Levels in N^{14} at 11.74 and 11.82 Mev

J. K. Bair
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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The known angular distribution of the $C^{13}(p,p'\gamma)C^{13}$ 3.68-Mev gamma rays is not sufficient to determine uniquely the spin and parity of the 11.74-Mev N^{14} level for the case of arbitrary channel-spin mixing. To resolve this ambiguity the angular distribution of the inelasticity scattered protons has been measured. Of the previous possibilities, $J^{\pi}=1^{+}$, $2^{\pm}$, and 3^{-}, the assignment 1^{+} is selected. A new level is found at 11.82 Mev in N^{14} having a width of about 100 kev, and decaying through the 3.09-Mev level in C^{13}. An angular distribution of the inelasticity scattered protons from this new level shows strong interference effects.

I. INTRODUCTION

THE level structure of N^{14} has recently[1] been investigated by measurements of the yield and angular distribution of the gamma rays from the 3.68- and 3.09-Mev levels in C^{13} following excitation by inelastic proton scattering. Angular distributions of the 150-kev wide level occurring at an energy of excitation in the N^{14} compound nucleus of 11.74 Mev (bombarding proton energy of 4.52 Mev) were not sufficient to uniquely determine the spin and parity of the level. The angular distributions could be fit in the case of arbitrary channel-spin mixing ratios by the assignments 1^{+}, $2^{\pm}$, or 3^{-}. In an attempt to resolve this ambiguity, the angular distribution of the protons inelasticity scattered from this level has been measured using the ORNL 60° deflection, double focusing, uniform field, reaction product magnet.[2]

II. EXPERIMENTAL PROCEDURE

C^{13} targets were prepared[3] by converting barium carbonate to acetylene[4] and then depositing the carbon in an electrical discharge between two 5-micro-inch nickel foils placed in a low-pressure acetylene atmosphere.[5] As is usual with targets made by this technique, the actual composition of the layer and its thickness were uncertain. The targets were, however, quite thin compared to the natural level width and sufficiently thin that, with the magnet exit slits set for the minimum resolution, flat top peaks were obtained for the inelastic proton groups.

Protons from the 5.5-Mev Van de Graaff were collimated by an adjustable slit system. The collimated beam produced a spot about 1 by 2 mm at the target located in the scattering chamber. The analyzer magnet was set at a solid angle of approximately 0.005 steradian. The magnet is located so as to deflect particles vertically upward after being emitted from the target at an angle of 15°±5° above the horizontal plane. A sliding vacuum seal in the target chamber permits continuous rotation of the magnet for laboratory angles of 15° to 149°. The protons were detected by a CsI(Tl) crystal and photomultiplier at the exit focus of the magnet. Pulses from the crystal were displayed on a 20-channel analyzer. Figure 1 shows the differential count rate for an incident proton energy of 4.52 Mev due to the low-energy (approximately 300 kev) inelastic protons going to the 3.68-Mev level in C^{13}, as measured at a laboratory angle of 146°. The open circles were taken with the magnet set at the peak; the solid circles were obtained with the magnet set just off the peak, and they constitute a measure of the background. Figure 2 shows a magnetic field traversal for this same group taken with the exit slits widened sufficiently that they controlled the over-all resolution, as indicated by the flat top. The angular distribution data were taken with this slit adjustment. The datum plotted at a given angle in the distributions is the height of the flat top corrected for background by subtracting the average count rate off the peak. These data are corrected for laboratory to center-of-mass conversion.

III. EXPERIMENTAL RESULTS AND CONCLUSIONS

Figure 3 shows the angular distribution of the inelastic protons going from the 11.74-Mev (4.52-Mev

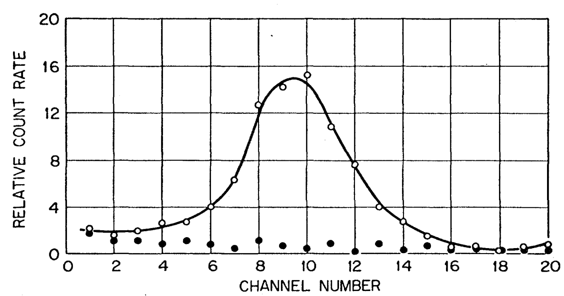

FIG. 1. Differential count rate due to the low-energy (approximately 300 kev) inelastic protons going to the 3.68-Mev level in C^{13}. The incident proton energy was 4.52 Mev and the magnetic spectrometer was set at a laboratory angle of 146°. The open circles were taken with the magnet set at the peak and the solid circles were obtained with the magnet set just off the peak.

