

The evolution of Europa's primordial hydrosphere composition during the accretion phase

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Europa, one of Jupiter's Galilean moons, will be intensively explored by two upcoming space missions : *JUICE* and *Europa Clipper*. The potential presence of a subsurface ocean below its ice crust raises great interest, especially regarding its potential habitability. Nevertheless, the composition of such subsurface ocean as well as its origin and evolution remain poorly constrained, particularly with respect to the volatile inventory of its hydrosphere.

The composition of Europa's subsurface ocean was likely influenced throughout time by the interactions taking place between its underlying rocky mantle and the water ocean. Such geochemical reactions impact the volatile inventory in the hydrosphere, the pH and the salinity. Moreover, it is possible that, shortly after accretion, Europa's surface temperature was hot enough to sustain an open-ocean in equilibrium with a primordial atmosphere, affecting the volatile distribution in the hydrosphere as well.

This study aims to explore how Europa's initial inventory of oceanic volatiles was affected during its early evolution by modelling the chemical evolution of its hydrosphere during accretion. It is assumed that the hydrosphere formed from the delivery of ice-rich planetesimals and solids. As Europa accumulates mass through accretion of surrounding material and bombardment by impactors, both its size and the volume of its hydrosphere increase. The surface temperature is calculated from a combination of impact heating and thermal input from the circumjovian disk (Bennacer et al. 2025). At each time step, we compute the composition of the primordial atmosphere and the evolving ocean, taking into account the water-rock interactions occurring both at the ocean-rocky mantle interface and between the rocks in suspension in the ocean and the volatile-rich water. Chemical equilibria associated with water-rock interactions are calculated using *PHREEQC*, while atmosphere-ocean exchange is modeled following the framework of Amsler Moulanier et al. (2025a). The transport of species throughout the water column is modelled as well, using a diffusion transport scheme.

Our results provide an overview of how Europa's accreted volatile inventory in the hydrosphere was influenced by the processes occurring during its early evolution. In particular, we highlight the key role of water-rock interactions in controlling the chemical evolution of the ocean, as well as its pH and salinity. In the context of the upcoming *JUICE* and *Europa Clipper* missions, the aim of such work is to draw the link between the formation scenario of Europa and the future measurements of volatile abundance in the exosphere, that could be indicative of its current subsurface ocean composition.