LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the twentieth of the preceding month; for the second issue, the fifth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Directions of Discontinuous Changes of Magnetization in a Rotating Monocrystal of Silicon Iron

We have continued, by a more powerful method, the study[1] of Barkhausen effects in a monocrystal specimen wherein $\mathbf{H}_a$, the applied magnetic field intensity, changes in direction but not in magnitude. Instead of using a two-element galvanometer (G. E. oscillograph) to record the impulses in the two search coils (with axes at right angles) surrounding the disk specimen, we use a cathode-ray oscillograph. With each pair of deflector plates fed through a suitable amplifier by one of the search coils we obtain an excursion of the luminous spot on the screen in a direction which corresponds to the direction of any sudden change in magnetization, $\Delta\mathbf{I}$, occurring in the specimen. A photographic record is made covering selected short intervals during the slow and uniform rotation of $\mathbf{H}_a$ in the plane of the disk. Fig. 1 shows how the directions of large changes, $\Delta\mathbf{I}$, are related to the momentary direction of $d\mathbf{H}_a/dt$ and to the directions in the disk (four in number) which correspond most nearly to axes of the form $<100>$. By large changes we mean those which give a trace on the photograph (at one-fourth size) at least two millimeters in length, i.e., long enough to make the azimuth of the trace determinate. Many traces too short for individual measurement occur somewhere near the angles at which long traces are observed.

The specimen, for which we are indebted to Dr. W. E. Ruder of the General Electric Company's Research Laboratories, is a disk of 3 percent silicon iron, 1.33 cm in diameter and 0.023 cm thick, cut from the rectangular piece furnished us. The orientation and perfection of the crystal were tested by taking Laue photographs both before and after annealing (2.5 hr. at 870°C). A slight improvement in the symmetry of the Laue spots resulted from this treatment, and there was no indication in the final state of any residual strain. Neither the orientation of the axes nor the angular distribution of $\Delta\mathbf{I}$ were noticeably altered by annealing.

Evidence for the heterogeneity of magnetization at this value of $\mathbf{H}_a$ is furnished by the fact that $\Delta\mathbf{I}$ varies over a considerable range of angles about the momentary value of $d\mathbf{H}_a/dt$. This means that many changes $\Delta\mathbf{I}$ take place in which the magnetic potential energy density seems to increase, i.e., $\mathbf{H}\cdot\Delta\mathbf{I}<0$. The reasonable view is that the local direction of $\mathbf{H}$ in the parts affected differs so much from the direction of $\mathbf{H}_a$ that the anomaly is apparent rather than real. The same difficulty arises on the descending branch of any ordinary hysteresis loop for $\mathbf{H}_a>0$.

The largest excursions of the spot frequently show changes in the direction of $\Delta\mathbf{I}$ during the time of tracing, so that narrow loops or zigzags are traced. This seems to mean that a major discontinuity can traverse regions in which the change in the direction of magnetization is widely different from that in regions where a discontinuity is likely to grow to observable size.

Fig. 1 shows that practically all of the large changes are explicable as due to simple reversals along one of the directions of easy magnetization, here of the form $<100>$. At lower $\mathbf{H}_a$ this preference is not nearly so marked. At

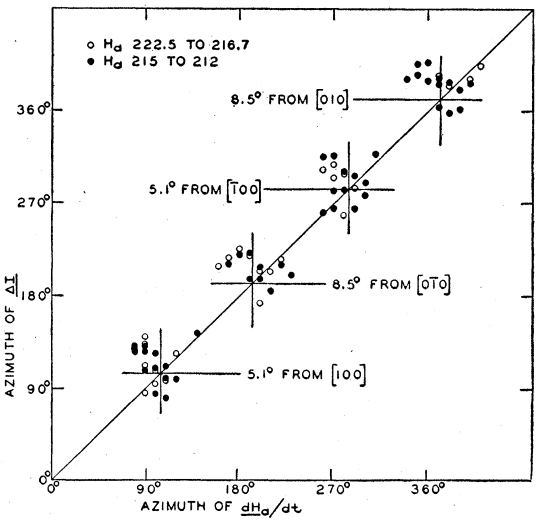

FIG. 1. Angular distribution of $\Delta\mathbf{I}$. The abscissa is the momentary direction of $d\mathbf{H}_a/dt$, the ordinate is the direction of $\Delta\mathbf{I}$, both referred to an arbitrary zero line on the specimen. The 45° line represents the locus of $\Delta\mathbf{I}$ if always parallel to $d\mathbf{H}_a/dt$. Points above the line have $\mathbf{H}_a\cdot\Delta\mathbf{I}$ negative, points below it have $\mathbf{H}_a\cdot\Delta\mathbf{I}$ positive. If only reversals along directions of form $<100>$ are possible the points should lie at the intersections of horizontal and vertical lines so marked. The values of $\mathbf{H}_a$ are indicated. One rotation required 250 seconds.

[1] F. J. Beck, Jr., and L. W. McKeehan, Phys. Rev. **41**, 385; **42**, 714–720 (1932).

the same time the number of large changes becomes less. The probable error in the measured azimuth of a single $\Delta\mathbf{I}$ may be set at $\pm 5°$. This was estimated by picking up the $\Delta\mathbf{I}$ from a small rod of the same silicon iron rotated about a transverse axis in the same field and search coils. We know that each $\Delta\mathbf{I}$ in such a specimen must lie very close to its axis of figure. The angular resolving power in the earlier work[1] was not so high as that now attained and we suggest that the results then obtained were inconclusive mainly for this reason.

