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Authors
McGrath, Robert L.
Hardy, J.C.
Cerny, Joseph.

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University of California

Ernest O. Lawrence Radiation Laboratory

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Lawrence Radiation Laboratory and Department of Chemistry
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ABSTRACT

The excitation energies of the lowest 0^+ T=2 states in ^{28}Si and ^{28}Al have been measured using (p,t) and (p,^{3}He) reactions on ^{30}Si. The isospin-forbidden particle decay modes of the ^{28}Si analogue state have been investigated; $\Delta T=2$ alpha emission to the ^{24}Mg ground state predominates.

In the past several years the lowest T=2 isobaric analogue states in a number of $T_z=0$ or 1 light nucleides have been located.[1)] These states were first observed using two-nucleon transfer reactions[2,3)] and, later, in several instances[4,5)] as isospin-forbidden compound-nucleus resonances. Since the states have no available isospin-allowed particle decay modes, their widths are expected to be relatively small and all available data are consistent with this expectation, the widths being less than the experimental resolution in the transfer reaction studies (upper limits about 20 to 80 keV) and less than 2.5 keV for the states in ^{20}Ne,[4)] ^{24}Mg, and ^{32}S,[5)] which were observed using resonance techniques. In general, the T=2 states of $T_z=0$ nucleides lie at least 3.5 MeV above proton or alpha particle (isospin-forbidden) decay thresholds; these narrow widths imply that charge-dependent interactions only slightly perturb the T=2 wave functions. Studies of the partial widths for both particle and gamma decay provide information about the components of wave functions admixed by these interactions either into the T=2 states or the residual states formed by the decay process. The results can reflect directly upon the character of the charge-dependent forces themselves.

This letter reports the measurement of the excitations of the lowest T=2 states in ^{28}Si and ^{28}Al utilizing the ^{30}Si (p,t) ^{28}Si and ^{30}Si (p,^{3}He) ^{28}Al reactions. These states have spin-parity 0^{+} and are analogues of the ^{28}Mg ground state. In addition, by examining coincidences between tritons forming the ^{28}Si T=2 state, and protons or alpha particles from its decay, the decay branching ratios to ^{27}Al (ΔT=1 or 2) and ^{24}Mg (ΔT=2) states have been determined. A previously reported[6)] attempt to populate this ^{28}Si state via proton scattering on ^{27}Al was unsuccessful, although tentative evidence for its observation at 15.13 $\pm$ 0.020 MeV via the ^{26}Mg (^{3}He,n) ^{28}Si reaction has been reported.[7)]

Triton and ^{3}He energy spectra at angles from 14 to 36 degrees (lab) were obtained with the 46 MeV proton beam of the Berkeley 88-inch cyclotron bombarding a 420 μ g/cm^{2} evaporated silicon foil enriched to 89% ^{30}Si. Standard techniques were followed in these measurements.[2)] The coincidence data were collected with three telescopes – a triton telescope and two "decay" telescopes. Each telescope consisted of ΔE, E and E-reject silicon detectors (the last being used to reject particles that passed through the E counter) and fed electronics built around Goulding-Landis[8)] particle-identifier systems. The triton telescope, subtending 9.2×10^{-4} sr, was positioned at +22 degrees, the second maximum in the L=0 angular distribution to the analogue state. Fast-slow coincidences were required between tritons in this telescope and either identified protons or particles stopping in the ΔE counters (50μ thick) of either decay telescope. The latter telescopes were positioned at -90 and -125 degrees and subtended about 1.3×10^{-2} sr. Energy signals from all free triton events together with coincident events and their associated logic signals were fed to a multiplexer-analog-to-digital-converter and, subsequently, into an on-line computer.

The triton energy spectrum shown at the top of fig. 1 was accumulated during the coincidence experiment, but is representative of the region of higher excitation in the spectra obtained during the earlier angular distribution measurements. The prominent peak located at 15.206 ± 0.025 MeV in ^{28}Si is identified as the lowest 0^+, T=2 state; the ^{3}He data[9] yield the ^{28}Al analogue excitation as 5.983 ± 0.025 MeV. These excitations were established using known Q-values of ^{16}O and ^{12}C target-contaminant reactions and agreed with Coulomb predictions. The 0^+ spin-parity assignment is based on the angular distribution shapes being characteristic of L=0 angular momentum transfer.[2,9] The isospin assignment is based further on the ^{28}Si, ^{28}Al cross section ratios. If the charge-dependent forces are weak, this ratio depends only on isospin Clebsch-Gordan coupling coefficients and momentum factors, and agrees with our experimental results. The total widths of both states are negligible compared with the 100 keV (triton) and 125 keV (^{3}He) experimental resolutions.

