Evaporation of Neutrons from Alpha Induced reactions on ^{55}Mn and ^{209}Bi Nuclei

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Introduction

Several models like ALICE-91, CASCADE, PACE2, ACT, COMPLET [1] etc., are available in the literature and are generally used for theoretical calculations of excitation functions (EFs) for light and heavy ion induced reactions. In all the codes except ACT, the configuration of the codes is such that they predict the total cross-section only for the population of the residual nuclei. However, the code ACT calculates the cross-sections for the production of both the ground as well as isomeric states. In the work reported [2], the code ACT based on the lines of codes STAPRE was used using consistently the same set of parameters. At moderate excitation energies, reactions induced by nucleons and light-heavy ions are found to proceed through CN as well as PE emission [2] as such, precise measurement of EFs for such cases and their analysis may be used to find out the relative contribution of equilibrium and PE processes. With a view to provide a large set of cross-section data and to study the mechanism of PE emission, a program of precise measurement and analysis of cross sections, of ^{55}Mn and ^{209}Bi by alpha particles induced reactions is going on at many places. These measurements may provide a broad database for testing the capability of theoretical model codes with respect to calculating cross-section. The objective of the present work is to investigate the mechanisms of alpha-particle induced reaction on ^{55}Mn, a light nuclide and ^{209}Bi, a heavy nuclide with various projectile energies on similar channels with the help of computer code COMPLET. The different reaction channels studied are:

$^{55}_{25}Mn(\alpha,n)^{58}_{27}Co$,
$^{55}_{25}Mn(\alpha,2n)^{57}_{27}Co$
$^{55}_{25}Mn(\alpha,3n)^{56}_{27}Co$
$^{55}_{25}Mn(\alpha,4n)^{55}_{27}Co$
$^{209}_{83}Bi(\alpha,n)^{212}_{85}At$,
$^{209}_{83}Bi(\alpha,2n)^{211}_{85}At$
$^{209}_{83}Bi(\alpha,3n)^{210}_{85}At$,
$^{209}_{83}Bi(\alpha,4n)^{209}_{85}At$

The mechanism of compound and pre-compound reactions have been investigated. The comparative analyses of the cross sections of the two target nuclides were conducted. Using these measured values, the calculated values were compared and some important conclusions were drawn.

Experimental Details and Computer Code

Experimental method Nuclear data evaluation is carried out on the basis of the experimental data and theoretical model of calculations. The code COMPLET is a nuclear reactions code which was designed for versatility and ease to use in the bombarding energy range of a few MeV to several hundred MeV. The code COMPLET is based on same philosophy as the former code COMPLEX and an extension of code INDEX [3]. COMPLET code is an extension of the code ALICE-91 and INDEX. These two codes employ the Weiss Kopf-Ewing model for the statistical part and geometry dependent hybrid model of M. Blann for the pre-equilibrium emission. The code COMPLET gives the result of compound reaction and compound nucleus plus pre-equilibrium reaction. The projectile energy is measured in MeV and the cross-sections are measured in mb. In COMPLET code a pre-equilibrium process in two stages is assumed. The particles in the initial configuration (n0 = EX1 + EX2 + EX3) can be neutron, proton or alpha particle, represented by the exciton numbers EX1, EX2 and EX3 respectively. It is customary to use the initial number n0 exciton separated in to proton and neutron above and holes below the Fermi level as at parameter to match theoretical prediction with experimental excitation function. The requirement of detailed input parameters was sacrificed to achieve this goal. The code

COMPLET provides yields and spectra for all reactions populated by all combinations of n; p; d; and can provide all input parameters internally. The running time of the code is very short. This code includes damping of fission widths above a critical temperature R0. The code COMPLET includes pre-equilibrium neutron, proton and alpha emission up to two particles, as well as evaporation of neutrons, protons, alphas, deuterons, tritons and hellions.

Results and discussion

^{57}Co is produced when a particle strikes the target nucleus ^{55}Mn and emits two neutrons.

Table 1. Theoretical and measured cross-sections for the reaction $^{55}_{25}Mn(\alpha, n)^{58}_{27}Co$

Energy (MeV)	**σ** – Exp. (mb)	**σ**- -compound (mb)	**σ**-pre- -compound (mb)
20	290	408	391
25	85	76.6	108
30	26.2	20.5	56.7
35	19	10.2	35.8
40	5.5	2.85	25.8
45	2.93	1.31	25.3
50	1.54	0.98	14.6
55	1.59	0.41	11.5
60	1.27	0.28	9.14

As can be seen from the Table 1, the trend of the experimental results are in very good agreement with the theoretical results generated for compound reaction particularly in the energy range 30 MeV to 60 MeV. There are no signatures of pre-equilibrium reaction and only compound nucleus formation is taking place.

Table 2. Theoretical and measured cross-sections for the reaction $^{209}_{83}Bi(\alpha, 3n)^{210}_{85}At$

Energy (MeV)	**σ**– Expt. (mb)	**σ** -compound (mb)	**σ** - pre-compound (mb)
30	55	495	412.8
35	1112	1490	1321
40	1180	1234	1213
45	500	201.4	503
50	392.6	16.42	293.8
55	150	1.107	199.6
60	168.8	0.068	149.5

This channel is obtained by evaporation of three neutrons from the composite nucleus. As can be seen from the Table 2, the trend of the experimental result is the same as the theoretical result. It is clearly observed that theoretically measured values for pre-equilibrium reactions using COMPLET code are in very good agreement with the experimentally measured values of cross section in the energy range 40 - 60 MeV. Hence pre-equilibrium reaction is more dominant.

For channels n and 2n, the theoretical cross-section of the compound reaction of Mn shows dominance in the energy range of 20 MeV to nearly 40 MeV. As the energy of the projectile increases to 60 MeV the theoretical cross-section of the compound reaction of Mn declines and the theoretical cross-section of the pre-equilibrium reaction of Bi starts to dominate.

For channels 3n and 4n the theoretical cross-section of the pre-compound reaction of Bi shows dominance in the energy range of 30 MeV to nearly 55 MeV. As the energy of the projectile increases to 60 MeV theoretical cross-section of the pre-compound reaction of Bi starts to drop gradually.

This indicates as lesser number of neutrons evaporates the theoretical cross-section of the compound reaction of light nuclei shows dominance at lower end of energies and gradually decreases as the energy increases. Pre-equilibrium reaction of heavy nuclei start raise as the energy shifted to 60 MeV. As the number of evaporated neutrons increases the pre-equilibrium reaction of heavy nuclei gradually diminishes.

References:

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