Isotope ratio analysis solves complex problems

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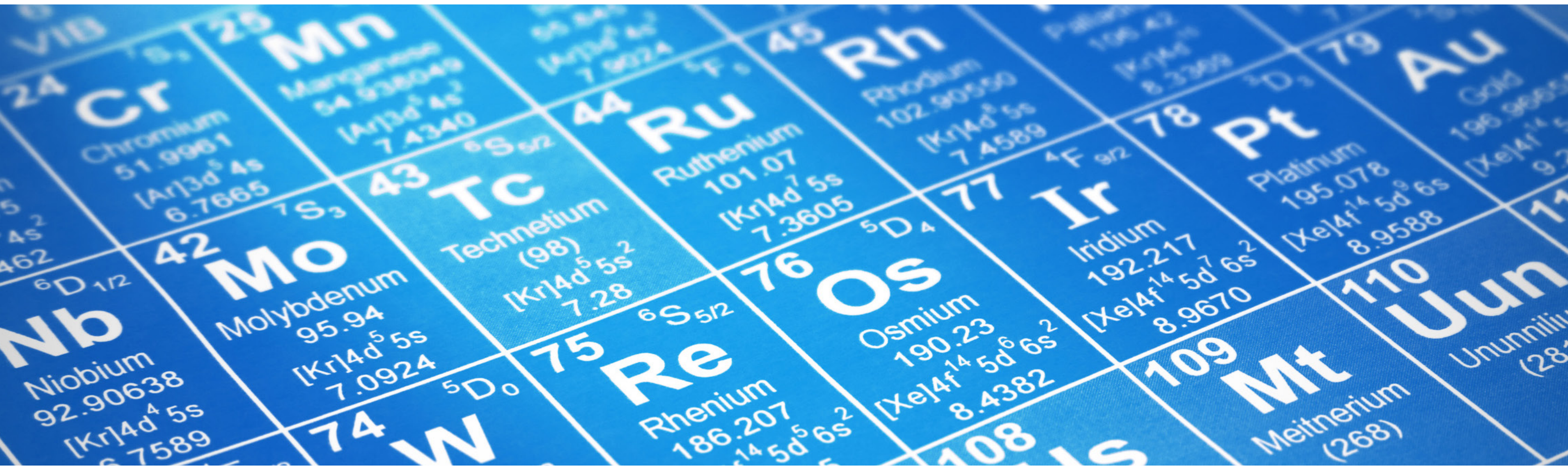

The ALS specialty lab in Luleå, Sweden is one of very few laboratories in the world offering commercial isotope ratio testing services not only for radiogenic systems (Sr, Nd, Pu, U) and light stable isotopes (Li, B, Si), but also for heavy stable elements such as Ag, Ca, Cd, Cu, Fe, Mg, Mo, Si, and Zn. All of these isotope ratio tests can be used as a fingerprint to provide information about origin or geological age, and have potential to be used for tracing pollution and exposure sources.

Introduction to isotope ratio analysis

The isotopic composition of an element can be affected by factors such as its source, exposure to weathering, biological and biochemical processes, or the geological age of a material, and can provide valuable characteristic and diagnostic information.

Isotope ratio analysis is used to accurately measure very small differences in the ratios of different isotopes of an element, and is a powerful tool for many disciplines, such as geology, geochronology, geochemistry, forensic sciences, human nutrition, health studies, and archaeology. Most people are familiar with radiocarbon dating, perhaps the most famous use of isotope ratio analysis, where the ratio of radioactive Carbon-14 to Carbon-12 isotopes can accurately determine the age of organic materials up to around 60,000 years. Isotope Ratio Mass Spectrometry (IRMS) is widely used to measure stable isotope ratios of the most common light elements, including Carbon (C), Nitrogen (N), Sulfur (S), Oxygen (O), and Hydrogen (H).

Measurement of stable isotope ratios of heavier elements tends to be more challenging, requiring specialized instrumentation, and typically requiring preconcentration, because heavy element concentrations are very low in most sample types. Some of the most common isotope ratio tests and applications for heavy elements are shown in Table 1. A more extensive overview of heavy element and other non-traditional stable isotope applications for groundwaters can be found in Elemental stable isotope assessment of groundwater contamination: Recent Developments (see References).

