Nonexistence of the 14.6-MeV State in Be^7†

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(Received 1 July 1968)

A level has been previously reported at an excitation energy of 14.6 MeV in Be^7 from a study of the $B^{10}(p,\alpha)Be^7$ reaction using range techniques. This reaction has been reexamined using energy-sensitive detectors, and the α particles previously attributed to this level have been identified, instead, as recoiling Be^7 ions and as α particles from the breakup of recoiling Be^8 nuclei.

INTRODUCTION

In 1955, in a study of the $B^{10}(p,\alpha)Be^7$ reaction using a range-sensitive particle detector consisting of a variable pressure air absorption chamber and three proportional counters, Reynolds[1] observed a very intense peak at a laboratory angle of 30° and with a range equivalent to that for 4.4-MeV α particles. This peak, α_5, was interpreted as corresponding to a level in Be^7 at an excitation energy of 14.6 MeV. Because he was able to observe this group at only one angle, Reynolds states that he could not eliminate the possibility that it might have been a 4.1-MeV He^3 group corresponding to an excited state at 13.4 MeV in Be^8. However, in view of our present knowledge of the structure of Be^8 this seems highly improbable.

No additional evidence for the existence of this state has ever been found, although this region has been covered by reactions such as $Be^9(p,t)Be^7$.[2] The properties of a state at such a high excitation energy in Be^7 which is populated via the $B^{10}(p,\alpha)Be^7$ reaction many times more strongly than any of the lower-lying states would be very important to an understanding of the structure of Be^7. Therefore, questions concerning not only the existence of this level but also the reasons why it should be so strongly populated by the $B^{10}(p,\alpha)Be^7$ reaction have led us to duplicate as closely as possible the 1955 measurements to see what new light could be shed on this enigma.

PROCEDURE AND RESULTS

A 150-μg/cm^2 self-supporting B^{10} target (92.2% B^{10} and 7.8% B^{11}) was bombarded by an 18.57-MeV proton beam from the Yale MP tandem. The resulting charged particles were detected using transmission-mounted silicon surface-barrier detectors with collimating apertures 0.50 cm in diameter located 20 cm from the target. The spectrum shown in Fig. 1 was obtained at a laboratory angle of 30°, using a 200-μ detector with an anticoincidence requirement on a 2-mm detector behind it in order to eliminate the contributions from high-energy protons which are not stopped by the 200-μ detector. This spectrum should correspond quite closely to that obtained by Reynolds,[1] except that Fig. 1 is plotted as a function of energy instead of range. Similar spectra were obtained in the present experiment from 15° to 30° in 5° steps and from 30° to 90° in 10° steps. The identifications of the peaks in Fig. 1 are based on their relative energies and on their kinematic behavior as a function of angle. The most prominent peak in the spectrum occurs at the energy at which one would expect to find the α_5 peak reported in Ref. 1. However, the kinematic behavior of this peak, as a function of angle, clearly identifies it *not* as an α-particle group but as the recoiling B^{10} nuclei from $B^{10}(p,p)B^{10}$ elastic scattering. B^{10} ions of this energy (4.5 MeV) do not have sufficient range to have been the cause of the α_5 peak. (To have the same range as a 4.4-MeV α particle, a B^{10} ion must have an energy of $\approx$15 MeV.[3])

In order to determine if there might also be a 4.4-MeV α-particle group hidden under the B^{10} recoils in our 30° spectrum, spectra were also obtained using a 0.5-mg/cm^2 nickel foil in front of the detectors to shift the B^{10} recoils away from the region of interest. Figure 2

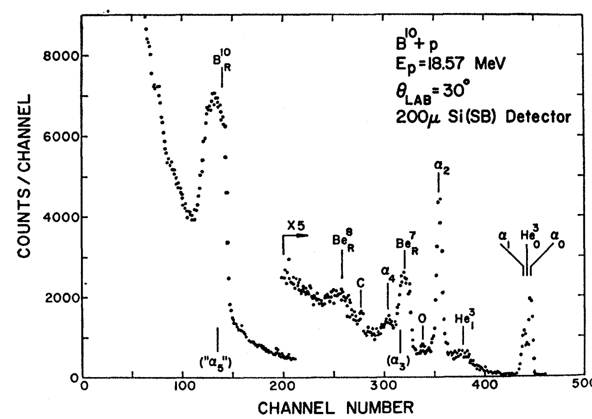

Fig. 1. Charged-particle spectrum resulting from the bombardment of a B^{10} target by 18.57-MeV protons. A 200-μ Si(SB) detector was used with an anticoincidence requirement on a 2-mm Si(SB) detector behind it. Charged-particle groups resulting from several $B^{10}+p$ reactions are identified. The groups labeled C and O are α-particle groups from the $C^{12}(p,\alpha_0)B^9$ and $O^{16}(p,\alpha_0)N^{13}$ reactions due to carbon and oxygen contaminants in the B^{10} target.

