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## *ON KINETIC TRANSITIONS*

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It is known that when a thermodynamic force X (a gradient of an electric or chemical potential, a temperature gradient, etc.) acts on a system in thermodynamic equilibrium, a generalized flow J develops which is proportional to that force. We wish to note that in many cases when X is increased above a certain critical value $X_c$ the state of the system becomes unstable and several degrees of freedom are created in it—periodic internal motions develop; the function J(X) while remaining continuous, has a break at the point $X_c$. (We do not consider here transitions in which the function J(X) is itself discontinuous.)

Examples of such a change in the flow J are, for example, the break in the curve of the heat flow upon the start of convection in an ordinary [1] and a conducting [2] (in a magnetic field) fluid, the break in the curve of the "effective viscosity" when eddies form in a fluid between rotating cylinders, [3] the break in hydrodynamic resistance during magnetohydrodynamic flow, [4] the break in the characteristic of a gas discharge in a magnetic field, [5] the break in the dependence of current upon voltage in a magnetic field in a solid, [6] etc.

The physical reason for the appearance of the break is the following: the presence of internal motions in the supercritical region leads to a spatial redistribution of force X in the system, in which the changes in the force $\delta X$ are proportional, when the supercriticality $X - X_c$ is small, to the square of the amplitude of the internal motions $\xi$ (there is no linear term, owing to the periodicity of the motion); at $X > X_c$, the amplitude increases until the condition $\delta X \sim X - X_c$ begins to be fulfilled, so that $\xi \sim \sqrt{X - X_c}$, and the supplementary flow $\delta J$, quadratic with respect to $\xi$, is proportional to the supercriticality: $\delta J \sim X - X_c$. Consequently, the function J(X) is continuous at $X = X_c$ but its first derivative has a finite discontinuity.

$$(J)_{X_c+0} - (J)_{X_c-0} = \Delta J = 0 \tag{1}$$

$$(\partial J / \partial X)_{X_c+0} - (\partial J / \partial X)_{X_c-0} = \Delta (\partial J / \partial X) \neq 0, \infty. \tag{2}$$

The critical value $X_c$ depends, generally speaking, on a set of external parameters $\alpha$. If we differentiate (1) with respect to $\alpha$, we get

$$\Delta (\partial J / \partial \alpha)_X = - (dX_c/d\alpha)\, \Delta (\partial J/\partial X)_\alpha; \tag{3}$$

thus the partial derivative $\partial J/\partial\alpha$ is also discontinuous at $X = X_c$, the relation (3) can be used both for an experimental check on the nature of the transition [if the two jumps $\Delta(\partial J/\partial X)$ and $\Delta(\partial J/\partial \alpha)$ and the slope of the transition curve $X_c = X_c(\alpha)$ are measured] and to express some discontinuities through others.

When two thermodynamic forces, $X_1$ and $X_2$, are present, the kinetic transition takes place on the curve $\Phi(X_{1c}, X_{2c}) = 0$. In that case the jumps $\Delta(\partial J/\partial X)$ are connected by relations analogous to (3):

$$\begin{aligned} \Delta (\partial J_1/\partial X_1)_{X_2} &= - (dX_{2c}/dX_{1c})\, \Delta (\partial J_1/\partial X_2)_{X_1}; \\ \Delta (\partial J_2/\partial X_1)_{X_2} &= - (dX_{2c}/dX_{1c})\, \Delta (\partial J_2/\partial X_2)_{X_1}. \end{aligned} \tag{4}$$

Eliminating $dX_{2c}/dX_{1c}$, we get

$$\Delta (\partial J_1/\partial X_1)_{X_2}\, \Delta (\partial J_2/\partial X_2)_{X_1} = \Delta (\partial J_2/\partial X_1)_{X_2}\, \Delta (\partial J_1/\partial X_2)_{X_1} \tag{5}$$

Equations (5) are analogous to the Ehrenfest relations [7] between the jumps of the second derivatives of thermodynamic potentials at the point of a second-order thermodynamic transition.

