Origin of Non-Hydrocarbon Gases in Petroleum Systems – A Review

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ABSTRACT

Natural gas in the Earth's crust typically contains 70 to 100% methane, 1 to 10% ethane, lesser amounts of propane through hexane, and traces of higher hydrocarbons. Nitrogen (N2), carbon dioxide (CO2), and hydrogen sulfide (H2S) vary from traces to 100%. Non-hydrocarbons impact the economic value of produced gas by diluting the BTU value of the hydrocarbons. CO2 and H2S pose operational problems for field infrastructure. H2S is a serious threat to human health. Noble gases occur in trace to minute amounts in reservoirs. More than 0.3% helium increases the economic value of a gas accumulation. Noble gases provide precise information on the origin and movement of sedimentary fluids because the isotopic composition of noble gases uniquely indicates the origin of fluids in which they are dissolved, or the physical processes of migration and mixing of these fluids.

Sources of N2 in petroleum reservoirs include the atmosphere (air contamination and evaporites), magma (mantle outgassing), oxidation of kerogen-derived ammonia in pore waters, and high-temperature release from inorganic fixed ammonium in potassium-rich silicates. N2 stable isotope (δ15N) data cannot be used to quantify the contributions of different N2 sources in subsurface fluids because of uncertainty in the isotopic range of various end members and the overlapping range of δ15N for respective nitrogen end members. The combined use of δ15N and noble gas systematics, however, effectively facilitates the interpretation of N2 sources in petroleum reservoirs.

Sources of CO2 in petroleum reservoirs include sedimentary organic matter and organic acids, microbial degradation or oxidation of hydrocarbons, thermochemical sulfate reduction (TSR), inorganic dissolution of carbonates, and magma. Variations in the stable carbon isotope composition (δ13C) of CO2 and hydrocarbons might be diagnostic of gas origins, but the δ13CO2 of high-CO2 reservoirs often falls within the overlapping range of carbonate breakdown and magmatic degassing making it difficult to distinguish between these sources. The high solubility of CO2 in water, and its high reactivity, complicates the interpretation of CO2 sources because the extent of gas phase interaction with formation water is a critical parameter in determining CO2 sinks. The integration of noble gas systematics can be used to constrain CO2 sources and interaction with formation waters.

H2S can be generated in the subsurface by bacterial sulfate reduction, thermal cracking of sulfur-rich organic matter or sulfur-rich oil, TSR, and hydrolysis of metal sulfides in highly acidic reservoirs. In addition, there are several operational H2S generation mechanisms related to well completion methods. Combined use of sulfur and carbon isotope systematics, produced water chemistry, reservoir petrology, and seismic data are necessary to correctly determine the source of H2S in petroleum reservoirs.