THERMOELECTRIC POWER OF CESIUM NEAR THE CRITICAL TEMPERATURES AND PRESSURES

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The problem of a plasma thermoelectric element is discussed in the literature either as applied to the conditions of a rarefied plasma [1, 2] or to the conditions of dense vapors, but neglecting the interaction between the particles [3]. Yet in Cs vapor at $T \sim 2 \times 10^3$ °K and $p \sim 10^2$ atm (these are precisely the figures cited in [3]) the energy per charged particle of the interaction between the charged particles and the neutrals is proportional to the density, $U = An$, and its order of magnitude is comparable with or larger than the kinetic energy $V > T$. This leads to an exponential dependence of the degree of ionization on the density [4]. In a plasma thermoelectric element, the pressure between contacts is constant, and the degree of ionization on the cold end can be even larger than at the hot end, owing to the density difference.

We performed a number of experiments on the thermoelectric properties of Cs in the region of critical p and T. The measuring cell was machined from a niobium rod in the form of a cup, or else was ready-made of tungsten [5]. A tube of pure beryllium oxide was inserted inside the cup. The cesium was poured in a special box in the tube, where a metallic rod was also inserted. The distance between the bottom of the tube and the end of the rod was varied from zero to 20 mm. The measuring cell was inserted into a tubular graphite heater in such a way that the maximum temperature was at the bottom of the cup of the cell. By moving the rod inside the beryllium-oxide tube it was possible to establish the required temperature drop. Tungsten thermocouples VR=5 + VR=20 were attached to the exterior of the cell. The rate of heating of the cell was chosen to be such as to enable the temperature read by the external thermocouples to become equalized with the temperature in the interior of the cell. In the upper cell there was room for the cesium to expand. To eliminate convective flow, boron-nitride powder was poured between the oven and the wall of the heating element. The heating element together with the measuring cell was inserted in the working chamber, where pure argon was admitted at the required pressure. The argon pressure was transmitted to the cesium through the free surface of the cesium in the expansion volume. The thermoelectric power was measured with a voltmeter having a high internal resistance. The temperature was recorded with an automatic millivoltmeter. The purpose of the experiment was to obtain as large an emf as possible, and therefore, to assess the thermoelectric capabilities of such an element, the measurements were made with large temperature

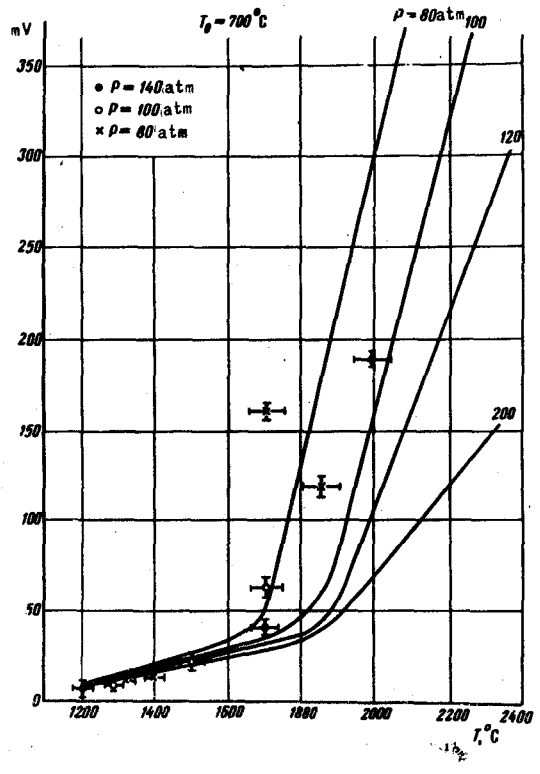

Fig. 1

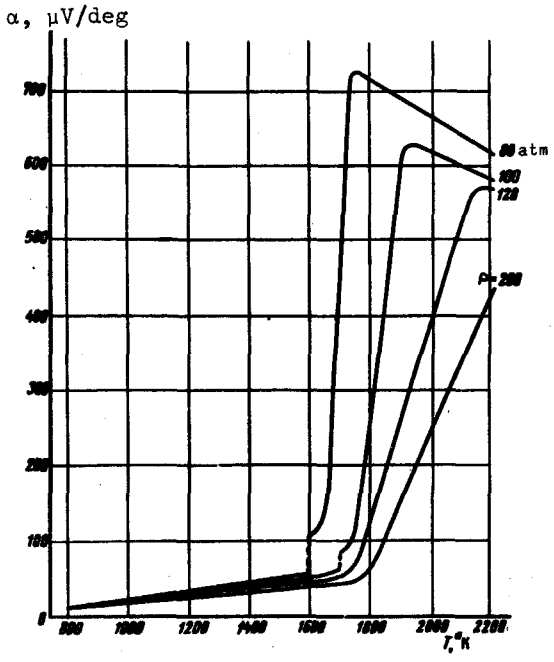

Fig. 2

drops. The measurement results for pressures of 80, 100, and 140 atm are shown by the points in Fig. 1.

