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Deliquescence of salt nanocrystals

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Deliquescence is the process by which a solid picks up water vapor from the atmosphere spontaneously and forms a solution. The deliquescence of a salt crystal is characterized by the deliquescence relative humidity (DRH) of the salt. Salt nanocrystals deliquesces differently than the bulk salt crystals. It has been shown in previous study that in comparison to the DRH of the bulk NaCl crystals (75.3% RH), the DRH of NaCl confined in nanoporous silica materials decreases from 73 to 58% as the pore size decreases from 89 to 8 nm [1]. Contrary to that, the DRH of levitated nano-sized NaCl crystal increases to 83% RH as the crystal size decreases to 6 nm [2,3].

The present work focuses on the deliquescence of salt crystals (NaCl and KNO₃) confined in mesoporous SBA-15 and MCM-41 silicas having pores upto 3 nm. Salt-silica-composite materials were prepared by impregnating the porous materials with salt-solutions avoiding over-filling of the available pore volumes. After drying, water vapor sorption isotherms of bulk salts, unloaded porous materials and the respective salt-silica-composites were determined. The experimental results reveal that the deliquescence of salt crystals confined in pores occurs not only far below the DRH of bulk salts but also much earlier than the capillary condensation in the unloaded porous materials. Even the capillary condensation in unloaded MCM-41 silicas is significantly lower than the DRH of bulk salts. Thus, in contrast to DRH of levitated salt nanocrystals, the DRH of confined nanosized salt crystals decreases with decreasing pore size.

A thermodynamic model approach, based on the combination of an ion-interaction model, the Laplace equation and the Kelvin equation, is used to predict the deliquescence of both levitated and confined nanosized salt crystals. The calculations agree well with the experimental results and reveal that the shift in the DRH is largely the result of the curvature of the vapor-liquid interface that is formed during deliquescence [1]. In contrast, the influence of Laplace pressure and size of the crystal on the solubility is small.

Participation

In-Person

References

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