

Exploring Disk Chemistry: The Role of C/O Ratios in Planetary Formation

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Rocky exoplanets are expected to exhibit compositions that differ substantially from those formed in solar-like protoplanetary disks, particularly in systems with elevated carbon-to-oxygen (C/O) ratios. Conventional models, which assume a tripartite interior structure of silicates, metals, and volatiles, often overlook diverse mineralogical phases that could emerge under non-solar conditions [1, 2]. This study examines the influence of variations in disk chemistry on planetary building blocks, focusing on environments with $C/O > 0.8$.

From a stellar abundance dataset of FGK-dwarfs obtained through uniform spectroscopic analysis [3], we utilize stars with $C/O > 0.8$ as proxies for reduced disk compositions. For the system Al-Ca-Ti-Fe-Cr-Ni-Si-Mg-Na-S-C-N, we perform equilibrium condensation calculations at 10^{-4} bar and temperatures of 1900–400 K in FactSage software, incorporating solid solutions and reduced species often overlooked in previous studies. Furthermore, we apply a Gaussian feeding-zone model with the mean temperature, T_0 , and standard deviation, σ , treated as free parameters to simulate planetary bulk compositions [4].

Our results reveal distinct condensation sequences that vary with C/O ratios. For C/O up to ~ 0.8 , little deviation from the canonical solar condensation sequence is observed, consistent with prior studies [2, 5]. Transitional sequences (C/O between 0.8–0.91) show similarities to solar-like systems but also condense (Ca,Mg)S, graphite, and Fe_xSi , delaying silicate and oxide condensation. At $C/O > 0.91$, reduced sequences dominate, with carbides, sulfides, and graphite as primary high-temperature condensates, reducing silicate and oxide fractions. These deviations are most pronounced above 700 K, with gas-phase reactions below this temperature yielding comparable oxygen fugacities (fO_2) independent of C/O. Planets formed from high C/O disks exhibit higher Fe and lower O and Mg abundances. Additionally, C and N partially condense at high T_0 , contrasting with their absence in solar-like disks above 400 K. We anticipate O-poor, C- and N-bearing planets to be hallmarks of high C/O disk condensation.

References:

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