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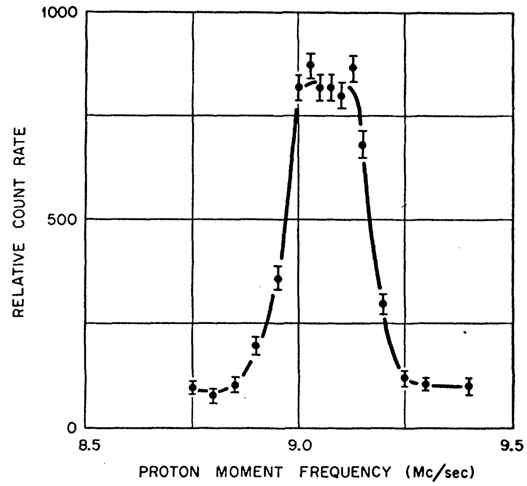

FIG. 2. Magnetic field traversal for the group in Fig. 1. The exit slits were sufficiently wide that they controlled the over-all resolution, as indicated by the flat top.

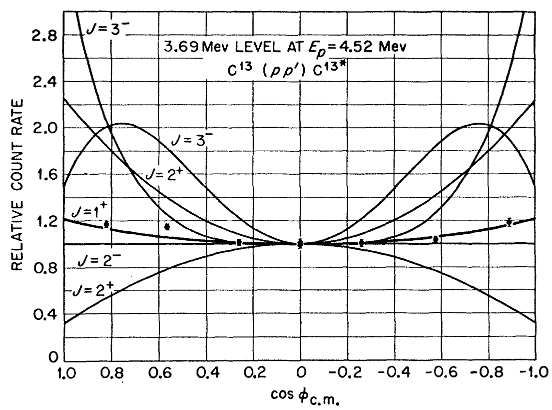

FIG. 3. Angular distribution of the inelastic protons going from the 11.74-Mev (4.52-Mev bombarding proton energy) level in N^{14} to the 3.68-Mev excited state in C^{13}. The points plotted are the relative center-of-mass yields, as a function of the cosine of the center-of-mass scattering angle. Errors shown are statistical standard deviations only.

bombarding proton energy) level in N^{14} to the 3.68-Mev excited state in C^{13}. The points plotted are the relative center-of-mass yields, as a function of the cosine of the center-of-mass scattering angle. Errors shown are statistical only. Also shown as solid curves in Fig. 3 are the theoretical p,p' distributions for the spin, parity, and channel-spin mixing ratios which gave satisfactory fits to the inelastic scattering gamma-ray angular distribution data.[1] The p,p' data thus exclude the $J^\pi = 2^\pm$ and 3^- possibilities.

The curve labeled $J=1^+$ is a least-mean-square fit of the data to a Legendre expansion, $W=P_0+B_2P_2$. The value of B_2 so obtained is 0.13, with an estimated error of ± 0.03. From the gamma-ray distributions two possible $J=1^+$ fits could be obtained. The first of these requires 85 to 100% entrance $s=0$ with greater than 99% exit $s'=2$ and α positive (where α is the ratio of

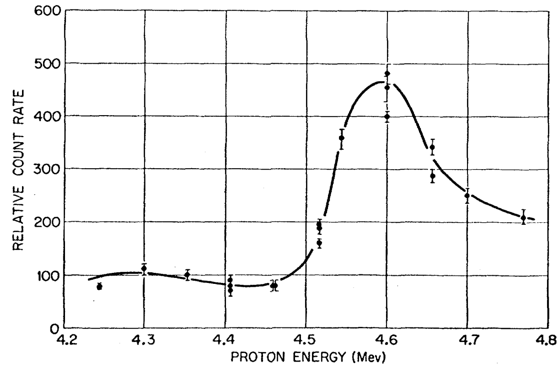

FIG. 4. Yield of inelastic protons going to the 3.09-Mev level in C^{13} as a function of incident proton energy. The laboratory scattering angle was 146°. No anomaly is observed at 4.52 Mev but at 4.60 Mev a maximum with a width of $\Gamma \approx 100$ kev is resolved.

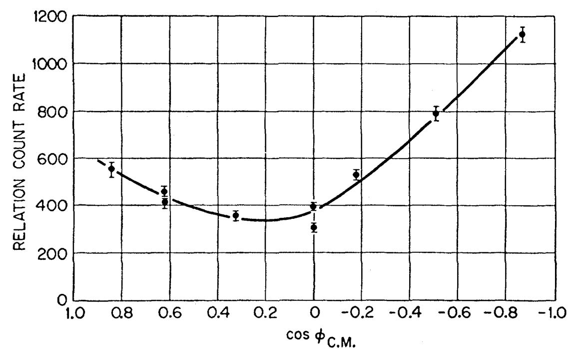

FIG. 5. Angular distribution of the inelastic protons going to the 3.09-Mev state in C^{13}. The bombarding proton energy was 4.60 Mev. The data plotted are the intensities corrected to center of mass as a function of the cosine of the center-of-mass angle.

the amplitude of exit channel spin 2 to that for exit channel spin 1). This condition gives a p,p' fit of $W=P_0+B_2P_2$ with $0.14 \leqslant B_2 \leqslant 0.19$ not in disagreement with the experimental B_2 of 0.13 ± 0.03 obtained above. The value of $B_2=0.14$ corresponds to 85% entrance channel spin 0 and 99% exit channel spin 2, α positive. The second set of conditions for $J=1^+$, as obtained from the gamma-ray data, required greater than 69% $s=0$ and greater than 34% $s'=2$ with α negative. The corresponding inelastic proton distribution is given by $W=P_0+B_2P_2$ with $-0.60 \leqslant B_2 \leqslant 0.20$ in agreement with experiment. Our value of $B_2=0.13$ furnishes a second set of parameters for $J^\pi=1^+$ in agreement with both the gamma-ray and the inelastic proton data. For this second case $B_2=0.13$ corresponds to over 77% entrance channel spin 0 and over 94% exit channel spin 2.

