Labile organic molecules detected from a Ryugu A0535 grain

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Ryugu samples, brought back by Hayabusa2 [1], contain about 3-5 wt% of carbon [e.g., 2-4], about 2/3 of which is present as organic matter [2]. Various organic compounds have been identified in Ryugu samples from insoluble organic matter [e.g., 5] to solvent-soluble organic molecules that include prebiotic molecules [e.g., 3, 4, 6-8]. Ryugu samples resemble CI chondrites chemically, mineralogically, and petrologically [e.g., 2, 9], but CI chondrites have been weathered on Earth since their fall [e.g., 2]. TG-MS (thermogravimetry coupled with mass spectroscopy) analysis of Ryugu (A0040) and Ivuna (CI) showed that Ivuna contain more interlayer water molecules in smectite that were lost at <200°C than Ryugu, suggesting that smectite in CI chondrites may have been contaminated by terrestrial water [2]. TG-MS analysis also confirmed water release from sulfates (and possibly ferrihydrite), which were formed by terrestrial weathering, in Ivuna at <250°C [2]. In this study, to further investigate the release of volatile components from Ryugu and carbonaceous chondrites, we performed thermal decomposition experiments, coupled with mass spectroscopy, in a vacuum furnace.

We analyzed the Ryugu grain A0535 (0.9 mg), collected at the first touchdown site, and ~1 mg grains of Orgueil (CI1), Murchison (CM2), Allende (CV3), and Tarda (C2-ungrouped). The sample was placed in a platinum crucible and heated from room temperature up to 1000°C at a rate of 20°C/min at a total pressure of ~10^{-5}–10^{-4} Pa using a vacuum furnace [e.g., 10]. Gases released from the sample were monitored by a quadrupole mass spectrometer (MKS Microvision2) using electron impact ionization as positive ions in the range of mass-to-charge ratio (m/z) of 1–100.

The overall gas release patterns of H_2O, CO_2, and SO_2 from Ryugu A0535 were consistent with those from Ryugu A0040 reported by [2]. The main release of H_2O from Ryugu A0535 occurred at 500–600°C due to dehydroxylation, followed by the main CO_2 release due to decomposition of carbonates at higher temperatures. Dehydroxylation of phyllosilicates and decomposition of carbonates were also observed for Orgueil, Murchison, and Tarda, while Allende did not show clear release peaks of H_2O and CO_2. Less H_2O was released from Ryugu A0535 at <200°C than from Orgueil, and the total amount of SO_2 released from Ryugu A0535 was less than that from Orgueil. These observations are explained by terrestrial oxidative weathering of Orgueil that resulted in the incorporation of interlayer water into smectite and the formation of ferrihydrite and sulfates.

A remarkable observation in the gas release pattern of Ryugu A0535 was the clear detection of ions, such as CH^+, CH_2^+, CH_3^+, and CH_3O^+, from organic molecules at ~100°C. This demonstrates that Ryugu A0535 had never been heated above 100°C on Ryugu. No other carbonaceous chondrites showed such a release of ions at ~100°C, except for the release of interlayer water from Orgueil. This indicates that organic molecules were released from the interlayer of smectite [11] and that Orgueil may have lost their interlayer organic molecules through the interaction with terrestrial moisture. Tarda (fell in 2020) has a similar mineralogy to CI chondrites except for the products of terrestrial weathering and contains abundant smectite [12]. Tarda showed neither significant release of H_2O nor organic molecules at ~100°C, implying that Tarda have already lost the interlayer organic molecules or that such organic molecules were not originally present. The present study indicates that Ryugu sample has a huge potential to investigate the co-evolution of organic molecules and hydrous minerals on carbonaceous planetesimals.

References

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