efited from discussing the problem of thermodynamic fluctuations with E. Abrahams, W. A. Little, P. C. Martin, and E. Montroll.

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# SINGLE-PARTICLE STATES BUILT ON THE SECOND $0^+$ STATE IN $^{90}$Zr†

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The proton excitation function of the first excited ($0^+$, 1.75 MeV) level in $^{90}$Zr has been measured. Three prominent analog resonances are found, which are single-particle excitations built on this excited state similar to those built on the ground state.

The excitation function of protons scattered inelastically by $^{90}$Zr has been measured from $E_p = 4.5$ to 10.0 MeV at various angles. This region in the compound nucleus $^{91}$Nb contains the analog of the low-lying states in $^{91}$Zr. The results of these measurements clearly indicate that certain excited states of the nucleus $^{91}$Zr consist of single-particle excitations of a neutron and a core which is the first excited state of $^{90}$Zr ($0^+$, 1.75 MeV).

Inelastic analog resonance scattering has been previously identified[1] and its ability to give nuclear structure information pointed out.[1,2] Inelastic resonance scattering has been used to identify the particle-hole character of the residual state involved.[3] The present method differs from the latter in that it concerns states in the parent analog nucleus. Moreover, it involves states which are weakly excited by the reaction $^{90}$Zr$(d,p)^{91}$Zr. Because of the low yield in the $(d,p)$ reaction, which implies a small spectroscopic factor, resonant effects of the analogs of these states are expected to be small in the elastic excitation function. This was indeed observed to be the case.

The elastic excitation curves, in general, exhibit three resonances. These correspond to the parent analog states in $^{91}$Zr with large spectroscopic factors: $d_{5/2}$, g.s.; $s_{1/2}$, 1.21 MeV; and $d_{3/2}$, 2.06 MeV.[4] The analog of the $g_{7/2}$, 2.21-MeV state is seen only at far backward angles and its weak intensity, as well as the reduced strength of the $d_{5/2}$, g.s., is explained by the small penetrability of the potential barrier.

The inelastic excitation curves to the first excited state of $^{90}$Zr ($0^+$, 1.75 MeV are shown in Fig. 1. Again there are three prominent resonances. These resonances have about the same spacing as the $d_{5/2}$, $s_{1/2}$, and $d_{3/2}$ analog states seen in the elastic excitation curve. However, they are shifted upwards by an amount nearly equal to the excitation energy of the first excited state in $^{90}$Zr. The decay properties of these resonances show that to a considerable extent, these states have a structure represented by a single particle built on the first excited state of $^{90}$Zr.

The parent analogs of these states have been reported in the $(d,p)$ work of Cohen.[4] They have weak intensities and his published results are the following: $d_{3/2}$, 1.48 MeV; $s_{1/2}$, 2.58 MeV; and $d_{3/2}$, 3.70 MeV. The 1.48-MeV level has an angular distribution characterized by $l_n = 2$ and is assigned $d_{3/2}$. With this same experimental evidence, however, Ramavataram[5] concluded that this level was $d_{5/2}$. With the identification $d_{5/2}$, $s_{1/2}$, and $d_{3/2}$, these levels have the same particle configuration as the three single-particle levels built on the ground state. This shell model interpretation is the simplest example of weak coupling which can be presented in the framework introduced by de Shalit and Talmi.[6] This is not presenting a surprising result, since the weak coupling model should predict the data as found. The situation found

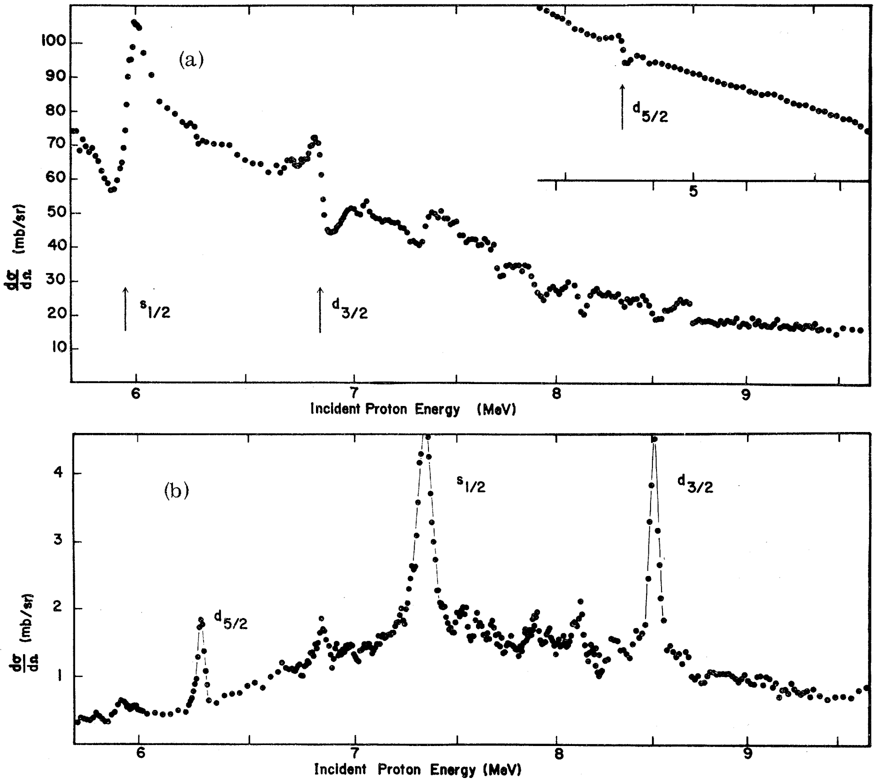

FIG. 1. (a) The excitation function $^{90}\mathrm{Zr}(p,p)^{90}\mathrm{Zr}$ for elastic scattering at the laboratory angle 150 deg. (b) The excitation function $^{90}\mathrm{Zr}(p,p')^{90}\mathrm{Zr}$ for inelastic scattering to the $0^+$, 1.75-MeV state. Because of obstructions due to the impurity peaks of $^{12}\mathrm{C}$ and $^{16}\mathrm{O}$, the data could not be taken continuously at any single backward angle. Consequently, the data from 5.6 to 6.9 MeV and 8.2 to 9.6 MeV are taken at 150 deg, the data from 6.9 to 7.8 MeV are taken at 130 deg, and the data from 7.8 to 8.2 MeV are taken at 170 deg. The scale for the cross section applies only to the 150-deg data. Data at 130 and 170 deg were scaled to match the existing curve at 150 deg.

here is somewhat unusual in that the result obtained is relatively uncomplicated, possibly because of the nature of the low-lying $0^+$ state in $^{90}\mathrm{Zr}$. The similarity of the energy spacing of these two sets of states is evidence that the first excited state is formed by proton excitation. This low-lying $0^+$ state is generally thought to be about 70% $[1g_{9/2}(p)]^2$ and 30% $[2p_{1/2}(p)]^2$ while for the ground state the percentages are interchanged.

At present most analog inelastic scattering data are not understood sufficiently well to give information on nuclear structure. In particular, the excitation curves to the $2^+$, 2.18-MeV; $5^-$, 2.31-MeV; and $3^-$, 2.75-MeV states in $^{90}\mathrm{Zr}$ have a number of resonances which cannot be easily explained. With a coupling model which has more detail, inelastic analog resonance data will permit an understanding of the structure of these states.

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