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Atomic data and spectral line intensities for Mg VI

E. Landi [a,*], A.K. Bhatia [b]

[a] ARTEP, Inc. at Naval Research Laboratory, Washington, DC 20375, USA
[b] NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA

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Abstract

Electron impact collision strengths, energy levels, oscillator strengths, and spontaneous radiative decay rates are calculated for Mg VI. The configurations used are $2s^22p^3$, $2s2p^4$, $2p^5$, $2s^22p^23s$, $2s^22p^23p$, and $2s^22p^23d$, giving rise to 72 fine-structure levels in intermediate coupling. Collision strengths are calculated at five incident energies, 12, 24, 36, 48, and 60 Ry. Excitation rate coefficients are calculated as a function of electron temperature by assuming a Maxwellian electron velocity distribution. Using the excitation rate coefficients and the radiative transition rates, statistical equilibrium equations for level populations are solved at electron densities covering the range of 10^8–10^{14} cm^{-3} at an electron temperature of $\log T_e(\mathrm{K}) = 5.6$, corresponding to maximum abundance of Mg VI. Relative and absolute spectral line intensities are calculated and compared with observations of a solar active region.
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* Corresponding author.
E-mail address: landi@poppeo.nrl.navy.mil (E. Landi).

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Contents

1. Introduction

Magnesium is one of the most abundant elements in the universe, its abundance being $\sim 2.7 \times 10^{-5}$ smaller than that of hydrogen. Magnesium ions emit a host of spectral lines that are commonly observed in solar and astrophysical plasmas in nearly all possible physical conditions. Nitrogen-like Mg (Mg^{5+} or Mg VI) is formed in plasmas at temperatures between 10^5 and 10^6 K, and its maximum ionic abundance occurs at around 4×10^5 K when the plasma is in ionization equilibrium [1]. Given their temperature of formation, Mg VI lines have been observed in solar transition region plasmas, both in quiet and active conditions [2,3]. Recently, the Coronal Diagnostic Spectrometer [4] and the SUMER instrument [5] on board the SOHO satellite have routinely observed Mg VI lines in the solar atmosphere at all conditions. Mg VI lines have recently been identified also in the spectrum of the symbiotic stars AG Dra and RR Tel from Hubble/STIS observations [6].

Mg VI lines are found in all spectral ranges from the soft X-ray at around 120 Å, to the extreme ultraviolet (at around 270 and 350 Å), and in the ultraviolet between 1300 and 3000 Å. Soft X-ray lines are due to allowed $n = 3 \rightarrow n = 2$ transitions, EUV lines come from allowed $n = 2 \rightarrow n = 2$ transitions, and UV lines come from forbidden transitions within the ground configuration. Mg VI lines can be used for density diagnostics using ratios from allowed $n = 2$ lines, and temperature diagnostics from ratios between lines emitted by configurations with different principal quantum number n. They have been used to study the solar atmosphere in a number of instances [7–9].

As we have noted, Mg VI is formed at around 4×10^5 K, a temperature very similar to the temperature of formation of Ne VI. This makes it possible to study the Mg–Ne relative abundance, and indeed this ratio has been used in a variety of studies of the abundances in the solar upper atmosphere ([10,11] and references therein). The possibility of directly comparing Mg and Ne abundances is of great importance, since these two elements have very different first ionization potentials (FIP): the Ne FIP is 21.6 eV and the Mg FIP is 7.6 eV. In the Sun, abundance anomalies between the photosphere and the corona have been found, in the sense that the relative abundance of elements with low FIP (FIP $\leqslant$ 10 eV) to those with high FIP (FIP $\geqslant$ 10 eV) is higher in the corona than in the photosphere. No theoretical model has yet been able to explain this phenomenon. Mg VI/Ne VI constitute an excellent ion pair to investigate the "FIP effect," also because some of the strongest lines in the spectra of these two ions fall between 399 and 404 Å and have been observed by high-resolution spectrometers ([12,2,13] and references therein).

Recently, Bhatia and Young [13], Ramsbottom and Bell [14], and Zhang and Sampson [15] have calculated complete sets of atomic data and transition rates for the lowest configurations of Mg VI. The latter has considered only the lowest three configurations (the $n = 2$ complex), while Bhatia and Young [13] and Ramsbottom and Bell [14] also included in their atomic model the $2s^22p^23s$ configuration, for eight additional fine-structure levels. However, the omission of

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