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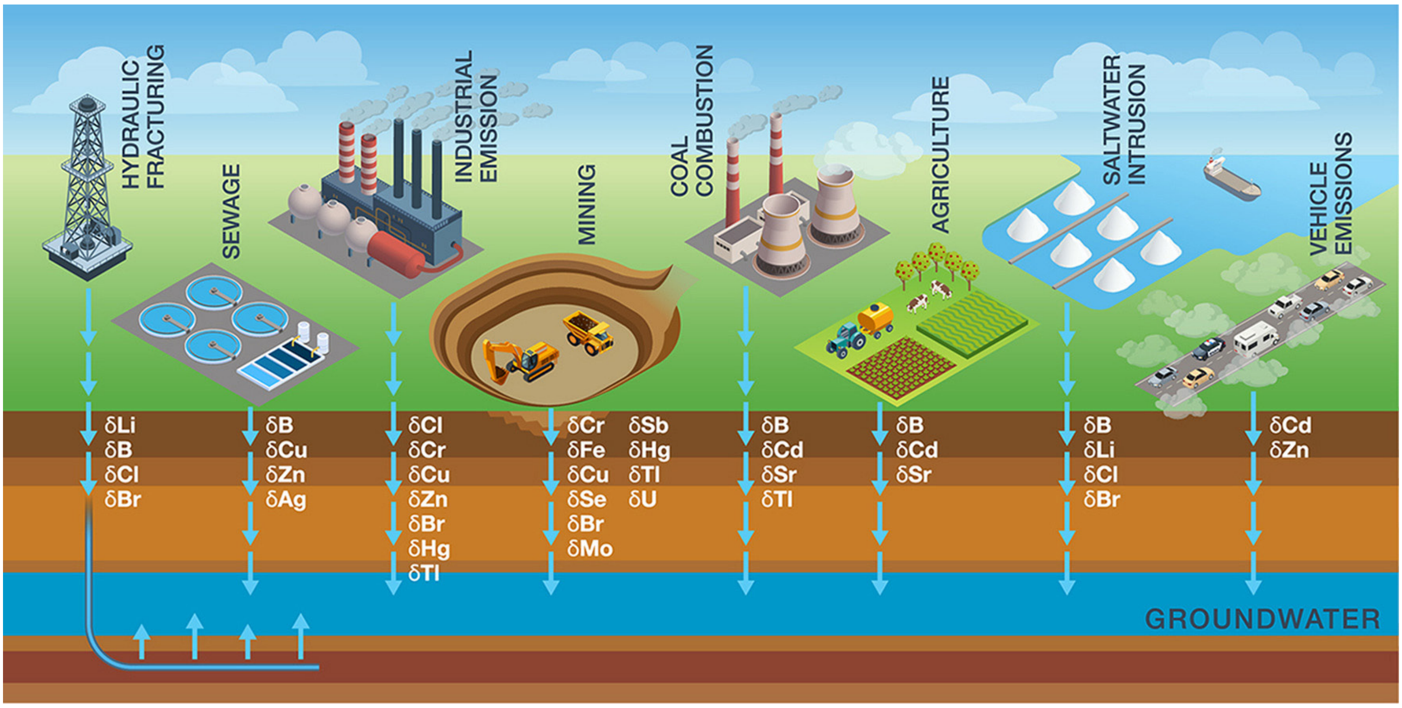
Table 1. Common non-traditional isotope ratio applications

Isotope system	Isotopes measured	Common applications
Boron, B	$^{10,11}B$	Enrichment control in the nuclear power industry, tracing pollution sources
Lead, Pb	$^{204,206,207,208}Pb$	Tracing pollution and exposure sources, geology, geochronology, provenance studies, forensics, archaeology
Neodymium, Nd	$^{143,144}Nd$	Geology, geochronology, provenance studies
Selenium, Se	$^{77,78,82}Se$	Detecting and monitoring post-mining attenuation of Selenium at mining sites
Strontium, Sr	$^{86,87}Sr$	Geology, geochronology, provenance studies, forensics
Uranium, U	$^{234,235,238}U$	Enrichment control in the nuclear power industry, tracing pollution and exposure sources
Other heavy elements	Stable isotopes of Silver (Ag), Calcium (Ca), Cadmium (Cd), Copper (Cu), Iron (Fe), Magnesium (Mg), Molybdenum (Mo), Silicon (Si), Zink (Zn)	Geology, tracing pollution and exposure sources



