Measurement and estimation of cross- sections of ^{138}Ba (n, 2n) ^{137m}Ba and ^{55}Mn (n, α) ^{52}V reactions at 14.8 MeV neutron energy

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Introduction

Recently, the cross-sections of the fast-neutron induced reactions have gained importance, due to their requirement as basic data in nuclear technologies, including design calculations for fusion and fission reactors, accelerator driven system, etc. In addition, the cross-sections are also useful in the studies of reaction mechanism, nuclear structure, neutron dosimetry, radiation damage to materials, activation analysis, shielding, etc. The applications of neutron induced nuclear reactions are also increasing in applied field, such as biomedical, cancer therapy, production of radio-isotopes, etc. The data related to the variations of the cross-sections with the neutron energy are also important for studying the excitation of nuclei to different energy levels and subsequent decay to ground state, either directly or through different energy levels including meta stable state. Although 14 MeV neutron induced reactions have been extensively studied especially using activation technique due to availability of monoenergetic neutrons from D-T reaction, however, existing nuclear data show large discrepancies between the reported cross-sections for an element at the same neutron energy.

In the present work, the cross-sections for the formation of meta stable state ^{137m}Ba through ^{138}Ba(n,2n), and the unstable ground state ^{52}V through ^{55}Mn (n , α) reaction induced at 14.8 MeV neutron energy have been measured, using standard activation method and off-line gamma ray spectrometric technique. The theoretical values of cross-sections for these reactions were also estimated from reaction threshold to 20 MeV, using the TALYS-1.2 computer program. The choice of the nuclear reactions is made because large discrepancies exist in the reported cross-sections, and a few measurements around 14.8 MeV neutrons have been reported. The cross-sections measured in the present work have been compared with the EXFOR database and also with the theoretical cross-sections obtained using the Talys-1.2 computer code.

Experimental

For this work, the neutron generator facility of Department of physics, University of pune was used, in which 14.8 MeV neutrons are produced through ^{3}H (d, n) ^{4}He reaction (Q = 17.59 MeV). For the measurement of cross-sections, powders of the enriched stable isotopes of the respective elements were used. Each sample was made by packing known weight of the elemental powder along with an aluminium foil of known weight, in a polyethylene vial. Such three samples, each of ^{138}Ba and ^{55}Mn were made. For neutron irradiation, the sample was positioned at 0^0 angle, with reference to the deuterium beam on the tritium target, and at a distance ~ 50 mm from the irradiation head. The 14.8 MeV neutrons were produced by bombarding an 8 Ci tritium target with 175 KeV deuteron ions, at a beam current ~ 100 μA. The ^{27}Al(n, p)^{27}Mg reaction (Q = -1.82 MeV) was used as a standard for neutron flux measurement. Each Ba sample was irradiated separately with 14.8 MeV neutrons for 8 minutes. Similarly, each Mn sample was irradiated for 10 minutes. The neutron flux on the sample during the irradiation period was ~ 10^7 n/cm^2/s.Table-I gives the details of the nuclear reactions and their related nuclear data used in the present work.

Table I: Measured reactions and decay data.

Nuclear Reaction	Half-life (min)	Gamma -Ray Energy (MeV)	Branch -ing Ratio (%)
$^{138}Ba(n,2n)^{137m}Ba$	2.552	0.6616	89.90
$^{55}Mn(n, \alpha)^{52}V$	3.743	1.4340	100
$^{27}Al(n,p)^{27}Mg$	9.458	0.8437	71.8

After neutron irradiation, the sample was brought to the counting room and the induced gamma ray activities of the unstable residual nuclei were measured by a HPGe detector coupled to a MCA. Energy resolution of the detector was 1.85 KeV at 1.33 MeV gamma energy of ^{60}Co. The photo peak efficiency of the detector was determined using standard gamma sources. The counting period was kept equal to the irradiation period, decided by the half-live of the radio-isotope produced. The area under each photo peak was determined using standard GENIE-2K software.

The cross-section for each nuclear reaction was obtained using the following relation;

$$\sigma = \frac{A\lambda}{Na\varepsilon\varphi(1-e^{-\lambda t_{irr}})e^{-\lambda t_d}(1-e^{-\lambda t_c})}$$

where, A, λ, N, a, ε , Φ, t_{irr}, t_d, and t_c are observer activity, decay constant, number of atoms of the isotope of the element, gamma ray abundance, efficiency of the detector , neutron flux, irradiation period, cooling period and counting period respectively.

Results and discussion

For $^{138}Ba(n,2n)^{137m}$ reaction, the theoretically estimated and measured cross-section obtained in the present work , along with a few literature cross-sections are given in Fig.1.It is observed in Fig.1 that for this reaction, only a few values of cross-sections have been reported over the neutron energy range 14 to 16 MeV. The theoretical values of cross-sections estimated in the present work with the choice of ldmodel-2 (Back shifted Fermi gas model using TALYS) are in good agreement with the corresponding literature experimental cross-sections, as well as with the present cross-section.

For $^{55}Mn(n,a)^{52}V$ reaction, the theoretically estimated and measured cross-section obtained in the present work, along with a few literature cross-sections are given in Fig.2.However, the cross-sections estimated with the ldmodel-2 do not match with the some of the experimental cross-sections of the EXFOR database. The cross-section at 14.8 MeV neutrons measured in the present work is close to the theoretical value obtained with the choice of ldmodel-1 (Constant tempreture+Fermi gas model)

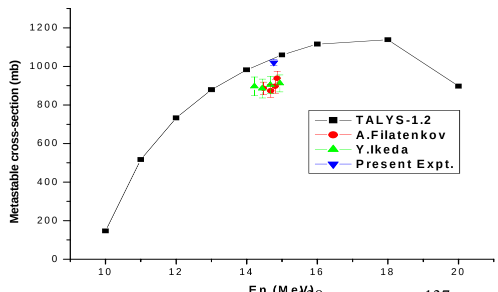

Fig.1: Excitation function of $^{138}Ba(n, 2n)^{137m}Ba$

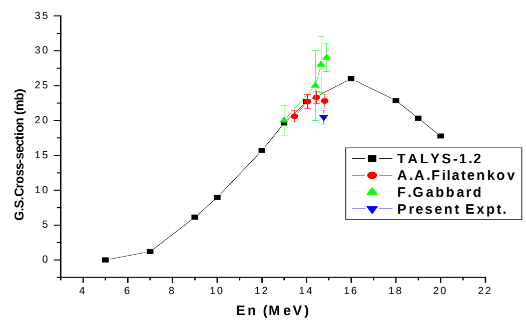

Fig.2: Excitation functions of $^{55}Mn(n, \alpha)^{52}V$

Conclusion

The cross-sections measured in the present work are in good agreement with corresponding theoretical values estimated by using TALYS-1.2 code.

References

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