Thermodynamics of Complex Systems

Principles and applications

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Preface

The reader is invited to look at the complex systems that we encounter in reality (living biological organisms and populations of species, including the human population with special subsystems: a national economy, monetary system, science etc) from the point of view of thermodynamics. A complex system can be considered as a thermodynamic system, which is described not only by *fundamental variables*, characterizing thermodynamic equilibrium, but also by a set of extra, *internal variables* that describe deviations of the thermodynamic system from the equilibrium situation. The existence of internal variables is the distinguishing mark that separates complex thermodynamic systems from simple ones. In fact, a very complex system appears to be a metastable construction, described by internal variables; the conventional thermodynamics variables like volume, pressure and so on do not play an essential role in description of behaviour of a very complex system. However, energy and entropy appear to remain the fundamental concepts in thermodynamics of complex systems.

Non-equilibrium thermodynamics appears to be a universal basis for the description of behavior of a complex system, and, in the first chapters of the book, I try to represent the main concepts and principles of non-equilibrium thermodynamics in a way applicable both to open systems and to situations far from equilibrium. The consecutive use of the concept of *thermodynamic internal variables* allows us to take into account the complexity of the system and to describe its dynamics. The exposition begins with the definition of a thermodynamic system and is developed before the reader step by step; although, perhaps, it could be easier for him to have preliminary knowledge of some notions from physics and thermodynamics. In the subsequent chapters, some samples of application of the general theory of thermodynamics of complex systems is considered. I hope that the presented concise formulation can be helpful for those who are occupied with applications of thermodynamics to the description of real objects.

The scheme of disposition was born when I was delivering lectures to my students of applied mathematics in the framework of the Course on Methods of Mathematical Modeling many, many years ago. So, I suppose, the book can be used by the students of different specialties who are going to develop mathematical models of real phenomena. The form of lectures did not assume long excursions into the history of concepts and principles of thermodynamics, so that my list of literature is not as large as it should be. I am realizing that some important work and authors may not be mentioned (I am sorry for that!), and this is only the consequence of the situation.

The drafts of the chapters of the book were presented for discussion on the site ResearchGate (https://www.researchgate.net/). I am grateful to those who sent me comments on my work: Ben Akih kumgeh, Théodore Bouchez, Erik Brown, Delton

Chen, Vera Maura Fernandes de Lima, Marc Le Goc, Purushottam D Gujrati, Luciano Martinez-Balbuena, Wolfgang Muschik, Alfredo Pereira Junior, Marko Popovic, Vit Průša, Bartolomé Sabater, Robert Shour, A M Toikka, Mohammad Wahiduzzaman. Their suggestions have helped me, I hope, to improve the text. Nevertheless, all possible mistakes are mine. I shall be glad to hear any comments on the book.

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Author biography

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Vladimir Pokrovskii is a Professor of Applied Mathematics. He is an expert in mathematical modelling of complex natural and artificial systems. He graduated from the Department of Theoretical Physics, Tomsk State University. His qualification was acquired at the Institute of Chemical Physics of AH USSR, investigating the behaviour of suspensions and polymers. He is known as a prominent researcher of dynamics of polymers: the second edition of his monograph *The Mesoscopic Theory of Polymer Dynamics*, issued by Springer in 2010, is included in the list of Best Reference Books on Polymer Dynamics, used by students of top universities, institutes and colleges in the USA. He has developed an original course of lectures *Methods of mathematical modelling*, delivered to students of applied mathematics of the Altai Polytechnic Institute and the Moscow Institute of Economics and Statistics, that includes classical examples from areas of mechanics, physics, chemistry, biology and economy. Persistent attempts to understand the essence of economic processes have provided material for the book *Econodynamics. The Theory of Social Production*, the third edition of which was published by Springer in 2018. Vladimir Pokrovskii has authored some other monographs (published in Russian) and more than 150 papers (in Russian and English).