Measurement of activation cross sections in alpha induced reactions on natural Zn

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Introduction

Medicinally important radio nuclides are generally produced using either neutron irradiation at reactors or light charged particle induced reactions from accelerators. Reactor produced radio nuclides are generally β^- emitters whereas cyclotron produced radioisotopes are positron emitters. There are many nuclides which can be produced in high specific activity using cyclotrons. For the optimization of production of a particular radionuclide and their radiochemical separation with high radionuclide purity, accurate experimental cross section data are often a necessity [1]. Though a large number of literature data are available for several well established radio-nuclides, there are few nuclides for which more data are required. As variable energy light charged particle proton and alpha beams are available at VECC cyclotron, Kolkata, we had initiated work on cross section measurements of medicinally important radio nuclides for which sufficient data are either unavailable or to strengthen the database. This type of work will help to optimize the radio nuclide production methods, validate the nuclear reaction codes etc.

In this work, we have measured the activation cross sections of $^{nat}Zn(\alpha,x)$ $^{66,67,68}Ga$ reactions up to 48 MeV and compared the results with available literature data and TENDL-2021 nuclear data library based on the TALYS-1.96 code. These radioisotopes have important applications in nuclear medicine as diagnosis and therapy depending on their decay characteristics. ^{68}Ga ($T_{1/2}$=67.71min) is produced from electron capture (100%) decay of ^{68}Ge ($T_{1/2}$=270.95 days) which is directly produced in alpha induced reaction on Zn. Hence, $^{68}Ge/^{68}Ga$ generator is an alternate method for production of ^{68}Ga where medical cyclotron facility is unavailable on-site.

Experimental

Experiment was performed using alpha beam from cyclotron at VECC, Kolkata. Standard stacked foil activation technique was employed. Targets were high purity (99.9%, 50 μm thickness) Zn foils. Two stacks consisting of Zn target foils, Cu foils for beam current monitor and Al catcher foils were prepared. After each foil, one Al catcher foil was kept. The stacks were irradiated with 48 and 35 MeV initial alpha beam energies of ~70 and ~30 nA currents for 1 h. Energy degradation in each foil of the stack was calculated using SRIM 2013 code. After irradiation each target foil along with the catcher foil was packed and counted several times using HPGe detector system. Efficiency calibration was done using standard ^{152}Eu sources. Cross sections (σ(E)) were calculated using standard activation equation [1].

Results and discussion

Activation cross sections of medicinally important radio nuclides $^{66,67,68}Ga$ as well as ^{69}Ge and ^{65}Zn produced from $^{nat}Zn(\alpha,x)$ reactions were measured. A gamma ray spectrum of the irradiated Zn target at 48 MeV alpha beam energy is shown in Fig. 1.

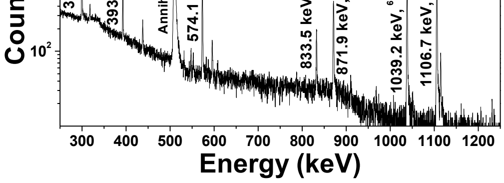

Fig. 1 Gamma ray spectrum acquired after 24 hrs cooling period of the $^{nat}Zn(\alpha,x)$ reactions at 48 MeV energy. Radio nuclides with energies are marked for the gamma ray peaks.

Table 1: Nuclear spectroscopic data of the studied radio nuclides from $^{nat}Zn(\alpha,x)$ reactions

Nucl-ides	**Half-life**	**Decay Mode (%)**	**E_γ (keV)**	**I_γ (%)**
^{66}Ga	9.49 (3) h	EC + β^+ (100)	1039.2	37.0 (20)
^{67}Ga	3.2617 (5) d	EC (100)	300.217	16.64 (12)
^{68}Ga	67.71 (8) min	EC + β^+ (100)	1077.34	3.22
^{68}Ge	270.95 (16) d	EC (100)	-	-
^{69}Ge	39.05 (10) h	EC + β^+ (100)	1106.77	36
^{65}Zn	243.93 (9) d	EC + β^+ (100)	1115.539	50.04 (10)

$^{66,67,68}Ga$, ^{69}Ge and ^{65}Zn were identified from the measured spectra. Nuclear data of the studied radioisotopes are given in Table 1. Excitation functions of $^{nat}Zn(\alpha,x)$ $^{66,67,68}Ga$, ^{69}Ge and ^{65}Zn were measured up to 48 MeV. Here only eexcitation function of $^{nat}Zn(\alpha,x)^{68}Ge/^{68}Ga$ is shown in Fig. 2 along with previously published literature data [2-4] and theoretically predicted data from TENDL-2021 based on TALYS-1.96 code [5].

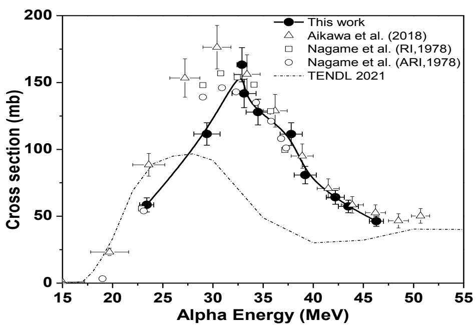

Fig.2 Excitation function of $^{nat}Zn(\alpha,x)^{68}Ga$ reaction. Experimentally measured cross section data are compared with available literature data and TENDL-2021 nuclear data library. Our data are fitted with line to guide the eye.

^{68}Ge ($T_{1/2}$=270.95) is produced directly from ^{nat}Zn (α,x) reactions which decays to ^{68}Ga ($T_{1/2}$=67.71 min) via electron capture (100%). ^{68}Ga disintegrates to stable ^{68}Zn partially by positron emission (88.88%) with a maximum energy of 1899.1 keV and partially by electron capture (11.11%). As there are no gamma ray transitions for decay of ^{68}Ge to ^{68}Ga, production of ^{68}Ge was indirectly measured using 1077.34 keV gamma rays of ^{68}Ga after a cooling period of about four months. ^{68}Ga produced directly from ^{nat}Zn is considered to be decayed completely in this time. So measured cross sections are independent cross sections.

Conclusion

Activation cross sections of medicinally important radio nuclides as well as other produced radioisotopes were measured using well known stacked-foil activation technique followed by the measurement of gamma activity for $^{nat}Zn(\alpha,x)$ $^{66,67,68}Ga$, ^{69}Ge and ^{65}Zn reactions. Results were compared with the available literature data and TENDL-2021. There are only few literature available for the systematic study on alpha induced reactions on natural Zn for the production of these radio nuclides. Our data are found to be in good agreement for ^{66}Ga, $^{68}Ge/^{68}Ga$ and ^{65}Zn within experimental uncertainties. Thick target yields of the radio nuclides from the measured cross section data were also calculated. All experimental data will be presented during the symposium.

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