

How alkenes react in marine hydrothermal systems

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Organic carbon transformations play an important role in oceanic hydrothermal systems, such as the production and accumulation of oil and natural gas, as well as serving as a source of energy and food for subsurface life. Among the groups of organic compounds observed in hydrothermal vents, alkenes are of particular interest because they are not only a key intermediate linking other organic functional groups but also potential precursors to prebiotic compounds. Identifying the reaction pathways and mechanisms of alkenes is essential to understand how organic carbon is transformed and interconverted in hydrothermal fluids. In this study, we conducted both laboratory experiments and geochemical modeling of alkenes under simulated hydrothermal conditions, and three major pathways including hydration, oxidation, and dimerization are observed for alkenes. Hydration and dimerization of alkenes are favored in acidic hydrothermal solutions, whereas oxidation of alkenes remains relatively unaffected over the studied pH range. Hydrothermal interactions between alkenes and dissolved metal salts are also examined, which can significantly influence the pathway distribution of alkenes. The presence of acidic metal salts enhances the alkene hydration in unbuffered hydrothermal solutions, while the effect becomes minimal in well pH-buffered solutions. In contrast, alkene dimerization is not only affected by the acidity of the metal salts, but is also driven by the speciation and complexation of specific metal ions. In addition, alkene oxidation can become more favorable in the presence of oxidizing metal salts, although to a lesser extent than that of hydration or dimerization. Experimental observations are also consistent with thermodynamic predictions, which further highlights a controlling effect of solution chemistry and dissolved metal speciation on organic carbon transformations in natural hydrothermal environments.