The Interaction of Neutrons with Normal and Parahydrogen

Teller[1] and Schwinger and Teller[2] have shown that (1) the spin dependence of proton-neutron forces and (2) the real or virtual character of the singlet level of the deuteron can be investigated by the scattering of slow neutrons by *o*- and *p*-H_2. The preliminary report of Halpern, Estermann, Simpson, and Stern[3] indicates that the cross sections of *o*- and *p*-H_2 differ. We have performed a series of scattering experiments using a beam of slow neutrons emerging from a "howitzer"[4] which could be cooled to 90°K by circulating liquid air. The neutrons emerging at ~100°K are absorbed in boron 1.6 times as strongly as those emerging at room temperature, thus indicating considerably better cooling than heretofore obtained (the simple $1/v$ law gives $(300°/100°)^{\frac{1}{2}}$ for complete equilibrium at both temperatures). After being defined by Cd cylinders and diaphragms the neutron beam passed through two thin walled "cerium" glass cells enclosed in the vacuum space of a Dewar and into each of which *n*-H_2 or *p*-H_2 could be condensed independently. The transmitted neutrons were detected by a BF_3 pressure ion chamber connected to a linear amplifier. Absorption by the glass Dewar system was approximately 6 percent. The *ortho-para* composition of the hydrogen from any cell was determined upon removal by comparison of its vapor pressure with that of freshly condensed *n*-H_2. Corrections were made for the self-conversion of the *n*-H_2 during the measurements.[5] The observations and results are summarized in Tables I and II, and also in Fig. 1, each transmission being the average of several measurements. Table II indicates qualitatively that filtration of the neutron beam through *p*-H_2 increases the transmission for *p*-H_2 and decreases it for *n*-H_2. The trend of the transmissions with decreasing neutron temperature indicates that the average neutron energy of the unscattered beam is further reduced by filtration through liquid *p*-H_2. The cross section for *p*-H_2 then is $\sim 14 \times 10^{-24}$ cm², and for *n*-H_2 is $\sim 75 \times 10^{-24}$ cm².

TABLE I. *Transmission data and calculated neutron scattering cross sections per hydrogen molecule.*

Composition % *o*-H_2	Neutron temperature °K	Cell thickness cm	Transmission	Cross section per molecule $\times 10^{24}$ cm^{-2}
74.2	~300	0.234	0.780	48.6
73.9	"	.35	.695	47.4
74.0	"	.58	.538	48.7
73.3	"	.93	.371	48.6
74.5	~100	.234	.720	64.2
72.6	"	.58	.449	63.0
74.0	"	.814	.34	60.6
1.7	~300	.234	.871	27.1
3.0	"	.58	.671	31.4
2.5 est.	"	.814	.593	29.3
1.4	~100	.234	.911	18.0
6.5	"	.58	.740	23.6
5.0	"	.814	.690	20.8

Transmission values apply to the slow neutrons absorbed by Cd, and have a calculated precision of ±2 percent.

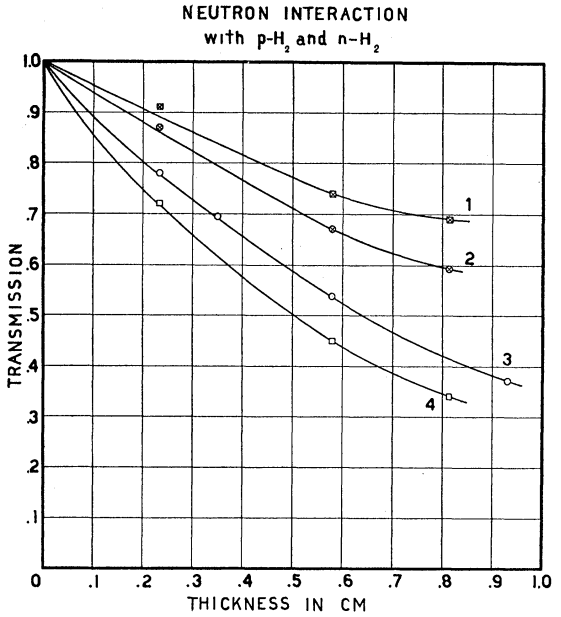

FIG. 1. Transmission of neutrons through liquid *n*- and *p*-H_2. 1, *p*-H_2, ~100°K neutrons; 2, *p*-H_2 ~300°K neutrons; 3, *n*-H_2, ~300°K neutrons; 4, *n*-H_2, ~100°K neutrons.

