Chapter 1
Introduction

The goal of this book is the analysis of some aspects of atmospheric physics and chemistry on the basis of elementary processes in the Earth's atmosphere, as well as global atmospheric properties and phenomena that are based on these processes. This book has common features with [1] for the kinetics of excited air. Here we consider mostly other aspects of this general problem including radiative and aerosol processes, and also respective atmospheric phenomena. In consideration of atmospheric phenomena, we are grounded on observational and measured data using simple reliable concepts and models. Taking elementary processes in excited air as a basis, we use appropriate global models and concepts including the global circuit model [2] for electric processes in the atmosphere and the model of standard atmosphere [3–6]; that is, we use an average of atmospheric parameters over the globe. This allows us to obtain detailed information about atmospheric properties or phenomena in a simple form. Following is a list of such problems to deepen understanding on the basis of this analysis.

1. Collisions of neutral aerosols in different aggregate states leads to their charging, and the subsequent fall of positive and negative aerosols with different falling velocities leads to charge separation in the atmosphere and the creation of atmospheric electric fields as a source of atmospheric electrical phenomena. Charged aerosols constitute cumulus clouds, and due to a charge, growth of aerosols in cumulus clouds proceeds with a lower rate compared with that for neutral aerosols. Then from rates of the coagulation process and the lifetime of a cumulus cloud it follows that a typical charge of aerosols in cumulus clouds includes $Z = 25-30$ electron charges. Ionization of atmospheric air is realized by seconadary Mev-energy particles which are formed in nuclear rections involving Gev-energy protons or neutrons.

2. Note a significant role of cosmic rays in atmospheric processes. Atmospheric ionization by cosmic rays is important for aerosol discharging and creating a plasma that does not allow for clouds to expand in a surrounding space. In addition, showers of cosmic rays initiate the beginning of lightning in a thunderstorm.

3. The atmospheric optical depth u for infrared radiation is approximately equal to $u = 2.7$, as follows from the analysis of the energetic balance of the Earth and its atmosphere. The greenhouse atmospheric effect is determined mostly by atmospheric

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water, and, as follows from the subsequent analysis, the above optical depth may be created by atmospheric aerosols if (1−2) % of atmospheric water is converted in aerosols. This may cause anxiety because of an atmospheric instability for the global climate that can be changed by a weak action. Next, according to NASA data [7], the average Earth temperature has increased by (0.8 ± 0.1)°C from 1880 up to now. Keeping in mind the huge effort to obtain this value which requires monitoring by thousands of meteorological stations because temperature fluctuations are tens of degrees, one can note that this change corresponds to an increase of the total mass of atmospheric water by approximately 10 %. The press and TV convince us that the main reason for the above temperature increase is an accumulation of atmospheric CO_2 because its concentration in the atmosphere has increased by about 30 % during the twentieth century. In this book we analyze the contribution of atmospheric CO_2 in the greenhouse effect step by step and find that doubling of the CO_2 concentration in the atmosphere leads to an increase of the Earth's global temperature by (0.4 ± 0.2)°C and at the contemporary rate of change of the CO_2 concentration the doubling of its concentration will take 130 years. Thus, the contribution of atmospheric CO_2 to the greenhouse effect of the atmosphere is several times less than that from atmospheric water. This contribution also depends on the manner of CO_2 generation, so that deforestation acts more strongly on the balance of atmospheric CO_2 than that due to combustion of fossil fuels.

4. In spite of a small ozone concentration (<0.01 %) in the stratosphere, it is important both for absorption of ultraviolet solar radiation and for thermal balance of the stratosphere. But seasonal and daily fluctuations of the ozone concentration are compared with its concentration, as well as its average concentration in various parts of the globe. The latter is reflected by the term "ozone hole" for poles where the ozone concentration at the poles is less than approximately twice that at equatorial regions, but this does not characterize an absorption of ultraviolet radiation in atmospheric air. For example, the probability of reaching the Earth's surface for ultraviolet solar photons, which mostly are absorbed by ozone molecules, is $\exp(-200)$ in an equatorial zone and $\exp(-100)$ at the poles. The same changes relate to daily and seasonal ozone concentrations, so that the term "ozone hole" does not correspond to a meaning of these words.

Although above we enumerate some atmospheric problems that are distorted in the press or are not taken into account in atmospheric science, it is not the main goal of this book, which consists of an academic description of elementary atmospheric processes and their kinetics. This, together with other atmospheric reviews and books, allows us to formulate the physical picture of atmospheric processes and to correct some positions of this description. Let us demonstrate this for electrical atmospheric processes. One can consider processes of atmospheric electricity as a secondary phenomenon with respect to water circulation through the atmosphere [8]. The central process of atmospheric electricity is the charging process as a result of collisions of aerosols that are located in different aggregate states. This characteristic of the charging process follows from the experiment [9] which, in the author's opinion, is underestimated.