The coincidence data, displayed as two-dimensional energy spectra, exhibited events distributed along bands determined by the three-particle final-state kinematics. Final states including both the ^{27}Al ground state and (0.84 + 1.01) MeV states (the latter two being unresolved) were evident in the triton-proton arrays. Coincident events with more than 2 MeV energy loss in the ΔE decay counters could unambiguously be identified as alpha particles. These alpha-particle events fell along bands in the triton-ΔE arrays which corresponded to the ^{24}Mg ground state and 1.37 MeV state.

The zero spin of the $T=2$ state insured isotropic particle decay in the ^{28}Si recoil coordinate system; thus, decay properties could be ascertained without angular correlation measurements. Indeed, two decay telescopes were necessary primarily as a means to increase the data acquisition rate. Nevertheless, because of the low triton cross section for populating the $T=2$ state ($\sim 80\mu b/sr$) and a counting-rate limit of about 30,000 cps in the decay ΔE counters, only about 3.2 events per hour associated with the decay of this state were recorded.

Events lying along different kinematic bands were "projected" onto the triton energy axis and the summed projections from both decay telescopes are shown in the lower portion of fig. 1. The net counts attributed to the various $T=2$ decay modes were found by summing the projected spectra over the energy interval containing the $T=2$ triton peak as determined from the singles spectrum at the top of the figure, and subtracting: 1) the "real" three-particle continuum background; and 2) the "chance" background. The former was assumed to vary smoothly over the $T=2$ energy interval and, hence, was calculated by interpolating the background height on either side of this interval. The chance background was calculated in the usual way from the known singles counting rates. Both background subtractions were small compared to the strong alpha + ^{24}Mg ground state transition; the real and chance backgrounds accounted for 7 and 1.8 counts, respectively, compared to a total of 102 observed events.

Finally, branching ratios were found by comparing the net coincidence events in the various projections to the number predicted from the triton singles counts, decay telescope geometries, and the Jacobian relating the laboratory and ^{28}Si recoil coordinates. The sum of branching ratios to the three lowest ^{27}Al states and the lowest two states of ^{24}Mg was $89.1 \pm 15.7\%$. This sum was expected to be near 100% for two reasons. First, previous results[10] on the lowest T=2 states of ^{24}Mg and ^{20}Ne indicated that the partial widths for particle decay account for most of the decay strength: the total width of the ^{20}Ne state is about 2 keV[4] whereas typical isospin-allowed gamma transition widths are of the order of 100 times smaller than this. Second, energetically allowed particle transitions to most higher states of ^{27}Al or ^{24}Mg which could not be studied in the present experiment would populate residual states having intrinsic structures similar[11] to the observed lower-lying states; such transitions would therefore be significantly retarded because of decreasing barrier penetration factors. Figure 2 summarizes the present results. The summed branching ratios have been renormalized to 100% for clarity; it is not implied that gamma decays or unobserved particle decays could not make small contributions to the total width. Clearly, alpha emission to the ^{24}Mg ground state dominates the decay strength. As an additional check, the ratio of branching ratios for this transition derived independently from both decay telescopes — separated by

35 degrees — is 1.08 ± 0.23 which is consistent with the required isotropic decay of spin-zero states.

In self-conjugate nuclei, $\Delta T=2$ isospin impurities (necessary to explain alpha emission) can arise only from the isotensor component of charge-dependent interactions. The contrast with the $T=2$ state in ^{24}Mg which decays principally by proton emission[10] is striking, and an attempt to understand the decay properties in terms of admixtures of specific two-particle, two-hole states in these nuclei is being undertaken. It would certainly still be of interest to have information on the absolute width and other properties of this $T=2$ state which can be obtained using compound nucleus resonance techniques. However, from the present results, it is apparent that the most fruitful approach would be in searching for $L=0$ ($\Delta T=2$) $\alpha + {}^{24}Mg$ resonances rather than $L=2$ ($\Delta T=1,2$) $p + {}^{27}Al$ resonances.