Several factors warrant further consideration before final conclusions are drawn. Temperature distributions of the neutrons are only roughly Maxwellian. The effect of a long "tail" of high energy neutrons becomes more important at low temperatures. However, on the basis of the theory, the trend of the cross sections as the neutron temperature is lowered (downward for *p*-H_2, upward for *n*-H_2) proves conclusively that spin dependent forces exist. Also the magnitude of the effect shows definitely that the singlet state of the deuteron is virtual. A preliminary reduction of the data for ~300°K neutrons shows the *ortho* cross section to be 2.5 to 3 times the *para* cross section, which is in agreement with the values calculated

TABLE II. *"Filtration" experiments making use of two cells: Passage through the cells was in the order indicated. Neutron temperature ~100°K.*

Composition % *o*-H_2	Cell thickness in cm	Transmission of 2 cell unit	Transmission of 2nd cell for filtered beam from 1st cell	Transmission of 2nd cell alone
6.5 1.4	0.58 0.234	0.690	0.932	0.911
5.9 74.3	0.58 0.234	0.50	0.68	0.72
73.7 16.2	0.58 0.234	0.39	0.87	0.87*
74.2 73.4	0.58 0.234	0.34	0.76	0.72

* Calculated from transmission of 0.014 *o*-H_2.

by Schwinger and Teller on the assumption of a virtual singlet state of the deuteron. The theory predicts p-H_2 to be practically transparent to slow neutrons, although fast ones are strongly scattered. Consequently filtering through liquid p-H_2 should be quite effective in eliminating the high energy tail of a neutron beam. The filtration experiments are in qualitative agreement with this prediction of the theory.

A series of measurements of the neutron-proton cross section, using H_2O, gives an average of 42.2×10^{-24} cm^2 for 300°K neutrons, and 56.0×10^{-24} cm^2 for ~100°K neutrons, a ratio of 1.325. Measurements of O and N cross sections using liquid O_2 and N_2, give average values of 4.05 and 12.7×10^{-24} cm^2, respectively, for 300°K neutrons. A complete description of the experiment and interpretation of the results will appear in a future issue of the *Physical Review*.

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Diffraction Patterns of Silicon Iron Crystals Oscillating Magnetostrictionally

The question as to whether magnetostriction oscillation of single crystals of magnetic substances would produce effects in their Laue diffraction patterns similar to those observed when crystals such as quartz and tourmaline are excited by piezoelectric oscillation has recently been investigated. Through the courtesy of Dr. S. Dushman of the General Electric Company, we were able to obtain some specimens of silicon iron in the form of strips, approximately 1.5 cm wide, 30 cm long, and of thickness 0.0095, each of which contained several large single crystals of silicon iron. A special holder was built which allowed placing a properly clamped strip in any orientation so that symmetrical Laue pictures could be obtained. Radiation from a broad focus universal tube run at 60 kv and 4 ma produced satisfactory blackening after exposures of ten hours.

The oscillator, which covered quite a range of frequencies in order to match the resonances of strips of different lengths, was of the Hartley type and utilized a type 10 tube. The test strip was coupled to a push-pull amplifier driven by the oscillator through the use of suitable coupling coils. Resonance was indicated by observing the motion of a few grains of sand placed on a small mica plate affixed to one end of the specimen.

Nine sets of corresponding Laue pictures were obtained under conditions as nearly identical as possible. In one picture of each set, the strip was at rest and in the other it was driven magnetostrictionally.

The results, though not as decisive as one might wish, indicate that magnetostriction oscillation acts similar to piezoelectric oscillation. The nine sets of photographs were submitted to the independent judgment of ten persons about the laboratory with the result that eighty percent of the choices indicated the pattern of the oscillating crystal as the more intense.

We tried also the same procedure with some single iron crystals furnished by Dr. P. P. Cioffi of the Bell Laboratories. These were in the form of small wires but of such short lengths that, with the available equipment, it proved impossible to drive them.

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The First USSR Cyclotron

By aid of the cyclotron apparatus of the State Radium Institute the first beams of protons (energy 0.5–2.1 Mev) and of hydrogen ions (0.1–1.0 Mev) have been obtained.

The excellent field homogeneity of the especially constructed electromagnet permitted the construction of a chamber with thin bottoms, tightly compressed in vertical position between the poles, and with vacuum between the poles' faces and the bottoms. No corrections of the field by use of shims were required. The chamber's internal diameter is 600 mm, protonic exit radius is 256 mm. In our first experiments it appeared, that the chamber had an accessory ion source, besides that of the glowing filaments. The intensity of proton beam obtained without electron emission of the filament attains some 10^{-9}A. This phenomenon is to be attributed to the hydrogen ionization by the high frequency at maximum voltages, approximately equal to those required for a glow discharge. Our suggestions are supported by a letter to the Editor of your journal by P. Gerald Kruger, G. K. Green, and F. W. Stallmann[1] who also have observed analogous effects, and who suggest a similar explanation.

Of great interest is also the deflection system of our cyclotron. By means of an especially constructed filter system (condensers and RF chokes) there is obtained a shift of the voltage phase between the deflecting plate and the accelerator and a decrease of the gradient arising between them.

In the future the deflecting plate will be placed in the interior of the accelerator. The deflecting potential will be applied with aid of a water-cooled RF resistor. Theoretically this method will be most advantageous because of the particle beam getting into the deflector exit when the accelerator and the deflecting plate are at equal potentials.

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