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February 1969

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ISOSPIN PURITY AND DECAY OF THE T = 3/2 ANALOGUE STATE IN ^{17}F

J. C. Hardy, John E. Esterl, R. G. Sextro, and Joseph Cerny

February 1969

Abstract Submitted

for the Conference on Nuclear Isospin

February 1969

Isospin Purity and Decay of the T = 3/2 Analogue State in ^{17}F.* J. C. HARDY, JOHN E. ESTERL, R. G. SEXTRO, and JOSEPH CERNY. Lawrence Radiation Laboratory, Berkeley.--All allowed β^+-decay branches of the $T_z = -3/2$ nucleus ^{17}Ne lead to states in ^{17}F which are above the proton separation energy. From the *relative* intensities of the emitted proton groups *absolute* log *ft* values can be determined for all significant branches, including the superallowed decay to its T = 3/2 analogue in ^{17}F (E_x = 11.197 MeV). We bombarded TiO_2 foils with a 45 MeV ^3He beam and swept the recoils with helium into a well-shielded counting chamber 15 feet away in ∿100 msec. Particle decays were detected in a ΔE-E counter telescope (FWHM = 40 keV) and particle-γ coincidences were observed using a NaI(Tl) detector. The analogue state was observed to emit protons to the ground, first, third, and fourth excited states of ^{16}O. The log *ft* value for the decay branch feeding it was determined to be 3.35±0.10, indicating that the isospin purity of the state is ≳87%. Three states around 8 MeV have log *ft* values ≤4.2; one may be the missing member of a pair of states involving the "anti-analogue" configuration.

*Work performed under the auspices of the U. S. Atomic Energy Commission.

Submitted by:

John C. Hardy

ISOSPIN PURITY AND DECAY OF THE T = 3/2 ANALOGUE STATE IN ^{17}F*

J. C. Hardy, John E. Esterl, R. G. Sextro, and Joseph Cerny

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The $T_z = -3/2$ nucleus ^{17}Ne β^+-decays to levels in ^{17}F. With the exception of decay branches to the ground and first excited states, both first-forbidden, all branches lead to levels which are above the proton separation energy. From the *relative* intensities of the emitted proton groups, *absolute* log *ft* values can be determined for all significant ^{17}Ne decay branches with a precision not afforded by other methods. In particular, since the strength of the super-allowed decay to the T = 3/2 analogue state is determined predominantly by the Fermi matrix element, an accurate evaluation of its log *ft* value provides a sensitive measure of the isospin purity of the state. Further, the particle decays of such an analogue state provide more details about its configuration and are of considerable general interest (1). The observation of delayed-particle emission can be a selective and precise method for studying both properties. Of the previous investigations of ^{17}Ne (2-4) only one (4) observed analogue state decays and, although incomplete in this respect, it indicated that the log *ft* value to this state might be anomalously high. Any significant discrepancy from the calculated value (5) of 3.29 would imply admixtures of lower-isospin configurations into the analogue state.

We wish to present here the preliminary report of a series of experiments which studied the decay of ^{17}Ne. Targets of TiO_2 were bombarded in the external 45 MeV ^3He beam of the Berkeley 88-inch cyclotron producing ^{17}Ne from the reaction $^{16}O(^3He,2n)^{17}Ne$. Six foils were stacked

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0.5 mm apart and mounted in a 5 cc counting chamber. At half-second intervals helium gas was swept through the target chamber picking up the recoil nuclei and transporting them through two liquid nitrogen traps to a well-shielded 75 cc counting chamber 15 feet away. The gas transport was accomplished using a sequence of remotely controlled solenoid valves and resulted in a transit time from target to counting chamber of ∿100 msec. After a counting period of 350 msec the chamber was pumped out in preparation for the next cycle. The counting chamber was conical with a cooled (to -20°C) ΔE-E counter telescope mounted internally at the apex and a 2" × 2" NaI(Tl) crystal mounted externally at the base. The ΔE counters used were phosphorus-diffused silicon and ranged in thickness from 14 to 50 μ; the 1 mm E counter was lithium-drifted silicon. Energy signals from these detectors were fed into a Goulding-Landis particle identifier after requiring a fast (2τ = 10 nsec) - slow coincidence between them. The total energy signals corresponding to protons or alphas were then time-sorted into eight groups of a pulse-height analyzer to provide lifetime as well as energy data. Coincidences (2τ = 50 nsec) between identified protons and γ's were also recorded and the energies of both were stored two dimensionally.

