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PRODUCTION AND POLARIZATION OF BETA-EMITTING PROJECTILE FRAGMENT ^{43}Ti

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ABSTRACT

The projectile fragmentation of ^{46}Ti on Au and C targets has been studied at 116*A* MeV. For one of the fragment nuclei, ^{43}Ti, production cross sections, longitudinal momentum distributions, angular distributions, and fragment polarization were observed. The observed angular distribution and the spin polarization of ^{43}Ti for the C target suggested negative angle deflection of the nuclei due to the nuclear attractive potential. The magnetic moment of ^{43}Ti was determined by means of β-NMR technique as $|\mu| = (0.85 \pm 0.02)\ \mu_N$.

1. Introduction

The projectile fragmentation process in high energy heavy ion collisions provides us with unstable nuclei far from the stability line. Utilizing both the isotope separation technique for such projectile fragments and the β-NMR (Nuclear Magnetic Resonance) technique, we have been studying magnetic moments of $f_{7/2}$-shell mirror nuclei. Since the production of unstable nuclei through the projectile fragmentation process and the reaction polarization in such projectile fragments are the important techniques for this kind of study, clear understanding of the reaction mechanism is very important.

The production cross section and the momentum distribution have been important observables for the study of the projectile fragmentation process[1,2]. Based on these observations, theoretical understanding of the reaction mechanism has been developed[3,4]. Since the orbital deflection of the projectile fragments was observed through broadening of the angular distribution[5], the projectile fragmentation process in the 100*A* MeV region was found to be an unique testing ground of the combined Coulomb-nuclear potential. For the study of this orbital deflection the spin polarization became an important observable besides the above mentioned observables because of its unique capability to detect the sign of the deflection angle.

Polarization phenomena in heavy ion collisions have been studied experimentally in various energy regions from 10*A* to 100*A* MeV[6,7,8]. For the projectile fragmentation, a simple fragmentation model[9] was developed and it has explained qualitatively the experimental polarizations fairly well[7,8]. In addition, fragment polarization was found to be an excellent probe for the sign of the deflection angle. In the case of heavy targets like Au, the sign of the deflection angle was determined to be positive. In the case of light targets, however, the sign is not yet clear. A study has been carried out at intermediate energies with lighter fragments[10], but not at high energies with heavier fragments.

In the present experiment, the production cross sections, longitudinal momentum distributions, angular distributions, and the spin polarizations of the projectile fragment, ^{43}Ti(I^{π}=7/2$^-$, $T_{1/2}$=0.50 sec) has been observed for ^{46}Ti on Au/C collisions at a high incident energy of about 100*A* MeV for better understanding of the reaction mechanism and for application to the magnetic moment study.

2. Experimental

The present experimental setup and the technique is essentially the same as previous one[8]. The ^{43}Ti nuclei were produced through the projectile fragmentation of ^{46}Ti at an effective energy of (116 ± 8)*A* MeV on a C(Au) target of 260(480) mg/cm^2 in thickness at the Bevalac of Lawrence Berkeley Laboratory (LBL). The ^{43}Ti nuclei that emerged from the target at a certain deflection angle θ_L were separated and momentum analyzed by the Beam-44 fragment-separator[11]. The energy of the ^{43}Ti nuclei was controlled by an energy degrader the thickness of which was controllable in order to implant the nuclei into a thin catcher. The catcher used for the experiment was a 100 μm thick Pt foil cooled down to 90 K which gave us a spin relaxation time long enough to maintain the polarization created in the collision for the lifetime of ^{43}Ti. NMR on the ^{43}Ti nuclei has been observed by means of asymmetric beta decay under the static magnetic field H_0=6.878kOe.

3. Results and discussion

The production cross sections of the ^{43}Ti fragment were measured for both Au and C targets. The obtained production cross section for the C target was about 1 mb which agrees with theoretical predictions. The cross section for the Au target was smaller than that for the C target by factor of 3. This target mass dependence cannot be reproduced by simple fragmentation models such as the abrasion-ablation model[3] which predicts a considerably larger cross section for the Au target. Therefore, besides the usual abrasion-ablation process a new process must play an important role in the production of ^{43}Ti suppressing the cross section for heavier targets. One of the explanations may be attributed to the immediate Coulomb breakup of the produced ^{43}Ti at the instant of the collision.

