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Li^7 Quadrupole Moment. III*

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The electric-quadrupole moment Q of the Li^7 nucleus has been calculated on the basis of the Wigner supermultiplet theory with configuration mixing that preserves the partition symmetry and LS coupling. The experimental value of Q can be obtained with an *ad hoc* mixture of configurations in which the p shell alone is excited and in which the ground configuration is predominant (65%). The linearly independent symmetrized seven-nucleon wave functions for the $^{22}P[4+3]$ states arising from the $1s^31p^31d$ configuration have been constructed and the matrix elements of Q evaluated. The experimental value of Q can be obtained with *ad hoc* mixtures of $1s^41p^3$, $1s^41p^22p$, $1s^41p^21f$, and $1s^31p^31d$ in which the proportion of the ground configuration is over 85%. All of the electromagnetic and beta-decay properties of the $A=7$ nuclei are explained on this model.

THE electromagnetic properties of the Li^7 nucleus and the Be^7 K-capture process have been treated in two previous papers[1,2] on the basis of the supermultiplet theory with configuration interaction. It has been shown that the good agreements between the supermultiplet theory and experimental results for the magnetic moment, the magnetic dipole strength $B(M1)$ for the $^2P_{1/2}\rightarrow{}^2P_{3/2}$ transition between the lowest states, and the Gamow-Teller matrix element for the Be^7 K capture are all unaffected by configuration admixtures preserving the partition symmetry and LS coupling. The theory also predicts a relation between the electric-quadrupole moment Q and the electric-quadrupole strength $B(E2)$ for the $^2P_{1/2}\rightarrow{}^2P_{3/2}$ transition, which is independent of the configuration admixture and is also in good agreement with experiment.[2,3] Configuration mixing is needed to understand the magnitudes of the experimental values[4,5] of Q and $B(E2)$, which are both larger than predicted from the ground configuration $1s^41p^3$.

In I and II the admixed $^{22}P[3]$ states were derived from the configurations $1s^41p^21f$ (one) and $1s^41p^22p$ (two states), and we found that the largest negative value of Q obtainable from the mixture (i.e., the lowest eigenvalue of the Q matrix) was $-0.4456\langle r^2\rangle_{1p}\approx-0.045$ b. The "experimental" value of Q is -0.043 b and is subject to several uncertainties as discussed in II. The proportion of $1s^41p^3$ in the corresponding eigenfunction was found to be 35%. We wish to point out first that the value of Q changes very little, near the lowest eigenvalue, when the proportions of the mixture are altered, and that a value of $Q=-0.410\langle r^2\rangle_{1p}$ can be obtained with a mixture of the same states which is predominantly $1s^41p^3$ (60%). By including the $1s^41p^23p$ configuration we have obtained $Q=-0.429\langle r^2\rangle_{1p}$ with the mixture: $1s^41p^3$ (65%), $1s^41p^21f$ (10%), $1s^41p^22p$ (20%), and $1s^41p^23p$ (5%).

We have now included the $^{22}P[4+3]$ states arising from the configuration $1s^31p^31d$. The symmetrized seven-nucleon wave function for the state $^{22}P_{3/2}$ ($1s^31d\,D[4]$, $1p^3\,P[3]$) is given by[6]

$$\Psi_d=(3!4!)^{-1/2}\sum_{P_\pi,P_\nu}(-1)^{P_\pi+P_\nu}P_\pi P_\nu\Phi_{P^1}\{D_{1s^31d[4]}(1234)\times P_{1p^3[3]}(567)\}\times\alpha_1\beta_2\alpha_3\beta_4\alpha_5\alpha_6\beta_7,$$

where the neutrons are labeled 1, 2, 6, 7 and the protons 3, 4, 5. The orbital function Φ_{P^1} is vectorially composed from the symmetrized $1s^31d\,D[4]$ and $1p^3\,P[3]$ state functions. The diagonal matrix element of Q for the function Ψ_d is $-(41/250)\langle r^2\rangle_{1p}$ and the nondiagonal element connecting Ψ_d with the ground state is $(30^{1/2}/25)\langle r^2\rangle_{1p}$; there are no connecting elements to the other states. We have considered mixtures of this $1s^31p^31d$ state with $1s^41p^3$, $1s^41p^21f$, and with one of the $1s^41p^22p$ states (the other is unimportant). A value of $Q=-0.425\langle r^2\rangle_{1p}$ can now be obtained with the mixture: $1s^41p^3$ (80%), $1s^41p^21f$ (6%), $1s^41p^22p$ (12%), and $1s^31p^31d$ (2%), and also with the mixture: $1s^41p^3$ (86%), $1s^41p^21f$ (2%), $1s^41p^22p$ (4%) and $1s^31p^31d$ (8%). The phases of the $1s^41p^21f$ and $1s^31p^31d$ states are opposite to those of the $1s^41p^3$ and $1s^41p^22p$ states. Thus the configuration $1s^31p^31d$ is particularly helpful in explaining a large value of $|Q|$.[7] We have also constructed two linearly independent $1s^31p^31d$ functions for the state $^{22}P_{3/2}(1s^3S[3], 1p^31dP[4])$ and find that they make a small additional contribution to the value of Q. Details of the construction of the seven-nucleon wave functions and the calculation of the matrix elements of Q will be published later.

