Parity of the 5.83-MeV State of N^{14}†

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The lifetime of the $J=3$ 5.83-MeV level of N^{14} has been examined with pulsed-beam and coincidence techniques. The 5.83-MeV state was populated by means of the $C^{12}(He^3,p)N^{14}$ reaction. The mean life obtained for the 0.73, 5.83 → 5.10-MeV transition is ⩽0.3 nsec. This limit for the mean life, together with the polarization measurement of Rose *et al.*, establishes the relative parity of the 5.83- and 5.10-MeV levels to be the same. Since the 5.10-MeV level has been established as 2- by Warburton *et al.*, the parity of the 5.83-MeV level is −.

INTRODUCTION

THE 4.91-, 5.69-, 5.10-, and 5.83-MeV levels of N^{14} have been proposed to be the $T=0$ ($s^4p^9 2s_{1/2}$) and ($s^4p^9d_{5/2}$) states of N^{14} with spins and parities 0−, 1−, 2−, and 3− by Warburton, Rose, and Hatch.[1] The experimental evidence for the suggested identification of these states has been summarized by these authors and others.[2,3] Recently, the 5.10-MeV level in N^{14} has been shown to be 2− by Warburton, Alburger, Gallmann, Wagner, and Chase,[4] and the relative parity of the 5.10- (2−) and the 5.83-MeV ($J=3$)[1] states of N^{14} has been measured by Rose, Wihlein, Riess, and Trost.[5] Rose *et al.* measured the plane polarization of the 0.73-MeV transition (5.83 → 5.10 MeV). The polarization measurement results indicate the relative parity of the 5.83- and 5.10-MeV states is the same, if the 0.73-MeV transition is mainly dipole. Warburton, Rose, and Hatch have set an upper limit on the lifetime of the 0.73 MeV gamma ray using a Doppler-shift technique. They find the transition is mainly dipole and give a limiting value for the ratio of the quadrupole to dipole reduced matrix elements, δ, as $|\delta|\leqslant 0.15$. With this value of δ, Rose *et al.*[5] conclude that the relative parity of the 5.83- and 5.10-MeV states is the same. In view of the 2− assignment to the 5.10-MeV state by Warburton *et al.*,[4] the 5.83-MeV state is then 3−. However, Warburton and Pinkston[2] have shown that the Doppler-shift lifetime measurement is fast enough to demand extremely large (∼5%) isotopic spin impurities in the wave functions for the 5.10- and 5.83-MeV states of N^{14}. Thus, it is important to check the Doppler-shift lifetime measurement and to obtain the relative parity of these two states in a way which does not depend on this lifetime measurement. Using the $C^{12}(He^3,p)$ reaction and the pulsed-beam technique, we have found an upper limit for the lifetime of the 0.73-MeV gamma ray and established an independent limit for the absolute value of the mixing ratio δ.

EXPERIMENTAL PROCEDURE

The pulsed-beam facility at the Brookhaven National Laboratory research Van de Graaff, together with the "Gatti-type" time-to-height conversion system described in previous papers[6–8] was used for this measurement. Figure 1 illustrates the general experimental arrangement. N^{14} was produced with the $C^{12}(He^3,p)$ reaction. The carbon target was prepared by evaporating a collodial dispersion of carbon in alcohol on a Ta backing. A thin target was used to enhance the production of the 5.83-MeV state N^{14} relative to states below the 5.83-MeV level. The target was bombarded with a 2.9-MeV He^3 beam with an average current of 0.1 μA. The beam was pulsed externally with a 7.6

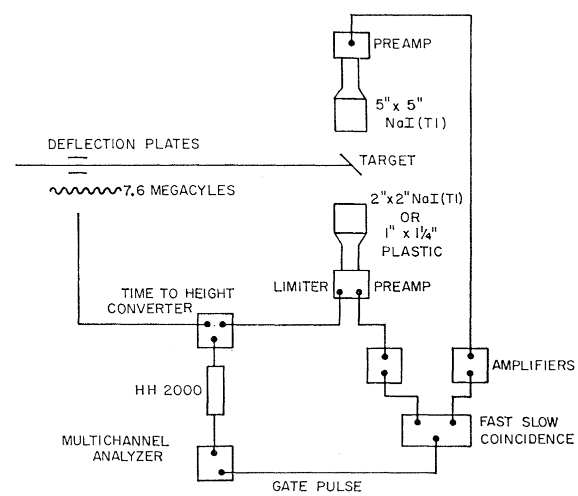

FIG. 1. Block diagram of the experimental arrangement.

