Evaporation residue excitation function measurement for ^{19}F + ^{194,198}Pt reactions

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Introduction:

Nuclear dissipation is one of the active fields in the present day nuclear physics research. Experimental signatures for dissipation are observed through large excess in pre-fission neutrons, γ-ray multiplicities from the compound nucleus, giant dipole resonance (GDR) γ-rays, light charged particles and evaporation residues in comparison to standard statistical model, for the heavy-ion induced fusion-fission or fusion-evaporation reactions (ERs) [1]. From the analysis of a large set of experimental data, it is well established that there exists a large dissipation at nuclear temperature above 1 MeV. But most of these probes are not sensitive to the dissipation within saddle. The ER cross-section is a probe which is sensitive to dissipation within the saddle point. Hence, the study of ER cross-section can be helpful in estimating the dissipation effects inside the saddle point. Also the other motivation for these measurements is to see the effect of shell closure on dissipation. With this motivation the evaporation cross-sections for ^{19}F + ^{194,198}Pt are measured at beam energy of 101 to 137.3 MeV. Of the above systems ^{19}F + ^{194}Pt populates ^{213}Fr (N = 126) shell closed compound nucleus (CN) whereas, other system populate ^{217}Fr (N = 130) non-shell closed CN.

Experimental Arrangement:

The experiment was carried out at HYbrid Recoil mass Analyzer (HYRA) using Pelletron + LINAC at IUAC, New Delhi. Pulsed beam of ^{19}F with repetition rate of 4 μs and energy varying from 101 to 137.3 MeV, was bombarded on isotopic enriched targets of ^{194}Pt (thickness, 265 μg/cm^2 on 10 μg/cm^2 C backing with enrichment > 96.5 %) and ^{198}Pt (thickness, 170 μg/cm^2 on 20 μg/cm^2 C backing with enrichment > 91.6 %). The targets were placed at the center of 120 mm diameter scattering chamber and two Si surface barrier detectors were mounted at ± 23^o (at distance of 23 mm from target position) with respect to beam direction. These detectors were used to monitor the beam flux and normalize the ER yield to obtain absolute ER cross-section. To verify our measurement, the data were collected at two beam energies (90.1 and 96.1 MeV) for ^{194}Pt and ^{198}Pt, where the ER cross-sections were earlier reported by Mahata *et al.* [2].

During the experiment the first stage of HYRA [3] was operated in gas-filled mode at 0.15 Torr He gas. This stage has the configuration QQ-MD-Q-MD-QQ, where QQ is quadrupole doublet, MD is magnetic dipole and Q is quadrupole singlet. The gas-filled HYRA was isolated from the beam line vacuum with the help of a self supporting Ni foil of thickness 1.3 mg/cm^2. The focal plane detector system consisted of a position sensitive MWPC detector. A time-of-flight (TOF) spectra was generated using anode of MWPC as start and RF of beam as stop. Further a two dimensional plot was generated using TOF and energy loss signal of MWPC. It provided a clean separation of ERs from beam-like contamination.

Data analysis and results:

The total ER cross-section can be obtained using the expression;

$$\sigma_{ER} = \frac{Y_{ER}}{Y_M}\,\frac{\Omega_M}{\eta_{HYRA}}\left(\frac{d\sigma}{d\Omega}\right)_{Ruth}$$

