that $f(0)$ decreases rapidly with increasing energy above 100 Mev. A potential consisting of a strong repulsion surrounded by an attractive well possesses this characteristic, owing to the circumstance that interference between the repulsion and the surrounding well causes the S phase shift, and hence its contribution to the scattering amplitude, to become negative at high energies.

An interaction of this type, containing a singlet central repulsion of radius 0.60×10^{-13} cm, has already been suggested[3] in connection with high energy p-p scattering measurements. We have calculated the neutron cross sections using forward scattering amplitudes obtained from this potential, with results for aluminum given in curve B of Fig. 1. We conclude from Fig. 1 that if one is restricted to a simple model for the nucleon interaction, the sharp drop in the observed neutron cross section at high energies requires that this model contain a strong central repulsion.

It is important to note that this argument sheds no light on the tensor component of the interaction, since tensor forces of any kind will make only small contributions to $f(0)$.

A more detailed account is in preparation, including a discussion of the effect of the presence of other nucleons on the two-body nucleon cross sections.

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The $T+T$ Reactions

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The interaction of tritons with tritons may lead to three nuclear reactions:

$$T+T\rightarrow He^4+2n+\ \ 11.3\text{ Mev} \quad (1)$$

$$\rightarrow He^5+n\ +\sim10.5\text{ Mev} \quad (2)$$

$$\downarrow$$

$$He^4+n\ +\sim\ 0.8\text{ Mev}^1$$

$$\rightarrow He^4+n^2. \quad (3)$$

The first reaction is a 3-body disintegration resulting in continuous energy distributions for the α-particles and neutrons. The second reaction is a two-stage process recognizable by a neutron group at ~8.8 Mev. Reaction (3) postulates the formation of a di-neutron which, if its lifetime were sufficiently great, would be accompanied by an α-particle group of small energy spread. To distinguish these reactions measurements have been made of the energies of the disintegration products emitted at 90° to the triton beam.

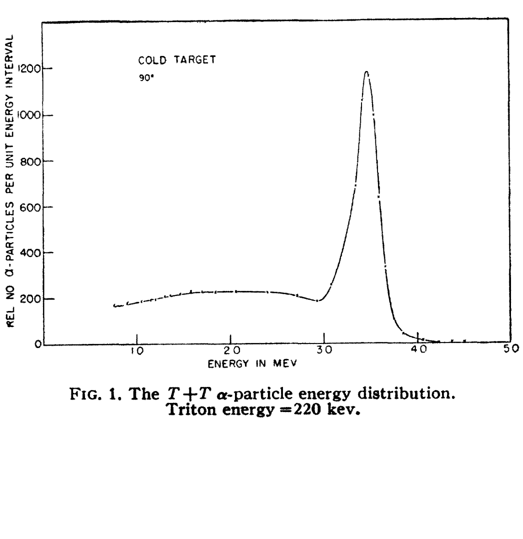

FIG. 1. The $T+T$ α-particle energy distribution. Triton energy = 220 kev.

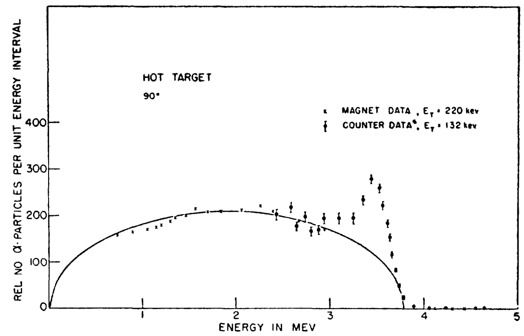

FIG. 2. The $T+T$ α-particle energy distribution. The solid line is the theoretical distribution based on classical statistical mechanics. Probable errors are indicated. E_T is triton energy.

