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Structure of light proton-rich nuclei on the drip-line

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1. INTRODUCTION

Among proton-rich unstable nuclei on the light proton drip-line, nuclear structure of ^{21}Mg, ^{17}Ne, ^{13}O, ^{11}N and ^{9}C have been investigated by the three-neutron pick-up reaction (^{3}He,^{6}He). The angular distributions measured for this reaction have shown a characteristic feature of a transferred angular-momentum (L) dependence [1,2], which provides spin-parity assignments for the new levels in these nuclei. Here, the results on the nuclear structure of ^{17}Ne and ^{11}N are reported.

The nucleus ^{17}Ne was almost unknown before, except that the mass excess had been determined and a few states had been suggested [3]. Many $T = \frac{3}{2}$ states were known in the other three members (^{17}N, ^{17}O and ^{17}F). Thus, the inclusion of the data on ^{17}Ne levels has enabled an extensive analysis in terms of the Isobaric Multiplet Mass Equation (IMME) for several excited state quartets. This is the first report on such an extensive analysis in the same mass system for a wide range in excitation energy.

The ^{11}N nucleus was investigated to learn about the structure of A = 11 system. This mass has been intensively studied, specially because of the halo structure observed in ^{11}Li and the spin parity-inversion of the ^{11}Be ground-state. The ^{11}N nucleus was totally unkwon before except for the possible ground-state [4].

2. STRUCTURE OF ^{17}NE AND THE LEVEL SHIFT

The $^{20}Ne(^3He,^6He)^{17}Ne$ and $^{14}N(^3He,^6He)^{11}N$ experiments were performed at the Sector-Focusing Cyclotron of the Institute for Nuclear Study, University of Tokyo. In these experiments the incident energy of the ^3He beam was about 70 MeV and a gas target was filled with isotopically enriched ^{20}Ne and $^{nat}N_2$. The momentum spectra of ^6He particles were measured by a high resolution QDD-type magnetic spectrograph [5] and detected by a hybrid-type gas proportional counter placed on the focal plane [6]. A thin plastic scintillator was set just behind the proportional counter for energy and time-of-flight measurements.

The energy spectrum of the low-lying levels in ^{17}Ne is shown in Figure 1. This spectrum is the summation of all the energy spectra obtained between $\Theta_{LAB} = 7.0^o$ and 38.0^o. Each spectrum used in this summation were normalized to the spectrum at 10.0^o for the integrated charge, the target thickness and the solid angle. The transferred angular momentum, the spin and the parity were assigned for nine of these levels. The low-lying negative-parity states in ^{17}Ne arise from coupling a $p_{\frac{1}{2}}$ neutron-hole to low-lying positive-parity states in ^{18}Ne. Besides these $2p-1h$ configurations, positive parity states of $3p-2h$ configuration are also present.

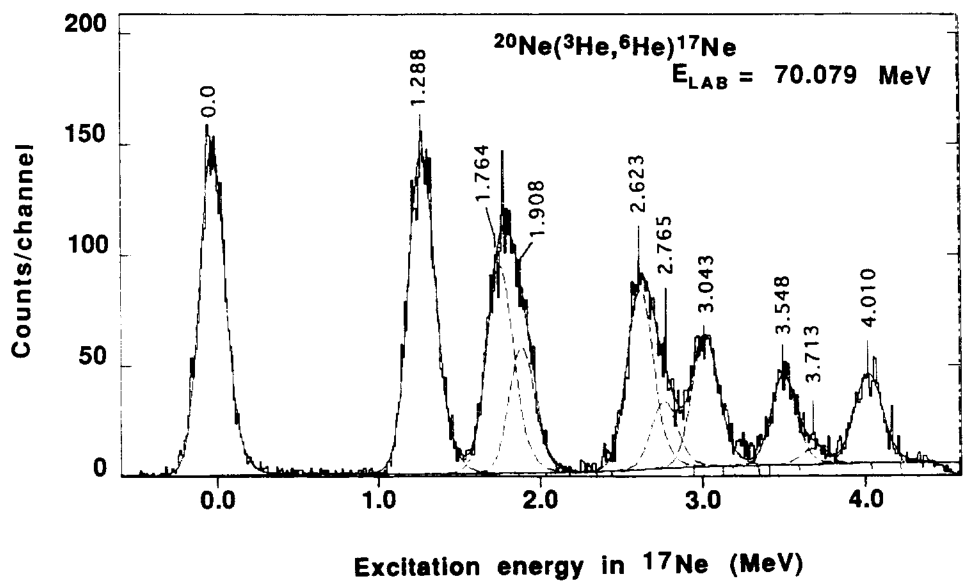

Figure 1: The summed energy spectrum of ^{17}Ne.

