ORGANICS ON FE-SILICATE GRAINS: POTENTIAL MIMICRY OF METEORITIC PROCESSES?

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Introduction: Currently, it is unknown what exact process or combination of processes produced organics that are found in meteorites or are detected in comets and nebulas. One particular process that forms organics involves Fischer-Tropsch type (FTT) reactions.

Fischer-Tropsch type reactions produce hydrocarbons by hydrogenating carbon monoxide via catalytic reactions. The overall reaction is represented by

$$nCO + (2n + 1)H_2 + \text{catalyst} \rightarrow C_nH_{2n+2} + nH_2O + \text{catalyst}.$$

The products of these reactions have been studied using 'natural' catalysts [1] and calculations of the efficiency of FTT synthesis in the Solar Nebula suggest that these types of reactions could make significant contributions to the composition of material near three AU [2]. We use FTT synthesis to coat amorphous Fe-silicate grains [3] with organic material to simulate the chemistry in the early Solar Nebula. We used lab-synthesized amorphous Fe-silicate grains for the catalyst because they might better simulate the starting materials found in protostellar nebulas. A brief description of the synthesis of these grains is given in §Experiments.

This work is different from previous studies because we focus here on the carbonaceous material deposited on the grains. In our experiments, we roughly simulate a model of the nebular environment where grains are successively transported from hot to cold regions of the nebula. In other words, the starting gases and FTT products are continuously circulated through the grains at high temperature with intervals of cooling. Overall, organics generated in this manner could represent the carbonaceous material incorporated into comets and meteorites. We present the analyses of the organics produced using pyrolysis gas chromatography mass spectrometry (GCMS) and compare the results with those organics found in the Murchison meteorite.

Experiments: We circulate CO, N_2, and H_2 gas through amorphous Fe-silicate grains that are maintained at 500°C (see Fig. 1). The grain catalyst was synthesized in the lab by combusting silane (SiH_4) in the presence of iron pentacarbonyl ($Fe(CO)_5$) at 500°C with pure molecular oxygen in a flowing stream dominated by hydrogen. Helium is bubbled through $Fe(CO)_5$ resulting in an Fe-silicate smoke with grains that have a radius of about twenty to thirty nanometers. These grains are then transferred to the FTT reaction system (Fig. 1).

The FTT gases required for the reaction are passed through the heated grains and then through an FTIR spectrometer to monitor the reaction progress. We track water, methane, carbon dioxide, and carbon monoxide. Each cycle begins with 75 torr N_2, 75 torr CO, and 550 torr H_2 before the grains are brought to 500°C. After the gas has circulated for a predetermined amount of time, the heating element is turned off and the gas is pumped away. We repeat this process twenty to forty times. The catalyzed grains were analyzed two different ways. In one case they were sequentially extracted, derivitized with BSTFA and analyzed using GCMS. In the other the reaction products were analyzed via pyrolysis GCMS, with a heating rate of 500 °C/s , T_{max} = 610 °C.

Analyses: Extractions were made on the catalyzed sample using water, methanol, and a combination of benzene and methanol. None of these extractions showed any carbonaceous material. However, pyrolysis was a completely different matter. Pyrolysis of the catalyzed material did not initially give a lot of information so the material was demineralized in order to extract and concentrate the organic matter. We used a demineralization process that is also used for meteorites. It was only after the samples were

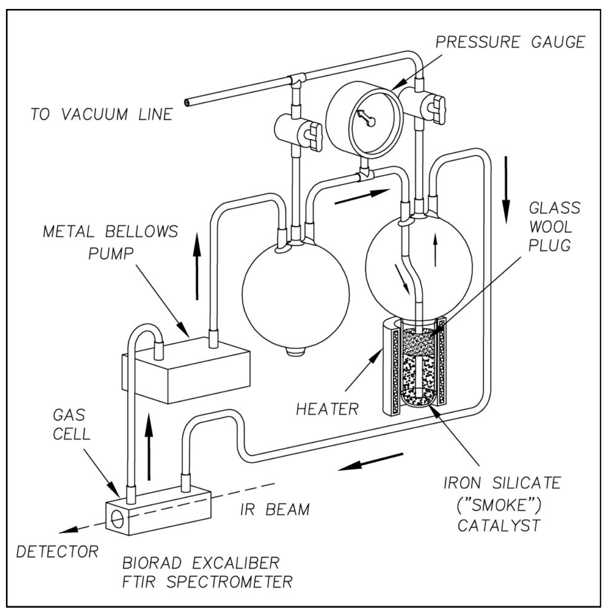

Fig. 1. FTT reaction system

demineralized that we determined that we produced something that is similar to that which is found in meteorites. We identified the following classes of compounds: saturated and unsaturated hydrocarbons, alkyl-benzenes, phenols, styrenes, and traces of poly-cyclic aromatic hydrocarbons.

Note on pyrolysis: Pyrolysis is a forensic analytical method. Pyrolysis literally ‘blasts’ apart the original compound and as the gases recombine during the analysis we end up with a fingerprint of what was originally there. This analysis is commonly used to determine the organic content of meteorites. Unfortunately there is no definitive signature for meteoritic organics. In order to determine whether organic material is similar to what is found in meteoritic organics, it is necessary to compare classes of compounds and distribution of these compounds to those found in meteorites.

Discussion: We compared our results to organics identified in the Murchison meteorite (also demineralized and analyzed by pyrolysis GCMS). Murchison is a good starting point because it has been well studied. While our samples show similarities with the Murchison sample there are also differences. The compounds of classes mentioned earlier have been identified in Murchison but not necessarily in the same amounts. Note that if we produced organic compounds as predicted by FTT reactions, we might expect to only see aliphatic (chain) hydrocarbons. While we did produce more aliphatics than what is found in Murchison, we also produced aromatic (ring) compounds, which is promising in that there is an array of aromatics in meteorites [4]. The figures below show a couple ‘pyrograms’ for comparison between our sample and Murchison.

Summary: So what does all of this tell us? The reactions clearly synthesize macromolecular (solvent insoluble) organic phases that when pyrolyzed bear similarity to insoluble organic fractions of Murchison. While this does not prove that such reactions are the source of meteoritic organic matter; it does provide support for the viability of the hypothesis underlying these experiments. These grains can now potentially serve as the first step to the next set of experiments to see what other secondary processes may have effected meteoritic organics.

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