TABLE I. Depolarization cross sections.

$(10^{-16}\ \text{cm}^2)$		
$\sigma(\text{Ne}^m\text{-He})$ =	0.430	±0.022
$\sigma(\text{Ne}^m\text{-He})$ =	16.6	±0.8
$\sigma(\text{Ar}^m\text{-He})$ =	6.2	±0.4
$\sigma(\text{Ar}^m\text{-Ne})$ =	26	±2
$\sigma(\text{Ar}^m\text{-Ar})$ =	100	±7
$\sigma(\text{Ar}^m\text{-Xe})$ [a] ~	127	
$\sigma(\text{Xe}^m\text{-He})$ =	15	±1
$\sigma(\text{Xe}^m\text{-Ne})$ =	38	±2
$\sigma(\text{Xe}^m\text{-Ar})$ =	61	±4
$\sigma(\text{Xe}^m\text{-Xe})$ =	190	±16

[a] There is considerable uncertainty in this value (see text).

collisions is shown without error limits. In practice, we found that with the addition of even small amounts of Xe (~10 μ) to the Ar discharge, the Ar metastable density was too low to yield acceptable optical pumping signals. The cross section shown is the result of a single measurement at low pressures, and is to be taken as suggestive only.

We also point out that the cross section for Xe^m-Xe collisions may contain the effects of metastability exchange. Hadeishi and Liu have reported the observation of exchange collisions between metastable Xe^{131} and Xe^{131} ground-state atoms.[3] Our samples contained natural Xe. We were unsuccessful in our attempts to observe a nuclear polarization of the odd Xe isotopes. Linewidth measurements at $g_J = 2$, due to the even isotopes of metastable Xe, and at $g_F = 1.2$, due to the $F = \frac{3}{2}$ levels in Xe^{131} and the $F = \frac{5}{2}$ levels in Xe^{129}, yielded similar values for the spin-relaxation time. This would tend to suggest that under the conditions of our experiment, metastability exchange collisions do not contribute to the reported linewidth.

Notable by its absence are measurements with Kr. We have no reason to expect that Kr metastable atoms could not also be optically pumped in a similar fashion. It was simply not among the gases in our stockroom.

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Acoustic Instability in Weakly Ionized Gases

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It is shown, in contrast with earlier work, that energy transfer between hot electrons and neutrals in a weakly ionized gas does not lead to an acoustic instability, if proper care is taken to account for the nonstationary nature of the neutral equilibrium.

It has been recently suggested[1-3] that acoustic waves in a weakly ionized plasma may be driven unstable under certain conditions, if the electrons are maintained at a higher temperature than the neutrals. The energy source of the instability is the energy transferred from the electrons to neutrals by elastic collisions. The mechanism of amplification is related to the fact that a perturbation in the gas density due to the sound wave leads to a perturbation in the electron density, which, in turn, modifies the energy transfer between electrons and neutrals in a manner that favors the growth of the wave. In these investigations,[1-3] the time dependence of the equilibrium temperature of the neutrals has been ignored. A careful study of the results reveals, however, that the growth rate of the instability has a magnitude comparable to the rate of change of the equilibrium neutral temperature; under these conditions it is improper to neglect this latter time dependence. In this paper, we show that if this nonstationary nature of the equilibrium temperature of neutrals is taken into account, then the acoustic instability found in the other papers[1-3] disappears.

We start with the usual fluid equations[4] for the neutral component:

$$\frac{\partial \rho_1}{\partial t} + \rho_0 \nabla\cdot \vec{u}_1 = 0 \ , \tag{1}$$

$$\rho_0 \frac{\partial \vec{u}_1}{\partial t} + \nabla p_1 = 0 \ , \tag{2}$$

$$\tfrac{3}{2} \rho \frac{\partial T}{\partial t} + \rho T \nabla\cdot \vec{u} = H m_n \ , \tag{3}$$

where ρ, u, T have their usual meanings (of course, referring to the neutral component), T is written in place of KT, where K is the Boltzmann constant, $p = \rho T/m_n$ is the fluid pressure, and H is the rate of energy transfer from electrons to neutrals per unit volume. (The only way in which the electron component enters the analysis is through this energy transfer; in other words, we are considering the perturbation of the sound waves in the neutral fluid due to the energy supply from the electron fluid.) Note that Eqs. (1) and (2) are linearized, whereas (3) is written in its full nonlinear form. Further, following Ref. 2, we have ignored any sources or sinks in the continuity and momentum conservation equations. We have also ignored all the usual damping mechanisms, such as the thermal conductivity, viscosity, etc., since we find that the instability disappears, even without including them. The quantity H can be expressed as[2]

$$H = 4(m_e/m_n)(\tfrac{1}{2} m_e v_e^{\,3}) N_e N_n \langle \sigma \rangle \ , \tag{4}$$

where m_e is the electron mass, m_n is the mass of a neutral, N_e and N_n are the corresponding equilibrium concentrations, v_e is the electron thermal speed related to the electron temperature by $\frac{1}{2} m_e v_e^{\,2} = \frac{3}{2} T_e$, and $\langle \sigma \rangle$ is an average cross section for the scattering of electrons by neutrals. We may now substitute Eq. (4) in Eq. (3), divide by $\frac{3}{2}\rho$ on both sides, and write the equilibrium and first-order components of the resulting equation:

$$\frac{\partial T_0}{\partial t} = A \ , \tag{5a}$$

and

$$\frac{\partial T_1}{\partial t} + \tfrac{2}{3} T_0 \nabla\cdot \vec{u}_1 = A(n_e/N_e) \ , \tag{5b}$$

where

$$A = \tfrac{8}{3} (m_e/m_n)(\tfrac{1}{2} m_e v_e^{\,3}) N_e \langle \sigma \rangle \ . \tag{6}$$

