A Decrease in the Electrical Resistance of Gold with a Magnetic Field at Low Temperatures

In connection with another investigation we have made measurements on the resistance of a sample of gold wire to which 0.1 percent of silver had been added. At about 8°K the resistance passes through a minimum and at 2°K it has increased about 3 percent above the minimum value. This effect has been observed previously by de Haas, de Boer and van den Berg[1] and the present observations are in agreement with their results. The minimum resistance is 0.0957 of the value at the ice point.

We have also made measurements in the presence of a magnetic field at liquid helium temperatures. At 4.23° the resistance increased with a magnetic field; however, at 1.63°K the resistance decreased by over 1 percent when a field of 8000 gauss was applied. The data are shown in Table I. A more complete study is in progress. The sample consisted of number 40 wire wound on a spool, the axis of which was parallel to the magnetic field.

TABLE I. *Change of resistance of gold with a magnetic field.*

$T=1.63$°K		$T=4.23$°K	
H_{Gauss}	$(\Delta R/R)\times 10^4$	H_{Gauss}	$(\Delta R/R)\times 10^4$
1630	-5.1	1630	$+2.8$
2450	-10.5	2450	4.8
3300	-18.7	3230	6.4
6110	-62.2	6040	15.7
8490	-112.3	8490	26.8

The above reversal in sign and the minimum in resistance are presumably related. A decreasing resistance with magnetic field has previously been observed only in the case of ferromagnetic metals and has been ascribed to effects related to ferromagnetism. A series of gold-silver alloys covering the range 10 to 90 mole percent was also investigated. These materials have no appreciable temperature coefficient of resistance below 10°K and their resistance is practically independent of magnetic field to 8000 gauss.

W. F. GIAUQUE
J. W. STOUT
C. W. CLARK

Department of Chemistry,
University of California,
Berkeley, California,
May 19, 1937.

[1] de Haas, de Boer and van den Berg, Physica **1**, 1115 (1934); de Haas and van den Berg, Physica **3**, 440 (1936).

Connection Between the Second Virial Coefficient and the Phases of Collision Theory

In a recent paper on "Quantum Theory of the Equation of State at Low Temperatures"[1] the writer derived the exact quantum formulae for the second virial coefficient for gases obeying the various statistics, the one for the Einstein-Bose statistics, for example, being, in the absence of any discrete state,

$$B=-\frac{N\pi^{\frac{3}{2}}\lambda^3}{2}+2\sum_{\text{even } l}(l+\tfrac{1}{2})B_l \tag{1}$$

with the same notation as in the paper cited.

For high temperatures, it was there shown how the quantum formulae for all statistics go over to the classical. Up till now, however, no satisfactory formula has been developed for the low temperature region. And it is just this region which is the most interesting, for at low enough temperatures, it should be possible to verify experimentally, at least for helium, the difference between the statistics theoretically predicted. This ought to be possible since at the lowest temperatures the virial coefficient for the Einstein-Bose statistics is theoretically twice as large as for the Boltzman statistics. And even though the Slater-Margenau potential may be quite inaccurate, there is a margin of a hundred percent difference between the two statistics, which leaves room enough to decide from the experimental data—all the more so, since, as we shall show in a later paper, the virial coefficient is relatively not so sensitive to the potential at the lower temperatures.

In the attempt to find an expression for the virial coefficient valid at low temperatures, the writer was led to derive an *exact* expression for B_l. The result is simply

$$B_l=-8\pi^{\frac{1}{2}}\lambda^3N\int_0^\infty dk e^{-\lambda^2k^2}d\eta/dk, \tag{2}$$

where η is the phase shift in the wave function for two radially interacting molecules. *This expression is valid over the whole temperature region.* The proof will be left to a later paper. We will only show here, that for the case of rigid spheres (2) reduces to the formula given by Uhlenbeck and Beth.[2] For, with rigid spheres,

$$\eta=-\tan^{-1}\left(\frac{J_{l+\frac{1}{2}}(k\sigma)}{J_{-l-\frac{1}{2}}(k\sigma)}(-1)^l\right),$$

so that

$$\frac{d\eta}{dk}=-\frac{2}{\pi k}\frac{1}{J^2{}_{l+\frac{1}{2}}(k\sigma)+J^2{}_{-l-\frac{1}{2}}(k\sigma)}.$$

Substitution in (2) gives the Uhlenbeck and Beth result.

This work will be developed more fully when the calculation for the phases is completed.

LEON GROPPER

New York University,
Washington Square College,
May 18, 1937.

[1] L. Gropper, Phys. Rev. **50**, 963 (1936).
[2] G. E. Uhlenbeck and E. Beth, Physica **3**, 729 (1936).

