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Experimental determination of siderite stability and application to Martian Meteorite ALH84001

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ABSTRACT

The pressure-temperature equilibrium curve of the reaction siderite + hematite = magnetite + CO_2 was determined in the range 5–12 kbar and 480–650 °C by piston-cylinder experiments, with NaCl as a pressure medium. Silver oxalate was used as a CO_2 source and samples were buffered at hematite-magnetite oxygen fugacity. Reaction progress was monitored by extent of CO_2 gas loss and by X-ray diffraction (XRD) analysis.

The data define a univariant curve, which is described by $P = -14.599 + 0.025T + 0.000027\,T^2$ with P in kbar and T in °C. Calculations based on these data give ΔH^0_f (298K) siderite = –760.6 ± 0.9 kJ (kilojoules) from the oxides. The formation of siderite requires a specific range of ambient oxygen and carbon dioxide fugacities, dependent upon temperature and pressure. The stable assemblage of siderite and magnetite, at a given temperature and pressure, implies more restrictive ranges of oxygen and carbon dioxide fugacities, defined by reactions among siderite, magnetite, graphite, and hematite. Experimental and thermodynamic investigation of the Fe-C-O system indicates that the formation of magnetite along with Ca-Fe-Mg carbonate globules by inorganic processes is possible and may be relevant to Martian meteorite ALH84001. Decarbonation of the siderite component of the carbonate, either by a transient heating event or by a change in oxygen fugacity of a coexisting fluid, may have formed the observed grains, although this study does not address the size or morphology of magnetite grains formed by this mechanism.