Experimental determination of volatile evolution and recovery from carbonaceous asteroid simulants

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Abstract

It has been shown that water and other useful volatiles can be produced from hydrated and hydroxylated mineral phases in carbonaceous meteorites by vacuum pyrolysis [1], this has made carbonaceous asteroid bodies on which similar phases exist attractive as potential raw materials for volatile production to support human space exploration. For this study, we have built an experimental laboratory vacuum system designed to test the technical validity of radiatively heating bulk volatile-rich minerals while recovering evolved gases as ice to enable effective Asteroid ISRU. A furnace sitting within the main vacuum chamber supplies heat which is applied in stepped ramps and holds; initially from ambient to 300 ^{0}C and subsequently in 100 ^{0}C steps to a max of 700 ^{0}C. A quadrupole mass spectrometer (Stanford Research Systems RGA200) scanning from 1 to 200 amu characterizes the composition of the changing atmosphere as gases are produced by the sample and simultaneously captured by a Liquid Nitrogen cold trap operating at -196 ^{0}C and under vacuum. K-type thermocouples placed at specific locations within the sample mass yield information on the nature and progress of heat and mass transfer. Preliminary results show that H_2O and CO_2 are the major gas species produced from basic serpentine minerals which have Lizardite with an average composition of $Mg_3Si_2O_5(OH)_4$ as the major phase, significant dehydroxylation starts at the 500 ^{0}C plateau with the rate limited by heat and mass transfer through the sample, the cryotrap has proved capable of freezing H_2O, CO_2, SO_2 and CH_4 out of the atmosphere at varying efficiencies. Measures of volatile recovery can be estimated from partial pressure readings obtained from the Mass Spectrometer and also from the change in sample mass after a test run compared to the mass of ice recovered.

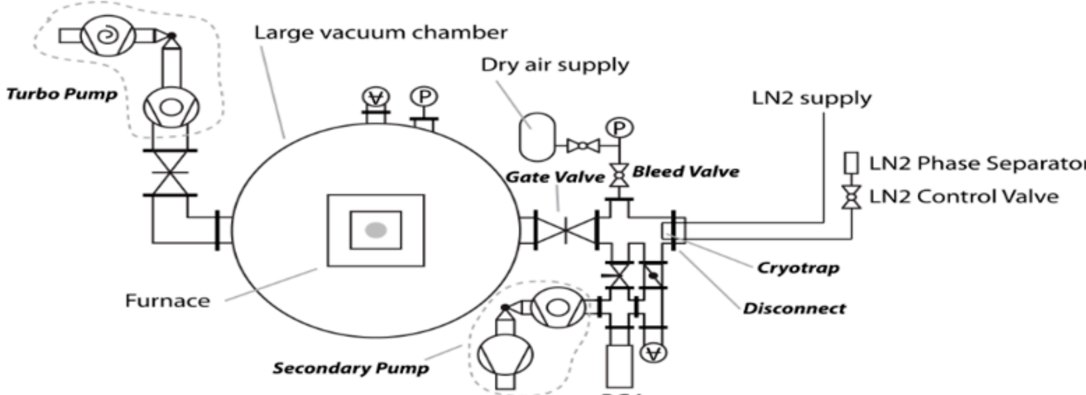

Figure 1. Schematic showing Laboratory Vacuum System setup

[1] ten Kate, I. L., et al. (2010). "VAPoR—Volatile analysis by pyrolysis of regolith—An instrument for in situ detection of water, noble gases, and organics on the Moon." *Planet. Space Sci*., 58(7-8), 1007-1017