Study of (n,2n) cross section for Ce and Nd isotopes at 14.2 MeV

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Introduction

Studies of neutron induced nuclear reactions are useful to get information of the exited states of atomic nuclei and nuclear reaction mechanism [1]. This paper describes the measured cross section data for (n,2n) reaction for ^{140}Ce, ^{142}Ce, ^{142}Nd and ^{150}Nd. Cerium and Neodymium are rare earth element. These elements are always present as minority in structural material of nuclear reactor. Cerium oxide along with uranium oxide are used as a nuclear fuel for space nuclear power applications [2]. In spent nuclear fuel these elements are formed as fission products. As these elements are the part of the structural material of nuclear reactor, they are getting irradiated by neutrons during the nuclear fission and fusion process. In fusion reactor the DT fusion reaction produces 14 MeV neutrons. It is necessary to study neutron induced reactions for such elements. The measurements of the nuclear reaction cross section give accurate data to validate different nuclear models. It also gives the information about the nuclear structure. In present case the following nuclear reactions are studied.

$$^{140}_{58}Ce(n,2n)^{139}_{58}Ce$$
$$^{142}_{58}Ce(n,2n)^{141}_{58}Ce$$
$$^{142}_{60}Nd(n,2n)^{141}_{60}Nd$$
$$^{150}_{60}Nd(n,2n)^{149}_{60}Nd$$

The (n,2n) nuclear reactions are important as they are considered as neutron multiplier reactions. The cross section are measured at 14.2 ± 0.2 MeV and compared with the existing data available in EXFOR (Exchange Format) data base. Neutron activation analysis technique was used for the analysis of the experimental data. The theoretical calculations have been performed using the nuclear modular codes EMPIRE-3.2.2.The measured cross sections are important to enhance the nuclear data, as well as for the fusion reactor and fission reactor. The experimental measurements and theoretical calculations are discussed here.

Experimental Method

The AN-400 Van de Gradff Accelerator of Banaras Hindu University, India was used to produce 14 MeV neutron via ^{3}H(d,n)^{4}He reaction using thick target of 8 Ci at 280 keV deuteron energy [3]. Uniformly mixed Al with the isotopes ^{140}Ce, ^{142}Ce, ^{142}Nd and ^{150}Nd, pressed into the form of pellet of 2.0 cm diameter and of the thickness ~ 2-3 mm each. Pellets were used as a cylindrical experimental target. A ^{152}Eu disc source of same diameter was placed between the pallets at different positions. Gamma spectrum at each position measured with high resolution HPGe detector (1.8 keV FWHM at 1332 keV gamma energy) and 4096 channel multi channel analyzer. Efficiency of detector was calculated at different energies of ^{152}Eu without and with sample to remove self-shielding effect of the sample. The samples were irradiated with a beam current of 30 μA for 2 hr to 6 hr. The reaction products were identified by characteristics gamma tabulated in table-1. The gamma spectra were measured for each sample using the above mentioned detector setup. The cross section of the interested (n,2n) reactions were calculated from the measured peak counts using the following activation equation .

$$\sigma = \frac{\mathbf{AiA}_{\boldsymbol{\Gamma}}\boldsymbol{\lambda}}{(\mathbf{N_T}\cdot\mathbf{N_P}\cdot\mathbf{I_\Gamma}\cdot\boldsymbol{\varepsilon})(\mathbf{1}-\mathbf{e}^{-\boldsymbol{\lambda}\cdot\mathbf{t_i}})\cdot(\mathbf{1}-\mathbf{e}^{-\boldsymbol{\lambda}\cdot\mathbf{t_c}})\cdot(\mathbf{e}^{-\boldsymbol{\lambda}\cdot\mathbf{t_w}})}$$

where,

A_i = Gram Atomic Weight of the target

A_Γ = Peak Counts of gamma energy

t_c = Counting time

t_i = irradiation time

t_w = Cooling time

N_T = No of targets

N_P = Incident neutron flux

λ = Half-life of the product isotope

I_g = Gamma intensity

ε = Efficiency of detector at gamma chosen

Table 1: Measured Cross-section data compared with existing data from EXFOR data base

Reaction / Half-life of daughter	Gamma Energy (KeV)/ abundance (%)	Measured Sigma (mb)	Exfor Database (Latest) Sigma (b)
^{140}Ce(n,2n)^{139}Ce (137.5d)	166	1690±17	1725±69 [4]
^{142}Ce(n,2n)^{141}Ce (32.55d)	145	1857±18	1913±77 [4]
^{142}Nd(n,2n)^{141}Nd (2.5h)	1127	1722±17	1623±62 [5]
^{150}Nd(n,2n)^{149}Nd (1.73h)	221	1833±18	1737±68 [5]

Theoretical Calculation Using Nuclear Modular Code - EMPIRE

Theoretical nuclear model calculation has been performed to estimate the cross section of all above reactions using nuclear modular code EMPIRE-3.2.2 [6]. Illustrative example for ^{142}Ce(n,2n)^{141}Ce is shown in Fig. 1. The required parameter for the input file such as nuclear mass, discrete energy levels, optical model potential, level densities etc. have been taken from latest RIPL-3. The calculation for all the reactions with optimized parameters will be discussed at the time of presentation.

Conclusion

Cross section of (n,2n) reactions for the isotopes ^{140}Ce, ^{142}Ce, ^{142}Nd and ^{150}Nd are measured at 14.2 MeV using activation technique. The measured data has been compared with the recent EXFOR data as well as the cross-section calculated with nuclear model calculation EMPIRE-3.2.2.

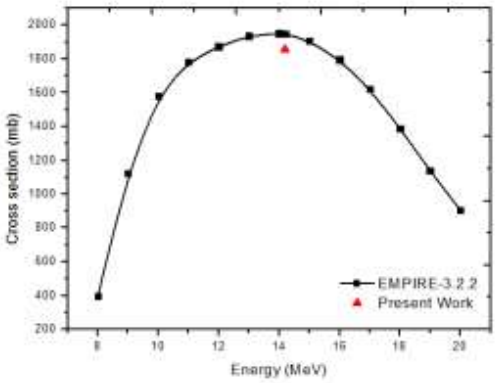

Fig. 1 Comparison of our measured cross-section for ^{142}Ce(n,2n)^{141}Ce with EMPIRE-3.2.2.

References

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