SEARCH FOR THE TRINEUTRON*

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Since the existence of the trineutron would be very important in the understanding of the few-nucleon problem, a search for the trineutron in the reaction $T(n,p)n^3$ with 20.8-MeV neutrons has been made. No evidence for the existence of the trineutron was found.

In this Letter we wish to report an experimental attempt to detect the existence of the trineutron, n^3, a bound state of three neutrons. Ajdačić et al.[1] have reported the possible existence of the trineutron through the reaction $T(n,p)n^3$. Although the nonexistence of the dineutron[2] and the tetraneutron[3] has essentially been confirmed by several experimental and theoretical papers, Mitra and Bhasin[4] suggest that the trineutron could possibly exist even though the dineutron and tetraneutron do not. They conclude that a moderately attractive ^3P force could bind the three neutrons together since the $^1S_0$ force, which predominates in the dineutron and tetraneutron, is negligible for the trineutron.

On the other hand, from the pairing rule of Baz', Gol'danskii, and Zel'dovich[5] which states that the binding energy of the $(2m+2)$th neutron is always greater than the binding energy of the previous $(2m+1)$th one, one can argue that n^3 does not exist because of the apparent nonexistence of n^4. However, this rule is rigorous only within the limits of the shell model and is not necessarily expected to apply for the very lightest nuclei, such as the trineutron. Baz', Gol'danskii, and Zel'dovich[6] also conclude that the existence of the trineutron is extremely improbable, because an excited state of tritium (and possibly He^3) would then have to exist. Systematically, the binding energy of the trineutron should be negative since the binding energy of the third neutron is already negative for He^5 and is systematically decreasing with decreasing Z.

If the trineutron does exist, however, it would be of great importance in the understanding of the few-nucleon problem, and for this reason we have essentially repeated the experiment of Ajdačić et al.[1] using higher energy neutrons, better energy resolution, and a multidimensional electronic detection system. The Oak Ridge National Laboratory 5.5-MV Van de Graaff accelerator was used to accelerate an 8-μA beam of 4.0-MeV deuterons into a tritium gas cell producing 20.8-MeV neutrons in the forward direction by the reaction $T(d,n)He^4$. These neutrons entered a second tritium gas cell and the charged-particle products of the reaction $n+T$ were detected at 0° using a ΔE-E solid-state surface-barrier telescope. The outputs of the ΔE and E detectors were sorted by two-parameter analysis with 64 channels of ΔE versus 64 channels of $\Delta E+E$, where $\Delta E+E$ is the total charged-particle energy. With this method of analysis we could easily distinguish protons, deuterons, and tritons with an over-all energy resolution of better than 300 keV. The background was measured by replacing the tritium with He^4 gas in the second tritium cell.

The known charged-particle product reactions in the $n+T$ interaction are

$$n+T \to n+T, \quad \text{elastic scattering};$$
$$\to p+3n, \quad Q=-8.49 \text{ MeV};$$
$$\to d+2n, \quad Q=-6.26 \text{ MeV}.$$

Ajdačić et al.[1] found a peak in the proton spectrum at 6.4 MeV with a neutron bombarding energy of 14.4 MeV which they identify as being due to the trineutron:

$$n+T \to p+n^3 \quad (Q=-7.5 \text{ MeV}).$$

This corresponds to a binding energy of 1.0 MeV for the trineutron.

Figure 1 is the recoil triton spectrum mea-

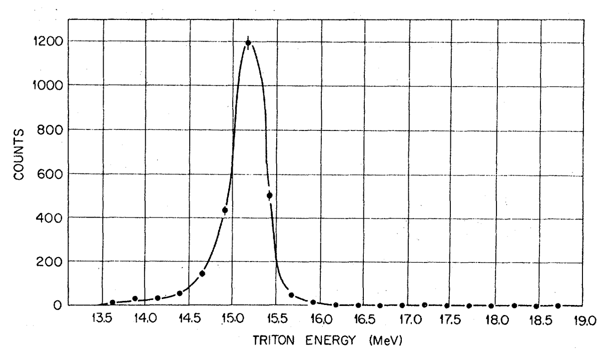

FIG. 1. Triton spectrum (lab system) at 0° from the reaction of 20.8-MeV neutrons with tritium. A smooth curve has been drawn as an aid in following the data.

