

How to detect sodium chloride on Europa's surface?

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Abstract

We will present results of a study characterizing the dehydration rate of hydrohalite as a function of temperature and UV irradiation. These results will help to understand the surface history and ocean composition of Europa by comparing remote sensing data from future Europa Clipper instruments to a systematic catalog of laboratory analogs.

1. Context

The analysis of evaporites on Europa's surface will remain the only way to probe its subsurface ocean in near future. The ocean composition, and therefore potential habitability, is assumed to be driven by geophysical/chemical processes on the seafloor.

Contrary to previous assumptions, recent observations indicate that chloride salts – rather than sulfate salts - could be Europa's most abundant non-ice surface species. Nevertheless direct evidence of salt species has been largely inconclusive.

The main problem in detecting salts is their spectral nature: most species are spectrally neutral across the visible and infrared wavelength range. The search has therefore to be concentrated on hydrated or radiolytic altered states of minerals.

The presence of hydrated salt minerals was proposed after the Galileo mission [1]. Hydrated states of salts usually display characteristic absorption features in the near- and mid IR range. The same is true for Raman scattering.

The only hint to the presence of salts in the visible range is the formation of color centers: a crystallographic defect where anionic vacancies are replaced by unpaired electrons, which leads to specific absorption bands. [2] suggested this mechanism as an alternative explanation for Europa's surface coloration, rather than sulfur chemistry.

This work will provide the means to interpret the data acquired by future missions to icy worlds such as Europa Clipper and JUICE. Sodium chloride on Europa's surface may be directly and unambiguously identified, if the characteristic spectral features of hydrohalite or color centers were observed. If features of hydrohalite were found, they would indicate a relatively young terrain.

2. Sample material

We selected sodium chloride dehydrate (hydrohalite; $\text{NaCl} \cdot 2\text{H}_2\text{O}$) as candidate material for our study since it is the only stable hydrated state of sodium chloride under Europa conditions and NaCl has been proposed to relatively abundant on Europa. Hydrohalite forms below -0.15°C under varied conditions of NaCl concentrations and water activity.

3. Results

Comparison studies show that the freezing rates of NaCl-brines play a crucial role in hydrohalite formation efficiency. Flash frozen droplets contain a significant lower concentration of hydrohalite than slowly frozen slabs. This finding might be important when comparing exposition scenarios on Europa such as vapour driven plumes or effusive flows.

By freezing a saturated brine volume, the hydrohalite crystals are embedded within the ice matrix. Initially the ice suppresses the dehydration process. Only when the ice starts to sublime at the surface, the non-ice component forms a residue layer of pure hydrohalite, which starts to dehydrate.

Additional to thermal exposition ultraviolet radiation accelerates the dehydration mechanism.

The formation of color centers has, so far, been observed by three different mechanisms: spontaneous in thermal vacuum at low temperatures ($<150\text{K}$), UV irradiation and electron irradiation. However,

timescales, necessary doses and penetration depth are different.

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References

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