The Hidden Solute: How Dissolved Atmospheric Gases Change Liquid Physicochemical Properties

Mert Acar[1], Duccio Tatini[2], Barry W. Ninham[3], Pierandrea Lo Nostro[1]

[1] Department of Chemistry "Ugo Schiff", University of Florence, Sesto Fiorentino (FI), Italy
[2] Department of Biotechnology, Chemistry and Pharmacy, University of Siena, Siena (SI), Italy
[3] Department of Applied Mathematics, Research School of Physical Sciences and Engineering, Australian National University, Canberra (ACT), Australia

mert.acar@unifi.it

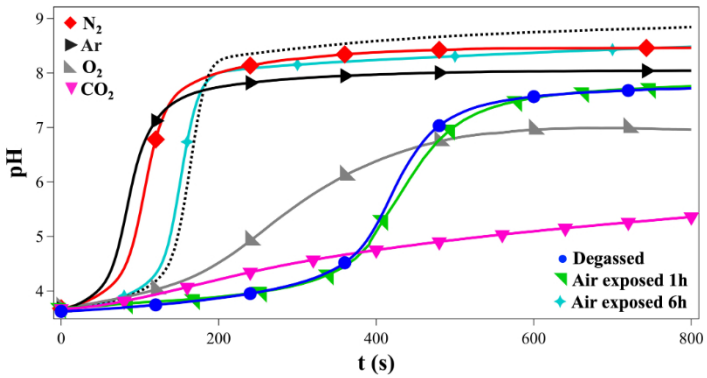
Real water is not simply H_2O as atmospheric gases are always dissolved in it, and even more so in many organic liquids, where the solubility of gases may be much greater than that in water. Yet the collective role of dissolved gases as active physicochemical species remains entirely unaccounted for by current theories. This is a blind spot at the very foundation of liquids' physical chemistry.

We showed that complete degassing with the freeze-and-thaw process produces dramatic, reproducible effects across aqueous and non-aqueous systems. For example, oil-water and hydrocarbon-perfluorocarbon binary systems remain stable for some time without the intervention of any surfactant, and phase separation times extend by orders of magnitude [1]. Electrolyte conductivity, cloud-point temperatures, and the UV-Vis spectrum of bromothymol blue all change markedly upon the removal of the dissolved gases [1,2]. Urease enzymatic activity is suppressed [3]. Bubble coalescence exhibits ion-specific modulation [1], revealing that gas/liquid nanointerfaces respond markedly to solute identity and yet the molecular origin of this ion specificity remains elusive.

Sequential re-admission of individual gases maps re-adsorption kinetics and shows that the perturbation is reversible but remarkably slow. Full urease recovery requires nearly six hours, with paradoxically, chemically inert N_2 and Ar accelerating urease activity [3]. Oxygen concentration needs about three hours to restore, bromothymol blue spectra 45 minutes [2], triacetin-water demixing over 400 minutes. All these prove that dissolved gases reshape solvent structure rather than act as chemical reagents or inert species.

These results can be interpreted in terms of gas nanobubble interactions with solvent molecules and of the formation of gas/liquid nano- and microinterfaces. Disentangling the physicochemical contributions of dissolved gas species opens a new frontier for molecular, colloidal, and biochemical anomalies that have long resisted theoretical interpretation.

Keywords:
dissolved gas, nanobubbles, chemistry in solution, complex systems



Urease catalyzed urea hydrolysis raises pH in unbuffered aqueous solutions. Sigmoidal pH vs. time curves show blank (dashed), degassed, and gas-readmitted conditions, revealing the role of dissolved gases in modulating enzymatic kinetics.

References:

[1] Ninham, B. W.; Lo Nostro, P. Unexpected Properties of Degassed Solutions. *J. Phys. Chem. B* **2020** , *124* (36), 7872–7878.
[2] Tatini, D.; Anselmi, E.; Cabrucci, G.; Acar, M.; Ninham, B. W.; Lo Nostro, P. Ionochromism, Solvatochromism and Effect of Dissolved Gases on the Spectral Properties of Bromothymol Blue. *J. Mol. Liq.* **2022** , *365* , 120196.
[3] Acar, M.; Tatini, D.; Romani, V.; Ninham, B. W.; Rossi, F.; Lo Nostro, P. Curious Effects of Overlooked Aspects on Urease Activity. *Colloids Surf. B Biointerfaces* **2025** , *247* , 114422.