The momentum distribution of the α-particles was investigated using a 90° analyzing magnet[2] with a resolution of 3 percent in momentum. The α-particles were detected by their scintillations in a ZnS screen. Sufficient intensity was obtained by bombarding a brass block with a 200 μa unresolved beam containing 10 percent tritons, some of which were absorbed on the brass and acted as a target. The bombarding energy was 220 kev. The relative number of α-particles per unit energy interval in the range 0.7–4.5 Mev is shown in Fig. 1. Scattered tritons from the beam prevented measurements below 0.7 Mev. The intensity of low energy α-particles has been corrected for the effect of charge exchange in the target.[3] Superimposed on the continuous distribution from reaction (1) is a group of α-particles at 3.5 Mev from the $T+D$ reaction. The high intensity of this group can be explained by the large yield of this reaction at low energies[4] and the natural deuterium content in the beam and in traces of oil on the target.

As the $T+D$ peak might obscure a small group of α-particles associated with the formation of an unstable di-neutron, it was necessary to reduce the deuterium contamination. Best results were obtained by bombarding a metal strip, maintained at a dull red heat, with a resolved beam of mass 5 ions [$H\ H\ T^+$]. Heating the target prevented deposition of oil vapor. An extended investigation of the upper portion of the α-particle distribution was made under these conditions with a proportional counter and thirty-channel pulse analyzer.[5] The complete energy distribution is shown in Fig. 2.

The α-particle distribution shows no group corresponding to the formation of a di-neutron, unless such a group coincides in energy with that of the $T+D$ α-particles. The absence of an α-particle group at an energy greater than 3.8 Mev, the energy corresponding to a di-neutron of zero binding energy, leads to the conclusion that a bound state of the di-neutron, if it exists at all, is formed in fewer than 1 percent of the disintegrations. If the di-neutron exists in a virtual state with a mass exceeding that of two neutrons by an amount equivalent to an energy E, an α-particle group with energy $3.8-E/3$ Mev will be observed whose width will depend on the lifetime of the state. For $E\leq0.6$ Mev an upper limit of 1 percent of the disintegrations may be placed on the existence of an α-particle group of width ~0.2 Mev corresponding to a di-neutron of lifetime $\sim3\times10^{-21}$ sec.

The neutron energy distribution shown in Fig. 3 was obtained from measurements of proton recoils in Ilford C2 100μ-emulsions placed at 90° to the triton beam. A light target assembly was used to reduce the neutron scattering. Since no correction has been made for the small effect of scattering, the distribution may be distorted so as to increase the apparent number of low energy neutrons. Recoil protons from monoenergetic 14-Mev $T+D$ neutrons were observed, but have not been included in Fig. 3. There is some evidence for a peak at ~8.8 Mev corresponding to

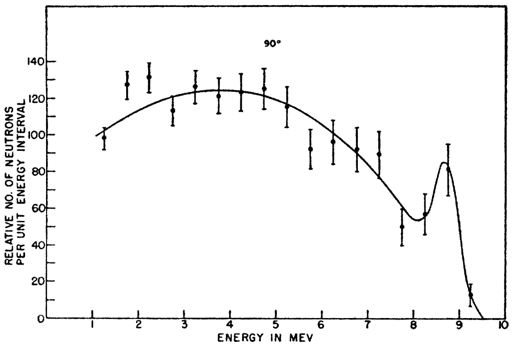

FIG. 3. The $T+T$ neutron energy distribution. Triton energy = 220 kev. Probable errors are indicated.

the formation of He^5 in its unstable ground state. Owing to its short lifetime, this nucleus disintegrates while in motion. This results in an energy spread of its disintegration products; the neutron energy lies between 0.05 and 1.93 Mev, the associated α-particle energy between 0.6 and 2.5 Mev. These particles are not resolved from the 3-body distribution from reaction (1).

The neutron measurements at 90° indicate that either the yield of reaction (2) is small or the neutron and the He^5 are emitted at angles near 0° or 180° to the beam. In the latter case only a few of the breakup α-particles can be observed at 90° owing to the large momentum of the He^5 nucleus. Thus, in either case, the observed α-particle energy distribution is due largely to the 3-body disintegration. Within the present experimental error, the α-particle energy distribution indicates the partition of energy among the products of the 3-body disintegration to be in fair accord with classical phase space considerations,[6] although there is some slight evidence for an angular correlation favoring emission of both neutrons in the same hemisphere.

