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New high-spin state at 3.95 MeV in ^{19}O[‡]

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Results of the ^{13}C(^{7}Li, p)^{19}O reaction, at a bombarding energy of 16.0 MeV, suggest the existence of a new state at 3946.8 ± 2.5 keV in ^{19}O, having $J^\pi = \frac{7}{2}^-, \frac{9}{2}^\pm, \frac{11}{2}^\pm$, or $\frac{13}{2}^+$, with $\frac{9}{2}^-$ or $\frac{7}{2}^-$ preferred.

[NUCLEAR REACTIONS ^{13}C(^{7}Li, p), $E(^7\text{Li}) = 16.0$ MeV, $E_x = 3.95$ MeV, new high-spin state.]

A state at an excitation energy of 3.945 MeV[1] in ^{19}O is populated with an $l = 1$ angular distribution[2,3] in the reaction ^{18}O(d,p)^{19}O, leading to a spin-parity assignment of $(\frac{1}{2}, \frac{3}{2})^-$. Measurement of vector analyzing power in the same reaction with polarized deuterons[3] yields a unique J^π assignment of $\frac{3}{2}^-$. And yet, this state is populated extremely strongly in the reaction ^{13}C(^{7}Li,p)^{19}O, implying that the state has high spin. The only consistent explanation is that a doublet exists here.

A spectrum of the ^{13}C(^{7}Li,p)^{19}O reaction obtained at a bombarding energy of 16.0 MeV and a laboratory angle of 78.75° ($\theta_{\text{c.m.}} \approx 87°$) is displayed in Fig. 1. Experimental details have been described previously.[4]

The 3.945-MeV state is the strongest state in the spectrum. Its angular distribution is plotted in Fig. 2. The extracted excitation energy, averaged over the first 12 angles and measured relative to the strong 2778.7 ±0.8-keV[1] level is 3946.8 ±2.5 keV.

In a previous study[4] of this reaction at the same bombarding energy, it was observed that the angle-integrated cross sections, σ_{tot}, were proportional to $2J+1$, where J is the spin of the final state. Similar results from the present study are displayed in Fig. 3. Here, σ_{tot} is plotted as a function of $2J+1$ for all states below 5.3 MeV that have unique J^π assignments. The linear relationship is obvious. This result is expected, of course, for a compound-nucleus reaction if certain conditions hold.[5] The first people to use the $2J+1$ rule in connection with Li-induced reactions were Carlson and McGrath.[6] It was used much earlier in other reactions.[7]

In the present work, the average value of $\sigma_{\text{tot}}/(2J+1)$ is 14.9 for positive-parity states and 19.9 for negative-parity states. (Such differences between negative- and positive-parity states have been observed previously.[8]) From these results, we would have expected a total cross section for the 3.945-MeV state of about 80 μb. Yet the observed cross section is 269 μb, more than three times the expected value. It thus appears that the 3.945-MeV "state" is actually a doublet, with the new member having high spin. If we subtract the expected contribution for a $\frac{3}{2}^-$ state, we are left with a σ_{tot} of 189 μb, still larger than that observed for any other low-lying state. Using the measured values of $\sigma_{\text{tot}}/(2J+1)$, this would imply $2J+1 \approx 9.5$, $J = \frac{9}{2}$, if the new state has negative parity, and $2J+1 \approx 12.7$, $J = \frac{11}{2}$, if it has positive parity. It would appear, then, that this new state is either $J^\pi = \frac{9}{2}^-$ or $\frac{11}{2}^+$. We would not expect the present results to be off by more than one unit of J, so that $J^\pi = (\frac{9}{2}, \frac{7}{2}, \frac{11}{2})^-$ or $(\frac{11}{2}, \frac{9}{2}, \frac{13}{2})^+$.