The $T = \frac{3}{2}$ quartet analog states in mass A = 17 have been completed for six levels, namely, $\frac{1}{2}^-, \frac{3}{2}^-, \frac{5}{2}^-, \frac{1}{2}^+, \frac{5}{2}^+$ and $\frac{7}{2}^-$. Using the mass excess energies of the four members of the multiplets, an analysis in terms of the IMME, $M(A,T_z) = a + b \cdot T_z + c \cdot T_z^2 + d \cdot T_z^3$, was performed. The b, c and d coefficients plotted as a function of excitation energy in ^{17}Ne are shown in Figure 2. As can be seen in the figure, the b and c coefficients for the negative parity states have a weak linear dependence on excitation energy.

The systematics of the b coefficients for the negative parity states is opposite to the A dependence, which is $b(A) \approx -0.2A$ for $A \leq 40$. However, this systematics of A dependence included only coefficients for ground-states and for some few first excited states [7]. The c coefficients have an oscillatory behavior as a function of mass, while the systematics obtained here show a slight linear dependence. The systematics of the b coefficients for the positive and negative parity states seem to be consistent with the $3p-2h$ and $2p-1h$ configurations expected, respectively, for these states.

The d coefficient obtained for the negative parity states are consistent with zero. However, the d coefficient derived for the positive-parity $\frac{5}{2}^+$ state has a significant deviation from zero ($d = -17.0 \pm 6.9\ keV$). A non-zero d, i.e., a deviation from the standard IMME (including c coefficient), suggests significant second or higher order perturbation corrections of the Coulomb interaction or charge-symmetry breaking nuclear interactions. Another possibility is that the reduction of the Coulomb energy due to the radial expansion of the wave function of the valence nucleons produces a non-zero d coefficient [8]. In the neutron-rich members of a multiplet the neutrons are converted to protons in the analog states, and due to increase of the Coulomb repulsion, the wave function would radially extend to some degree. If the nucleons are barely bound or unbound, i.e., on or near the top of the potential barrier, the extention may be even more accentuated. This could be the case for the present $\frac{5}{2}^+$ state, which is unbound by 1123 keV, while the $\frac{1}{2}^+$ state is unbound by only 408 keV.

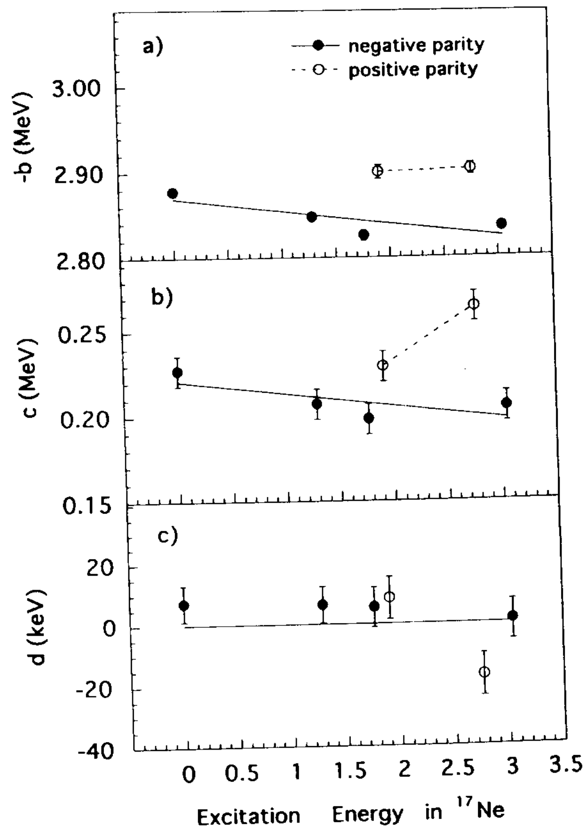

Figure 2: The coefficients of the IMME as a function of the excitation energy in ^{17}Ne; **(a)** the b coefficients, **(b)** the c coefficients and **(c)** the d coefficients.

3. STRUCTURE OF ^{11}N

The structure of ^{11}N was investigated by the ^{14}N(^{3}He,^{6}He)^{11}N reaction, and the energy spectra at 9 angles between $\theta_{LAB} = 6.8^o$ to 25.0^o were obtained. The peak corresponding to the previously known possible ground-state was resolved in two peaks. The angular distributions observed for these two peaks have shown distinct behaviors at the forward angles indicating that they may correspond to different transferred angular momentum dependence. This supports the possible assingment $J^\pi = \frac{1}{2}^+$ and $J^\pi = \frac{1}{2}^-$ for the first two level. Some other excited states were also obverved and more detailed analysis on these levels are in progress. Nuclear structure of A=11 system will be studied based on the results.

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