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Thermodynamic simulation of an experimental condensation sequence at high C/O ratio

MARWANE MOKHTARI[1], LAURENT FULCHERI[2], VANDAD-JULIEN ROHANI[2], FRANÇOIS CAUNEAU[2], BERNARD BOURDON[3] AND GUY LIBOUREL[4]

[1]LGL-TPE
[2]Mines ParisTech-PERSEE
[3]LGLTPE, CNRS
[4]Observatoire de la Côte d'Azur
Presenting Author: marwane.mokhtari@ens-lyon.fr

Most of the condensation studies are based on the theoretical calculations of equilibrium conditions during the cooling of a gas of solar composition [1, 2]. So far, the validity of this approach was assessed by comparing model results with the composition of chondrites [3]. Here, we investigate the experimental condensation of a chondritic gas in a large volume plasma torch at atmospheric pressure (PERSEE/Lagrange). A grounded ordinary chondrite was injected in a plasma formed between three graphite electrodes, which led to a C/O ratio close to 1 in the chondritic gas. In such conditions, the first phases to condense are reduced C-rich grains [4]. This experiment produced condensates on a graphite substrate with variable compositions along a thermal gradient below the plasma.

Using thermodynamic calculations in equilibrium conditions at fixed T and P, we have reproduced the observed condensed phases including graphite, FeSi, etc... The computed mineralogical sequence was in excellent agreement with the observations. Furthermore, this experiment allows us to quantify the kinetics effects taking place during condensation. To explain the observed chemical pattern, the vapor must remain oversaturated during its path, implying a kinetic delay and preventing total equilibrium conditions to occur during condensation.

These results are in good agreement with the previous numerical studies that considered thermodynamic equilibrium during condensation at high C/O ratio. The nature and compositions of the different phases are of crucial interest to understand element behaviour, including trace elements, during condensation in C-rich systems (AGB S-stars). The condensation led to a sizeable amount of phases found in reduced environments such as those leading to enstatite chondrites and presolar grains formation: SiC, FeSi and CaS. This opens new perspectives for understand the behavior of major and trace elements in carbon-rich astrophysical settings.

References:

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