In conclusion we should like to express our thanks to Dr. R. F. Taschek and his colleagues for valuable discussion of the Los Alamos experiments on the $T+T$ reactions.[7]

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Solidification of He^3

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WE have recently succeeded in solidifying He^3 and have determined a portion of the melting curve by the blocked capillary technique.[1] The melting pressure was found to change from 40.5 atmos at 1.02°K to 56.6 atmos at 1.51°K.

A schematic diagram of the apparatus is shown in Fig. 1. In order to perform the experiment with the amount of gas available (190 cc STP) it was necessary to keep the volume of the system small. This was accomplished by filling the Bourdon gauges (*B* and *G*) with mercury and by using 0.1-mm i.d. stainless steel tubing for the U-tube (*D*) in the helium cryostat (*E*)[2] and 0.5-mm i.d. tubing for the connections outside the cryostat. The other U-tubes (*C* and *F*) were immersed in liquid nitrogen to prevent mercury from plugging the smaller tubing in the cryostat. The apparatus was evacuated and filled through the high pressure valves (*A* and *J*). The gas in the reservoir (*H*) was compressed with mercury displaced by means of the hydraulic system (*I*). The Bourdon gauges, which had 1-lb/in.[2] graduations and a range of 0 to 1000 lb/in.[2], were calibrated with a pressure balance while filled with mercury.

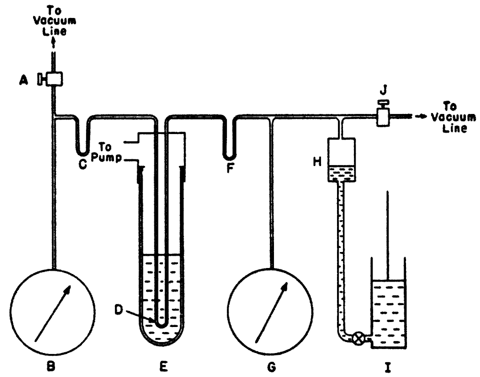

FIG. 1. Solidification apparatus (schematic).

As the pressure in the system was slowly increased, at a constant cryostat temperature, the two gauges gave the same reading until the solidification pressure was reached, and then gauge (*G*) continued to rise while gauge (*B*) remained constant. Upon lowering the pressure the gauge readings again became equal at the solidification pressure. A single measurement was made with He^4, and the solidification pressure was found to be 25.2±0.1 atmos at 1.09°K, in satisfactory agreement with the more accurate value of 25.10 atmos found by Swenson.[3] The data for He^3 are plotted in Fig. 2. The equation of the curve in this figure is

$$P = 27.0 + 13.0T^2 \text{ atmos } (1.02 \text{ to } 1.51\text{°K}), \qquad (1)$$

and it represents the He^3 melting pressure in the range of the measurements with a mean deviation of 0.1 atmos.

With the aid of Eq. (1) an upper limit can be calculated for the volume change on melting, ΔV, by substituting the entropy of the liquid in equilibrium with the vapor[2] for the entropy of melting, ΔS, in the relation

$$dP/dT = \Delta S/\Delta V. \qquad (2)$$

It is assumed that the thermal coefficient of expansion of liquid He^3 is positive, and hence that the entropy of the liquid decreases when the liquid is compressed from the vapor pressure to the melting pressure. The result is $\Delta V < 1.2$ cc/mole at 1°K. This is smaller than the volume change of 2.1 cc/mole for He^4 at this temperature[3] but is reasonable because of the higher melting pressure of He^3.

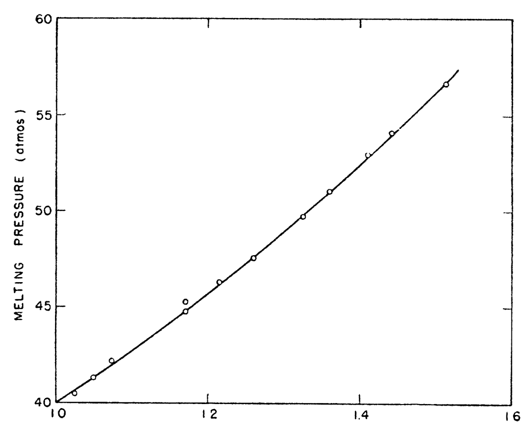

FIG. 2. Melting pressure of He^3.