If we restrict our attention to low-frequency acoustic disturbances, then we can assume that the perturbations in the gas density and the electron density are equal in magnitude and in the same phase,[2,3] i. e.,

$$n_e/N_e = n_n/N_n = \rho_1/\rho_0 \ .$$

Equation (5b) is then modified to

$$\frac{\partial T_1}{\partial t} + \tfrac{2}{3} T_0 \nabla\cdot \vec{u}_1 = A(\rho_1/\rho_0). \tag{5b$'$}$$

Eliminating T_1 and u_1 from Eqs. (1), (2), and (5b′), and Fourier analyzing in space, we get

$$\ddddot{\rho}_1 + (k^2/m_n)(\tfrac{5}{3} T_0 \dot{\rho}_1 + A\rho_1 + \rho_1 \dot{T}_0) = 0, \tag{7}$$

where k is the wave number and the dot denotes a partial-time derivative. If we neglect the time dependence of the equilibrium temperature and assume $\rho_1 \propto \exp[(-i\omega + \Delta)t]$, we get (assuming $\Delta \ll \omega$)

$$\omega = kc, \quad \Delta = (3A/10T_0) = \tfrac{3}{10} (\dot{T}_0/T_0) \ , \tag{8}$$

where $c = \frac{5}{3} (T_0/m_n)^{1/2}$ is the acoustic speed and Eq. (5a) has been used to replace A by $\dot{T}_0$. Substituting for A from Eq. (6), one can show that

$$\Delta = (18/5\sqrt{5})(m_e/m_n)^{1/2} (T_e/T_0)^{3/2} \, c N_e \langle \sigma \rangle \ ,$$

which is identical to $c\beta_2$ of Ingard[2] [his Eq. (14)] with γ replaced by $\frac{5}{3}$. Thus, we see that if the time dependence of the equilibrium temperature is ignored we recover the result of Ingard,[2] and our analysis also predicts an acoustic instability. Let us now retain the $\dot{T}_0$ term in Eq. (7) and further assume $\rho_1 \propto \exp[\int(-i\omega + \Delta)dt]$, where ω is itself a function of time. In this case, we get

$$\omega = kc, \quad \Delta = -\tfrac{3}{10} (\dot{\omega}/\omega) = -\tfrac{3}{20} (\dot{T}_0/T_0) \ . \tag{9}$$

It is immediately noted that the acoustic waves do not grow, but rather get damped because of the energy transfer between electrons and neutrals.

The above analysis is restricted to low-frequency acoustic waves only; however, it is suspected that our conclusion holds for higher acoustic frequencies also.

Finally, we would like to emphasize that in any investigation of instabilities in systems with "slowly" time varying equilibria, it is necessary to compare the growth rates (if any) with the rate of change of the equilibrium, before any definite conclusions can be drawn.

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Temperature Dependence of Electron Attachment in I_2 Vapor*

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The temperature dependence of electron attachment in I_2 vapor has been measured over the temperature range from 253 to 467 °K. The attachment coefficient was found to increase with temperature over the range studied, varying from 0.9×10^{-10} to 4.2×10^{-10} cm^3/sec. Studies involving selective heating of the electrons indicate that for a gas temperature of 298 °K the attachment coefficient increases from 1.8×10^{-10} to 2.8×10^{-10} cm^3/sec as the electron thermal energy was increased from 0.04 to about 0.27 eV.

I. INTRODUCTION

Previous studies have been made to determine the dependence on electron energy of the dissociative attachment process for iodine molecules at thermal energies.[1-3] However, the temperature dependence of the attachment coefficient for the case where the electrons and gas molecules are in thermal equilibrium has not been reported. As an extension of recent studies[4] concerning dissociative electron attachment in iodine vapor at 295 °K, the current study has involved determination of the thermal electron attachment coefficient for iodine as a function of temperature over the temperature range from 253 to 467 °K. Thus, in the present case the effect on the dissociative attachment coefficient of populating higher vibronic levels in I_2, as well as the effect of shifting the electron energy distribution, can be examined. Such an examination has been carried out by Shipsey,[5] using the data reported herein.

The dissociative electron attachment processes studied can be described as follows:

$$I_2 + e \to I + I^- . \tag{1}$$

This process was found by Fox to be the only significant mechanism by which electrons having energies up to a few electron volts are attached to iodine.[1] In the present case, the attachment coefficient has been determined under the assumption that electron losses by processes other than dissociative attachment can be essentially ignored.[4] Under such an assumption, the time dependence of the electron number density can be approximated by

$$n_e \approx n_e(0) e^{-\nu_a t} , \tag{2}$$

where n_e is the electron number density at some point in the cavity and $n_e(0)$ is the electron number density at some initial time. In Eq. (2), ν_a is the attachment frequency and t is time. The attachment coefficient k is given as follows[4]:

$$k = \nu_a / n_g , \tag{3}$$

where n_g is the iodine-molecule number density. In the above expressions, Maxwellian energy distributions for the particles are assumed. In order to determine to what extent Eq. (2) was valid, values for the ambipolar diffusion coefficient were obtained at elevated temperatures so that diffusion losses could be separately assessed.

In addition to determining the attachment coeffi-