Introduction

This catalogue contains mainly the atomic data needed in the astrophysical investigations of low-density plasma. It is a revised and extended version of the "Catalogue of Atomic Data for the Rarefied Astrophysical Plasma" (Golovatyj et al. (1991)).

Low-density plasma. As different forms of the low-density astrophysical plasma we can consider the intergalactic and the interstellar media, the matter of the gaseous nebulae (planetary and diffuse), the regions in the vicinity of active galaxies and quasars, the solar and stellar coronae and several other astronomical subjects. The ion concentration in the plasma varies in broad limits from about 10^{-7} cm^{-3} to 10^{9} cm^{-3} and kinetic temperature from $5{\cdot}10^{3}$K to 10^{7}K. In these plasma objects there proceeds generation of emission spectral lines. The low-density astrophysical plasma is practically transparent in all spectral lines excluded the series of resonance lines which arise due to electron transitions to the ground state of most abundant ions of abundant elements. The bound state populations and corresponding line intensities of such targets are predominantly determined by the cascade processes which populate the states. The preceding absorption processes in the radiative transfer are photoionization and excitation in optically thick resonance spectral lines. In the low-density astrophysical plasma the majority of atoms and ions are placed in the ground state. In calculations of spectra generated by such plasma structures besides probabilities of spontaneous transitions only the induced transition rates to the low excited states and to continua are needed. This circumstance reduces essentially the atomic data set indispensable in computations of the spectra of the low-density plasma targets compared with the set needed in calculations of spectra of essentially denser stellar atmospheres.

We shall use the following notations: A^{i} and B^{i} are the i-fold ions of elements A and B, the notations $n(\mathrm{A}^{\mathrm{i}})$ we use for number density of corresponding atoms or ions and the symbols n_k denote the number densities of ion in the atomic state k (the occupation number). The excited states we denote by prime added to the ion symbol, say $\mathrm{A}^{\mathrm{i}\prime}$, but the autoionization states are doubly primed ($\mathrm{A}^{\mathrm{i}\prime\prime}$). As usual we shall use a standard notation XI for neutral atom, XII for its singly ionized ion et al. This means, for example, that symbols N^{3+} and NIV for triple ionized nitrogen are identical.

The cross-sections and rates of physical processes in a low-density astrophysical plasma. The full list of physical processes, proceeding in a rarefied astrophysical plasma includes the impact, fusion and decay processes which are accompanied by electron transitions from one state to another. In the present paper we confine our analysis with the following most important processes:

the radiation transitions between discrete bound levels($\mathrm{A}^{\mathrm{i}} + \gamma \leftrightarrow \mathrm{A}^{\mathrm{i}\prime}$),

the photoionization and the photorecombination ($\mathrm{A}^{\mathrm{i}} + \gamma \leftrightarrow \mathrm{A}^{\mathrm{i}+1} + \mathrm{e}$),

the excitation and deactivation (de-excitation) by electron impacts ($\mathrm{A}^{\mathrm{i}} + \mathrm{e} \leftrightarrow \mathrm{A}^{\mathrm{i}\prime} + \mathrm{e}$),

the dielectronic recombination and autoionization ($\mathrm{A}^{\mathrm{i}\prime\prime} \leftrightarrow \mathrm{A}^{\mathrm{i}\prime} + \mathrm{e}$),

the charge transfer ($\mathrm{A}^{\mathrm{i}+1} + \mathrm{B}^{\mathrm{j}} \leftrightarrow \mathrm{A}^{\mathrm{i}} + \mathrm{B}^{\mathrm{j}+1}$),

the electron impact ionization ($\mathrm{A}^{\mathrm{i}} + \mathrm{e} \rightarrow \mathrm{A}^{\mathrm{i}+1} + 2\mathrm{e}$).

The reversed process of the last process in the list – the triple impact recombination is negligible in conditions of a rarefied astrophysical plasma. More detailed description of physical processes studied by us is given in the corresponding sections of the explanatory text to the atomic data tables. Here we only mention that for reactions of the type $\mathrm{A} + \mathrm{B} \rightarrow \mathrm{A}' + \mathrm{B}'$ the transition rate per unit time and unit volume is given by expression $< \sigma v > n(\mathrm{A})\mathrm{n}(\mathrm{B})$. The averaged reaction rate in this expression is defined by

$$q = < \sigma v > = \int \sigma(v) v f(v)\, dv,$$

where $f(v)$ is the velocity distribution of colliding particles taken to be the Maxwellian one, characterized by temperature T. If one of the colliding particles is photon we have to integrate over the photon frequency distribution of the external radiation field. The external radiation field distribution in the most cases we shall assume to be the diluted Planckian one, specified by effective stellar temperature $T_\star$.

The units of measure. For convenience we shall give here the units of measure for quantities, describing the cross-sections and rates of elementary processes.

a. *The energy units.* In the atomic spectroscopy the energy of particles and photons usually is expressed in electron-volts (eV), ergs, wave numbers (cm^{-1}) , Kelvin degrees (K) and Rydberg units (Ry). The transformation coefficients between the quantities are illustrated by the following table:

unit of measure	eV	erg	cm^{-1}	K	Ry
1 eV	1	1.602-12	8065.48	11604.5	7.350-2
1 erg	6.242+11	1	5.034+15	7.243+15	4.587+10
1 cm^{-1}	1.240-4	1.986-16	1	1.439	9.113-6
1 K	8.617-5	1.381-16	6.950-1	1	6.334-6
1 Ry	13.606	2.180-11	1.097+5	1.579+5	1

b. *The cross-section units.* The cross-sections in atomic physics are usually measured in cm^2, megabarns (Mb $= 10^{-18}\mathrm{cm}^2$), or the hydrogen ground-state Bohr orbit areas ($\pi a_0^2 = 8.797 \cdot 10^{-17}\mathrm{cm}^2$).

c. *The process rates.* In two-particle collisions its rate is measured in $\mathrm{cm}^3\mathrm{s}^{-1}$ units. The higher-order impacts for conditions of rarefied astrophysical plasma media can be ignored.

In the present manual only the data concerning elementary processes, which proceed in rarefied astrophysical plasma media are given. Both the numerical values and the approximate half-empirical formulae for cross-sections and process rates, compiled from different published papers, have been presented.

The formulae for computation of intensities of spectral lines and continua of rarefied plasma have been given. The computation results are given for different mechanisms of line formation. In the present study we represent only the atomic data for computation of spectra of low-density astrophysical plasma (most known kinds of it are gaseous nebulae), their thermal and ionization structure.