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Assignment of 0^- to the 2.99-MeV level in ^{38}K via the ^{40}Ca(d, α)^{38}K reaction

D. G. Rickel, N. R. Roberson, and J. David Turner
Duke University and Triangle Universities Nuclear Laboratory, Duke Station, Durham, N. C. 27706*

H. R. Weller†
University of Florida, Gainesville, Florida 32611
and Triangle Universities Nuclear Laboratory, Duke Station, Durham, North Carolina 27706*

D. R. Tilley
North Carolina State University, Raleigh, N. C. 27607
and Triangle Universities Nuclear Laboratory, Duke Station, Durham, North Carolina 27706*

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The ^{40}Ca(d, α)^{38}K reaction has been studied with a tensor polarized deuteron beam using an annular detector at 180°. These measurements allow a 0^- assignment to be made to the 2.99-MeV level in ^{38}K.

[NUCLEAR REACTIONS ^{40}Ca(d, α). Measured $\sigma(180°)$ with tensor polarized beam. Deduced J^π.]

It has been shown[1,2] that the α particle yield at 0° and 180° for the (d,α) reaction on a 0^+ target vanishes when populating natural parity levels if the incident deuteron beam is polarized along the beam axis with $t_{20} = -\sqrt{2}$.[3] This result follows from simple angular momentum coupling arguments. For similar reasons, a yield from 0^- levels can only be obtained at 0° and 180° if there is an $m_s = 0$ component of the beam. The yield, therefore, is a maximum for these angles when $t_{20} = -\sqrt{2}$. For other unnatural parity levels there are no similar constraints.

The analyzing power T_{20}[4] is given by

$$T_{20} = \sqrt{2}\,\frac{N_1 - N_0}{2N_1 + N_0},$$

where N_1 is the α particle yield for the level of interest with a deuteron beam with $t_{20} = Q/\sqrt{2}$ and N_0 is the yield with $t_{20} = -Q\sqrt{2}$. The first t_{20} indicates that most of the deuterons have $m_s = +1$ while the second indicates $m_s = 0$. The quantity Q is the quench ratio[5] and is a measure of the deviation of the tensor polarization from the maximum possible value. For $Q = 0.74$, T_{20} should be 0.52 for natural parity levels and -1.05 for 0^- levels. For other unnatural parity levels, T_{20} fluctuates between these two values as a function of deuteron energy. It has been argued[6] that in this instance, for a sufficient number of measurements taken over an adequate energy region, T_{20} should average to -0.27. Thus the behavior of T_{20} with changing deuteron energy becomes an indicator of whether a level being populated has natural or unnatural parity or is 0^-. This effect has recently been used to make level assignments in several nuclei.[6,7] In the present work the technique was applied to the reaction ^{40}Ca(d, α)^{38}K to resolve the 0^-, 1^+ uncertainty[8] in the assignment of the 2.99-MeV level of ^{38}K.

The α particle yields were measured at 180° for several levels in ^{38}K, including the 2.99-MeV level, at deuteron energies ranging from 5.9 to 6.8 MeV. A recent detailed study of the ^{40}Ca(d, α)^{38}K reaction located the level of interest (hereafter referred to as the 2.99-MeV level) at 2991.9 ± 1.3 keV.[9] This high-resolution spectrograph study showed no evidence for the existence of a previously proposed[10] level at 3.05 MeV in ^{38}K. Therefore, the possibility that our data could be contaminated by a second level near 3 MeV in ^{38}K can confidently be ruled out. The deuteron beams with tensor polarization were produced by the Triangle University Nuclear Laboratory (TUNL) Lamb shift polarized ion source and had quench ratios of 0.74 ± 0.03. A self-supporting foil of natural calcium was used for the target which was placed at a distance of 108 mm from a 300 mm^2 annular silicon surface barrier detector. The detector was fully depleted with a thickness of 80 μm, which was adequate to stop the α particles but not the elastically scattered deuterons. The detector subtended an angle of 178.2° to 175.3° with respect to the beam. The energy resolution of the system, including kinematics broadening and target thickness effects, was approximately 40 keV. The α particle spectra at $E_d = 6.4$ MeV for beam polarizations of $m_s = +1$ and 0 are shown in Fig. 1.

