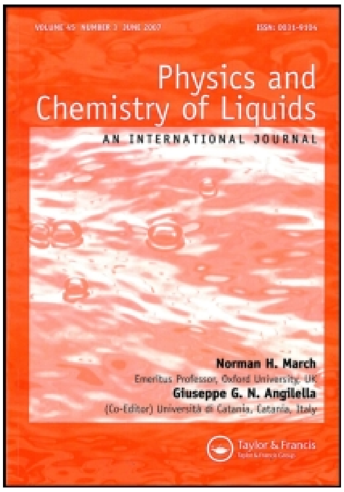

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LETTER

NERNST-EINSTEIN RELATION AND EFFECTIVE VALENCE IN A STRONGLY COUPLED TUNGSTEN PLASMA

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The Nernst-Einstein relation between electron mobility and diffusion is employed together with very recent measurements of Kloss *et al.* on strongly coupled tungsten plasma, to throw light on the effective valence of W as the thermodynamic state is varied.

Keywords: Effective valence; strongly coupled plasma

Measurements of the electrical conductivity of fluid tungsten for subcritical and supercritical thermodynamic states have been reported very recently by Kloss *et al.* [1]. The ionic density in their experiments ranged from 4×10^{21} to $6\times10^{22}\mathrm{cm}^{-3}$, while the temperature scale embraced was from 3700 to 13000 K. The strongly coupled and degenerate plasmas used in these experiments were produced by rapid heating of a wire-shaped probe of metallic tungsten using a fast electrical discharge.

Figure 5 of the paper by Kloss *et al.* plots electrical conductivity σ versus ionic number density n_i, over the entire range of density explored in the experiments. In the present Letter, we have chosen to replot their conductivity data in a manner motivated by our earlier analysis [2] of similar experiments carried out by DeSilva and Kunze [3] on Cu plasmas.

The idea presented in our earlier study of the electrical conductivity of Cu plasma was to start from the Nernst-Einstein relation between mobility μ and electronic diffusion coefficient D, namely

$$\mu = \frac{D}{k_B T} \tag{1}$$

where $k_B T$ is the thermal energy associated with temperature T. Writing the conductivity in terms of the electron density n_e through

$$\sigma = n_e e^2 \mu \tag{2}$$

one finds immediately using eqn. (1):

$$\sigma = \frac{n_e e^2 D}{k_B T} \tag{3}$$

Rearranging eqn. (3) so that $Dn_e^{2/3} \propto D/(\text{length})^2$ appears, as in our previous work, eqn. (3) becomes

$$\sigma n_e^{-1/3} T = (Dn_e^{2/3})\left(\frac{e^2}{k_B}\right) \tag{4}$$

For monovalent Cu, $Dn_e^{2/3} = Dn_i^{2/3}$ turned out to be independent of the thermodynamic state in the strongly coupled plasma regime[2].

This has therefore motivated us to plot for W plasma the quantity Y defined by

$$Y = \sigma n_i^{-1/3} T \tag{5}$$

as a function of temperature T. Note that Y differs from the left-hand side of eqn(4) by a factor proportional to the cube root of the effective valence Z.

While σ and n_i are well specified in the paper of Kloss *et al.*, [1] there is some question as to the choice of data for the temperature. Thus, in the upper part (a) of their Figure 5, they plot measured temperature of the wire *versus* n_i for a wire explosion with lowest and highest energy input. We have used data from both these curves, and Figure 1 shows Y defined above *vs* T for the upper temperature solid curve, while Figure 2 is for the choice of T from the lower temperature curve.

