UNBOUND NUCLIDE ^{7}B†

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(Received 10 November 1967)

The mass and width of the ^{7}B ground state have been measured using the reaction ^{10}B(^{3}He, ^{6}He)^{7}B, thus completing the mass-seven isospin quartet. During the course of the experiment new values for the excitation energies of the ^{8}B second excited state and the ^{7}Li and ^{7}Be lowest $T=\frac{3}{2}$ states were found.

The mass and width of the ground state of the $T_z=\frac{3}{2}$ unbound nuclide ^{7}B have been measured using the reaction ^{10}B(^{3}He, ^{6}He)^{7}B. These data, together with those recently reported[1] on ^{7}He, complete the mass-seven isospin quartet in which all members are unbound with respect to $T=\frac{3}{2}$ particle-decay modes. Previously, the mass 9, 13, 21, and 37 bound $T=\frac{3}{2}$ quartets have been completed[2-4] and in general (but see Ref. 3) the isobaric multiplet mass equation[5] (IMME) correctly described the measured masses.

A 50-MeV ^{3}He beam generated by the Berkeley 88-in. cyclotron was used to bombard a 280-μg/cm^2 carbon-backed ^{10}B target, and reactions induced on a 300-μg/cm^2 ^{11}B target were used for energy calibrations. Since (^{3}He, ^{6}He) reactions on light targets typically have laboratory cross sections of ~1 to 4 μb/sr,[4] a particle identification system for low-yield nuclear reactions was employed. This system utilizes two four-counter semiconductor telescopes and has been previously described.[4,6] Both telescopes were similar; one consisted of a 142-μ $\Delta E2$, 109-μ $\Delta E1$, 147-μ E, and 500-μ E-reject (anticoincidence) counter. The data were acquired and treated in a manner completely analogous to that described in Ref. 4.

The ^{6}He energy spectra taken at 14.1° (laboratory) arising from bombardment of both ^{10}B and ^{11}B targets are shown in Fig. 1. Counter thicknesses and a requirement of 2.5-MeV minimum energy loss in the E counter limited observable ^{6}He events to energies between ≈34 and 26 MeV. The original data were summed over ten channels to improve the statistics; the over-all resolution was about 230 keV. Because of a 7% ^{11}B impurity in the ^{10}B target, there is a small peak in the upper spectrum of Fig. 1 that corresponds to the ^{8}B ground state.

The close similarity of the Q values and kinematics of the reactions ^{10}B(^{3}He, ^{6}He)^{7}B and ^{11}B(^{3}He, ^{6}He)^{8}B made the latter useful for energy calibrations. The reported ^{8}B level structure[7] consisted of the ground, 0.78-, and 2.17-MeV states. Since a 2.17-MeV excitation for the ^{8}B second excited state appeared inconsistent with the ^{11}B(^{3}He, ^{6}He)^{8}B data, the reaction ^{10}B(p,t)^{8}B was investigated at six angles with 43.7-MeV protons. Triton peaks corresponding to the ^{10}C and ^{14}O ground states, due to ^{12}C and ^{16}O target contaminants, offered excellent energy calibrations. The excitation and width (full width at half-maximum) of this ^{8}B state were found to be 2.33±0.04 MeV and 390±40 keV; this new excitation was adopted in establishing the ^{7}B mass.

Figure 2 shows a ^{6}He energy spectrum constructed by summing data from both telescopes placed at 14.1° and subtracting the ^{8}B impuri-

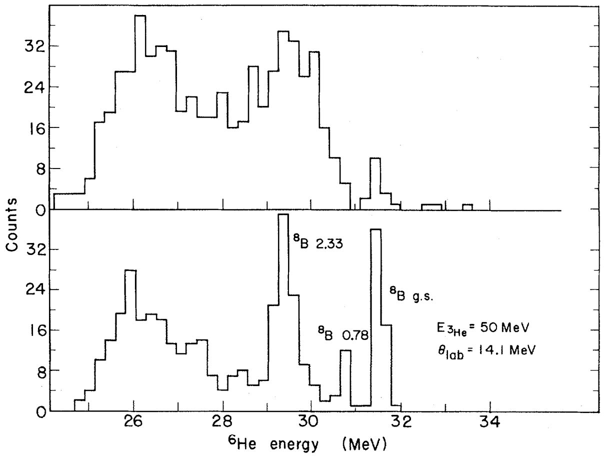

FIG. 1. ^{6}He energy spectra from the reactions ^{10}B(^{3}He, ^{6}He)^{7}B (top) and ^{11}B(^{3}He, ^{6}He)^{8}B (bottom). The upper spectrum contains weak ^{8}B groups due to a 7% ^{11}B target impurity.

