

Stars	Density	Temp.	Viscosity $k$ in e.s.u.	Conductivity in gm./cal.	Self-Diffusion D	Diffusion $D_{12}$
Model-Giant (Chapman)	0.1	$7 \times 10^6$	$9.986 \times 10^{-3}$	13.3	$1.998 \times 10^3$	14.93
Capella	0.1234	$9.08 \times 10^6$	.02	2.70	$6.6 \times 10^3$	10.3
Model-Dwarf (Kothari)	$1.36 \times 10^6$	$1.37 \times 10^7$	$6.904 \times 10^2$	$1.685 \times 10^5$	6.048	
$\epsilon_2$ Eridani	$9.8 \times 10^4$	$10^8$	3.719	$3.242 \times 10^4$	1.350	
Sirius B	$5 \times 10^4$	$10^9$	1.216	$1.658 \times 10^5$	.683	
" "	"	$10^8$	1.216	$1.658 \times 10^4$	.688	
" "	"	$1.37 \times 10^7$	1.216	$2.271 \times 10^3$	.688	

calculated for comparison. It is noticed that viscosity and diffusion are effected by density alone increasing with increasing density while conductivity is a function of temperature as well.

For the relativistic case  $I(\theta)$  involves a factor  $(1 - v^2/c^2)$  and hence is greatly diminished while for  $v \sim c$ ,  $I(\theta) \sim 0$  and hence,  $k$ ,  $\mathcal{S}$  and  $D$  have zero values.

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<sup>1</sup> Ganguli and Mitra, *Curr. Sci. ; Ind. Jour. Phys.*, 1934, 9, 81.

<sup>2</sup> For references see Mott and Massey, *Atomic Collisions* (Cambridge).

<sup>3</sup> Mott and Massey, *Proc. Roy. Soc., A*, 1933, 140, 145, 436; also Mazumdar, *Z. Phys.*, 1934, 91, 706.

<sup>4</sup> Wentzel, *Ibid.*, 1927, 40, 590.

<sup>5</sup> Mott, *Proc. Roy. Soc., A*, 1932, 135, 429.

Note on Surface Tension and Its Variation  
with Temperature.

IN connection with a recent note<sup>1</sup> of Sibaiya "On the ratio of temperature co-efficients of surface tension and density" it may be pointed out that Cantor<sup>2</sup> who followed the same method as Sibaiya obtained the value of the ratio 2.33 instead of 2.

The nature of the cohesive forces has been studied in detail in recent years and the following relationship between Van der Waals force and the surface tension has been established.<sup>3</sup>

$$\text{Van der Waals Constant } a = 2\pi \int_0^R \psi(z) dz$$

$$\text{Surface Tension } \gamma = \pi \rho^2 \int_0^R z \psi(z) dz$$

Lately London<sup>4</sup> has given a quantum-mechanical expression of Van der Waals force. According to him the interaction

energy between two similar molecules is given by

$$\epsilon = -\frac{3}{4} \cdot \frac{a^2 J}{R^6} = \frac{k}{R^6}$$

where  $J$  is the ionisation potential,  $a$  the polarisability and  $R$  the distance between the molecules. This corresponds to the potential  $\psi(z)$  of Laplace. By introducing the above expression for  $\psi(z)$  we have

$$\gamma = \frac{\pi k \rho^2}{4d^2} \dots \dots \dots (1)$$

Expression (1) was derived by Gyemant<sup>5</sup> as well by considering the surface energy originating from electric dipole.

By differentiating (1) with respect to  $T$

$$\frac{d\gamma}{dT} = \frac{2\pi k \rho}{4d^2} \frac{d\rho}{dT} - \frac{\pi k \rho^2}{4} \cdot \frac{2}{d^3} \cdot \frac{dd}{dT} + \frac{\pi \rho^2}{4d^2} \cdot \frac{dk}{dT}$$

or,

$$\frac{1}{\gamma} \cdot \frac{d\gamma}{dT} = \frac{2}{\rho} \frac{d\rho}{dT} - \frac{2}{d} \cdot \frac{dd}{dT} + \frac{1}{k} \cdot \frac{dk}{dT} \dots (2)$$

If  $\beta$  be the co-efficient of cubical expansion = thrice the co-efficient of linear expansion,

$$\frac{1}{\gamma} \cdot \frac{d\gamma}{dT} = -2.66 \beta + \frac{1}{k} \frac{dk}{dT} \dots (3)$$

