In conclusion I express my thanks to V. L. Ginzburg for suggesting the problem and for his assitance in the work.

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On Particle Energy Distribution at Multiple Formation

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IN Landau's work[1] there was developed a hydrodynamic theory of the formation of particles resulting from the collision of high energy nucleons. As is known, the resolution of this hydrodynamic problem concerning energy spread into evacuated space consists of two parts: wave motion and a nontrivial solution[2].

As regards the problem of multiple formation, the main role in the angular distribution of the particles is played by the nontrivial solution region, since it is here that the principal portion of the entropy of the system lies. The approximate solution of the problem of scattering, given by Landau, represented an asymptotic expression of the nontrivial solution of the scattering section remote from the boundary region separating it from the moving wave. In Landau's solution the latter was completely ignored. Accordingly, the question arises as to how far the disregard of the wave motion is justified when computing particle angular and energy distribution. It is to the examination of this problem that the present letter is devoted.

For the entropy S_p and energy E_p of the wave we have the expression:

$$S_p = nT_0^3 V_0 \int\limits_{x_1/l}^{ct/l} s_p u_p d\left(\frac{x}{l}\right), \qquad (1\text{a})$$

$$E = mT_0^4 V_0 \int\limits_{x_1/l}^{ct/l} {}^4/_3 \varepsilon_p u_p^2 d\left(\frac{x}{l}\right). \qquad (1\text{b})$$

Here l is the longitudinal extent of the system at the start of the scattering, $mT_0^4 4/3\, \epsilon_p u_p^2$ and $nT_0^3 s_p u_p$ are the densities of the energy and entropy of the wave, T_0 and V_0 are the initial temperature and volume of the system, n and m are constants. Integration is effected over the entire region occupied at the given moment by the moving wave, that is to say, from the boundary line it shares in common with the nontrivial solution section x_1 to the leading edge of the wave $x = ct$.

It should be noted that the coefficients before the integrals in (1a) and (1b) represent respectively the complete entropy and energy of the system. Therefore, the portions of the entropy α and the energy β contained in the moving wave will be equal to

$$\alpha = \frac{S_p}{S} = \int\limits_{x_1/l}^{ct/l} s_p u_p d\left(\frac{x}{l}\right), \qquad (2\text{a})$$

$$\beta = \frac{E_p}{E} = {}^4/_3 \int\limits_{x_1/l}^{ct/l} \varepsilon_p u_p^2 d\left(\frac{x}{l}\right), \qquad (2\text{b})$$

where u_p is a component of the four-velocity of the element.

Taking into consideration that $u_p \gg 1$ and making use of the Riemannian solution for a simple wave function, we can express ϵ_p, s_p and u_p as follows

$$\varepsilon_p = \left[\frac{(ct - x)(c - c_0)}{(ct + x)(c + c_0)}\right]^{2c_0/c}, \qquad (3\text{a})$$

$$s_p = {}^4/_3 \left[\frac{ct - x}{ct + x}\,\frac{c - c_0}{c + c_0}\right]^{c/2c_0}, \qquad (3\text{b})$$

$$u_p = {}^1/_2 \left[\frac{ct + x}{ct - x}\,\frac{c + c_0}{c - c_0}\right]^{1/2}, \qquad (3\text{c})$$

where c is the velocity of light and $c_0 = c/\sqrt{3}$ the velocity of sound. Substituting (3a), (3b) and (3c) in (2a) and (2b) and introducing a new variable $z = (ct - x)/l$, we obtain for α and β the following evident expressions:

$$\alpha = {}^1/_2 \left(\frac{c - c_0}{c + c_0}\right)^{{}^1/_2[(c/c_0) - 1]} \times \int\limits_0^{z_1} \left(\frac{z}{(2ct/l)\, z}\right)^{{}^1/_2[(c/c_0) - 1]} dz, \qquad (4\text{a})$$

$$\beta = {}^1/_3 \left(\frac{c - c_0}{c + c_0}\right)^{(2c_0/c)-1} \times \int_0^{z_1} \left(\frac{z}{(2\,ct\,/\,l)\,z}\right)^{(2c_0/c)-1} dz. \quad (4b)$$

