REACTIONS INDUCED BY HIGH ENERGY ^{6}Li IONS AND

IN-BEAM γ-RAY SPECTROSCOPY OF N=80 AND N=78 NUCLEI

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Recently there has been considerable interest in the high-spin unique parity states of odd-mass nuclei having small to moderate deformations (e.g., the so-called "transitional nuclei"). Considerable success in the interpretation of the band structure in these nuclei has been achieved using the rotation-aligned coupling scheme of Stephens and the extension by Meyer-ter-Vehn to the case of triaxially deformed nuclei, especially in the A=190-200 region. The A=140-150 transitional region should also be a fruitful field of investigation since there are a number of nuclei with $11/2^{-}$ isomeric states which have moderate deformation. In addition, there are now available a number of theoretical calculations on the shapes of these nuclei.

We have been carrying out a systematic in-beam γ-ray spectroscopic study (using ^{6,7}Li beams) of odd mass Eu (Z=63) and Tb (Z=65) nuclei with $78 \leq N \leq 90$. For the nuclei with $N \geq 82$, the experiments have been conducted using the FN Tandem at Notre Dame where one can evaporate at most four neutrons from the compound nucleus, and they have been extended at IUCF to the nuclei with $N \leq 82$. The Eu nuclei cannot be reached using (α,xn) reactions because no stable Pm target exists. Light Tb nuclei are not easily reached using (α,xn) reactions since even ^{149}Tb (N=84) would require the (α,6n) reaction using the lightest stable Eu (A=151) target. Many stable isotopes of Nd and Sm are available, and it is clear that the (^{6}Li,xnγ) reaction when $x \leq 5$ will lead to interesting nuclei. For example, the ^{142}Nd (^{6}Li, 5n) reaction leads to ^{143}Eu and the 7n exit channel to ^{141}Eu. Similarly, one could obtain ^{143}Tb (N=78) using the (^{6}Li, 7n) reaction on a ^{144}Sm target.

Enriched, metallic self-supporting targets are prepared by reduction and subsequent mechanical rolling. Ge(Li) detectors are used to obtain singles, angular distribution, and coincidence data. Event-by-event recording on magnetic tape is employed at IUCF and the data are analyzed off-line at Notre Dame. In addition, time-correlated data based on the rf of the cyclotron is obtained. In order to ascertain the yields of the various exit channels, we have acquired excitation function data for ^{6}Li induced reactions, on a number of even-mass Sm and Nd rare earth targets with beam energies ranging from 55 to 99 MeV. The Nd targets were employed because the (xn) exit channels populate Eu nuclei which are well known from experiments at Notre Dame. The ^{150}Sm target was used because the (αxn) exit channels also populate Eu nuclei.

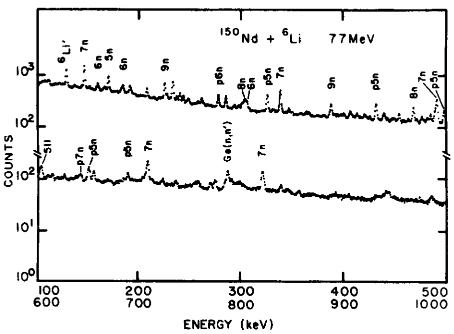


Figure 1.

In the excitation experiments, yields were determined for a particular nucleus by summing the intensities of the γ rays feeding the ground state. Normalization of the data was achieved by measuring the charge collected in a Faraday cup. Fig. 1 displays the singles spectrum obtained for 77-MeV ^{6}Li ions on a ^{150}Nd target. Major exit channels are (7n) and (8n) with a cross section of ∿300 mb and the (p5n) channel with a cross section of ∿180 mb. Fig. 2a shows the energy dependence of the cross section for the (xn) exit channels; Fig. 2b shows the (pxn) exit channel and the sum of the (αxn) exit channel cross sections.

Fig. 3 presents some of the results of a calculation using M. Blann's code OVERLAID ALICE for 55-MeV ^{6}Li on ^{150}Nd and 77-MeV ^{6}Li on ^{150}Sm.

Fig. 3a shows the experimental cross sections as a function of the atomic mass of the product nucleus for the (xn) exit channels compared with the predictions of the ALICE calculation. Although the calculation overestimates the magnitude of the cross section, the shape and position of the maximum of the curve agree with the experimental data. In addition the relative cross sections for the various (xn) exit channels are reproduced fairly well. A measure of the amount of breakup (^{6}Li → d + α) at each energy can be computed by comparing the experimental maximum cross sections to those predicted by ALICE where one breakup fragment (i.e., the alpha or deuteron) is a "spectator" and the other induces xn reactions. (See Figs. 3b & c.) For example at 77 MeV the ratio of maximum cross sections for the xn, pxn and αxn exit channels is observed

