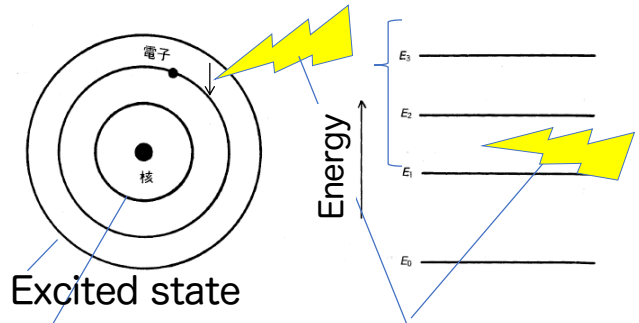
Plasma Chemistry 1 — Atomic Spectroscopy

Modeling of atomic and molecular processes and measurement of electron temperature and density

Spectral lines from plasmas

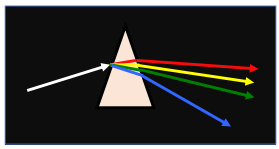


Excited state

Ground state

Light emission with its wavelength of energy difference

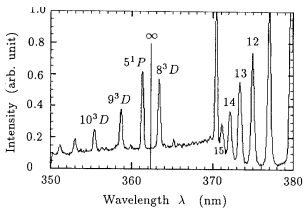
·Spectroscopic measurement of plasma will tell you the density of excited states of atoms and ions.



·The properties of various plasmas can be found.

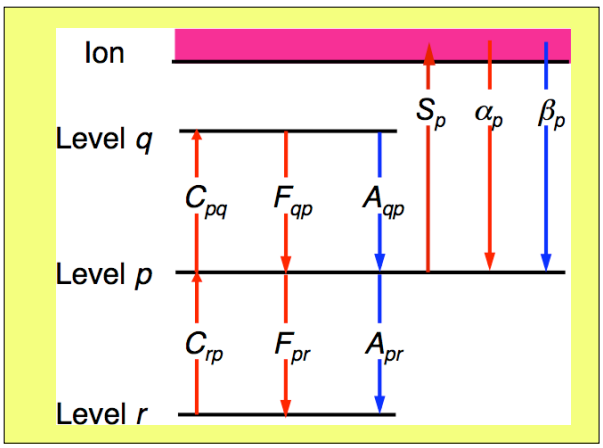
But need to be modeled

Because the plasma is in the state of non-equilibrium, and doesn't obey the Boltzmann law.



Example of hydrogen-helium mixed recombination plasma (UV region)

Population and depopulation of excited states

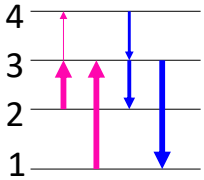


C e⁻ - Excitation
F e⁻ - Deexcitation
A Radiative transition

S e⁻ - Ionization
α Three-body recombination
β Radiative recombination

Extraction and modeling of main processes to determine electron temperature and density from several visible emission lines

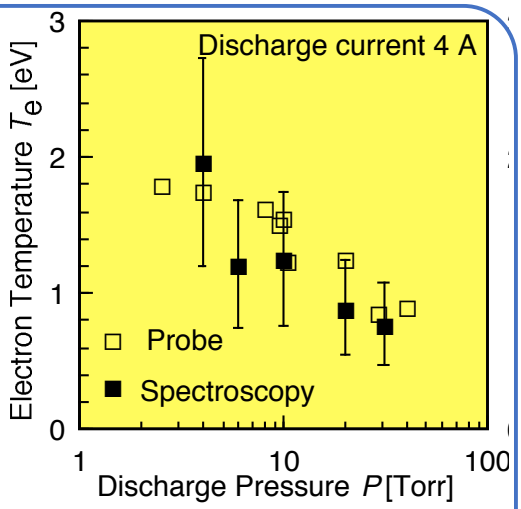
For the example RHS, $C_{13}N_eN_1 + C_{23}N_eN_2 + A_{43}N_4 = C_{34}N_eN_3 + A_{32}N_3 + A_{31}N_3$, etc.



Measurement of Ar plasma

- The value of electron temperature T_e obtained by this method roughly agrees with that by the probe measurement
  - It can even capture the trend of variation !
  - As a result of the simplification of the model, $|\Delta T_e|/T_e \leq 39$ % is sufficient for practical use.

We succeeded in measurement of T_e and N_e in Ar plasma, which is widely used in industry.



Examples of specific applications
- Semiconductor processes
- Optical film deposition processes

K. Kano, M. Suzuki, and H. Akatsuka; Plasma Sources Sci. Technol., **9**, 314 (2000).
H. Akatsuka; Phys.Plasmas **16**, 043502 (2009)
H. Akatsuka; Adv. Phys. X, **4**, 257 (2019).
Y. Yamashita et al., IEEE trans. Plasma Sci. **50**, 1875 (2022).