PARTICLE TRANSFER REACTIONS

POSSIBLE OBSERVATION OF THE $1/2^+[880]$ ORBITAL IN ^{249}Cm

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A crucial element in theoretical estimates of the half-lives of nuclides in the super-heavy region is the spacing of single particle orbitals near the Fermi level. One way to get information about these orbitals is to study the spectra of the heaviest actinides. We have been engaged in a long term study[1] of the actinides and have identified deformed orbitals, such as the Nilsson orbital $1/2^-[521]$, that have large components from the spherical orbitals above the Z=114 gap. The observation of this level has given us detailed information on the splitting of the spherical $f_{7/2}$ and $f_{5/2}$ proton orbitals.[2] We have also identified[3] deformed neutron states having large components from the spherical orbitals above the N=184 gap, such as the orbitals $1/2^-[761]$ and $1/2^-[750]$. This gives us information on the positions of the spherical orbitals $h_{11/2}$ and $j_{13/2}$. In addition to the importance of these levels in determining the stability of the super-heavy elements (N$\sim$184), they also play an important role in understanding the stability of the newly discovered[4] very heavy elements (N$\sim$160).

The position of the $k_{17/2}$ orbital plays a crucial role in the stability of elements with N$\sim$184. Because of its large degeneracy, it has a large influence on the magnitude of shell corrections in this region. The lowest deformed component of the $k_{17/2}$ orbital is the Nilsson orbital $1/2^+[880]$, which is expected to lie below 2 MeV in nuclei with neutron numbers greater than 152. As yet this orbital has not been observed, and the possibility of observing it was the motivation for the experiment described here. In an earlier high resolution (d,p) study[3] of ^{251}Cf, we were able to identify all of the neutron single-particle states between the well known gap at N=152 and the gap at N=164, and their energies are in good agreement with calculated values. Several orbitals above the N=164 gap were identified and found to be at excitation energies in fairly good agreement with our theoretical estimates. The same calculation that gives these estimates predicts that the $1/2^+[880]$ orbital should be found at 1400 keV in ^{251}Cf. However, this orbital does not have any low l components and it would not be populated in (d,p) reactions. An angular momentum decomposition of this orbital indicates that it is $\sim$80% $k_{17/2}$. Such orbitals are strongly populated in (^{4}He,^{3}He) reactions.[5] Because of the intense radioactivity associated with ^{250}Cf, the longer-lived isotone, ^{248}Cm, has been used in the present experiment. The nucleus ^{249}Cm is an isotone of ^{251}Cf and hence the ^{249}Cm level ordering should be similar to that of ^{251}Cf.

The experiment ^{248}Cm(^{4}He,^{3}He) was performed at the Indiana University Cyclotron Facility. The Cm target was prepared by molecular plating the material on a 75 μg/cm^2 carbon foil. A beam of 100 MeV α-particles was incident on the target and the emerging ^{3}He ions were momentum analyzed with the K600 magnetic spectrometer. The beam current was 25 pnA and the spectra were measured at angles of 4°, 6°, 10°, 12° and 16° degrees. Spectra with a ^{208}Pb target were also measured at these angles. The effectiveness of the (^{4}He,^{3}He) reaction for the identification of high-l states was checked by measuring a spectrum (Fig. 1) with a metallic ^{232}Th (0.7 mg/cm^2) target. In the spectrum below 500 keV, the dominant peak is the I=15/2 member of the 7/2$^-$[743] rotational band at 252 keV which was previously known. The next strongly populated level is at 988 keV, which has been interpreted as the 15/2 member of the 9/2$^-$[734] particle state (u$^2\sim$ 1) and has been identified in the isotone ^{235}U at 990 keV.

