# Spectroscopic Characteristics of Highly Charged Ions in the Water Window range

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The study of highly charged ions of heavy elements such as bismuth, lead and gold produced in laser-induced plasmas holds great promise for enhanced molecular microscopy. These ions are of significant interest due to the water window (23-44 Å) emission line spectra which are useful for in vivo molecular imaging. Development of collisional radiation models (CRMs) with detailed atomic processes of high charged ions are important to understand and predict emission line spectra from the highly charged ions in various plasma conditions. We have developed and used a CRM to analyse extreme ultraviolet (EUV) spectra of bismuth highly charged ions obtained by a compact electron beam ion trap (CoBIT) [1] at NIFS.

The current CRM incorporates collisional (de)excitation and ionization by a mono-energetic electron beam in CoBIT. Energy levels, collisional cross sections, and radiative decay rates for highly charged ions are calculated using the FAC [2] and HULLAC [3] codes.

As shown in Figure 1, the water window EUV spectra of $Bi^{19+}$ to $Bi^{24+}$ ions, measured by CoBIT, are analysed using current calculations. Emission lines series, such as 4f-7,6,5g (A, B, C) and 5s-7p(G), are identified in the experimental spectra, except for $Bi^{22+}$ (Pm-like) and $Bi^{23+}$ (Nd-like). The absence of distinct emission lines for these ions may be attributed to the presence of metastable states $4f^{13}5s^2$ and $4f^{13}5s$, respectively.

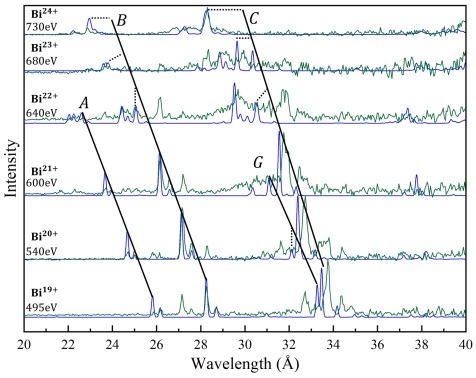


Fig 1. Isonuclear sequence emission line spectra of $Bi^{19+}$- $Bi^{25+}$ ions in CoBIT (red) and calculated spectra (blue) in the water window range.

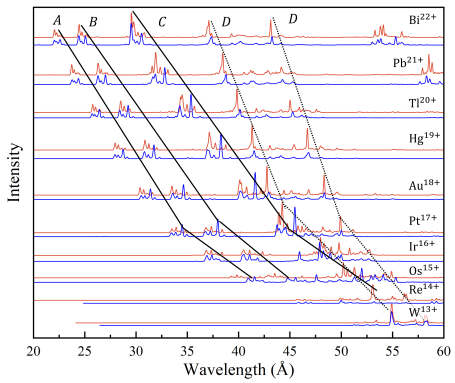


Fig 2. Calculated emission line spectra of the Pm-like isoelectronic sequence for elements of Z = 74 − 83.

The present CRM also calculated the emission lines for the Pm-like isoelectronic sequence of elements with atomic numbers Z=74-83 as shown in figure 2. Emission lines for transitions 4f-5,6,7g, 5s-7p, 4d-4f (D)are predicted to occur in the 20 – 60 Å range. It is observed that emission line spectra characteristics change at Z = 77 (Ir), where the ground state configuration shifts from $4f^{14}5s$ (Z > 77) to $4f^{13}5s^2$ (Z ≤ 77).

References

[1] N. Nakamura et al., Review of Scientific Instruments, 2008, 79(6): 063104.

[2] M. F. Gu, Canadian Journal of Physics, 2008, 86(5): 675-689.

[3] A. Bar-Shalom et al. 2001, 71(2-6): 169-188.