Due to the fact that the plates did not record electrons of energies exceeding 60 to 70 kev it was not possible, in general, to observe the track of a particle of 1600 gauss-cm entering the emulsion. For this reason tracks of a minimum length of approximately 20 microns were recorded, having at one end the familiar cluster of developed grains corresponding to the stopping of the particle and a decreasing grain density towards the other end where the track is either lost in the background or in some cases comes close to the surface of the emulsions. This criterion should eliminate a large fraction of the electrons due to the x-rays produced by the P^{32} source since these electrons will have in general rather low energies resulting in shorter tracks.

Plate 1 was scanned along the lines *b* and *c*. As can be seen from the two diagrams to the right of Fig. 1, the peaks in the number of tracks per millimeter in the direction of scanning (representing an area of 0.25 mm²) are displaced with respect to each other. From the position of the points *B* and *C* indicated in the figure and the position of each peak it is seen that the displacement of the peaks is approximately that which is to be expected for electrons having traversed the spectrograph (momentum approximately 1600 gauss-cm) and being further deflected by the magnetic field before being stopped in the emulsion. The left column of Fig. 1 shows the results of the scanning along rows *a*, *b*, and *c* of plate 2 in which case the appearance of positive particles was expected. It can be seen that peaks appear which coincide with the points *A*, *B*, and *C*. This indicates that they are due to the passage of positively charged particles through the spectrograph. Plate 3, which was scanned along line *b*, did not show any peak. All the three plates showed about the same number of tracks per millimeter (satisfying our conditions) in regions other than the peaks from which it follows in view of the great difference in the exposure times that the contribution of x-rays due to the P^{32} electrons to this background is negligible. Taking three tracks per millimeter as background and considering the difference in the exposure time, the ratio between positive particles and electrons of around 1600 gauss-cm, averaged for lines *b* and *c*, is found to be $\approx 8\times 10^{-4}$.[15] No attempt was made to find a difference between the tracks obtained with both directions of the field. No difference was apparent by casual observation.

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[12] The radioactive P^{32} was supplied by the Isotope Branch of the Atomic Energy Commission, Oak Ridge, Tennessee.
[13] The use of a mica window counter as a detector gave inconclusive results due to the difficulty of ascertaining whether particles found to traverse this (evacuated) spectrograph with a field supporting the passage of positive particles were not actually electrons scattered through the spectrograph. Another complication was the sensitivity of the counter to x-rays produced by the P^{32} electrons.
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[15] In a cloud-chamber investigation by Groetzinger, Ribe, and Kahn, to be published, it was found that the ratio of positives to electrons of all momenta with track lengths in excess of four centimeters is approximately 3×10^{-4} for a P^{32} source on an aluminum backing and approximately 2×10^{-2} for particles emerging from 0.5 g/cm² of lead covering the source.

Neutron Production by Proton Bombardment below the (*p*,*n*) Threshold*

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A SMALL neutron yield has been observed when deuterium or beryllium was bombarded by protons at voltages below the established (*p*,*n*) threshold. The experimental observations on these yields are shown in Figs. 1 and 2. Several possible experimental causes such as target contamination, beam contamination with deuterons, and gamma-ray sensitivity of the neutron detectors have been considered but are insufficient to explain this "sub-threshold" neutron yield.

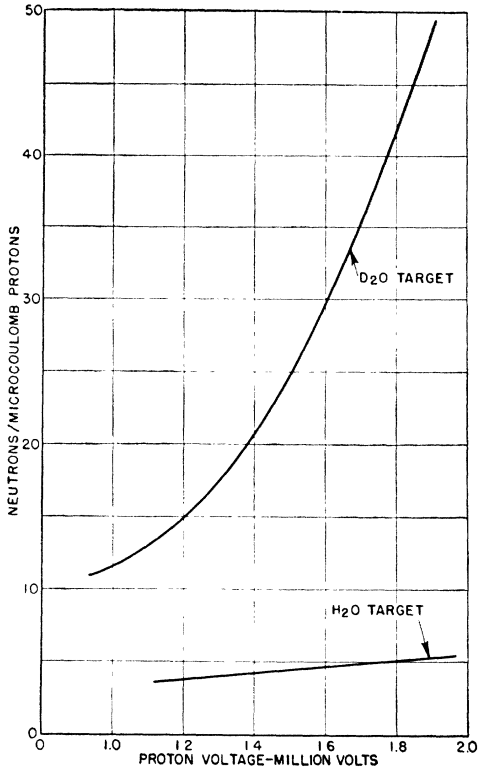

FIG. 1. Neutron yield from deuterium.

