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Introduction – What are Isotopes?

Isotopes are atoms of elements with different numbers of neutrons. They can give a slight shift in the weight and chemical reactivity of a chemical element. Chemical elements such as hydrogen and oxygen are made up of smaller components, such as protons, neutrons and electrons. An element is distinguished from other elements by its number of protons; this number is constant to one element. The number of neutrons to an element can fluctuate and defines the isotope of that element. For example, the hydrogen element will always have 1 proton, but hydrogen can have different isotopes based on the number of neutrons. If the hydrogen element has only one neutron, it is called a hydrogen atom since this is the most common structure for a hydrogen element. If it has two neutrons, it is called a deuterium atom which is still a hydrogen element but can behave chemically different due to the second neutron and slightly different weight. In the environment, the difference between isotopes of a particular element can result in slightly different chemical behavior and allows scientists to monitor specific processes based on measured isotope values for a compound containing a specific set of isotopes or of a specific atom itself.

How are Isotopes Used in the Raton Basin?

Isotopes can be used by scientists in state agencies, oil and gas companies, and consultants to help understand processes in the environment and to understand potential impacts due to oil and gas operations. One such case in the Raton Basin is the use of isotopes found in methane gas to potentially identify the source of and movement of methane in the basin.

Methane gas occurs naturally in groundwater aquifers in most geological sedimentary basins worldwide, including the Raton Basin. Methane gas exists in a dissolved state in groundwater and will effervesce or “bubble out” when it is pumped to the surface due to a decrease in pressure to atmospheric pressure. Private water well owners may encounter spurting or bubbling taps, a common result of this phenomenon. Methane gas can pose an explosion or asphyxiation hazard if allowed to build up in a confined space, and well owners are strongly encouraged to vent their water supply systems when gas is present.

Coalbed methane (also known as CBM) is a relatively new natural gas energy source and plays a large role in Colorado’s energy production, especially in the Raton Basin. Many private water well owners have expressed concerns that methane gas could migrate from CBM wells to nearby aquifers and into private water wells.

Is Isotope Sampling Required in the Raton Basin?

The Colorado Oil and Gas Conservation Commission (COGCC) regulates the Colorado oil and gas industry including CBM activities in the Raton Basin. As part of the monitoring requirements regulated by the COGCC, oil and gas companies are required to attempt to sample nearby private water wells prior to drilling a new CBM well and after completion of this new well. The regulations require a list of key water quality components to be analyzed for in the sample that could indicate potential impact from CBM activities to the quality of water reaching the private water well. If methane is present in a private water well sample at concentrations greater than 2 milligrams per liter (mg/L), the rules then require an isotopic analysis on the carbon and hydrogen elements that comprise the methane gas.

The type of methane gas in a sample can be biogenic, thermogenic, or a mixture of the two depending on the hydrogeologic system. The methane takes on characteristics that are dependent on the source of carbon and hydrogen that are converted into methane and site specific conditions such as temperature and pressure.

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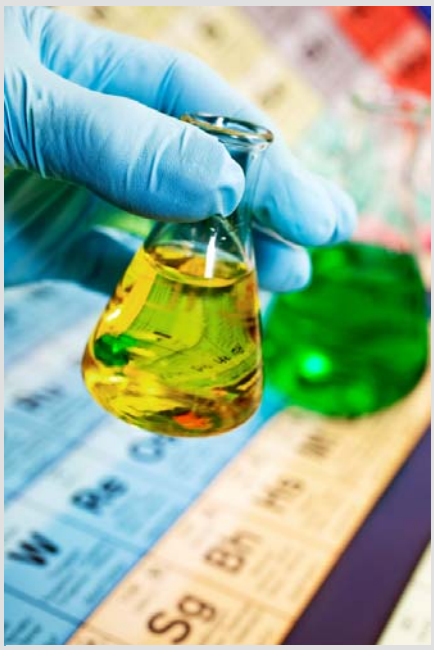
Biogenic and Thermogenic Methane Gas

- Biogenic methane is produced by subsurface microorganisms called methanogens that produce methane from organic matter or other carbon sources as a metabolic byproduct in anoxic conditions. While methane is often referred to as “bacterial gas” the methanogens are classified as archaea, a group of microorganisms very distinct from bacteria. Biogenic methane is a common natural source of methane gas in groundwater aquifers used for water well supplies.
- Thermogenic methane gas is produced at depth underground by an abiotic (non-microbial) process due to increased pressure and temperature during burial and is commonly associated with deep oil and gas reservoirs.
- Gas from CBM wells in the Raton Basin is comprised of a contribution of both biogenic and thermogenic gas.



Isotopic Analysis

Composition and isotopic analyses can be used simultaneously to help determine whether gas in a non-CBM well, such as a private or monitoring well, is of biogenic or thermogenic origin, or a mixture of the two and whether or not it is associated with oil and gas practices or naturally occurring. Changes in the values before drilling and after completion can also potentially indicate whether the methane is anthropogenic or naturally occurring.

Methane gas typically contains a small amount of ethane. The proportion of methane to ethane in a gas can help determine its origin. Biogenic gas typically contains above 1000 times more methane than ethane. The CBM produced gas in the Raton Basin is primarily thermogenic in origin but contains a mixture of both biogenic and thermogenic gas and is primarily >90% methane. Isotope analyses of carbon and hydrogen in methane can be used to help determine sources of methane when compositions alone are ambiguous. However, isotope values tend not to be reliable at lower concentrations.

Further explanations of isotopes:
Biogenic methane is typically produced via carbon dioxide (CO_2) reduction:
$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$

Or acetate fermentation:
$CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$

Because carbon from dissolved inorganic carbon (DIC), represented above as carbon dioxide, is the source of methane production or a product of methanogenesis, the resulting carbon isotopes in DIC also provide insight into the origin and subsequent geochemical changes of methane.

Isotope Examples

In environmental applications of isotopes, it is common to measure ratios of different isotopes rather than a single isotope and report them as changes indicated by the Greek symbol “d" in per mil units. For example a sample of methane will contain at least two isotopes of carbon, carbon-12 and carbon-13. These are the most common carbon atoms. The ratio of the carbon-13 to carbon-12 isotopes, relative to a known standard ratio, multiplied by 1,000 (‰, per mil, similar to percent) provides the “d" notation value used in environmental applications. The carbon isotope ratio for a methane sample would then be reported as $d^{13}C$ of methane.

Additional information on isotopes can be found at the website: www.ratonbasinwatershed.org.

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