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Bubble Tracks in a Hydrogen-Filled Glaser Chamber*

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GLASER[1] first showed that the boiling of superheated ethyl ether was sensitive to ionizing radiation, and later photographed the bubble tracks in his apparatus. A liquid-hydrogen chamber would have a number of attractive features, and it is therefore not surprising that several groups have been working to produce such a device. At Chicago, Hildebrand and Nagle,[2] working in cooperation with Glaser, have produced superheated liquid hydrogen, and have shown that it boils sooner in the presence of a γ-ray source. We have taken the next step, but with somewhat different technique, and can report the photography of bubble tracks in hydrogen. (See Fig. 1.)

The bulk of the Chicago apparatus was immersed in a bath of hydrogen which was boiling at atmospheric pressure, but the bubble chamber was in the vapor space, and superheated by a coil of resistance wire. This arrangement involves problems of heat transfer and temperature measurement, in addition to some serious problems if photography were to be attempted. We have therefore immersed our bubble chamber in a bath of hydrogen which boils at high pressure; this provides a convenient heat reservoir, whose temperature is easily controlled by a pressure regulator. First, hydrogen is condensed into the bubble chamber at a pressure somewhat higher than that over the bath. After temperature equilibrium has been established, the following cycle is initiated: (1) The pressure in the bubble chamber is suddenly reduced to one atmosphere. (2) At a variable time after the pressure release, an electronic circuit triggers a stroboscopic lamp, which takes a photograph of the chamber, and (3) pressure is reapplied to the chamber to condense any bubbles that may have formed.

We have been unable to duplicate the long times of superheat

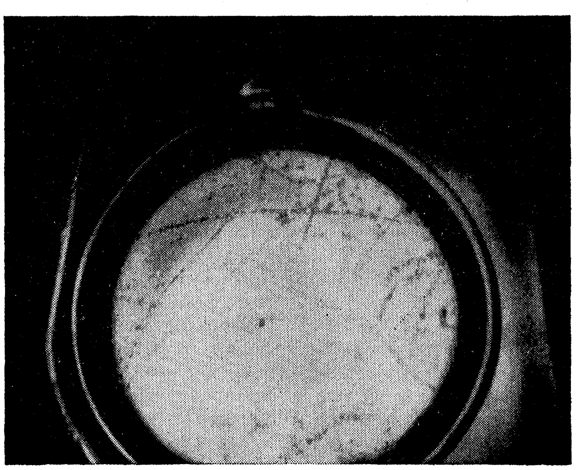

FIG. 1. 1½-inch chamber irradiated with a Po-Be source.

reported by the Chicago group, but we have been using considerably higher degrees of superheat. We were discouraged by our inability to attain the long times of superheat, until the track photographs showed that it was not important in the successful operation of a large bubble chamber. Tracks have even been observed in cases where the liquid hydrogen was not completely condensed in the chamber prior to expansion.

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Angular Distribution of Deuterons from $N^{14}(p,d)N^{13}$†

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BUTLER'S interpretation[1] of the angular distribution of particles from (d,p) and (d,n) stripping reactions has yielded much information on the spins and parities of nuclear states.[2] By the reciprocity theorem,[3] a similar analysis should apply to the inverse processes, (p,d) and (n,d) pickup. Most pickup reactions

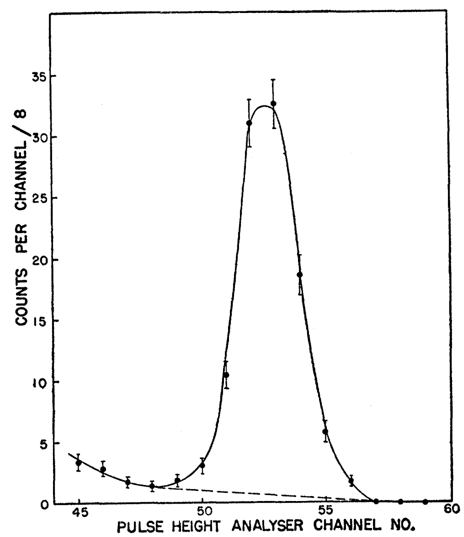

FIG. 1. Gated scintillation counter spectrum at 15° in the laboratory system. The peak consists of $N^{14}(p,d)N^{13}$ ground-state deuterons. Background was estimated from the general shape of the curve and from spectra taken with larger absorbers (which move the deuteron peak to a lower pulse height).

have Q's which are negative and several Mev in magnitude, so it is necessary to select low-energy deuteron groups in the presence of background caused by relatively high-energy protons. Because of this difficulty, angular distributions from (p,d) reactions have been examined in a few favorable cases[4,5] only.

A thin NaI crystal in a scintillation counter may be used to distinguish deuterons from proton background. The maximum possible energy loss of any deuteron passing normally through such a crystal comes from a deuteron whose range in NaI is equal to the thickness T of the crystal. This deuteron *just* stops in the crystal and loses its entire energy E_T. A higher-energy deuteron will pass through the crystal and lose energy $<E_T$ because of the smaller rate of energy loss at higher energy. A similar relation holds for protons, but, since the range of a proton is greater than the range

of a deuteron of the same energy, the maximum energy loss of a proton is $\approx\frac{3}{4}E_T$.[6] Therefore, deuterons of energy E_T will give larger pulses from the scintillation counter than will protons of any energy.

