were selected (see the upper histogram and the dashed line in the diagram; experimental data are plotted using exact calculations of angle). Analogous grouping is not obtained for angle η_b.

I wish to thank G. S. Saakian for reviewing this communication.

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285

Electroacoustic Waves in a Gas Discharge Plasma with Consideration of Volume Recombination

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IN a previous paper[1] electroacoustic waves were studied, taking into account the production of ionized particles but not considering volume recombination. This occurs along with recombination at walls[2] and plays an important role in some cases (e. g. in molecular gases). The present work deals with the effect of volume recombination on the behavior of electroacoustic waves.

Three possible cases are considered 1. all particles ultimately diffuse to the walls where recombination takes place; 2. recombination takes place only in volume, and 3. both volume recombination and recombination of the walls take place at the same time.

The behavior of the electrons and ions is described by the system of hydrodynamic equations derived earlier[1]. On the assumption that the neutral atoms do not move and that the electrons and ions are separately thermalized, the system of equations becomes (in the notation used earlier)

$$\frac{\partial\sigma^-}{\partial t}+\frac{\partial}{\partial x_\alpha}(\sigma^- v_\alpha^-)=Z^-\sigma^- - R^-\sigma^+\sigma^-, \qquad (1)$$

$$\frac{\partial\sigma^+}{\partial t}+\frac{\partial}{\partial x_\alpha}(\sigma^+ v_\alpha^+)=Z^+\sigma^+ - R^+\sigma^-\sigma^+,$$

$$\frac{\partial}{\partial t}(\sigma^- v_\alpha^-)+\frac{\partial}{\partial x_\rho}(\sigma^- v_\alpha^- v_\rho^-)$$

$$=-\frac{\theta^-}{m^-}\frac{\partial\sigma^-}{\partial x_\alpha}+\frac{e\sigma^-}{m^-}E_\alpha-\alpha_-\sigma^- v_\alpha^-,$$

$$\frac{\partial}{\partial t}(\sigma^+ v_\alpha^+)+\frac{\partial}{\partial x_\rho}(\sigma^+ v_\alpha^+ v_\rho^+)$$

$$=-\frac{\theta^+}{m^+}\frac{\partial\sigma^+}{\partial x_\alpha}-\frac{e\sigma^+}{m^+}E_\alpha-\alpha_+\sigma^+ v_\alpha^+,$$

$$\partial E_\alpha/\partial x_\alpha=4\pi e(\sigma^-/m^- - \sigma^+/m^+),$$

where $R^-\sigma^+\sigma^-$ and $R^+\sigma^-\sigma^+$ are the mass recombination rates of electrons and ions respectively.

Assuming cylindrical symmetry and neglecting, as before, terms quadratic in the particle velocities, we obtain a set of equations for the relative deviations n^- and n^+ from stationary solutions* $\sigma_0^-(r)$ and $\sigma_0^+(r)$, i. e., setting

$$\sigma^-=\sigma_0^-(1+n^-), \quad \sigma^+=\sigma_0^+(1+n^+), \qquad (2)$$

On replacing $\sigma_0^-(r)$ and $\sigma_0^+(r)$ by their average values over r, the equations become

$$(3)$$

$$\frac{\partial^2 n^-}{\partial t^2}-\frac{\theta^-}{m^-}\frac{\partial^2 n^-}{\partial z^2}+(\alpha_- - Z^- + R^-\overline{\sigma_0^+})\frac{\partial n^-}{\partial t}+\omega_e^2 n^-$$

$$=(\omega_e^2-\alpha_- R^-\overline{\sigma_0^+})n^+ - R^-\overline{\sigma_0^+}\frac{\partial n^+}{\partial t},$$

$$\frac{\partial^2 n^+}{\partial t^2}-\frac{\theta^+}{m^+}\frac{\partial^2 n^+}{\partial z}+(\alpha_+ - Z^+ + R^+\overline{\sigma_0^-})\frac{\partial n^+}{\partial t}+\omega_i^2 n^+$$

$$=(\omega_i^2-\alpha_+ R^+\overline{\sigma_0^-})n^- - R^+\overline{\sigma_0^-}\frac{\partial n^-}{\partial t},$$

where ω_e and ω_i are the characteristic frequencies of the electronic and ionic oscillations.

Equations (3) have progressive wave solutions

$$n^- = n_0^- \exp(i\omega t - ikz), \qquad n^+ = n_0^+ \exp(i\omega t - ikz).$$

The dispersion relation between ω and k is determined by the equation:

$$\{k^2 - (m^-/\theta^-)[\omega^2 - i(\alpha_- - Z^- + R^-\overline{\sigma_0^+})\omega - \omega_e^2]\} \quad (4)$$

$$\times \{k^2 - (m^+/\theta^+)[\omega^2 - i(\alpha_+ - Z^+ + R^+\overline{\sigma_0^-})\omega - \omega_i^2]\}$$

$$= (m^-/\theta^-)(m^+/\theta^+)[(\omega_e^2 - \alpha_- R^-\overline{\sigma_0^+})$$

$$+ i\omega R^-\overline{\sigma_0^+}][(\omega_i^2 - \alpha_+ R^+\overline{\sigma_0^-}) + i\omega R^+\overline{\sigma_0^-}]$$

We now consider the three cases mentioned earlier.

