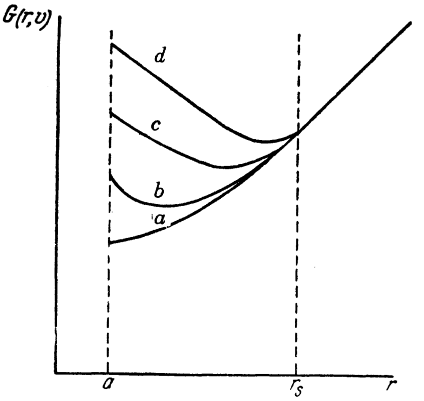
$$v > \sqrt{-2e\varphi(a)/M\left[\left(\frac{r_s}{a}\right)^2 - 1\right]} \qquad \text{(3a)}$$

(for these velocities an absence of threshold motion is assumed, i.e., $r_0 = a$); and

$$v < \sqrt{-2e\varphi(a)/M\left[\left(\frac{r_s}{a}\right)^2 - 1\right]} \qquad \text{(3b)}$$

(for these velocities it is assumedthat the motion has a threshold val.ue, and that the threshold sphere coincides with sheath boundary r_s).



Condition (3a) leads to the conclusion that $p(r_s) > p(a)$. Curves *a* and *b* in the graph satisfy this condition. However, with curve *b* there is threshold motion, and $r_0 > a$. From condition (3b) it follows that $p(r_s) < p(a)$. Curves *c* and *d* satisfy this requirement. It is obvious from the curves that in this case $r_0 < r_s$. Since for curves of type *b*, $p^2(r_0 v) < p^2(av)$, and for curves of type c, $p^2(r_0 v) < p^2(r_s v)$, therefore Eq. (2) shows that calculation of current *F* in a Langmuir model with a sheath, using the above method, results in values of ion probe current known to be too high. As a matter of fact, even calculations using Langmuir's equations result in ion current values smaller than those obtained by experiment. This is due to the fact that assumption 1, which does not allow for a field outside the sheath, and which assumes that ion velocity at the sheath boundary is equal to velocity at a large distance from the probe, constitutes a poor approximation for ions. An approximate expression for ion current, taking into account the field outside the sheath, is given in reference 3.

Assumption of three-halves-power law potential distribution inside the sheath is proper when ions inside the sheath are moving radially. Since, in Langmuir's model, the threshold sphere lies within the sheath, use of the three-halves-power law is not proper. At the same time, for assumptions made in reference 3, the threshold sphere lies outside the charged sheath, and three-halves-power law can be applied.

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Adiabatic Process at High Temperatures

I. L. Aptekar' and B. L. Timan
Dneperpetrovsk Mining Institute

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In connection with the effect of thermal ionization on the thermal properties of gases at high temperatures[1], it is of interest to consider an an adiabatic process, taking the thermal ionization into account. In this case, the original equation for an adiabatic process will have the following form:

$$pdV + dU' + I_1 dN_1 = 0 \qquad (1)$$

where *dV* is the increase in volume, I_1 is the energy of single ionization, *dU'* is the increase in internal energy of the gas, dN_1 the increase in the number of ions in the heating of the gas.

The expression *pdV* can be found from the Mendeleev-Clapeyron equation:

$$pdV = \frac{(N + N_1)\, kTdV}{V}. \qquad (2)$$

The internal energy of the gas can be written in the following form:

$$U' = 3/2\,(N + N_1)kT. \qquad (3)$$

Denoting the degree of ionization by $x = N_1/N$ and substituting Eqs. (2), (3) in Eq. (1), we obtain the equation

$$\frac{3}{2}(1 + x)\frac{dT}{T} + \left(\frac{3}{2} + \frac{I_1}{kT}\right)dx + (1 + x)\frac{dV}{V} = 0. \qquad (4)$$

At the same time, the formula of Sack, which characterizes the degree of ionization of the gas at a given temperature and pressure, can be written in the form[2]

$$\frac{1-x^2}{x^2}=p\frac{c'}{T^{5/2}}\exp\left\{\frac{I_1}{kT}\right\}=\frac{(1+x)c''}{VT^{3/2}}\exp\left\{\frac{I_1}{kT}\right\}.$$

