A Search for Resonance Scattered Protons from B^{11} and F^{19}

W. R. KANNE,* R. F. TASCHEK AND G. L. RAGAN
University of Wisconsin, Madison, Wisconsin

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Preliminary work in search of the resonance scattering of protons from B^{11} and F^{19}, at the lowest energy resonance in each case, is reported. Such scattering was not observed, but upper limits for it are established and a sensitive method for observing small deviations from Rutherford scattering is described. The proton energy producing the resonance in boron has been determined to be 163 ± 6 kev.

INTRODUCTION

THE nature of the intermediate excited state of C^{12} produced by the resonance capture of 163-kev protons by B^{11} is of great interest, and available information about it does not lead to unique conclusions.[1] An attempt was made to observe the resonance scattering of these protons in order to lead to a determination of the angular momentum of those effective in producing the excited state. The experiments are still in a preliminary state, but since our work has temporarily shifted to another problem, it is considered advisable to make a brief report of them at this time.

The energy of the protons producing the resonance in boron was determined independently of the scattering experiments by an excitation curve of the gamma-rays from a thick target. Figure 1 shows the curve obtained with coincidence Geiger-Mueller counters and gives the value of 163 ± 6 kev for the proton energy.[2] Results obtained with a single counter are in agreement with this value.

EXPERIMENT

The existence of resonance scattering should manifest itself by a deviation from the Rutherford angular distribution for protons of the resonance energy. The scattered protons were detected by ionization chambers (Fig. 2) at 45° and 105° with respect to the proton beam, or 48.7° and 110° in the center of mass system. Their apertures were chosen roughly in inverse ratio to the Rutherford scattering at these angles. By joining their collecting plates electrically and collecting charges of opposite sign on the two chambers, it was possible to detect small differences in their ionization currents. A deviation from Rutherford scattering should produce a change in this difference at the resonance energy. Because of fluctuations which are perhaps attributable to slight variations in either beam direction or beam spreading, it was necessary to use chambers symmetrical on opposite sides of the beam. Then two identical chambers at 45° collected current of opposite sign to that collected by two identical chambers at 105°.

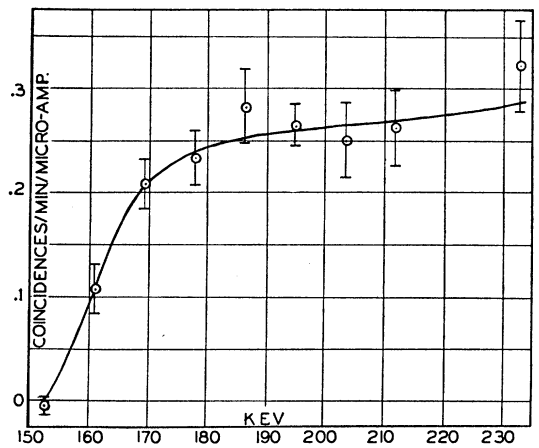

FIG. 1. Coincidence counter excitation curve of gamma-rays from protons on a thick boron target. Current measured is total beam current, of which about one-fourth is proton current.

* Now at Illinois Institute of Technology.

[1] J. O. Oppenheimer and R. S. Serber, Phys. Rev. **53**, 636 (1938); Haxby, Allen and Williams, Phys. Rev. **55**, 140 (1939); and E. L. Hill and R. O. Haxby, Phys. Rev. **55**, 147 (1939). Further references are given in these papers.

[2] Other values for this resonance voltage are 180 kv by Williams, Wells, Tate and Hill, Phys. Rev. **51**, 434 (1937); 160 kv by Allen, Haxby and Williams, Phys. Rev. **53**, 325 (1938); 180 kv by W. Bothe and W. Gentner, Zeits. f. Physik **104**, 685 (1937); 165 ± 4 kv by Waldman, Waddel, Callihan and Schneider, Phys. Rev. **54**, 1017 (1938); and 172 ± 5 kv by R. B. Bowersox, Phys. Rev. **55**, 323 (1939). The voltmeter used in the present work is described in reference 4.

The resultant current charged an Edelmann electrometer, whose sensitivity was determined periodically by observing the effect of the ionization from a sample of uranium oxide. The slits of the ionization chambers were covered with foils of aluminum leaf, but each chamber had a gas connection to the scattering chamber. These foils were necessary in order to observe the Rutherford angular distribution for protons scattered from air and may have served to stop recoil atoms.

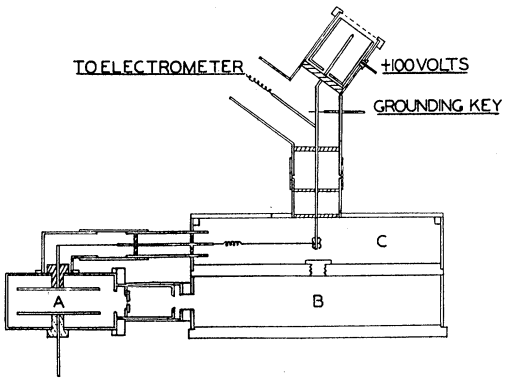

FIG. 2. Details of ionization chamber (A), showing connection to scattering chamber (B) and shielded electrical connections to electrometer. Removable sector in lid of shielding box (C) permits connection of electrometer to any desired ionization chambers.

The scattering chamber was connected to the accelerating tube by a differential pumping system built along lines suggested to us by Professor A. Ellett,[3] details of which are given in Fig. 3. The "fine" and "coarse" pumps are 4" brass pumps of the type described by Sloan, Thornton and Jenkins.[4] The fine pump exhausts into the coarse pump, which is heated by 900 watts and is exhausted by a two-stage mercury diffusion pump backed by a Cenco Megavac. With this system it is possible to maintain 3-mm Hg pressure of hydrogen gas in the scattering chamber with an increase in pressure of 7.5×10^{-5} mm Hg in the accelerating tube. For completely satisfactory operation of the accelerating tube, 2 mm Hg is the maximum pressure.

