§31. Spectra of Neutral Carbon for Plasma Diagnostics

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1. Introduction

In the magnetic controlled fusion research, the impurity atoms and ions play an important role for plasma cooling, meanwhile, the radiation also contains the information on the nature of plasma, and the spectroscopy of the radiation can be used to measure the plasma parameters.

Recently, Sergeev et al [1] have perfomed carbon pellet experiments on W-7AS, and observed several CI lines. The situation of the pellet cloud plasma may change from the cold dense plasma (with cloud density $n_{CL} \sim 10^{15} - 10^{17} cm^{-3}$ and cloud temperature $T_{CL} \sim 1 - 50eV$) to hot ambient plasma (with electron density $n_e \sim (0.5 - 10)10^{13} cm^{-3}$ and temperature $T_e \sim 100{-}3000eV$). In so large varied condition, the CR model is needed to calculate the spectra, in which both ionizing and recombining plasma should be included. In this article, using the CR model including 79 states with the principal quatumn number $n \leq 6$ and $l \leq 4$, we calculate the line spectra and line intensity ratios in the ionizing and recombining plasma. In the recombining plasma, both the continuum spectra of radiative recombination and the satellite lines of dielectronic recombination are included in our calculations.

2. Rate equation

The population densities of the i-th state of carbon atoms, n(i), is described by the following rate equation:

$$\frac{dn(i)}{dt} = \{\sum_{j\neq i} n_e C_{ji} n(j) + \sum_{j>i} A_{ji} n(j)\} - \{\sum_{j\neq i} n_e C_{ij} n(i) + \sum_{j<i} A_{ij} n(i)\} - \sum_k n_e S_{ik} n(i) + \sum_k n_e \alpha_{ki} n_+(k), \quad (1)$$

where n_e is the electron density and $n_+(k)$ is the population density in the k-th state of a singly charged ion. The electron impact excitation and ionization, spontaneous radiation, radiative recombination, dielectronic recombination and three-body recombination processes are included in our caculation. According to the method of the quasi-steady-state solution , the population of excited states can be divided into two components, which are called the recombining plasma and the ionizing plasma, respectively.

3. Atomic data

The collisional excitation rate coefficients for $n \leq 4$ are calculated by R-matrix, and others are calculated by Mewe's semi-empirical formula using the oscillator strength f_{ij} and excitation energy E_{ij}. Electron impact ionization rate coefficients are estimated by Lotz's empirical formula. Radiative recombination rate coefficient is obtained by detailed balance from the photoionization cross sections. Dielectronic recombination rate coefficient is calculated by Cowan's code.

4. Results and discussion

In our calculation, we found when $T_e > 2$ eV, the collisional-radiative ionization rate coefficients are much larger than the collisional-radiative recombination rate coefficients, in the equilibrium or near-equalibrium region, the ionizing process dominates the recombining process; when $T_e < 0.8$ eV, the collisional-radiative recombination rate coefficients are much larger than the collisional- radiative ionization rate coefficients, the recombining process dominate over the ionizing process; when $0.8eV < T_e < 2eV$, no process dominates and it is the mixing of the ionizing and recombining processes. In different parameter range, the different transition lines should be choosed to measure the plasma parameters, because they have different dependences on the plasma parameters.

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[1]. V. Sergeev, private communication, 1998.