Tracing geothermal fluid interactions in Iceland using noble gases

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Geothermal fluids provide geochemical insights into volcanic systems. Noble gases are ideal tracers of fluid provenance and processes in the subsurface. We present noble gas isotope and abundance data (He, Ne, Ar, Kr, Xe) from 29 geothermal gas samples: 16 from geothermal well discharges and 13 from natural fumarole emissions. Samples are taken from both the Northern Rift Zone (NRZ) and Western Rift Zone (WRZ) of Iceland as well as from one locality (Kerlingarfjöll) in the Mid-Iceland Belt (MIB). Helium isotopes are MORB-like in the NRZ, with values up to 16.92R_a in the WRZ and MIB. Neon isotopes show enrichment in primordial $^{20}Ne/^{22}Ne$, plotting close to the solar-air mixing line. Helium and neon isotope systematics are decoupled, consistent with previous studies. Argon, krypton and xenon isotopes are air-like. Atmosphere-derived noble gas (ANG) isotopes (^{20}Ne, ^{36}Ar, ^{84}Kr, ^{130}Xe) are strongly correlated and show evidence for solubility-controlled fractionation. A pure air-saturated water source for ANG isotopes is inconsistent with our observations; a small (10%) external contribution with a noble gas composition similar to the sorbed component measured in oceanic sediments is required. Multi-stage gas-liquid water equilibration is required to explain observed ANG fractionation, suggesting boiling/condensation/degassing in the subsurface geothermal system. Concentrations and stable isotope ratios of other major geochemical species show relationships with $^3He/^4He$ values. In some cases (e.g., δD and $\delta^{18}O$ of H_2O), this is likely to be a superficial relationship due to the geographic distribution of MORB vs. OIB $^3He/^4He$ signals and fractionation of water isotopes with increasing latitude. However, other correlations (e.g., δD and $\delta^{13}C$ of CO_2) may indicate deeper source or process controls.