Evaporation in bulk water, ethanol–water, and aroma–ethanol–water mixtures: interplay of geometry, composition, and interfacial processes

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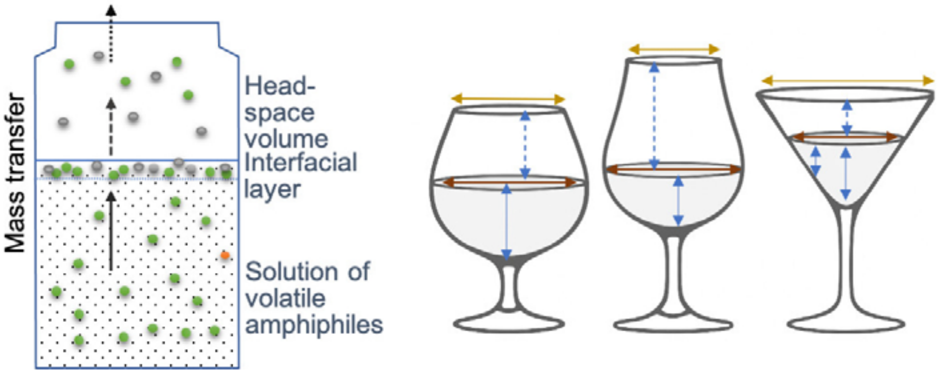
The evaporation of pure water and binary and ternary mixtures of ethanol and water containing aroma molecules will be discussed, with a focus on how composition and evaporation geometry influence evaporation dynamics and interfacial properties. Experiments were conducted in a controlled environment, employing gravimetric measurements and maximum bubble pressure tensiometry to track changes in weight, composition of the solution and surface tension over time. For pure water, the evaporation rate per unit area depends on the size of the exchange opening between the semi-closed headspace and open air. However, when normalised by liquid volume, this dependence on geometry is eliminated, indicating that gas-phase transport through the headspace is the rate-limiting step. In ethanol–water systems, the relative and absolute evaporation rates of the components are defined by alcohol concentration, surface-to-volume ratio, and liquid-phase diffusion path. Counterintuitively, for a 40 wt% ethanol solution, the largest evaporation area yields the highest absolute mass loss of ethanol; however, the greatest reduction in ethanol concentration occurs in the system with the smallest surface area [1]. Further results for ethanol solutions in the 5–80 wt% concentration range will be presented. In the ethanol–geraniol mixture, the surface tension remained nearly constant during evaporation, suggesting the presence of a persistent ethanol–geraniol interfacial layer that retards geraniol desorption [2]. We demonstrate that, in mixed solutions of volatile components, bulk-phase evaporation is governed by coupled gas-phase transport, liquid-phase diffusion, and interfacial kinetics, which are modulated by system geometry. These results pave the way for new approaches to studying beverages, where headspace volume and airflow set olfactory perception.

Keywords:
bulk-phase evaporation; ethanol–water mixtures; aroma compounds; diffusion-controlled evaporation; surface tension; mixed interfacial adsorption



Schematic representation of: (Left) co-adsorption in the interfacial layer and desorption into the gas phase of volatile amphiphiles in mixed aqueous solutions; (Right) examples of glasses for beverages. The lines indicate the geometric parameters, such as the diffusion paths, evaporation areas.

References:

[1]. Soboleva, O. A.; Tsarkova, L., Evaporation in bulk water, ethanol–water, and aroma–ethanol–water mixtures: interplay of geometry, composition, and interfacial processes. *Food Hydrocolloids* **2026,** *172* , 111937.
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