

Isotope variations of heavy elements: a perspective from light isotopes

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Published literature data on isotope variations of heavy elements such as Fe, Cu, Zn, Mo and Tl will be discussed from the perspective of light element geochemistry. Special emphasis will be given on Fe isotopes. At present some confusion exists on the definition of measurement values and on the use of standards.

The so far observed isotope variations at low temperatures are on the order of 1 ‰ for Zn ($^{66}\text{Zn}/^{64}\text{Zn}$), 2 ‰ for Cu and Tl, 3 ‰ for Mo ($^{97}\text{Mo}/^{95}\text{Mo}$) and more than 5 ‰ for Fe ($^{56}\text{Fe}/^{54}\text{Fe}$). The magnitude of fractionations depends on the relative mass difference among isotopes. At magmatic temperatures isotope fractionations decrease by about one order of magnitude, for iron they are still above analytical uncertainty. Fractionation mechanisms responsible for the observed variations should be the same as for light elements but so far the actual fractionation mechanisms have not been clearly resolved. For instance equilibrium fractionations have been documented for iron in high temperature rocks, but still have to be proven in low temperature rocks. The role of biological fractionations also remains unclear, but by analogy from light elements should play a very important role, especially in the case of iron. However, contradictory results have been obtained till now: abiotic iron reduction/oxidation reactions reveal fractionations being similar in direction and magnitude to microbial reactions. Therefore, iron isotope signatures cannot be taken as indicators of biological fractionations. Nevertheless abundant evidence suggests that organisms preferentially enrich the lighter isotope during biosynthesis.

In contrast to light elements, fractionations due to adsorption and scavenging processes seem to be very important for heavy elements. This can be demonstrated when discussing fractionation patterns of different heavy elements found in iron oxides. In summary isotopes of heavy elements appear to be good tracers for the study of biosphere-geosphere interactions. Future studies will reveal the full potential of these new isotopic tracers.

Continuous radon measurement in groundwater

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Radon (Rn) as a Groundwater Tracer

The noble-gas radionuclide ^{222}Rn (half-life: 3.8 days) is a natural non-reactive tracer for the estimation of residence times of young groundwater and a good proxy for groundwater flow modeling. After infiltration, Rn concentrations build up (ingrowth from the parent radionuclide) in the ground water. A steady state between ingrowth and decay is established after about 15 days [4 half lives (1)].

Continuous Radon Measurement

The optimum interval of batch Rn measurements in groundwater is about one hour, when measured with α -spectrometry (solid-state semiconductor detectors). Laboratory experiments have shown that Rn can be measured in a continuous mode, at intervals down to 0.1 hours. Changes in Rn concentrations due to mixing of two different water sources can be traced on-site after equilibration of Rn among air and water [about 0.7 hours (2)].

Results and Discussion

In a two-well and a single-well (push-pull) injection-withdrawal flow field of a heterogeneous aquifer of glaciofluvial gravel-and-sand outwash, anoxic ground water containing dissolved iron and manganese was purged in a series of experiments with aerated injection water. During these experiments, steady-state Rn concentrations of 6 - 8 Bq/L were found in the groundwater of the extraction well. In the injection water, Rn was completely gassed out (< 1 Bq/L). Non-reactive tracers added to the injected water (^3He and uranine) revealed residence-time distributions in both flow fields, with mean values of several hours. A decrease of the Rn concentrations in the two-well flow field down to 4 Bq/L, and a slow concentration increase after a sudden drop down to 2 Bq/L, in the push-pull flow field allowed to trace the breakthrough of the aerated water. This compared well with the breakthrough of ^3He and uranine and with the concomitant analysis of batch Rn samples.

Conclusion

For the analysis of short-term changes in groundwater composition, continuously monitored Rn is better suited than the measurement of single samples.

References

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