Cosmic rays are of importance for atmospheric electricity and electrical atmospheric processes. Air ionization by cosmic rays in the troposphere and above the tropopause is important for the Earth's discharge, which is charged negatively [10, 11]. In reality, the study of cosmic rays starts from investigation of air ionization in the troposphere [12]. But the role of cosmic rays in processes of atmospheric electricity is not restricted by ion formation in the troposphere. One of the problems of atmospheric electricity is the origin of lightning. Because a typical electrical field strength in a thunderstorm due to a cloud charge is two orders of magnitude lower than the breakdown of electrical field strength in air, the development of lightning is impossible from one seed electron. It is possible as a result of streamer propagation, but approximately 10^8 electrons must be gathered in a small volume for streamer realization [13] in order to create electrical field strengths above the breakdown. The analysis [14] shows that known mechanisms do not explain this stage of lightning evolution. Evidently, the answer for this follows from the specific investigations in the Tien Shan station of cosmic rays [15] where the correlation was observed between showers of cosmic rays and radio emission from lightning that is evidence of lightning origin as a result of atmospheric ionization by cosmic showers.

Lightning or electrical breakdown of the atmosphere is a stage of atmospheric electricity that leads to negative charging of the Earth. The contemporary state of lightning physics is represented in Uman's books [16–19], where experimental methods are given and observational parameters of lightning are obtained in detail. The theoretical analysis of lightning development is contained in the Bazelyan and Raizer books [20–23] where models are used on the basis of electric schemes and a uniform plasma. Therefore we describe this phenomenon briefly, referring to the above books and mentioning only some aspects of this phenomenon where physics of elementary and other processes are able to give a new standpoint.

However, we correct the appropriate atmospheric electricity parameters if they contradict the results of the special analysis. In particular, the first stage of lightning, the stepwise leader, is an ionization wave that forms a conductive channel for subsequent propagation of a lightning electric current. In order to conserve a plasma in this channel during leader propagation, it is necessary to suppress attachment of electrons to oxygen molecules, and this is realized due to a heightened channel temperature. This temperature is expected above 5000 K according to [20–23]. On the basis of rate constants of the electron attachment process in the following we prove that this boundary temperature is about 1200 K.

Next, it is supposed on the basis of measurements that the lightning leader transfers on average a charge of 5 C that corresponds to a negative charge gradient along the leader channel $\sim 10^{-3}$C/m [14]. One can see that at a channel radius of 10 cm this corresponds to the number density of excess electrons on the order of 10^{11}cm^{-3}. At this excess number density of electrons the electric potential of 50 MV, a typical potential of a thundercloud, arises at a length of 1 m; that is, the ionization wave is locked at such distances. This means that the statement about a charge transfer at the stepwise leader stage is wrong, and an indicated transferred charge of 5 C relates to other stages of lightning evolution.

The above examples for lightning demonstrate the possibilities of using rates of microphysical processes in the analysis of atmospheric processes and phenomena. Returning to lightning, note that such an approach allows us to compare the contribution of various mechanisms to energy release in the lightning channel during propagation of an electric current through it, the lifetime of the conductive channel in the absence of an electric current in it, the character of expansion of the conductive channel in time, and so on. All this may be added to a contemporary understanding of the lightning physics.

The analysis of the Earth's ionosphere as one of the objectives of this book is based, in the first place, on elementary processes involving its atomic particles. According to H.S.W. Massey, the classic atmospheric physics and physics of atomic collisions, "A detailed understanding of the ionospheres of the Earth and planets requires knowledge of the rates of many ionic reactions as well as of electron recombination coefficients and photoionization cross sections" [24]. Indeed, the Earth's ionosphere contains nonequilibrium excited air; that is, its properties are determined by processes involving its atomic particles, and this air nonequilibrium starts from photoionization and photodissociation of atmospheric air under the action of solar radiation. Study of the ionosphere develops in this manner (e.g., [25–28]). Below we collect information about elementary processes that is useful for ionospheric properties.

Thus, the goal of this book is to give a simple and reliable analysis of atmospheric processes and corresponding properties of the Earth's atmosphere on the basis of physical laws and rate constants of elementary processes involving atmospheric particles. This analysis allows us to ground some existing concepts of atmospheric physics and chemistry with additional information. As a result, the analysis gives a new perspective on some aspects of processes and phenomena under consideration, and some additions to the contemporary physical picture of the Earth's atmosphere. Briefly, we consider the Earth's atmosphere as a physical object, and this approach allows us to determine definitely the mechanisms of some atmospheric phenomena with estimations for their parameters.

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