

CHEMICAL PROCESSES IN EXOPLANET ATMOSPHERES Channon Visscher, Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, Colorado, 80302 (visscher@boulder.swri.edu)

Observations of an increasing number of transiting exoplanets (over 200 confirmed candidates as of April 2012) provide means to infer planetary properties such as orbital eccentricity, inclination, mass, and radius (and thus density, which in turn provides clues about bulk composition). In addition, spectral and photometric observations at primary transit and secondary eclipse, and of planetary phase variations throughout the orbit, are providing increasingly powerful ways to characterize the chemical composition and opacity sources in exoplanet atmospheres [e.g., see 1, for review]. Despite these advances, the underlying physical and chemical processes giving rise to observational properties remain incompletely understood. Theoretical models are therefore needed to interpret observations of exoplanet atmospheres. Moreover, the increasing availability and quality of spectral and photometric observations provide improving constraints for the chemical models.

Equilibrium models give a good first-order approximation of chemical speciation in the atmospheres of giant planets, which are cool enough for the formation of molecules yet warm enough for sufficiently rapid reaction kinetics [3, 4, 8]. However, planetary atmospheres are also subject to processes which lead to departures from thermochemical equilibrium, including UV-driven photochemistry and/or rapid atmospheric transport (quenching). We recently developed a photochemical and thermochemical kinetics and diffusion code [6, 7, 9, 10] to explore the transition between each chemical regime (thermochemical, photochemical, quench). Our results for H-C-N-O chemistry can be used to help explain observations of H₂O, CO, CO₂ and CH₄, and to examine sensitivity to atmospheric mixing rates, orbital and diurnal effects, and elemental abundance variations (in particular the C/O ratio), paying particular attention to disequilibrium species (e.g., CH₄, NH₃, HCN, C₂H₂) which affect the spectral and photometric behavior of extrasolar planets.

In addition to mixing and photochemical effects, condensate formation (assumed to follow equilibrium in our chemical models) is also expected to play an important role. Clouds can remove absorbers from the gas phase, obscure absorption features from gases at deeper levels, scatter incoming radiation, and add their own absorption features [e.g., see 5, for review]. The condensation curves of a number of potentially important cloud-forming species are shown in Figure 1.

Although our models are specifically developed for hydrogen-rich objects (e.g. Jupiter, Saturn, brown dwarfs, and extrasolar giant planets), the chemical processes that we explore play a general role in the atmospheres of low-mass (including terrestrial) planets (e.g., chemical equilibrium and reaction kinetics of surface-atmosphere interactions). We will discuss how the major chemical processes – thermochemistry (including condensation), quench chemistry, and photochemistry – shape the observational properties of extrasolar planets.

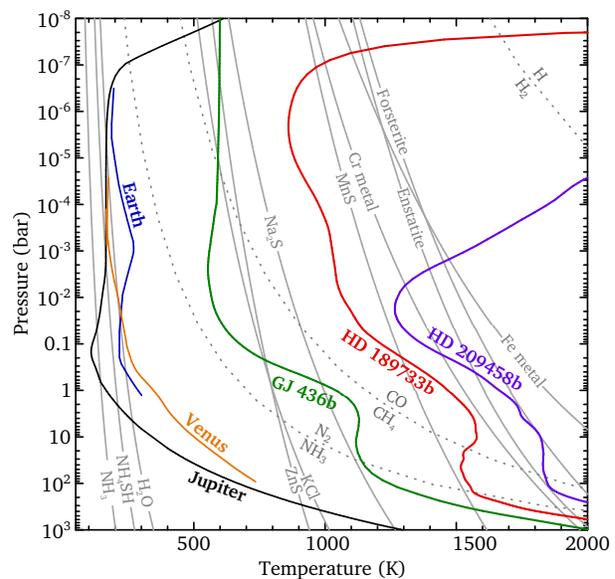


Figure 1: Representative P - T profiles with major gas-phase (dashed gray lines) and condensate chemistry (solid gray lines) in a solar-composition gas [2]. Earth and Venus profiles (from 0 to 100 km) are shown for comparison of P - T conditions.

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