CHIANTI

An Astrophysical Database for Emission Line Spectroscopy

CHIANTI TECHNICAL REPORT No. 21

The CHIANTI level-resolved ionization and recombination files (reclvl and cilvl)

Ver 1.0, 26 June 2018, Peter Young

Level-resolved ionization and recombination rates were added to CHIANTI 5 for some ions (Landi et al., 2006, ApJS, 162, 261). The rates are stored in cilvl and reclvl files, which have the same format. Further details about the implementation of these processes are given in CHIANTI Technical Report No. 21. The present document gives the formats for these files.

1 General information

The cilvl and reclvl files give the rates for transitions *into* the ion. For example, the fe_22.cilvl file gives the rates for ionization from Fe XXI to levels of Fe XXII; the fe_22.reclvl file gives the rates for recombinations from Fe XXIII to levels of Fe XXII.

2 File formats

The cilvl and reclvl files have the same format. For each transition there are two lines of data. The first gives the temperatures at which the rates are tabulated, and the second line gives the rates.

2.1 Line 1 format

Column 1 – atomic number *i3*
The atomic number of the ion. Not read by the software.

Column 2 – spectroscopic number *i3*
The spectroscopic number of the ion. For example, 22 corresponds to XXII. Not read by the software.

Column 3 – index of the initial state *i3*
The index of the start level from which the transition begins. For the models introduced in CHIANTI 5, this will always be 1. It can be considered to be the ground level of the ionizing/recombining ion, but it is not read by the software (see CHIANTI Technical Report No. 20).

Column 4 – index of the final state *i4
The index of the final level of the transition. These indices correspond to the indices given in the elvlc file for the ion. Not read by the software.

Columns 5 onwards – log temperatures *f10.2*
Logarithm (base 10) of the temperatures at which the rates are tabulated. Note that, although each transition has its own temperature array, in practice the software assumes all transitions (for both ionization and recombination) have the same temperature array.

2.2 Line 2 format

Column 1 – atomic number *i3*
The atomic number of the ion. Not read by the software.

Column 2 – spectroscopic number *i3*
The spectroscopic number of the ion. For example, 22 corresponds to XXII. Not read by the software.

Column 3 – index of the initial state *i3*
The index of the start level from which the transition begins. For the models introduced in CHIANTI 5, this will always be 1. It can be considered to be the ground level of the

ionizing/recombining ion, but it is not read by the software (see CHIANTI Technical Report No. 20).

Column 4 – index of the final state *i4
The index of the final level of the transition. These indices correspond to the indices given in the elvlc file for the ion.

Columns 5 onwards – rate coefficients *e10.3*
Rate coefficients for transitions entering the level specified in column 4, tabulated for the temperatures specified on line 1. Units are cm^3 s^{-1}. Note that the rate includes the direct ionization/recombination rate and the contribution from cascading into the level following ionizations/recombinations to higher levels.

Comments section
The comments section begins with a '-1' on a single line. The comments are in free format. The comments section is then closed with a '-1' on a single line.

3 Reading the cilvl and reclvlc files

Both files are read together with the same routine, called read_ionrec. As an example, the calling sequence for Fe XXII is:

IDL> zion2filename,26,22,fname
IDL> read_ionrec, fname, rec_rate, ci_rate, temp_ionrec,luprec,lupci,status,rec_ref,ci_ref

The outputs are identified in Table 1. Note that the number of transitions in the outputs will be different for the ionization and recombination files.

Although a temperature array is provided for each transition, the output temperature array is only 1D. Therefore there is an implicit assumption that *the temperature array is the same for all transitions of both the recombination and ionization files*. The temperature array returned by read_ionrec actually corresponds to the first transition of the reclvl file.

The status output will be either 1 or -1. The former indicates the reclvl and cilvl files were successfully found and read. The latter indicates, the two files were not found.

Table 1. Outputs of the read_ionrec routine.

Output	Data	Type
REC_RATE	Recombination rates	Double [ntrans, ntemp]
CI_RATE	Ionization rates	Double [ntrans, ntemp]
TEMP_IONREC	Log_{10} Temperatures	Float [ntemp]
LUPREC	Index of final state (recombination)	Integer [ntrans]
LUPCI	Index of final state (ionization)	Integer [ntrans]
STATUS	Read status	Float
REC_REF	File comments (recombination)	String array
CI_REF	File comments (ionization)	String array

Appendix

1 Update history

Ver. 1.0, 26-Jun-2018: document created.