# Statistical model calculations on $\alpha$-induced reactions of medical use

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## Introduction

Several $\alpha$-induced nuclear reactions are of pertinence in the production of radioisotopes that are of use in theranostic applications. These isotopes span the entire nuclear chart from the light nuclei in the A$\sim$30 region such as $^{28}$Mg and $^{30}$P, to the heavy nuclei in such as A$\sim$200 region, such as $^{211}$At[1]. Some of these isotopes are used for diagnostic purposes through techniques such as PET (Position Emission Tomography) and SPECT (Single-Photon Emission Computerized Tomography). These include $^{30}$P, $^{38}$K, $^{77}$Br, $^{95/97}$Ru, $^{147}$Gd etc. Isotopes such as $^{211}$At are of use in $\alpha$-targeted internal radiotherapy. The $^{77}$Br isotope is also of use in Auger electron therapy. $\alpha$-induced reactions have been of facility to populate isomeric states [in nuclei] with decay properties appropriate for therapeutic applications. These states are typically at low excitation energies and decay to the ground state by highly converted transitions. The low energy conversion electrons or the avalanche of Auger electrons that result can be applied for internal therapy with localized precision. The isomeric states such as $^{193m}$Pt($13/2^+$), $^{195m}$Pt($13/2^+$) and $^{117m}$Sn($11/2^-$) befit such purpose and are preferably produced in $\alpha$-induced reactions. Such significance of $\alpha$-induced reactions in the societal context warrant efforts towards understanding the different reaction parameters that impact them. Statistical model calculations based on Hauser-Feshbach formalism [2] is expected to cater for the purpose. The present work is directed at identifying the optimum parameter set in such calculations for theoretically reproducing the experimentally known cross sections of the afore mentioned reactions. These parameters may then be applied to predict optimum production conditions of these and of similar reactions that lead to be isotopes of interest.

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## Methodology

There are different codes for implementing statistical model calculations. TALYS [3] has been chosen for the present study owing to the comprehensive choice of models included in its framework. Some of the parameters/factor that are expected to impact the (cross-section) calculations maximally include the optical model potential(OMP), the level density(LD), the gamma strength function(GSF) and the pre-equilibrium(PE) modeling. Different sets of these parameters have been used to fit the data on reactions of interest as available from the EXFOR [4] database. The calculations have also been extended to estimate the thick target yield (TTY) of radioisotopes of interest. The latter is imperative in the production exercise of the isotopes.

## Results and Discussion

Different $\alpha$-induced reactions with targets of light, intermediate and heavy nuclei have been investigated in this study. Some of the reactions are as follows; $^{27}$Al($\alpha$, n)$^{30}$P, $^{35}$Cl($\alpha$, n)$^{38}$K, $^{40}$Ar($\alpha$, p)$^{43}$K, $^{75}$As($\alpha$, 2n)$^{77m}$Br, $^{92}$Mo($\alpha$, n)$^{95}$Ru, $^{144}$Sm($\alpha$, n)$^{147}$Gd, and $^{209}$Bi($\alpha$, n)$^{211}$At.

Its has been generally noted that the OMP Alpha potential of Avrigeanu et al. [5] and GSF from Brink-Axel Lorentzian have resulted in a reasonable representation of the experimental cross-section data for the aforementioned reactions. As far as the LD model is concerned the Constant Temperature + Fermi gas model (CTM), Back-shifted Fermi

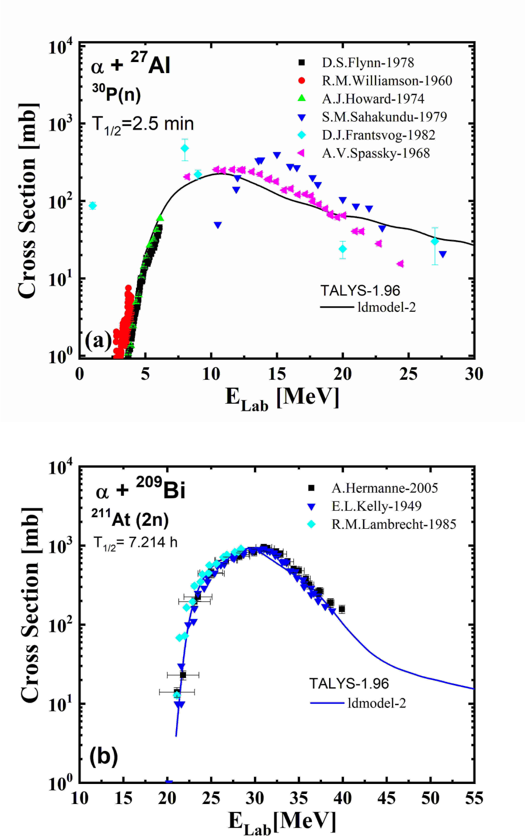


FIG. 1: Experimental excitation function data [4] along with model calculated TALYS (solid line) estimation for radioisotope (a) $^{27}$Al($\alpha$, n)$^{30}$P and (b) $^{209}$Bi($\alpha$, n)$^{211}$At.

gas Model (BFM), and Generalised Superfluid Model (GSM) have been used. For the PE model Exciton model (that include Numerical transition rates with energy-dependent matrix) was used.

Fig-1 illustrates the plots of experimental data for two different reactions along with the respective theoretical calculations. The parameters that best represented the experimental cross-section of $^{27}$Al($\alpha$, n)$^{30}$P and $^{209}$Bi($\alpha$, n)$^{211}$At reactions have been further used to calculate the respective TTY. The results are illustrated in Fig-2. The overlap is satisfactory between TTY determined using the experimental cross-section data and the theoretical

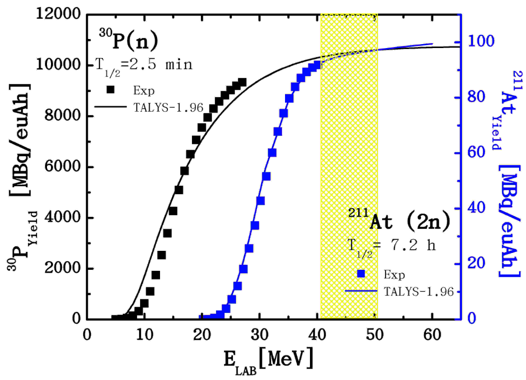


FIG. 2: Thick target yield for the radioisotopes $^{30}$P and $^{211}$At. The experimental best fit data is shown by solid symbols, whereas the TALYS optimized model predicted excitation function data is represented by solid lines.

values estimated using the parameters that reproduced the experimental cross-sections.

Efforts are in progress to further optimize the parameters to represent cross-sections of a wider variety of reactions. The same is expected to facilitate the identification of systematic trends in the applicability of models for the different parameters that impact the reaction cross-sections.

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