Fig. 12. Electron scattering through 180° by a phonon having the minimum wave number which can cause an Umklapp process.

to eliminate the effects of their different lattice properties, the more distorted the Fermi surface the higher the resistivity. With these ideas in mind let us now look at the magnitude of the resistivities of the monovalent metals.

In comparing the resistivity of different metals it is important to compare not the resistance ρ of a cube of side 1 centimeter but rather that of a cube containing, for example, 1 gram atom of material—that is, the atomic resistivity $\rho/V^{1/3}$ where V is the gram-atomic volume. Moreover, in order to bring out the dependence of the resistivity on the properties of the electrons (for example, the shape of the Fermi surface), the resistivities must be compared at temperatures at which the lattices are in similar states—that is, at temperatures at which the amplitude of the lattice vibrations is some certain fraction of the interatomic distance. This means that, in the high-temperature "classical" region, one should compare not the atomic resistivities but rather the "reduced" atomic resistivities $\rho(M\theta^2 V^{1/3}/T)$. (The derivation of this result is rather similar to that of the Lindemann melting formula; here M is the mass of the ions and θ, the characteristic lattice temperature.) The actual temperature T is immaterial since at high temperatures ρ/T tends to reach a constant value and it is this limiting value, at constant density, which we take. A comparison of the reduced resistivities is made in Table 2 (column 10), in which θ_o is taken from specific heat measurements (20). These Debye θ_o values, which can be taken as a measure of the temperature dependence

of the phonons, are now quite well established, although in sodium and lithium the low-temperature crystallographic transformations introduce some uncertainty. I should also point out that, since the noble metals have a face-centered cubic structure while the alkali metals have a body-centered cubic structure (except for sodium and lithium at low temperatures), the comparison between the two sets of metals cannot be taken too literally, although the general features should be correct.

It may be seen that of all the monovalent metals, potassium and sodium are outstandingly good conductors, rubidium and cesium are successively poorer, and lithium and the noble metals are worse still. Among the noble metals, silver has the lowest reduced resistivity. This classification corresponds broadly with what is at present known about the Fermi surfaces of the monovalent metals.

Having considered the magnitudes let us now consider the temperature dependence of the resistivity. This is largely governed by the temperature dependence of the number of phonons in the lattice—that is, by the Debye θ_o. But as we saw in discussing Umklapp processes, the low-temperature resistivity does not depend only on the behavior of the phonons; it also depends on the Fermi surface. If the metal has a distorted Fermi surface, the electrical resistivity tends to remain higher (because of the increased number of Umklapp processes) at low temperatures than that of a metal with a spherical Fermi surface at the same reduced temperature (that is, with the

same number of phonons excited). Roughly speaking, θ_R (which is a measure of the temperature dependence of ρ_i) is proportional to the lowest temperature at which ρ_i behaves classically —that is, the temperature at which ρ_i departs from linearity with T. This temperature should therefore be lower for metals in which Umklapp processes can persist to lower temperatures. Thus we should expect θ_R/θ_o to vary with the degree of distortion of the Fermi surface; for a metal with a distorted Fermi surface the ratio should be lower than for a metal with an undistorted Fermi surface. The values of this ratio are given in Table 2 (column 9), and they show roughly the sort of variation we should expect: sodium and potassium have exceptionally large values for the ratio, the other metals have lower values. Interestingly enough, these lower values are all close to unity; why the values of θ_o and θ_R should be about equal for these metals is not, I think, altogether understood.

These comparisons suggest that the pressure coefficients might likewise be understood, at least qualitatively, in terms of distortion of the Fermi surface. Table 2 (column 4) shows that the values of $d \ln K/d \ln V$, which measure the change of interaction constant with volume, do fit into the pattern. For example, all the noble metals have negative values and so does lithium. These are the monovalent metals with the most distorted Fermi surfaces. Sodium and potassium, the two metals with nearly spherical Fermi surfaces, have values of $d \ln K/d \ln V$ which are decidedly positive; rubidium has an intermediate value. For cesium the data needed here are not reliable, but as we shall see below, cesium too fits into the general picture.

Although there is a clear correlation between the pressure coefficients of resistivity and distortion of the Fermi surface, we still have to understand why in a metal with a spherical Fermi surface $d \ln K/d \ln V$ is positive whereas in a metal whose Fermi surface touches the zone boundary it is negative. This is a theoretical problem which has not yet been fully solved. Nevertheless, let us consider first the example of a spherical Fermi surface which, for simplicity, we shall assume does not distort under pressure (21). A positive value for $d \ln K/d \ln V$ means that a decrease in volume causes the electrons to interact less with the lattice waves. Decreasing the volume increases the Fermi