Measurement of relative production cross-section of 3n and 4n evaporation channels of an α-induced fusion reaction

Mahua Chakraborty[1], H. Pai[2] and G. Mukherjee[2*]
[1]Physics Department, Indian School of Mines, Dhanbad, Jharkhand. INDIA
[2]Physics Group, Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata 700064, INDIA
* email: gopal@vecc.gov.in

Introduction

In a fusion evaporation reaction, a variety of residual nuclei can be produced at high excitation energy and at high angular momentum, depending on the number of evaporated particles. The number of evaporated particles (neutrons and charged particles), in a particular reaction, depends on the excitation energy imparted into the compound system which in turn depends on the energy of the projectile. For heavy compound systems, near mass region A = 200, mostly the neutron evaporation takes place as the coulomb interaction between the charged particles and the compound system acts as a barrier to prohibit the evaporation of protons and other charged particles. In a heavy-ion induced, fusion evaporation reaction, the compound nucleus is produced at a higher excitation energy compared to that produced in an α-induced reaction. For the gamma ray spectroscopic study of the high spin states of a residual nucleus, the heavy-ion induced reactions are advantageous as one can impart large angular momentum but the large number of channels that can be produced in such a reaction may be a disadvantage of such reaction. Because of the large number of channels, it becomes difficult to separate the channels, particularly when the gamma ray energies of the various residual nuclei are close by, as is the case for the nuclei in mass A ~ 200 region. The advantage of the α-induced reaction is the production of only one most significant evaporated channel for particular bam energy. Hence, one can do a channel selection by varying the energy of the α-beam. However, it is also important to know the cross-section of the other les significant channels which may be considered as the contaminants. Here, we are reporting the measurement of the ratio of production of the 4n and 3n evaporation channels from an α-induced reaction and the experimental ratio has been compared with the PACE-IV calculations.

Method

Recently, an experiment was performed at the Variable Energy Cyclotron Centre, Kolkata (VECC) using a 48-MeV α beam from the K-130 cyclotron on a ^{197}Au target. The main aim of the experiment was to study the gamma spectroscopy of ^{197}Tl produced in the 4n channel [1]. Apart from this most significant channel at this energy, 3n evaporated channel, leading to ^{198}Tl, was also produced. To get an idea about the relative cross-section of the above two evaporated channels, we have measured their ratio of the production cross-section. In the above experiment, the in-beam gamma-rays were detected using a clover HPGe, a LEPS and a single crystal HPGe detector. At the end of the in-beam experiment, gamma ray data were also collected when the beam was put off. These off-beam gamma-ray data were used to measure the above ratio. During the beam off period, the ground states of the residual nuclei ^{197}Tl and ^{198}Tl decays by electron capture decay (ec) to various states in the daughter nuclei ^{197}Hg and ^{198}Hg, respectively, with the half-lives of 2.84 hr and 5.3 hr [2].

The gamma rays, emitted from the excited states in these daughter nuclei, are detected in the gamma detectors during the beam off period with singles trigger. A representative gamma ray spectrum recorded during the beam-off period has been shown in Fig. 1. Most of the gamma-rays have been identified as belonging to ^{197}Hg and ^{198}Hg. They are marked in Fig. 1. The relative cross-section of the production of the daughter nuclei ^{197}Hg and ^{198}Hg can be measured from the sum of the total intensities of the transitions decaying directly to the ground states of these nuclei. To total transition intensities (I_t)

were obtained from the gamma ray intensities (I_g) using the relation $I_t = (1+a_{tot})I_g$ where a_{tot} is the total internal conversion coefficient of the gamma ray transition, calculated using the online code given in Ref. [3]. The measured area under the peak of each gamma ray was normalized by their relative efficiencies to get the gamma ray intensities I_g. The intensity obtained in this way will be the production intensity of the parent nuclei decaying to the excited states of the daughters. Therefore, the above intensity will have to be normalized by the fraction of the parent decays to the excited states. From Ref. [2], we have found that the 53% of the ground state of ^{197}Tl decays to the ground state of ^{197}Hg. Therefore, the measured intensity corresponds to the 47% of the total production of ^{197}Tl ground states which decay to the excited states in ^{197}Hg. Similarly, 97% of the decays of ^{198}Tl go to the excited states of ^{198}Hg.

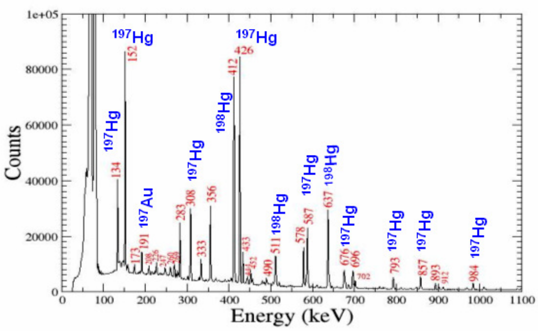

Fig. 1: The gamma ray spectrum recorded during the beam-off period. A few of the gamma rays have been marked to which they belong.

Results and Discussion

In this way, we have obtained the ratio of the production cross-section of ^{197}Tl:^{198}Tl as 6.8 $\pm$ 0.3. To compare this with the calculations, we have calculated the production cross section of different evaporated channels from the above reactions using the code PACE-IV. The result of the calculations and the comparison has been shown in Fig. 2. In this Figure, the calculated cross-sections have been plotted as a function of the incident α beam energy. The ratio of the calculated cross-sections of ^{197}Tl and ^{198}Tl has been obtained as 7.3 at the beam energy of 48 MeV. By normalizing the experimental cross section of ^{198}Tl with the calculated one, we have obtained the measured cross section of ^{197}Tl at the beam energy of 48 MeV, which may be compared with the calculated cross-section of ^{197}Tl and this is plotted in Fig. 2 as the filled circle. It can be seen that this value agrees well with the calculated value.

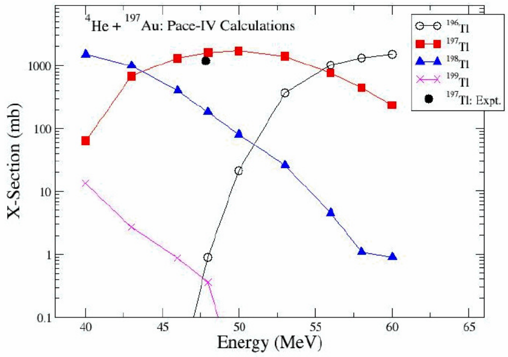

Fig. 2: Comparison of calculated (PACE-IV) and measured production cross section of 3n and 4n channels.

Acknowledgement

We thank the experimental nuclear physics group members of VECC and SINP for their efforts during the data taking. We also acknowledge the help of the cyclotron operators at VECC for providing good α-beam and UGC-DAE-CSR for providing an HPGe detector. One of the authors (MC) would like to thank the head of the Physics Department, ISM, Dhanbad and head, Physic group, VECC for allowing her to carry out this work as her M.Sc summer project.

References

[1] H. Pai et al., Proc. DAE-NP Symp (2011)
[2] http://www.nndc.bnl.gov/ensdf/
[3] http://bricc.anu.edu.au/