greater than 16°, there is satisfactory agreement with the experimental results in the $p : q$ ratio. For smaller angles the agreement breaks down, and our calculation of the coefficient r of the term $r \cos 2\varphi$ comes out to be several times larger than the experimental value.

As is proposed in Ref. 1, it is necessary to consider that the state of the deuteron makes a major contribution, and leads to the diminuation of the coefficient r in front of $\cos 2\varphi$.

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Some New Possibilities of Ionic Phenomena in Metastable Liquids

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IONIZING PARTICLE TRACKS are produced in the usual bubble chambers[1] through the budding of nucleation voids directly accompanying the passage of ionizing particles, and are generated as the result of ponderomotive micro-entrainment among the accumulated mutually repelling ions or else as the result of micro-explosions due to local heating. The short lifetime of these phase nuclei does not permit their use for delayed track production, which to a certain extent limits the usefulness of the usual bubble chambers, assuming only semiautomatic registration of particles in preliminary saturation. (This condition increases interest in the investigation of the density, lifetime and dynamic growth of these *primary* phase centers, and in attempts at very high speed photographic registration of the tracks, such as could be done by using pulses from highly sensitive electro-optical tubes[2] or by other optical recorders, activated by the scattering or the emission of light by these optical inhomogeneities. Such inhomogeneities arise virtually along the entire particle track, not only under metastable conditions, but even without pressure drops, in stable heated or aerated liquids, for example, near the boiling point, and especially strongly near the critical point).

A series of suggested methods for the proposed accomplishment of the automatic operation of bubble chambers employs the possibility of formation of *secondary* centers for the initiation of the action on the remaining ions. Among such methods are, for example, the proposal[3] to use the local energy liberated upon the recombination of ions, the formation of phase nuclei through dissipative drifting of ions in an external electric field or else in the field of an approaching ion of opposite charge, attempts at influencing the ions by high frequency electromagnetic waves[4], *etc.*, using various ways of changing the dynamics of recombination of the ions by the application of an external electric field.

Without stopping to evaluate the effectiveness of these methods for various working liquids in bubble chambers, let us examine possible new methods of revealing the presence of single ions, based on the stratification of a working liquid composed of heterogeneous components in ion fields.

Let us assume that the molecules of a profusely dissolved substance (for example, a gas, vapor or liquid) possess a dipole moment markedly exceeding the dipole moment of the solvent liquid. Then the strong inhomogeneous electric field due to ion formation leads to a sharp change in the concentration of the solution in the vicinity of the ions (local enrichment or quasi-liquid complex formation). If the lifetime of the ion exceeds the time needed to establish localized statistical diffusion equilibrium (and it is indeed these relatively long-lived ions, for which this condition is known to be fulfilled, that we are interested in), then in accord with the Boltzmann formula the local concentration of the solution at a distance r from the center of

the ionic field is equal to:

$$K(r) = \frac{n_s}{n_l} = K(\infty)\exp\left\{\frac{1}{kT}\int_0^{E'(r)}(p_s - p_l)\,dE'\right\},$$

where p_s and p_l are the effective averaged (over the direction of the field) molecular dipole moments of the dissolved substance and solvent liquid respectively. These quantities depend, generally speaking, on the field intensity and on the temperature. E' is the effective electric field acting on the molecules ($E' \approx a(r)e/r^2$, where e is the ionic charge, and $a(r) \approx \frac{2}{3\varepsilon(r)} + \frac{1}{3}$) takes the local polarization of the mixture into account, can vary only in a narrow range: $0.3 < a(r) > 1$.

For the sake of illustration we shall evaluate the order of magnitude of the dimensions of the zone of adequate enrichment. Assuming for the sake of simplicity on the zone boundary $(p_s - p_l) \sim 10^{-18}$ C.G.S. electrostatic units, approximately equal in order of magnitude to the intrinsic dipole moment of a polar molecule, let us examine a solution of polar gas molecules in a less polar or nonpolar liquid. Then, the condition of adequate enrichment, say for $\ln\frac{K(r_1)}{K(\infty)} \sim 2$, yields $r_1 > 10^{-7}$ cm for $T < 300°K$.

For a very weak or vanishingly small electric field in the zone of enrichment (with approach toward or recombination with a center of opposite charge, or with neutralization of the ion at the electrode, occurring in surface development of the track projection on the electrode, *etc.*) the attraction power acting on the molecule in the zone of enrichment is sharply decreased. The excess quasi-gaseous pressure (if the dissolved substance has sufficient volatility) exerts an effect on the adjacent layer of the liquid and is able to promote a microexplosion of the liquid and the production of nucleation voids, resulting in a bubble with assured instability of the state (superheat or supersaturation of the working liquid).

This process of ion development, which is basically different from the development mechanism used in the usual bubble chambers, produces development centers as long as the recombination of ions continues. This process can be used not only during preliminary saturation, but also during delayed instability.

Obviously, the greater the relative difference of the dipole moments or polarizability of the solvent and solute molecules, the more valid is this description of the possible mechanism of development; the faster it occurs, and the greater is the instability of the system.

Among the shortcomings of methods for delayed track development which use the effects arising on the recombination of ions is the need for providing enough recombining ions, during a given time interval, to produce supersaturation also in the time interval during which a strongly unstable state exists. In view of the sharp decrease in the number of ions recombining per unit time, it is apparently necessary to use special electric fields, such as an alternating field to attract and repel the ions at certain instants of time.

