STATES IN ^{163}Ho AND ^{167}Tm POPULATED THROUGH THE (p, t) REACTION ON ^{165}Ho AND ^{169}Tm

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The (p, t) reaction at 30 MeV on the deformed nuclei, ^{165}Ho and ^{169}Tm, strongly populates collective states in the residual nuclei. Indirect multiple-step processes evidently play an important role, and the reaction is a powerful tool for populating higher-lying rotational band members.

Previous work involving the (p, t) reaction on the spherical ^{141}Pr nucleus [1] and the strongly deformed ^{159}Tb nucleus [2] has demonstrated the potential of this reaction as a very powerful tool for probing collective characteristics. In particular, the study of the ^{159}Tb(p, t) reaction revealed large cross sections associated with the population of β- and γ-vibrational and ground-state rotational band members.

In the present study $\approx$400 μg/cm^2 metallic targets of the elements were bombarded with 30 MeV protons accelerated by the Michigan State University sector-focused cyclotron. The scattered tritons were analyzed with an Enge split-pole magnetic spectrometer and collected on nuclear emulsions. All spectra were taken at the scattering angle of 20° with an overall energy resolution of $\approx$10 keV FWHM.

A triton spectrum obtained from ^{165}Ho is shown in fig. 1. In this spectrum one finds a strong population of the $K^\pi = \frac{7}{2}^-$ [523] ground-state rotational band with level spacings similar to those occuring in the same band in ^{159}Tb. From Coulomb excitation experiments conducted on ^{165}Ho by Seaman et al. [3], one would expect from systematics to observe the $K^\pi = \frac{3}{2}^-$ and $\frac{11}{2}^-$ γ-vibrational bands at $\approx$500 keV and $\approx$700 keV, respectively. And indeed one does observe a set of states originating at 562 keV which appear to have some intensity interrelationships. If one assumes that the 562 and 618 keV states are the first two members of the $K = \frac{3}{2}$ γ-vibrational band and that higher members are generated by parameterizing the simple $I(I+1)$ energy relationship, one finds convincing evidence for the presence of additional members up to a spin of $\frac{15}{2}$. However, no evidence for the presence of a $K = \frac{11}{2}$ γ-vibrational band could be found in our spectrum.

As in the case of ^{159}Tb [2], the (p, t) reaction on ^{165}Ho is found to strongly populate rotational as well as vibrational states in the residual nucleus. The present study has identified six members of the $K = \frac{7}{2}$ ground-state rotational band and seven members of the $K = \frac{3}{2}$ γ-vibrational band. Moreover, with the single exception of the 791 keV peak, these states completely exhaust the (p, t) reaction strength occurring below the pairing gap in the ^{163}Ho nucleus. The origin of the strongly excited 791 keV state cannot be determined from our data since it does not appear to have any relationship to any other states in our spectra. Being below the pairing gap, this state certainly must be a collective excitation, but whether it be a β, γ or octupole state is not clear from our data alone.

The triton spectrum from the ^{169}Tm(p, t) reaction appears in fig. 2. As in the previous results, the ground-state rotational band of ^{167}Tm is found to be strongly

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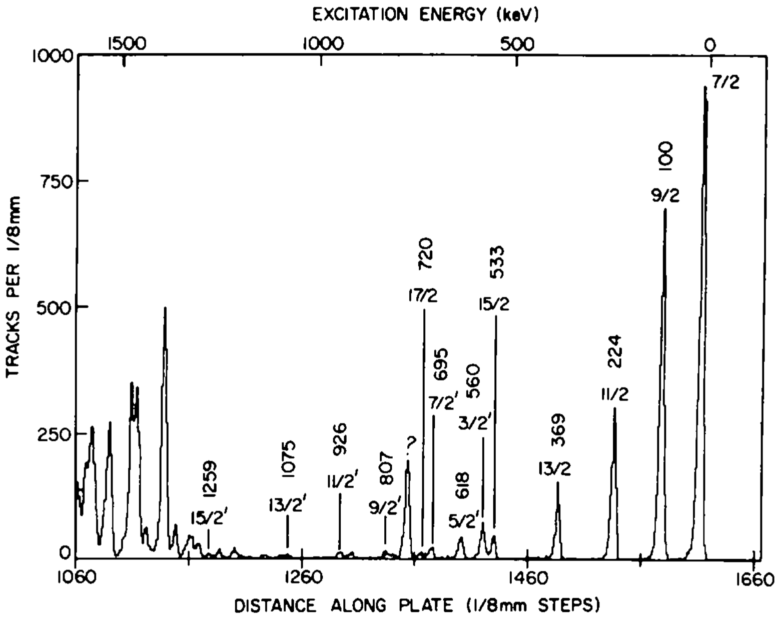

Fig. 1. The ^{165}Ho(p, t) spectrum taken at θ = 20°. Peaks corresponding to the members of the ground-state band and the $K_0 - 2$ γ-vibrational band are labeled with unprimed and primed spins, respectively. For more complete information, see ref. [2].

excited by this reaction; however, because of the rather large decoupling parameter associated with this $\frac{1}{2}^+$[411] band, its first two members have not been resolved. Nevertheless, at least six members of this rotational band are found to be populated. Coulomb excitation experiments conducted on ^{169}Tm [3] have identified a $K^\pi = \frac{3}{2}^+$ γ-vibrational band at 571 keV in this nucleus. Based on this information and the previous results obtained for ^{157}Tb and ^{163}Ho, the series of three states originating at 600 keV have all the appearances of being members of a γ-vibrational band. However, a consistent energy relationship cannot be established between these states for an assumed band head spin of either $\frac{3}{2}$ or $\frac{5}{2}$. Because of their extremely low intensity, it is entirely possible that only one or two of these states belong to the $K = \frac{3}{2}$ γ-vibrational band expected in this region.

