An experimental study of sulfate reduction in hydrothermal environments within Europa

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The Jovian geologically-active icy satellite—Europa possesses an interior ocean, which is one of the most promising habitable environments beyond Earth. However, little is known about its chemical composition and geochemical cycles. Recent observations of Europa’s surface suggested that a large quantity of exogenic sulfate would have been supplied to the ocean over geological time (Fischer et al., 2015; Ligier et al., 2016). Nevertheless, the fate of exogenic sulfate is poorly understood. Here, we report the results of laboratory experiments on sulfate reduction in hydrothermal environments that possibly occurs on Europa’s seafloor (e.g., Lowell and Dubose, 2005). Using a newly-developed hydrothermal experimental system, we obtain the reaction rates at pressures of 100–130 MPa and for various pH. Our results show a strong pH dependence of the reaction rate; that is, sulfate reduction proceeds effectively at pH < 6; whereas, it is highly inhibited at pH > 6. Through thermochemical equilibrium calculations, we also demonstrate that hydrothermal environments would be as a sink of exogenic sulfate by forming sulfides if Europa’s seafloor rocks are composed of basalt. In this case, the seawater would contain Na^+, Mg^{2+}, Cl^-, and H_2S, which are consistent with recent findings of Na/Mg chlorides on Europa’s geologically-active surface regions (Fischer et al., 2015; Ligier et al., 2016). By contrast, if Europa’s rock component is chondritic, hydrothermal sulfate reduction would not proceed effectively due to alkaline fluid pH. This would result in an accumulation of sulfate in Europa’s ocean over geological time, leading to occurrence of a Na^+, SO_4^{2-}, and CO_3^{2-}-rich ocean. We suggest that salt compositions on Europa are a promising indicator for the rock composition and occurrence of hydrothermal activity within this moon. Our predictions of the surface materials on Europa may be testable by future observations using large telescopes and instruments onboarded on spacecrafts, including ALMA, Europa Clipper, and JUICE.

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