Letters to the Editor

On Bubble Chambers

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THE MECHANISM of bubble formation incident to the passage of particles through a superheated liquid still remains unclear. Many authors (see for example Bertanza *et al.* [1]) consider that the bubbles are due to electrostatic repulsion of positive ions produced by the ionizing particle and that the thermal process in the formation of the bubble can be neglected. In this communication we assume that the thermal process is the predominant one in bubble formation.

Let us examine a superheated liquid. It is known that for every metastable phase there exist certain minimal dimensions which an accumulation of another phase must attain in order for the latter to be more stable than the initial one. During the passage of a charged particle through matter there form δ-electrons of different energies, which lose their energy over a relatively short section of path. Let us assume that the entire energy of the δ-electron is released in the form of heat; then for the formation of a bubble we must have localization of a certain amount of energy $E_{\min}$ in a region commensurate with the dimensions of the bubble. If we further assume that the formation of the bubble occurs isothermally, then for $E_{\min}$ we obtain

$$E_{\min} = Nq + pV + 4\pi r_{\min}^2 \alpha. \tag{1}$$

If the liquid is weakly superheated, we can use for $r_{\min}$ the familiar expression [2]

$$r_{\min} = 2\alpha/(p_0 - p).$$

To determine the number N of vapor molecules we can make use of the equation of state for an ideal gas. Finally we obtain for $E_{\min}$

$$E_{\min} = [16\pi\alpha^3/(p_0 - p)^2] \times [1 + 2p_0(p/p_0 + q/kT)/3(p - p_0)], \tag{2}$$

where α is the surface tension, p_0 is the pressure with a plane interface, p is the pressure in the superheated liquid, q is the heat of evaporation per molecule, and T is the temperature of the superheated liquid.

The δ-electrons of different energies will produce bubbles having different radii; finally at some energy E' the δ-electron will be capable of forming several bubbles; however, since such electrons form visible tracks branching off from the track of the ionizing particle they can be disregarded. Thus the problem is to find the number of δ-electrons of energy $E_{\min} \le E \le E'$; this number, on the basis of our assumption, will be equal to the number of bubbles formed. It can readily be shown that the number of δ-electrons per unit length is given by the expression

$$g(\beta) = \frac{e^2}{\pi v^2 \hbar} \times \sum_j \int_{\omega_j + E_{\min}/\hbar}^{\infty} \frac{\operatorname{Im}\varepsilon}{|\varepsilon|^2}\left[\ln\frac{2mv^2E'}{(\hbar\omega)^2|1-\beta^2\varepsilon|} - \beta^2 \operatorname{Re}\varepsilon\right] d\omega, \tag{3}$$

where

$$\varepsilon = 1 + \frac{4\pi Ne^2}{m}\sum_j \frac{f_j}{\omega_j^2 - \omega^2 - ig_j\omega},$$

and the other symbols are in the conventional notation. If we consider small superheats, then $E_{\min} \gg \omega_j\hbar$ (here $\hbar\omega_j$ is the ionization potential of the atom). Assuming that $g_j \ll \omega_j$, we obtain

$$g(\beta) = \frac{2Ne^4}{mv^2}\frac{\varepsilon^0}{E_{\min}^2}\left[\ln\frac{2mv^2E'}{E_{\min}^2 D(\beta^2)} - \beta^2\right],$$
$$D(\beta^2) = 1 - \beta^2 + \beta^2(4\pi Ne^2\hbar^2/E_{\min}^2 m), \quad \varepsilon_0 = \sum_j f_j h g_j. \tag{4}$$

A characteristic feature of (4) is the strong dependence of $g \sim (p_0 - p)^6$ on the superheat. The value of E' is determined from the conditions of the experiment (E' is of the order of $10^4 - 10^5$ ev), although actually the choice of E' does not substantially affect the results.

[1] Bertanza, Martelli, and Zacutti, Nuovo cimento 9, 487 (1955).
[2] L. Landau and E. Lifshitz, *Statistical Physics*, M., 1951.

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