The observed longitudinal momentum distributions (lower part of Fig. 1) were reproduced well by the Fermi motion of the nucleons only (Goldhaber model[4]). On the other hand, the observed angular distributions, namely the transverse momentum distributions, were broader than those due to the Fermi momentum for both the Au and the C targets as shown in Fig. 2. For the Au target, this broadening can be explained by the orbital deflection due to the strong Coulomb potential. For the C target, however, the distribution was even wider than the classical grazing angle, suggesting another mechanism such as the deflection due to the attractive nuclear potential.

The spin polarization of the ^{43}Ti fragment in the ^{46}Ti on C collision has been measured at a deflection angle θ_L=1.5° as a function of the fragment momentum as shown in Fig. 1. Here, the sign of the polarization parallel to the vector $\boldsymbol{p}_i \times \boldsymbol{p}_f$ is

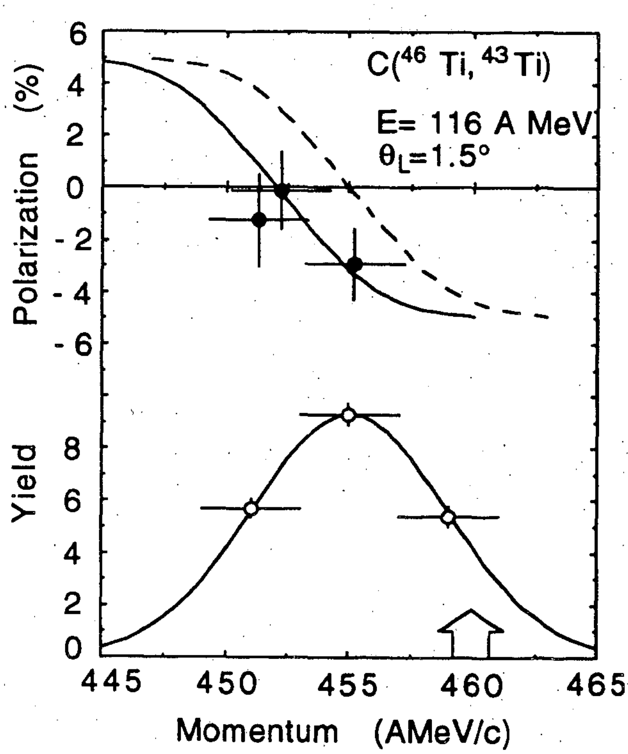

Fig. 1. Momentum dependence of spin polarization of ^{43}Ti.
The arrow indicates the momentum corresponding to the beam velocity. The broken line is the polarization predicted by a simple model multiplied by 1/20. The solid line is the same curve shifted by 3*A* MeV/c. The lower part of the figure shows the longitudinal momentum distribution

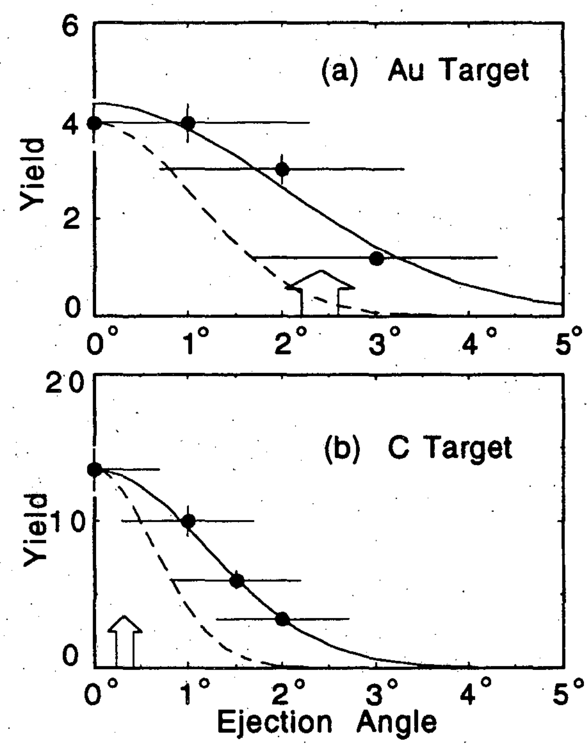

Fig. 2. Angular distributions of ^{43}Ti. The arrows indicate classical grazing angles. Solid lines are the Gaussians best fit to the data. Broken lines are the predictions with only the Fermi momentum.

