DIELECTRIC PROPERTIES OF AMMONIA AND METHANOL SLURRIES. APPLICATIONS TO ICY MOONS.

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Introduction: The data provided by the Cassini [1] and Galileo [2] missions indicate that liquid water could exist under the icy crust of different icy moons. For this to happen, it has been proposed that these oceans and/or liquid reservoirs contain antifreezer compounds (salts, volatiles) that would allow the water to be liquid at low temperatures. The non-water ice materials detected on the surface of Europa related to tectonic features [3] and in the jets of Enceladus [4] support that they must be endogenous.

Possible compounds that could be present in aqueous oceans of the outer solar system would be volatiles, such as ammonia [5] and methanol [6]. Both compounds at low concentration in the H_2O-volatile system may form water ice slurries in a wide range temperature from the low melting point of these systems. Slurries with other hydrated solids may form at high concentration of the volatiles (Fig. 1).

The JUICE (ESA) and Europa Clipper (NASA) spacecrafts will depart to the Jupiter system to explore several of its icy moons in the coming years. Among the instruments they carry are RIME (JUICE) and REASON (Europa Clipper), radars with 9 MHz (both missions) and 60 MHz antennas (REASON only), with which they intend to study the internal structure of the Galilean moons. The possibility of finding liquid water with salts or volatiles, such as dissolved ammonia and methanol, is feasible, so it is necessary to study the dielectric properties of the mixtures to interpret their possible presence from the radar signals. Here we show the results for the binary systems with volatiles to be applied either in these moons or for future missions to Saturn´s moons, as Titan or Enceladus.

Methodology: Real permittivity (ε´) and electrical conductivity (σ) of 15 and 30 wt% ammonia aqueous solutions and in 15 and 70 wt% methanol aqueous solutions were measured (Fig. 1) in the laboratory.

A BDS80 Broadband Dielectric Spectroscopy system (Novocontrol) was used for these experiments. Regarding the experimental conditions, measurements have been carried out at atmospheric pressure, in a temperature range between 143 and 303 K and in a frequency range between 1 and 10^7 Hz.

The samples were frozen to 143 K from the initial 303 K at a rate of 5 K/min, stabilizing the temperature every 10 K to measure their properties throughout the defined frequency range.

Results: The electrical data obtained so far show that the slurries have clear patterns according to the phase composition (Fig 1).

In the cases with different concentration of ammonia, in the 15 wt% sample two stability regions within the phase diagram are recognized and three in the case of the 30 wt% sample (Table 1) in which their values show clear differences between them. Under conditions of having equivalent phase, the permittivity values of the sample with more ammonia content are higher, and different enough to not to be confused with the behavior of a different phase.

In the case of systems with methanol, the studied slurries are found in a range of different stability regions. For both methanol concentrations, the initial phase (higher temperature, liquid) has an identical real permittivity value. For the whole studied temperature range, the results for both compositions show clear differences for their permittivity values, in such a way that sample and stability region could be unequivocally identified.

With the obtained conductivity and permittivity data we have been able to calculate the attenuation of the signal at 10 kHz and 10 MHz (Eq 1):

$$\alpha \cong \sigma/(2c\varepsilon_0\sqrt{\varepsilon'} \quad \text{(Eq. 1)}$$

By representing the temperature evolution of the attenuation, changes can be observed when the studied solutions evolve from one phase to another one (Fig 2).

Conclusions: Water ice slurries with methanol and ammonia show different wave attenuation, real permittivity and electrical conductivity values depending on the fraction of the stable solid phase, which crystallize in the solution.

If volatile compounds in the aqueous system form slurries within the crust of icy moons, they could be identified by the contrast with the true permittivity value of pure water ice (3.0 to 3.1) [7].

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References: [1] Nimmo, F. et al (2007) Nature, 447, 289-291 [2] Zimmer, C. et al (2000), Icarus 147, 329–347 [3] Greeley R. et al. (1998) Icarus 135, 4 [4] Porco, C.C. et al (2006) Science 311, 1393 [5] Waite J. H. Jr. et al. (2006) Science 311, 1419 [6] Hodyss R. et al (2009) Geophysical Research Letters. 36, L17103 [7] Pettinelli, E. et al (2016) Earth and Planetary Science Letters 439 11–17

Sample	ε´	T (K)	Stability region
Ammonia 15 %	8.7	183	Water ice slurry
	2.6	163	Solid
Ammonia 30 %	51.3	233	Liquid
	12.3	183	Water ice slurry
	3.5	163	Solid
Methanol 15 %	39.8	273	Liquid
	15.1	223	Slurry
	3.0	153	Hydrated methanol slurry
Methanol 70 %	39.8	273	Liquid
	7.1	153	Hydrated methanol slurry

Table 1. Real permittivity values for the studied samples.