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[1] E. K. Warburton, H. J. Rose, and E. N. Hatch, Phys. Rev. **114**, 214 (1959).
[2] E. K. Warburton and W. T. Pinkston, Phys. Rev. **118**, 733 (1960).
[3] *Nuclear Data Sheets*, compiled by T. Lauritsen and F. Ajzenberg-Selove, (Printing and Publishing Office, National Academy of Sciences–National Research Council, Washington 25, D. C., 1962), sets 5 and 6.
[4] E. K. Warburton, D. E. Alburger, A. Gallmann, P. Wagner, and L. F. Chase, Jr. (to be published).
[5] H. J. Rose, F. Wihlein, F. Riess, and W. Trost, Nucl. Phys. **36**, 583 (1962).
[6] J. V. Kane, M. A. El-Wahab, J. Lowe, and C. L. McClelland, in *Proceedings of the International Conference on Nuclear Electronics, Belgrade, 1961* (International Atomic Energy Agency, Vienna, 1962).
[7] J. Lowe, C. L. McClelland, and J. V. Kane, Phys. Rev. **126**, 1811 (1962).
[8] J. Lowe, Brookhaven National Laboratory Report, BNL 6140, 1962 (unpublished).

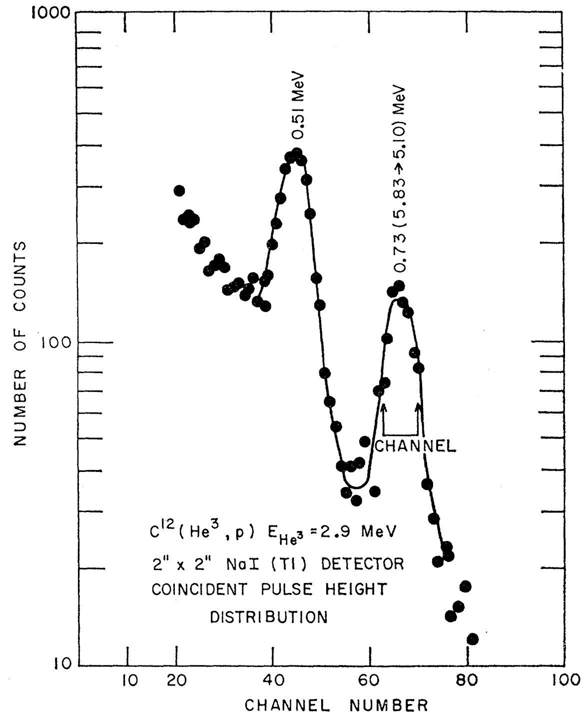

FIG. 2. Pulse-height distribution of the low-energy gamma radiation following the cascade decay of the 5.83-MeV level of N^{14}. The low-energy radiation was required to be in coincidence with gamma radiation following the decay of the 5.10-MeV level. The 0.73, 5.83 → 5.10-MeV gamma ray is evident. There is some annihilation radiation present in the spectrum. The low-energy radiation was detected with a 2-in.-diam by 2-in.-long NaI(Tl) detector.

Mc/sec deflection voltage. The gamma radiation from the target impinged on two detectors at 180° to each other and at 90° to the beam axis. One of these detectors was mounted on a RCA type C-7260B photomultiplier tube. The anode signal of this tube drove a limiter, which was coupled to the time-to-height converter system. A linear output was taken from a dynode of this tube—this output was integrated and amplified. Time spectra of the 0.73-MeV gamma ray were taken using both a 2-in.-diam by 2-in.-long NaI(Tl) crystal and a 1-in.-diam by $1\frac{1}{4}$-in.-long Nash and Thompson plastic scintillator detector. The NaI(Tl) detector was used to take advantage of its good energy resolution; the plastic scintillator was, however, used in the final run as better timing resolution is obtainable with it. In either case the front face of this detector was about $1\frac{1}{2}$ in. from the target. In order to sort out the 0.73-MeV gamma ray, a 5-in.-diam by 5-in.-long NaI(Tl) detector was placed as indicated above. The front face of this detector was about 3 in. from the target. The linear output from the preamplifier associated with this detector was amplified and placed in fast (25 nsec)—slow (2 μsec) coincidence with the amplified linear output from the "fast" photomultiplier and detector. Pulse-height selection on the amplified output associated with the 5-in.-diam by 5-in.-long NaI(Tl) detector included events above the 2.13-MeV gamma ray of N^{14}; pulse-height selection on the amplified linear output of the other detector [NaI(Tl) or plastic scintillator] included the 0.73, 5.83 → 5.10-MeV transition. Figure 2 indicates the coincident pulse-height distribution of the events in the 2-in.-diam by 2-in.-long NaI(Tl) detector. The channel setting for the 0.73-MeV gamma ray is also indicated in the figure. When coincidence conditions were satisfied, a multichannel analyzer was gated on, and the time-to-height converter output associated with the 0.73-MeV gamma ray was analyzed and stored. Figure 3 displays the coincident pulse-height distribution observed when the 2-in.-diam by 2-in.-long NaI(Tl) crystal was replaced with a 1-in. diam by $1\frac{1}{4}$-in.-long plastic scintillator.

