Preface

"More is different" is a famous aphorism of P.W. Anderson, who contributed rather a lot to the development of condensed-matter physics in the latter half of the 20th century. He claimed, by this aphorism, that macroscopic systems behave in a way that is qualitatively different from microscopic systems. Therefore, additional rules are needed to understand macroscopic systems, rules additional to the fundamental laws for individual atoms and molecules. An example is provided by the various kinds of phase transitions that occur. The state of a sample of matter changes drastically at a transition, and singular behavior is observed at the transition point. Another good example in which quantity brings about a qualitative difference is the brain. A brain consists of a macroscopic number of neural cells. It is believed that every brain cell functions like an element of a computer. However, even the most sophisticated computer consists of only a limited number of elements and has no consciousness. The study of the human brain is still developing.

On the other hand, the paradigm for macroscopic matter, namely thermodynamics and statistical physics, has a long history of investigation. The first and second laws of thermodynamics and the principle of equal probability in statistical physics have been established as laws that govern systems consisting of a macroscopic number of molecules, such as liquids, gases, and solids (metals, semiconductors, insulators, magnetic materials, etc.). These laws belong to a different hierarchy from the laws at the microscopic level, and cannot be deduced from the latter laws, i.e. quantum mechanics and the laws for forces. Therefore, a "theory of everything" is useless without these thermodynamic and statistical-mechanical laws in the real world. The purpose of this book is to explain these laws of the macroscopic level to undergraduate students who are learning statistical physics for the first time.

In this book, we start from a description of a macroscopic system. We then investigate ideal gases kinematically. Following on from the discussion of the results, we introduce the principle of equal probability. In the second and third chapters we explain the general principles of statistical physics on the basis of this principle. We start our discussion by defining entropy. Then temperature, pressure, free energy, etc. are derived from this entropy. This concludes Part I of the book. In Part II, from Chap. 4 onwards, we apply statistical physics to some simple examples. In the course of this application, we show that entropy, temperature, and pressure, when defined statistical-mechanically, coincide with the corresponding quantities defined thermodynamically. We consider only thermal-equilibrium states in this book. Most of our examples are simple systems in which interaction between particles is absent. Interaction, however, is essential for phase transitions. For an illustration of how a phase transition occurs, we consider a simple ferromagnetic system in Chap. 7. At this point, readers will be able to obtain a general idea about statistical physics: how a system in equilibrium is treated, and what can be known. In Part III, some slightly more advanced topics are treated. First, we consider first- and second-order phase transitions in Chaps. 8 and 9. Then, in Chap. 10, we return to our starting point of the ideal gas, and learn what happens at low temperature, when the density becomes higher.

Physics is one of the natural sciences, and the starting point of an investigation is the question "Why does nature behave like this?" Therefore, it is a good attitude to ask "why?" This question should be aimed only at natural phenomena, though. In this book, we give an explanation, for example, for various strange characteristics of rubber. However, it is often useless to ask "why?" about the methods used for solving these questions, or how an idea or concept used to treat a problem was obtained. For example, it is not fruitful to ask how the definition of entropy was derived. The expression for the entropy was obtained by a genius after trial and error, and it cannot be obtained as a consequence of logical deduction. Logical deduction can be done by a computer. Great discoveries in science are not things that can be deduced. They are rushes of ideas to the head. Some students stumble over these whys and hows of the methods, and fail to proceed. We hope that you will accept the various concepts that geniuses have introduced into science, and enjoy the beauty of the physics developed by the application of such concepts.

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