In this regard the proposed methods of development which utilize the effect of electric fields from the side on the ions, excel markedly, since in this case the effectiveness of development is determined by the number of ions caught up rapidly by the effected influence, and not by the change in the number of ions, as was the case previously. The application of the field can be accomplished with negligibly small delay (with an associated small instability of the state), or else fortuitously combined with the field that weakens of the recombination of the ions (upon triggering of the system by the passing particle).

The effect of the formation of phase nuclei in heated or aerated liquids in the presence of ions moving under the influence of an electric field, or in the presence of changes in the local ionic fields, holds great interest not only in regard to the possibility of automatic particle track registration, but also because it is a unique means of initiating phase transitions under the influence of electric fields.

Among other manifestations of the effect of electric fields in the specific conditions considered above, it is worth noting that the establishment of easier conditions for the production of nucleation bubbles and a high ion density along the particle track in the liquid can facilitate the localization of discharge along the track and the production of a gas-vapor canal for visualization of the track (for example, limited discharge along the track, intersecting a series of flat thin electrodes submerged in the liquid with alternating potentials, *etc.*).

It is also of interest to investigate the dynamics of current-induced compression of discharge in liquid systems of special physical interest metastable or near-boiling liquids, which consequently exhibit a low breakdown resistance to the discharge voltage actually produced in the gas-vapor phase

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Phenomenological Study of the Effect of Nonconducting Medium in Quantum Electrodynamics

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AS IS KNOWN (see, for instance, the review by Feinberg [1]), the influence of the surrounding medium on the collision of particles with a small longitudinal momentum transfer can become considerable even for high energies. Furthermore, the influence of the surrounding medium must necessarily be important in the higher order perturbation calculations because, in the integration over the 4-momentum of virtual photons, one necessarily has to include the wavelength region for which the presence of the neighboring atoms cannot be ignored. This was pointed out for the first time by Landau and Pomeranchuk [2] who noted that the magnitude of the radiative corrections is strongly influenced by the multiple scattering of the electron in the medium. Ter-Mikaelian [3] noted that the radiative corrections should be especially strongly influenced by the deviation, for soft quanta, of the dielectric susceptibility $\varepsilon(\omega)$ from unity.

In view of this, it would be of some interest to construct a covariant Feynman-Dyson perturbation theory for a phenomenological quantum electrodynamics in a medium.

A non-covariant formulation of quantum electrodynamics was given by Ginzburg [4] and Sokolov [5] and was later expanded by Watson and Jauch [6]. For the construction of a covariant perturbation theory in a medium, it is convenient to use the formulation of phenomenological quantum electrodynamics proposed by Tamm, in which the properties of the medium are described by the dielectric and magnetic susceptibility tensor $\varepsilon_{\nu\lambda\rho\sigma}$ which relates the field tensor $F_{\nu\lambda}$ to the induction tensor $H_{\nu\lambda}$:

$$H_{\nu\lambda} = \varepsilon_{\nu\lambda\rho\sigma} F_{\rho\sigma}. \tag{1}$$

In homogeneous isotropic matter, $\varepsilon_{\nu\lambda\rho\sigma}$ has the form

$$\varepsilon_{\nu\lambda\rho\sigma} = \mu^{-1} (\delta_{\nu\rho} + \varkappa u_\nu u_\rho)(\delta_{\lambda\sigma} + \varkappa u_\lambda u_\sigma). \tag{2}$$

Here u_ρ is the 4-velocity of the medium, μ is the magnetic susceptibility, $\varkappa = \varepsilon\mu - 1$, $\varkappa$ and μ are invariants; the Feynman notation is used. If the potential of the electromagnetic field is introduced in the usual way

$$F_{\rho\sigma} = \partial_\rho A_\sigma - \partial_\sigma A_\rho \tag{3}$$

and the components are constrained to the auxiliary condition

$$\partial_\rho (A_\rho + \varkappa u_\rho u_\sigma A_\sigma) = 0, \tag{4}$$

then, from the field equation

$$\partial_\nu H_{\nu\lambda} = -j_\lambda \tag{5}$$

and from (2) – (4) one obtains the following equation for the potential

$$\mu^{-1} (\partial_\rho^2 + \varkappa (u_\rho \partial_\rho)^2)(\delta_{\lambda\sigma} + \varkappa u_\lambda u_\sigma) A_\sigma = -j_\lambda. \tag{6}$$

In the Heisenberg representation of quantum theory, the field operators satisfy the same equation (5); the commutation relations for the free field operators have been found in Ref. 6. The rules for the computation of the scattering matrix elements can be easily obtained, for instance by the method of Galanin [8]. But, instead of the usual Green function for photon, the formulae will involve the Green function for the free equation (6), determined by

$$\mu^{-1} (\partial_\rho^2 + \varkappa (u_\rho \partial_\rho)^2)(\delta_{\lambda\sigma} + \varkappa u_\lambda u_\sigma) G_{\lambda\nu}(x, x') = -\delta_{\sigma\nu}\delta(x - x'), \tag{7}$$

Changing to the momentum representation, it is easy to obtain the following expression for the Green function:

$$G_{\lambda\nu}(x, x') = (2\pi)^{-2} \int d^4k \mu \left(\delta_{\lambda\nu} - \frac{\varkappa}{1+\varkappa} u_\nu u_\lambda\right) \times \{k_\rho^2 + \varkappa (u_\rho k_\rho)^2\}^{-1} \exp ik(x - x'). \tag{8}$$