RESULTS AND DISCUSSION

Figures 4 and 5 display the accumulated pulse-height distributions of the time-to-height converter output for each of the detectors used. Figure 4 represents the time distribution obtained with the 2-in. diam by 2-in.-long NaI(Tl) detector; the upper limit for the mean life of the 5.83-MeV state obtained is $\tau_m \leqslant 1.2$ nsec. Figure 5 represents the time distribution obtained when the 0.73-MeV radiation is detected with the plastic

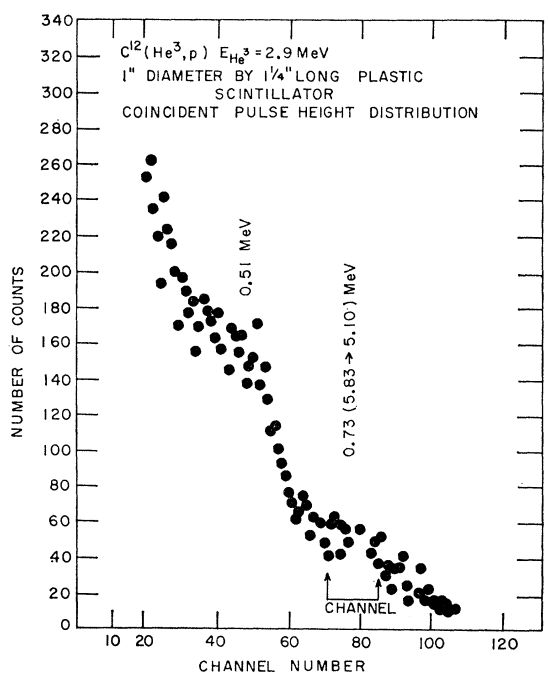

FIG. 3. Pulse height distribution of the low-energy gamma radiation following the cascade decay of the 5.83-MeV level of N^{14}. The low-energy radiation was required to be in coincidence with gamma radiation following the decay of the 5.10-MeV level. The 0.73, 5.83 → 5.10-MeV gamma ray is evident. There is some annihilation radiation present in the spectrum. The low-energy radiation was detected with a 1-in.-diam by $1\frac{1}{4}$-in.-long plastic scintillator.

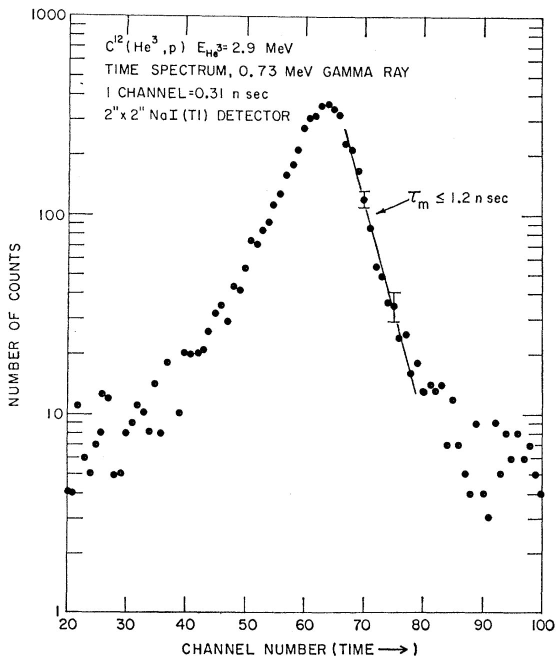

FIG. 4. Time spectrum of the 0.73, 5.83 → 5.10-MeV gamma radiation. The 0.73-MeV gamma rays were detected with a 2-in.-diam by 2-in.-long NaI(Tl) crystal. Pulse-height selection for the 0.73-MeV gamma ray is indicated in Fig. 2.