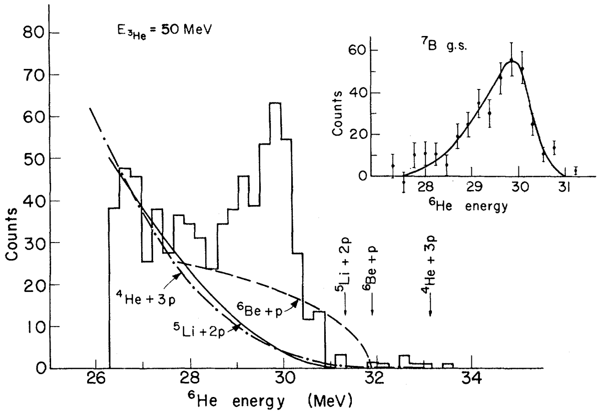

FIG. 2. A composite ^{10}B(^{3}He,^{6}He)^{7}B energy spectrum obtained by summing data from two counter telescopes at 14.1° (lab) and subtracting the ^{8}B impurity spectrum. Particle thresholds are marked along the energy axis and the shapes of three-, four-, and five-body phase space distributions are given by the dashed, solid, and dot-dashed lines, respectively. The four-body curve has been subtracted from the spectrum to obtain the peak in the inset which is attributed to the ground state of ^{7}B.

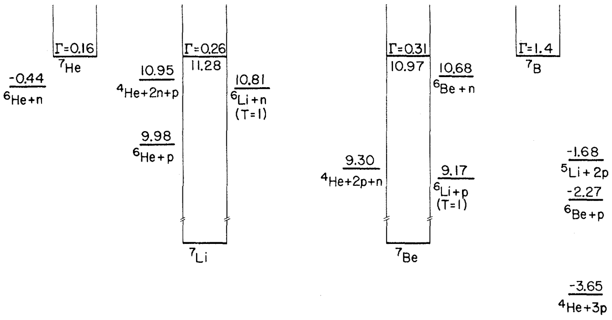

FIG. 3. Excitations (relative to their respective ground states), widths, and $T=\frac{3}{2}$ particle-decay thresholds of members of the mass-seven isospin quartet given in MeV. (The ^{6}Li $T=1$ state is at 3.56 MeV; see Ref. 7.)

ty spectrum; the cutoff at 26.2 MeV corresponds to the lowest energy that could be reliably counted in both systems. The ^{4}He + 3p, ^{6}Be +p, and ^{5}Li + 2p thresholds are marked along the energy axis; the broad peak at about 29.8 MeV is attributed to the unbound ground state of ^{7}B. Expected shapes of three-, four-, and five-body phase-space distributions are indicated by the dashed, solid, and dot-dashed lines, respectively. The data suggested that the ^{7}B peak is superimposed on a continuum background composed of the ^{5}Li + 2p and/or the ^{4}He + 3p phase-space distributions; the peak in the inset is the result of subtracting from the raw spectrum the ^{5}Li + 2p distribution normalized as shown in Fig. 2. Spectra at two other angles, 10° and 19.65° (laboratory), were obtained in order to check the kinematical behavior of the peak shown in Fig. 2. At both angles the energy and width of the observed peak were consistent with the ^{7}B assignment. The mass excess [^{12}C = 0] of ^{7}B was found to be 27.94 ± 0.10 MeV. Its width was determined to be 1.6 MeV with no background subtraction, and 1.3 or 1.4 MeV, respectively, with the ^{5}Li + 2p or ^{4}He + 3p distributions normalized as shown in Fig. 2 subtracted from the data. A representative width for the ^{7}B ground state of 1.4 ± 0.2 MeV may be taken from these results. The laboratory cross section for the ^{7}B ground-state transition was 1.6 ± 0.4 μb/sr at 14.1°; for comparison, the ^{8}B ground-state and 2.33-MeV-state cross sections were 3.6 ± 1.0 μb/sr and 6.9 ± 1.9 μb/sr, respectively.

