Atomic structure calculations and study of plasma parameters of Al-like ions

Arun Goyal

Department of Physics, Ramjas College, University of Delhi, Delhi-110007, India

E-mail: arun.goyal.du@gmail.com

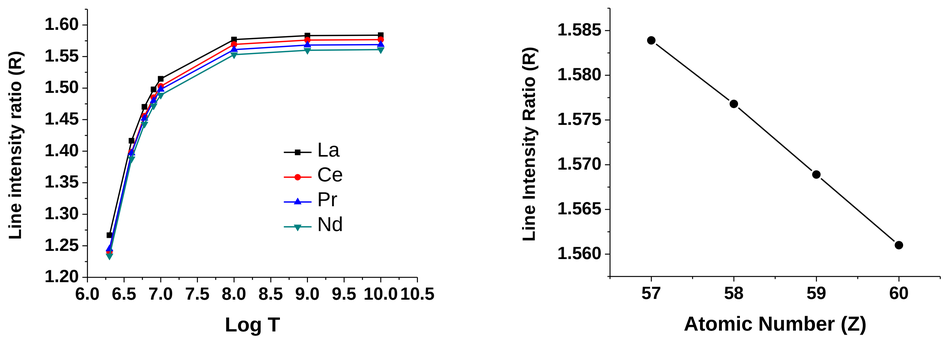
Abstract

In the present work, the spectroscopic properties and plasma characteristics of Al-like ions (57-60) are investigated in an extensive and detailed manner by adopting GRASP package based on fully relativistic Multi-Configuration Dirac-Fock (MCDF) wave-functions. We have presented energy levels of lowest 148 levels for Al-like ions. We have also provided radiative data for electric dipole (E1), magnetic dipole (M1), electric quadrupole (E2) and magnetic quadrupole (M2) transitions for Al-like ions. We have also done a similar parallel calculation by employing fully relativistic distorted wave flexible atomic code (FAC) to check the reliability and authenticity of our results. Our calculated energy levels match well with our FAC results and other available results and we have discussed the discrepancies of our results with them. The variation of the line intensity ratio, electron density, plasma frequency and plasma skin depth with plasma temperature and nuclear charge are discussed graphically in detail for optically thin plasma in local thermodynamic equilibrium (LTE). We believe that our obtained results may be beneficial in future for comparisons and identification of spectral lines, in plasma modelling andin fusion and astrophysical plasma research.

Introduction

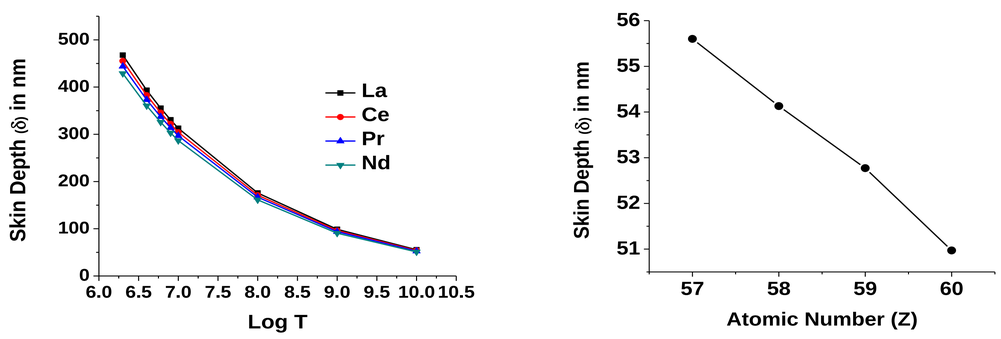
In recent years, characterization of plasmas has become an interesting and significant area of research for understanding and analyzing the utilization of multi-lateral spectroscopic sources. To achieve controlled fusion in the nuclear reactors, there is a need of high plasma temperature and electron density must be at least 10^{21} cm^{-3}. Therefore, I have studied the variation of line intensity ratio, electron density, plasma frequency and skin depth at high values of plasma temperature in optically thin plasma in LTE for Al-like ions. I have also analyzed the effect of electron density and plasma temperature on the plasma parameter and coupling parameters for the diagnosis and characterization of cold, dense and strongly coupled plasma at high temperature. In the present work, I have implemented General Purpose Relativistic Atomic Structure Package (GRASP) code for the calculation of atomic data of Al-like ions .I have used these atomic data for further calculation of plasma parameters of Al-like ions. In our calculations, I have considered two spectral lines $3s^2 3p\ ^2P^o_{1/2} - 3s^2 3d\ ^2D_{3/2}$and $3s^2 3p\ ^2P^o_{1/2} - 3s3p^2\ ^2P_{1/2}$. The present calculations will be beneficial and helpful for investigation and breakdown of fusion and astrophysical plasma [1-3].

