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Methods for Using Argon-39 to Age-Date Groundwater using Ultra-Low-Background Proportional Counting

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Content

Argon-39 can be used as a tracer for age-dating glaciers, oceans, and groundwater to study the mean residence time (or age distribution) to better refine groundwater models. Multiple environmental tracers are used in groundwater modeling to cover a wide range of ages. Established tracers covering the age range of 50 years or less typically use H-3 (12.3 year half-life) or Kr-85 (10.7 year half-life) while the age range of 1,000 years or greater is covered by C-14 (5,730 year half-life). With a half-life of 269 years, Ar-39 fills an intermediate age range gap (50-1,000 years) to better define the age distribution of groundwater aquifers recharging on the time scale of 50-1,000 years.

Detection of Ar-39 depletion is challenging by direct beta counting. Currently only the deep underground laboratory in Bern and shallow underground laboratory at Pacific Northwest National Laboratory (PNNL) have demonstrated sufficient sensitivity for direct beta counting of Ar-39.

We present the methods employed for arriving at an age-date for a given sample of argon degassed from groundwater. This includes the degasification of groundwater, purification of the extracted gas, detector loading process, and data analysis techniques.

Groundwater samples were collected in collaboration with the U.S. Geological Survey (USGS) in Fresno, California (2014) and Modesto, California (2015). The degassed samples were shipped to PNNL and then processed to extract purified argon for direct beta counting in an ultra-low-background proportional counter (ULBPC) in PNNL's Shallow Underground Laboratory.

Prior to counting a groundwater sample, characterization measurements for each ULBPC are collected in the ultra-low-background counting system. Each ULBPC measures a geologic argon sample recovered from a carbon dioxide gas well, which represents the detector only background where no Ar-39 is present in the sample. A modern argon sample is also measured using commercial, atmospheric argon (containing "modern" levels of Ar-39). With these two bounding measurements of modern and geologic argon, we have defined the limiting cases for groundwater samples and thus, all groundwater samples will fall somewhere between the age range of modern and geologic argon.

An example of a groundwater age-dating measurement will be presented from end-to-end starting with the sample collection, to purification and detector loading, and finally to the measurement and analysis.

About the Presenter

Emily K. Mace is a Senior Research Scientist at the Department of Energy's Pacific Northwest National Laboratory (PNNL). She received her Masters in Physics from Purdue University in 2006. Ms. Mace has a background in radiation detector development and characterization. She has participated in growing the ultra-low-background capabilities of PNNL including characterization of the ultra-low-background proportional counters and the ultra-low-background counting system in PNNL's Shallow Underground Laboratory. In the Shallow Underground Laboratory, Emily measures samples in the ultra-low-background counting system for applications of environmental science and treaty verification. Emily has also worked in safeguards to develop a UF6 unattended cylinder verification station (UCVS) for non-destructive assay of UF6 cylinders to verify U-235 mass using full volume measurement techniques. Emily has participated in field campaigns using the UF6 technology in deployments at both foreign and domestic enrichment facilities.

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