At 1000 keV one finds a series of highly excited, closely spaced peaks whose doublet nature defies all attempts at sorting these states into groups of common origin. The presence of a $K = \frac{1}{2}$ vibrational band at this energy would be consistent with previous results obtained for ^{157}Tb [2] and could easily account for the composite nature of some of the peaks in this region. However, without higher resolution, a meaningful interpretation of states in this region cannot be made.

The series of three states originating at 1380 keV appear to have some type of common origin. The energy spacing between these peaks suggest a $K = \frac{5}{2}$ rotational band. However, since these states appear to be above the pairing gap in this nucleus, one can only speculate as to their $K = \frac{5}{2}$ γ-vibrational origin.

More experimental data, including complete angular distributions, will be necessary to complete the sorting out of bands in these nuclei. They will also aid in determining the mechanisms more specifically. However, the present studies have demonstrated that complex states are populated with relative ease; therefore, the (p, t) reaction on odd-mass deformed nuclei must be a complex one, probably involving higher-order processes, such as multistep shape distortions of the nucleus, depending on where on the nuclear surface the pair of neutrons is plucked out. For these odd-mass nuclei the as yet unknown details of the nuclear wave functions will be important in determining the exact mechanisms. And, just as important, the (p, t) reaction is a powerful spectroscopic

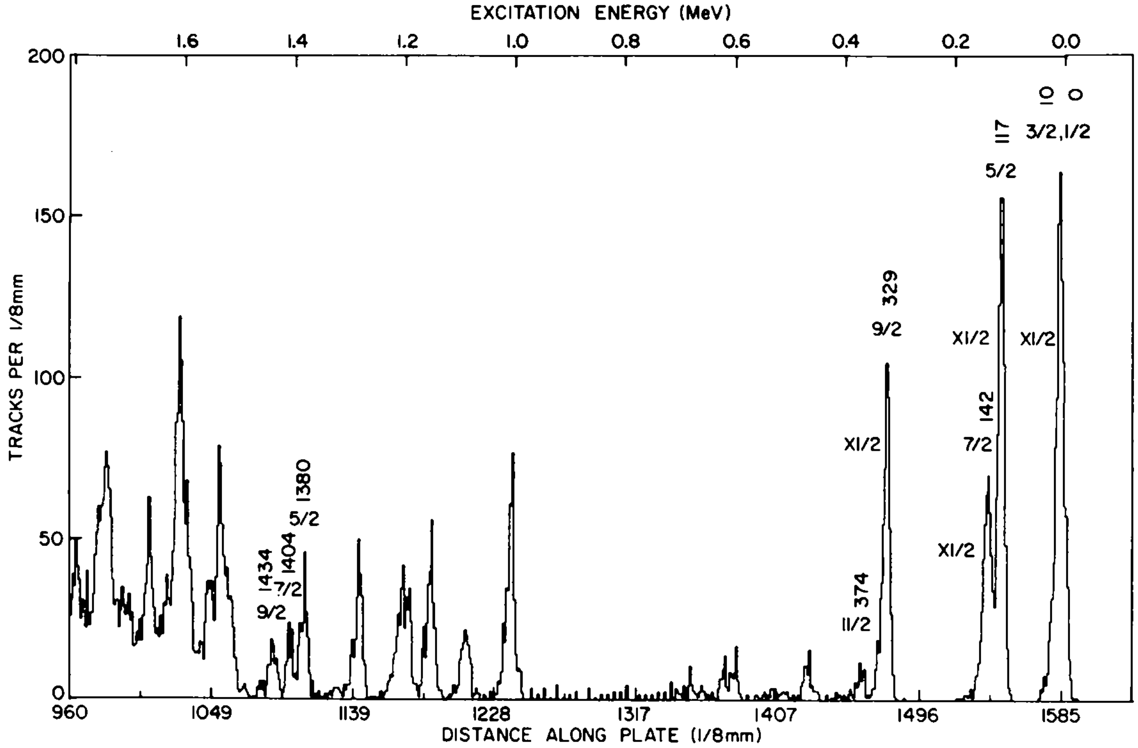

Fig. 2. The ^{169}Tm(p, t) spectrum taken at θ = 20°. Peaks correcponding to the members of the ground-state rotational band are labeled with the appropriate spins. Spins with primes denote possible presence of members of the $K_0 + 2$ γ-vibrational band. For more complete information, see ref. [2].

tool for exciting higher-lying members of rotational bands in these nuclei.

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