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Discovery of Beta-delayed Two-proton Radioactivity in ^{22}Al and ^{26}P*

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Discovery of Beta-delayed Two-proton Radioactivity in ^{22}Al and ^{26}P*

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Among the highly proton-rich nuclides are candidates for two-proton radioactivity, originally proposed by Gol'danskii$^{1)}$, as well as candidates for beta-delayed two-proton radioactivity. Gol'danskii has also discussed the latter decay mode$^{2)}$ and has suggested a number of nuclides that might provide its initial examples, among them the light, odd-odd, T_z=-2 isotopes. The recent discovery$^{3)}$ of the first known member of this series, ^{22}Al, and the subsequent observation$^{4)}$ of the next higher member, ^{26}P (both as beta-delayed, isospin-forbidden, single proton emitters), made these two nuclides ideal candidates for a search for this new mode of decay. These two nuclides have now been observed also to decay by beta-delayed two-proton radioactivity (more detailed results on ^{22}Al have been submitted for publication$^{5)}$).

^{22}Al($\tau_{1/2}$ ~ 70 ms) and ^{26}P($\tau_{1/2}$ ~ 20 ms) were produced via the (^{3}He,p4n) reaction on ^{24}Mg and ^{28}Si targets, respectively, using 110 MeV ^{3}He^{+2} beams of 3-7μA from the 88-inch Cyclotron at the Lawrence Berkeley Laboratory: the effective cross section for their observation as high energy (7-8 MeV), beta-delayed single proton emitters was ~ a few nb. A helium jet system and a high geometry, three-element particle telescope (ΔE1,ΔE2,E) were used to search for two-proton decay events. Symmetrically divided, circular "ΔE1" (24 μm for ^{22}Al, 14 μm for ^{26}P) and "ΔE2" (155-170 μm) detectors were employed to observe coincident, low-energy protons with each telescope subtending 4.5% of 4π sr. A standard 500 μm E detector placed behind and in coincidence with either of these two-counter telescopes observed the high energy groups from beta-delayed single proton decay as a monitor of the reaction.

Figure 1(a) presents the two-dimensional proton-proton coincidence spectrum obtained following the decay of ^{22}Al and figure 1(b) shows the summed proton energy spectrum (with peaks at 4.139±0.020 MeV and 5.636±0.020 MeV). Although the exact corresponding center of mass

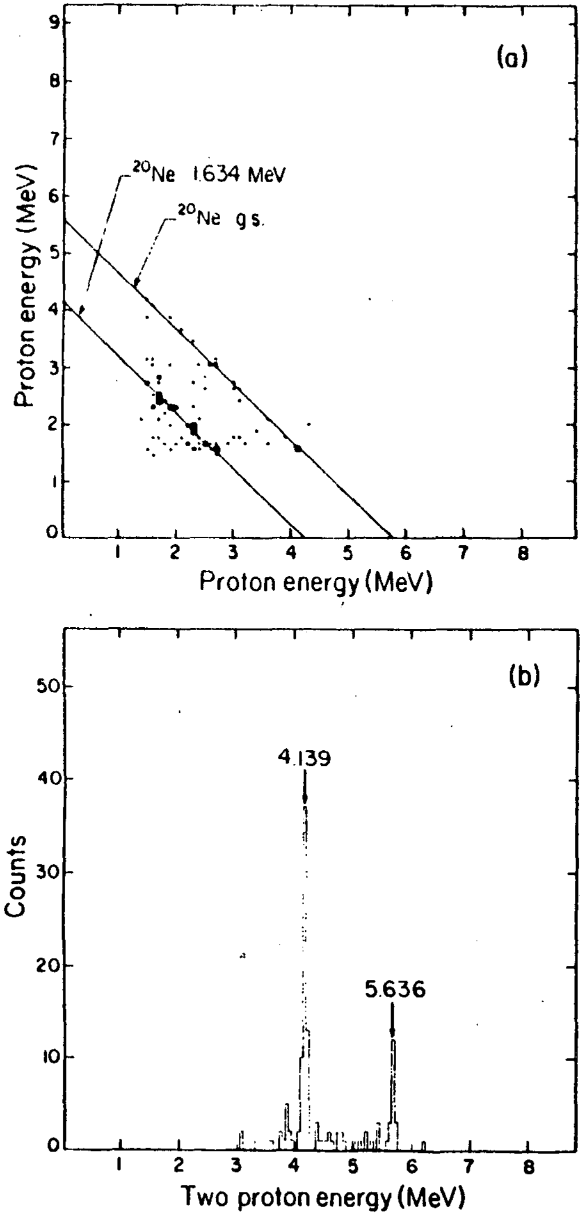

Fig. 1. (a). A proton-proton coincidence spectrum following the beta decay of ^{22}Al (E_p^L vs. E_p^R). (b). A summed energy spectrum for the two-proton coincidences in (a): ($E_p^L + E_p^R$).

