Integral cross section of ^{19}F(γ,n)^{18}F reaction at 14 MeV bremsstrahlung photon

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Introduction

^{18}F is a pure positron emitter used for positron emission tomography(PET) scan. Primarily ^{18}F is produced via cyclotron using an enriched water target. Major 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 these channels, ^{18}O(p,n)^{18}F is the widely using channel for the production of ^{18}F. Along with ^{18}F, a large number of unwanted activation products are formed due to the bombardment of the primary proton beam and the energetic neutron produced in the reaction itself[1]. This in turn contaminates the ^{18}F isotope and causes patients to absorb extra dose. Transportation of the radioactive isotope to the hospitals is also a major issue, as the useful activity of the isotope will lost due to its shorter half-life. Production of the ^{18}F isotope using the medical linac inside the hospital site itself will bring down the major issues regarding the conventional method.

In the present study, the production of ^{18}F from ^{19}F using medical linac is being explored. The integral cross section of the reaction is determined using the bremsstrahlung photons. The most studied ^{115}In(γ,n)^{114}In^m reaction was used as the monitor to determine the integral cross section. Table I shows the reaction channels of the sample and monitor, corresponding Q values, gamma energyies under study, and half-life of the residues.

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TABLE I: Photon induced reactions and corresponding parameter values under study

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

Materials and Methods

Experiment was carried out using 14 MeV photons available from Varian CLINAC-iX, medical linear accelerator facility. Photon activation method was used for irradiating LiF and indium foil targets simultaneously. Pellet of LiF sample of thickness 320 mg and indium foil of thickness 212 mg was used in the experiment. Residual activity of the activated samples were measured after reasonable cooling time, using Kromeck CZT (Cadmium Zinc Telluride semiconductor detector) gamma spectrometer.

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 correction 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.

Calculation of integral cross sections

The integral cross section over the incident bremsstrahlung endpoint energy 14 MeV is determined via the flux normalization method. Yield of the sample and the monitor was determined from the experiment. Experimental data of the monitor reaction $^{115}In(\gamma,n)^{114}In^{m}$ was taken from the EXFOR data library [2]. Theoretical integral cross sections are calculated using nuclear reaction code Talys 1.96. Monitor reaction is selected in such a way that, nearby q-value systems cover the same area of the bremsstrahlung spectrum[3]. The integral cross section of the reaction can be obtained from the yield of the irradiated sample, using the relation

$$\frac{Y_s}{Y_m} = \frac{\int_{E_{th}}^{E_\gamma} \sigma_s(E)\phi(E)dE}{\int_{E_{th}}^{E_\gamma} \sigma_m(E)\phi(E)dE} \tag{2}$$

where Y_s is the yield of sample and Y_m is the yield of monitor reaction, E_{th} and E_γ are the threshold and bremsstrahlung end point energies, σ_s and σ_m are the theoretical cross sections of the reactions $^{19}F(\gamma,n)^{18}F$ and $^{115}In(\gamma,n)^{114}In^{m}$ respectively.

Integral cross section of the monitor reaction is used to determine the integral cross section of the reaction $^{19}F(\gamma,n)^{18}F$. The cumulative cross section obtained for the reaction $^{19}F(\gamma,n)^{18}F$ is shown in Fig 1.

Result and Discussion

The integral cross section of $^{19}F(\gamma,n)^{18}F$ reaction has been determined via photon activation method. Theoretical model calculations are done using nuclear reaction code TALYS 1.96. Theoretical parameters are optimized using the measured data points. Previously measured data for the same reaction at 20 MeV[4] is also included in figure 1. The analysis shows the theoretically estimated integral cross section reproduces the experimentally measured cross section for $^{19}F(\gamma,n)^{18}F$.

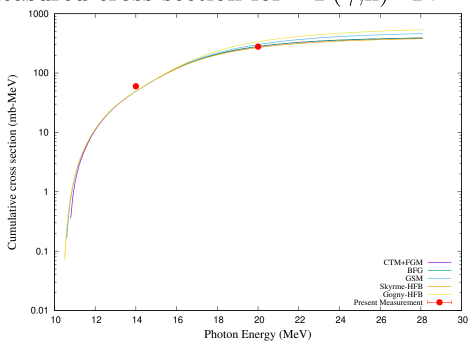

FIG. 1: Cumulative cross section corresponding to $^{19}F(\gamma,n)^{18}F$ reaction. Theoretical line shows the Talys model calculations.

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References

[1] J. Carbajo Chaves *et al.*, Radiation Physics and Chemistry *126*, p.32-36 (2016)

[2] P.C.K.Kuo *et al.*, Nuclear Physics A, **499**, 328,(1989)

[3] C.V Midhun *et al.*, Nuclear Science and Engineering **194**, p.1-6 (2019)

[4] Shaima Akbar *et al.*, Proceedings of the DAE Symp. on Nucl. Phys. 66 (2022)