In reference 1 it was concluded that the 3.09-Mev gamma rays resonated very little at 4.52-Mev proton energy, but that there was some indication of a broad maximum at about 4.6-Mev bombarding energy. To verify these points a yield curve at a laboratory scattering angle of 146° was obtained for the inelastic protons going to the 3.09-Mev level in C^{13}. This is shown in

Fig. 4. No anomaly is observed at 4.52 Mev, but at 4.60 Mev a maximum with a width $\Gamma \approx 100$ kev is resolved.

An angular distribution of these inelastic protons to the first excited state is shown in Fig. 5, where the bombarding proton energy was 4.60 Mev. The data are the intensities corrected to center of mass plotted as a function of the cosine of the center-of-mass angle. The distribution shows strong interference effects with a level of opposite parity. No analysis of level parameters has been attempted.

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Delayed Neutrons from N^{17}†

G. J. PERLOW, W. J. RAMLER, A. F. STEHNEY, AND J. L. YNTEMA
Argonne National Laboratory, Argonne, Illinois
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The energies of the delayed neutrons which follow the decay of N^{17} have been measured by means of a triple proportional-counter recoil spectrometer. The N^{17} was obtained from the $C^{14}(\alpha,p)N^{17}$ reaction at a mean α-particle energy of 25-Mev. Two neutron groups were observed, with energies of 1.22 ± 0.06 Mev and 0.426 ± 0.018 Mev. These correspond to neutron emission from the $\frac{3}{2}^-$ states of O^{17} at 5.38 and 4.55 Mev, respectively. This result is consistent with the expected J^π of $\frac{1}{2}^-$ for the ground state of N^{17} and with the small stripping widths for these levels in $O^{16}(d,p)O^{17}$. The ratio of the intensity of the high-energy group to the low-energy one is 1.6, which corresponds to a ratio of 4 for the squares of the β-decay matrix elements.

INTRODUCTION

THE nucleus N^{17} decays by β decay to excited states of O^{17} with a half-life of 4.1 sec.[1] At least some of these lie above the neutron separation energy and therefore decay predominantly and promptly by neutron emission.

Alvarez[2] measured the neutron energy by examining the energy of the O^{16} ions which recoiled from the neutron emission in a proportional counter. He deduced a neutron spectrum centered at 0.9 Mev and having a width at half-maximum of less than 0.5 Mev. He also measured the β rays in coincidence with the neutrons and obtained an end point of 3.7 ± 0.2 Mev. Hayward[3] made use of proton recoils in a hydrogen-filled cloud chamber. She found the neutron energy to be peaked at about 1 Mev with a width at half-maximum of approximately 0.2 Mev. There was, in addition, some evidence for a weak emission of higher energy neutrons. The mass excess $(M\text{-}A)$ of N^{17} has been determined from the $B^{11}(Li^7,p)N^{17}$ reaction[4] as 12.93 ± 0.06 Mev.[5] From this value of the mass excess and the observed neutron and β spectra, one would conclude that the β decay proceeds primarily to the $\frac{3}{2}^+$ level of O^{17} at 5.08 Mev. It seemed of interest to attempt a more accurate identification of the levels of O^{17} to which the β decay from N^{17} proceeds, especially since decay to the $\frac{3}{2}^+$ state requires an unlikely ground-state configuration of N^{17}: This has been done by measuring the spectrum of neutron energies.

EXPERIMENTAL PROCEDURE

The N^{17} was produced by the reaction $C^{14}(\alpha,p)N^{17}$ at the Argonne 60-in. cyclotron. The 43-Mev beam was degraded by absorbers to about 28 Mev where the cross section is known[6] to be maximal. The target contained 41% elemental C^{14}. It was prepared by generating CO_2 from active $BaCO_3$ obtained from Oak Ridge, and reducing it in a quartz tube with hot magnesium. The fused mass resulting from the reaction was treated with HCl and then with HF and HNO_3. Only carbon remained after filtering and washing. This was compressed into a pellet of 1-cm diameter containing 14 mg of the isotopic mixture and was sealed between Al foils 0.001 in. thick. The external α beam of the cyclotron was focused by means of 3 sets of quadrupole magnets to produce a beam of approximately 2 μa over a 0.25-in. diameter region at the target. The target was placed at 45° to the beam inside a tube separated from the cyclotron beam tube and was cooled by an air jet which then passed through a filter and into the air exhaust system. The filter was checked periodically for activity to avoid contamination in the event the target container ruptured. The cyclotron shutter was controlled by a

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