To determine the influence of the interaction between the electrons and the neutral elements of the thermoelectric properties of a dense plasma, we introduced into the Boltzmann equation for the electrons an additional force $-\nabla U_{ea} = A'\nabla n$.[1] By solving the kinetic equation in the approximation of a Lorentz gas (a more rigorous allowance for the collisions apparently does not change the order of magnitude of the quantities), we obtain for the electric current

$$j = \sigma\left[-\nabla\left(\phi + \frac{U_{ea}}{e} + \frac{\mu_0}{e}\right) - \alpha\nabla T\right] \qquad (1)$$

where μ_0 is the chemical potential of an ideal electron gas, and the thermal-emf coefficient α is determined in this approximation by the known expression

$$\alpha = \frac{k}{e}\left[\frac{1}{T}\frac{\int r v^2 \epsilon \frac{\partial f_0}{\partial \epsilon} d^3v}{\int r v^2 \frac{\partial f_0}{\partial \epsilon} d^3v} - \frac{\mu_0}{T}\right] \qquad (2)$$

The notation is standard (see [3]).

The electric self-field in the volume of the plasma at $j = 0$ is given by

$$-\nabla\phi = \alpha_p \nabla T, \qquad (3)$$

where

$$\alpha_p = \alpha + \frac{1}{e}\left(\frac{\partial U_{ea}}{\partial T}\right)_p + \frac{1}{e}\left(\frac{\partial \mu_0}{\partial T}\right)_p.$$

We note that although the expression for the electric field (3) contains the electron-atom interaction potential U_{ea}, the observed thermal emf is given by the usual expression for an ideal electron gas. α was calculated in the approximation $\tau \sim \varepsilon^{-1/2}$, and the electron density in the expression for μ_0 was connected with the gas density by the relation $n_e = (n/\lambda^3)^{1/2}\exp(-1/2T)$, where $\lambda = (2\pi\hbar^2/mT)^{1/2}$. The dependence of the ionization potential on the density was determined from the data on the conductivity of Cs [5, 6] (it was assumed that the mobility depends little on the atom density). The ionization potential is not a linear function of the density in the entire density interval.

[1] In the gas approximation, $A' = \hbar^2\sqrt{\pi}q/m^*$, where q is the cross section for the electron scattering by the neutral atom and m^* is the effective mass.

Figure 2 shows a plot of $\alpha(T)$ at constant pressure. The data on the equation of state of Cs for these conditions were taken from [7]. The maximum of the thermal emf is due to the fact that when T increases at constant pressure the main term in α, which is proportional to $I(p, T)/T$, first increases, since I increases as a result of the decrease in density, but then decreases when I becomes equal to the ionization potential I_0 of the atom. At lower temperatures α is small, since the electrons are degenerate in this case. Figure 2 (solid curves) shows calculations of the potentials

$$U = -\int_{T_{cold}}^{T_{hot}} \alpha dT$$

with $\alpha(T)$ taken from Fig. 1. The results of the calculations agree in order of magnitude with the measurement data.

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SPONTANEOUS PARAMETRIC EMISSION OF THE α-HIO_3 CRYSTAL

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This paper is devoted to the first observation of spontaneous parametric radiation in a biaxial α-HIO_3 crystal belonging to class 222 of rhombic syngony.

It is known that when a crystal with quadratic nonlinearity is illuminated with a laser beam there is probability that the photon from the laser (henceforth referred to as the pump) with frequency ω_p will decay spontaneously into two photons, one with the signal frequency ω_1 and the other with the supplementary frequency ω_2 [1]:

$$\omega_p = \omega_1 + \omega_2. \quad (1)$$

The frequencies ω_1 and ω_2 of the parametric radiation are determined primarily by the dispersion characteristics of the crystal, since the process proceeds effectively when the following condition is satisfied:

$$\mathbf{k}_p = \mathbf{k}_1 + \mathbf{k}_2, \quad (2)$$