With this system the energy resolution (FWHM) for identified particles was ∿40 keV; the spectra extended down to 1 MeV for protons and 4 MeV for alphas without appreciable background; and the counting geometry was such that adequate statistics could be obtained for p-γ coincidences. These properties represent a significant advance over previous β^+-delayed proton experiments.

Proton spectra from the decay of ^{17}Ne are shown in both halves of Fig. 1. Center-of-mass proton energies (±30 keV) are shown for all observed peaks, the energy calibration having been determined from the peaks marked 4.07, 4.92, 5.47, and 10.60 MeV which are due to the decay (2,4) of known states (6,7) in ^{17}F at 4.698, 5.523, 6.039, and 11.197 MeV respectively. Protons following the decay of ^{17}Ne should be characterized by its lifetime, and the lifetimes for all peaks marked in the spectra were extracted and found to be compatible with 115±5 msec. The best value for the ^{17}Ne lifetime taken from the present and previous (2-4) results is 109±3 msec.

In the bottom half of Fig. 1 is a singles proton spectrum obtained when using a 14 μ ΔE counter, and below it is a spectrum recorded simultaneously of those protons

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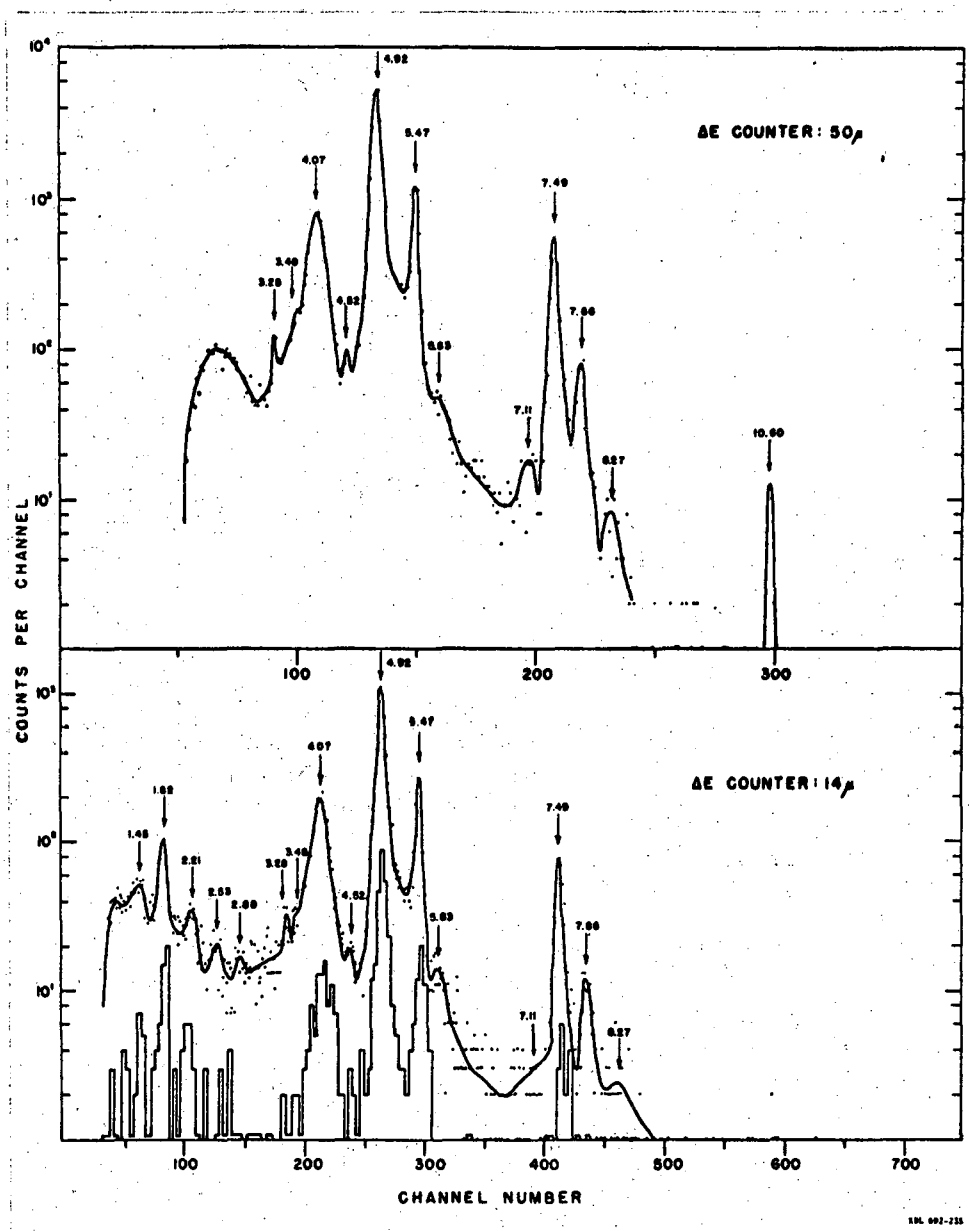

