Journal of Statistical Physics, Vol. 95, Nos. 3/4, 1999

Book Review: *Nonequilibrium Statistical Mechanics. Ensemble Method*

Nonequilibrium Statistical Mechanics, Ensemble Method. Byung Chan Eu, Kluwer, Dordrecht, The Netherlands, 1998, $173.00.

This book is the second attempt of the author to provide a microscopic basis to the Thermodynamics of Irreversible Processes.[1] The macroscopic foundations of the subject are presented in Chapter 2 where he has certainly improved on his initial attempt in ref. 1 by deriving a local differential form for a non-equilibrium thermodynamic potential here called calortropy which, based on an inequality derived by Clausius over one hundred years ago, satisfies all the desired properties, including its consistency with the second law of thermodynamics. This quantity turns out to be different from the Clausius entropy but reduces to it for the special case of reversible or linear irreversible processes. A method, which is certainly not unique, is provided to construct the calortropy in terms of possible observables in an irreversible process, here chosen to be the generalized fluxes, so defining the appropriate thermodynamic space. This stage constitutes a real improvement upon the other existing versions of extended irreversible thermodynamics specially insofar as their consistency with the second law is concerned. The next three chapters contain a brief review of the Boltzmann equation and its properties which will serve as the basis of what may be considered the medular contribution of the book. Here it is of special interested to distinguish between the ordinary solutions to the Boltzmann equation and the so called thermodynamics branch of such solutions which is relevant in the study of fluctuations.

The main objective of the book is discussed in Chapter 7. Here the reader must be carefully warned in various aspects. First, is the sought parallelism with standard Gibbs ensemble approach in equilibrium statistical mechanics. This is more semantical than practical; Gibbs phase space, Liouville equation and the deep meaning of ensembles are never used. The author works only with the Boltzmann equation, in μ-space and averages

0022-4715/99/0500-0811$16.00/0

of dynamical quantities are taken with a projection of the solutions to Boltzmann's equation onto the thermodynamic space defined in Chapter 2. The general idea is then to be able to compute the relevant quantities that appear in the differential for the calortropy using formal analogies of the concept of partition functions as defined by Gibbs. Here arises a second warning. The thermodynamic branch of the solution to Boltzmann's equation is used in parallel to discuss on the one hand, the possibility of finding a way to give a sound basis to irreversible thermodynamics using the Maxwell–Grad moment method, which after lengthy and elaborated discussions is finally dismissed, and on the other, to give the sought "non-equilibirum statistical foundations" to the macroscopically derived differential form for the calortropy. Regretfully, there are two versions of the partition function approach given, Sections 7.3 and 7.10 respectively, which I couldn't see how to relate in a simple logical way. What is worst is that they are separated by three sections dealing with the importance of Boltzmann's relative entropy and its use on the corresponding theory of fluctuations, a section on resummation methods for the Maxwell–Grad method, a section on constitutive equations for the fluxes and the hydrodynamic equations which are hardly related to the partition function method of Section 7.3. Fluctuations are clearly important to discuss but they should have been left to a later stage. On the other hand equations for the fluxes and the derivation of the hydrodynamic equations ought have been more clearly related to the use of non-equilibrium partition functions. This continuous trend of thinking is entirely lost in the midst of many mathematical details which are of secondary importance to the use of the announced formalism. By the time one comes back to the main trend namely, the promised partition function method which is taken once more in 7.10, the overall picture is confusing. Moreover the chapter essentially ends with calculations to the lowest order terms of the exceedingly complicated mathematical formulas which are contained in the non-equilibrium partition function, and difficult to asses.

In Chapter 8, Transport Processes in Fluids, after showing that the method is at grips with linear irreversible processes, as it should, a few examples are treated for which the hidden power of the impressive structure worked out in the previous chapter, hardly shows up. Chapters 9 and 10 are formal attempts to extend the method to the case of ideal quantum fluids and dense fluids. In neither case practical applications are given.

Had the author concentrated on how one can provide a rigorous method to justify his differential form for the calortropy by using the ideas of Sections 7.3 and 7.10 to obtain the corresponding hydrodynamic equations for the non-conserved variables and calculating the unknown dynamic equations of state (transport coefficients) for ideal gases, classical and quantum, the sensation of having, at least for these systems, a non-equilibrium statistical theory of irreversible process may have been accomplished. The way the material is presented makes the book very hard to read and to grasp the main points behind the arguments. One is left with the feeling of wondering if such a tremendous effort is worth to obtain an understanding of the microscopic basis of irreversible thermodynamics. As the author himself recognizes, many applications have to be worked out before one can coldly and objectively assess the virtues of the formalism specially in the case of non-ideal systems.

REFERENCE

1. *Kinetic Theory and Irreversible Thermodynamics* (John Wiley & Sons, 1992).

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