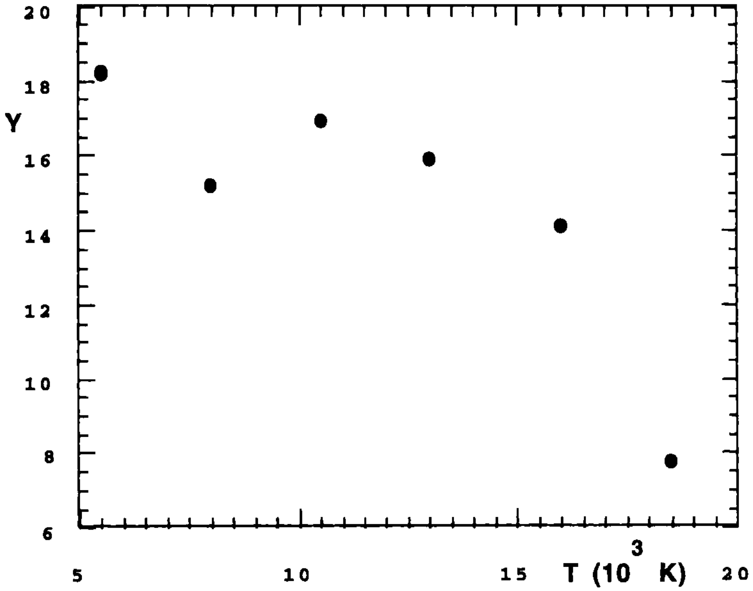

FIGURE 1 Plot of the electrical conductivity data of Kloss *et al.* [1] for strongly coupled W plasma. Form Y *vs* T, where $Y = \sigma n_i^{-1/3} T$ is motivated by use of Nernst-Einstein relation, with constancy (i.e. independence of thermodynamic state) of 'chemical rate' $\approx D/(\text{length})^2 \propto D n_e^{2/3}$ as found for monovalent Cu plasma where $n_i = n_e$. Temperature is taken from upper 'measured' temperature curve of Figure 5 of Kloss *et al.* [1].

The product $Y = \sigma n_i^{-1/3} T$ is seen in both cases, even though there is considerable scatter at least partly coming from our reading of the data, to decrease substantially with increasing temperature T. The above argument, based on eqns (1)–(5), would interpret this decrease as reflecting the variation $Z^{1/3}$ with temperature.

Under 'normal' conditions, Slater [4], for example, records the outer electronic configuration of the W atom as sd^5, suggesting, as noted also by Kloss *et al.* [1], that near the melting point $Z = 6$. Likalter in a private communication to Kloss *et al.* has proposed $Z \approx 3$ at the critical point, and for the maximal observed expansion in their work Kloss *et al.* propose $Z \approx 1$. These values are not inconsistent with the curves shown here in Figures 1 and 2, bearing in mind the substantial scatter among the points plotted.

In summary, the earlier interpretation offered from the results on Cu plasma obtained in the conductivity measurements of DeSilva and

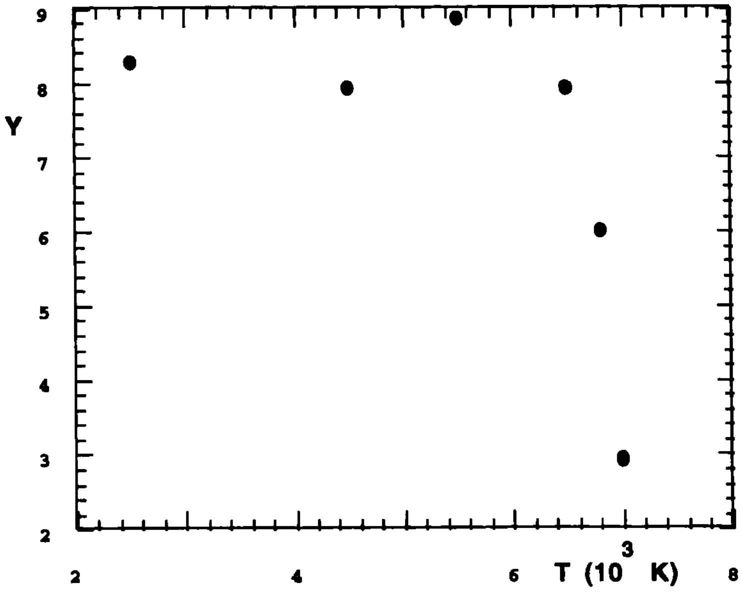

FIGURE 2 Same as Figure 1 except that T is from lower curve of Figure 5 of ref. 1.

Kunze [3] has been shown here to permit the extraction of the effective valence Z as a function of temperature for W plasma from conductivity measurements. The results are quite compatible with the proposals made by Kloss *et al.* [1].

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References

[1] Kloss, A., Motzke, T., Grossjohann, R. and Hess, H. (1996). *Phys. Rev.*, E **54**, 5851.
[2] March, N. H. and Tosi, M. P. (1995). *Phys. Chem. Liquids*, **29**, 273.
[3] DeSilva, A. W. and Kunze, H.-J. (1994). *Phys. Rev.*, E **49**, 4448.
[4] Slater, J. C. (1960). *Quantum Theory of Atomic Structure*, Vol. I, (McGraw-Hill, New York 1960). p.194.