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Radiative rates for E1, E2, M1, and M2 transitions in S-like to F-like tungsten ions (W LIX to W LXVI)

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ABSTRACT

Calculations of energy levels, radiative rates and lifetimes are reported for eight ions of tungsten, i.e. S-like (W LIX) to F-like (W LXVI). A large number of levels have been considered for each ion and extensive configuration interaction has been included among a range of configurations. For the calculations, the general-purpose relativistic atomic structure package (GRASP) has been adopted, and radiative rates (as well as oscillator strengths and line strengths) are listed for all E1, E2, M1, and M2 transitions of the ions. Comparisons have been made with earlier available experimental and theoretical energies, although these are limited to only a few levels for most ions. Therefore for additional accuracy assessments, particularly for energy levels, analogous calculations have been performed with the flexible atomic code (FAC).

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Contents

1. Introduction

Tungsten (W) is one of the most important constituents of tokamak reactor walls [1]. Additionally, it radiates strongly over almost all ionisation stages. For example, the most intense emission lines of W ions [1] are from W XXII to W L in the VUV to the soft X-ray region, covering an electron temperature range from about 0.5 to 5.0 keV. Similarly, Pütterich et al. [1] have predicted emission features from W LXI to W LXIX in the 0.1–0.15 nm, 1.8–4.0 nm and around 8 nm ranges. However, to assess radiation loss and for modelling plasmas, atomic data (including energy levels and oscillator strengths or radiative decay rates) are required for many of the W ions. Their need for atomic data for several ions, including those of W, has increased significantly due to the developing ITER project. Therefore, several groups of people are actively engaged in producing atomic data.

Early calculations for a number of W ions (W XXXVIII to W XLVIII) were performed by Fournier [2]. He adopted a relativistic atomic structure code, but reported only limited results for energy levels and oscillator strengths (f-values). A thorough critical compilation of experimental, theoretical and analytical energy levels of W ions (W III through W LXXIV) has been undertaken by Kramida and Shirai [3] and has been further reviewed by Kramida [4]. These energy levels, along with some spectral lines, are also available on the NIST (National Institute of Standards and Technology) website at http://www.nist.gov/pml/data/asd.cfm. Recently, spectra in the EUV wavelength range (4–20 nm) have been measured by Ralchenko et al. [5], for a number of W ions, namely W LV to W LXIV. Similarly, Clementson et al. [6] have discussed spectroscopy of many W ions (W XLVII to W LXXII). On the other side, calculations have been performed for several W ions, such as by Quinet [7] for W XLVIII to W LXII. Although he adopted the GRASP code for the calculations, his reported results for energy levels and radiative rates (A-values) are confined to forbidden lines within the $3p^k$ and $3d^k$ configurations. However,