Study of (n,p) and (n,α) cross-sections for ^{232}Th, ^{231}Pa, ^{233}U isotopes

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Introduction

The ^{232}Th-^{233}U fuel cycle is a key to advanced reactor technology. It is an option that not only closes the cycle but also allows the significant reduction of the inventory of long lived nuclear waste. Spallation neutrons convert fertile ^{232}Th to fissile ^{233}U and drive the fission reaction in the uranium [1]. Thorium produces 200 times more power than uranium. Thorium does not require significant refining, unlike uranium and has a higher neutron yield per neutron absorbed.

In the recent years, there has been a renewed effort, both in the forefront of theory as well as experiment to address nuclear data needs. Among the different concepts of nuclear power generation, i.e. accelerator driven system (ADS), fast reactor, advanced heavy water reactor (AHWR), compact and high temperature reactors, nuclear data such as neutron induced reaction cross-sections of fuel elements in the range of medium to fast neutron energies are of great importance [2-3]. At higher energies charge particle emission [(n,p) and (n,α)] cross-sections are also competing, due to which there will be generation and accumulation of hydrogen (^{1}H) and helium (^{4}He) gases inside the fuel pellets and fuel pins. The production of gases inside the fuel pellets would lead to swelling and embrittlement which may result finally to failure of mechanical integrity of the fuel assembly.

Till date, the study on actinides is mainly done, for (n,f) and (n,γ) from thermal to higher energies [4-5]. For light and medium nuclei considerable information is available on (n,p) and (n,α) reactions [6]. However, for heavy nuclei (actinides), no data exist. Earlier, very few measurements were done at thermal energy for ^{233}U(n,α) and ^{232}Th(n,α) reactions. There are no detailed theoretical and experimental study done on neutron induced charged particle reactions i.e. (n,p) and (n,α) for ^{232}Th, ^{231}Pa and ^{233}U. Such type of neutron induced cross-section at higher energies (here, up to 20 MeV) are also important from ADS point of view.

Therefore, the study of neutron induced reaction cross-sections in the charged particle emission in this energy region will help us to understand the energy dependence of activation cross-sections in detail, thereby providing a complete database that will lead to better understanding of mechanisms of the nuclear reactions.

The present study describes nuclear model calculations of (n,p) and (n,α) reaction cross-sections for ^{232}Th, ^{231}Pa and ^{233}U isotopes.

Current status of the present work

Very few experimental data are available for these nuclear reactions in the EXFOR database. There are only two measurements of ^{232}Th(n,α) and ^{233}U(n,α) reactions at thermal energy with the cross-sections 0.001 mb and 0.3 mb respectively [7-8]. There is no experimental as well as evaluated data available for ^{231}Pa.

Nuclear Model Calculations

Neutron induced excitation functions of ^{232}Th(n,p), ^{232}Th(n,α), ^{233}U(n,p), ^{233}U(n,α), ^{231}Pa(n,p) and ^{231}Pa(n,α) reactions have been performed with recent nuclear reaction model code TALYS-1.6 [9]. The required inputs like nuclear masses, discrete energy levels, optical model potential and level densities of the nuclides involved in the calculations have been taken from latest RIPL-3 [10]. Before running TALYS code, we have optimized the input file.

The computed cross-sections together with the experimental data taken from EXFOR data library [11] and the evaluated data files CENDL-3.1 (China, 2009) were plotted for all cases. Figs. 1 & 2 show the illustrative cases of ^{232}Th(n,α) and ^{232}Th(n,p) reaction cross-sections. Energy spectra of outgoing proton and alpha particle have also been calculated. The detailed calculations and results will be presented.

Conclusions

We have highlighted the importance of such kind of study and performed nuclear model calculations for (n,p) and (n,α) reaction on ^{232}Th, ^{231}Pa and ^{233}U isotopes for first time. It is strongly recommended to carry out the nuclear model calculation with reliable parameter set in the high energy range on such type of nuclear reactions, especially when there are no experimental data.

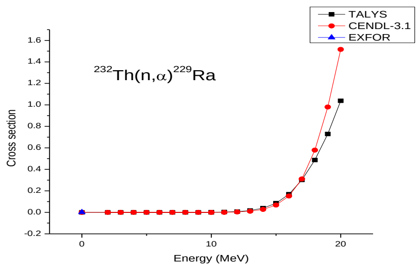

Fig.1.

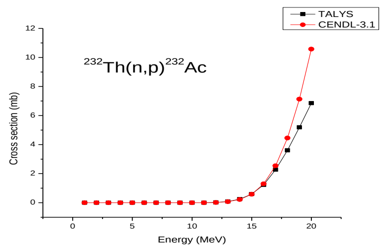

Fig.2.

Figs. 1 & 2 TALYS-1.6 based excitation functions of (n,p) and (n,α) reactions of of ^{232}Th, along with experimental data and evaluated data files [CENDL-3.1 (China, 2009)]

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