I INTRODUCTION AND BASIC CONCEPTS(*)

The mechanics of macroscopic systems with many degrees of freedom does not usually allow a rigorous treatment, since the equations of motion are prohibitively difficult to solve in all but a few special cases. Even in these cases, however, one is confronted with the more fundamental difficulty that the information available in practice is far from being sufficient to select the particular solution that best describes a given individual system. In fact, the actual observations normally furnish no more than a small set of macroscopic data, whereas the knowledge of all the many dynamical variables would be required to fully determine the state of the system. With the underlying mechanical process thus largely unspecified, one can account for the observed properties only by resorting to statistical methods.

The foundations of statistical mechanics are due to *Josiah Willard Gibbs* (1839-1903), but their historical roots go back to the development of the kinetic theory of gases. A first major insight was achieved in the eighteenth century by *Daniel Bernoulli* (1700-1782), who realized that the pressure of a gas arises from the impact of the molecules on the walls of the container and thus was able to explain Boyle's law for ideal gases, which states that the pressure is inversely proportional to the volume. The introduction of statistical methods, however, did not occur until about a hundred years later, primarily through the work of *James Clerk Maxwell* (1831-1879) and *Ludwig Eduard Boltzmann* (1844-1906). Maxwell deduced the velocity distribution of molecules of a gas in equilibrium by showing that the distribution remains stationary under the influence of molecular collisions. Boltzmann went further to study the time-dependence of the distribution function and its approach to equilibrium; he also recognized the statistical significance of the concept of entropy in the sense that it is measured by the logarithm of the probability of finding a gas in a given equilibrium state.

A more general problem, however, was raised through the somewhat earlier development of thermodynamics. This subject had been brought to its completed form by *William Thomson* (later Lord Kelvin) (1824-1907) and *Rudolf Emmanuel Clausius* (1822-1888) with the general formulation

(*) Sections marked with an asterisk are taken verbatim (with only minor editing) from the handwritten Bloch manuscript.

of the first and second laws and the clarification of such concepts as work, heat, temperature, and entropy. Since the laws of thermodynamics are valid for any macroscopic system, their explanation in mechanical terms required a generalization of the statistical method to encompass all possible cases. Likewise, it is necessary to go beyond the motion of mass points considered in the kinetic theory of gases, and to use as a basis the laws of mechanics in their most general form. The methods of Gibbs are based on the formulation developed by *William Rowan Hamilton* (1805-1865), where a system is characterized by its energy, given as a function of the general coordinates and their conjugate momenta, which determine the equations of motion. Since the work of Gibbs preceded the advent of quantum theory, it refers entirely to classical mechanics, and important modifications are required in the extension to quantum mechanics. The essential statistical elements, however, are common to both; following the historical line, they will first be introduced from the classical viewpoint and later adapted to quantum statistics. In fact, it was the attempt to apply classical statistics to black-body radiation that led *Max Planck* (1858-1947) to the introduction of the quantum of action and, hence, to the beginnings of quantum theory.