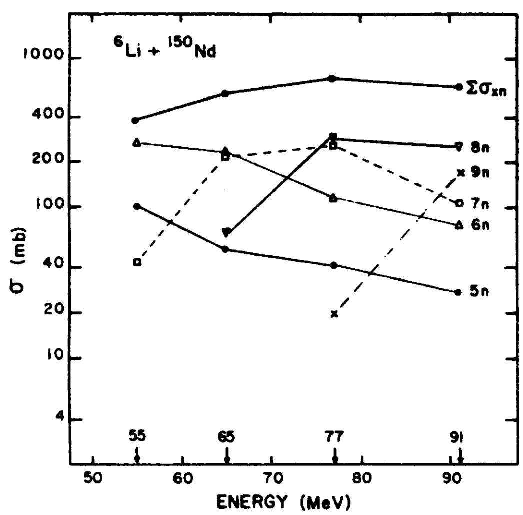


Figure 2a.

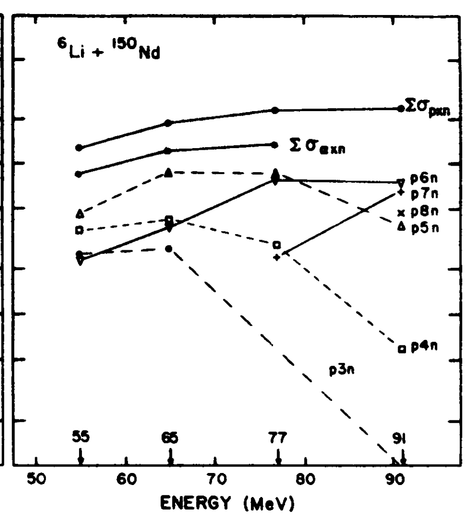
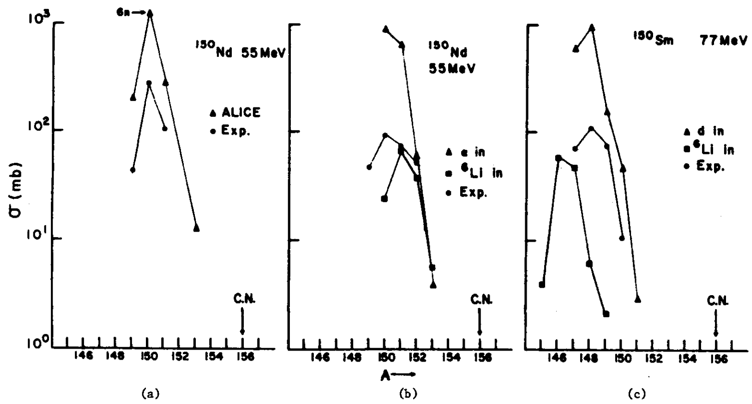


Figure 2b.



Figures 3a, b, c. Experimental and theoretical yields of ^{6}Li-induced reactions as a function of the A of the product nucleus. Fig. 3a is for (xn) exit channels, Fig. 3b is for (pxn) exit channel, and Fig. 3c depicts an (αxn) exit channel. Figs. 3b and 3c also include calculations involving the breakup of the Li projectile.

experimentally to be 3:2:1. ALICE predicts this ratio to be 3:0.6:0.1 for no breakup, whereas by weighting the appropriate (d,xn) and (α,xn) reactions, the experimental data can be reproduced. A manuscript on this work is now being prepared for publication.

Our first coincidence experiment at IUCF was carried out in January 1977 and employed the ^{142}Nd (^{6}Li,5n) ^{143}Eu reaction at 66 MeV. Four-parameter data ($E_{\gamma 1}$, $E_{\gamma 2}$, $\Delta t_{1,2}$, and $\Delta t_{\gamma\text{-}RF}$) were recorded in event-by-event mode on magnetic tape using the code DERIVE. Certain deficiencies appeared in this first run: for about 20% of the coincidence events one or more of the ADCs recorded a zero and 5% of the data was wasted due to the overflows in the ADCs. Analysis of the data is continuing at Notre Dame. There are a number of disagreements in the interpretation of the states above the $11/2^-$ state in ^{143}Eu. The decay data of Firestone[1] et al., and the decay results and meager in-beam data from the (α,p4nγ) experiments of Wisshak[2] et al., do not agree and we feel that we will have more and better data on the higher lying states. We should also have data on ^{144}Eu and ^{142}Eu from this experiment and these will be analyzed.

We expect that a number of difficulties will be corrected in the next experiment and we plan to pursue coincidence and angular distribution experiments on ^{143}Eu, ^{145}Eu, ^{145}Tb and ^{143}Tb as proposed.

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1) R.G. Firestone, et al., MSU Progress Report, 1974-1976, p. 68.

2) K. Wisshak, et al., Z. Phys. A277, 129 (1976).