Taking the logarithm of both sides and differentiating this expression, we get

$$-\frac{dx}{1-x}-\frac{2dx}{x}+\frac{3}{2}\frac{dT}{T}+\frac{dV}{V}+\frac{I_1}{kT^2}dT=0. \quad (5)$$

Multiplying this equation by $(1+x)$ and subtracting the result from Eq. (4), we have

$$\frac{1+x}{1-x}dx+\frac{2dx}{x}+\left(\frac{7}{2}+\frac{I_1}{kT}\right)dx. \quad (6)$$

$$-\frac{I_1 dT}{kT^2}(1+x)=0.$$

Upon integrating this equation, we find the dependence on temperature of the degree of ionization of the gas in an adiabatic process:

$$\frac{5}{2}x-2\ln\frac{(1-x)}{x}+\frac{I_1}{kT}(1+x)=C \quad (7)$$

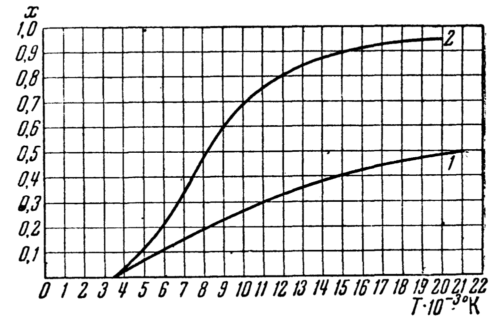

FIG. 1

Curve 1 in Fig. 1 represents the dependence on temperature of the degree of ionization x of Cs vapor for an adiabatic process, taking ionization during the process into account. For comparison, there is drawn in the same figure the dependence on temperature of the degree of ionization, if the pressure is expressed in terms of the temperature in Sack's formula, making use of the equation for an adiabatic process without taking ionization into account. It is evident that curve *1*, which corresponds to the actual case (with ionization), lies below curve *2*, the calculation of which ignored the effect of ionization during the process.

We now investigate how the thermal ionization during an adiabatic process affects the dependence of the pressure on the temperature. From Sack's equation it follows that

$$\frac{p}{T^{5/2}}=\frac{1}{c'}\frac{1-x^2}{x^2}\exp\left\{-\frac{I_1}{kT}\right\}.$$

Expressing the ratio I_1/kT by x from Eq. (7), and substituting in the latter equation, we get

$$\frac{p}{T^{5/2}}=\frac{x^{2/(1+x)}}{x^2}\frac{(1-x^2)}{(1-x)^{2/(1+x)}} \quad (8)$$

$$\times\exp\left\{\frac{5}{2}x\right\}\frac{1}{c'C^{1/(1+x)}}.$$

This equation characterizes the effect of ionization on the temperature dependence of the pressure during an adiabatic process.

We shall now consider Eq. (8). As $x \to 0$, Eq. (8), as should be expected, undergoes a transition to the usual equation for an adiabatic process:

$$\frac{p}{T^{5/2}}=\frac{1}{Cc'}=\text{const.} \quad (9)$$

As $x \to 1$, which corresponds to complete ionization, Eq. (8) becomes

$$\frac{p}{T^{5/2}}=2\frac{1}{C^{1/2}c'}\exp\left\{\frac{5}{2}\right\}. \quad (10)$$

It is clear from the latter equation that, at a high degree of ionization of the gas, a much lower temperature corresponds to a given pressure in comparison with the case which obtains in the absence of ionization.

