Table III gives a more detailed report of the g-values and their origin in various isotopes. It is of interest that the proton (type 2 and 2′) produces j and l-values that are small at the beginning of the periodic table and increase more and more with higher elements.[8] On the other hand the neutrons of type 3 and 3′ retain their small j and l-values throughout the periodic table. One may interpret this in the sense that the single proton is bound to the surface of the nucleus while the single neutrons are bound inside.

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[8] Only Tl^{81} is an exception with $j=\frac{1}{2}$. This behavior makes us suspect that our scheme of type 2 and the g-formula (a) does not apply here. The experimental g-value of Tl is rather uncertain, too, depending on whether one applies the interpolation formulas of Goudsmit or of Fermi-Segrè. For these two reasons we have marked Tl in Table III with question marks and have not drawn it in Fig. 1.

Small-Angle Inelastic Scattering of Electrons in Helium, Hydrogen and Mercury

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The inelastic scattering of electrons by helium, hydrogen and mercury is measured for angles very close to the forward direction, ranging from 0° to 15° scattering. Those electrons are studied which have suffered losses of 21.1 volts, 12.6 volts and 6.7 volts, respectively, for the three gases. The initial energies range from 100 to 300 volts. The scattering per unit solid angle is found to reach a maximum at a fairly small angle and then decrease to a lower value at zero angle. The position of the maximum is a function of energy and not of momentum as predicted by the Born theory.

A PRELIMINARY report of some results on the inelastic scattering of electrons of medium energy in the region around the forward direction was made[1] at the New York meeting of the American Physical Society in 1933. Since that time Whiddington[2] and others have published results, first confirming and later failing to confirm the anomalies reported in the behavior of the scattering cross sections at very small angles. It was originally intended to continue the work with some changes in the apparatus, but this has not been possible, so the results already obtained are put on record. The gases used were helium, hydrogen and mercury, those electrons being studied which had lost 21.1 volts, 12.6 volts and 6.7 volts, respectively, in the three gases. The initial energies of the electrons were approximately 100 volts, 150 volts, 200 volts and 300 volts. The range of angles covered was about 0° to 15°.

The apparatus used is shown diagrammatically in Fig. 1. The source of electrons is a cylindrical, indirectly heated cathode. Immediately surrounding it is an electrode whose potential can be varied for focussing purposes. The main accelerating field is between the cathode and the anode. The anode is insulated from the main part of the apparatus, although at the same potential, in order that a galvanometer may be connected between them to measure the current leaving S_1. Scattering takes place in the region R. Scattered electrons go through slits S_2 and S_3 into the electrostatic analyzer,[3] A. Those of the proper energy go on through S_4 to the collector, where they are measured by a two-tube FP-54 amplifier. The dimensions of the slits are: lengths of all, 3 mm; widths, S_1, 0.15 mm, S_2, 0.14 mm, S_3, 0.28 mm, S_4, 0.27 mm. The radii of the plates of the electrostatic analyzer are 5 and 6 cm.

The part of the apparatus containing the cathode and anode is movable about an axis through O. Its movement is read on a divided circle, the readings of which, after the zero has been determined by letting the main beam pass through S_2 and S_3, give the angle of scattering of those electrons entering the analyzer. Gas is admitted to the apparatus at I and pumped out at

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[1] S. N. Van Voorhis, Phys. Rev. **43**, 777A (1933).

[2] Whiddington, Emerson and Taylor, Nature **132**, 65 (1933); Poultney and Whiddington, Nature **133**, 685 (1934).

[3] Hughes and Rojansky, Phys. Rev. **34**, 284 (1929).

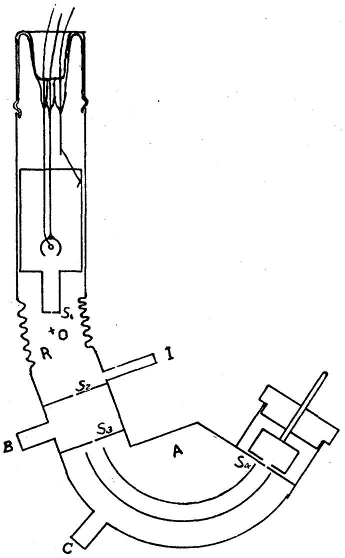

FIG. 1. Diagram of apparatus.

B between the slits and at *C* from the analyzer chamber. The pumping speeds are such that the pressure in the analyzer chamber is about 1/30 of that in the scattering region. Pressures are read on a McLeod gauge, which unfortunately had to be connected back in the gas supply system so that its readings are about twice the actual pressure in the scattering chamber. Since no attempt is made to determine absolute values of scattering cross sections, this does not matter. The pressures used range from 10^{-2} mm of Hg down in the case of hydrogen and helium. Mercury is admitted by placing ice instead of liquid air on a trap in the line to *I*.

