The theoretical value of s_c/s_e was determined from Bethe's theory, s_c being an average value computed from,

$$s_c = \frac{\int s(E)I(E)dE}{\int I(E)dE}.$$

The integration was performed graphically from Blackett's energy-distribution curve (I *vs.* E) for the ionizing component at sea level,[5] using Bethe's theory for the values of $s(E)$. Since the form of Bethe's curve is not dependent on the substance of the absorber, there is real meaning to the comparison of the theoretical value of s_c/s_e for hydrogen with the experimental value for the helium-butane mixture.

It is clear that the results given here are essentially in agreement with theory. Cosyns' method, which employs only one counter, seems to be subject to scattering effects to a greater extent than he indicates.

Hazen's value of s_e was obtained from the cloud-chamber tracks of twenty-one beta-particles in the 0.4–7.0-Mev range, which may account somewhat for the discrepancy in this case, since the primary ionization rises quite sharply for energies less than 1 Mev.

The construction of a beta-ray spectrometer is now in process, which should make possible an accurate determination of $s(E)$ for various gases. This measurement for hydrogen is being made at the present time by the method herein described.

The author wishes to express his sincere appreciation of the frequent advice and suggestions of Mr. W. E. Ramsey.

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Divergent Beam X-Ray Photography of Metallic Single Crystals

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October 1, 1947

WE have observed a new type of x-ray diffraction phenomenon in Laue patterns of certain alloys. The phenomenon is similar to the Kikuchi lines which are found in electron-diffraction patterns of thick crystals; it is the same as that observed by Dr. Kathleen Lonsdale on using a very special x-ray tube as described in a recent report.[1] On using this tube which provided a widely divergent beam of x-rays, she found that a pattern of fine white absorption lines and black diffraction lines on a grey background could be produced, under suitable conditions, from single crystals of diamond and organic substances. Such patterns could be used for determinations of crystal orientation and precise lattice constants and for an evaluation of the perfection of the crystal.

On using a somewhat different technique we have observed similar patterns when single crystals of solid solution alloys, which contained iron or cobalt, were irradiated with copper radiation. Patterns for the alloy Cunico and for an Alnico alloy are shown by Figs. 1 and 2. Instead of a widely divergent primary beam, we used a collimated beam of radiation from a tube with a copper target and the usual transmission Laue camera. The normal Laue spots are evident in the patterns. Apparently the required widely

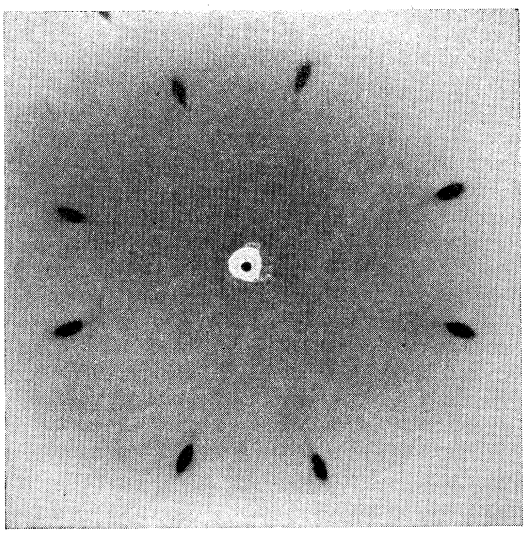

FIG. 1. Laue pattern of Cunico (50 percent Cu, 29 percent Co, 21 percent Ni). Face-centered cubic crystal oriented with [010] parallel to incident beam of Cu radiation. White arcs originated in diffraction from background Co secondary radiation.

