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condensed matter physics. In the past, condensed matter physics has been dominated by the study of materials containing light elements such as hydrogen, lithium, boron, carbon, nitrogen, and oxygen. These elements combine to form a large number of interesting materials, including liquid and solid water, diamond, graphene, boronene, carbon nitride, carbon nanotubes, boron-carbon-nitride nanotubes, and crystalline and porous silicon-carbide. It has long been assumed that the physical properties of heavy-element materials (e.g., transition metals) are more complex than those of light-element materials. Although this seems intuitively reasonable, physical reality does not always conform to human intuition. An increasing number of studies have found that light-element materials exhibit full quantum effects (especially when nuclear quantum effects are non-negligible), resulting in novel and complex physical phenomena.

The concept of full quantum effects arises naturally from the Schrödinger equation. In this book, the term *full quantum effects* denotes the physical and chemical properties predicted by the full quantum theory with nuclear and electronic degrees of freedom included. By "full quantum theory," we mean those theories and computational approaches that not only consider the quantized electrons of a macromolecular or condensed matter system in the Schrödinger equation but also account for the quantized nuclei as well as the coupled motion of these quantum particles. In quantum chemistry, it is preferable to solve the Schrödinger equation directly in terms of the wavefunctions of the electrons and nuclei. However, such studies are generally only possible for small-scale systems containing at most a few atoms. For condensed matter systems with a large number of atoms, the customary first step is to apply the Born-Oppenheimer approximation from computational physics; then, various further approximations are used to solve the Schrödinger equation. For example, the nucleus is normally considered to be a classical point-like particle, because its mass is much larger than that of the electron. In most cases, only the electrons are strictly described by wavefunctions. Even if the Born-Oppenheimer approximation holds, this approach neglects the quantum coupling between the motions of the electrons and the nuclei. Treating the nuclei and the electrons separately and simply summing the solutions automatically implies the adiabatic approximation.