where Y_{ER} is the evaporation residue counts, Y_M is monitor counts, Ω_M is solid angle of monitor detector, η_{HYRA} is transmission efficiency of HYRA and $(d\sigma/d\Omega)_{Ruth}$ is differential Rutherford cross-section. The transmission efficiency is the ratio of the ERs detected at focal plane to the total number of ERs produced at target position. The relative yields of all the isotopes are obtained from the experimental data along with the solid angle and Rutherford cross-sections. The angular acceptance of HYRA changes with the beam energies, which in turn results in change of η_{HYRA}. To compensate for this change in η_{HYRA} all the energy points under study are normalized using the weighted angular distribution for each PACE2 predicted ER channel at lowest energy. The angular distribution is obtained using TERS [4] code. The angular distribution of ^{16}O + ^{194}Pt system is found to be similar to the systems under study. Hence, the transmission efficiency (η_{HYRA}) obtained by Prasad *et al.* [5] for ^{16}O + ^{194}Pt reaction, normalized with the angular acceptance, is used in present study for obtaining the absolute cross-sections. The transmission efficiencies of 1.033 ± 0.16 and 0.97 ± 0.147 are obtained for ^{19}F + ^{198}Pt and ^{19}F + ^{194}Pt reactions respectively.

The ER cross-sections of the ^{194}Pt and ^{198}Pt obtained in present measurement are in agreement with the measurement carried out by Mahata *et al.* [2]. The experimentally obtained cross-sections are compared with the theoretical models predictions (PACE2 and HIVAP). It is observed that the PACE2 prediction with default parameters ($a = A_{CN}/9$, $a_f/a_n = 1$ and $k_f = 1$) under predicts the ER cross-sections. By using the statistical model parameters (for ^{217}Fr, $a = A_{CN}/9$, $k_f = 1.17$ and $a_f/a_n = 1.050$ and for ^{213}Fr, $a = A_{CN}/9$, $k_f = 1.17$ and $a_f/a_n = 1.015$) obtained by Mahata *et al.* [2] by simultaneous fitting of the fission and ER cross-sections, it is observed that the experimental ER cross-sections, for ^{213}Fr are explained very well with PACE2 prediction, but explains only lowest energy for ^{217}Fr. This observation is also supported by the observation of Back *et al.* [6] about low dissipation for shell closed CN. Since ^{213}Fr is shell closed CN, so it is expected to have low dissipation hence explained well by PACE2 prediction, but for ^{217}Fr the dissipation effects will be considerable hence, PACE2 under predicts the experimental results.

Also the calculations are carried out using barrier passing model and standard statistical model incorporated in HIVAP code [7]. The potential parameters (nuclear potential depth, V_o = 68 MeV/fm, radius parameter, r_o = 1.12 and diffuseness, d = 0.75 fm) are obtained by fitting the experimental fusion cross-section for both the reactions. The shell and pairing corrections on fission barriers are taken into account. The level density parameter is obtained by Toke and Swiatecki formula for level density parameter. The Sierk fission barrier is multiplied by 0.82 in order to explain the measured ER cross-sections. It is observed in literature that lowering of fission barrier (0.82-0.85), by nearly the same amount, explained the ER cross-sections of other Fr isotopes [8].

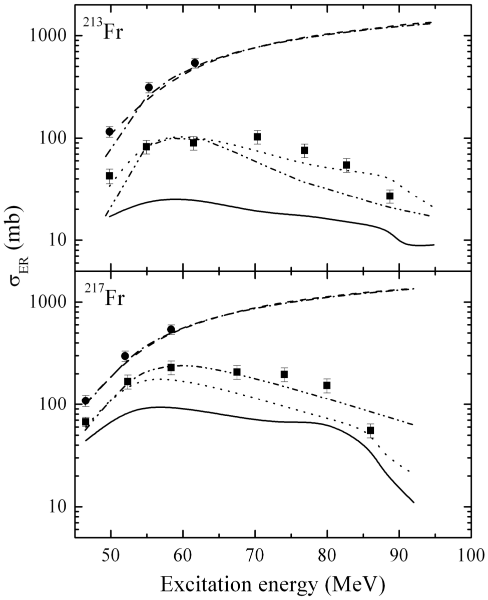

Figure 1: Experimental ER cross-section (solid square) and fusion cross-section (solid circle) along with the PACE2 predicted fusion (dashed line) and ER cross-section using default parameter (solid line) and Mahata *et al.* parameters (dotted line). The HIVAP predicted fusion (dash dotted line) and ER (dash double dotted line) cross-section are also shown.

References

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