

# **Isotope systematics of geothermal fluids – effects of aqueous speciation, boiling and water-rock interaction**

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Among the major goals of geothermal geochemistry is to identify the source of the geothermal fluids and the processes influencing their chemical composition. However, such can be difficult given that geothermal systems are characterized by many phases (vapor, liquid and solid) and components. Stable isotope systematics has been among the major tools in tracing the source and reactions of various components in geothermal fluids. Commonly, this is based on identifying the variable end-member components in the system and mixing ratios, or alternatively, comparing temperature dependence of isotope fractionation of given reactions with the measured isotope systematics. Isotopes of a given element fractionates upon reactions with key reactions in geothermal systems being aqueous speciation, vapor-water partitioning and water-rock interactions, these depending on solution composition, temperature and pressure. In turn, the key processes affecting geochemical composition in geothermal fluids include water-rock interaction, boiling and condensation, oxidation and mixing between various types of fluids. In order to study the effects of various reactions and processes affecting isotope systematics of geothermal fluids, isotope geochemical models were developed by combining aqueous speciation, gas-water partitioning and water-rock modelling together with isotope fractionation and isotope mass action equations. Using these geochemical models, isotope systematics for vapor, liquid and solid phases can be simulated upon processes like boiling, progressive water-rock interaction and mixing. Examples of such modelling will be given for sulfur and carbon in geothermal systems and these compared with data on isotopic systemic of natural geothermal fluids. Based on these models it is concluded that the key factors controlling, for example sulfur and carbon isotope systematics of geothermal fluids, are two, the isotope composition of the source material and isotope fractionation associated with aqueous and vapor speciation and how these changes as a function of processes occurring in the system including boiling and fluid-rock interaction.