SPHERES OR CUBES – HOW DO SALT DROPLETS DRY?

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Introduction
Spray drying is the industrial process of producing powders by rapidly evaporating sprays of droplets (micrometres in size) in a stream of hot gas. The process is highly popular in the pharmaceutical industry as well as in the production of food and personal care products. Whilst used globally, the drying process is still poorly understood. There are millions of droplets evaporating in a spray dryer in just a few seconds in highly turbulent flows, so it is impossible to study the drying process inside the chamber of the dryer.
Experimental measurements are needed!
Examples of spray dried products:
• Many drug powders (for inhalers), antibiotics and vaccines
• Infant milk formulations and food powders
• Washing detergent powders

Experimental Methods

1. The Electrodynamic Balance (EDB): Evaporation Rates
One single, charged droplet is levitated in an electrodynamic field, and the environmental conditions (temperature and humidity) can be varied to study droplet evaporation without contact with any surfaces.

2. The Falling Droplet Column (FDC): Dried Particles for Imaging
A stream of droplets evaporate as they fall down the column, so that dried particles are collected at the bottom. The shape and size of the particles can be determined by imaging them with a Scanning Electron Microscope.

3. Modelling: Understanding the distribution of components in a droplet
In a drying droplet, water evaporates from the surface and the solute (e.g. NaCl) remains. Will this lead to a build-up of solute at the surface?

Results
Using sodium chloride (NaCl) as a model system, we study how the evaporation rates of micron-sized aerosol droplets affect the final particle shape, as this is important for the particle properties. Using the EDB, we measure the evaporation rates:*

The evaporation rate of water from aqueous NaCl increases if the temperature is increased, or if the NaCl concentration is decreased, as these aspects increase the vapour pressure of water. How will this increase in evaporation rate affect the final particle morphology?

We model the internal concentration profiles in a droplet through the evaporation process. The model shows that the droplet with the fastest evaporation rates (red dataset) has a more steeply rising surface concentration:

Conclusion
Using a combination of evaporation measurements using the EDB, modelling, and imaging of dried particles from the FDC, we have demonstrated the link between changes in the evaporation rate and the shape of the dried particles. Even for a simple system of an aqueous solution of NaCl, the final particle shape can vary from a single, cubic crystal to a hollow sphere of multiple connected crystals.

This is highly important for the field of spray drying, where different particle structures formed from the evaporation of liquid droplets would strongly affect the properties of the resulting product, such as the solubility of infant milk powder or its shelf life.

References:
2. Ilerkar et al., J. Colloid Int. Sci., 2003, 265, 296

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We perform single-droplet evaporation experiments to better understand the complex processes occurring in a spray dryer.

* The evaporation rates were measured using the EDB. We also can determine when the evaporating droplet , because the elastic light scattering light and dark fringes...