scintillator; this gives $\tau_m \leqslant 0.3$ nsec. These values for the mean life are taken directly from the slopes of the time distributions. These limits on the mean life are not in contradiction with the Doppler-shift measurement.[1] The Weisskopf estimate for the 0.73-MeV transition is 3.7×10^{-8} sec for $M2$ radiation.[9] The Weisskopf estimate multiplied by a factor of 10 to include possible enhancement is taken as an upper limit for the transition speed. Taking into consideration the branching of the 5.83-MeV state[1,3] the experimentally determined limits for the mean life of the 0.73-MeV transition then give $|\delta| \leqslant 0.8$ and $|\delta| \leqslant 0.3$, respectively, for the ratio of the quadrupole to dipole mixing ratio. From their measured value of the anisotropy of the 0.73-MeV gamma ray, Warburton, Rose, and Hatch[1] have determined two ranges of δ; $0 \leqslant \delta \leqslant 0.9$ and $-5.6 \leqslant \delta \leqslant -4$. We have found $|\delta| \leqslant 0.3$ if the transition is $M2+E1$. Therefore, δ is limited to the range $0 \leqslant \delta \leqslant 0.09$. However, Rose *et al.*[5] state that for $0 \leqslant \delta \leqslant 0.09$ their polarization measurement is only consistent with the $5.83 \rightarrow 5.10$-MeV transition being $M1+E2$. This rules out the possibility that the transition is $M2+E1$. Therefore, the character of the transition is $M1+E2$, and the relative parity of the two states is the same. The 5.10-MeV state has been assigned[4] 2− ; thus, the $J=3$, 5.83-MeV state is 3−. This conclusion is in agreement with the argument based on the Doppler-shift lifetime measurement explained in the Introduction. The negative parity assignment for the 5.83-MeV state is in agreement with an earlier conclusion of Warburton, Rose, and Hatch[1]; based on the lower limits of the matrix elements of the octupole component of the $5.83 \rightarrow 0$ transition, they found that an odd-parity assignment for the 5.83-MeV state was preferred.

[9] D. H. Wilkinson, in *Nuclear Spectroscopy*, edited by F. Ajzenberg-Selove (Academic Press Inc., New York, 1960).

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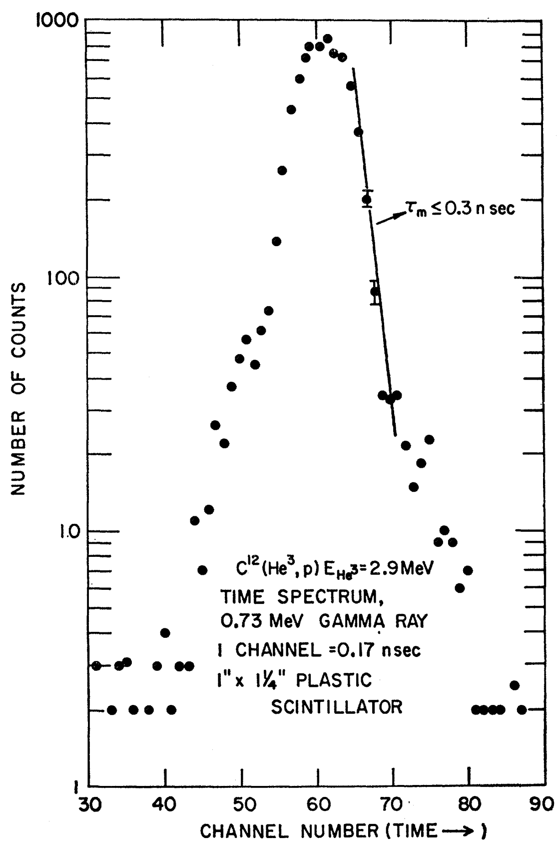

FIG. 5. Time spectrum of the 0.73, 5.83 → 5.10-MeV gamma radiation. The gamma rays were detected with a 1-in.-diam by 1¼-in.-long plastic scintillator. Pulse-height selection for the 0.73-MeV radiation is indicated in Fig. 3.