Characterizing Nanometer sized particles suspended in a gas

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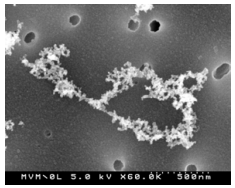
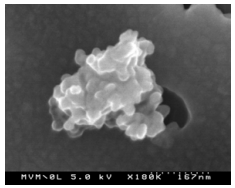
Particle research

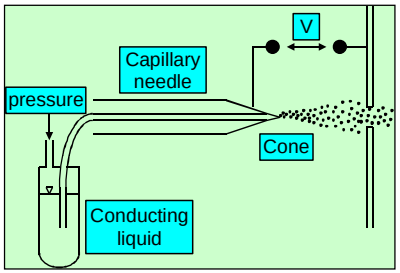


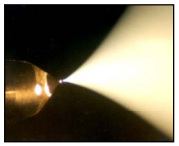


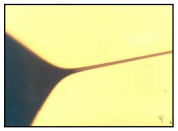
As scientific and industrial interest shifts towards smaller particles, and physical and biological sciences merge, the need arises to separate, characterize and sense particles or biomolecules having diameters from 1 to some 10 nm, in terms of their size, mass and shape. Generating size standards in this size range is also of vital interest.

Several instruments developed or perfected at Yale are able to perform such tasks, and are described here.

Aerosol Generation



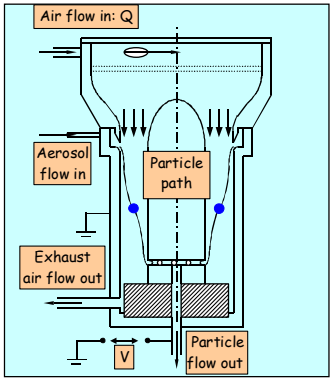


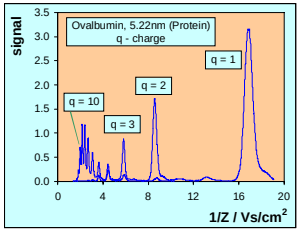


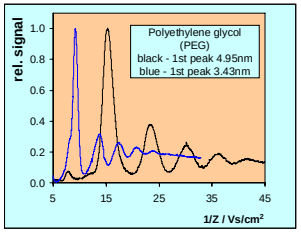
In our research most of the particles are produced via electrospray. A conducting liquid containing the particles (dissolved or suspended) is driven through a capillary, whose sharpened end is charged to a high voltage. The liquid meniscus turns into a cone, from whose tip droplets are generated. These droplets dry and only the non-volatile particles remains in the air. The singularly small size of these jets (~ 10 nm) enables forming particles smaller than 1 nm

Differential Mobility Analyzer- DMA

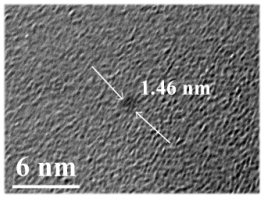
The electrical mobility of a charged particle is simply related to its size, and is readily measured by subjecting it to a combination of electric and flow fields, as in the DMA sketched below, where the main flow field is axially down, and the electric field is radial.







Our work has extended the traditional DMA size range from above some 5-10 nm down to less than 1 nm. Resolutions nearing 100 are made possible by running the DMA laminarly at Reynolds numbers approaching 10^5. This enables the isolation of small molecules, bio-molecules, industrial polymers (below left), etc., under atmospheric pressure conditions. Further analysis by mass spectrometry, electron microscopy (below), etc, is feasible.



TEM image of a single polyethylene glycol molecule with mass ~ 1000 amu (A. Nasibulin V.T.T. Finland)

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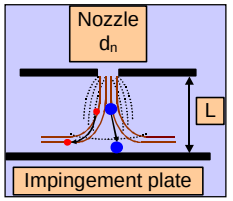
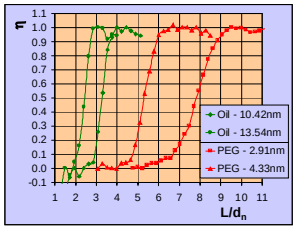
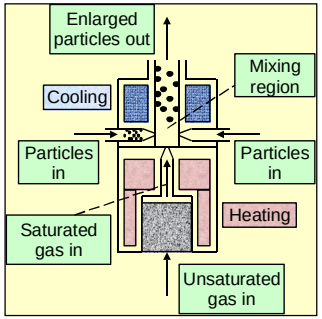
Hypersonic Impactor





The Hypersonic Impactor (HI) sizes particles according to their mass/drag. Particles above a critical size are captured on the plate, while smaller ones remain suspended. This critical size is controlled by the distance L between the nozzle and the impingement plate. The lower sizing range is about 2 nm for unit density materials.

Particle Size Magnifier (PSM)



In order to detect individual nanometer particles optically they must first be enlarged. This is implemented via vapor condensation on the particles. A saturated vapor is cooled down by mixing, becomes super-saturated, condenses on the particles, and enlarges them.

The PSM in our laboratory is the only instrument able to sense individual **subnanometer** particles. It is an original modification by former Yale Ph.D. M. Gamero of an earlier instrument of Prof. K. Okuyama (U. Hiroshima)