Protons of energy 18.7 Mev struck a melamine[7] target $\approx$0.001 in. thick, and the reaction products passed through an Al absorber into a thin NaI(Tl) crystal[8] in a scintillation counter. The Al absorber thickness was varied until the deuterons of the group being studied had energy E_T on reaching the crystal. These deuterons then appeared as a peak at maximum pulse height when the pulses from the scintillation counter were recorded on a 20-channel pulse-height analyzer.[9]

It was found that a small proportion of protons gave anomalously large pulses in the scintillation counter; presumably these were high-energy protons scattered through large angles in the crystal. A thin proportional counter[10] was introduced between the Al absorber and the scintillation counter to reduce this background. Since protons of energy $\geqslant E_T$ have a smaller mean rate of energy loss than deuterons of energy E_T, a discriminator could be set to accept all the proportional counter pulses from the deuterons and reject most of the pulses from these protons. The output of the discriminator was used as a coincidence gate for the pulse-height analyzer.

Figure 1 shows the gated scintillation counter spectrum obtained at 15° (lab) from the deuterons to the N^{13} ground state [$N^{14}(p,d)N^{13}$, $Q=-8.3$ Mev]. Figure 2 gives the angular distribution of the deuterons and indicates[1] an $l_n=1$ angular momentum transfer. This shows that the ground states of N^{13} and N^{14} have opposite parity and is consistent with the usual assignment of 1+ to the N^{14} ground state. The measurement thus agrees with the results of Bromley[11] on the $C^{13}(d,n)N^{14}$ angular distribution, and disagrees with the tentative results of Benenson[12] on the same reaction.

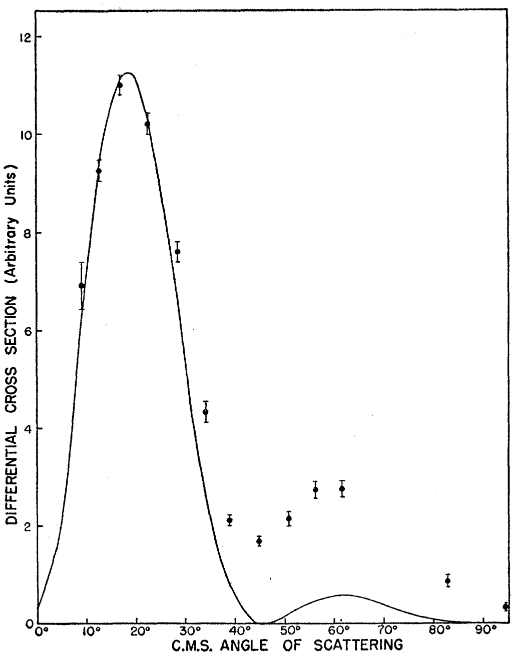

FIG. 2. Angular distribution of the $N^{14}(p,d)N^{13}$ ground-state deuterons in the center-of-mass system. Bars on the experimental points indicate standard deviations. The curve was calculated from Butler's formula (see reference 1) for $l_n=1$ and $r_0=5.4\times10^{-13}$ cm. Corresponding curves for $l_n=0$ and $l_n=2$ would peak at 0° and 30°, respectively. Experimental results greater than theoretical predictions for large angles are also a common feature of stripping reactions (see reference 1).

It has been suggested[13] that a measurement of the angular distribution of the deuterons to the first excited state of $N^{13}(\frac{1}{2}+)$ would give information about the N^{14} ground state useful in interpreting the slow C^{14} β decay. The deuterons from this reaction [$N^{14}(p,d)N^{13*}$, $Q=-10.7$ Mev] were searched for at angles of 12°, 20°, and 30° (lab), and none were found above background. The intensity of the excited state transition with $l_n=2$, $l_n=1$, and $l_n=0$ was less than 4 percent, 4 percent, and 15 percent, respectively, of the intensity of the ground-state transition ($l_n=1$). Since the N^{13} ground state is expected to be a $(p)^{-3}$ configuration and the first excited state $(p)^{-4}s$, this result indicates that the admixture of $(p)^{-4}s^2$ and $(p)^{-4}sd$ configurations[14] in the N^{14} ground state [predominately $(p)^{-2}$] must be small.

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The Elastic Scattering of Photons*

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THE absorption of high-energy photons with the subsequent emission of nuclear particles, primarily neutrons, has been studied extensively, and the cross sections as a function of energy have been shown to have maxima near 15 Mev. It can be shown by a very general dispersion argument that associated with the total absorption there will be an elastic scattering of the photons. The general features of the absorption curves (width, position of maxima) can be obtained from a measurement of the elastic scattering as a function of photon energy. This scattering has been discussed in a number of theoretical papers,[1] and several experiments[2] have been performed to detect this radiation. Stearns used a NaI(Tl) scintillation spectrometer to observe the scattering of the gamma rays from the $Li(p,\gamma)$ reaction by various nuclei. The results indicated that the total elastic scattering cross section at 17 Mev is a few millibarns for the heavy elements.

The purpose of this experiment is to measure the elastic scattering cross section as a function of photon energy and is an extension of the Stearns experiment. X-rays produced by the NBS 50-Mev betatron are scattered from targets of gold, lead, and uranium, about one mean free path thick. The detector[3] consists of a NaI(Tl) crystal five inches in diameter and four inches long viewed by a DuMont five-inch diameter photomultiplier tube. The electronic equipment consists of a linear amplifier and a series of discriminators with associated scaling units. The outputs of the discriminators are gated so that only pulses occurring in a 40-μsec gate around the 10-μsec beam pulse are registered. The bias of one of the discriminators is set so that only photons having energies above ninety percent of the maximum energy are detected; this