Variation of Line Intensity Ratio



- Line Intensity ratio increases very rapidly with plasma temperature upto 10^8 K.
- After plasma temperature equal to 10^8 K, line intensity ratio becomes constant.
- Line intensity ratio decreases very rapidly with nuclear charge for plasma temperature 10^{10} K.
- By comparing our calculated line intensity ratio with the measured ratio at different delay times, experimentalists can achieve the time window where the plasma is in LTE and optically thin.

Variation of Skin Depth

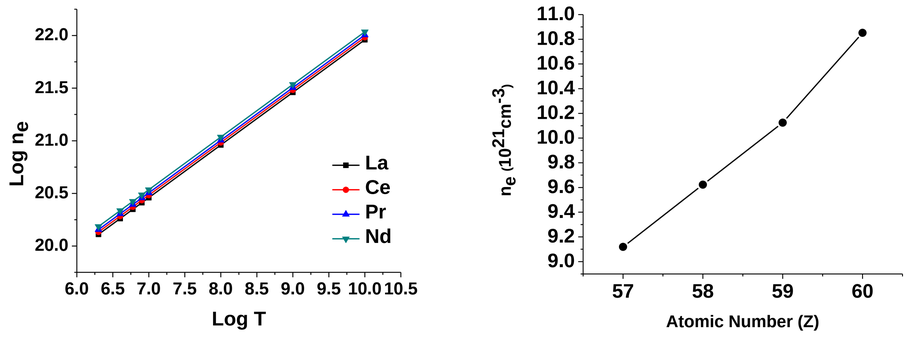


- Skin depth decreases very rapidly with plasma temperature.
- At low temperature, the skin depth of Al-like La is large as compared to other Al-like ions.
- As plasma temperature increases, the difference between skin depth of Al-like ions decreases.
- At 10^{10} K, skin depths for Al-like ions are very close to each other.
- Skin depth decreases very rapidly with nuclear charge for plasma temperature 10^{10} K.

Conclusion

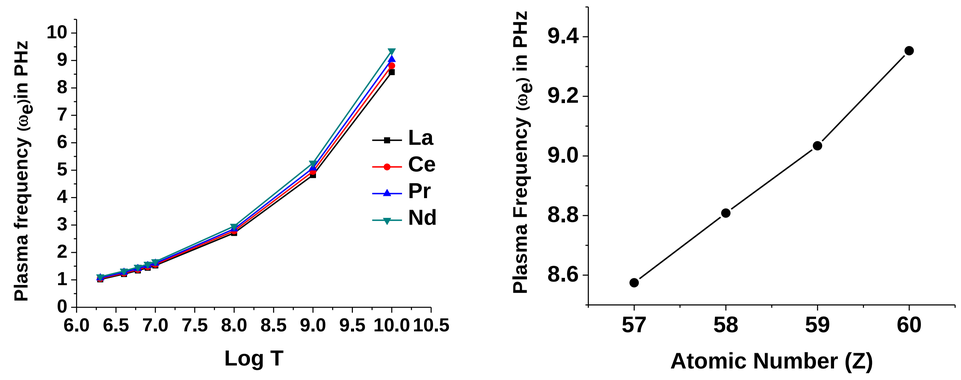
- Line intensity ratio and plasma parameters are important for the characterization of plasma in white dwarf and neutron stars. The plasma of Al-like ions are cold, dense and strongly coupled at higher temperatures.
- Behavior of line intensity ratio, electron density, skin depth and plasma frequency are investigated with plasma temperature and nuclear charge for Al-like ions.
- The work may be useful in the modeling and characterization of plasma and several applications related to fusion and astrophysical plasma, nano-plasmonic applications etc.

Variation of Electron Density



- Logarithmic value of electron density increases linearly with logarithmic value of plasma temperature.
- This shows that number of collision in plasma increase with plasma temperature.
- Electron density also increases very rapidly with nuclear charge at 10^{10} K .
- Coupling parameter is directly proportional to the cube root of electron density. So Coupling parameter will be greater than 1. Therefore, the plasma will be cold, dense and strongly coupled.

Variation of Plasma Frequency



- Plasma frequency increases expeditiously with plasma temperature.
- At low temperature, plasma frequency for Al-like lanthanide ions is very close.
- As plasma temperature increases, the difference between plasma frequency of Al-like ions increases.
- Plasma frequency increases very rapidly with nuclear charge for plasma temperature 10^{10} K.

Acknowledgement

- I would like to acknowledge U.G.C, India for financial in the form of fellowship. I am also thankful to Prof. Man Mohan for their guidance and valuable suggestions.

References

1. S.T.A. Kumar, D.J.D. Hartog, B. E. Chapman, et al., J. Plasma Phys. Control. Fusion 54, 012002 (2012).
2. D.M. Surmick, C. G. Parriger, J. Phys. B 48, 115701 (2015).
3. D. M. Surmick, C. G. Parriger, J. Phys. Conf. Ser. 548, 012046 (2014).