

uniform constant magnetic field is applied. One can attempt to detect this effect using a thin solid plate put into the gas which should be dragged by the rotation of the gas. We have performed such experiments.

The positive column was produced in a vertical cylindrical tube which contained activated electrodes at both ends and which was completely symmetrical about both the vertical axis and the horizontal plane. The presence of activated electrodes at both ends enabled us to change the direction of the current in the tube. The upper electrode was pierced, and through it was passed a thin quartz fiber (length 30 cm, diameter  $20\mu$ ) hanging along the axis of the tube. The fiber supported a vertically suspended rectangular mica plate with a mirror stuck on it in the middle. This enabled us to observe the position of the plate by the usual means of a light beam and scale.

Two coils with a narrow gap between them to let the light beam through were put on the tube. The current passing through the coils produced a constant magnetic field in the tube which was parallel to the tube axis and to the current in it. The degree of uniformity of the field over the tube was not less than 97%. The coils and the tube were put in coaxial positions by regulating screws which could raise the base of the coils.

We performed the experiments in inert gases, mainly in argon, and partly in neon. The gas pressure was varied between 100 and  $500\mu$  Hg. The following observations were made:

1. When a constant magnetic field was applied to the plasma the plate suspended in it deviated from its initial position; once the vibrations around the new equilibrium position were damped out the plate remained deflected at a constant angle. Such a deflection was observed in both gases and for all pressures and magnetic fields (from 100 to 800 oe) used. The deflection was appreciable (more than several degrees) and could easily be observed, even without a scale.

The stationary character of the effect in a system with a constantly acting restoring force (the elasticity of the fiber) shows that the effect is produced by the constant magnetic field and not by the turbulent inductive electrical field which is produced when the magnetic field appears.

2. When we reversed the direction of the magnetic field the deflection of the mobile system was also reversed.

3. However, when the direction of the current in the tube was reversed, the direction of the deflection of the suspended system remained the same. This shows that the effect is not caused by

the plasma current and the applied magnetic field not being completely parallel, for otherwise the effect would reverse its sign when the direction of the current in the tube was reversed.

A possible cause of this magneto-mechanical effect is that the magnetic field produces a rotation of the positive column around its longitudinal axis. This could be caused by the diffusion of the ions and electrons in the plasma in the magnetic field in a direction perpendicular to this field and to the direction of the concentration gradient ("Hall diffusion current," see reference 2). The concentration gradient is in the radial direction in a cylindrical plasma and the "Hall diffusion currents" of the free electrons and of the ions must be in opposite azimuthal directions. The momenta of the two currents are unequal and the gas as a whole will thus begin to rotate.<sup>1</sup>

Further quantitative studies of this effect will enable us to verify the correctness of this interpretation.

<sup>1</sup>W. H. Bostick and M. A. Levine, Phys. Rev. **97**, 13, (1955).

<sup>2</sup>L. Spitzer Jr., Physics of Fully Ionized Gases, Interscience, New York, 1956.

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263

### ON THE HOLE COMPONENT OF THE FERM SURFACE IN BISMUTH

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AS reported previously,<sup>1,2</sup> new high-frequency oscillations associated with a group of holes were observed during a study of the anisotropy of magnetic susceptibility in Bi at very low temperatures. Further investigation showed that the shape of the Fermi surface for this group consists, to a first approximation, of an ellipsoid of rotation, elongated along the trigonal axis, which has the following parameters. Area of the principal sections: perpendicular  $S_1 = 6.75 \times 10^{-42} \text{ gm}^2 \text{ cm}^2/\text{sec}^2$  and parallel to the trigonal axis  $S_2 = 25.75 \times 10^{-42} \text{ gm}^2 \text{ cm}^2/\text{sec}^2$ ; hole concentration  $n^{\text{H}} = 0.34 \times 10^{18} \text{ cm}^{-3}$ ; bounding

Fermi energy  $E_0^H \approx 2.5 \times 10^{-14}$  erg ( $E_0^H/k \approx 180^\circ\text{K}$ ); effective mass in the plane perpendicular to the trigonal axis  $m_1^H = m_2^H = 0.05 m_0$  ( $m_0$  is the free electron mass) and in the direction of the trigonal axis  $m_3^H = 0.7 m_0$ .

The magnitude of the anisotropy of the hole surface and the value of the effective masses are in good agreement with recently published work on cyclotron resonance<sup>3</sup> in Bi ( $m_1^H = m_2^H = 0.068 m_0$  and  $m_3^H = 0.92 m_0$ ) and on the anomalous skin effect<sup>4</sup> ( $m_3^H/m_1^H = 12.8$ ). In these works, and also in Reneker's, this group of holes has been described by the anomalously small value of bounding energy ( $E_0^H = 0.18 \times 10^{-14}$  erg,  $E_0^H/k = 13^\circ\text{K}$ ) which was suggested by Heine<sup>6</sup> and by Strelkov and Kalinkina<sup>7</sup> to explain the appreciable electronic specific heat of Bi.

