LINE-BROADENING AND SHIFT RATES OF ALKALI-METAL VAPOR PERTURBED BY NOBLE GAS ATOMS

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The measurement and theory of the perturbation of radiation emitted or absorbed by an alkali-metal atom in the presence of a partial pressure of noble gas atoms has important applications both for precision-frequency microwave and optical sources needed for quantum sensing, and for the study of conditions in stellar atmospheres for certain types of white and brown dwarf stars, and exoplanets. Variation in the pressure and temperature of the ambient conditions prescribes the relevant theoretical model of atomic collisions for describing the effect on the emission profiles or absorption profiles of the alkali-metal atom's resonance lines. Under low pressures of perturbing noble gas atoms, below 1bar, and at temperatures not far from room temperature, e.g. the conditions in alkali-metal vapor cells used as frequency standards, atomic collisions cause broadening and frequency shift of the resonance lines. In contrast, for a noble gas such as helium at pressures of hundreds of bars, and at temperatures of several thousand Kelvin, the shape of the spectral line wings are substantially modified. We report quantum scattering calculations, using ab initio interatomic potentials for the interaction of the alkali-metal + noble gas atom, to obtain the temperature-dependence of the line broadening and shift rates for the sodium D1 and D2 resonance lines in the presence of helium (Na-He), and for the Rb D2 line in the presence of argon (Rb-Ar). We also compute the high-pressure, high-temperature Na-He D2 resonance line shape, far into the wings, using a unified semi-classical theory, for comparison with observed spectral features from astrophysical sources.

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