defined to be positive, where p_i and p_f are the momentum vectors of the incoming and the outgoing particles. As shown in the figure, the observed polarization was very close to zero on the low momentum side and was negative around the central momentum at which the yield is maximum. This decreasing trend in the fragment polarization was the reverse of that observed for the fragments produced in the ^{40}Ca on Au collision[8], where the polarization increased with momentum as predicted for the positive angle deflection. So, the present trend observed in the fragment polarization suggests dominance of the negative angle deflection due to the nuclear attractive potential. The observed polarization was reasonably reproduced by the simple fragmentation model[9] combined with an additional energy dumping for the component of negative deflection due to longer interaction time for the component.

NMR effects for ^{43}Ti were observed as a function of radio frequency as shown in Fig. 3. A resonance was found at a frequency $f = (1.27 \pm 0.03)$ MHz. From the resonance frequency the magnetic moment of ^{43}Ti was deduced to be $|\mu| = (0.85 \pm 0.02)\ \mu_N$. The value is significantly smaller than the single particle value $-1.91\mu_N$, indicating a strong quenching effect resulting from meson exchange currents and configuration mixing. A shell model calculation[12] with the first order configuration mixing predicts $-0.754\ \mu_N$, and the semi-empirical odd-nucleon model[13] predicts $-0.784\ \mu_N$, both of which reproduces the observed value fairly well.

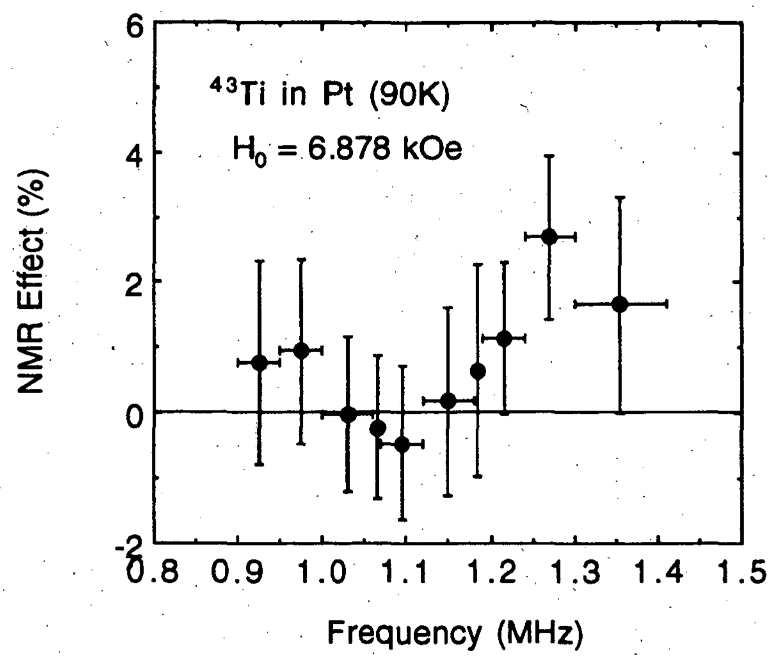

Fig. 3. NMR spectrum for ^{43}Ti in cooled Pt.

From the obtained moment of ^{43}Ti and the known moment of ^{43}Sc, the isoscalar and the isovector moments of the mirror pair were deduced to be $\mu^{(0)}$= (1.89 ± 0.02) μ_N and $\mu^{(1)}$= -(2.74 ± 0.02) μ_N, respectively. While the isoscalar moment is very close to the single particle value, the isovector moment is strongly quenched. The shell model calculation[12] with the first order configuration mixing predicts $\mu^{(1)}$= -2.71 μ_N, which agrees with the present value very well. It may indicate that the higher order configuration mixing effect almost cancels the meson exchange effect, as in the case of the mass A= 40±1 system.

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