Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.6129

Development of a Tritium Ingrowth and Dissolved Noble Gas Analysis Facility

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Tritium, helium, and noble gases are valuable tracers for assessing aquifer dynamics, groundwater recharge climate conditions, water residence time, and groundwater geochemistry. Since the 1960’s peak in tritium in recharge from atmospheric nuclear weapons testing, the bomb tritium in groundwater has decayed and the tritium in recharge has assumed a modern, seasonally variable value, typically in the range of 1–10 TU. These conditions have meant that tritium analysis has the most utility when combined with low detection limits, and the value of the tritium-helium-3 dating technique has increased as it can provide much narrower mean transit times compared to tritium-based assessments. The modern, post bomb, tritium input regime also presents new opportunities to assess the spatial and temporal variability of tritium in precipitation and dispersion of tritium sourced helium-3 along groundwater flow paths. Additionally, dissolved noble gases in water provide unique indicators of climate conditions as well as forensic indicators of interactions with crustal fluids with water in shallow aquifers.

To execute continental-scale synoptic studies using these tracers, we have developed an automated facility for processing noble gas and low-level tritium samples via helium-3 ingrowth. Here we present our findings in constructing the system, developing the sample purification process, and validating the system. Our approach uses a custom multi-port sample purification line, Gifford-McMahon cryogenic coolers, and a Thermo-Fisher Helix SFT helium isotope ratio mass spectrometer. Initial performance assessments show that the system can measure tritium with limits of detection better than 0.01 TU with precisions in the range of 1 %. The abundances of the noble gases can be determined with precisions in the range of 1 % – 5 %. The Helix SFT is designed for helium isotope analysis with detectors situated for simultaneous detection of helium-3 and helium-4. We have found that routine automated measurement of helium isotopes is possible with careful attention to laboratory conditions and peak alignment. Additionally, we demonstrate detection resolution and quantification of all noble gases on both Faraday and electron multiplier detectors with modified ion source settings.