Theoretical calculations and evaluation of alpha induced nuclear reactions on ^{121}Sb

T. Athira[1], B. Satheesh[2],* Aparna Gopinath[1], and P. T. Abiya Rose[3]

[1] *Department of Studies and Research in Physics Payyanur College, Payyanur Edat PO - 670327, Kerala, INDIA*

[2] *Department of Physics, Mahatma Gandhi. Govt. Arts College, Chalakkara, New Mahe 673311, U.T. of Puducherry, INDIA and*

[3] *Department of Physics, Govt Arts and Science College, Meenchanda, Kozhikode -673018, Kerala, INDIA*

Introduction

The aim of this work was to investigate in general the excitation functions, isomeric cross section ratio and decay scheme of alpha - particle - induced nuclear reactions on ^{121}Sb. I^{124} ($T_{1/2}$ = 4.1760 day; $E_{\beta+}$ = 2.13 MeV; $I_{\beta}+$ = 22%) radionuclide; It is one of the important positron emitters for nuclear medicine with its suitable uses for radio immunotherapy with Positron Emission Tomography (PET) [1]. Cross - section measurements, astrophysical S - factor calculation studies provide the opportunity to test statistical models [2]. The experimental and theoretical cross sections of the ^{121}Sb(α, n)^{124}I reaction, which plays a particularly important role in the production of ^{124}I. The ground state decay properties of the nuclide ^{123g,m}Te, decay scheme and isomeric cross section ratio are have been rather ambiguous. The astrophysical significance of ^{123g,m}Te are follows: The nuclide ^{123g,m}Te and its neighboring tellurium isotopes with mass numbers of A = 122 and 124 are pure S - process nuclide's produced only in the slow neutron capture (S - process) in stars. Astrophysical S - factor the major typical of a reaction is the cross section σ(E), which has the size of a superficial and related on energy also the cross section at stellar energies is governed by Coulomb effects. The astrophysical S - factor is defined as, $S(E) = \sigma(E).E.\exp(2\pi\eta)$, where, η is the Sommerfeld parameter, $(Z_1Z_2e^2)/\hbar\nu$.

*Electronic address: `satheesh.b4@gmail.com`

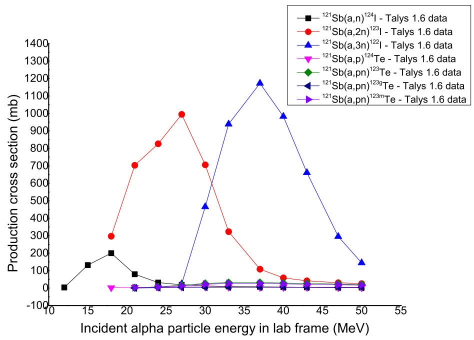

FIG. 1: Theoretically calculated excitation functions (TALYS 1.6) for the reactions ^{121}Sb(α, n)^{124}I, ^{121}Sb(α, 2n)^{123}I, ^{121}Sb(α, 3n)^{122}I, ^{121}Sb(α, p)^{124}Te, ^{121}Sb(α, pn)^{123g,m}Te, ^{121}Sb(α, pn)^{123g}Te and ^{121}Sb(α, pn)^{123m}Te.

The astrophysical S - factor is particularly useful in low energy regions. Empirical measurements of $\sigma(E)$ at low energies measurement are mostly not available (because of the Coulomb barrier exponentially depress low - energy cross sections) [3]. Keeping this in view we are investigated the excitation functions of ^{121}Sb(α, n)^{124}I, ^{121}Sb(α, 2n)^{123}I, ^{121}Sb(α, 3n)^{122}I, ^{121}Sb(α, p)^{124}Te and isomeric cross section of the nuclide ^{123g,m}Te for the reaction ^{121}Sb(α, pn)^{123g,m}Te from 12 - 50 MeV using the nuclear model codes TALYS 1.6.

Nuclear model calculations

The normalized experimental data were compared with the results of nuclear model calculations using two codes, EMPIRE and TALYS. The nuclear reaction code system,

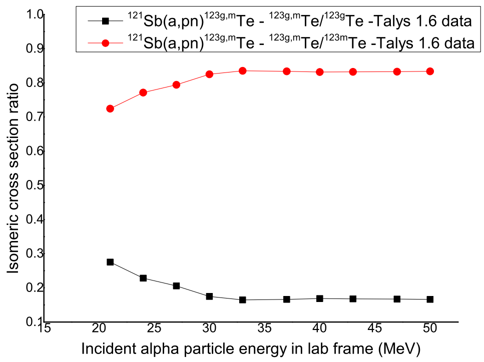

FIG. 2: Theoretically calculated (TALYS 1.6) isomeric cross-section ratio for the reaction ^{121}Sb(α,pn)^{123g,m}Te.

TABLE I: ^{121}Sb(α,pn)^{123g,m}Te - ^{123m}Te/^{123}Te - TALYS 1.6 data and ^{123}Sb(α,pn)^{123}Te - ^{123g}Te/^{123}Te - TALYS 1.6 data. m - isomeric state and g - ground state

Energy (MeV)	^{123m}Te/^{123}Te	^{123g}Te/^{123}Te
21	0.72429	0.27571
24	0.77149	0.22851
27	0.79435	0.20565
30	0.82509	0.1749
33	0.83524	0.16476
37	0.8335	0.1664
40	0.83140	0.16860
43	0.83194	0.16806
47	0.83281	0.16719
50	0.8336	0.1663

EMPIRE 3.2.3 - MALTA, has been designed to perform nuclear reaction calculations over a wide range of energies and incident particles. EMPIRE is equipped with a complex system of codes to describe all the important nuclear reaction mechanisms. TALYS, a nuclear reaction software developed at NRG Petten and CEA Bruyres - le - Chtel, provides a continuous and smooth description of nuclear reactions over a wide energy and mass range. Nuclear reactions induced by neutrons, protons, deuteron's, triton's, helions, alphas and photons can be simulated in the 1 keV to 200 MeV energy range.

1. Results and discussion

The excitation function based on the TALYS-1.6 code calculation is shown in FIG. 1. The isomeric cross section ratio (ICR) for both ^{123g}Te/^{123}Te and ^{123m}Te/^{123}Te are plotted in FIG. 2.and TABLE I represents ^{123}Sb(p,n)^{123}Te - ^{123m}Te/^{123}Te - TALYS 1.6 data and ^{123}Sb(p,n)^{123}Te - ^{123g}Te/^{123}Te - TALYS 1.6 data. m - isomeric state and g - ground state. In all the calculations the default options for the direct reactions were used. From the TALYS 1.6 data for ^{124}I production the optimum energy range was found to be Eα = 15$\longrightarrow$21 MeV. The isomeric cross section ratio ie., ^{123m}Te/^{123} is maximum 0.83524 at 33 MeV and ^{123g}Te/^{123} is maximum 0.27571 at 21 MeV. The isomeric cross section ratio is strongly depends on the relative spin states of the isomeric and ground state, here ^{123g,m}Te have the spin and parity J^{π} (1/2+, 11/2-). Thus it is expected that at very low incident energies the ground state is initially populated followed by the higher levels. When sufficient energy is reached the population of higher spin stat increases with energy independent of relative energy states. The details will be presented.

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