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Mass-asymmetric fission in the ^{40}Ca+^{142}Nd reaction

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Abstract. Shell effects play a major role in fission. Mass-asymmetric fission observed in the spontaneous and low energy fission of actinide nuclei was explained by incorporating the fragment shell properties in liquid drop model. Asymmetric fission has also been observed in the low energy fission of neutron-deficient ^{180}Hg nuclei in recent β-delayed fission experiments. This low-energy β-delayed fission has been explained in terms of strong shell effects in pre-scission configurations associated with the system after capture. Calculations predicted asymmetric fission for heavier Hg isotopes as well, at compound nuclear excitation energy as high as 40 MeV. To explore the evolution of fission fragment mass distribution as a function of neutron and proton numbers and also with excitation energy, fission fragment mass distributions have been measured for the ^{40}Ca+^{142}Nd reaction forming the compound nucleus ^{182}Hg at energies around the capture barrier, using the Heavy Ion Accelerator Facility and CUBE spectrometer at the Australian National University. Mass-asymmetric fission is observed in this reaction at an excitation energy of 33.6 MeV. The results are consistent with the β-delayed fission measurements and indicate the presence of shell effects even at higher exciation energies.

1 Introduction

Nuclear fission is a dynamic process involving large scale collective motion, often affected by a subtle interplay of macroscopic and microscopic effects during the transition of the fissioning nucleus from its ground state deformation to the scission point. Fragment mass distributions are an important observable in fission which provides crucial information about the potential-energy landscape of the fissioning system. Fragment mass distributions have been observed to be predominantly asymmetric in the spontaneous or low energy fission of most of the actinide nuclei [1], which could not be explained solely by using the liquid drop model (LDM) [2]. The experimental observations were explained by incorporating the fragment shell properties near the scission configuration, particularly the spherical shell closure ($Z = 50$, $N = 82$) or deformed neutron shells ($N = 88$) [1, 3], within the LDM frame work.

Recent observations of mass-asymmertic fission of the Hg isotopes in β-delayed fission experiments [4, 14] indicated the role of shell structures other than fragment shells in deciding the fission outcomes. The low yield of symmetric fission in ^{180}Hg populating ^{90}Zr ($Z = 40$, $N = 50$) led to the speculation that fragment shell effects, though significant in the potential energy surface near scission, must not play a major role in determining the mass split in this nucleus.

Even though β-delayed fission experiments allowed us to access the low energy fission regime of the neutron-deficient nuclei in the mass 180-200 region, the availability of nuclei undergoing this process is severely limited by the stringent conditions on β-decay Q-values and branching ratios [4]. Also, the maximum available excitation energy for the fissioning system is restricted by the Q-value of the parent nucleus [4]. In the actinide region, it is observed that [1, 5] the fragment mass division becomes symmetric with increasing excitation energy, as shell effects generally wash out at higher excitations. In order to understand the evolution of fission fragment mass distribution as a function of neutron and proton numbers (N and Z) of the fissioning system and the excitation energy in the neutron deficient Hg region, we measured the fission fragment mass distributions of ^{182}Hg populated through the fusion reaction ^{40}Ca+^{142}Nd at energies around the capture barrier. The results are compared with the latest experimental data available in the same mass region for the fis-

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