The Ioffe-Regel criterion and saturation of electrical resistivity in metals

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The electrical resistivity of metals normally saturates if it reaches values on the order of 0.1 mΩcm. This happens when the apparent mean free path l becomes comparable to the separation d of two atoms, the Ioffe-Regel criterion. Several striking exceptions, however, have been observed, in particular some high-T_c cuprates and doped fullerenes. We present a model of transition metal compounds, in which noninteracting electrons are scattered by phonons. This model leads to resistivity saturation. Using the f-sum rule, we show how the Ioffe-Regel condition can be derived, by assuming that (i) the electrons are noninteracting and (ii) the temperature is much smaller than the band width. We next consider models of high T_c cuprates, focusing on the strong correlation between the electrons. From the f-sum rule, we conclude that one should expect saturation also for these systems. Due to the violation of assumption (i), however, the saturation resistivity can be very large, and the Ioffe-Regel criterion may be strongly violated. Finally, we present a model of doped fullerenes, in which noninteracting electrons couple to intramolecular phonons. Due to the violation of assumption (ii) and the coupling to intramolecular phonons, this model shows no saturation.