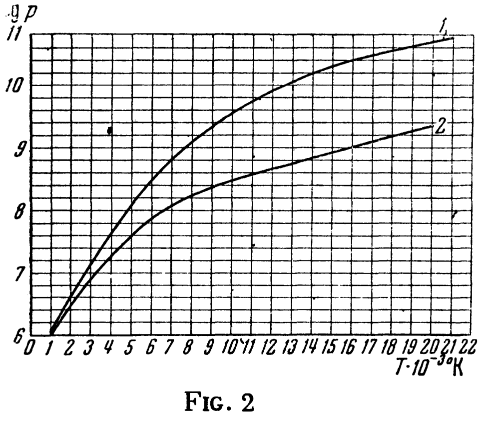

FIG. 2

We compare the dependence $p(T)$ from Eq. (8) with Eq. (9). The dependence of $p(T)$ is plotted in Fig. 2. Curve *1* corresponds to Eq. (8), curve *2*, to Eq. (9). As can be seen from Fig. 2, the curve which corresponds to Eq. (8) lies above the curve corresponding to the adiabatic process, for which ionization is not taken into account. This is evidently explained by the fact that with an increase in temperature in the adiabatic process, the number of particles in the system increases as a result of the ionization. This effect, in turn, increases the pressure of the gas. The figure shows that at high temperatures, the pressure in an adiabatic process, computed by Eq. (9) is almost 100 times smaller than the pressure computed by the equation in which ionization has been considered. This circumstance should be very significant for the consideration of adiabatic processes in gases taking place at high temperatures.

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Stable Dipole Moment of Aerosol Particles

A. A. SPARTAKOV AND N. A. TOLSTOI
Leningrad Technical Institute

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NEW methods of investigation of electro-optical phenomena in hydrophobic colloids[1,2] based on the measurement of the modulation of light passing perpendicularly to the lines of the electric field through a parallel plate condenser (Fig. 1, *b, c*) upon which a square-wave voltage is impressed, show that the colloidal particles in aqueous media possess a stable dipole moment of a very considerable magnitude[2]. It is assumed that this stable dipole moment is caused by spontaneous orientation of water molecules possessing a stable dipole adsorbed on the surface of the particle[2]. The unipolarity (in the mean effect) of this orientation makes it possible to treat the film of water adsorbed on the particle as a surface electret[2].

We have carried out an analogous experiment with an aerosol. Light, passing through 3-5 cm of tobacco smoke is modulated by the field of a square-wave voltage (see Figure). The modulation curve shows a periodic decrease in the transparency of the medium. This effect can be observed for any direction of polarization of light. Each reversal of the field produces a reiteration of the modulation wave. Since the field intensity E in the condenser (of the order of 300 v/cm) is of constant magnitude (E^2 = const), the re-orientation of smoke particles brought about by light modulation is possible only when the smoke particle is itself polar, i.e. it possesses a stable dipole moment.

The electro-optical properties of smoke may therefore be similar to those of hydrophobic colloids. It should be mentioned that, for the case of smoke, modulation of light is maintained up to much higher frequencies than is the case for an aqueous colloid. Undoubtedly, this is connected with the difference in viscosity of the respective media. It is our opinion that the origin of the stable dipole moment of smoke particles is likewise connected with the orientation of adsorbed polar molecules on the surface of particles. The influence of moisture on the magnitude of the observed effect implies that, in this case also, polar molecules of water are involved.

The establishment of polarity of smoke particles may be important in the explanation of aggregation mechanism of uncharged particles in smoke.

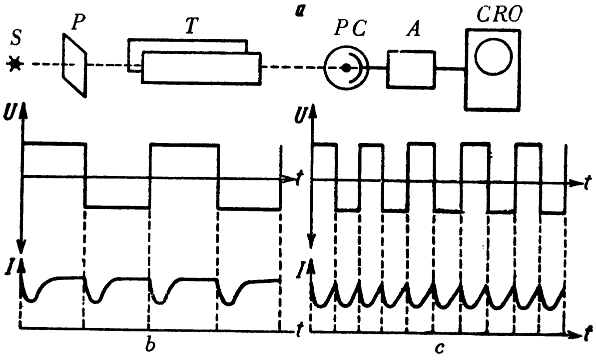

FIG. 1. *a)* Simplified diagram of the experimental setup: S-light source ; P-polaroid; T-tank with the parallel plate condenser, filled with tobacco smoke; PC-photoelectric cell; A-amplifier; CRO-cathode ray oscilloscope (Russian type EO-7).

b) Modulation of light by low-frequency square-wave (10-100 cps): U-voltage on the condenser; I-intensity of passing light.

c) Modulation of light by high-frequency square-wave (~ 1000 cps).

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