

a normal process for electrical resistivity because it can produce scattering through larger angles. This is particularly important at low temperatures where normal processes can cause only small angle scattering.

It turns out that the elastic properties of the alkali metals are very strongly anisotropic (this point has been particularly stressed by Bailyn 1960) and this can have the effect of enhancing umklapp scattering, particularly at low temperatures. Indeed, it is mainly for this reason that umklapp processes are found to predominate in the resistivity of the alkali metals right down to the lowest temperatures of practical interest (Bailyn 1960).

In table 11 we list values of the elastic anisotropy parameter $C_{44}/2(C_{11} - C_{12})$ for those alkali metals for which elastic measurements have been made. (We are referring now only to the b.c.c. phases.) For an isotropic material the parameter would be 1. The square root of this parameter measures the ratio of the velocities of shear waves in the (100) and (110) directions. From the values in the table it is seen that in some of the metals these velocities can differ by a factor of as much as 3.

TABLE 11. ELASTIC ANISOTROPY PARAMETERS IN THE ALKALI METALS

metal	$2C_{44}/(C_{11} - C_{12})$		observer
	Bailyn's* values	experimentally observed	
lithium	9.60	9.35	Nash & Smith (1959)
sodium	11.06	7.14	Daniels (1960)
potassium	10.27	6.71	Smith & Smith (1964)
rubidium	10.15	—	—
caesium	9.77	—	—

* Bailyn (1960).

Quite recently, Woods, Brockhouse, March, Stewart & Bowers (1962) have determined directly the phonon dispersion relations in sodium by means of thermal neutron diffraction and this has stimulated a number of theoretical studies of the resistivity of the lighter alkali metals, in particular sodium. These calculations produce fairly good agreement with experiment and we shall refer to them later.

4.1.3. *The Fermi surface*

Table 12 summarizes the experimental information about the Fermi surfaces of the alkali metals; it is seen that in sodium and potassium the surfaces are effectively spherical, in rubidium nearly so, while in lithium and caesium the surfaces are appreciably different from spheres. Ham (1962) has made theoretical calculations of the properties and shapes of the Fermi surfaces of the alkali metals. His calculations overestimate the distortions of the surfaces but they give the right qualitative sequence of distortion through the series; in addition, Ham has calculated how the properties of the Fermi surfaces should change with volume. Although again these calculations may be quantitatively in error, it seems probable that they will give the correct qualitative picture.

Attempts to infer the shapes of the Fermi surfaces from various physical properties of the metals have tended to ignore elastic anisotropy and, perhaps for

this reason, have also overestimated the distortion of the Fermi surfaces (Cohen & Heine 1958; Ziman 1959; Dugdale 1961; Collins & Ziman 1961). The important point is that elastic anisotropy and distortion of the Fermi surface can produce similar effects on transport properties and without further knowledge their effects are hard to distinguish.

Bearing in mind these ideas, let us now look at the experimental results. To help in understanding the heavier alkali metals we shall find it useful to make some comparisons between all the alkali metals, particularly since we now have comparable experimental data on the resistivity of all of them.

TABLE 12. ANISOTROPY OF THE FERMI SURFACE IN THE ALKALI METALS

metal	maximum radial distortion from a sphere	observer
lithium	about 5%	Stewart <i>et al.</i> (1964)
sodium	probably $< 5 \times 10^{-4}$	
potassium	15×10^{-4}	Shoenberg & Stiles (1964)
rubidium	1%	
caesium	about 5%	Okumura & Templeton (1965)

4.2. *The magnitude of the resistivity*

Bailyn has calculated the magnitude of the resistivities of all the alkali metals. In table 13 we make a comparison of these calculated values with the most recent experimental values. It is seen that apart from lithium the agreement is everywhere within a factor of 2 and for sodium, potassium and rubidium is much closer still. Bailyn assumed in his calculations that the Fermi surfaces were spherical, although he recognized that for lithium this was a poor approximation. More recent calculations of the resistivity of lithium by Hasegawa (1964), which take account of the distortion of the Fermi surface, have improved the agreement for this metal. The comparatively small distortions of the Fermi surfaces of rubidium and caesium, which we now know to exist, might be enough to account for the remaining discrepancies between the theoretical and experimental values of ρ_i in these metals.

TABLE 13. RESISTIVITIES ($\mu\Omega$ CM)

	lithium	sodium	potassium	rubidium	caesium
temperature ($^{\circ}$ K)	297	125	70	211	158
ρ (theor.)*	2.0	1.4	1.4	5.6	5.0
ρ (exp.) ($p = 0$)	9.4	1.5 ₆	1.1 ₇	8.1	9.4
ρ (exp.) ($V = V_0$)†	9.5	1.4 ₉	1.1 ₃	6.9	8.5

* Bailyn (1960).

† V_0 is the molar volume of the solid at 0° K under zero pressure.

4.3. *How the resistivity depends on temperature*

Figures 1 and 2 show that if we plot the resistivity as a function of temperature at constant density, the resistivity at high temperatures for both rubidium and caesium is linear and very closely proportional to the absolute temperature. This is true both at the density corresponding to zero pressure at 0° K and at the two