The areas of the peaks labeled in these spectra were computed for all of the deuteron energies by summing the counts in the region of interest and subtracting the background which was determined by fitting a linear plus Gaussian function to the data. Table I lists the analyzing powers T_{20} of

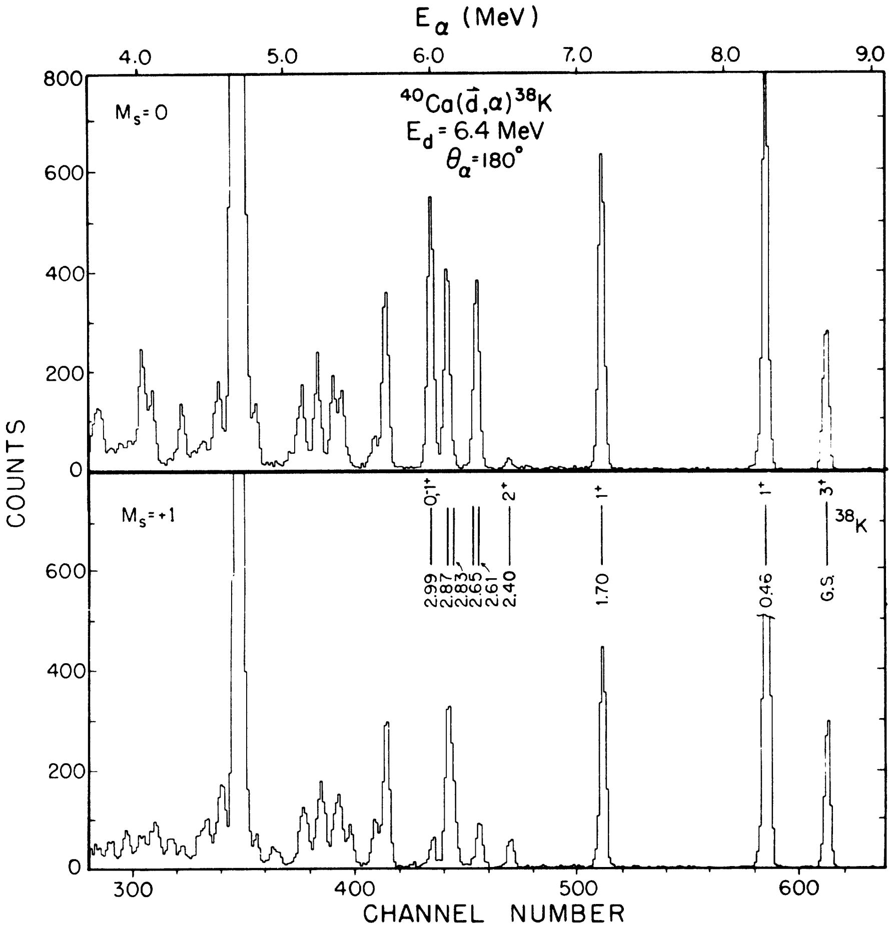

FIG. 1. Comparison of the α particle spectra for $m_s = 0$ and $m_s = 1$ incident deuterons.

several levels up to and including the 2.99-MeV level. From this table it is seen that the 1^+ and 3^+ levels (unnatural parity) have analyzing powers with fluctuations much greater than the uncertainties in the measurements. The values of T_{20} for the 2^+ level at 2.40 MeV and the 2.99-MeV level remain constant within the uncertainties at all the deuteron energies. This is expected for the 2^+ level since it has natural parity. The average value and average error of T_{20} for this case are 0.45 ±0.05, very close to the predicted value of 0.52. Since the average value and average error of T_{20} for the 2.99-MeV level are -1.02 ± 0.05, it is concluded that the assignment of this level must be 0^-. The fact that the measured T_{20} for the natural parity level and the 0^- level differed slightly from the predicted values can be attributed to the finite acceptance angle of the particle detector and uncertainties in the measured beam polarization. The results of this experiment reemphasize the power of this recently proposed technique[2] for identifying 0^- levels in odd-odd nuclei.

TABLE I. The experimentally determined analyzing powers T_{20} obtained at $\theta_{lab} = 180°$ as described in the text. The errors represent the statistical uncertainties associated with the measured quantities. No entry implies that at these energies the population of the state was too small to obtain meaningful results.

E_x (MeV)	J^π	E_d(MeV) 5.9	6.1	6.4	6.6	6.8
0.0	3^+	0.35 ± 0.02	-0.04 ± 0.01	-0.02 ± 0.02	0.49 ± 0.01	0.21 ± 0.03
0.459	1^+	0.46 ± 0.01	-1.01 ± 0.01	0.13 ± 0.01	0.45 ± 0.02	-0.99 ± 0.01
1.698	1^+	-0.84 ± 0.02	-0.16 ± 0.02	-0.17 ± 0.02	-0.77 ± 0.02	-0.26 ± 0.04
2.403	2^+	0.44 ± 0.05	0.53 ± 0.05	0.39 ± 0.05		0.42 ± 0.06
2.992	0^-	-1.08 ± 0.09	-0.98 ± 0.05	-1.03 ± 0.03	-1.00 ± 0.05	

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