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ANGULAR MOMENTUM POPULATION IN FRAGMENTATION REACTIONS*

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Neutron-deficient nuclei with $N = 126$ have been populated following projectile fragmentation of a ^{238}U beam with energy 1 GeV/A. The decay of several previously reported isomers has been measured. This will allow us to calculate high-spin isomeric ratios and compare them with model calculations to allow a better understanding of the reaction mechanism.

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1. Introduction

In projectile fragmentation a heavy ion projectile at relativistic energies bombards a light target. When the reaction occurs at the periphery of the nucleus the process can be described using the two-step abrasion–ablation model [1]. First, during the abrasion phase the collision between the projectile and the target takes place, producing an excited prefragment. Due to the high kinetic energies involved in the reaction, the relative velocity between projectile and target is large compared to the Fermi velocity of the nucleons. Therefore in the overlap zone many nucleon–nucleon collisions take place, while in the non-overlapping zone the nucleons are little disturbed. Secondly, in the ablation stage, the excited prefragment evaporates nucleons and light particles until the final fragment is formed. The study of the angular momentum of the fragments allows a comparison with the predictions of the theory of fragmentation reactions, which can be calculated using the Monte Carlo code ABRABLA [2]. This model considers the angular momentum to be generated by the internal angular momentum of the nucleons removed during the abrasion stage of the fragmentation. Experimentally we can determine only the total population of all the states decaying into the level of interest. This is quantified in terms of the isomeric ratio $R_{\rm exp}$ which is defined as the probability that, following the reaction, a nucleus is produced in an isomeric state. The theoretical calculation assumes that all states with angular momentum higher than that of the isomeric state will decay into it, and therefore gives an upper limit. This is called the sharp cutoff approximation and has been justified for isomers lying close in energy to the yrast line [2]. Therefore the ratio between the experimental and theoretical isomeric ratios is expected to be equal to or less than one. Some recent work [3, 4] has reported that the experimental data for spins greater than $16\hbar$ contradicts this theory, with isomeric ratios larger than the calculated ones being observed. Fig. 1 shows that ratios increasing with spin have been observed. This was thought to be due to a collective compo-

Ion	I^π	$R_{\rm exp}$[%]	$\rho_{\rm theo}$[%]
^{211}Fr	$29/2^+$	5.7(19)	9.4
^{212}Fr	15^-	7.5(18)	8.5
^{213}Fr	$29/2^+$	12(8)	11.1
^{214}Ra	17^-	6.8(23)	2.4
^{215}Ra	$43/2^-$	3.1(6)	0.21
^{215}Ac	$(29/2^+)$	4.8(12)	3.8

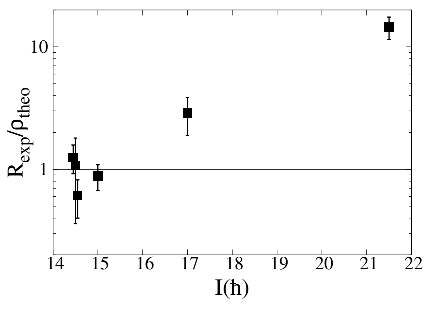

Fig. 1. Ratios between experimental and calculated isomeric ratios and their values from [4]. For further information on isomeric ratios see [5].

nent of angular momentum in the prefragment which is expected to increase with spin [4]. More recently [6], better agreement with the data has been obtained by considering the abrasion stage in the framework of a relativistic transport model and the ablation stage as a sequential binary decay. Further improvement is proposed by coupling the spins of the hole states with those of the excited nucleons. This contribution reports on an experiment performed at the GSI facility in Germany, to obtain experimental data on isomeric ratios of states of higher spin than have been previously observed.

2. Experimental details and data analysis

In order to populate the nuclei of interest, a beryllium target of thickness 2.5 g/cm^2 was bombarded with a $E/A = 1$ GeV ^{238}U beam provided by the SIS-18 synchrotron. The beam intensity was 10^6 ^{238}U ions per 10 second beam spill. The fragmentation products were separated and identified in the FRagment Separator FRS [7] operated in achromatic mode. Nuclei were selected in terms of Z and the mass-to-charge ratio (A/Q). For this experiment two TPC detectors were placed on either side of the MUSIC ionization chambers to increase the resolution for the ion tracking calculations. Also for first time, an automatic system was installed in the MUSIC detectors to allow the data to be corrected for varying pressures on an event-by-event basis. Finally, delayed gamma rays were measured with the RISING gamma-ray spectrometer in its stopped beam configuration [8].

Several previously reported isomeric states have been identified in three magnetic rigidity settings centred on ^{212}Rn, ^{210}Th and ^{214}Th. The three lower panels in Fig. 2 show the γ-ray decays from ^{209}At ($29/2\hbar$) [9], ^{210}At ($15\hbar$,$19\hbar$) [10] and ^{211}At ($39/2\hbar$) [11]. The top panel shows data from ^{213}Rn where there is evidence of the decay from $25/2\hbar$ and $31/2\hbar$ isomeric states. There is also tentative evidence for the 1258 keV transition which is in the decay path of a $55/2\hbar$ isomeric state at 5.929 MeV [12]. This would represent the highest discrete spin state identified in a fragmentation reaction.

3. Summary and conclusions

The decay of high angular momentum states has been observed following ^{238}U projectile fragmentation. Ongoing analysis of this data will provide isomeric ratios, which will allow an extension of the knowledge of the projectile fragmentation reaction mechanism. Such information is of general interest for the production and use of isomeric radiactive beams.

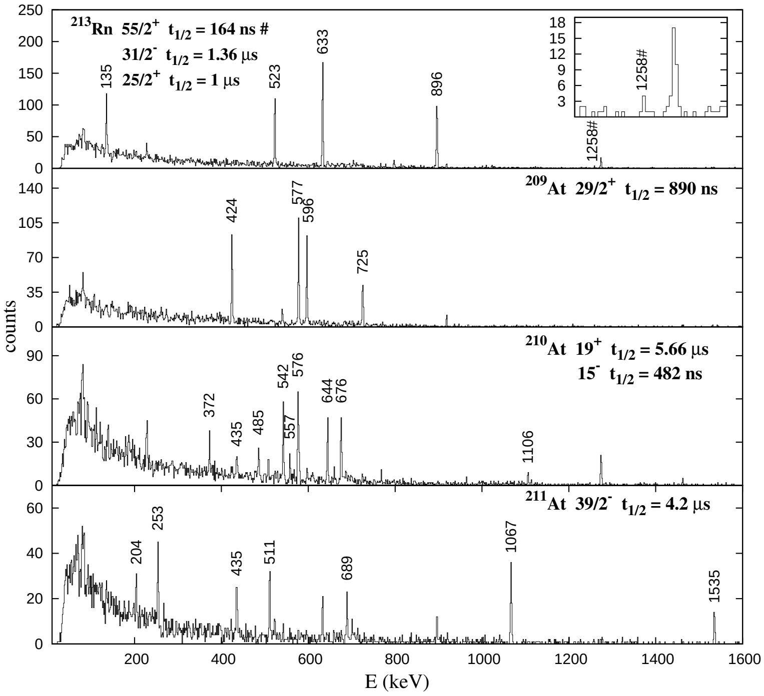

Fig. 2. Delayed γ-ray spectra from ^{209}At,^{210}At,^{211}At and ^{213}Rn [9–12], respectively. The transitions not labeled are from the decays of neighbouring nuclei. For details see the text.

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