† Work supported by the U. S. Atomic Energy Commission under Contract No. AT(30-1)-3223.
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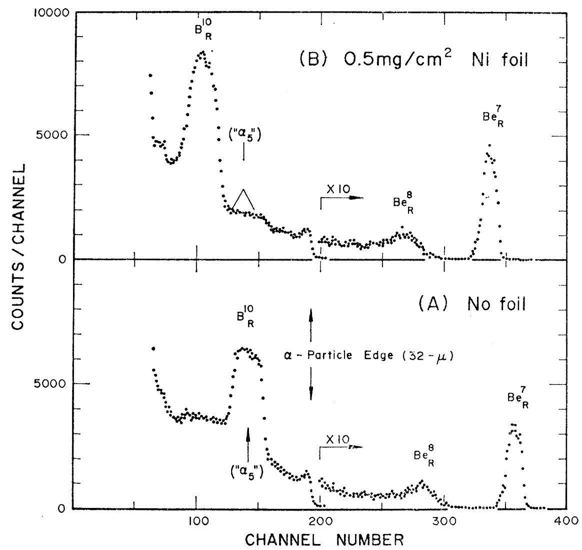

FIG. 2. A comparison of charged-particle spectra obtained with and without a 0.5-mg/cm² nickel degrading foil in front of a 32-μ Si(SB) detector. These spectra were measured at a laboratory angle of 30°, and peaks are identified corresponding to recoil groups from the $B^{10}(p,\alpha)Be^7$, $B^{10}(p,He^3)Be^8$, and $B^{10}(p,p)B^{10}$ reactions. The expected location of Reynolds's α_5 peak is indicated in both spectra; in (B) the expected size of the α_5 peak is also indicated for the case that its intensity is equal to that of the α_2 group at this angle.

shows a comparison of the spectra obtained from a 32-μ detector (in anticoincidence with a 2-mm detector behind it) with and without the 0.5-mg/cm² nickel degrading foil. (The location of the Be^7 and Be^8 recoil groups in these spectra, at energies greater than the 6.1 MeV maximum energy for α particles in this 32-μ detector, is another verification of their identifications as heavy-ion recoils.) The triangle in Fig. 2(B) indicates the expected location of the α_5 peak (shifted 300 keV to take account of the effect of the nickel foil) and the expected size of this peak based on a 300-keV width[1] and assuming an intensity for the α_5 group *equal* to the intensity of the α_2 group. The α_5 group reported in Ref. 1 was at least seven times as intense as the α_2 group. Hence, one is forced to the conclusion that the α_5 peak observed by Reynolds does not correspond to a group of α particles populating an excited state in Be^7 at 14.6 MeV.

The 11.6-MeV Be^7 recoils (see Fig. 1) from the $B^{10}(p,\alpha_0)$ and $B^{10}(p,\alpha_1)$ reactions can be shown to have almost exactly the same range as 4.4-MeV α particles. Measurements of the range of Be^9 ions by Hower and Fairhall[4] give a Be^9 range in aluminum of 4.5 mg/cm² at 11.6 MeV which, when corrected for the difference in masses, gives a Be^7 range at this energy of 4.7 mg/cm² compared to the 4.8-mg/cm² range of 4.4-MeV α particles.[5] The Be^7 recoils clearly must have been present in the range spectrum of Ref. 1 and must have accounted for part ($\sim 0.8\times\alpha_2$) of the α_5 peak. Furthermore, the 9.0-MeV Be^8 recoils (see Fig. 1) from the $B^{10}(p,He^3)Be^8$ reaction will also have the same range as 4.5-MeV α particles and must, therefore, also have been present in the range spectrum and have contributed to the α_5 peak. The detection of a Be^8 recoil depends on the simultaneous detection of both of the breakup α particles in the Be^8 decay cone which in the present case has a maximum half-angle of 6°. The solid angle subtended by Reynolds's detector (0.95-cm aperture located 16.5 cm from the target) is six times larger than the solid angle of the detector used in the present measurement, but is still small compared to the solid angle of the Be^8 decay cone. Thus, compared to the present experiment, the larger solid angle of the earlier experiment increased its efficiency for detecting both α particles from the Be^8 recoils by a factor of 6 *relative* to the efficiency for detecting Be^7 recoils or α_2. Therefore, on the basis of the energy spectra reported here there must have been a peak in Reynolds's spectrum at a range corresponding to 4.5-MeV α particles due to Be^7 and Be^8 recoils and with an intensity about $3\frac{1}{2}$ times greater than the intensity of the α_2 peak. This accounts for essentially half of the α_5 peak.

The detection of only one of the breakup α particles from the Be^8 recoils also contributes counts to this region of the range spectrum. These single α particles result from Be^8 recoils covering the range of angles from 24° to 36° and will therefore have a spread in energy of $\gtrsim 550$ keV. The broad "shoulder" distribution in Fig. 2(B), between channels 125 and 155, is quite consistent with the spectrum expected from such α particles. Although such a distribution is too broad to account for Reynolds's α_5 peak directly, it would give rise to a pedestal on top of which the narrower Be^7 and Be^8 recoil groups would then be added. On the basis of the relative sizes of Reynolds's experimental geometry and the Be^8 breakup cone and the distribution of α particles in that cone, single α-particle events will be several times more likely than the Be^8 recoil events, and such a pedestal could then easily account for the remainder of the α_5 peak. In fact, the shape of the α_5 peak in Ref. 1 (with a considerable broadening and its base) is not at all inconsistent with this description. Furthermore, it should be noted that the range measurements of the α_5 peak were made at the residual-range limit of the detector and are therefore subject to quantitative uncertainties concerning the effects of this low-energy cutoff on the low-energy side of the α_5 peak and on the estimates of the shape and intensity of the continuum under this peak.

In conclusion, the energy spectra in Fig. 2 show that, at a proton energy of 18.57 MeV and a laboratory angle of 30°, the intensity of any α-particle group from the $B^{10}(p,\alpha)Be^7$ reaction corresponding to an excited state at 14.6 MeV in Be^7 is less than 2% of the intensity previously reported.

[4] C. O. Hower and A. W. Fairhall, Phys. Rev. **128**, 1163 (1962).
[5] C. F. Williamson, J. P. Boujot, and J. Picard, Centre d'Etudes Nucléaires de Saclay Report No. CEA-R 3042, 1966 (unpublished).