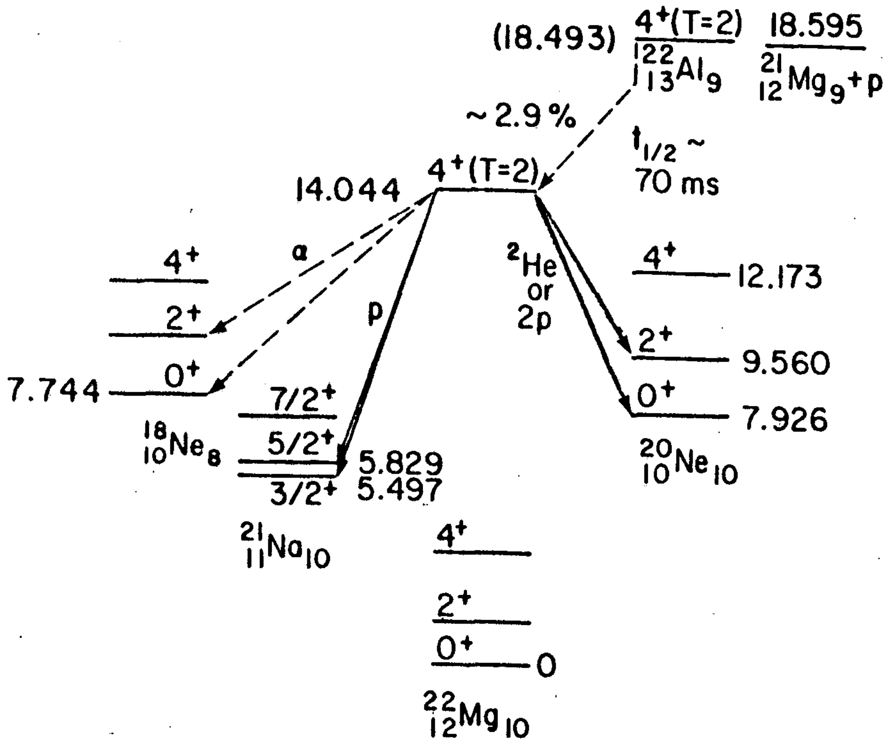

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Fig. 2. Proposed partial decay scheme for ^{22}Al.

energies depend on the mechanism of two-proton emission, these peaks can be shown to correspond to transitions from the T=2 analog state in ^{22}Mg (fed by the superallowed beta-decay of ^{22}Al) to the ground and first excited state of ^{20}Ne. Figure 2 illustrates the various observed decay modes of ^{22}Al; all open particle-decay channels from the ^{22}Mg(4+), T=2 state are isospin forbidden, making this state relatively narrow.

Two of the possible mechanisms available for the emission of two protons in this decay include A) single step ^{2}He emission[1,2)] (a proton pair coupled to a $^{1}S_{0}$ configuration) and B) a sequential two-step process proceeding through an intermediate state (or states) in ^{21}Na. Considering the stronger decay branch, ^{2}He emission to the ^{20}Ne (1.634 MeV) state should occur within relative laboratory angles of $\lesssim 40°$ (see ref. 5). Since the telescope pair could detect angles of 0-70°, it could observe coincident protons arising from either mechanism. ^{2}He emission should show a distribution centered about $E_p^L=E_p^R$ with a shape determined by the detector configuration and the final state interaction. Sequential emission would also be (trivially) symmetric about $E_p^L=E_p^R$ but would be expected to show distinct proton groups corresponding to transitions through the intermediate state(s) in ^{21}Na. The data of figure 1(a), with their limited statistics, cannot conclusively establish the mechanism; the observed variation in energies and yields could result from either a ^{2}He type distribution or sequential decay through several states in ^{21}Na or both. See reference 5 for a more complete discussion.

Differences from the above arising in the possible beta-delayed two-proton decay mechanism of ^{26}P, however, can help clarify our general understanding of these results. ^{26}P should have a 3^+, T=2 ground state, so that, following its superallowed beta-decay to the 3^+, T=2 state in ^{26}Si, only sequential proton decay to the ^{24}Mg ground state is allowed (spin-parity conservation forbids ^{2}He emission). A decay scheme for ^{26}P is presented in figure 3. Figure 4(a) shows the summed, coincident two-proton energies arising from the decay of nuclides produced in the 110 MeV ^{3}He bombardment of ^{28}Si: both ^{26}P and ^{22}Al are observed. By setting a gate on the transitions corresponding to ^{26}P decay to the ^{24}Mg ground state (via ^{26}Si), one obtains the proton-proton coincidence spectrum shown in figure 4(b). Strong evidence for sequential decay is observed: the great majority of the coincident events

