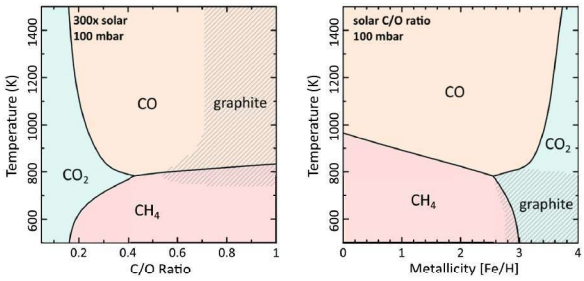
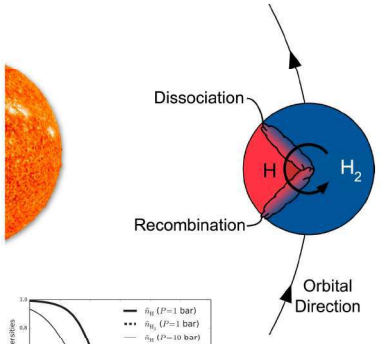
Graphite formation: precursor to hazes?

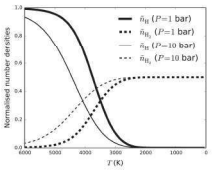


May prevent C/O from becoming $\gg 1$

Moses et al. (2013, ApJ, 777, 34)

Yet another exoplanet example: ultra-hot Jupiters





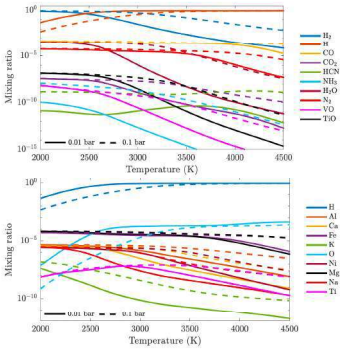
These strange objects have:

Dayside chemistry resembling a star

Nightside chemistry resembling a planet

Bell & Cowan (2018, ApJL, 857, L20)

Yet another exoplanet example: ultra-hot Jupiters



Equilibrium chemistry calculations predict:

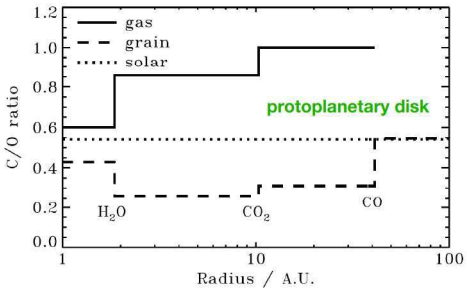
1. CO and H_2O to be the most abundant molecules
2. Metals to be in their atomic or ionic form (not locked up in molecules or minerals)
3. H^- to be dominant enough that it is the main source of the spectral continuum

At these high temperatures, UHJs are expected to be cloud-free and have atmospheres close to chemical equilibrium.

Therefore, UHJs are chemically simple objects.

Kitzmann et al. (2018, ApJ, 863, 183)

Formation history from chemical abundances?



Key idea: carbon to oxygen ratio traces formation location

Caveats: pollution of envelope, pebble accretion, migration

Oberg et al. (2011, ApJL, 743, L16)

Goals of the current lecture

- Introduction to basic quantities (essentially thermodynamics).
- Equilibrium chemistry versus chemical kinetics
- Hierarchy of equilibrium chemical systems (as coupled systems of polynomial equations)
- Quenching approximation (of disequilibrium chemistry)
- Equations of chemical kinetics
- Why the Line et al. (2014) inference of CO_2/CO abundance ratio is actually chemically impossible

Basics of atmospheric chemistry

forward reaction

$$a_1 X_1 + a_2 X_2 \leftrightarrows b_1 Z_1 + b_2 Z_2$$

X_1 and X_2: reactants Z_1 and Z_2: products

reverse reaction

a_i and b_i: **stoichiometric coefficients**

Stoichiometry:
e.g. one needs 1 carbon atom and 4 hydrogen atoms to form one molecule of methane (CH_4)