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States of ^{34}P†

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The ^{34}S(t,^{3}He)^{34}P reaction has been used to study the mass and low-lying excited states of ^{34}P, using 23 MeV tritons and a quadrupole-dipole-dipole spectrometer. The mass excess of ^{34}P is −24 545 (20) keV. Excited states have been observed at E_x = 423, 1605, 2225, 2309, and (3345) keV (±10 keV). Spectra of the ^{24}Mg(t,^{3}He)^{24}Na reaction show no evidence for a previously reported state at E_x = 2.46 MeV in ^{24}Na.

[NUCLEAR REACTIONS ^{34}S(t,^{3}He), ^{24}Mg(t,^{3}He), E = 23.0 MeV; measured $\sigma(\theta)$. ^{34}P deduced levels. New mass of ^{34}P. No evidence for previously reported state in ^{24}Na.]

I. INTRODUCTION

The ^{34}S(t, ^{3}He)^{34}P reaction provides a means of accurately measuring the mass and observing the low lying excited states of ^{34}P. The β^- decay of ^{34}P to several of the states of ^{34}S has been studied by Goosman, Davids, and Alburger.[1] They determined the half-life of ^{34}P to be 12.45 ± 0.10 sec and its mass excess to be − 24 546 ± 45 keV. The character of the decay to known states of ^{34}S determines $J^\pi = 1^+$ for the ground state of ^{34}P. No excited states of ^{34}P have been reported.[2]

II. EXPERIMENTAL PROCEDURES AND RESULTS

The ^{34}S(t, ^{3}He)^{34}P reaction was studied using a 23 MeV triton beam from the LASL three-stage Van de Graaff facility and a magnetic spectrometer of the Q3D type which uses a focal plane detector system involving a 1 m long helix detector with 0.8 mm spatial resolution.[3]

The Sb_2S_3 target, enriched[4] to 85.6% ^{34}S, was 140 μg/cm^2 thick and was deposited on a 30 μg/cm^2 carbon foil. At each angle at which the ^{3}He ions were detected, runs with an isotopic S target and an enriched ^{24}Mg target were also made. All targets were oriented at 30° to the incident triton beam.

The calibration of channel number versus the energy of the outgoing ^{3}He ions was made by studying the known groups from the (t, ^{3}He) reaction on ^{24}Mg: The excitation energies of states of ^{24}Na in the relevant excitation region are known[5,6] to ± 0.05 to ± 0.3 keV; the ground state Q value is[7] − 5496.0 ± 1.5 keV. The measurement of the ^{34}S(t, ^{3}He)^{34}P reaction was made at θ_{lab} = 20° → 35° in 5° steps. Angles smaller than 20° were impossible because of the large cross section of the ^{1}H(t, ^{3}He)n reaction which appears as a very broad peak.

Figure 1 shows typical spectra taken at θ_{lab} = 30° and 25°, at two values of the magnetic field. The groups labeled 0 → 5 correspond to the ground state and to excited states of ^{34}S: see Table I. The other peaks are due to excited states in ^{32}P, as

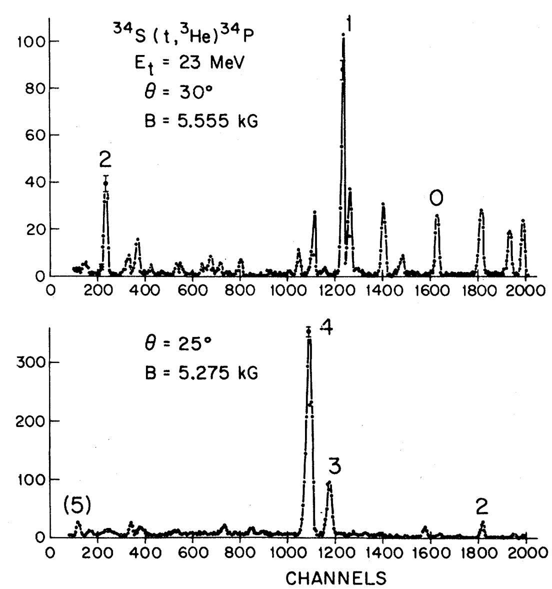

FIG. 1. Spectra of the ^{3}He ions from the ^{34}S(t, ^{3}He)^{34}P reaction at E_t = 23.0 MeV and at θ = 30° (B = 5.555 kG) and 25° (B = 5.275 kG). The ordinate shows the average number of counts recorded in a five-channel bin, the abscissas show the channel number. The numbered groups are due to states in ^{34}P: See Table I. Unnumbered groups are due to the ^{32}S(t, ^{3}He)^{32}P reaction.

TABLE I. States of ^{34}P from ^{34}S(t, ^{3}He)^{34}P.

