INVESTIGATION OF ISOBARIC ANALOG STATES BY (p,n) REACTIONS FOLLOWED BY PROTON EMISSION*

A. I. Yavin, R. A. Hoffswell, L. H. Jones, and T. M. Noweir
Department of Physics, University of Illinois, Urbana, Illinois
(Received 9 May 1966)

In this note we wish to present a new method for the investigation of proton-unstable isobaric analog states. Let $(Z+1)^{A*}$ denote the analog of the ground state of the nucleus Z^A. It is customary to study such a state by observing the outgoing neutrons or tritons in (p,n)[1,2] or (He^3,t)[3,4] charge-exchange reactions. Such a state is also studied as a compound-nucleus resonance in (p,p) and (p,n) reactions.[5] All these experiments require knowledge of the exact incident energy and small energy spread in the incoming beam. We suggest that when the state $(Z+1)^{A*}$ is proton unstable, it would be advantageous to study this state by the observation of protons from its decay. For example, in the two-step reaction

$$Z^A + p \rightarrow (Z+1)^{A*} + n$$
$$\hookrightarrow Z^{A-1} + \tilde{p},$$

we propose to observe the $\tilde{p}$ proton from the decay of $(Z+1)^{A*}$ to the ground state of Z^{A-1}.

In the present experiment, the reaction $Zr^{91}(p, n\tilde{p})Zr^{90}$ was selected[6] as a favorable example, since Nb^{91*} is proton unstable, but neutron stable. Figure 1 shows the relevant level diagram for this reaction. Proton spectra were recorded at a laboratory scattering angle of 135°. Particle identification was accomplished by the use of 90- and 2100-μ detectors to a $\Delta E \cdot E$ mass-discrimination setup. Figure 2(a) gives a pulse-height spectrum from bombardment of Zr^{91} by 12.35-MeV protons. The $\tilde{p}$ peak is indicated, as well as peaks corresponding to elastic and inelastic scattering of protons from Zr^{91} and from O^{16} and C^{12} contaminants. Other spectra were recorded at inci-

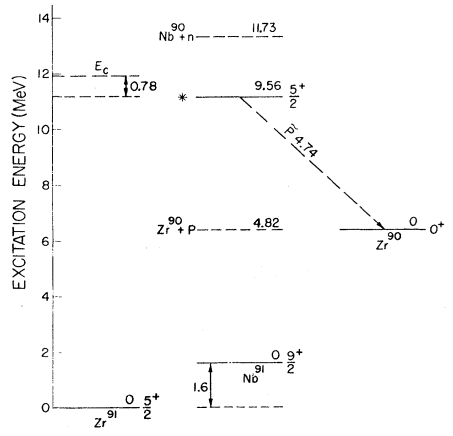

FIG. 1. Level diagram for the reaction $Zr^{91}(p,n\tilde{p})Zr^{90}$.

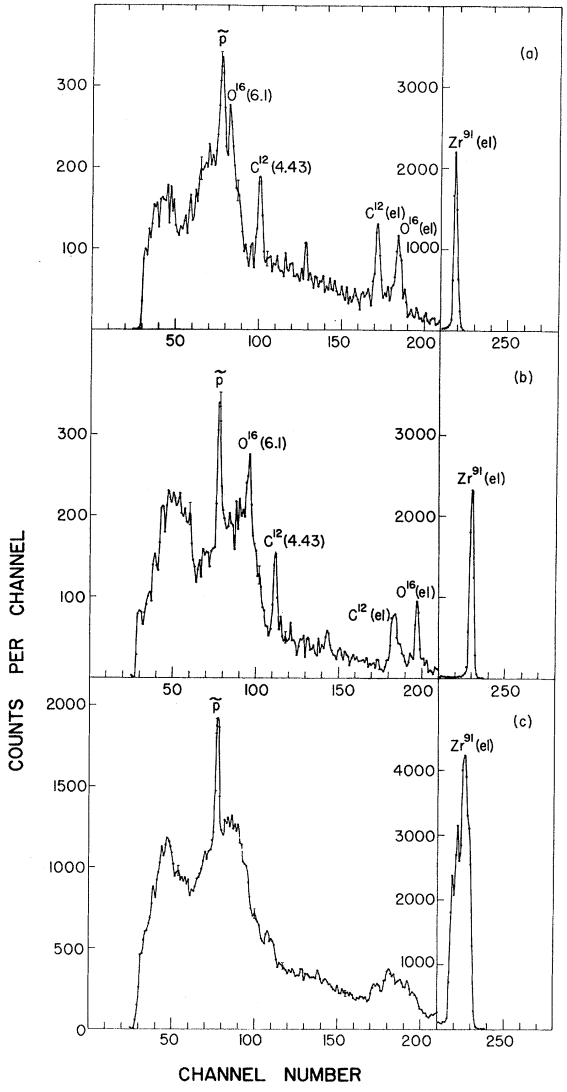

FIG. 2. (a) Proton spectrum resulting from the bombardment of Zr^{91} with 12.35-MeV protons. (b) Proton spectrum resulting from the bombardment of Zr^{91} with 12.95-MeV protons. (c) Sum of proton spectra corresponding to incident proton energies ranging from 12.35 to 12.95 MeV in steps of approximately 120 keV.