1. Volume recombination absent; all electrons and ions produced diffuse to the walls and recombine there. Putting R^- and R^+ equal to zero in Eq. (4), we get

$$\{k^2 - (m^-/\theta^-)[\omega^2 - i(\alpha_- - Z^-)\omega - \omega_e^2]\}$$

$$\times \{k^2 - (m^+/\theta^+)[\omega^2 - i(\alpha_+ - Z^+)\omega - \omega_i^2]\}$$

$$= (m^-/\theta^-)(m^+/\theta^+)\omega_e^2\omega_i^2,$$

in agreement with the earlier result[1].

2. No recombination at walls, the rate of production of particles being in equilibrium with the volume recombination in the stationary state. In this case $Z^- - R^-\sigma_0^+ = Z^+ - R^+\sigma_0^- = 0$, and the dispersion relation becomes

$$[k^2 - (m^-/\theta^-)(\omega^2 - i\alpha_-\omega - \omega_e^2)]$$

$$\times \quad [k^2 - (m^+/\theta^+)(\omega^2 - i\alpha_+\omega - \omega_i^2)]$$

$$= (m^-/\theta^-)(m^+/\theta^+)[(\omega_e^2 - \alpha_- R^-\sigma_0^+)$$

$$- i\omega R^-\overline{\sigma_0^+}][(\omega_i^2 - \alpha_+ R^+\overline{\sigma_0^-}) - i\omega R^+\overline{\sigma_0^-}].$$

The zeroth order solutions of this equation are

$$k^2 = (m^-/\theta^-)(\omega^2 - i\alpha_-\omega - \omega_e^2),$$

$$k^2 = (m^+/\theta^+)(\omega^2 - i\alpha_+\omega - \omega_i^2).$$

It is seen that, in contrast to the results of reference 1, there is no variation in the damping coefficient, so that sustained or increasing ionic oscillations are not possible.

3. Both volume and wall recombination present. The zeroth order solutions are

$$k^2 = \frac{m^-}{\theta^-}[\omega^2 - i(\alpha_- - Z^- + R^-\overline{\sigma_0^+})\omega - \omega_e^2],$$

$$k^2 = \frac{m^+}{\theta^+}[\omega^2 - i(\alpha_+ - Z^+ + R^+\overline{\sigma_0^-})\omega - \omega_i^2].$$

Thus the consideration of simultaneous volume recombination and recombination by diffusion to the walls leads to waves with a decreasing damping coefficient. Here, however, in contrast to the previous work, the variation of the damping coefficient depends not just on the rate of ionization but on the difference between that rate and the volume recombination rate.

In summary, it is seen that it is the relative importance of bulk and surface recombination in the stationary state of a gaseous discharge plasma which determines the variation of the damping coefficient of the plasma oscillations with the rate of production of ions. The most rapid decrease in the damping coefficient with increasing ionization occurs when there is negligible diffusion to the walls. The decrease is slower when volume recombination is appreciable and vanishes when it is dominant. Since volume recombination becomes important in discharges in molecular gases it may be expected that no sustained or increasing plasma waves will be possible in them. It should be noted also that in tubes of large section an analogous effect will occur even for a not very large volume recombination rate because of the relative increase of ion loss in volume.

In conclusion we consider it our pleasant duty to thank A. A. Zaitsev for his advice on many questions pertaining to the present paper and also G. V. Spivak for discussions on the physical meaning of the results.

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* The stationary solutions for this case have been investigated previously[3], starting from the diffusion equation. It is easily shown that the solution in our case has the same form.

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288

Polarization of the Nuclei of Ferromagnetic Atoms

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DURING the past years several indirect methods have been proposed for obtaining oriented nuclei (see references 1,2). Still another method of obtaining polarized nuclei is proposed in the present note.

It is possible to polarize nuclei of ferromagnetic atoms in the following manner. Ferromagnetics which contain nuclei possessing spins are cooled to very low temperatures (for this purpose it is necessary to bring the ferromagnetic into thermal contact with a cooled paramagnetic salt). An external magnetic field exceeding the saturation field is then superimposed on the ferromagnetic. Complete polarization of the shell spins is then obtained.

In turn this brings about a significant polarization of the nuclei (owing to the great magnitude of the field, forming a shell on the nuclei, and also due to the very low temperature) The relaxation of the nuclear spins will be rapid since it is tied in with the interaction of nuclei with the conduction electrons.

The advantage of the ferromagnetic method consists in the fact that by this means a target is obtained free of foreign atoms. The drawback of this method is that it is applicable only for polarization of nuclei of ferromagnetic atoms.

Shchegolev, Alekseevski and Zavaritskii have observed anisotropy in the γ-rays emitted from the nuclei of Co^{60}, when polarized by the ferromagnetic method. At a temperature of the order of 0.05 - 0.08°K intensity, the γ-intensity radiation along the external field is about 10-15% less than in the perpendicular direction.

In conclusion, I wish to express thanks to N. E. Zavaritskii and to I. F. Shchegolev, who reported the results of their measurements.

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300

The Rotation of the Plane of Polarization in Electrolytic Solutions by a Magnetic Field

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OKAZAKI[1], in a careful study of the Faraday effect, found that in aqueous solutions of strong electrolytes, the effect could be considered as made up of additively of two parts, the so-called molar rotations of the different ions.