Analog transitions in the $A = 30$ system*

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The γ-ray decay of the 2^+, $T=1$ state at $E_x = 4.183$ MeV in ^{30}P was investigated. A new branch $(2\pm1)\%$ to the 0^+, $T=1$ state at $E_x = 0.677$ MeV was found. The decay mode is discussed in terms of isospin and an estimate of the lifetime of this state is derived.

[NUCLEAR REACTION $^{29}Si(p,\gamma)$, $E = 0.70-0.75$ MeV, measured $\sigma(E; E_\gamma, \theta)$, deduced ^{30}P level branching. Enriched ^{29}Si target.]

A comparison of analog electromagnetic transitions is a useful test of the validity of selection rules based on the concept of isospin. According to these rules,[1] the reduced strength of a transition connecting two levels of the same isospin can be written as

$$|M_{M\lambda}|^2 = (S + T_z V)^2 \quad . \tag{1}$$

The symbols S and V denote matrix elements of the isoscalar and isovector interaction, respectively, which are reduced in space and isospace. From this basic expression it follows that within a T multiplet with $T \geq 1$ the $2T+1$ analog transition strengths are determined by only two independent parameters S and V.

Within the s, d shell fairly good agreement with these predictions has been found for the $E2$ transitions between the two lowest $T = T_> = 1$ states in the nuclear mass triplets $A = 18$ (Ref. 2), 26 (Ref. 3), 30 (Refs. 4, 5) and 34 (Ref. 5).

In this note we report an extension to transitions from the second 2^+, $T_> = 1$ multiplet in the mass $A = 30$ system consisting of the nuclei $^{30}Si(T_z = -1)$, $^{30}P(0)$, and $^{30}S(+1)$ (Fig. 1). The $E2$ transition strengths to the 0^+, $T_>$ ground states are known to be $|M_{E2}|^2 = 1.3 \pm 0.3$ Weisskopf units (W.u.) (Ref. 6) for ^{30}Si and $|M_{E2}|^2 = 0.6 \pm 0.2$ W.u. (Ref. 4) for ^{30}S. Since the $T_z = 0$ nucleus ^{30}P has low-lying $T_<$ as well as $T_>$ states, the interesting $E2$, $T_> \to T_>$ analog transitions are obscured by very strong $M1$, $T_> \to T_<$ transitions (Fig. 1). The second 2^+, $T_>$ state at $E_x = 4.183$ MeV is known to decay with a very short lifetime ($\tau < 15$ fs, Ref. 6) to the two lowest $J^\pi = 1^+$, $T_<$ states. No branch to the 0^+, $T_>$ state at $E_x = 0.677$ MeV has been reported.

A search for this branch was made at the $E_p = 731$ keV resonance in the reaction $^{29}Si(p,\gamma)^{30}P$ which has a 19% decay[7] to the 2^+, $T_>$ state at 4.183 MeV. An enriched (95%) $^{29}SiO_2$ target (thickness ≈ 5 keV) was bombarded with protons from the 3-MV Stanford Van de Graaff generator. Beam intensities were typically between 1 and 2 μA. The γ rays were detected with a Ge(Li) detector with an active volume of about 50 cm^3 and a resolution of 3.8 keV at 1333 keV. Spectra were taken on and off resonance with the Ge(Li) detector placed at angles of 35 and 90° at a distance of $d = 2.7$ cm. Figure 2 shows the interesting parts of a spectrum taken at 35° for a total accumulated charge of 100 mC. A normalized spectrum taken off resonance at the same angle has been subtracted from these data. In addition to the known $M1$, $\Delta T = 1$ transitions of energies 4.183 and 3.474 MeV, a weak γ ray at $E = 3.506$ MeV is observed which is identified as the missing analog $E2$, $\Delta T = 0$ transition on the basis of the following facts: (i) The γ ray is resonant; (ii) Its energy fits with the expected value and cannot be explained by any other possible

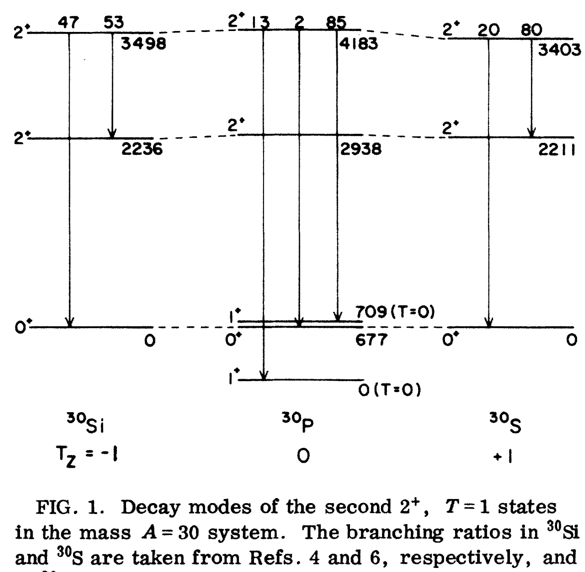

FIG. 1. Decay modes of the second 2^+, $T=1$ states in the mass $A=30$ system. The branching ratios in ^{30}Si and ^{30}S are taken from Refs. 4 and 6, respectively, and in ^{30}P from the present work. The energies are given in MeV. The isospin of all states is $T=1$ unless otherwise noted.