The magnitude of z_1 is determined from the condition of continuity existing at the boundary line between the nontrivial solution section and the moving wave. If for the nontrivial solution section we use Khalatnikov's method[3], we shall easily obtain an equation for z_1 as follows:

$$z_1 = \left(\frac{2ct}{l} - z_1\right)^{(2c_0-c)/(2c_0+c)} \times \left(\frac{c + c_0}{c_0}\right)\left(\frac{c - c_0}{c_0}\right)^{(2c_0-c)/(2c_0+c)} \quad (5)$$

For t we naturally use the critical time t_k, i.e., the time element corresponding to the beginning of the free scattering, when the energy flux density and the temperature of the moving wave (or to be more exact, at the boundary line separating the moving wave from the non-trivial solution section) diminish to such an extent that further interaction of the particles with each other can be disregarded. As to the magnitude of the critical time element t_k or more exactly, of $2ct_k/l$, it can be said beforehand that it is much larger than unity, while the magnitude of z_1 is of the order of unity and $z_1 \ll 2ct_k/l$.

Making use of this fact and applying formulas (3a) and (3b), we can evaluate the magnitude of $2ct_k/l$ by expressing it in terms of the critical values for energy flux density and temperature; namely,

$$\frac{2\,ct_\kappa}{l} = \frac{c - c_0}{c_0}\,\varepsilon_p^{-(2c_0+c)/4c_0}. \quad (6)$$

But

$$\varepsilon_p = (T/T_0)^4,$$

where T is the temperature of the medium itself at the moment when scattering begins, which temperature it is natural to assume to be equal to uc^2, and T_0 is the initial temperature associated with the full energy of the laboratory system

$$\frac{2\,ct_\kappa}{l} = \left(\frac{c - c_0}{c}\right)\left(\frac{E_0}{\mu c^2}\right)^{(2c_0+c)/4c_0}. \quad (7)$$

Considering that

$$z \ll 2\,ct_\kappa\,/l,$$

we find that α and β can be expressed as follows:

$$\alpha = {}^4/_3 \left(\frac{c - c_0}{c_0}\right)^{c_0/(2c_0+c)} \times \left(\frac{2\,ct_\kappa}{l}\right)^{-c_0/(2\,c_0+c)} = {}^4/_3 \left(\frac{E_0}{\mu c^2}\right)^{-1/4}, \quad (8a)$$

$$\beta = \frac{c}{6\,c_0}\left(\frac{c + c_0}{c_0}\right)\left(\frac{c - c_0}{c_0}\right)^{(2c_0-c)/(2c_0+c)} \times \left(\frac{2\,ct_\kappa}{l}\right)^{-(2c_0-c)/(2c_0+c)} = \frac{c}{6c_0}\left(\frac{c + c_0}{c_0}\right)\left(\frac{E_0}{\mu c^2}\right)^{-(2c_0-c)/(4c_0+c)}. \quad (8b)$$

Substituting the numerical values in formuals (8a) and (8b), we find that when the energy of the primary nucleon is

$$E_0 = 10^{12}\ \text{eV}$$

the moving wave carries away 14% of the entire entropy and 44% of the energy of the system, and that when the energy is $E_0 = 10^{18}$ev the wave carries away 0.45% of the entropy and 17% of the energy. The absolute number of particles carried away by the moving wave, at the aforementioned energies, appears to be unchanged, and of the order of unity.

These estimations show that the moving wave carries away a comparatively small portion of the entropy and a small number of particles, but may carry a substantial portion of the energy of the entire system. In any case, it is in the moving wave that the most energetic particle is to be found. It should be noted that the magnitude of the energy of the moving wave is easily affected by whatever assumption is made as to the nature of the particles it contains (all of the results obtained in the preceding refer to the case where the system contains only π-mesons). If we take into account the possibility that along with π-mesons the moving wave may contain also a nucleon[4], the portion of energy that is carried by the wave amounts to 60-70%.