Picture 1. Non-traditional stable isotope ratio applications for groundwater (Current Opinion in Environmental Science & Health 2022, 26:100330)

ALS capability for isotope ratio analysis

ALS in Luleå has more than 30 years of research and commercial testing experience for stable isotope ratio analysis using both High Resolution Sector Field ICP-MS (ICP-SFMS) and Multi-Collector ICP-MS (MC-ICP-MS) instrumentation. Our expert team has made substantial contributions to the field of isotope ratio analysis with 170 peer-reviewed publications. ALS in Luleå offers isotope ratioanalyses for more than 20 stable and radiogenic isotopic systems in a variety of sample matrices with high precision, even where sample concentrations are very low.

Most isotope ratio tests require high precision, because the differences observed in isotope ratios for most elements are small. MC-ICP-MS is used for the most demanding isotope ratio measurements, where the best possible precision is required. For example, age dating of

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rocks and meteorites using isotopic ratios of Samarium (Sm) and Neodymium (Nd) requires a precision of at least 0.002%, which can only be achieved with MC-ICP-MS. The uncertainties with ICP-SFMS are higher, ranging from about 0.05-1% (depending on test), but are sufficient for some applications. Test results for isotopic ratios are typically reported as delta values in units of parts per thousand (ppm), which relate to internationally accepted reference standards for each isotope system.

Isotope ratio testing recquirements and options

Isotope ratio tests are available for a wide variety of matrices, including (but not limited to) natural and process waters, wastewaters, soils, sediments, aerosols, vegetation, biota, food products, clinical samples, archaeological objects, metals, and alloys.

Isotope ratio tests and application requirements are complex. Experts at ALS in Luleå discuss requirements with the clients to determine the most appropriate options, which may require customized sample preparation techniques such as matrix removal, analyte preconcentration, and purification in addition to IRMS analysis. Our chemists can advise about sampling amounts and preparation techniques needed for different matrices to meet the minimum amounts required for our test methods (as shown in Table 2).

ALS offers the fastest testing available anywhere for isotopic ratio analysis of heavy elements, with routine turnaround times of 6-10 working days (after receipt of samples at ALS Scandinavia), and with rush analysis possible for some tests – much faster than most university isotope ratio labs.

Table 2. Isotope ratio test options and required elemental amounts.

Isotope system		Isotopes measured	ICP-SFMS	MC-ICP-MS
			Min. abs. amount (ng total)*	Min. abs. amount (ng total)*
Boron	B	10, 11	0.01	500
Calcium	Ca	42, 43, 44		25.000
Cadmium	Cd	110, 112, 113, 114		100
Chromium	Cr	52, 53		100
Copper	Cu	63, 65		1000
Iron	Fe	54, 56, 57		10.000
Lead	Pb	204, 206, 207, 208	1	250
Lithium	Li	6, 7	200	1000
Magnesium	Mg	24, 25, 26		25.000
Mercury	Hg	199, 200, 201, 202		100
Molybdenum	Mo	95, 96, 97, 98		10.000
Neodymium	Nd	143, 144		500
Osmium	Os	187, 188	0.01	5
Plutonium	Pu	239, 240	0.00005	
Radium	Ra	226	0.00002	
Silicon	Si	28, 29, 30		100.000
Silver	Ag	107, 109		100
Strontium	Sr	86, 87	50	500
Thallium	Tl	203, 205		100
Thorium	Th	230, 232	50	200
Uranium	U	234, 235, 236, 238	5	200
Zink	Zn	64, 66, 68		2000

Min. abs. amount = minimum absolute amount

*minimum amount can vary depending on matrix, please contact ALS in Luleå for more information.

References
Elemental stable isotope assessment of groundwater contamination: Recent developments, Ilia Rodushkin, Emma Engström, Simon Pontér, and Maddalena Pennisi, Current Opinion in Environmental Science & Health 2022, 26:100330.

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