# Investigation of neutron induced reaction cross section data in the mass region $A = 50 - 96$ by EMPIRE code

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## Introduction

The neutron induced reaction cross-section data such as (n, $\gamma$), (n, n$'$), (n, p) and (n, $\alpha$) reactions of structural materials such as Fe, Ni, Zr, Nb etc. are required for design calculations in both thermal and fast neutron based nuclear reactor design, maintenance and waste estimation [1]. The reaction data of high precision is required for bio medical fields for production of radio-isotopes, cancer therapy. Recent advanced concepts in reactor technology such as accelerator-driven sub-critical systems (ADSs) and long lived radio active waste incineration require cross section data data up to high neutron energies of 200 MeV [2]. High neutron energies open up complex reaction mechanism leading to direct reactions and several multi particle emissions from compound system as well as pre-equilibrium emissions. In addition to fission reactor applications, these neutron induced reactions are important also for fusion technology, such as both neutronics and estimation of micro structural defects leading to problems of structural integrity, embrittlement of the first wall structural and blanket components of the fusion reactors. For these reactions most of the experimental data are available in the range of 0-25 MeV. Above this energy range, one has to rely on theory. In order to obtain reliable model calculations in the high energy region, we need to have a model that can explain the existing experimental data in the low energy range. In the present work a quantitative analysis has been carried out for neutron induced reactions of Cr, Fe, Ni and Zr within the framework of EMPIRE to investigate the sensitivity of various model parameters and compared the results with experimental data.

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## Calculations and results

We have calculated neutron induced cross sections for stable isotopes of Cr, Fe, Ni, Zr using the code EMPIRE 3.2. These calculated results for (n,2n), (n,p) and (n, $\alpha$) were then compared with the experimental cross sections, taken from the IAEA reaction data web site EXFOR [3]. All the major reaction mechanisms like, fusion, direct reaction, fission, pre-equilibrium emission are considered in EMPIRE. For CN decay this code uses the Hauser-Feshbach model. The optical model parameters are taken from Reference Input Parameter Library (RIPL-2)[4] library, which provides nuclear masses, ground-state deformations, discrete levels, decay schemes, level densities, moments of inertia and gamma strength functions. For (n,2n) reactions, Koning & Delaroche potential [5] was used and for (n,p) reactions F.G. Perey [6] potential was used. For these calculations default parameters of EMPIRE was used. LEVDEN=0 was used, which fits the experimental level densities and then uses the fitted values. Pre-equilibrium emission was included using the Monte Carlo Hybrid (DDHMS) pre-equilibrium model. With experimental level density and above mentioned potentials (n,2n) and (n,p), experimental reaction cross sections were well explained except one or two cases (like $^{50}$Cr) where disagreement is noticed at higher energies (Fig. 1). For (n,$\alpha$) reactions, Avrigeanu potential was used. The (n,$\alpha$) were slightly over predicting the cross sections in few isotopes like $^{62}$Ni. By slightly adjusting the level density parameter the (n,$\alpha$) reactions could be better reproduced (not shown here).

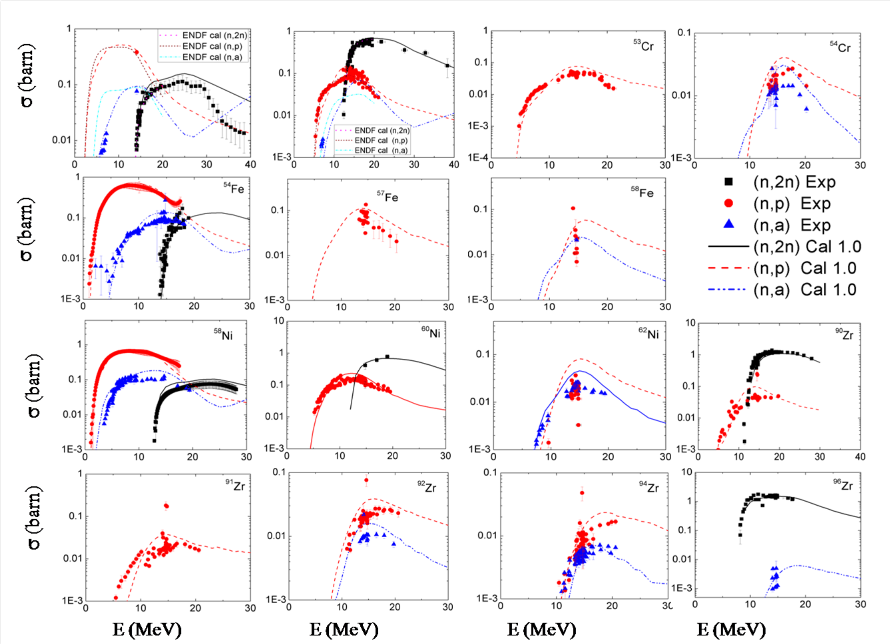


FIG. 1: Experimental (n,2n), (n,p) and (n, $\alpha$) cross sections for different isotopes of Cr, Fe, Ni, Zr along with the EMPIRE calculation.

## Conclusion

The results show a good agreement between experimental measurements and the EMPIRE calculations with default parameters. These three potentials, Koning & Delaroche, F.G.Perey and Avrigeanu are applicable over a large mass (A), atomic number (Z) range. In the present calculations, the A varied from 50 to 96 and Z from 24 to 40. Over such a long range the experimental data were well explained by the same set of parameters. This shows that EMPIRE code along with the Koning & Delaroche, F.G.Perey and Avrigeanu potentials can predict the cross sections for a range of stable nuclei. A comparative study of these calculations with experimental results and calculations using standard ENDF/B-VII.1 [7], JENDL-4.0 [8] libraries were also performed. Calculated cross sections for EMPIRE and ENDF/B-VII.1 are shown for $^{50,52}$Cr. In few systems EMPIRE fits experimental data better whereas in some case ENDF calculations are better. A more detail study on sensitivity of various models will be presented in the conference.

## References

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