Group No.[a]	E_x in ^{34}P (keV)	$\frac{d\sigma}{d\Omega}$[b] (μb/sr)
0	0[c]	4.2
1	423 ± 10	15
2	1605 ± 10	4.8
3	2225 ± 10	22
4	2309 ± 10	94
5	(3345)[d]	7

[a]See Fig. 1.
[b]E_t = 23 MeV, θ_{lab} = 25°; values are ±30%.
[c]Q_0 = −5.365 ± 0.020 MeV.
[d]Observed at only one angle because of experimental problems.

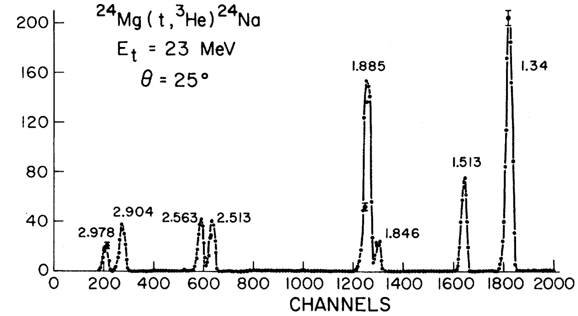

FIG. 2. Spectrum of the ^{3}He ions from the ^{24}Mg(t, ^{3}He)-^{24}Na reaction at θ = 25°, E_t = 23.0 MeV. The numbers which label each of the groups correspond to the excitation energies of known (Refs. 5 and 6) states of ^{24}Na, in MeV. The group labeled 1.34 comprises an unresolved group of three states. A state previously reported at E_x = 2.464 ± 0.008 MeV (see Ref. 2) is not observed. See also the caption of Fig. 1.

determined from the background runs made with the isotopic target. We determine the mass excess of ^{34}P to be − 24 545 ± 20 keV (using the masses for ^{34}S, t, and ^{3}He suggested by Wapstra and Gove[8]) from our measurement for Q_0 = − 5365 ± 20 keV. This value is in excellent agreement with the value for Q_0 determined from the mass excess of Goosman, Davids, and Alburger,[1] − 5365 ± 45 keV, and in very poor agreement with the earlier reports discussed in Ref. 2 of − 5030 ± 140 keV.

Figure 2 shows one of the calibration spectra of the ^{24}Mg(t, ^{3}He)^{24}Na reaction: We show it to demonstrate that the state at 2464 ± 8 keV, reported in Ref. 2, is not observed. It has not been observed either in the recent[5,6] ^{23}Na(d, p)^{24}Na work. The spectrum also serves to illustrate the resolution achieved in this work.

III. DISCUSSION

Since the ground state of ^{34}P has $J^{\pi} = 1^{+}$ it is likely that the 423 keV state is the other member of the $(2s_{1/2}^{-1}, 1d_{3/2}^{1})$ configuration, i.e., the 2^{+} state. The large energy gap to the next state of ^{34}P at 1605 keV reflects the large gap in single particle orbitals which is known[2] to occur for both neutron and proton holes as evidenced by ^{35}S and ^{33}P, respectively. States at E_x = 1.57 and 1.99 MeV (involving l transfers of 0 and 3) have been observed in the ^{34}S(d, p)^{35}S reaction by Kolalis *et al.*[9]: the spectroscopic strengths, $(2J+1)\,S_n$ are 0.5 and 3.0, respectively. A proton-hole state at E_x = 1.85 MeV in ^{33}P has been studied by Bearse, Youngblood, and Yntema[10] using the ^{34}S(d, ^{3}He)^{33}P reaction: $l = 2, S_p = 6.7$. One might then expect configurations in the region of $E_x \sim 1.5$ MeV of the type $(\nu s_{1/2} \times \pi s_{1/2})_{0^+,1^+}(\nu f_{7/2} \times \pi s_{1/2})_{3^-,4^-}$ and $(\nu d_{3/2} \times \pi d_{5/2})_{1^+ \to 4^+}$. Only three levels are seen in this region in ^{34}P but it is interesting to speculate on their origin. The levels at E_x = 2.23 and 2.31 MeV are quite strong relative to the low lying states. This situation is reminiscent of the situation in the ^{64}Zn(t, ^{3}He)^{64}Cu reaction[11] where large cross sections are seen to excited states containing neutron strength from an orbital of high degeneracy (the $g_{9/2}$ orbital) and having a parity opposite to that of the low lying states. In the present system the $(\nu f_{7/2} \times \pi s_{1/2})_{3^-,4^-}$ would satisfy such conditions: The 3^- state is the strongest group seen in the ^{64}Zn(t, ^{3}He)^{64}Cu reaction.

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