The results obtained indicate that proper consideration of the moving wave substantially influences the estimate of energy distribution at multiple particle formation, when the energy of the mutually colliding particles is $\sim 10^{12} - 10^{13}$ ev.

In conclusion, we wish to express our deep gratitude to S. Z. Belen kii for his valuable advice and suggestions.

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Investigation of the Field of Partial Pressures in a Diffusing Condensing Chamber

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THE distribution of supersaturations inside a diffusion chamber, and consequently the height and quality of the sensitive layer, depend on the temperature field and on the partial-pressure field. The temperature field inside a diffusion chamber was investigated in references 1 and 2. This communication describes a procedure and measurement results for the partial-pressure field.

A special instrument, namely an expansion diffusing chamber, was constructed to investigate the partial pressure field. The chamber is a glass-walled crylindrical container. The bottom of the chamber consists of two glass disks screwed together, and is cooled by liquid nitrogen, flowing through a spiral groove cut in the upper disk. The flow of nitrogen, and consequently the temperature of the bottom, are regulated by changing the pressure in a Dewar flask with a valve. The cover of the chamber is a brass plate with holes 7 mm in diameter distributed uniformly over the entire area. The brass plate is covered on the top with a rubber diaphragm which separates the working volume of the diffusion chamber from the volumes that connect with the atmosphere and with the vacuum system. The expansion is carried out in a container located above the working volume. A mercury manometer records the pressure in this container before the expansion and the common pressure in the system after the expansion. The degree of expansion is thus determined from the ratio of the pressures. The vapor source is the surface of ethyl alcohol filling a trough that is fastened to the upper cover. The diffusion chamber is filled with air at atmospheric pressure.

Generally speaking, the vapor partial pressure and temperature vary with the height within the volume of the diffusion chamber. Consequently, the cloud produced by the expansion does not form throughout the chamber, but only in those regions where the partial pressure exceeds a certain value. Knowing the temperature distribution and the degree of expansion, it is possible to determine the partial pressure of the vapor at the cross section where the boundary of a dense cloud produced by condensation on neutral or charged centers is located. By varying the degree of expansion, it is thus possible to determine the partial pressure field over the entire volume of the chamber.

The temperature inside the chamber is measured by a horizontally placed thermocouple, the height of which can be changed by means of a permanent magnet. The partial-pressure distribution obtained by the above method is shown in Fig. 1 (with the temperature distribution in the chamber being approximately as represented by curve 1 of Fig. 2).

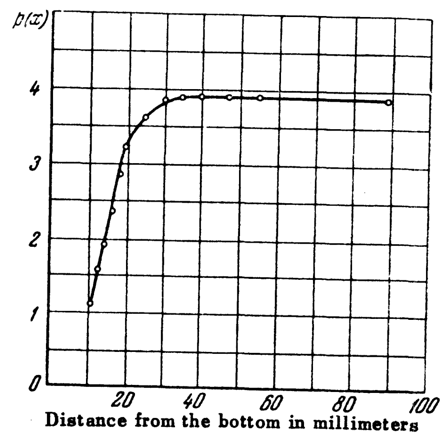

FIG. 1 Partial-pressure distribution in chamber. Height of sensitive layer is 15 mm.

The partial pressure is apparently constant over a considerable volume of the chamber, apparently because of the thorough mixing of the gas and the vapor. The fact that the temperature is constant in any horizontal cross section inside the chamber also indicates that the gas and vapor are thoroughly mixed.

To investigate the effect of the condensation on the partial pressure distribution, the chamber was irradiated inside with a gamma-ray source in such a way that, unlike in the preceding case, the expansion caused condensation on charged, rather than