Excitations (relative to their respective ground states), widths, and $T=\frac{3}{2}$ particle-decay thresholds for each member of the mass-seven isospin quartet are given in Fig. 3. The excitations and widths of ^{7}Li and ^{7}Be members are revised figures acquired both from a reanalysis of previously published data[8] from the reactions ^{9}Be(p,^{3}He)^{7}Li and ^{9}Be(p,t)^{7}Be and from an analysis of new data on these reactions utilizing a 45-MeV proton beam. Our final values show the lowest ^{7}Li $T=\frac{3}{2}$ state to lie at 11.28 ± 0.04 MeV with a width of 260 ± 50 keV, while the lowest ^{7}Be $T=\frac{3}{2}$ state lies at 10.97 ± 0.04 MeV with a width of 310^{+60}_{-40} keV.

For a very rough indicative calculation, the two-body $T=\frac{3}{2}$ decay widths of various members of the multiplet can be estimated using the width of ^{7}He, which is unbound only to the $l=1$ ^{6}He +n decay mode, after correcting for penetrabilities. Using the R-matrix penetrability factor and a radius given by $1.2(A^{1/3}+1)$ F, the estimated widths of ^{7}Li, ^{7}Be, and ^{7}B for decay to the lowest isospin-allowed two-body mode(s) are 250, 380, and 620 keV, respectively. In this approximation, the observed widths imply that available three- or four-body decay modes contribute to the width of ^{7}B, whereas these modes appear unimportant for the ^{7}Li or ^{7}Be $T=\frac{3}{2}$ states.

It is of interest to test the ability of the IMME

$$M(T_z)=a+bT_z+cT_z^2$$

to relate the masses of members of an unbound isospin quartet. The $T=\frac{3}{2}$ states in ^{7}He, ^{7}Li, and ^{7}Be can be used to predict a mass excess for ^{7}B of 27.76 ± 0.17 MeV, which is seen to be in good agreement with experiment. This agreement is interesting since, unlike the earlier investigations involving bound isospin quartets,[2-4] the members become increasingly unbound to allowed decay modes in moving from ^{7}He to ^{7}B, so that their wave functions could be quite different. Unfortunately, no theoretical estimates are available concerning the magnitude of expected deviations from the IMME in such multiplets.

We wish to thank Dr. Fay Ajzenberg-Selove for her generous gift of the ^{10}B and ^{11}B targets used in these experiments.

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†This work performed under the auspices of the U. S. Atomic Energy Commission.

*Work supported in part by the National Science Foundation.

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STUDY OF COLLECTIVE LEVELS IN TIN-116, TIN-120, AND TIN-124 BY INELASTIC ELECTRON SCATTERING

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(Received 28 September 1967)

We have observed the inelastic scattering of 150-MeV electrons from tin-116, tin-120, and tin-124. The main 2^+ and 3^- states have been studied. By comparison of the reduced transition probabilities $B_{\rm exp}(L\rightarrow 0)$ with the corresponding single-particle estimates $B_I(L\rightarrow 0)$, we have measured the collective character of these levels which changes appreciably from one isotope to another.

We have carried out an experiment on tin-116, tin-120, and tin-124 by inelastic electron scattering in order to study the electromagnetic properties of the $E2$ and $E3$ collective transitions in these nuclei. We used the electron beam of the linear accelerator of the Ecole Normale Supérieure at Orsay. The measurements were carried out with 150-MeV electrons and the total experimental energy resolution was 0.35%.

The electric multipole transitions are analyzed with transition charge densities[1] which are the convolution of

$$\rho_2(i,f)=\delta(r-R),\quad \rho_1=(2\pi g^2)^{-3/2}\exp(-r^2/2g^2) \quad (1)$$

and are proportional to the radial derivative of the static charge density. An analysis of the elastic scattering has given the values of the parameters R and g.[2] Thus, these transition charge densities are described by a smeared δ function situated at the surface of the nucleus; they do not correspond exactly with those given by the microscopic model of the nucleus.[3] In Born approximation, this leads to a form factor

$$|F_{IN}|^2=\beta_L j_L^{\,2}(qR_{\rm B})\exp(-q^2g_{\rm B}^{\,2})=\beta_L\mathcal{F}_L. \quad (2)$$

where $R_{\rm B}$ and $g_{\rm B}$ are parameters given by an analysis of the elastic scattering with Born approximation. In order to determine the experimental form factor we use the phase-shift point cross section as a reference. By normalization to the reduced experimental data we