Now in order to study the effect of temperature on  $k$  we must remember that

$$k = -\frac{3}{4} h\nu_0 a^2, \text{ where } a = a_0 + \frac{\mu^2}{3kT},$$

$$\nu_0 = \frac{e}{\sqrt{ma}} \text{ and } h\nu_0 = J.$$

If there is no permanent dipole moment ( $\mu=0$ )  $a$  and  $\nu_0$  and so  $k$  are independent of temperature. On the other hand if  $a_0 \ll \frac{\mu^2}{3kT}$ ,

the expression for surface tension reduces to the formula similar to Gyemant's and

$$k = -\frac{3}{4} \cdot \frac{hc}{\sqrt{m}} \cdot \frac{\mu^3}{(3k)^{3/2}} \cdot \frac{1}{T^{3/2}}, \text{ and}$$

$$\frac{1}{k} \cdot \frac{dk}{dT} = -\frac{3}{2T}.$$

It should however be noted that London's

formula is to be modified for complex substances such as liquids and solids. That solids have surface tension has now been pretty well established. In the case of adsorption of gases the adsorbed molecules are held to the surface of the adsorbent by cohesive forces. Now it has been observed that the same adsorbent may adsorb varying amounts of adsorbent, when subjected to different treatment. Activation of charcoal is a familiar instance. It is supposed that the specific surface increases with activation. Now if the total surface energy be the same then the increase of surface would be associated with the decrease of surface energy per unit surface and this would lead to a corresponding decrease of adsorption per unit area. This is not actually the case. The total adsorption increases and if the adsorption per unit surface is the same, this would mean constancy of surface energy. Thus for solids it is preferable to study surface tension by considering the surface density of molecules distributed over surface, the surface layer being one or several molecules thick and this  $\rho$  in the expression (1) should be replaced by  $1/\Omega$ ,  $\Omega$  being the available surface.

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<sup>1</sup> Sibaiya, *Curr. Sci.*, 1935, 3, 418.

<sup>2</sup> Cantor, *Wied. Ann.*, 1892, 47, 421; *Handbuch der Physik*, 7, 394.

<sup>3</sup> Lennard-Jones, *Proc. Roy. Soc., A*, 1928, 121, 247; *Fowler's Statistical Mechanics*, chap. X.

<sup>4</sup> Eisenschitz and London, *Z. Phys.*, 1930, 60, 520; London, *Z. F. Phys. Chem., B*, 1931, 2, 221.

<sup>5</sup> Gyemant, *Handbuch d. Phys.*, 7, 346.

<sup>6</sup> Lennard-Jones, *Proc. Phys. Soc.*, 1931, 43, 461.

<sup>7</sup> Polanyi and London, *Naturwiss.*, 1930, 18, 1099.

<sup>8</sup> Ganguli, *Koll. Zeit.* (In the press); Burrage, *Farad. Soc. Trans.*, 29, 445; Besl and Reinhardt, *Z. Phys. Chem.*, 1933, 166A, 81.

### Colloidalisation and Cold-Working of Metals.

THE subject of the magnetic properties of non-ferromagnetic metals has attained much interest recently in view of the work of Pauli, Sommerfeld and others on the theory of the metallic state.<sup>1</sup> The simplest picture of the metal that will suit our purpose consists of a lattice of metallic ions, the remaining electrons in each atom being associated with two or more nuclei and

considered as free or partly bound in accordance with their relative energy values. The susceptibility of the metal is to be considered as the sum of the susceptibilities of the ions and of the remaining or valency electrons of the individual atoms. The first part is a constant while the second is greatly influenced by the physical conditions. The large deviations in the values for metals obtained by different workers is to be attributed to the fact that their metals were not in the same state and hence the susceptibility of the valency electrons should have been greatly different.

The valency electrons may have large orbits as contemplated by Ehrenfest<sup>2</sup> for graphite and by Raman<sup>3</sup> for bismuth. Or they may be attached loosely to two close atoms, being considered as free or partly bound. On colloidalisation, the first type would give rise to decreased diamagnetism due to the fact that large orbits could not be possible at the surface. This conclusion has been experimentally established for graphite<sup>4</sup> and bismuth,<sup>5</sup> and in fact, in the case of graphite, Krishnan and Ganguli<sup>6</sup> have determined the direction of largest variation as the one parallel to the hexagonal axis.

In the case of good conductors, the state of affairs is different. The electrons on the surface of the atoms may be considered as free, the number of such electrons being of the same order as the number of atoms in the metal. Considered as free, the electrons possess the Pauli paramagnetism and if regarded as confined to a series of energy bands, they contribute a diamagnetic component.

Honda and Shimizu<sup>7</sup> have shown that cold-working in the case of copper and silver gives rise to increased diamagnetism. They have quantitatively accounted for this result as being due (1) to the decrease in paramagnetic component due to the diminution of free electrons caused by the expansion on cold-working (for which there is ample evidence from X-ray data<sup>8</sup>) and (2) to the increase in the diamagnetic component due to the increased number of bound electrons. They explain that the lattice constant is a little greater in the surface layer than in the interior, the normal value for the metal being reached at some hundred layers below the surface. Thus colloidalisation should be accompanied by increased diamagnetism quite similar to what is obtained in the case of cold-working.