As an example, let us examine the convection of a viscous conducting fluid, heated from below, between horizontal plates in an external magnetic field. In that case the difference in temperatures of the plates $\Theta$ plays the role of the generalized force X, and the heat flow between the plates q is the flow J. If we consider the magnetic field H as the parameter $\alpha$, we get from (3):

$$\Delta \left(\frac{\partial q}{\partial H}\right)_\Theta = - \frac{d\Theta_c}{dH}\, \Delta \left(\frac{\partial q}{\partial \Theta}\right)_H. \tag{6}$$

The flow in the transcritical mode is composed of molecular and convective flows: $q = q_0 + \delta q$; the molecular flow in a viscous conducting fluid does not depend on the magnetic field. According to linear theory, $d\Theta_c/dH \to 0$ as $H \to 0$; on the other hand, the value of $\Delta(\partial q/\partial\Theta)$ in the absence of a magnetic field is known, and we can get from (6) an expression for the convective flow in a weak magnetic field:

$$\delta q(H) \cong \delta q(0) - [\Theta_c(H) - \Theta_c(0)]\, \Delta(\partial q/\partial\Theta)_{H=0}.$$

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## *ON THE PROBLEM OF THE* D$^+$ *MESON*

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AT the 1959 International Conference on High Energy Physics in Kiev, Wang Kang-chang et al [1] suggested that one of the events recorded in a propane bubble chamber could be interpreted as the decay of a particle of strangeness +2 into a $K^0$ meson and a $\pi^+$ meson ($D^+$ meson). Subsequently, Yamanouchi [2] drew attention to the fact that some previously investigated anomalous cases of strange-particle decays could also be interpreted as a D-meson decay.

The existence of the $D^+$ meson is allowed by the Gell-Mann–Nishijima scheme, according to which it should be an isotopic singlet ($S = +2$, $T = 0$). The possible channels for the decay of this particle are

$$D^+ \begin{cases} \nearrow K^+ + \pi^0, \\ \searrow K^0 + \pi^+, \end{cases} \tag{1}$$

where the probability of the second branch should be double that of the first. The $D^+$-meson lifetime should be, as noted by Pontecorvo, [3] of the order $10^{-10}$ sec (the decay occurs with $\Delta T = 1/2$). Another possible isotopic singlet, the $D^-$ meson ($S = -2$, $T = 0$) should have similar properties.

Eisenberg et al [4] and Cook et al [5] conducted a search for the $D^\pm$ mesons among particles of $K^\pm$-meson beams. They showed that the amount of $D^\pm$ mesons in the extracted $K^\pm$-meson beams does not exceed $10^{-4}$—$10^{-3}$. It is obvious, however, that the method used by these workers is suitable only for the observation of long-lived particles ($\tau \approx 10^{-8}$ sec) and is unsuitable if $\tau \approx 10^{-10}$ sec.

An attempt to detect the $D^+$ meson in the direct vicinity of its assumed point of production was made by Nikol'skiĭ et al [6], who exposed an emulsion stack to a 9-BeV internal proton beam. In this work, however, the more probable branch of the $D^+$-meson decay ($D^+ \to K^0 + \pi^+$) could not be observed. Moreover, in proton interactions, the $D^+$ meson should be produced along with two strange particles (if we neglect the small probability of its associated production with a $\Xi$ hyperon), as a result of which the cross section for this process cannot be large.

In this connection, it is of interest to study the reaction

$$K^+ + p \to D^+ + \Sigma^+. \tag{2}$$

Since only two strange particles (including the $D^+$ meson) are produced in the final state, it can be hoped that the cross section is much larger.

In the present experiment, we attempted to observe the actual production and decay of the $D^+$ meson in a bubble chamber.

A propane bubble chamber with a pulsed magnetic field [7] was exposed to a beam of positive particles of momentum $\sim 1.8$ BeV/c containing, as was shown by the measurements of M. F. Likhachev and V. S. Stavinskiĭ, up to 9% $K^+$ mesons. A total of 14,000 pairs of pictures were scanned for cases of $D^+$-meson production and decay: