Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics, USSR Academy of Sciences (26–27 May 1976)

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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on May 26 and 27, 1976 at the Conference Hall of the P. N. Lebedev Physics Institute. The following papers were delivered:

1. *V. A. Alekseev, V. G. Ovcharenko and Yu. F. Ryzhkov*, The Metal-Dielectric Transition in Liquid Metals and Semiconductors at High Temperatures and Pressures in the Region of the Critical Point.
2. *I. S. Zheludev*, Optical Activity of Crystals Under the Action of an Electric Field (Electrogyration).
3. *S. A. Pikin*, New Electromechanical Effects in Liquid Crystals.
4. *G. T. Zatsepin*, Problems of Neutrino Astrophysics.
5. *B. M. Pontecorvo*, The Problem of Oscillations in Neutrino Beams.

We publish below brief contents of these papers.

V. A. Alekseev, V. G. Ovcharenko and Yu. F. Ryzhkov. *The Metal-Dielectric Transition in Liquid Metals and Semiconductors at High Temperatures and Pressures in the Region of the Critical Point.* Study of the electrical properties of metals and semiconductors during a continuous decrease in density is of great interest for understanding of the mechanisms transforming the electron spectrum from metallic to dielectric. This possibility arises in experiments in which a metal or semiconductor is heated under a constant above-critical pressure. The metals of interest to us—mercury and cesium—have critical-point parameters as follows: $P_{cr} = 1730 \pm 30$ atm, $T_{cr} = 1510 \pm 15\,^\circ C$, $\rho_{cr} = 5.9 \pm 0.23$ $g \cdot cm^{-3}$ for mercury[1] and $P_{cr} = 115 \pm 5$ atm, $T_{cr} = 1760$ $\pm 20\,^\circ C$, $\rho_{cr} = 0.4 \pm 0.022$ $g \cdot cm^{-3}$ for cesium.[2] The high temperatures and pressures, together with the high chemical activity of the metal and semiconductor vapors impose rigid requirements on the materials used in the experiment, and this has made conduct of the corresponding experiments difficult.

The very first measurements of the electrical conductivities of mercury and cesium indicated that they decrease steadily as the temperature rises toward the critical point (T_{cr}).[13-8] In the region of the transition from the metallic to the nonmetallic state, a decrease of approximately 20% in the density of the metal results in an electrical-conductivity decrease by a divisor of 10^3–10^4. This change in the electrical conductivities of metals with decreasing density is explained either within the framework of the homogeneous model proposed by Mott as a result of formation of a quasigap in the electron spectrum[9] or as due to a change in the number of conduction paths with metallic conductivity as a result of density fluctuations.[10,11] We report new experimental data from measurements of the conductivity and thermal emf of cesium and the thermal emf of mercury. All experiments were performed on apparatus of the type described in[10]. The conductivities were measured in specially prepared beryllium oxide and boron nitride cells with four electrodes (two current and two potential). The thermal emf was measured by the integrating method in the beryllium oxide cells. Temperatures were determined with tungsten-rhenium thermocouples. Figure 1 shows experimental values obtained for the electrical conductivities and thermal emfs of mercury and cesium at constant above-critical pressures. (We reproduce the conductivity data for mercury from[5].) It is easily seen that the thermal emfs of mercury and cesium reach values characteristic of metals at lower temperatures than do the electrical conductivities. We interpret the observed effect as a possible shunting of the thermal emf of formations with metallic conductivity. It is in this range that the density dependence of electronic conductivity is observed to be of the type $\ln\sigma \sim 1/\rho$ characteristic for the metal–nonmetal transition region[10] in the presence of conductive chains. The ef-

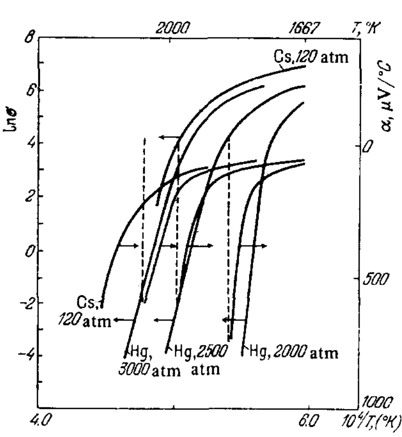

FIG. 1. Electrical conductivities and thermal emfs of mercury and cesium at various pressures.

