filament plate current. The counter characteristics affect the composition of the best solution very little. The following table contains the compositions and "kick" size for counters approximately the same as that described immediately above.

Table I.

Speed of count (min.$^{-1}$)	Size of kick (percent of filament-plate current)	Approximate volume percent of isopropyl alcohol
200	5–10	6
40	80–100	1

The amplifying tube can be any radio tube which will give a filament plate current of 3 or more milliamperes. The relay is an ordinary 680 ohms telegraph relay.

Argon gas at about 5 cm of Hg pressure is generally used in the counter, and the applied voltage is generally between 600 and 1500 volts.

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High-Speed Hydrogen Ions

In a paper on the production of high speed light ions without the use of high voltages[1] a method and apparatus were described in detail for producing 1,220,000 volt-protons. The value of such high-speed protons for studies of the atomic nucleus has been shown recently by Cockcroft and Walton.[2] Using the above mentioned apparatus, their results have lately been checked and somewhat extended in this laboratory by disintegration of the lithium nucleus.[3] It is obvious that for further nuclear studies ions of still higher energies will be exceedingly valuable and an apparatus of larger dimensions has now been developed which produces hydrogen ions with energies equivalent to 3,600,000 volt-electrons.

An essential part of the apparatus is an electromagnet which gives uniform fields over considerable areas; indeed, the maximum producible ion energies are proportional to the area of the useful region of the magnet's field.

Although the magnet now being used has an iron coil 45 inches in diameter, for this first step the pole face diameter has been reduced to 27.5 inches, giving fields in excess of 15,000 gauss over a gap of 3.5 inches. Actually only a region of 20 inches diameter in the center of the poles has been used in the present experiments. The chamber between the poles was evacuated by means of a high-speed pumping system which kept the pressure of heavy gases and vapors down to the order of 10^{-6} mm of mercury and a pressure of hydrogen of approximately 10^{-5} mm of mercury was maintained by a suitable capillary leak. The ions were produced in this hydrogen gas by an electron beam from a filament near the center of the chamber which could be moved to the proper position, i.e., such that the ions started from a point away from the geometrical center of the apparatus by a distance equal to the radius of their first circle in the magnetic field. The high-frequency fields were applied across the diametral gap between two large hollow semi-circular electrodes, (one of which was at ground potential) by means of a "tuned plate—tuned grid" oscillator circuit, using a Federal Telegraph 20 kilowatt water-cooled tube. Wave-lengths down to 25.8 meters were used and voltages applied on the electrodes of approximately 15,000 volts or less. At the edge of the 20 inch circle the ions passed through an electrostatic deflecting system which bent them out of the beam (and at the same time measured their energies) into a collector connected to a suitable electrometer. From the electrostatic voltages applied on the deflecting plates the energies were calculated, and were found to check closely in each case with those expected.

Using a 28.5 meter wave-length, and a magnetic field of 14,000 gauss, hydrogen molecule ions were produced with energies of 3,000,000 volt-electrons and with a current of approximately 10^{-9} amperes. Using 25.8 meters and 15,250 gauss, 3,600,000 volt ions were produced. Due to the efficient focussing action of the high-frequency electrodes, the ion currents remain approximately the same throughout the range from 1 to 3.6 million volts. These H_2^+ ions with energies of 3,600,000 volt-electrons are, for nuclear purposes, essentially equivalent to protons of energies

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[1] Ernest O. Lawrence and M. Stanley Livingston, Phys. Rev. **40**, 19 (1932).

[2] Cockcroft and Walton, Proc. Roy. Soc. **A137**, 229–242 (1932).

[3] Lawrence, Livingston and White, Phys. Rev. **42**, 150 (1932).

of 1,800,000 volt-electrons. Hydrogen molecule ions rather than protons were accelerated in the present experiments because protons require a much lower wave-length (for the same magnetic field), which is difficult to obtain due to the large capacity in the oscillating circuit.

It appears now entirely practicable to go to much higher energies by using a still larger chamber. However, it seems more desirable to hesitate awhile on the road to higher voltages and use these 1,800,000 volt protons for some nuclear studies. This we intend to do.

I wish to express my deepest gratitude to Prof. Ernest O. Lawrence for his constant help and guidance in this development, and to Commander T. Lucci for his invaluable assistance. These experiments have been made possible through the help of the Federal Telegraph Company, the Research Corporation and The Chemical Foundation.

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October 3, 1932.

The Heisenberg Theory of Ferromagnetism

The theory of the existence of ferromagnetism, due to Heisenberg,[1] disagrees in some of its consequences with experiment. It is here shown to be not quite as unphysical as has been supposed. Heisenberg's principal result is contained in the well-known simultaneous equations:

$$\begin{aligned} &\text{I.}\quad y=\tanh x \\ &\text{II.}\quad x=\tfrac{1}{2}(\beta-\beta^2/z)y+\beta^2y^3/4z \qquad (1) \end{aligned}$$

$\beta=zJ/kT=$(number of nearest neighbors of atom in crystal)$\times$(e.s. exchange integral)$/kT$.

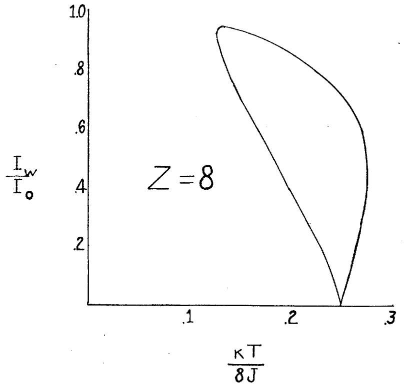

Fig. 1.

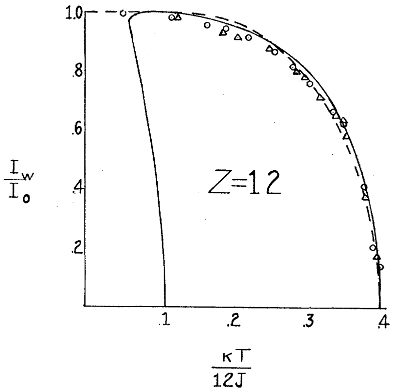

Fig. 2.

$y=I_w/I_0$. I_w is the magnetization in a field only strong enough to orient the large crystal spin (if extant) and to overcome the small magnetic interactions[2] of the electrons (here neglected). I_0 is the intensity of absolute saturation. The atomic spin is that of one electron.

The prevalent interpretation of these equations has been based on a graphical solution similar to that of the Weiss theory, neglecting the fact that II does not give a straight line

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[1] W. Heisenberg, Zeits. f. Physik **49**, 619 (1928).

[2] The magnetic interactions are largely responsible for direction effects, remanence, hysteresis, and demagnetizing forces, which may not be expected of the Heisenberg model, unmodified. One might expect hysteresis from the graphical manner of solving (1), but must bear in mind that the equations do not hold for zero external field, when the magnetization may change in direction. The part of the magnetization curve treated by (1) when the term $\mu H/kT$ is added to χ is, of course, only that beyond the usual experimental saturation. In that region Kapitza has measured that with 240,000 gausses the magnetization of Fe and Ni at room temperature increases not more than 1 percent. After simplifying (1) by taking II linear (see footnote 3), calculation shows that the increase for Ni should be 1 percent and for Fe less than one-tenth as much. The corresponding increase for Ni at 330°C should be about 10 percent.