Measurement and analysis of ^{19}F(γ,n)^{18}F reaction

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Introduction

Radioisotopes are widely used for radiological imaging, radiation therapy in the field of nuclear medicine. Most of these isotopes are produced through nuclear reactors, either as fission products or neutron activation. Since the accelerator technology is more developed, alternate routes of nuclear reactors are to be evaluated for the point of view of safety and cost effectiveness. Managing nuclear power plants, packing and transportation of such radioactive isotopes, contamination of toxic isotopes are major issues.

^{18}F is an important radioisotope used for positron emission tomography(PET) scan. In the medical field, the use of ^{18}F is keep on increasing which indicate the huge demand for ^{18}F. Various reaction channels such as ^{18}O(p,n)^{18}F, ^{19}F(n,2n)^{18}F, ^{19}F(γ,n)^{18}F, ^{16}O(t,n)^{18}F are available for the production of ^{18}F. Among this, ^{18}O(p,n)^{18}F is the most widely using channel that utilizes enriched ^{18}O water as target. In fact the half life of ^{18}F become a major barrier in the transportation of this isotope from cyclotron to the medical facility and the enriched water target makes the method much costlier. Also, in ^{18}F produced in accelerator driven system toxic hydrogen fluorides is found to be produced. In the present study, the production of ^{18}F from ^{19}F using medical linac is being explored.

Materials and Methods

Stacked foil activation method was used for irradiating LiF and indium foil targets simultaneously. Pellet of LiF sample of thickness 245.3 mg and indium foil of thickness 388.0 mg was used in the experiment. 20 MeV electron beam with dose rate 1000 cGy/min produced using Varian CLINAC-iX, medical linear accelerator was converted in to high intensity photon beam having end point energy 20 MeV using 1 mm lead target. Stack containing both the targets were irradiated for 20 minutes to attain required activity before counting. Residual activity of the activated samples were measured after reasonable cooling time, using Kromeck CZT (Cadmium Zinc Telluride semiconductor detector) gamma spectrometer.

TABLE I: Photon induced reactions and corresponding Q values, gamma energy and the half-life of the radioisotope formed

Reaction Channel	Qvalue (MeV)	Gamma Energy (KeV)	Half-life
^{19}F(γ,n)^{18}F	10.432	511	109.77 min
^{115}In(γ,n)^{114}In^m	9.038	190	49 days

In the photon activation analysis, the cross section can be calculated using the standard formula given as,

$$\sigma = \frac{A\lambda exp(\lambda t_2)}{N_0\phi\theta K G_\epsilon(1 - exp(-\lambda t_1)(1 - exp(-\lambda t_3))} \quad (1)$$

where A is the activity of gamma peak, λ is the decay constant of residual nucleus, N_0 is the no. of target nuclei per unit area of the irradiated sample, G_ϵ is the geometry dependent efficiency of the detector, θ is the branching ratio of the gamma ray, ϕ is the incident photon flux, K is the self absorption correc-

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tion factor for gamma ray in the sample and t_1,t_2,t_3 are respectively the irradiation time, the cooling time and the counting time of the sample.

After the irradiation, 511 KeV gamma rays were produced from the β^+ annihilation of ^{18}F. Activity of the sample was counted for 30 minutes dual time and the count rate was plotted against time after irradiation which is shown in Fig(1). In order to obtain accurate count rate, the background count consisting of naturally occurring β^+ emitters are subtracted. Fitting the data linearly gives the decay constant of ^{18}F, which confirms that the counted 511 KeV gammas are only coming from the activated ^{18}F isotope.

Theoretical Calculations

The flux of photon beam is taken from the measured bremsstrahlung spectrum by Midhun C.V et al[1]. Using this flux, integral cross section is determined for the monitor reaction for flux normalization. ^{115}In(γ,n)^{114}In^m reaction channel taken from EXFOR data library [2] has been used as monitor reaction to determine the integrated cross section of the monitor reaction. Theoretical integral cross sections are calculated using nuclear reaction code Talys 1.8. Monitor reaction is selected in such a way that, near by q-value systems cover same area of the bremsstrahlung spectrum. Integral cross section of the monitor reaction is used to determine the integral cross section of the reaction ^{19}F(γ,n)^{18}F. The cumulative cross section obtained for the reaction ^{19}F(γ,n)^{18}F is shown in fig 2.

Result and Discussion

The photon activation analysis of ^{19}F(γ,n)^{18}F reaction has been done using medical linear accelerator. The experiment was done for 20 MeV bremsstrahlung photons and the gamma counting was done using CZT detector. Estimated cross section of ^{19}F(γ,n)^{18}F reaction is obtained using the integrated cross sections of the monitor reaction ^{115}In(γ,n)^{114}In^m. Theoretical model calculations are done using nuclear reaction code Talys 1.8. The analysis shows the theoretically estimated integral cross section is in well agreement with the experimentally measured cross section for ^{19}F(γ,n)^{18}F.

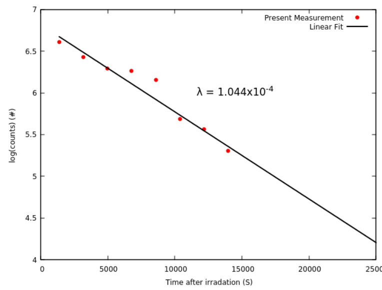

FIG. 1: Activity plot of ^{18}F. Red dots are the counts corresponding to gammas from ^{18}F and straight line is the linear fit.

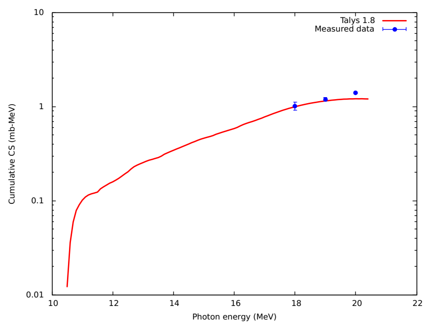

FIG. 2: Cumulative cross section corresponding to ^{19}F(γ,n)^{18}F reaction. Theoretical line shows the Talys model calculations.

Acknowledgments

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References

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