The work of Sixtus and Tonks[2] affords an explanation for the effect here observed. We suppose that Barkhausen discontinuities are propagated through a considerable volume only if they result in substantial and favorable changes of $\mathbf{H}$ in front of an advancing boundary. Since reversal of magnetization in any domain best meets this condition discontinuities which arise and proceed in this way have the best chance to grow to a size here observable. We have already pointed out that the largest Barkhausen discontinuities here observed may transcend this condition in their later stages.

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May 1, 1934.

[2] K. J. Sixtus and L. Tonks, Phys. Rev. **35**, 1441 (1930); **37**, 930–958 (1931); **39**, 357–358; **42**, 419–435 (1932); L. Tonks and K. J. Sixtus, Phys. Rev. **41**, 539–540 (1932); **43**, 70–80, 931–940 (1933).

The Heat of Dissociation of N_2

The observation[1] of the long sought intercombination band system $A^3\Sigma \rightarrow X^1\Sigma$ in N_2 has made possible a new determination[2] of the energy of dissociation of N_2. This value $D(N_2) = 7.4$ v seems at first glance to be in disagreement with either my[3] electron impact measurements or those of Tate, Smith and Vaughan.[4] This however is not the case. My results were that it requires 8.62 ± 0.02 v to form $N^+ + N$ from N_2^+. The question involved is the determination of the state of excitation of the N^+ and N formed by electron impact. Possible interpretations are listed below, where I.P. represents the energy necessary to form N_2^+ from N_2. The data in the last column are the result of using for I.P. the accurate value 15.65 ± 0.02 v obtained by Tate, Smith and Vaughan[4]

$N^+ + N$	$D(N_2^+)$	$D(N_2)$	$D(N_2)$
$^3P\ ^4S^0$	8.62 v	I.P.—5.86 v	9.79 v
$^1D\ ^4S^0$	6.73	I.P.—7.75	7.90
$^3P\ ^2D^0$	6.25	I.P.—8.23	7.42
$^3P\ ^2P^0$	5.06	I.P.—9.42	6.23
$^1S\ ^4S^0$	4.59	I.P.—9.89	5.76

As already discussed[3] $D(N_2) = 9.79$ v is certainly too great. The last two values, 6.23 v and 5.76 v seem unreasonably low and the decision rests between 7.90 v and 7.42 v. In my paper 7.90 v was chosen because it was in agreement with Birge's[5] extrapolation of the vibration levels of the A' state of N_2^+ obtaining $D(A') = 3.67$ v and $D(N_2^+) = 6.82 \pm 0.1$ v. If the extrapolation of $D(A')$ is too high and can be lowered to 3.1 v, $D(N_2^+)$ becomes 6.25 v and $D(N_2) = 7.42$ v in agreement with Kaplan and with our third possibility listed in the table. However if Birge's estimate of $D(A')$ and Kaplan's value of $D(N_2)$ are both correct, the value of I.P.[4] for N_2 must be incorrect. My results are in agreement with either alternative and cannot discriminate between the two possibilities.

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May 2, 1934.

[1] L. Vegard, Zeits. f. Physik **75**, 43 (1932).
[2] J. Kaplan, Washington Meeting Am. Phys. Soc. 1934, Paper 92. The conclusions presented at the Meeting were different from those contained in the Abstract.
[3] W. Wallace Lozier, Phys. Rev. **44**, 575 (1933).
[4] J. T. Tate, P. T. Smith and A. L. Vaughan, Phys. Rev. **43**, 1054A (1933).
[5] R. T. Birge, *Molecular Spectra and Molecular Structure*, Faraday Society, p. 713 (1929).

A Stable Hydrogen Isotope of Mass Three

The unexpected announcement at the Physical Society meeting last week by Bleakney and his colleagues from Princeton that they had now found evidence that their deuterium samples contain hydrogen atoms of mass three to the extent of a few parts per million, makes it desirable that we place on record the evidence which had led us to announce a similar conclusion in an abstract (on another subject) submitted for the same program.[1] Using the Allison magneto-optic method, Latimer and Young[2] last autumn announced the detection of a mass-three hydrogen isotope in a sample of heavy water, however, without being able to give a quantitative estimate.

The method we used depends on the simple fact, theoretically predicted and already verified by the comparison of proton and deuton ranges in air, that the rate of loss of energy by any high speed hydrogen nucleus of a given velocity projected into a gas (ion-pairs per millimeter path) is approximately the same irrespective of its mass, whereas

[1] Abstract No. 35, Bull. Am. Phys. Soc., April 10, 1934 (Program of the Washington Meeting). The qualifying phrase "but not proof" was inserted in the abstract, not by reason of any uncertainty in our observations or concerning the reality of the effect, but because we feel that adequate scientific proof of the existence of a new isotope cannot be obtained by any one method. We had not found time to verify our result by collision experiments and we wished to forestall the type of emphatic overstatement so usual in press and magazine reports of scientific news.
[2] W. M. Latimer and H. A. Young, Phys. Rev. **44**, 690 (1933).