On the Effects in Cosmic-Ray Intensity Observed During the Recent Magnetic Storm

The purpose of this letter is to indicate some effects in cosmic-ray intensity which were observed simultaneously at two stations during the magnetic storm of April 25 to 30, 1937. The data were obtained with Compton-Bennett meters, one at the Cheltenham (Maryland) Magnetic Observatory of the United States Coast and Geodetic Survey and the other at the Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The accompanying figure summarizes the observed effects. On it are plotted for the two stations, in Greenwich mean time, the departures, in percent of the absolute value, of each bi-hourly

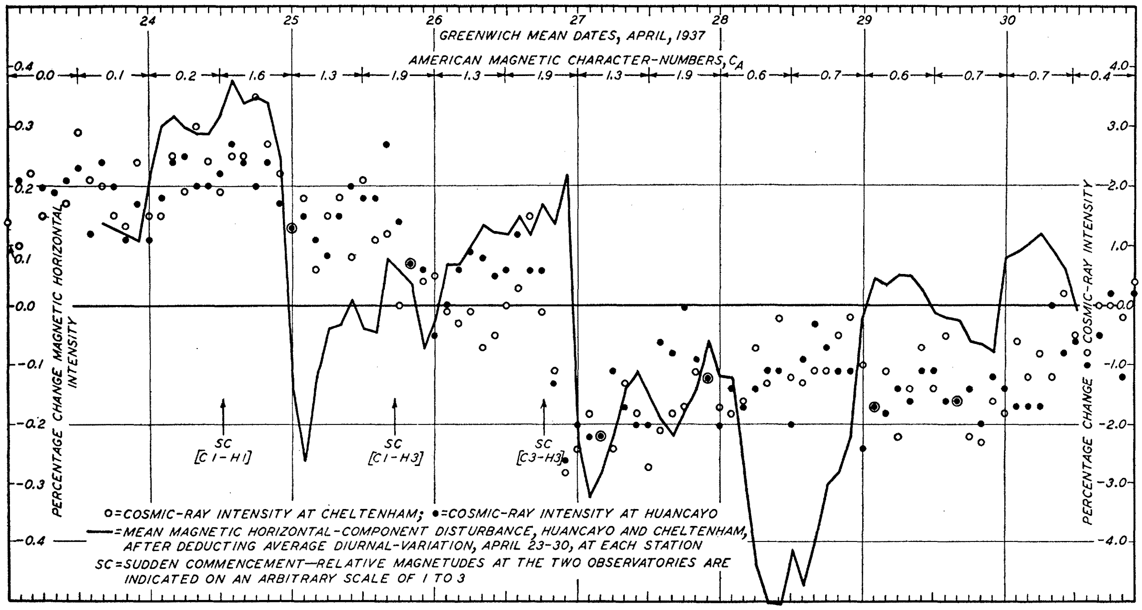

FIG. 1. Bi-hourly departures expressed in percentage of absolute values for cosmic-ray intensity and for disturbance of horizontal magnetic component April 23–30, 1937, Huancayo and Cheltenham magnetic observatories.

mean of cosmic-ray intensity, after eliminating bursts, reduced to constant barometric pressure.

The striking similarity of the simultaneous changes in *the bi-hourly means* of cosmic-ray intensity at the two stations is obvious. The separation of the stations excludes the possibility that this is due to barometric changes.

The decrease of nearly four percent in cosmic-ray intensity from April 23 and 24 to April 27 is much greater than the largest changes which have been observed heretofore at either station over a similar period. The intensity of the magnetic storm was also the greatest since these meters have been operating.

The solid curve in the figure indicates the departures in percent of absolute value of bi-hourly means of the horizontal component of the earth's field derived from the magnetograms recorded at the two stations. It shows several storms following the usual course of a magnetic disturbance, namely, an increase in the horizontal component, which often begins abruptly with a "sudden commencement" (SC); this increase usually continues for an hour or more and is followed by a rapid decrease and a slow recovery to normal after a day or two.

The primary field of a magnetic storm is known to arise from external causes and the major changes of that field can be ascribed to an external current-system.[1, 2] This current system is such that, at great distances external to it, the changes are approximately those which would arise from a change in the earth's moment of the same sign as the observed change in horizontal intensity. Thus the decrease in cosmic-ray intensity which appears to follow the decrease in the horizontal component is to be expected on the basis of the theory of Lemaitre and Vallarta. The storm effect—if substantiated by future observations—when considered in the light of the theory of the allowed cones of Lemaitre and Vallarta, may provide further information on the energy distribution of cosmic rays.

Rigorous analysis based on the theory of Lemaitre and Vallarta has not yet been attempted pending receipt of additional magnetic data to determine the uniform part of its external field of the storm. Some discrepancies between the changes in cosmic-ray intensity and the horizontal component of the earth's field may be expected since cosmic rays are probably affected mostly by the equivalent dipole changes in the earth's field. Some discrepancy may be expected also when one considers the effects of the induced current system.

It may be remarked that there is a noticeable similarity between changes in the daily means of cosmic-ray intensity at these two stations. This would seem a necessary but not sufficient condition for the existence of the 27-day variation in cosmic-ray intensity noted by Hess.[3]

While the evidence here presented cannot be regarded in itself as conclusive proof that the observed changes in cosmic-ray intensity are due to the external field of the magnetic storm, this hypothesis seems to be the most reasonable one.

We are under obligation (1) to the staff of the United States Coast and Geodetic Survey at Cheltenham—in particular G. A. Hartnell who is in charge of the meter—and (2) to the staff at the Huancayo Magnetic Observatory.

S. E. FORBUSH

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D. C.

[1] S. Chapman, Terr. Mag. **40**, 349–370 (1935).
[2] L. Slaucitajs and A. G. McNish, Rep. and Comm., Edinburgh Assembly, Internat. Union Geod. Geophys., Ass. Terr. Mag. Electr., Sept. 1936, 7 pp. (July 31, 1936).
[3] V. Hess, Terr. Mag. **41**, 345–350 (1936).