MARS, A CARBON RICH PLANET?—BEHAVIOR OF H AND C DURING EARLY CORE FORMATION—; Kiyoshi Kuramoto and Takafumi Matsui, Department of Earth and Planetary Physics, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan.

In this paper we try to estimate initial abundance and chemical forms of H- and C-bearing species in proto-atmosphere and -mantle of Mars. Fe rich core is a potential reservoir of the accreted H and C [1,2]. Several lines of evidence suggest that the martian core was formed during or just after the accretion [3]. It is likely that impacts of large planetesimals induce widespread (but not global) melting of proto-Mars and trigger segregation of metal [4]. Analysis of SNC meteorites suggests that building stones of Mars contain a significant amount of volatiles including H and C [5]. When a planetesimal size is large enough to generate a molten region (magma pond) at impact, a substantial portion of H and C contained in the planetesimal is expected to be buried in a magma pond. Of course some portion is subjected to an impact-induced degassing [6]. A portion of buried H and C may be partitioned to metallic iron and eventually transported to a planetary core. One of the factors controlling this process is the solubility of H and C in liquid form of metallic iron. On the other hand, the composition of degassed gas species depends on oxygen fugacity, which is controlled by the redox reaction with metallic iron and silicate. This can be evaluated using a thermodynamic model based on experimental data. Accreted amount of H and C as well as S-content in the core are important for this issue. We estimated them according to the two component model by Dreibus and Wänke [5].

C as much as approximately 5 wt% dissolves in liquid metallic iron at 1 bar and 1873K [8]. Because volume change with dissolution is small, its solubility does not change significantly even at high pressures at least $\sim$ 10GPa. Incorporation of S in liquid metallic iron substantially decreases the C solubility [8]. Since the martian core may contain $\sim$14 wt% of S [5], the saturated C content is estimated to be as low as 2$\sim$3 wt%, which is slightly dependent on temperature and pressure (Fig. 1). On the other hand, the accreted C content is estimated to be 6.2 wt% relative to the core mass. This suggests that more than half of the accreted C remain in the proto-atmosphere or mantle mainly as CO gas or graphite just after the metal segregation. Since the oxygen fugacity is estimated to be about 1 order of magnitude smaller than the IW buffer before the segregation of metal, CO is the dominant gas species compared to CO_2. Furthermore, amount of CO_2 dissolved in silicate melt plays negligible role in C budget in proto-mantle because of its low oxygen fugacity.

H buried in planetary interior is partitioned between silicate melt and liquid metallic iron during silicate-metal segregation in the magma pond. Because of the large solubility of H_2O into silicate melt, a substantial fraction of H is expected to be partitioned to the silicate melt as H_2O. Since existence of S and C decreases the solubility of H in liquid metallic iron, H may be partitioned largely to the proto-martian mantle.

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Graphite and CO in proto-mantle and proto-atmosphere are considered to be eventually reacted with H_2O. Therefore a large amount of CO_2 is generated, and there also occurs vigorous degassing of H_2 from proto-mantle and escape of H_2 from atmosphere to space. The amount of H_2O decomposed by this reaction may reach 1∼2% martian mass for the CO dominated case and 2∼4 % for the graphite dominated case, while the accreted H_2O is estimated to be 3.4%. This means that a significant portion of the accreted H_2O may be lost due to oxidation of such reduced C-bearing species. In extreme case, H_2O might be entirely lost by this mechanism. Whether or not this occurs depends on the ratio of CO/graphite, which is dependent on the impact degassing efficiency at each impact event. Such an extensive loss of H_2O might be consistent with the high D/H ratio of both martian atmosphere [8] and the hydrous mineral inclusion in SNC meteorite [9].

Since the present martian mantle is relatively oxidized, initial abundance of H_2O may be larger than that enough for its complete decomposition. In such a case, the proto-mantle is oxidized through H_2O degassing. Production of CO_2 or CO_3^{2-} in the interior region might be also possible, if such oxidized silicates are mixed with the graphite-bearing region of proto-martian mantle due to convention. This might induce SiO_2 poor volcanism, which appears to be consistent with the martian crustal formation [10].

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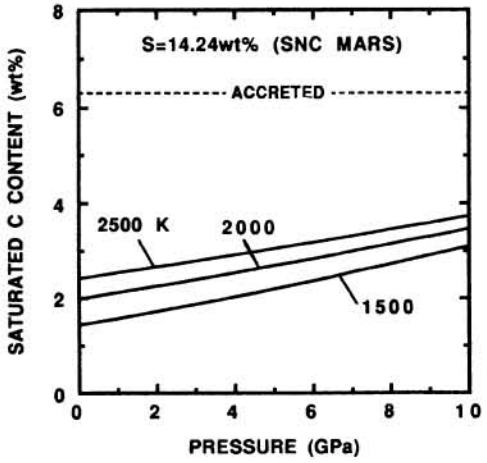

Fig. 1. Estimated saturated C content in Fe-S alloy (S=14.24wt%). Estimation is based on thermodynamic parameterization of Fe-S-C ternary system at 1 bar [7] and the partial molar volume of C in liquid metallic iron [11].

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