Characteristics of noble gas signatures in Snow

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Noble gas concentrations in water are ideal probes to study surface and groundwater dynamics by providing indication of flow paths, connectivity between aquifers, and water residence times. Recent studies have pointed to anomalies in noble gas concentrations derived from groundwater in fractured systems, likely due to the presence of rapid infiltration and preferential flow paths. It was suggested that such anomalies originate from conditions at high altitude when rainwater has had insufficient time to equilibrate with surface conditions [1]. Potential sources include also snow.

In order to document the noble gas signature in fresh snow, noble gas concentrations and isotopic ratios were measured in snow samples collected in Michigan between 2013 and 2016. Here, we outline a methodology for measuring noble gases in freshly collected snow samples that involves a two-step procedure where He and Ne are measured independently from Ar, Kr and Xe. The extremely fine-grained nature of the material created significant experimental challenges.

Our results show that snow has elevated He concentrations with depleted concentrations of other noble gases. In addition, He and Ne concentrations display relatively low variability among all measured samples (<14%), while Ar, Kr and Xe show large variability in their concentrations (>80%). These observations led us to investigate the structure of snow and potential host-sites within the crystal structure, which controls the solubility of each noble gas. Our results show that He and Ne, which have small atomic radii, are likely dissolved within the ice/snow crystal lattice itself while the Ar, Kr and Xe are likely accommodated by defects, including quenched liquid water inclusions. Consequently, the smaller variability recorded in light noble gases may be due to the fact that He and Ne are hosted within the snow crystal lattice structure istelf, whereas heavy noble gases rely on the presence of comparatively rare defects, which may randomly appear within the structure during snow formation.

These new results show that the noble gas signatures in snow are correspond to a mixture of air pockets trapped within the snow crystal, and to quenched water inclusions with dissolved noble gases.

[1] Warrier, et al., (2013). Geophys. Res. Lett., 40, 3248–3252.