We believe that the majority of these neutrons originate from a double process of the (*pd*, *dn*) type where the energetic deuterons are formed in the deuterium target by proton-deuteron scattering and in beryllium by the $Be^9(p,d)Be^8$ reaction. These deuterons, in turn, produce neutrons in the deuterium and beryllium targets.

In deuterium, a calculation of the number of neutrons expected from such a double process has been carried out from the known cross section for *p*–*d* scattering[1] and for the (*d*,*d*) process,[2] and assuming, for comparison with experiment, spherical distribution of the resulting neutrons, good agreement was found with the experimental results shown in Fig. 1.

Neutrons from proton bombardment of Be below the threshold were also reported by Richards[3] but only on thick targets. This suggested a ($p\gamma$, γn) double process as the origin of these neutrons. The cross section of this (γ,*n*) process is small[4] and the neutron yield should be proportional to the bulk of Be behind the thick target surface. This dependence was not observed.

The differential cross section multiplied by 4π at 138° of the $Be^9(p,d)Be^8$ and the competing $Be^9(p,\alpha)$ reaction have been measured for proton voltages between 0.2 and 1.4 Mev and found to be[5] between 0.1 and 0.3 barn. Taking 0.17 barn as an average value, an estimate of the deuteron yield can be made, based on 1-Mev proton bombardment of a 200-kv Be target. Assuming the number of neutrons from 1.3-Mev deuterons on a thick Be target is the order of 100 per million, this calculation involving (*p*,*d*) and (*d*,*n*) processes gives order of magnitude agreement with the number of neutrons observed below the threshold.

If the above explanation for the production of "sub-threshold" neutrons in D and Be is correct, a similar process would not be expected in other elements because beryllium appears to be the only element in which an exothermic (*p*,*d*) process is known. It is

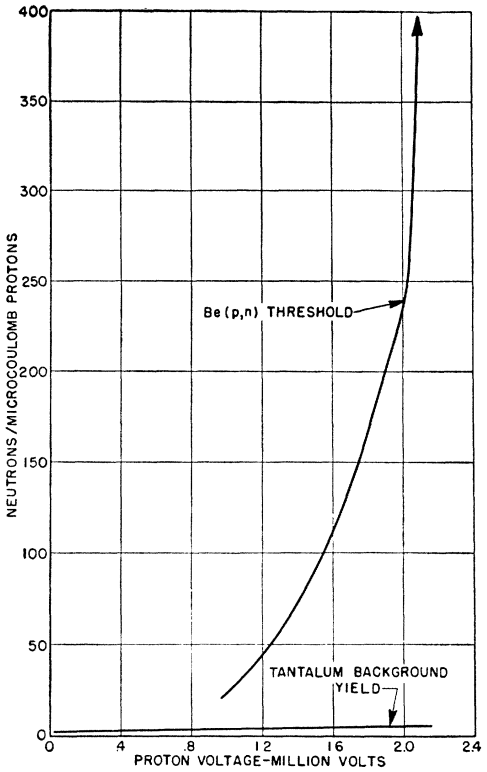

FIG. 2. Neutron yield from beryllium.

true that a $(p\alpha, \alpha n)$ process might contribute a small neutron yield especially where the (p,α) reaction is highly exothermic. However, the neutron yield from $(p\alpha, \alpha n)$ processes would be small compared to the corresponding (pd, dn) reaction because of the higher potential barrier and shorter range of the alpha-particle. From these considerations, it seems unlikely at present that the neutron yield below the threshold would affect the (p,n) studies of other elements.

* Assisted by joint program of the ONR and AEC.
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Private communication.

