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Introduction

Small macroscopic particles and clusters as systems of a finite number of bound atoms or molecules have been investigated since the nineteenth century. In this respect, one recalls some results from that century, among which is the conclusion by Michael Faraday [1, 2] that the radiation of candle flames results from the emission of soot particles. Another example relates to the generation of fine gold particles located in colloidal suspension [3]. Then one can govern by the final particle with the addition of salt, whereas adding micellar surfactant molecules (amphilic molecules) will prevent gold particles from sticking. This method was developed and became widespread in the twentieth century. In addition to this, Ostwald investigations [4, 5] explained the character of the growth of small particles as the result of atom evaporation from small particles and their attachment to large particles, later called "Ostwald ripening". One more example relates to so-called Aitken particles, which are small particles that scatter sunlight in the upper atmosphere [6, 7]. All these results became the basis for the contemporary understanding of the behavior of small particles and clusters and also provided the methods for their generation and detection.

Some cluster concepts arise from the study of aerosols, dust and mist particles in the Earth's atmosphere, domains and grains in solid solution, solid and liquid particles in suspensions and emulsions, islands and films on surfaces, and colloids in liquid solution due to the behavior of these objects and processes in gases and plasmas involving small particles and clusters. In particular, such concepts of cluster growth as coagulation and coalescence emerged from the concepts of "blood coagulation" and "coalescence of bones" in physiology. Therefore, the contemporary analysis of the properties of clusters and their behavior in gases and plasmas will be based on the results of previous investigations for analogous objects.

As specific physical objects, clusters arose in the eighties after the discovery of magic numbers, that is, numbers of atoms (or molecules) at which solid clusters have a heightened stability compared to that at neighboring sizes. Magic numbers correspond to complete atomic structures for clusters as systems of bound atoms or molecules, and the values of magic numbers depend on the character of interaction between cluster atoms. Cluster parameters as a function of the number of atoms have extrema at the magic numbers of atoms. For example, a cluster with a magic number of atoms has a higher binding energy of atoms and ionization potential

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than clusters with neighboring numbers of atoms. As physical objects, clusters occupy an intermediate position between atomic particles (atoms and molecules) on the one hand and macroscopic atomic systems (solids and liquids) on the other.

The goal of this book is the analysis of certain properties of clusters ranging in size from tens to billions of atoms as well as the analysis of processes involving clusters and cluster structures. These systems include cluster sources and generators where clusters are formed and grow under nonequilibrium conditions in gases or plasmas, and also the complex plasma that is an ionized gas containing particles or clusters. The structures formed by solid clusters or solid particles such as fractal aggregates, chain aggregates, and fractal fibers are studied in the book. Guided largely by simple methods based on analytic theoretical methods, we perform our analysis using individual problems, each of which considers a certain aspect of cluster behavior or cluster processes. The results of these problems will allow us to draw certain conclusions and make certain evaluations regarding clusters and complex plasmas. The problems may be useful both for students studying the physics of clusters or their applications as well as for professionals who seek an explanation for a particular cluster question.

The problems under consideration in this book are related to two types of cluster applications. First, understanding cluster processes allows us to analyze some natural and laboratory processes and phenomena. For example, in this manner one can optimize combustion processes from the standpoint of the formation of soot and solid combustion products. Second, an understanding of cluster behavior, together with a new experimental technique that allows one to analyze nanoparticles, will lead to the development of new branches of nanotechnology, for example, production of nanometer porous or sandwichlike films. We will give a more detailed list of cluster applications in the conclusions.

The issues raised in this book are represented in various books of cluster physics such as [8–22]. Moreover, the material in [17] serves as a basis for this book.