We should point out that  $n^H$  in one ellipsoid of revolution is  $0.34 \times 10^{18} \text{ cm}^{-3}$ , and is practically equal to the concentration of electrons in Shoenberg's three-ellipsoid model,  $n^e = 0.39 \times 10^{18} \text{ cm}^{-3}$ . These two groups of 'light' electrons and holes must evidently be responsible for the galvanomagnetic properties of Bi. The difference between the mean effective masses of the electrons in Shoenberg's three-ellipsoid model,

$$\bar{m}^e = [m_1(m_2 m_3 - m_4^2)]^{1/2} = 0.053 m_0$$

and of the holes in the one-ellipsoid model,

$$\bar{m}^H = (m_1^2 m_3)^{1/2} = 0.13 m_0$$

agrees well with the difference of mean mobilities  $\bar{\tau}/\bar{m}$  of the electrons and holes ( $\bar{\tau}^e/\bar{m}^e \approx 2\bar{\tau}^H/\bar{m}^H$ ) assuming approximately the same relaxation times.

Since the heat capacity of the 'light' holes is negligibly small compared with the observed<sup>7</sup> linear term in the heat capacity of Bi, we must assume that there exist at least three groups of carriers.<sup>8,1</sup>

<sup>1</sup> Brandt, Dubrovskaya, and Kytin, JETP **37**, 572 (1959), Soviet Phys. JETP **10**, 670 (1960).

<sup>2</sup> N. B. Brandt, Приборы и техника эксперимента (Instrum. and Meas. Engg.) No. 2 (1960).

<sup>3</sup> Galt, Yager, Merritt, and Cetlin, Phys. Rev. **114**, 1496 (1959).

<sup>4</sup> G. E. Smith, Phys. Rev. **115**, 1561 (1959).

<sup>5</sup> D. H. Reneker, Phys. Rev. **115**, 303 (1959).

<sup>6</sup> V. Heine, Proc. Phys. Soc. **A69**, 513 (1956).

<sup>7</sup> I. N. Kalinkina and P. G. Strelkov, JETP **34**, 616 (1958); Soviet Phys. JETP **7**, 426 (1958).

<sup>8</sup> N. B. Brandt and V. A. Venttsel, JETP **35**, 1083 (1958), Soviet Phys. JETP **8**, 757 (1959).

## PRODUCTION OF A $\Sigma$ HYPERON BY 8.3 Bev/c NEGATIVE $\pi$ MESONS

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ONE event of production and decay of a  $\bar{\Sigma}^-$  hyperon was found out of 40,000 pictures obtained by a beam of negative  $8.3 \pm 0.6$  Bev/c pions in a propane bubble chamber<sup>1</sup> with a constant magnetic field of 13,700 oe. A photograph and diagram of this event are shown. A  $\pi^-$  meson (track 1) gives a star at point O, from which emerge four charged particles of high energy (tracks 2, 6, 7, 16), two  $K^0$  mesons (tracks 4, 5, 14, 15), and one particle of low energy (short track 17). The track of the positively charged particle 2 is deflected at point A. At a distance of 7.7 mm from the point of deflection is a six-prong star. The center of the star lies in the plane of tracks 2 and 3 within the limits of the error of measurement ( $47'$ ). The decay of particle 2 at point A into particle 3 and a neutral particle N in the direction AB is in very good agreement with the kinematics of a  $\Sigma$  decay (see Table I). Track 3 is that of a  $\pi^+$  meson.

The momentum of particle N was determined by equating the perpendicular components of the momenta of particles 3 and N at point A.

Assuming a decay according to the scheme  $\Sigma^+ \rightarrow \pi^+ + n$ , we obtain  $M_2 = 1182 \pm 14$  Mev.

The energy and momentum balance at point B is given in Table II. Star B has five positive particles (tracks 8, 9, 11, 12, 13) and one negative (track 10). The negative particle is a  $\pi$  meson. Tracks 9, 11, 12, 13 stop in the chamber and we take them to be protons. Particle 8 has a high momentum and escapes from the chamber. From the measurements of ionization\* and momentum it follows that track 8 belongs to a  $\pi^+$  meson. The measurement of the energy balance at point B shows that the energy of the charged particles of the star is already much larger than the kinetic energy of a neutron with a momentum of  $1628 \pm 100$  Mev/c. Consequently, star B can be caused only by the annihilation of an antineutron on a carbon nucleus. The most probable reaction is

