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Solvation of Gaseous Nitrous Acid, Hydrogen Peroxide, and Ozone in the Bulk Water

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Abstract

Atmospheric air plasmas created in contact with water generate "plasma-activated water" (PAW) containing various reactive oxygen and nitrogen species (RONS), e.g., hydrogen peroxide (H_2O_2), nitrate (NO_3-) and nitrite (NO_2-) anions, and ozone (O_3), as well as other shortlived species. It has been reported by several groups that the PAW solutions are effective in killing and inactivating bacteria, having potential applications in biomedicine. PAW is considered as an example of the outcome of plasma-liquid interaction, where the RONS from plasma are transported into the water. The solvation potential of gases into liquids is given by Henry's law solubility coefficient kH which describes the solubility of the gas species in liquids, e.g., water. Plasma long-lived RONS: H_2O_2, HNO_2, and O_3 have kH of $\approx 9 \times 10^2$, 4.8×10^{-1}, and 10^{-4} mol m^3 / Pa, respectively. It means that the solubility of RONS generated in the gas phase varies markedly and even if their gaseous concentrations are equal, concentrations achievable in the aqueous phase differ significantly. The transport mechanism of HNO_2, H_2O_2, and O_3 into the bulk water is investigated here. The comparison of highly soluble H_2O_2 with the medium and weakly soluble HNO_2 and O_3 species can lead to a better understanding of the transport mechanism of gaseous RONS into the water and will enable optimization of the plasma-liquid interaction systems. The concentration of the transported HNO_2 into the water as (NO_2-) is measured using the UV-Vis absorption spectroscopic technique. In the gas phase, HNO_2 is partially decomposed into NO and NO_2 (NOx). The concentration of HNO_2 and NOx in the gas phase is measured using electrochemical gas sensors and the UV-Vis absorption spectroscopic technique. Due to the transport of HNO_2 into the water (aqueous phase), there is a depletion in the gas phase. The theoretical highest decrease of HNO_2 concentration in the gas is determined by Henry's law coefficient. It was found out that the measured concentration of HNO_2 in the bulk water is 3 orders of magnitude higher than that of O_3. This result corresponds to the ratio of HNO_2 and O_3 Henry's law coefficients.

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