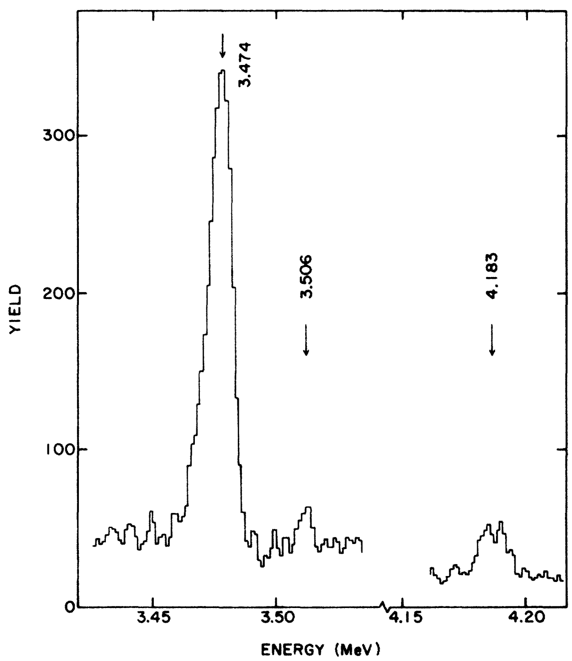

FIG. 2. Relevant parts of the γ-ray spectrum obtained with the Ge(Li) detector placed at 35°.

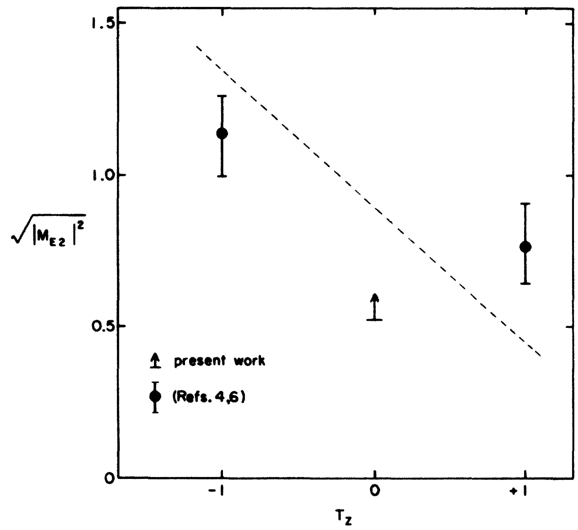

FIG. 3. The square roots of the $E2$ transition strengths plotted as a function of T_z. The transitions are those from the second 2^+, $T=1$ level to the lowest 0^+, $T=1$ levels in ^{30}Si ($T_z=-1$), ^{30}P(0), and ^{30}S(+1). The dashed line is obtained from a shell model calculation (Ref. 8).

transition between the known states of ^{30}P which could be produced in the reaction; (iii) Its observed Doppler shift of 5 ± 2 keV is of the same magnitude as that of the strong 3.474 MeV transition; (iv) The population parameters of the $E_x=4.183$ MeV state (as determined from the angular distribution of the 3.474 MeV transition) indicate that the intensity of the $2^+\to0^+$ transition should be larger at 35° than at 90°, as was indeed found in the spectra taken at these two angles. The branching ratio of this γ ray, corrected for angular correlation and the relative efficiency of the Ge(Li) detector, was estimated to be $2\pm1\%$. The strong branches to the ground state and the second excited state at $E_x=0.709$ MeV were found to be (13 ± 2) and $(85\pm2)\%$, respectively, which are in reasonable agreement with the values quoted in the literature.[6]

The value observed for the new branch limits the $E2$ strength to

$$|M_{E2}|^2>0.27\text{ W.u.}$$

This value then sets a lower limit on the squared isoscalar reduced transition matrix element S^2. From the complete set of transition strengths for the $A=30$ nuclei the following values for S^2 and V^2 are obtained:

$$S^2=0.9\pm0.3\text{ W.u.}$$

$$V^2=0.03\pm0.05\text{ W.u.}$$

The fact that the isoscalar part S^2 is the dominant term in the transition matrix elements is in agreement with results for the other known sets of analog transitions in this mass region. In Fig. 3 the square roots of the $E2$ strengths are plotted as a function of T_z; according to Eq. (1), they should lie on a straight line. For comparison, results of a shell model calculation[8] are also given. The over-all agreement is quite satisfactory.

With the isoscalar and the isovector parts of the $E2$ transition matrix elements now determined it is possible to give an approximate value for the lifetime of the second 2^+, $T_>$ state in ^{30}P which turns out to be

$$\tau=6.0\pm3.5\text{ fs.}$$

The $M1$ strengths of transitions to the ground state and the second excited state at 0.709 MeV are then estimated to be 0.93 ± 0.54 and 10.5 ± 6.0 (10^{-2} W.u.), which can be compared with the shell model values[8] of 7.0 and 4.9 (10^{-2} W.u.), respectively.

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