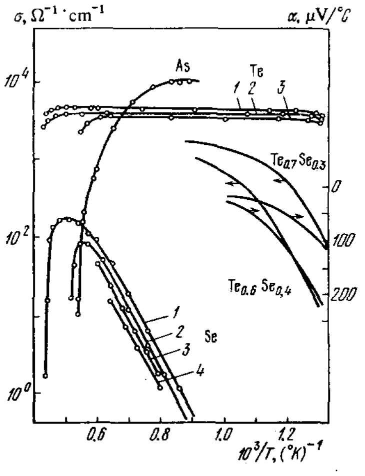

FIG. 2. Electrical conductivities of selenium, tellurium, arsenic, and the selenium-tellurium system at high temperatures. The thermal emf values from[12] are given for the selenium-tellurium system. Se: 1—100 atm, 2—500 atm, 3—165 atm, 4—103 atm; As: 330 atm; Te: 1—1600 atm, 2—1000 atm, 3—500 atm.

fect can be interpreted as shunting of the thermal emf by chains of regions with metallic conductivity.

It is interesting to note that a similar phenomenon is also observed in compound semiconductors in the liquid phase at the semiconductor–metal transition; for example, it is sufficient in the Se-Te system[12] to superimpose the electrical-conductivity and thermal-emf curves. Tellurium or tellurium compounds, which have metallic conductivity at these temperatures, may play the part of the metallic component in the transitional range (Fig. 2).

The transitional region is followed by a region in which the properties resemble those of liquid semiconductors, where the relation of the electrical conductivity σ to the thermal emf α can be described by a relation of the type $\ln\sigma \sim \alpha$, as for semiconductors. A further decrease in the density of the metal results in a region with the characteristic properties of a dense plasma.[13,14]

Abrupt "vanishing" of the thermal emf was observed in mercury with the approach to the critical isochor in[14–16] (this phenomenon was not observed in[15]). It has not been detected in cesium. It may reflect competition between the deepening of the wells that capture electrons due to density fluctuations and the simultaneous increase in their Fermi level.[14]

Figure 3 presents a diagram of state for mercury, showing the singularities at the transition from the metallic to the nonmetallic state[1)].

In conclusion, we present high-temperature ($T > T_{cr}$) electrical conductivities for selenium,[17,18] arsenic,[19] and tellurium[20] at above-critical pressures (Fig. 2). We note several singularities. Conductivity saturation

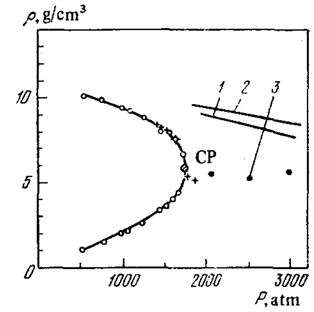

FIG. 3. P-ρ diagram of mercury[1]. 1—minimum conductivity level according to Mott, $\sigma = 200\ \Omega^{-1}\,\text{cm}^{-1}$; 2—level of thermal emf values $\alpha = 86.5\ \mu\text{V}/{}^\circ\text{C}$ (the expected value of the thermal emf on collapse of the quasigap); 3—points of zero thermal emf from[14]; + – points of zero emf values from[16] (CP is the critical point).

was observed for selenium with a value characteristic for the minimum of metallic conductivity[7]; this was followed by a sharp decrease in the conductivity with rising temperature, which we may attribute to localization of electrons on density fluctuations in accordance with Anderson's model.

For arsenic, the beginning of this transition is most probably masked by formations having high electrical conductivities. Only the initial phase of the transition is recorded in tellurium. Analysis of the experimental data indicates that the loss of metallic conductivity occurs in a density range corresponding to the liquid phase and is not accompanied by a first-order phase transition (reference was made to this possibility, for example, in[21]), while recent measurements of the heat capacity of cesium at high temperatures failed to show singularities that could be interpreted as a second-order phase transition.[22]

The materials of the paper were published in[2,10,14,17–20,23].

[1)] The measurements in[16] were made in a narrow pressure range around the critical point.

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