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FOOTNOTES AND REFERENCES

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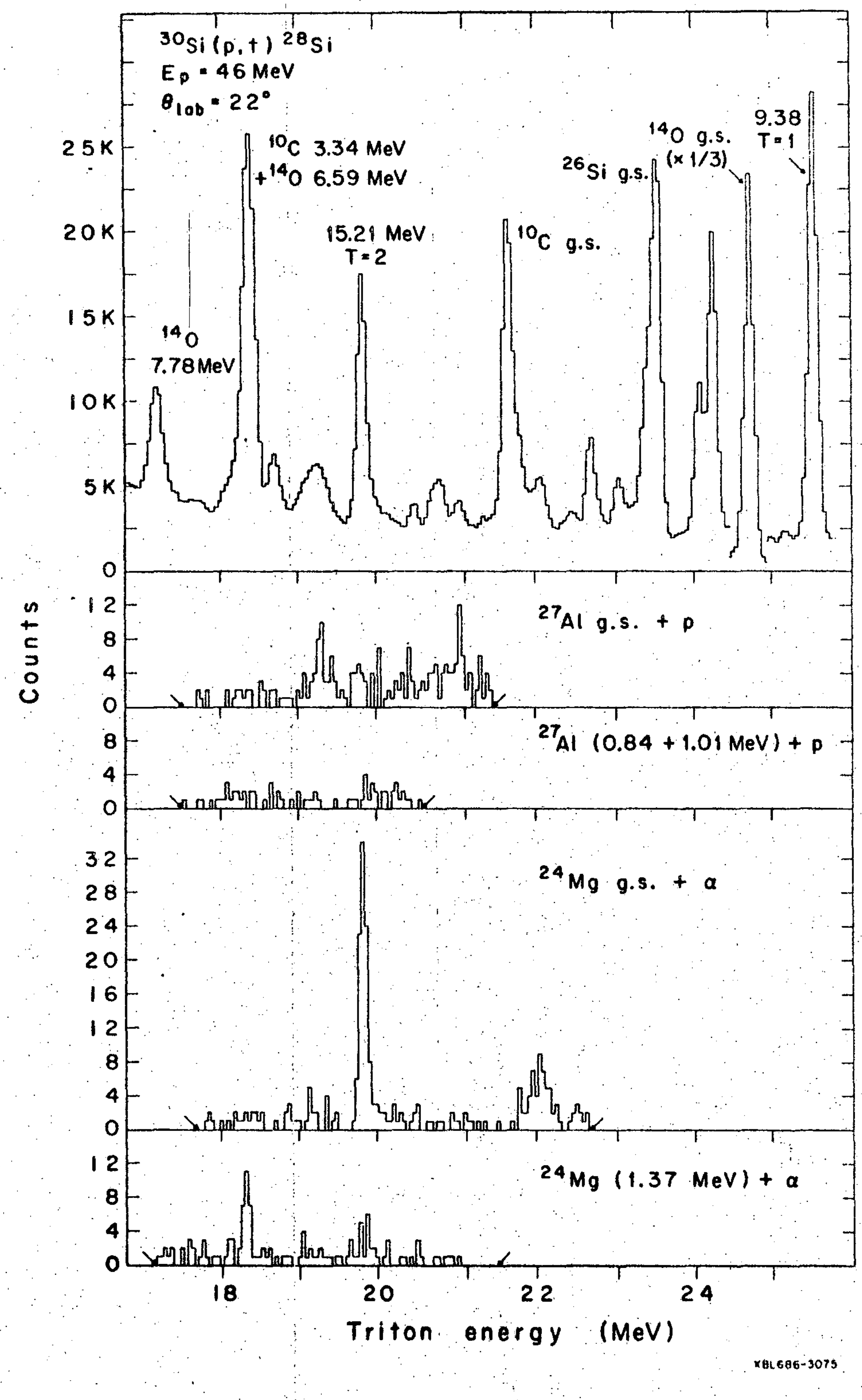
FIGURE CAPTIONS