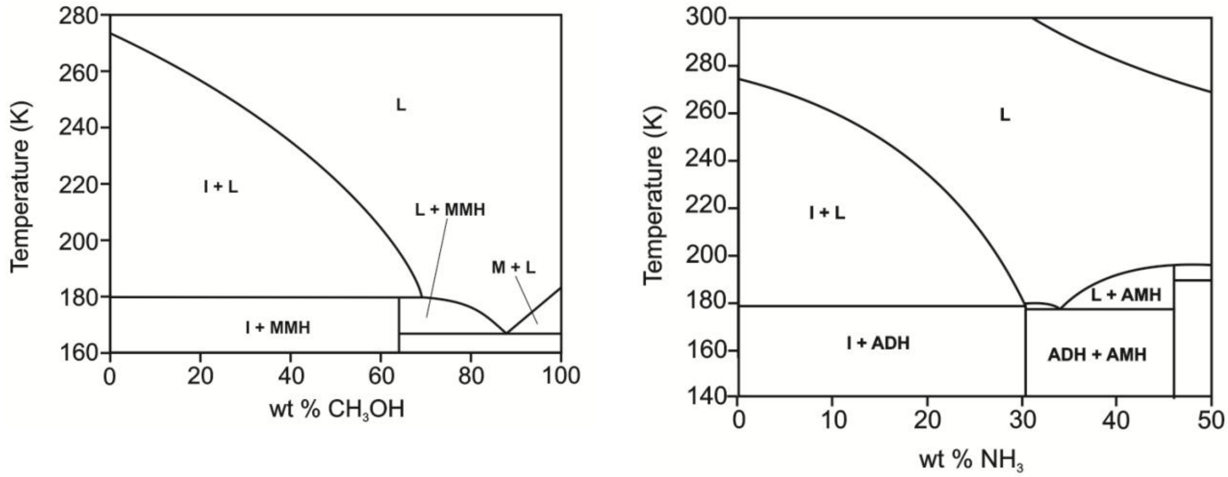

Figure 1. Phase diagrams for methanol (left) and ammonia (rigth) (MMH: methanol monohydrated, AMH: ammonia monohydrated, ADH: ammonia dihydrated)

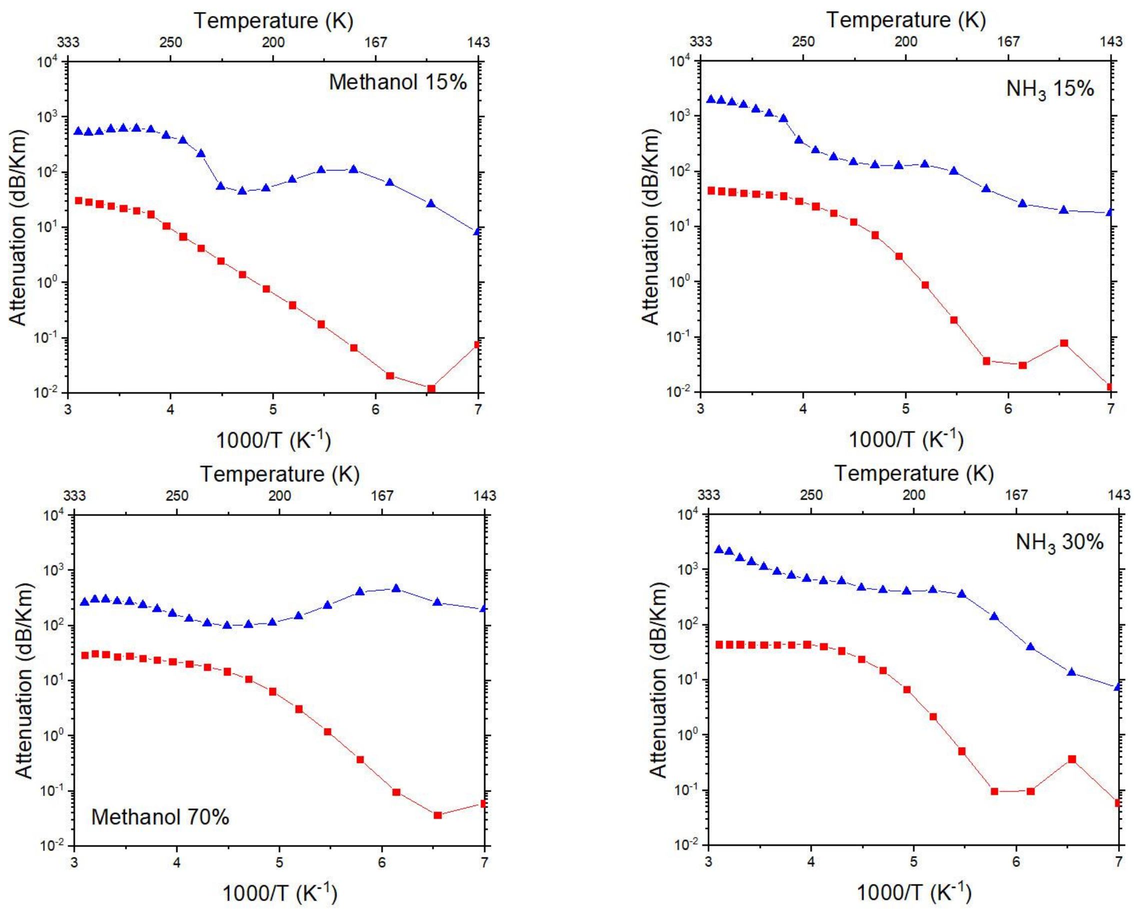

Figure 2. Attenuation at (10 kHz (red squares) and 10 MHz (blue triangles for the different solutions.