

Preface

In the first two books of the series *Fundamental Aspects of Plasma Chemical Physics*, we have discussed thermodynamics¹ and transport² of thermal plasmas characterized by equilibrium or quasi-equilibrium conditions. Plasma technology often uses working conditions very far from the equilibrium ones so that kinetic approaches are to be used to describe the properties of these plasmas. In this way we enter the scenario of *cold plasmas* which can present strong deviations from equilibrium of the internal energy distribution functions implying a loss of validity of the concept of temperature. A peculiar situation holds for electrons, which present a non-Maxwellian energy distribution function to be described by a suitable Boltzmann equation. Moreover the presence of non-Boltzmann vibrational and electronic distributions generates non-Arrhenius behavior of reaction rates, a point not easily perceived by researchers which extensively use the Arrhenius law for the relevant rates. Cold plasmas present average electron energies in the range 0.1–10 eV, while the translational temperature of heavy components ranges from room temperature to about 2,000 K. Ionization degrees well below 10^{-3} characterize this kind of plasmas which run in the torr and sub-torr pressure range even though it is nowadays possible to form atmospheric nonequilibrium plasmas. Cold plasmas are widely used in material science for cleaning, film deposition, plasma etching, surface activation, as well as to produce gas lasers (e.g., the CO₂ and excimer lasers) and negative and positive ion beams. Plasma medicine, biomaterial activation, plasma-assisted combustion, and numerous aerospace applications do extensively use cold plasmas for reaching important goals.

The present book tries to rationalize the description of cold plasmas through a chemical physics approach, in particular by using the state-to-state plasma kinetics which considers each internal state as a new species with its own cross sections.

¹M. Capitelli, G. Colonna and A. D'Angola "Fundamental Aspects of Plasma Chemical Physics. Thermodynamics" Springer Series in Atomic, Optical and Plasma Physics (2012) Vol.66.

²M. Capitelli, D. Bruno and A. Laricchiuta "Fundamental Aspects of Plasma Chemical Physics. Transport" Springer Series in Atomic, Optical and Plasma Physics (2013) Vol.74.

This approach needs complete sets of state-resolved cross sections, the knowledge of which at least for the most common diatomic species (O_2 , N_2 , and H_2) is continuously increasing. In addition kinetic approaches based on the solution of Boltzmann equation and/or by Monte Carlo methods are being discussed especially for the description of the electron and ion energy distribution function. Coupling between electron energy distribution functions (eedf) and nonequilibrium internal (rotational, vibrational, and electronic states) distributions through second kind collisions are such to superimpose interesting structures on eedf with large consequences on plasma reactivity. This coupling should be also extended to the dissociation and ionization kinetics promoted either by electron impact or by heavy particle collisions involving excited states.

The book can be considered divided into three parts: the first part is dedicated to the dynamics of elementary processes including also heterogeneous ones and the second part to the description of plasma kinetics through the construction of suitable master equations for both atomic and molecular plasmas. Finally the third part includes different applications in applied fields such as microelectronics, fusion, and aerospace. As in the first two books of the series, some overlaps occur in the different chapters to keep part of them self-consistent allowing undergraduate and PhD students as well as researchers to construct a personal road in the understanding of the relevant topics. It is worth noting that the book can be considered complementary to other books published by one of the present authors,^{3,4} on nonequilibrium plasma kinetics. An appropriate selection of the reported chapters can be used for courses on the kinetics of cold plasmas addressed to undergraduate and PhD students.

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³M. Capitelli Ed. "Non-equilibrium Vibrational Kinetics" Topics in Current Physics Springer (1986) Vol.39.

⁴M. Capitelli, B.F. Gordiets, C.M. Ferreira and A.I. Osipov "Plasma Kinetics in Atmospheric Gases" Springer Series in Atomic, Optical and Plasma Physics (1986) Vol.31.



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Kinetics

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