The effective scattering volume was determined graphically. The slits S_2 and S_3 determine a wedge-shaped region from which electrons might enter the analyzer. The effective scattering volume is the intersection of this wedge and the initial beam. It was found that by proper adjustment of the potential of the focussing electrode, the beam coming out of S_1 could be made very closely parallel, the intensity half a degree away from the center of the beam being down by a factor of a thousand. Therefore the assumption was made that the initial beam is strictly parallel. The scattering volume was found to be proportional to $1/\sin\theta$, where θ is the angle of scattering, down to angles of 1 or 2 degrees, providing the apparatus is in perfect mechanical adjustment.

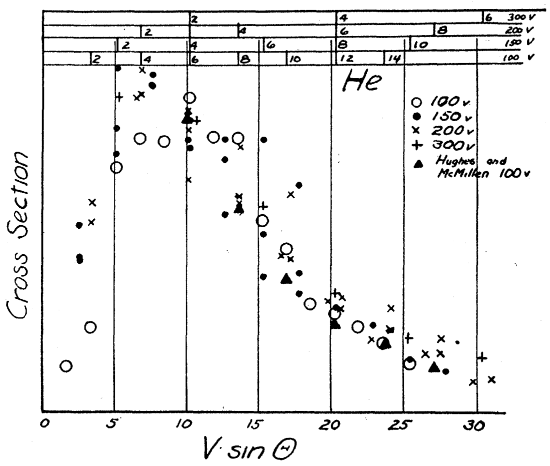

FIG. 2. Scattering in helium.

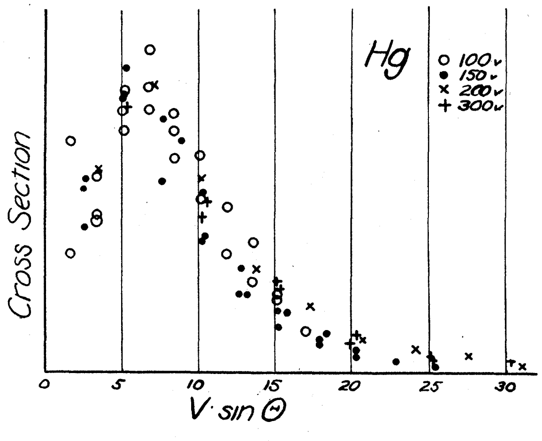

FIG. 3. Scattering in mercury.

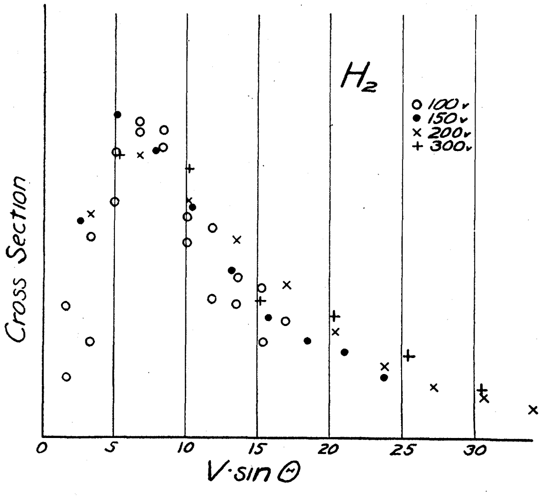

FIG. 4. Scattering in hydrogen.

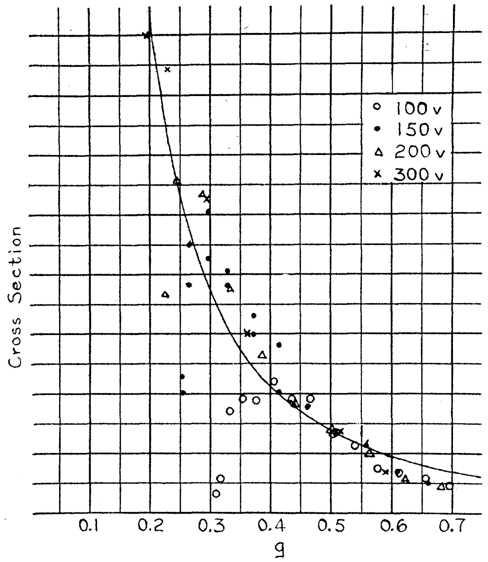

FIG. 5. Comparison of experimental scattering cross section with first approximation Born theory.

The equation used to reduce the observed scattered currents to values proportional to scattering cross section is

$$\sigma=(KI\sin\theta)/I^*p,$$

where I is the scattered current, I^* the current in the beam, p the pressure, and K is a constant involving numerical factors, the absolute size of the scattering volume, and the solid angle subtended by the collector at the scattering volume.

The results obtained are shown in Figs. 2, 3 and 4. The abscissa used is the product of the energy of the incident electrons in volts and the angle or sine of the angle of scattering. The ordinates are proportional to the scattering cross sections defined above. There is no theoretical justification for this method of plotting, but it was found early in the work that the results for different electron energies in a given gas could be superimposed by using this abscissa. On the figure for helium are shown the corresponding angles of scattering in degrees for the different electron energies used. Also shown are the scattering cross sections given by Hughes and McMillen[4] for 100 volt electrons in helium losing 21.1 volts. These have been made to fit at the smallest angle given by them, 6°. It will be seen that all the gases used show the common behavior of a maximum in the scattering at a small angle of from 2° to 6° depending on the energy of the electrons, followed by a decrease in scattering at zero angle.