dent proton energies ranging from 12.35 to 12.95 MeV in steps of approximately 120 keV. As the proton bombarding energy was increased, all elastic and inelastic peaks moved to higher channels. This can be seen in the spectrum of Fig. 2(b) taken at incident proton energy of 12.95 MeV. In contrast, the position of the $\tilde{p}$ peak did not change, thus proving that the $\tilde{p}$ proton results from a proton transition between two states. The six spectra were added to accentuate any proton group with energy largely independent of the incident proton energy, and their sum is shown in Fig. 2(c). As expected, this procedure extensively broadened all prominent peaks with the exception of the $\tilde{p}$ peak.

The total observed energy of the $\tilde{p}$ decay was 4.74 ± 0.03 MeV. From this, using recently reported Q values,[7] the Coulomb displacement energy is found to be 11.94 ± 0.03 MeV, which is in reasonable agreement with the value 11.75 ± 0.15 MeV measured by Anderson, Wong, and McClure[2] for Zr. Assuming isotropic distribution of the observed $\tilde{p}$ from the decay of Nb^{91*}, the integrated cross section for the reaction is approximately 5 mb. Further measurements of this type are in progress using other targets for which the analog state is proton unstable.

In conclusion we point out that the $(p, n\tilde{p})$ reaction, when feasible, has the advantage of the large cross section of the (p,n) reaction,[1] while at the same time bypassing the difficulties of neutron spectroscopy. Exact knowledge of the incoming proton energy is not needed, and a small energy spread in the incident beam is not required. In fact the larger the spread the more accentuated is the $\tilde{p}$ peak.

We are grateful to Professor P. Axel for his many useful suggestions and discussions.

*Work supported in part by the U. S. Office of Naval Research.

[1]J. D. Anderson, C. Wong, J. W. McClure, and B. D. Walker, Phys. Rev. 136, B118 (1964).

[2]J. D. Anderson, C. Wong, and J. W. McClure, Phys. Rev. 138, B615 (1965).

[3]A. G. Blair and H. E. Wegner, Phys. Rev. Letters 9, 168 (1962).

[4]R. Sherr, A. G. Blair, and D. D. Armstrong, to be published.

[5]J. D. Fox, C. F. Moore, and D. Robson, Phys. Rev. Letters 12, 198 (1964).

[6]Preliminary results were reported at the American Physical Society Conference on Isobaric Spin in Nuclear Physics, Tallahassee, Florida, March 1966 (unpublished).

[7]J. H. E. Mattauch, W. Thiele, and A. H. Wapstra, Nucl. Phys. 67, 32 (1965).

DISCREPANCIES IN PROTON-TRANSFER REACTIONS TO STATES WITH DIFFERENT ISOBARIC SPIN*

R. H. Siemssen, G. C. Morrison, and B. Zeidman
Argonne National Laboratory, Argonne, Illinois

and

H. Fuchs
Hahn Meitner Institut, Berlin, Germany

(Received 25 April 1966)

It is widely accepted that the direct reactions (d,n) and (He^3,d) are analogous processes involving proton transfer and that they should therefore yield the same reduced widths (spectroscopic factors). We have compared the relative spectroscopic factors from (He^3,d) reactions with those from (d,n) reactions to the low $T=0$ and $T=1$ states in the odd-odd nuclei B^{10}, N^{14}, and Al^{26}. In contrast to expectation, we find that in each case a smaller value of the relative spectroscopic factor for the $T=1$ states is deduced from the (d,n) reaction than from the (He^3,d) reaction, the spectroscopic factors being normalized to the $T=0$ ground states for the two reactions.

The (He^3,d) reactions leading to B^{10} and Al^{26} at $E(He^3)=17$ MeV and to N^{14} at 13 and 17 MeV were studied at the Argonne tandem Van de Graaff with a counter telescope. The (d,n) reactions leading to N^{14} and Al^{26} were measured at $E(d)=5.5$ MeV at the Hahn Meitner Institut with a pulsed-beam time-of-flight spectrometer. Both sets of observations were at forward angles. Relative spectroscopic factors