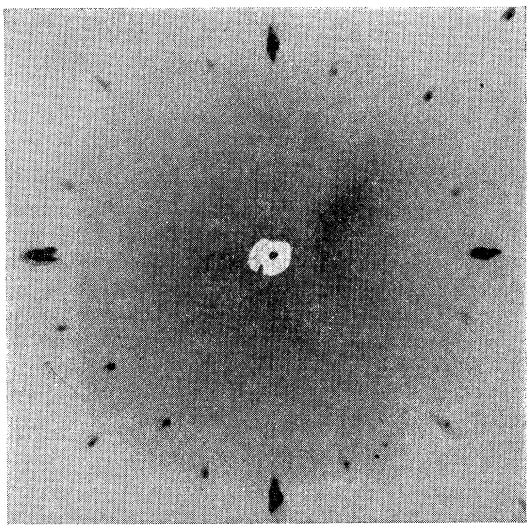

FIG. 2. Laue pattern of Alnico 4 (55 percent Fe, 28 percent Ni, 12 percent Al, 5 percent Co). Body-centered cubic crystal oriented with [010] parallel to incident beam of Cu radiation. White arcs originate in diffraction from background Fe secondary radiation.

divergent beam of x-rays originated at the specimen as secondary Co or Fe radiation which had been excited by the incident beam. The white arcs are quite prominent, while the dark lines are somewhat difficult to distinguish from the background. Fewer dark lines are expected since all reciprocal lattice points within the volume of reflection diffract corresponding rays from the scattered beam to leave the white lines, whereas only those rays diffracted in the forward direction reach the flat film and are detected as black lines. Black diffraction lines have been observed best where they fall in a region of the film remote from the center where background scattering is slight.

The technique which we used offers the advantage that the line pattern is supplemented by the normal Laue pattern on the same film and that the exposures are made with the sealed-off x-ray tubes which are so widely used today. The obvious disadvantages are the relatively long exposure times (8 to 16 hours) and possibly the limitation of materials which can be investigated directly; however, a technique probably could be developed for the examination of single crystals of other materials in which a piece of iron foil is placed in front of the sample as the source of divergent Fe radiation. Work is in progress to determine the utility of this new kind of x-ray diffraction analysis in the study of the solid-state reactions in the above alloys.

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Does the Electron Have an Intrinsic Magnetic Moment?

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September 29, 1947

THE hyperfine structure of the ground term of H^1 and H^2 is greater[1] than expected from nuclear magnetic moments by, respectively, 0.26 and 0.31 percent. The difference between these values is less certain than the approximate value 0.28 percent and will be assumed to be insignificant.[2] If the electron had a small, Pauli-type, intrinsic magnetic moment[3] μ_e the observed and calculated values would differ.

The effect of $\mu_e\rho_3(\mathbf{H}\sigma)$ in the Hamiltonian (Dirac's notation) is to change the hfs interval factor to

$$A=\frac{2\partial\mu_N}{ij(j+1)}\,Im\int_0^\infty\left[-k+\frac{\mu_e p_0}{e\hbar}\right]F^*G\,dr, \qquad (1)$$

where $k=l$, $-l-1$, respectively, for $j=l-\frac{1}{2}$, $l+\frac{1}{2}$. The functions F, G are, respectively, $-iF$, G of Roess.[4] Azimuthal, inner, and nuclear-spin quantum numbers are l, j, i. The magnetic field of nucleus at the electron is H, the nuclear magnetic moment is μ_N. The molecular-beam experiment gives $\mu_N/(\mu_0-\mu_e)$, where $\mu_0>0$ is the Bohr magneton. The atomic-beam experiment determines,[5] according to Eq. (1), the quantity $\mu_N(\mu_0+\mu_e/2)$. The theoretical ratio of the hfs to the molecular-beam value of μ_N contains, therefore, $1-\mu_e/2\mu_0$ as a factor. To explain the observed discrepancy one needs $\mu_e/\mu_0=-0.0056$, a small value which could have escaped detection. According to Eq. (1) the interval factors of s, $p_{1/2}$, $p_{3/2}$ terms contain μ_e in the factors $1+\mu_e/2\mu_0$, $1-\mu_e/2\mu_0$, $1+\mu_e/4\mu_0$ apart from factor $1-\mu_e/\mu_0$ which is needed in (1) if the apparent μ_N is substituted for the true value. In principle, ratios of interval factors for these terms could determine μ_e/μ_0.