The other low configurations, degenerate in the oscillator potential with those already considered, are: $1s^31p^32s$, $1s^21p^5$, $1s^41p2s^2$, $1s^41p1d^2$, and $1s^41p2s1d$. Higher configurations of interest are: $1s^41p^23p$, $1s^41p^22f$,

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[7] This was pointed out by D. Kurath (see footnote 23 of II).

$1s^41p2p^2$, and $1s^41p1f^2$. The matrix elements of Q connecting each of these nine configurations with the ground configuration all vanish and therefore these configurations have little influence on the value of Q. In conclusion it appears that the electromagnetic and beta-decay properties of the $A=7$ nuclei can be satisfactorily understood on the basis of the supermultiplet theory with configuration admixtures that preserve the partition symmetry and LS coupling. We wish to stress the uncertainties in the "experimental" value of Q and in the values of $\langle r^2\rangle_{1p}$ and the radial integrals, which were evaluated with oscillator eigenfunctions, and also the insensitivity of Q to variations in the proportions of the configuration admixture.

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O^{17} and O^{19} Lifetimes by a Particle-Gamma Coincidence Technique

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Lifetimes of the 96-keV and 1.47-MeV levels in O^{19} produced by the $O^{18}(d,p)O^{19}$ reaction have been measured from the distribution of time delays between protons and the appropriate decaying gamma rays. A solid-state detector was used both as a timing and as an energy-measuring device for the protons. The time-delay distributions were obtained with a time-to-height converter in the normal fast-slow coincidence arrangement. The measured half-lives of the 96-keV and 1.47-MeV levels in O^{19} are 1.39 ± 0.05 nsec and ≤ 75 psec, respectively. These results are compared with intermediate-coupling shell-model calculations. Using this particle-gamma coincidence technique a remeasurement of the lifetime for the 871-keV level in O^{17} produced by the $O^{16}(d,p)\,O^{17}$ reaction resulted in a half-life of 182 ± 5 psec.

I. INTRODUCTION

LOW-LYING states of the O^{19} nucleus have been studied both theoretically and experimentally. Intermediate-coupling shell-model calculations[1] predict a $\frac{5}{2}^+$ ground state and two states within about 1 MeV of the ground state with spins and parities of $\frac{3}{2}^+$ and $\frac{1}{2}^+$. Experimentally, levels are known to exist at 96 keV and 1.47 MeV.[2]

Stripping angular distributions for the $O^{18}(d,p)O^{19}$ reaction[3,4] indicate the transfer of $l_n=2$ and $l_n=0$ neutrons for the ground state and 1.47-MeV state, respectively, while the 96-keV state did not show a stripping pattern. These l values imply a $\frac{1}{2}^+$ assignment for the 1.47-MeV level and allow either $\frac{5}{2}^+$ or $\frac{3}{2}^+$ for the ground state. Beta-decay studies[2,5] favor the $\frac{5}{2}^+$ assignment for the ground state.

Givens *et al.*[6] determined the parity of the 96-keV level to be positive from a measurement of its K-conversion coefficient which implied an $M1$ transition and hence an even parity relative to the ground state. Angular correlation results of Allen[7] unambiguously assign a spin of $\frac{3}{2}$ to this level. This $\frac{3}{2}^+$ assignment for the 96-keV level is in agreement with the associated shell-model wave functions[1] which predict the observed small stripping width.

Zimmerman[4] has measured the lifetime of the 96-keV level as $t_{1/2}=1.21\pm0.20$ nsec by a recoil technique using the $O^{18}(d,p)O^{19}$ reaction. In this previous experiment, gamma rays were observed from recoiling excited O^{19} nuclei at various distances from the target; the lifetime was determined from a knowledge of the recoil velocity. Rather large uncertainties in the lifetime result from background corrections and the difficulty of determining precisely the stopping power for the O^{19} nuclei in the target. In addition, this measurement requires that the lifetime of the 1.47-MeV state is short relative to that of the 96-keV state, since the 96-keV state is populated predominantly by 1.37-MeV cascade gamma rays. The fact that the lifetime of the 1.47-MeV state satisfies this criterion was based partially on single-particle estimates for this transition.

Because of the success of the intermediate-coupling shell-model calculations for s-d nuclei, further information and accuracy on the lifetimes of the 1.47-MeV and 96-keV states of O^{19} are important as a closer check on the wave functions for these states. Thus, it is the purpose of this experiment to measure these lifetimes in a direct manner which is capable of ac-

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