Mineral-Water Reaction at High Pressures – Implications for Uranus and Neptune. S.-H. Dan Shim[1], C. Nisr[1], T. Kim[2], Y. J. Lee[2], A. Chizmeshya[1], K. Leinenweber[1], S. Chariton[3], V. Prakapenka[3], S. Speziale[4], Z. Liu[5], and H.-P. Liermann[6]. [1]Arizona State University (781E Terrace Mall, Tempe, AZ 85287; shdshim@asu.edu), [2]Yonsei University, [3]University of Chicago, [4]GFZ German Research Center for Geosciences, [5]University of Illinois at Chicago, and [6]Deutsches Elektronen Synchrotron.

Introduction: Uranus and Neptune have a thick H_2O-rich layer above the core (rocks and metals). Although the standard models have assumed no mixing between these materials, recent models have invoked significant amounts of heavy elements in the H_2O-rich layer with a compositional gradient to explain very little heat flow from the interior of Uranus [1, 2]. However, little is known about how heavy elements can exist there with long-term dynamic stability. Processes which can mix heavy elements in H_2O-rich layer are also important for understanding water-rich exoplanetary bodies [3]. We have conducted a series of experiments and density functional theory calculations to understand reaction between minerals and H_2O at high pressures and temperatures expected for the interiors of Uranus and Neptune. We also discuss implications of the experimental observations.

Methods: For high-pressure experiments, we loaded pure mineral phases together with H_2O in diamond-anvil cells. The mineral phases we studied are $(Mg,Fe)_2SiO_4$ olivine, (Mg,Fe)O ferropericlase, and SiO_2. The samples were laser heated to 700-2000 K in a H_2O medium at 7-110 GPa. X-ray diffraction patterns were measured in situ at high pressures and temperatures at the GSECARS sector of Advanced Photon Source. Infrared spectra of the samples were measured at Brookhaven National Lab. The recovered samples have been analyzed for chemical composition and morphology at Arizona State University and Yonsei University. We also have conducted density functional theory calculations (DFT).

Results: We found that olivine reacts with H_2O at high pressure and high temperature. The texture and chemical composition of the reaction products indicate that MgO is leached out from olivine and dissolved in H_2O. The solubility of MgO in H_2O peaks at 20-40 GPa. At pressure, the MgO solubility is comparable to the solubility of NaCl in H_2O at ambient conditions. SiO_2 component remains solid. Separate experiments showed that SiO_2 can contain a large amount of H_2O in the crystal structure at high pressure: $x = 0.2$ in $(Si_{1-x}H_{4x})O_2$. H_2O also alters the phase behavior of SiO_2, stabilizing NiAs-type structure at pressures above 60 GPa. The phase is not thermodynamically stable in dry SiO_2.

Discussion and Implications: Our observations found a significant amount of dissolved MgO in H_2O at high pressures and temperatures relevant to water-rich planets. The experimentally observed behavior of MgO could result in a compositional gradient in the outer layer of Uranus. After peaking at 20-40 GPa, the solubility would decrease with depth according to our experiments. The selective dissolution of MgO in H_2O could result in silica-rich rocky core. The large amount of H_2O dissolved in crystal structure of SiO2 solid polymorphs suggest that the rocky core of water-rich planet could be extensive hydrated (Fig. 1). It has been believed that the enhanced conductivity of H_2O through a series of phase changes play an important role for the observed magnetic field of Uranus and Neptune [4]. If a significant amount of MgO can be dissolved in the H_2O layer, MgO could affect the properties of the layer. It is also feasible that the H_2O and some heavy elements may experience mixing and de-mixing at different depths in the interiors of Uranus and Neptune, affecting the geochemical cycle.

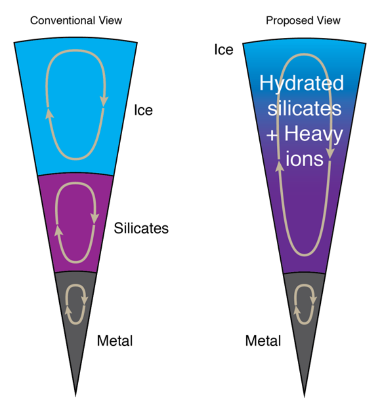

Figure 1: The internal structure of the water-rich planets. (Left) Conventional view. (Right) Proposed structure based on inter-solubility of rock and ice.

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References: [1] Nettelmann N. et al. (2016) *Icarus* 275, 107-116. [2] Vazan A. and Helled R. (2019) arXiv:1908.10682. [3] Howard A. W. (2013) *Science* 340, 572-576. [4] Redmer R. et al. (2011) *Icarus*, 211, 798-803.