Transition Probability Measurement of Lanthanide Elements Using Laser Induced Breakdown Spectroscopy (LIBS)

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Atomic data, such as the transition probabilities of heavy elements, holds great importance in astrophysical studies. The analysis of optical emission, specifically Kilonovae following neutron star mergers, requires highly accurate and precise transition probabilities for the elements involved. According to previous studies, heavy metals, particularly lanthanides such as La and Ce, contribute the most to the emission [1]. The current databases, such as NIST ASD [2], are incomplete, particularly for heavy elements. Therefore, this work focuses on evaluating and measuring the transition probabilities of lanthanide elements using laser-induced breakdown spectroscopy (LIBS), which is an atomic emission spectroscopic technique based on optical emission from laser-generated plasma. The emission serves as a fingerprint for the elements present in the sample, with the wavelength of emission lines indicating their identity and the intensity representing the concentration of the elements [3].

The emission intensity can also be used for determining unreported transition probabilities by observing their transitions at the same time as the transitions with existing transition probabilities in the local thermal equilibrium condition [4, 5]. In this study, we present the transition probabilities for La II lines measured using the LIBS technique. This study not only exhibits the application of LIBS for measuring transition probabilities, but also indicates the collaboration of experimental methodologies and established databases. The technique fills gaps in our understanding of heavy element behavior in astrophysical processes.

[1] M. Tanaka et al., Astrophys. J. 852, 109 (2018).
[2] A. Kramida, Yu. Ralchenko, J. Reader, and NIST ASD Team (2022), NIST Atomic Spectra Database (ver. 5.10).
[3] David A. Cremers, and Leon J. Radziemski, Handbook of laser-induced breakdown spectroscopy, John Wiley & Sons, (2013).
[4] Aberkane, S. M. et al. Laser-induced breakdown spectroscopy for determination of spectral fundamental parameters. Appl. Sci. 10, (2020)
[5] Naoi, Y et al. Laser Induced Breakdown Spectroscopy of Er II for Transition Probability Measurements. Appl. Sci. (2022), 12, 2219.