[3] R. D. Huntoon, A. Ellett, D. S. Bayley and J. A. Van Allen, Phys. Rev. **58**, 97 (1940).

[4] Sloan, Thornton and Jenkins, Rev. Sci. Inst. **6**, 80 (1935). Tests showed that the large pump designed by R. M. Zabel (Rev. Sci. Inst. **6**, 54 (1935)) is equally as effective as the pump used here. However, such a pump has exploded due to water getting on the glass boiler while operating at 900 watts.

Both the scattering chamber and the 4" iron cylinder are mounted on adjustment screws in an angle iron frame so that they can each independently be put into any desired position, both as to orientation and displacement, within the limits of the screws and the sylphon bellows. The large cylinder from which the gas is pumped was chosen of iron to reduce the effect on the proton beam of the stray field of the magnetic analyzer. The tapered section design of the collimating capillary was used to remove the possibility that protons scattered by the capillary, and consequently having reduced energy and altered direction, might proceed with the proton beam to the scattering gas. Each section is $\frac{1}{2}$" long and the hole is 2 mm diameter at its edge toward the accelerating tube and has a 2° taper.

Relative beam currents were measured by a monitor ionization chamber between whose plates the proton beam passed. Calibrations were obtained by comparing these monitor currents, measured by a galvanometer, with the scattering into a single ionization chamber at 45° at constant proton energy. The scattering was taken to be proportional to the beam current. Because of the low gas pressure, the voltage that could be used on the monitor chamber was not sufficient to produce saturated collection of the intense beam ionization, but the "calibration curves" were satisfactorily reproducible.

The high voltage was supplied by a transformer-rectifier set,[5] having a ripple of 1.4 percent amplitude.

BORON

Methyl borate, $B(OCH_3)_3$, was used at 0.8 mm Hg pressure as the scattering gas, even though only 7.7 percent of the total scattering is from boron. Despite the sensitivity of the detecting method, no change in the scattering at 105° as a function of voltage that was attributable to resonance scattering was observed. In this work each 45° chamber collected about 1.3 times as much ionization as each 105° chamber.[6] The

[5] Haworth, King, Zahn and Heydenburg, Rev. Sci. Inst. **8**, 486 (1937).

[6] This excess may be attributable to loss of electrons to the walls of the 105° chamber, which collected negative charges, and to a larger amount of multiple scattering into the chamber at 45°.

fluctuations in individual points, taken in 1- to 2-kv steps between 150 and 183 kv, were less than 10 percent from a straight line for any one run. Our maximum fluctuations were then 10 percent of 30 percent, or 3 percent of the reading given by the total ionization at 105°. Since the scattering from boron is 7.7 percent of the total scattering from methyl borate, it is possible to say that the resonance scattering from boron at 105° is less than 40 percent of the Rutherford scattering at that angle. This assumes that the resonance scattering makes a negligible contribution to the total scattering at 45°. We are hoping to repeat these experiments with improved technique and B_2H_6 as the scattering gas.

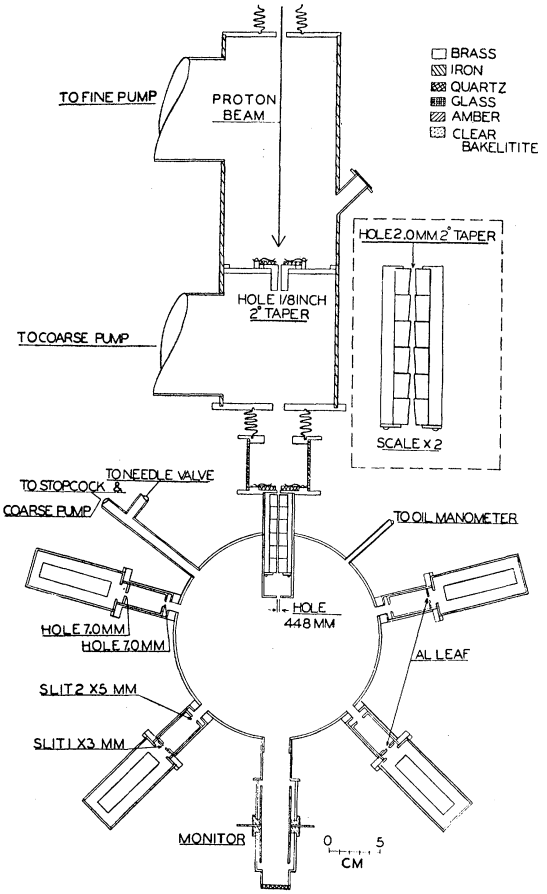

FIG. 3. Differential pumping system and scattering chamber. The enlarged view of collimating capillary in inset is double scale of main drawing.

FLUORINE

Similar experiments were performed with fluorine, in which case BF_3 gas is available, but the resonance voltage as given by Bernet, Herb and Parkinson[7] at 334 kv closely approaches our maximum voltage. Because the electrometer picked up long time drifts from sparks, it was not possible to get a great deal of data. The resonance region from 325 kv to 340 kv was covered in about 2-kv steps, and numerous points at lower voltages were taken without observing resonance scattering. Under the conditions of this part of the experiment, the normal drift rate was less than one division per minute. If resonance scattering from fluorine at 105° were 15 percent as intense as Rutherford scattering from it at that angle, it would have contributed an electrometer drift of one division per minute. This may be considered an upper limit for the resonance scattering from fluorine at 334 kv.

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[7] Bernet, Herb and Parkinson, Phys. Rev. **54**, 398 (1938).