RESEARCH OBJECTIVES

Traditionally, thermodynamics is a macroscopic discipline that relies on mechanical models to account for the microstructure of thermodynamic systems. Accordingly, it has been assumed that the problem of foundations consists of a complete reduction of thermodynamics to mechanical principles.

The present research is based on an essentially different point of view. We propose to show that thermodynamics can be extended in the microscopic direction and developed into a fundamental theory that is complementary rather than subordinate to the mechanics of indestructible particles.

Technically, the possibility of extending thermodynamics beyond its classical limits stems from the fact that the traditional axiomatics of thermodynamics is incomplete. While the formulation of a complete postulational basis at one stroke seems impossible at the present time, a method of successive approximation appears entirely practical. Each step in this approximation is a theory with its own postulational basis, mathematical techniques, and limitations of validity.

The theory representing the first approximation is an improved version of Gibbs' theory of phase equilibrium. We refer to this theory as the macroscopic thermodynamics of equilibrium. This theory can be briefly described as follows. Consider a cell division of space; the partitions are either mathematical walls, or physical walls, which are more or less restrictive of the transfer of additive invariants. Thermodynamic operations are manipulations of the constraints that increase or relax the constraints imposed on the system. After a thermodynamic operation has been performed, the system usually proceeds to a new equilibrium state. This is called a thermodynamic process.

The theory exhibits various improvements over the classical presentation. Thus, taking into account the role of symmetry leads to a new version of Gibbs' phase rule. Also, some well-known difficulties connected with the third law of thermodynamics are removed.

The discussion of symmetry necessarily involves the microstructure of the system and provides one of the avenues leading from the macroscopic theory to the microscopic theory.

The formalism of the macroscopic theory exhibits singularities at the critical points and near absolute zero. Their removal calls for a number of improvements that have been only incompletely investigated thus far. These improvements follow two main lines: statistics and correlations. The case of pure statistics, in which the additive invariants of the macroscopic theory become additive random variables, is relatively simple. We call this theory the statistical thermodynamics of equilibrium.

A satisfactory theory of space-time correlations, including, particularly, cases

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in which correlations stem from quantum dynamics, is still in its initial stage.

The most difficult part of the theory is dealing with the interplay of correlations and randomness. At present, this is merely a plan for future consideration.

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