Fig. 1. Proton spectra from the decay of ^{17}Ne. The histogram shows protons in coincidence with 511 keV γ rays; it gives three-channel sums.

in coincidence with 511 keV γ rays. The chance rate was negligibly small. Most of the coincident γ rays result from the annihilation of the positrons feeding levels in ^{17}F but note that the relative heights of the three peaks below channel 110 are approximately doubled in the coincidence spectrum. This indicates that they must correspond to proton decays to the first excited state (0^+) of ^{16}O which itself decays by internal pair conversion. The proposed decay scheme is shown in Fig. 2; energies of levels in ^{17}F are taken from references (6,7) except for those at 6.43 and 8.86 MeV which are results of this work. In addition to measured energies and coincidence results, account has been taken of the experimental peak widths to insure that they agree with the known (6) level widths.

Since the width of the analogue state is $\sim$0.5 keV (8), the peaks attributed to its decay (those marked 3.28, 3.48, 4.52, and 10.60 MeV) are the narrowest in the spectrum. They indicate decay to the ^{16}O ground (12±4%), first (26±8%), third (28±13%), and fourth (34±14%) excited states. No decay was observed to the 3^- second excited state of ^{16}O, nor was any α-decay observed to the ground state of ^{13}N. The upper limit for these decay modes was determined to be $\lesssim$10% of the total proton decays observed. Other possible proton and alpha groups would be sufficiently below the Coulomb barrier that their appearance is unlikely, and the γ-width is known to be small (8). The log *ft* value thus determined for the superallowed β^+-decay is 3.35±0.10.

Since the model-dependent Gamow-Teller matrix element is small ($\langle\sigma\rangle^2 \sim 0.1$) compared to the model-independent Fermi matrix element ($\langle 1\rangle^2 = 3$), any significant discrepancy of the measured log *ft* from its calculated value (5) of 3.29 should be interpreted as arising from admixtures of configurations with T = 1/2 into the analogue state wave function; such configurations would cause a reduction in the Fermi matrix element proportional to the percentage admixture. The experimental log *ft* value thus was used to determine the isospin purity of the analogue state to be $\gtrsim$87%.

Detailed calculations for levels in ^{17}F and the β^+-decay feeding them have been reported by Margolis and de Takacsy (9). There is good qualitative agreement with our results: of the ten 1/2- and 3/2- levels predicted below 10 MeV, we observe nine; we could not have seen levels above 8 MeV fed by decays with log *ft* values $\gtrsim$5.5. From these calculations, the wave function for the ground

