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The Simplest Metal: Potassium

The five alkali metals (Li, Na, K, Rb, Cs) are monovalent, so their conduction-electron momentum states occupy one half of the Brillouin zone. The periodic potentials which create the energy gaps at the (twelve) Brillouin-zone faces are small and therefore, the Fermi surface of each metal is nearly spherical.

The noble metals (Cu, Ag, Au) are also monovalent; but the periodic potentials which create energy gaps at the eight hexagonal faces of their zone are strong. Consequently the Fermi surface is distended along the $\{1, 1, 1\}$ directions until it is terminated by the energy gaps at the hexagonal faces. Such a Fermi surface is multiply connected; and this leads to a variety of conduction-electron orbits in the presence of a large magnetic field.

The anticipated electric, magnetic, optical, and thermal properties of a simple metal (possessing free-electron-like conduction electrons and, therefore, a spherical Fermi surface) have been elaborated in many monographs and textbooks published during the last seventy years. One would expect that most theoretical predictions would agree with experimental behavior found in alkali metals. The surprise is that such agreement is not found! The purpose of this volume is to document the many phenomena that have violated expectations during the last forty years and to collect in one place the research of the author and his collaborators which has led to a unified synthesis of alkali metal peculiarities.

Most of the experimental studies have focused on potassium. Many of the phenomena must be studied at low-temperatures so that the electron mean-free-path, λ , can be long. That is: $\lambda \gg r_c$, where r_c is the radius of a cyclotron orbit for an electron traveling at the Fermi velocity. Li and Na are disqualified because they undergo a martensitic transformation from their (room temperature) b.c.c. structure to close-packed alternatives near 78 K and 35 K, respectively. See [R38], i.e., reprint no. 38. Such transformations change a good single-crystal sample into a polycrystalline jumble. Long λ 's are then impossible. Although Rb and Cs do not suffer similarly, they are quite difficult to work with on account of their environmental chemical reactivity and mechanical softness.

Potassium is then the preeminent, simple metal of the periodic table. Its role in metal physics is analogous to that of hydrogen in atomic physics. The conduction-electron effective mass (near E_F) is $m^*/m = 1.25$. Furthermore, de Haas-van Alphen studies [Ref. 16, R5] indicate that the Fermi surface is spherical to within a few parts per thousand. Nevertheless, thirty phenomena, summarized in the content of this volume, show that the foregoing remark is strikingly inadequate. The research reprints, [R1], [R2], ..., [R65], presented in Part II, document (in a personal chronology) the ultimate reconciliation of the many anomalous phenom-

ena within a unified panorama. Interim summaries are: [R19], [R34], [R35], and [R45].

The fundamental influence that alters the anticipated behavior of conduction electrons in potassium is a spontaneous, collective breach of translation symmetry. For example, the electronic ground state might incorporate a spin-density-wave (SDW) or charge-density-wave (CDW) superstructure. Such a (time independent) modulation modifies the topology of the Fermi surface, and many important electron orbits are severely altered. Astonishing properties ensue.