Noble gases as physiological tracers for gas dynamics in human blood

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The exchange of the inert noble gases (He, Ne, Ar, Kr, Xe) between gas and liquids is controlled solely by the gas-exchange kinetics in the gas/liquid interface, and by the solubility equilibrium (Henry's Law). Noble gases are therefore excellent tracers for the physical processes involved in gas/fluid exchange, and they have widely been applied as environmental tracers in aquatic systems. Here, we present our first attempts in using noble gases to trace physiological processes in the human body, such as the gas exchange in the lung or the gas distribution within the human organism.

Blood samples were taken from an atecubital vein. Samples were transferred into copper tubes (sample containers) without exposure to air or any other gas phase, and copper tubes were sealed. After coagulation of the blood, the samples were centrifuged to separate the liquid blood plasma from the blood cells. Blood samples were then analysed by vacuum extraction and mass spectrometric quantification of the dissolved gases using the standard methods used for water and sediment samples.

While breathing ambient air, noble gas concentrations in blood plasma were very similar to those in air saturated water, However, the ^{3}He/^{4}He ratio was 10% higher in blood than in air-saturated water, which is possibly due to the difference in diffusivities of ^{3}He and ^{4}He isotopes in the air/blood interface of the lung. Also, the heavier noble gases were found to be enriched in the blood-cell fraction relative to the blood plasma.

Breathing air enriched with noble gases resulted in an increase of the noble gas concentrations in the blood, and a new steady state was attained within a few minutes. All noble gas concentrations increased with the same kinetics. This suggests that gas exchage is not limited by diffusion through the air/blood interface in the lung, and that solubility equilibrium is attained in the lung. In contrast to O_2, which is bound to hemoglobin, the steady-state noble gas concentrations were considerably lower than expected, which points to a secondary partitioning or loss of noble gases within the body.

Recent advances of noble gas geochemistry in aquatic systems

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Noble gases and bio-geochemically conservative transient trace gases (SF_6, CFCs) in aquatic systems have commonly been used to determine water residence times and to reconstruct past environmental and climatic conditions.

Recent conceptual and experimental developments have considerably extended the applicability of noble gas and transient gas analysis in aquatic systems. The mechanistic understanding of the formation of excess air (EA), a surplus of dissolved atmospheric gases commonly observed in groundwater, now allows robust interpretation of EA as a proxy for the hydraulic conditions during groundwater recharge, e.g., in areas that were covered by ice sheets during the LGM. Recent experimental breakthroughs now allow noble gas analysis in sediment pore fluids and in fluid inclusions of speleothems to reconstruct environmental condition from minutes amounts of water. Furthermore, the coupling of vacuum systems commonly used for noble gas analysis with and gas chromatographic methods allow combined analysis of noble gases and other gases (e.g., SF_6, CFCs, O_2, N_2) from a single water sample. This facilitates reliable EA correction for SF_6 and CFCs improving ground water dating. Finally, portable membrane-inlet mass spectrometers enable continuous and real-time analysis of noble gases and other dissolved gases directly in the field, allowing, for instance, quantification of O_2 turnover rates on small time scales.

In presenting these recent achievements, we intend to stimulate a broader discussion to define future applications of noble gases in conventional and unconventional aquatic systems.

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