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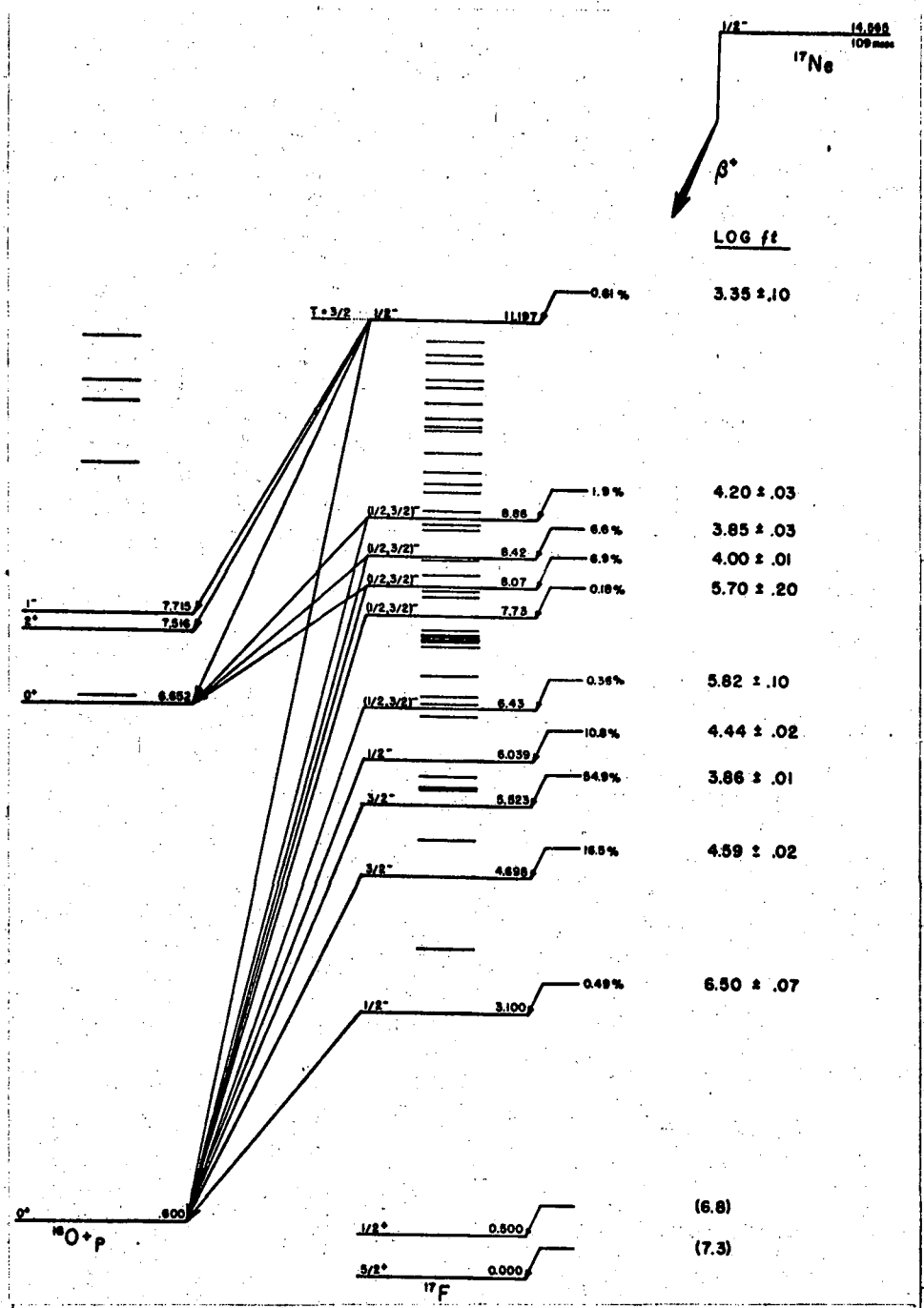

Fig. 2. Proposed decay scheme of ^{17}Ne.

state of ^{17}Ne and its (T = 3/2) analogue in ^{17}F is well represented by a ($p_{1/2}$) hole coupled to the ^{18}O ground state. The same components coupled to T = 1/2 will be referred to as the "anti-analogue" configuration. It is expected to be split between two $1/2^-$ states in ^{17}F; one is the state at 3.1 MeV, the other is calculated to be at ∿6 MeV. The β^+-decay to the former is correctly predicted to be retarded but for the latter a log *ft* value of 3.4 (the lowest in the spectrum except for the superallowed decay) is expected. Three states are observed around 8 MeV with log *ft* values ⩽4.2; it seems likely that one of these is the other state involving the anti-analogue configuration. (Another $1/2^-$ level without anti-analogue contributions is also predicted at ∿6 MeV; this presumably is the experimental level at 6.039 MeV.) Based on the experimental log *ft* values the components of the anti-analogue configuration in the levels at 3.1 and ∿8 MeV are approximately 85% and 15% respectively.

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