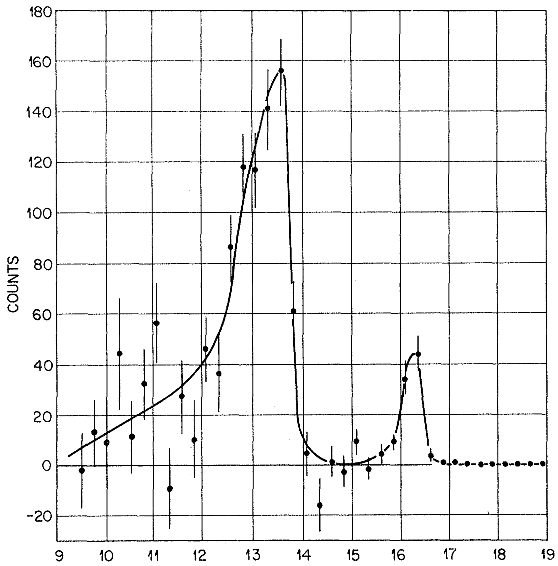

FIG. 2. Deuteron spectrum (lab system) at 0° from the reaction of 20.8-MeV neutrons with tritium. A smooth curve has been drawn as an aid in following the data.

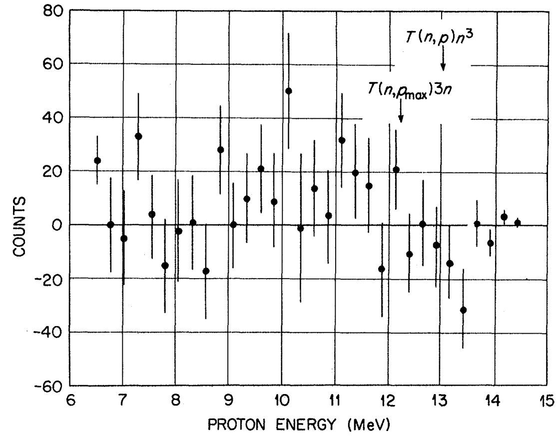

FIG. 3. Proton spectrum (lab system) at 0° from the reaction of 20.8-MeV neutrons with tritium. The arrows indicate the maximum possible proton energy from the reaction $T(n,p)3n$ and the position of the expected proton peak from the reaction $T(n,p)n^3$ under the assumption that the trineutron is bound by 1.0 MeV.

sured in the present experiment. This elastic-scattering cross section is estimated from known cross sections[7,8] to be about 50 mb/sr and was used to normalize the proton and deuteron spectra.

In the deuteron spectrum of Fig. 2 the peak at 13.6 MeV is due to the reaction $T(n,d)2n$ and indicates strong final-state interactions between the two neutrons. This asymmetric peak is as predicted by the final-state-interaction theory of Watson.[9] The 16.3-MeV peak is attributed to a small He^3 impurity resulting in the reaction $He^3(n,d)D$.

Finally, Fig. 3 is the proton spectrum. The maximum proton energy from $T(n,p)3n$ is 12.2 MeV, whereas the peak from the trineutron reaction, $T(n,p)n^3$, should be at about 13 MeV. No net counts are observed above 12.2 MeV. The integrated number of proton counts between 6.5 and 14.4 MeV is 163 ± 94 which corresponds to a cross section of 3.5 ± 2.0 mb/sr for the reaction $T(n,p)3n$.

If the trineutron cross section at 20.8-MeV neutron energy were equal to the 3.8-mb/sr cross section that Ajdačić et al. measured with 14.4-MeV neutrons, we should have counted 180 protons at about 13 MeV. Within the limits of our error, no evidence for the existence of the trineutron was found.

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