Shell-model calculations[9] predict the second $\frac{9}{2}^+$ state in ^{19}O at 5.61 MeV, the first $\frac{11}{2}^+$ state at 6.99 MeV, and the first $\frac{13}{2}^+$ state at 9.35 MeV. So it is unlikely that the new state has positive parity. However, if excitations out of the $1p$ shell are allowed, a number of negative-parity states are expected at low excitation energies. In fact, in a shell-model calculation[9] that assumes a ^{12}C core and allows particles to occupy the $1p_{1/2}$, $1d_{5/2}$, and $2s_{1/2}$ orbitals, $\frac{7}{2}^-$ states are predicted

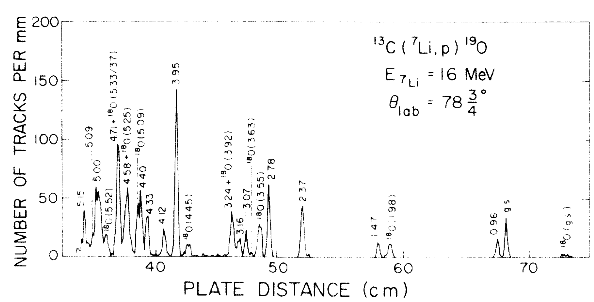

FIG. 1. Spectrum of the ^{13}C(^{7}Li, p)^{19}O reaction, at a bombarding energy of 16.0 MeV and a laboratory angle of 78.75°.

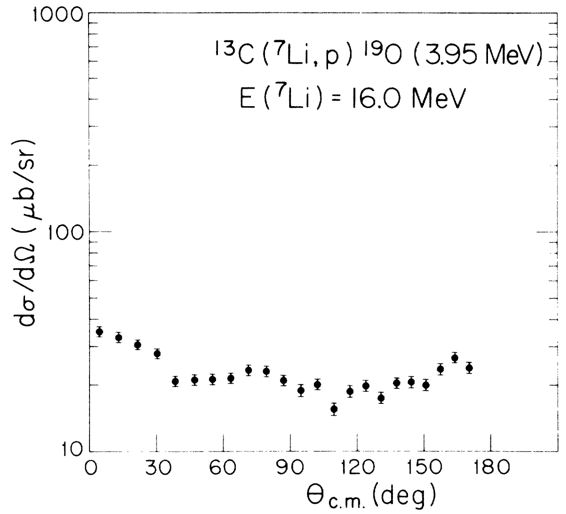

FIG. 2. Angular distribution of the ^{13}C(^{7}Li, p)^{19}O reaction leading to a state at 3946.8 ± 2.5 keV in ^{19}O.

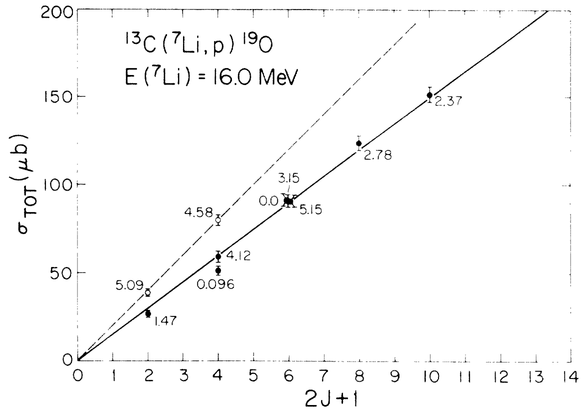

FIG. 3. Plot of σ_{tot} (angle-integrated cross sections 0°–180°) vs $2J+1$ for all states below 5.3 MeV in ^{19}O with known J^π values.

at energies of 4.01 and 4.97 MeV, and $\frac{9}{2}^-$ states at 4.29 and 4.72 MeV. So, a $\frac{9}{2}^-$ or $\frac{7}{2}^-$ state at 3.95 MeV is not at all unreasonable.

Clearly, an investigation of the γ decay of this state is necessary for a rigorous spin assignment. A state at 3.95 MeV has been reported[10] to γ decay to the $\frac{5}{2}^+$ g.s. (24 ±8%), to the $\frac{3}{2}^+$, 0.096-MeV state (48 ±8%), and to the $\frac{1}{2}^+$, 1.47-MeV state (28 ±4%), with no decay greater than 15% to other states. However, in that study, the state was populated in the ^{18}O(d,p)^{19}O reaction, which is unlikely to strongly excite a high-spin state. The present reaction might provide a means of populating the high-spin member of the doublet for γ-decay studies, although the measured cross section at 16 MeV is fairly small (~40 μb/sr at forward angles).

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