In Fig. 5 some of the results for helium are compared with the results of a simple calculation using the first approximation method of Born.[5] This was carried out using hydrogenic wave functions with effective nuclear charges Z_1 and Z_2 for the initial and final state of the atom, and gives for the scattering cross section, for small values of g,

$$\sigma=\frac{2^{12}}{3}\,\frac{k_m}{k}\,\frac{Z_1Z_2{}^3}{(2Z_1+Z_2)^6}\,\frac{\pi a^{o2}}{g^2},$$

where k_m and k are $2\pi/h$ times the momentum of the scattered and incident electron, respectively, a^o is the radius of the first Bohr orbit, and g is a quantity proportional to the momentum given to the atom in the encounter. It is given by

$$g=\left[(E^{\frac{1}{2}}-E'^{\frac{1}{2}})^2+4(EE')^{\frac{1}{2}}\sin^2\theta/2\right]^{\frac{1}{2}}$$

where E and E' are the energies of the electron before and after scattering expressed in terms of the Rydberg unit. The smooth curve in Fig. 5 is the expression const./g^2. The experimental results and the curve have been made to agree at $g=0.5$. It will be seen that the agreement is good at angles greater than that at which the maximum of scattering is found, but that at smaller angles the results for different energies of incident electrons are definitely not in agreement with the curve. It does not seem to be clear whether or not the higher approximations of the Born theory could give such behavior.

The fact that the scattered current is proportional to the gas pressure was checked, but difficulty in reading the current in the beam prevented a check of the proportionality between it and the scattered current. It is very important in working in this region of angles, that the apparatus be lined up so that the region defined by the collecting slits S_2 and S_3, and the initial beam shall intersect on the axis of rotation. If this is not the case, the scattered currents on the two sides will not be equal, and in extreme cases, a false decrease in scattering in the forward direction will be produced. The apparatus used here was

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[4] Hughes and McMillen, Phys. Rev. **44**, 20 (1933).

[5] Born, Zeits. f. Physik **38**, 803 (1926).

especially constructed to be in as good alignment as possible. Some difficulty was experienced in this work which was attributed to surface charges built up on small insulating patches. These produced random asymmetries in the scattered current, which, however, appeared and disappeared on both sides of the center. The results given here were taken when the disturbing effects were absent. It is not thought that mechanical misalignment is responsible for the results. The readings covered a space of two months, during which time the apparatus was taken apart and reassembled several times. Readings taken over this whole length of time were consistent. Also lack of alignment seem to be incapable of explaining the variation with voltage of the observed scattering. A further possible source of error lies in the fact that the apparatus is so built that the slit S_1 comes into the scattering volume at the smallest angles. This might increase the scattering volume above that calculated by the $1/\sin\theta$ rule, and also might allow electrons scattered by gas adsorbed on the slit to be registered. However, both of these causes would seem to make the scattering observed at these angles too large rather than too small.

Large Barkhausen Discontinuities and Their Propagation in Ni-Fe Alloys. II

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The relationships between longitudinal field, intensity of magnetization and velocity of propagation of large Barkhausen discontinuities have been investigated. For a constant velocity of propagation a linear relation has been found between intensity of magnetization and longitudinal field. The curves relating velocity and intensity of magnetization for a fixed value of longitudinal field resemble velocity-longitudinal field curves. The relationships between longitudinal field, circular field and the directions of strain axes have been investigated for pure nickel wire under combined torsional and tensile stresses. It has been found that only the component of field in the direction of maximum compression affects the velocity of propagation. The behavior of propagation phenomena for pure nickel is just the reverse of that observed for a 10 percent Ni-Fe alloy. This difference is probably related in some way to the difference in magnetostrictive properties of the two wires.

I. Introduction

In a Letter to the Editor of the *Physical Review* the writer[1] reported briefly some further results concerning the propagation of large Barkhausen discontinuities in Ni-Fe alloy wires. These results included experimental investigations of the dependence of the velocity of propagation upon intensity of magnetization and also investigations of the relationship between longitudinal field, circular field, direction of maximum strain and velocity of propagation for pure nickel wire. The purpose of the present paper is to present more completely the experimental data regarding those results.

II. Apparatus and Symbols

The apparatus used for velocity of propagation measurements was the same as for some previous investigations of propagation phenomena.[2] Intensity of magnetization measurements were made by a fixed point method in which the air field was completely balanced out by means of a variable mutual inductance in the primary and secondary circuits.

The symbols denoting the magnetic fields referred to in the following will be the same as those previously used.[2] These symbols are: H, the longitudinal magnetic field produced by a magnetizing solenoid; H_c the circular field (always specified at the surface of the wire) produced by sending a direct current through the wire; H_0, the critical field or the field corresponding to zero velocity of propagation.

The convention previously adopted[2] regarding the directions of the circular field relative to the strain axes will also be used here. This convention requires that a circular field in such a direction

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[1] R. E. Reinhart, Phys. Rev. **45**, 342 (1934).

[2] R. E. Reinhart, Phys. Rev. **45**, 420 (1934).