Chemical Shifts in the Magnetic Resonance of F^{19}

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SEVERAL instances have been reported recently[1-4] of the dependence of nuclear magnetic resonance frequencies on the nature of the chemical compound containing the nuclei. This "chemical effect," or magnetic shielding, has been discussed theoretically[5] but the complexity of the calculations permits their application only to the simplest molecules. We are presently making an experimental survey of the wide variety of existent polyatomic fluorine compounds to determine the influence of structural factors. Initial observations suggest that, in the simpler covalent compounds, the magnetic shielding of an F^{19} nucleus chemically bound to another element is related to the position of that element in the periodic table. For elements in a given period the shielding decreases with increasing atomic number, while for elements in the same group the shielding increases with increasing atomic number. Also, in complex fluorides the shielding depends on the inductive effects of neighboring chemical bonds. Measurements of the influence of temperature on the magnetic shielding in several compounds over a total range of 225° revealed no dependence larger than the experimental error.

Observations were made using conventional equipment,[6] and a permanent magnet with field of 6375 gauss. The magnetic shielding in an "unknown" was determined, at a fixed frequency of 25–54 Mc, by alternately measuring the field biasing current necessary to center the resonance on an oscilloscope, first for the unknown and then for another, reference compound. Only samples were interchanged; the coil containing the samples remained fixed throughout. With field inhomogeneities less than 0.1 gauss, sharp lines in liquids permitted measurements of differences in the resonance field to a probable error of ± 0.01 gauss or ± 1.5 p.p.m. of the external field. The temperature dependence was investigated by having the sample in a cryostat and a reference sample outside as parts of a dual system excited by the same oscillator. Resonances were viewed on either a dual oscilloscope or a standard oscilloscope with a manual switch. Samples which are gases at room temperature were observed with a similar arrangement.

In Fig. 1(A) are the results for the simpler fluorides, suggesting the periodicity of the magnetic shielding. Data for the N^{14} magnetic resonance[3] in NO_3^-, CN^-, and NH_4^+ and also[7] for B^{11} in BCl_3, BBr_3 and $B(OCH_3)_3$ follow the same rules. Observations on the P^{31} magnetic resonance[7] in PCl_3, PBr_3, PI_3, P_4, and H_3PO_4 follow the period rule but the magnetic shielding in PCl_3 is slightly greater than in PBr_3, counter to the group trend for F^{19}. Figure 1(B) lists the data for various complex fluorides, discussion of which will be given in a later article.

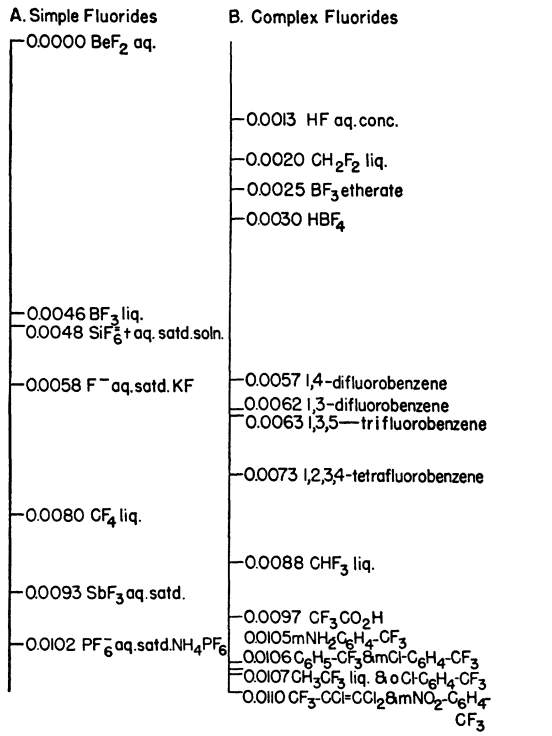

FIG. 1. Magnetic shielding of the F^{19} nucleus. The F^{19} resonance in BeF_2 is at the highest external field, thus exhibiting the largest magnetic shielding. Values given are percentage decrease in resonance field relative to BeF_2. [Except for BF_3 etherate, values in this list for compounds previously reported by Dickinson (reference 2) agree with his values when allowance is made for the difference in external magnetic fields, and a field calibration correction factor (reference 7) of 0.64 is applied to his values. Observations included Co, Cu, Fe, H, (NH_4), Mg, and Zn salts, which differed among themselves only slightly in excess of experimental error.]