Volatile Molecules Produced From Carbides of Iron, Calcium, and Manganese By Laser Pulse

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Studies of the abiogenic synthesis of organic molecules have been performed by laser microprobe/mass spectrometer analyses of carbides. The laser beam interaction with a target produces a plasma plume which is used to simulate the melting and evaporation processes of planetesimal matter caused by high-speed impact (1), and also the high heats and energies associated with the early solar nebula. A plasma plume, produced by laser pulse, contains ionized species, neutral species, and free radicals which may result in the formation of recombination and polymerization biproducts. The gases collected from presellected areas of carbides are extracted and analyzed for volatiles such as O, OH, H2O, C, C2H2, CO, O2, CO2, and hydrocarbons like CH4, C2H6, C3H8, C4H10, etc.

Iron carbide (Fe3C), calcium carbide (CaC2), and manganese carbide (Mn2C-Mn3C2) were mounted separately on aluminum disks, using torr seal (a low vapor pressure adhesive) and analyzed with the laser microprobe/mass spectrometer. Elemental abundances of H were determined by gas chromatography for the Fe3C and Mn2C-Mn3C2 samples and an elemental abundance for N in Fe3C were determined by similar methods. This was done to determine if enough H was present in the system to account for all the hydrocarbons formed by laser interaction and to know how much N remained in the iron carbide. The values of H in µg/g (error ± 2%) for Fe3C and Mn2C-Mn3C2 are 132.2 and 1224.7, respectively and the analysis of N for Fe3C ranged from 2.2 - 9.0 µg/g. Fe3C was synthesized from Fe3N and CO and produces molecules such as C, N, O, H2O, CO (C2H4), CO2 and hydrocarbons C1 to C3 groups when subjected to the laser pulse (Fig. 1). Because CaC2 or Mn3C-Mn3C2 are not formed by reactions with N an elemental analysis of N was not done and since CaC2 was made from acetylene and is expected to contain plenty of H, an analysis of H was not performed. CaC2 is formed by reacting CaO and acetylene and Mn2C-Mn3C2 is formed by reacting Mn and C. The gases detected from CaC2 and Mn2C-Mn3C2 after laser interaction contain molecules of C, O, H2O, CO (C2H4), C2H2, CO2 and hydrocarbons C1 to C8 from CaC2 (Fig. 2) and C1 to C8 from Mn2C-Mn3C2 (Fig. 3). The most prominent species produced in all analyses is m/z 28 corresponding to CO plus H2C=CH2 followed by a lesser abundance of hydrocarbons C2 to C8 and for the aromatic species m/z=78 and 91. In situ analysis of volatile elements and molecules in carbonaceous chondrites using identical techniques produced similar fragmentation patterns (2). The major volatiles are C, O, OH, H2O, C2H2, CO (C2H4), CO2, O2, H2S, COS, SO2, CS2, hydrocarbons ranging from C1 to C8, and aromatic hydrocarbons such as benzene and toluene.

The hydrocarbons produced by laser interaction with Fe3C, CaC2, and Mn2C-Mn3C2 are most likely due to the recombination and polymerization of free radicals and ionized species found in the plasma plume. Other analyses (3) have shown that through recombination and polymerization, hydrocarbons are generated from methane at high-temperature. The major components (benzene, naphthalene, acenaphthylene, phenanthrene, fluoranthene, and pyrene) are identified in a flow system by passing methane through silica gel at 1000°C. The results show that 97 percent of the total weight of the analyzed arenes have even number of carbon atoms and since C2 species are more stable at high temperatures than C1 species, the products formed will have an empirical carbon-skeleton of (C2)n. This data is analogous to the results obtained in our laser pulse experiments in that a recombination process are most likely occurring and the most abundant species are in the C2 group (C2H2, C2H4). Polycyclic Aromatic Hydrocarbons (PAH) have been identified in the Allende meteorite probed with two-step laser desorption/laser multiphoton ionization mass spectrometry (4) and in the Murchison meteorite by gas chromatography - mass spectrometry (5). It is interesting to see that some of the fragments detected in Allende (e.g. m/z=119) are also found in the mass spectra of the three carbides. Another analysis using laser pulse was done to collect gases on various ultra-mafic rocks and meteorites and then compared to impact vaporization gases (1). The residual gas mixture desorbed from such samples are composed of CO, CO2, H2O, O2, H2, N2, H2S, COS, CS2, hydrocarbons, mostly unsaturated, C1 to C8, HCN, and CH3CHO. Based on these results, it was suggested that the hydrocarbons were formed inside a hot and dense vapor cloud and not by pyrolysis of organic matter already present in the sample. Furthermore, since the gas mixture contained saturated, unsaturated and aromatic hydrocarbons, and precursors of organic matter, the possibility exists for enhanced abiogenic synthesis.

Hydrocarbons desorbed from Fe3C, CaC2, and Mn2C-Mn3C2 can participate in an abiogenic synthesis and in the presence of ammonia, dilute acid, and hydrogen cyanide are capable of forming amino acids or its precursors. Carbides treated with acid form hydrocarbons very similar to those seen during the laser interaction study. The hydrocarbons, C1 to C8, detected in the gas mixture produced by laser interaction with Fe3C are similar to the hydrocarbons, C3 to C7, identified from the reaction of Fe3C with deuterium labeled hydrochloric acid (DCl) (6). The hydrogenolysis of CaC2 and Mn3C-Mn3C2 with DCl is in progress and the hydrocarbons, if present, will be compared in the future to the hydrocarbons detected in gas mixtures produced by laser interaction with CaC2 and Mn3C-Mn3C2.

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