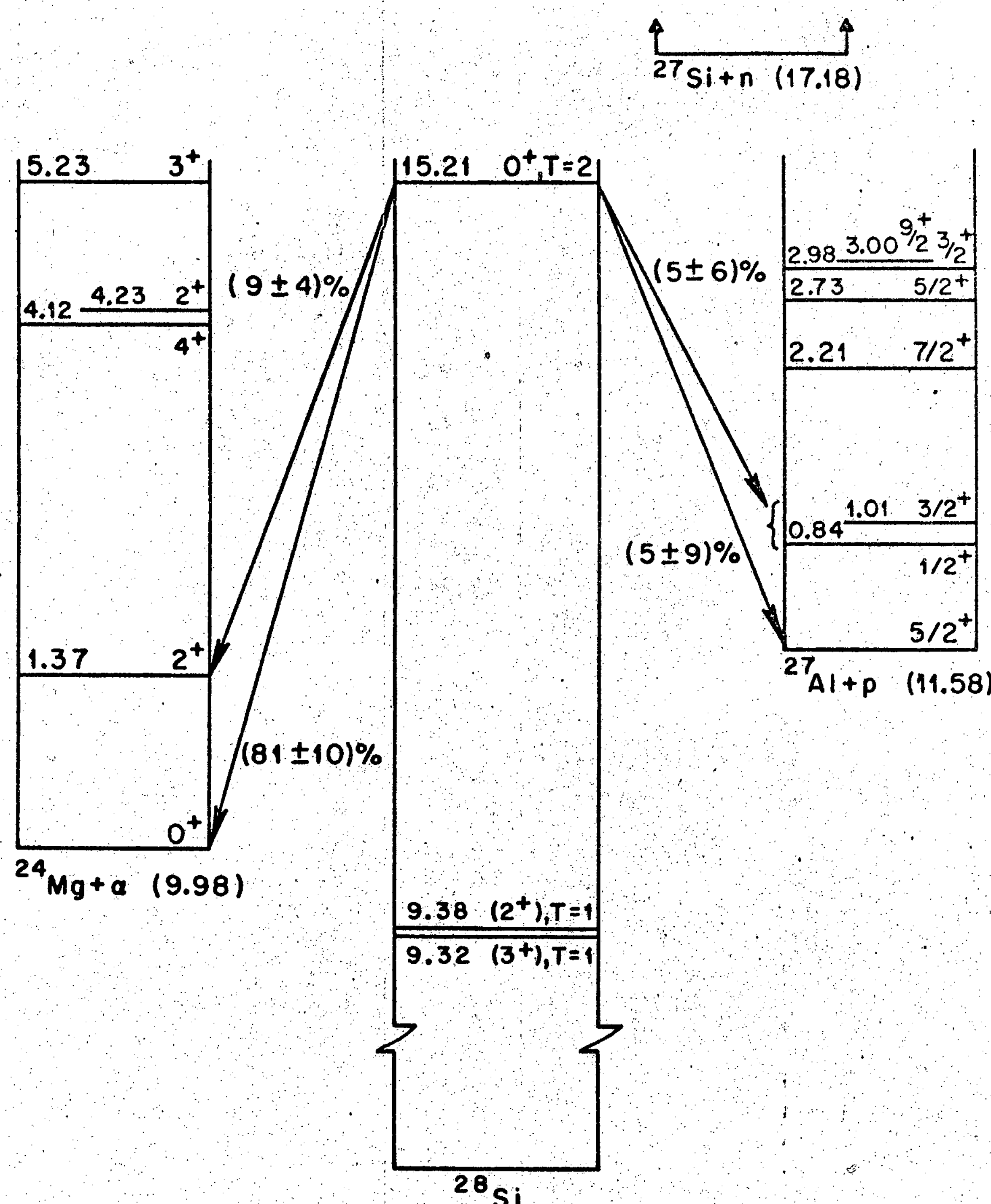
Fig. 1. The top spectrum presents the triton singles data containing a peak corresponding to the lowest ^{28}Si T=2 state at 15.206 ± 0.025 MeV. The lower spectra are summed projections from both decay telescopes of events lying along kinematic bands in the coincidence data onto the triton energy axis; the arrows in these spectra mark the energy cutoffs determined by kinematics and detector thicknesses.

Fig. 2. Energy level diagram showing the ^{28}Si T=2 state and the various available proton or alpha particle isospin-forbidden decay modes. The observed transitions are indicated by arrows; the numbers are fractional branching ratios normalized to 100% as discussed in the text. The energy level data are taken from reference 11.



^{30}Si (p,t) ^{28}Si
E_p = 46 MeV
θ_{lab} = 22°
^{10}C 3.34 MeV
+^{14}O 6.59 MeV
^{14}O
7.78 MeV
15.21 MeV
T = 2
^{10}C g.s.
^{26}Si g.s.
^{14}O g.s.
(× 1/3)
9.38
T = 1
^{27}Al g.s. + p
^{27}Al (0.84 + 1.01 MeV) + p
^{24}Mg g.s. + α
^{24}Mg (1.37 MeV) + α
Counts
Triton energy (MeV)
XBL686-3075

Fig. 1.



XBL686-3074

Fig. 2.