One expects the following additional effects of μ_e: (a) A modification of the Landé g factor through factor $1-2\mu_e/\mu_0$ in $g-1$. (b) The term $(-\mu_e)\rho_2(\mathbf{E}\sigma)$ caused by nuclear electric field contributes to the energy

$$\Delta E=-2\mu_e Im\int_0^\infty F^*G\,dr\leqq\frac{2\mu_e(1+k)Z^4Rch\alpha^2}{\mu_0(l+1)l(2l+1)n^3}, \qquad (2)$$

where n is the principal quantum number of a hydrogenic term, R is the Rydberg, and α is the fine structure constant. For $n=2$, $Z=1$ Eq. (2) gives

$$\Delta E=(-4,\,4/3)(\mu_e/\mu_0)(Rch\alpha^2/16)$$

for $2s$, $2p_{1/2}$, respectively. The displacement of $2s$ with respect to $2p_{1/2}$ of hydrogen is $(-16/3)(\mu_e/\mu_0)(Rch\alpha^2/16)$, which is about 1/33 of the $2p_{3/2}$, $2s$ doublet separation for $\mu_e/\mu_0=-0.0056$. The Lamb-Retherford $-2s+2p_{1/2}$ separation is roughly 3 times the above value. It is doubtful that Bethe's[6] electrodynamic shift theory of the Lamb-Retherford effect[7] is as yet quantitative enough to exclude the possibility of about $\frac{1}{3}$ of the effect arising from another cause.

The presence of the Coulomb energy in p_0 in Eq. (1) makes the integral diverge for s terms. The integral converges, however, if the Coulomb energy is made finite at small distances. A cut-off of the integral at $r\sim e^2/mc^2$ makes the contribution of the Coulomb energy to the integral of the negligible order $\alpha^2\log\alpha^{-2}$ of the term containing p_0. The quantity p_0 has accordingly been replaced by mc in the estimates.

It is not claimed that the electron has an intrinsic magnetic moment. Aesthetic objections could be raised against such a view. The only object of this note is to point out that the evidence considered above does not disprove a small μ_e of the order $\alpha\mu_0$.

If the discrepancy is due to an interaction between the electron and the nucleus of a local type, it is hard to see why it should have the same fractional value for the proton and the deuteron. In this case the effect would be practically confined to s terms, and one could, in principle, distinguish between it and the hypothesis of the intrinsic magnetic moment by comparing hfs interval factors for different spectroscopic terms.

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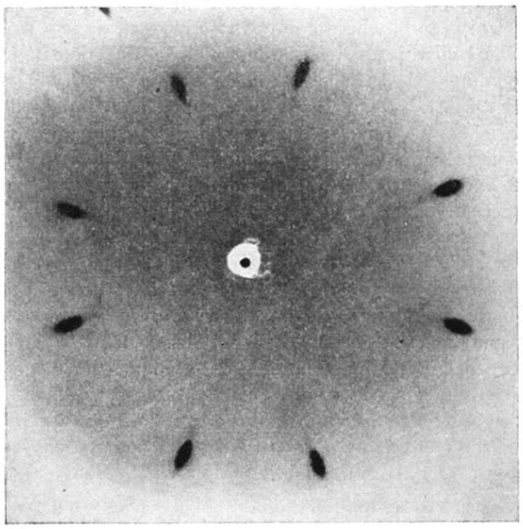

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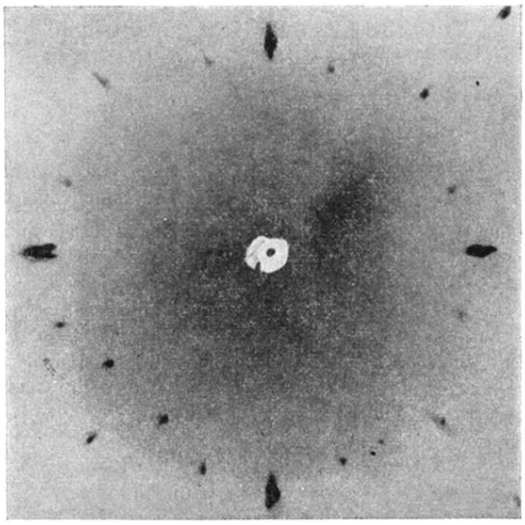

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