Pressure Dependence of the Hall Constant of the Alkali Metals*

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The pressure dependence of the Hall constant of the five alkali metals has been measured to 15 000 kg/cm² at room temperature. The purpose of the measurements was to investigate the effect of lattice constant on the warping of the Fermi surface. The Hall constant R is written as $1/Nec n^*$, where N is the number of carriers/cc and n^* expresses the deviation from the free electron value of the Hall constant. In all the alkalis except cesium, n^* decreases monotonically with increasing pressure; the decreases range from 5% in 15 000 kg/cm² for lithium to 8% in 15 000 kg/cm² for rubidium. In the case of cesium, n^* passes through a minimum at 5000 kg/cm² and rises to a value of 1.2 at 15 000 kg/cm². The change of n^* between room and liquid nitrogen temperatures was measured and is less than 3% for all the alkalis except lithium. In lithium, n^* decreases about 25% between room and liquid nitrogen temperature. The sign of the pressure dependence of n^*, as well as its magnitude, can be reconciled with recent band structure calculations by Ham only if highly anisotropic scattering times are considered. The pressure results are explained in a semiquantitative manner using a scattering time, τ, that varies by a factor of 3 over the Fermi surface. Consideration of the factors determining the scattering time indicates the both umklapp processes and the large elastic anisotropy of the alkalis contribute to the anisotropy of τ. A crude calculation shows that the present results can be explained by the effects of umklapp processes alone.

THE Fermi surface in metals has recently been extensively investigated, theoretically and experimentally. The alkali metals are of special interest, for they are expected to conform closely to a free electron picture, in which the electron energy E is proportional to the square of the electron wave number k, and in which the Fermi surface is consequently a sphere in k space. Furthermore, there have been some calculations which allow the shape of the Fermi surface to be deduced. The recent calculations by Ham[1] of the band structure of the alkali metals are of particular importance for several reasons. They provide curves of E vs k for the three principal directions in k space and allow the reduction of an approximate shape for the Fermi surface. They are made for the entire alkali series, using the same method in each case, and should give a qualitative picture of the change in the shape of the Fermi surface as one progresses through the series. They have been carried out for several values of lattice constant and provide a guide to how the Fermi surface should change under pressure.

Despite the fact that there has been considerable progress made in experimental techniques for studying the Fermi surface, the methods that proved very successful in investigating the noble metals, de Haas-van Alphen measurements using pulsed magnetic fields[2] and measurements of acoustic attenuation in magnetic fields[3] have not been applied to the alkali metals. This is in large part because of the difficulty of growing and preparing single crystals of these very reactive metals. Because these techniques for determining the shape of the Fermi surface are quite difficult, one can attempt to glean some information from measurements of the transport properties. In particular, it would be interesting to make such measurements as a function of lattice constant by performing them under pressure. The alkalis are particularly attractive for such measurements, since they are highly compressible; the linear contraction of potassium, for example, is 9% in 15 000 kg/cm². In order to take advantage of the pressures available in the laboratory, the experiment should be done at room or liquid nitrogen temperatures, since at liquid helium temperature the pressure transmitting fluid would freeze at relatively low pressures.

The simplest transport property to measure is the conductivity; Bridgman has measured the resistance of all five alkali metals as a function of pressure.[4–6] For a metal having a spherical Fermi surface the conductivity, σ, is given by

$$\sigma = Ne^2\tau/m^*, \tag{1}$$

where N is the number of electrons/cc, e is the electronic charge, τ is an isotropic scattering time, and m^* an effective mass.

For a nonspherical Fermi surface this expression is multiplied by a factor that depends upon the distortion of the surface. Olson and Rodriguez[7] give this factor for a particular type of warping. Since the conductivity depends upon the magnitude of the scattering time and upon the effective mass, both of which may have strong pressure dependences, Bridgman's data are difficult to interpret. Furthermore, since more detailed study shows the conductivity is relatively insensitive to distortion of the Fermi surface, these data are not useful for studying the pressure dependence of the surface.

On the other hand the expressions for the magneto-

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