, has opened up options for calculating cross-sections for various reactions channels . In the present work, using EMPIRE-3.0 with appropriate input data, we have computed excitation functions of $^{76-81}$Br (n,α) reactions from 10 MeV to 20 MeV and compared these with the existing experimental data as well as evaluated data file.

## Calculations:

The cross-sections are calculated by using full featured Hauser- Feshbach statistical model [3] with pre-equilibrium effects by invoking PCROSS [4] option in EMPIRE-3.0.
The nuclear structure input like nuclear masses, discrete energy levels densities of the nuclide involved in the calculations are taken from latest compilation available in RIPL-3 [5]. The recent and well tested global optical model potential for neutron given by Koning [6] have been taken in the present calculations. For exit channel (α -particle) we have chosen the optical model potential of Avrigeanu [7]. Pre-equilibrium emission and nuclear level density play an important role in determining the (n, α ) reaction cross-sections. Therefore, we have studied the effect of pre-equilibrium emission with both level density formalisms viz.

(i) Empire specific level density based on the dynamic approach to the level densities.It takes into account collective enhancements of the level densities due to nuclear vibration and rotation. The formalism uses the superfluid model below a critical excitation energy and the Fermi gas model above the critical excitation energy.

(ii) Parity dependent level densities based on Hartee-Fock Bogalyubov model adjusted for collective enhancement and neutron resonance spacings. HFB plus combinatorial model of NLD does not take Gaussian spin distribution and equipartition of parity and treats the shell, pairing and collective effects explicitly to estimate the spin and parity dependent level density for more than 8500 nuclei ranging from Z=8 to Z=220 and tabulated in an energy and spin grid ( U= 0 to 200 MeV and the lowest 30 spins) .

Pre-equilibrium emission of α particle was calculated in terms of the Iwamoto-Harada model (PCROSS). The module PCROSS includes a pre-equilibrium mechanism for clusters in the incoming and outgoing channels.

## Results and Discussions:

The computed cross-sections together with experimental data taken from EXFOR data library [8] and evaluated data file ENDF/B-VII.0 [9] were plotted for all cases. Figs. 1 & 2 show the illustrative cases of $^{81}$Br (n,α) reaction with both NLD options. As can be seen from the Fig. 2, the calculated values are in reasonable agreement with the experimental values and

evaluated data file ENDF/B-VII.0 with the option of α – particle (global) potential by Avrigeanu ; parity dependent nuclear level density (HF-BCS) formalism and PCROSS model for pre-equilibrium emission. There is a significant contribution of pre-equilibrium emission in (n, α ) reactions as evident from the Figures. In the case of Empire specific nuclear level density option ( Fig. 1) the values of cross-section show discrepancy from experimental and evaluated data file.

We conclude that the parity dependent level density along with PCROSS pre-equilibrium model and Koning optical potential parameter for neutrons in entrance channel and Avrigeanu optical potential for α particles in the exit channel are quite suitable in predicting (n, α ) reaction cross-sections in the MeV region.

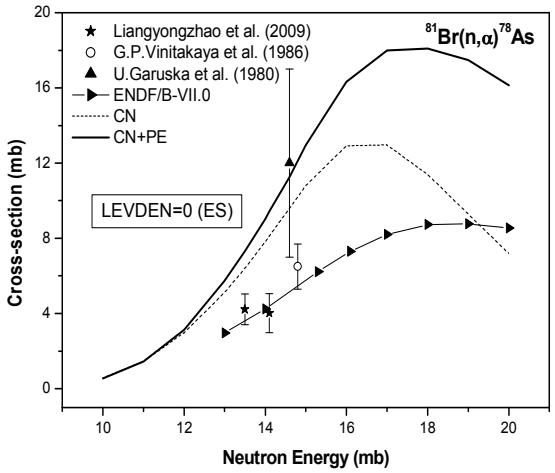


**Figure 1**

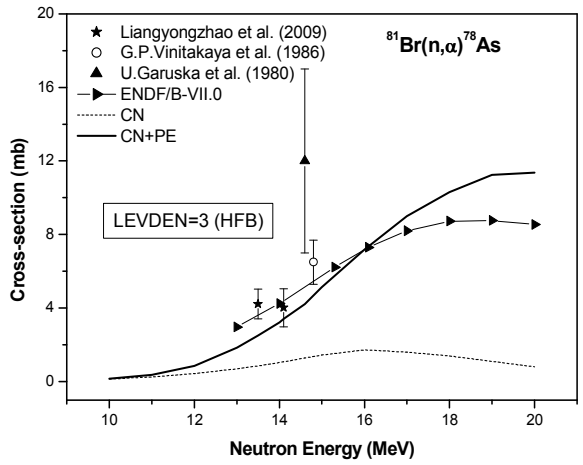


**Figure 2**

Figs. 1 & 2: Empire 3.0 based excitation functions of $^{81}$ Br (n,α) $^{78}$ As reaction with two NLD options (ES+HFB),respectively along with experimental and evaluated data file ENDF/B-VII.0

**CN** refers to Compound Nucleus mechanism
**PE** refers to pre-equilibrium emission
**ES** refers to Empire Specific approach based on superfluid model below $E_c$ and fermi model above $E_c$
**HFB** Parity- dependent level densities based on Hartee – Fock – Bogolyubov model

## References :


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