Production of radio-isotopes ^{197}Hg and ^{198}Au from ^{198}Hg

P. K. Saran[1], Maitreyee Nandy[2], P. K. Sarkar[3] and Sneh Lata Goyal[1,*]
[1]*Deptt. of Applied Physics, Guru Jambheshwar University of Sci. & Tech., Hisar-125001, Haryana, INDIA*
[2] *Saha Institute of Nuclear Physics, Kolkata – 700064, INDIA*
[3] *Health Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

* *Email:* goyalsneh@yahoo.com

Introduction

Studies on excitation functions of neutron induced reactions are of considerable importance for testing nuclear models as well as for practical applications. Mercury can be a suitable material for spallation neutron source in an accelerator driven system (ADS) if corrosion, due to chemical wetting, gradient mass transfer, and high density heat generation are taken care of. In order to design the target system, estimation of induced activity in the target is important among other factors. In an ADS this radioactivity is induced by neutrons along with that by the primary projectile. An ADS is operated at a few GeV beam energy, but often logistic studies are carried out at much lower energies. Quantitative knowledge of the induced activity at such operating parameters is important for proper planning of the experiments [1].

The aim of the present work is to determine the excitation functions of ^{198}Hg (n, 2n) ^{197}Hg and ^{198}Hg (n, p) ^{198}Au reactions for 1-50 MeV energy using statistical and pre-equilibrium nuclear reaction model codes. This will help us to determine the total yield and induced activities due to these radio nuclides. The computed excitation functions are compared with and the reported measured data and cross sections from ENDF database [2].

Model codes calculations

We have used ALICE-91, TALYS and EMPIRE 3.1 for our study.

ALICE-91

ALICE-91 is a well known code [3] that calculates pre-equilibrium (PEQ) cross-sections using hybrid or geometry dependent hybrid (GDH) model and evaporation or compound nuclear (EQ) through Weisskopf–Ewing (WE) formalism. GDH model is the modified version of hybrid model to include the effect of diffuse nuclear surface. In the present work we have used optical model inverse cross-section and Fermi gas level density options in ALICE.

TALYS-1.2

In TALYS-1.2 [4] code direct (DIR) reactions are calculated using rotational optical model. Two component exciton model estimates the PEQ particle emission and the angular distribution of these PEQ particles is determined using Kalbach systematics. EQ emission is calculated in the framework of Hauser-Feshbach formalism in competition to fission. In this work we have used numerical transition rates with energy dependent matrix element for exciton model (preeqmode=2), Fu's pairing energy [5] correction (pairmodel=1) and constant temperature + Fermi gas level density (ldmodel=1).

EMPIRE-3.1

Nuclear reaction code EMPIRE-3.1 code [6], accounts for three major nuclear reaction mechanism, i.e., direct (DIR), pre-equilibrium (PEQ) and compound nuclear reactions. Binding energies are determined using masses recommended by Audi *et al.* [7], or using theoretical predictions of Moller and Nix [8]. The code uses several PEQ models like PCROSS, multistep direct (MSD), multistep compound (MSC) and Hybrid Monte-Carlo Simulation (HMS). Statistical Hauser–Feshbach theory with different level density options is used to describe the EQ emissions. We have used the following input options of the code:
(a) EMPIRE1: Empire specific level densities, HMS and PCROSS PEQ models.
(b) EMPIRE2: Generalized super fluid model level densities, HMS and PCROSS PEQ models.

Results and Discussion

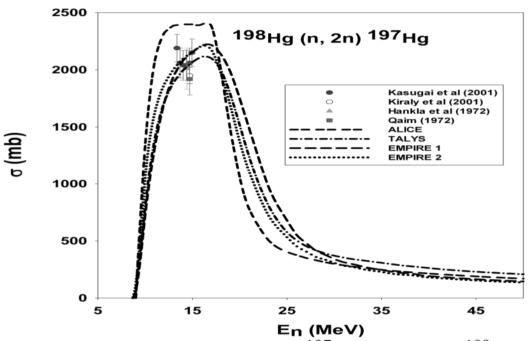

Fig1: Excitation function of ^{197}Hg from n+ ^{198}Hg

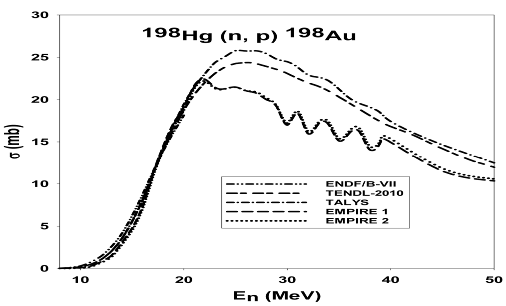

Fig2: Excitation function of ^{198}Au from n+ ^{198}Hg

We have shown in figures 1 and 2, the excitation functions of ^{197}Hg and ^{198}Au produced in neutron induced reactions on ^{198}Hg. In fig. 1 the calculated excitation functions for ^{197}Hg are compared with experimental data available between 13 – 16 MeV. Here the measured cross sections are fairly reproduced by TALYS and EMPIRE calculations, but they are overpredicted by ALICE-91. This is due to multiple PEQ emission and overprediction of EQ cross section by WE formalism considered in ALICE. Both for TALYS and EMPIRE results, the peak of the excitation function is shifted towards right, which is attributed to the Fermi gas level density formalism adopted. Beyond 15 MeV EMPIRE1 and EMPIRE2 results vary significantly which shows that EQ emission, which is strongly influenced by level density of residual nucleus, plays an important role in this reaction. In the case of ^{198}Au, our analysis showed that below 20 MeV, TALYS and EMPIRE calculations agree well with ENDF and TENDL results. Beyond 20 MeV the TENDL cross section are better reproduced by TALYS whereas EMPIRE produces an oscillation in the calculated excitation function.

Conclusion

This work on estimation of excitation function of ^{197}Hg and ^{198}Au showed that TALYS and EMPIRE calculations reproduce the measured cross sections for ^{197}Hg. ALICE largely over predicts the measured cross sections. It has also been observed that though the excitation functions calculated by the different models vary from one another, the total cross sections integrated over the entire energy range agree fairly with one another. Thus these reaction model codes can be used for estimation of total induced activity in a system.

Acknowledgement:

Financial support from DAE-BRNS, BARC, Mumbai by giving major research project (Sanction No. 2011/36/10-BRNS/0494) is thankfully acknowledged.

References

[1] H Hayashi, *et al*, Annals of Nuclear Energy **38** 637 (2011).

[2] www.nds.iaea.org/exfor/endf.htm Exptl. & Evaluated Nuclear Reaction Datafiles (ENDF) Database version of September 05, (2011).

[3] M Blann *Code ALICE/85/300*, LLNL Report NO. UCID-20169 (1985).

[4] A J Koning S Hilaire and M C Duijvestjjn, “TALYS: Comprehensive nuclear reaction modeling”, Proc. Int. Conf. on Nuclear Data for Sci. and Tech.—ND2004 AIP vol. 769 (eds) R C Haight, *et al*, 1154–1159 (2005).

[5] C.Y. Fu, Nucl. Sci. Eng. **86**, 344 (1984).

[6] M Herman, *et al,* “EMPIRE: nuclear reaction model code system for data evaluation”, Nucl. Data Sheets **108**, 2655 (2007)

[7] G Audi, A H Wapstra Nucl. Phys. **A595** 409 (1995).

[8] P Moller, J R Nix At. Data Nucl. Data Tables **26** 165 (1981).