EPSC Abstracts
Vol. 9, EPSC2014-733, 2014
European Planetary Science Congress 2014

Planetary Rock Compositions for Four Stellar Nebulae

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1. Introduction

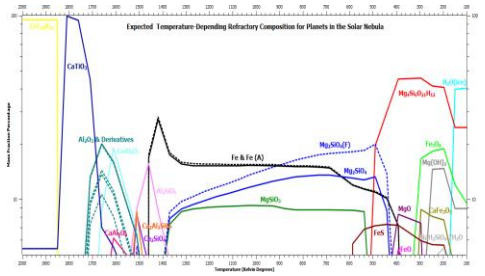
Chemical compositions of stars are known to exhibit significant variations from the Sun [1,2], thus the planets in other systems are also expected to differ chemically from the ones in the Solar System. Till now only a few terrestrial planet simulation studies have taken chemical composition of planets into consideration, yet with very limited variety [3]. Here are investigated what types of refractory bulk compositions could be expected for possible extrasolar and solar planets based on the chemistry of their parent stars and nebular temperature, although not applicable on close-in or solar gas giants.

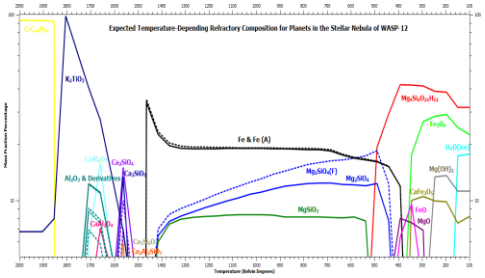
2. Methodology

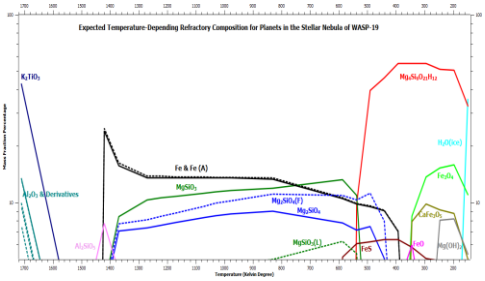
Disk compositions are assumed to correspond to that of the parent star, along with that disk elemental abundances represent the protostellar values [4]. Silicate and metal compounds formed in the disks are calculated with the HSC Chemistry software which computes the abundances of solid phases at equilibrium for given gas temperature and pressure. This treatment for the refractory species holds some similarities to the studies of [5] and [6], and equilibrium condensation assumption is already satisfied by various analyses of early chondritic meteorites [3, 6, 7, 8].

Four host stars are chosen as case studies due to availability of chemical composition data, even partially: the Sun, WASP-12, WASP-19, and XO-1. These three stars are G-type dwarfs like the Sun, yet more importantly, they are known to harbour close hot-Jupiters revolving about them.

3. Figures







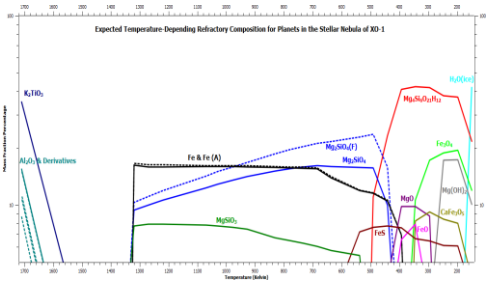


Figure 1: The leading species of expected refractory composition in the Nebulae of the Sun, WASP-12, WASP-19 and XO-1 respectively, on the basis of temperature. Dashed lines stand for derivative molecular combinations of species with curve of the same colour.

4. Results and Discussion

4.1. Magnesium-Bearing Species

The most dominant magnesium refractory compound in the disks of four case stars is $Mg_4Si_6O_{21}H_{12}$ (sepiolite). Being a magnesium silicate and a clay mineral, sepiolite appears to be the species with maximum contribution of crustal structures formed under the temperatures up to ~500 K. Where sepiolite begins decreasing, magnesium incorporates into another silicate compound, Mg_2SiO_4, which emerges above ~400 K. Mg_2SiO_4 forms reach their peaks around ~500 K, and show a smooth decrease with temperature till perishing at ~1400K. Apart from MgO, magnesium tends to always combine with silicon, and apart from distene ($Al_2O_3.SiO_2$), silicon tends to always combine with magnesium. So when the both are found together, they form various magnesium-silicate compounds, which are the fundamental contributors for rocky planets.

4.2. Iron-Bearing Species

The only iron-bearing species is magnetite (Fe_3O_4) at temperatures below ~350K, constantly falling from ~15% (~25% in WASP-12 case) of overall mass percentage. With higher temperatures magnetite loses its oxygen, and free iron dominates along its alpha-delta isotope. In regions hotter than ~1350 K, irons throw a peak almost doubling the percentage, and experience a dramatic decrease afterwards. The other iron species in the scene is pyrrhotite (FeS; iron 0.877-sulfide) in three cases but WASP-12. It takes 5-6% of overall rocky compounds in the temperature range of up to ~600 K. Lastly wuestite (FeO), known also as iron II oxide, is produced with a peak around ~350 K between 5-10% of total mass in three cases except the Sun.

4.3. Calcium-Bearing Species

The only calcium carrying species in cold zones is calcium triiron pentaoxide ($CaFe_3O_5$) which appears in regions colder than ~350 K with ~10% of contribution. In the interval of 1750-1500 Kelvin variations of calcium oxides combined with aluminium and silicates appear like $CaAl_4O_7$, Ca_2SiO_4, $Ca_2Al_2SiO_7$, Ca_3SiO_7 and Ca_3SiO_5.

4.4. Aluminium-Bearing Species

Aluminium oxide is observed in various forms of Al_2O_3. They can combine with calcium to form $CaAl_2O_7$, $CaAl_2O_4$ or disthene ($Ca_2Al_2SiO_7$) in the temperature range of 1750-1500 Kelvin.

Calcium and aluminium are observed only in hot zones for a short range of nearly 200 Kelvin, excluding $CaFe_3O_5$. Down to 1750 Kelvin, rocky parts of disks are dominated only by $CrC_{24}H_{36}$ and K_2TiO_3/$CaTiO_3$.

Although the order of abundances might change in each case, and a few species might appear and disappear in some of the disks as well, the general behaviours of species are quite similar for all the stars. Direct measurement data of elements have been available only for the Sun and WASP-12, but they do not radically differ from each other. Close abundances of elements result in alike nebular refractory distributions for all cases.

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