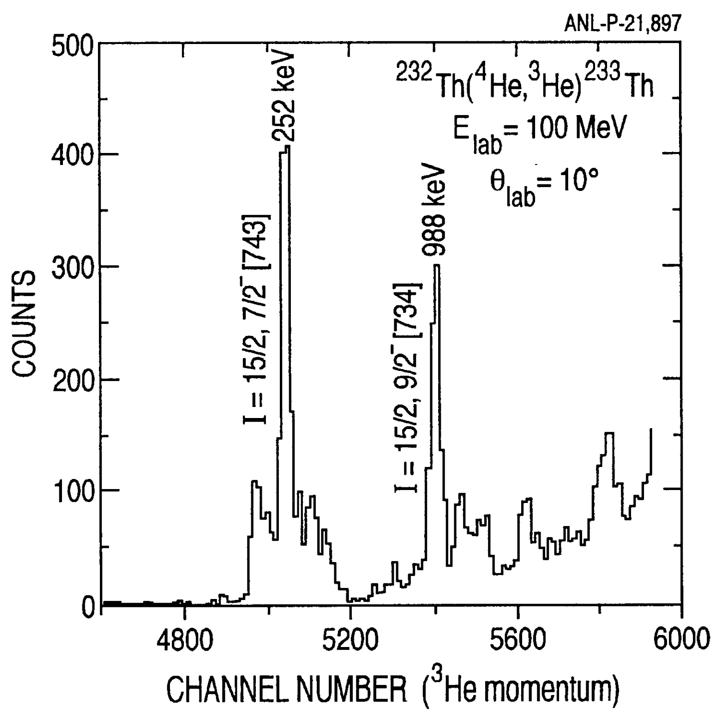

Figure 1. ^{232}Th(^{4}He,^{3}He) spectrum measured with the K600 magnetic spectrograph. The x axis represents momentum of outgoing ^{3}He ions.

In the ^{248}Cm(^{4}He,^{3}He) spectrum, a peak at 598 keV has been observed at all angles. This peak is identified as the 15/2 member of the 11/2$^-$[725] band. It has been identified at 570 keV in the isotone ^{251}Cf [3]. According to DWBA calculations, the strongest peaks in the (^{4}He,^{3}He) spectrum should be the $j_{15/2}$ and $k_{17/2}$ orbitals. Calculations indicate that the lowest two components of the k$_{17/2}$ orbital, the 1/2$^+$[880] and the 3/2$^+$[871] orbitals, should occur at ~1400 and ~1500 keV, respectively. The 17/2 member of the 3/2$^+$ band should be at ~2000 keV, whereas the 17/2 member of the 1/2$^+$ band should be at ~1500 keV because of the large decoupling parameter. The only component of the $j_{15/2}$ orbital which is expected to occur in this energy region is the 13/2$^-$[716] Nilsson state whose I=15/2 member should occur at ~ 1600 keV.

In the spectrum (Fig. 2), the two strongest peaks above 1 MeV occur at 1570 and 1900 keV. The lower peak has a cross section about twice that of the 1900 keV level. We tentatively assign this peak to the $1/2^+[880]$ band because the $1/2^+[880]$ band is expected to have a larger cross section than the $11/2^-[725]$ band.

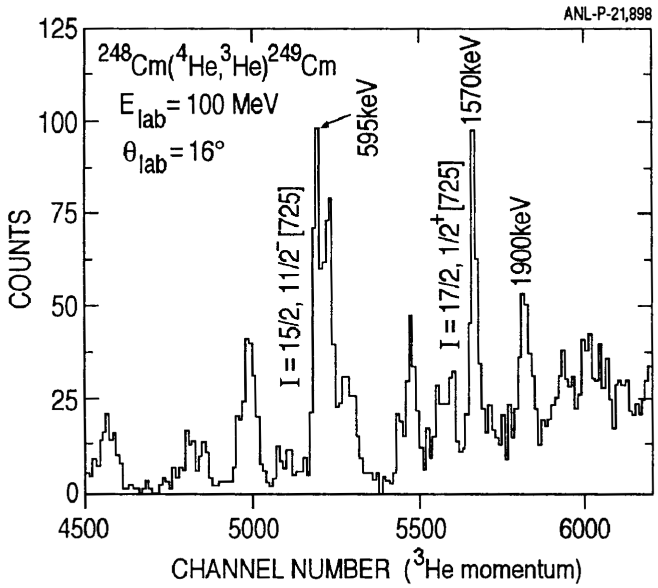

Figure 2. $^{248}Cm(^4He,^3He)$ spectrum measured with the K600 magnetic spectrograph. The x axis represents the momentum of the outgoing ^3He ions.

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