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Book Review: *Lectures on the Kinetic Theory of Gases, Non-equilibrium Thermodynamics and Statistical Theories*

Lectures on the Kinetic Theory of Gases, Non-equilibrium Thermodynamics and Statistical Theories. Ta-You Wu, National Tsing Hua University Press, Hsin Chu, Taiwan. $50.00 (226 pp.), ISBN 957-02-8205-3, Email: thup@my.nthu.edu.tw

The lecture notes by Ta-You Wu on the kinetic theory of gases, non-equilibrium thermodynamics and statistical theories, have recently been published by the National Tsing Hua University Press, Taiwan. Professor Ta-You Wu (1907–2000), a prominent researcher, writer, educator, and science administrator in China, Canada, the U.S., and Taiwan, was the third Chinese physicist to receive a Ph.D. in theoretical physics. One year after obtaining his Ph.D. from the University of Michigan, he returned to China in 1934 where he taught throughout the difficult wartime years. After the war he was the head of the Theoretical Division of the Physics Institute of the National Research Council of Canada and taught at SUNY Buffalo until his retirement in 1978. Later he moved to Taiwan and served as President of the Academia Sinica in Taipei from 1983 to 1994. Starting in the early 1960's, he single-handedly developed from scratch a scientific research program in Taiwan which became the National Science Council, the counterpart of NSF now with an annual budget about one tenth of that of the NSF's. In China, Taiwan, and among Chinese physicists, Professor Wu is widely known as the teacher of T.D. Lee and C.N. Yang, Nobel laureates of 1957, during their student years.

Professor Ta-You Wu is also known for his prolific writings in theoretical physics. His authoritative monograph, *Vibrational Spectra and Structure of Polyatomic Molecules*, written under the most difficult conditions during the war is well-known. Equally important are his eight volumes of lecture notes on theoretical physics. Educated under the influence of S.A. Goudsmit and G.E. Uhlenbeck of the Michigan (and Dutch)

School, Wu closely followed the development of modern physics at the time. While most of his lecture notes are not readily accessible to students and researchers in the West, it is very fortunate that the last set of Wu's lecture notes, delivered by Professor Wu at the ripe age of 87, is now being published as a book. The book, *Lectures on the Kinetic Theory of Gases, Non-equilibrium Thermodynamics and Statistical Theories*, records expanded lecture notes delivered by Wu in the Spring of 1994. In these lectures, Professor Wu presented in his unique style of clarity and simplicity, the formulation and development of kinetic theory, statistical physics, and non-equilibrium thermodynamics. The lectures cover a large part of the theory of non-equilibrium statistical thermodynamics, and examine the fundamental problem of the irreversible direction of time. The lectures are brief (223 pages), but are complete in the sense that the derivations of central results from clearly stated assumptions are given in full detail. The strength of the book lies in the five chapters, Chapters III–VII (133 pages), on kinetic theory and non-equilibrium statistical thermodynamics which contain materials not readily found in standard textbooks.

After an introductory statement of purpose for the lectures, professor Ta-You Wu discusses the laws of thermodynamics giving particular emphasis to a precise definition of the law of increasing entropy. This involves a clear separation of entropy as a sum of entropies of the system and of the surroundings. As is typical of the lecture style of professor Ta-You Wu, the treatment is short yet careful and complete.

Chapters III and IV of the lectures discuss the Boltzmann equation. It is shown how the law of increasing entropy is a consequence of probability assumptions implicit in the kinetic equation. Particular care is taken to describe properly how the conservation laws enter into the collision operators, and the resulting connection is made between collision operator properties and the macroscopic limit of fluid mechanics in gases. The justification of the Boltzmann equation proceeds along the lines set out by Bogoliubov which are derived in detail. The Frieman-Sandri theory of the Boltzmann equation is also discussed. The BBGKY hierarchy of equations must be terminated in order to obtain a closed kinetic theory (e.g. the generalized Boltzmann equation). Several termination procedures are discussed leading to closed kinetic theories for dilute gases. Professor Ta-You Wu again faces the problem that the BBGKY hierarchy is time reversal symmetric yet the resulting kinetic theories must choose an "arrow of time". The problem of dynamically and spontaneously breaking time reversal symmetry has been present starting from the pioneering statistical thermodynamic work of Boltzmann and Gibbs. But Professor Wu made it clear in his discussions where this symmetry breaking enters. In Chapter

V the Boltzmann equation is applied to the Vlasov-Landau theory of a dilute plasma, which is discussed from a physical kinetics viewpoint.

Professor Ta-You Wu goes on in Chapter VI to discuss the general irreversible processes in condensed matter from the viewpoint of linear transport coefficient matrices along the lines set out by Onsager. The symmetry properties of the matrices are derived on the basis of thermal fluctuations and microscopic reversibility. In all cases where a reasonable irreversible kinetic model has been useful in describing an approach to equilibrium, the final ensemble equilibrium probability distribution turns out to be either the micro-canonical distribution of Boltzmann or the canonical distribution of Gibbs. These are equivalent for large systems. While these results have not been rigorously derived from microscopic dynamics (no such derivation presently exists), it is argued that the results are eminently reasonable, and that the results can be and have been born out experimentally. The Einstein theory of Brownian motion is discussed from such a viewpoint, and Professor Wu then discusses several simply solvable models in thermal equilibrium. Methods of describing equilibrium fluctuations are also discussed. Both classical and quantum statistical thermodynamic canonical distributions are covered in a clear and concise manner.

In Chapter VII, Professor Ta-You Wu returns yet again to the problem which has haunted many other distinguished researchers, including R. Kubo and L.D. Landau, on the foundations of statistical physics: from whence comes the "arrow of time"? Each so-called derivation of irreversible kinetic model contains at least one point at which a statistical assumption chooses for the theorist a time direction. Landau was convinced that the derivation involved the irreversibility of quantum measurements but even Landau here admitted that he had no proof of such a conjecture. Here, the style of professor Ta-You Wu's lectures is to provide the mathematics, where it is available, to make the underlying assumptions explicit. Where no mathematical proofs are available, the qualitative discussions remain clear.

In summary, the lectures of Professor Ta-You Wu will prove to be very useful to students and researchers. The central and fundamental concepts of physical kinetics are more than adequately discussed, and those parts of the theory not yet understood are presented in a manner inviting the reader to contribute to their solution. While fewer topic are covered than may be found in, say, the treatise *Physical Kinetics* by L.D. Landau and E.M. Lifshitz, the simple yet elegant detailed discussions make the lectures a delight to read. As remarked by Professor T.D. Lee in his *Introduction* at the beginning of the book: "reading these lecture notes is an experience that will make you closer to the Master and to Nature". This

is a book that must be read by anyone who is serious about learning the foundations of equilibrium and irreversible statistical thermodynamics.

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