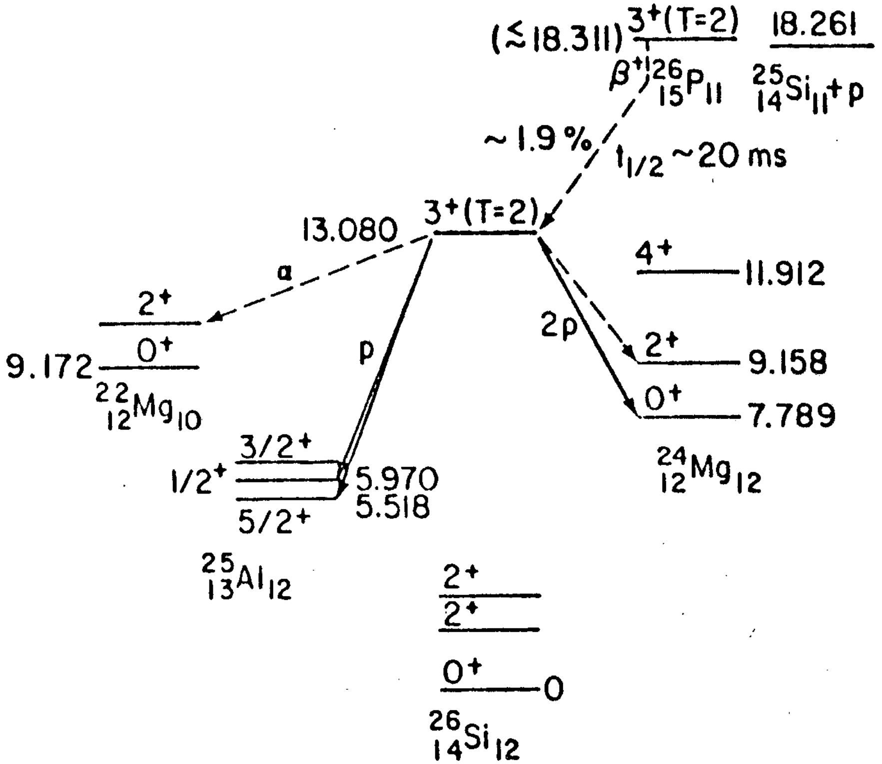

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Fig. 3. Proposed partial decay scheme for ^{26}P.

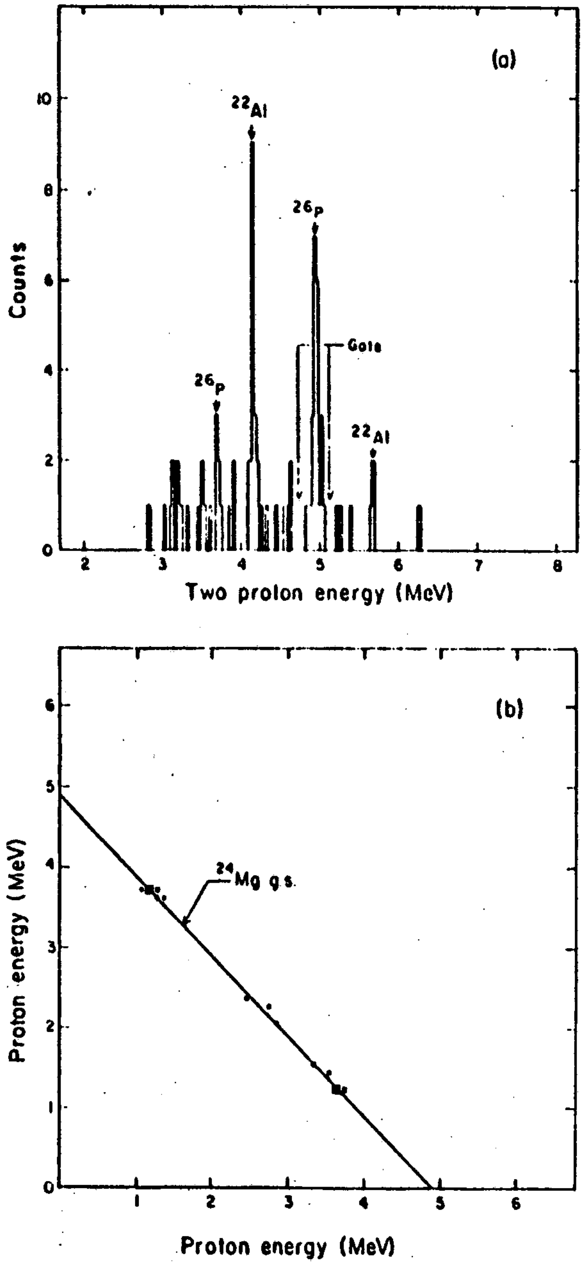

Fig. 4. (a). A summed energy spectrum for the two-proton coincidences arising from 110 MeV ^3He bombardment of ^{28}Si. (b). A proton-proton coincidence spectrum for the group shown within the gate in (a). See text.

correspond to a single decay channel involving a 3.7 MeV proton associated with a 1.2 MeV proton (preliminary values). Further experiments on the decay of ^{26}P are in progress: its weaker decay to the ^{24}Mg first excited state can occur by both decay mechanisms and so is of substantial interest for comparative purposes.

Additional studies on both ^{22}Al and ^{26}P are necessary to obtain A) higher statistics with this detector configuration and B) other angular correlation data to observe the changes in yield, peak shape, and laboratory energy of the emitted coincident protons. Although the beta-delayed two-proton decay of ^{26}P to the ^{24}Mg ground state appears clearly to occur by the expected sequential proton emission, the two-proton decay mechanism(s) following the beta-decay of ^{22}Al is uncertain. Should ^{22}Al decay have a component of ^{2}He emission, fascinating studies of a new form of radioactivity would become possible.

Footnotes and References

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