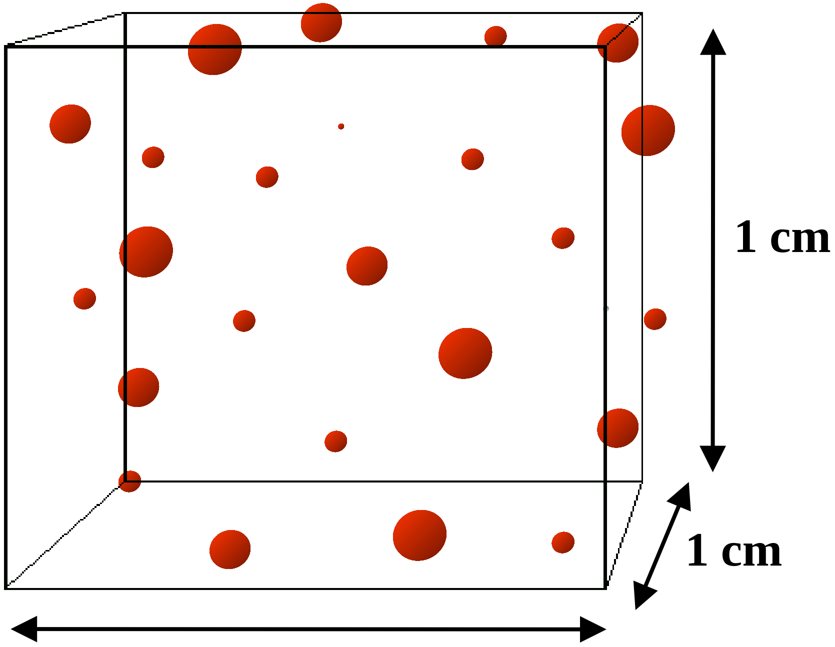
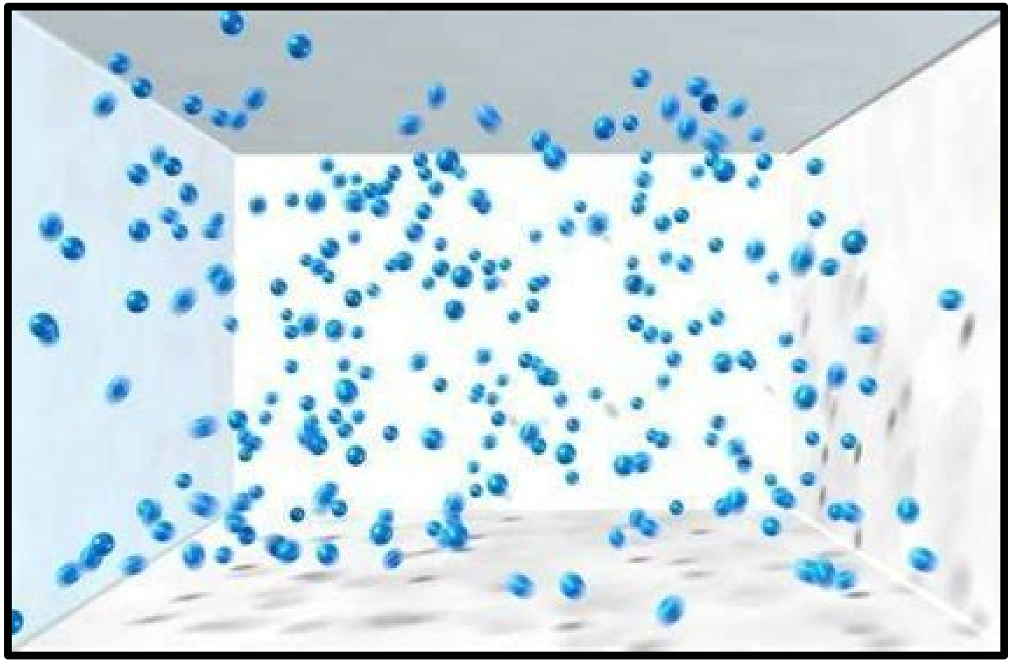
Nucleation: Particles + Water Vapor

Number of Aerosols per unit Volume

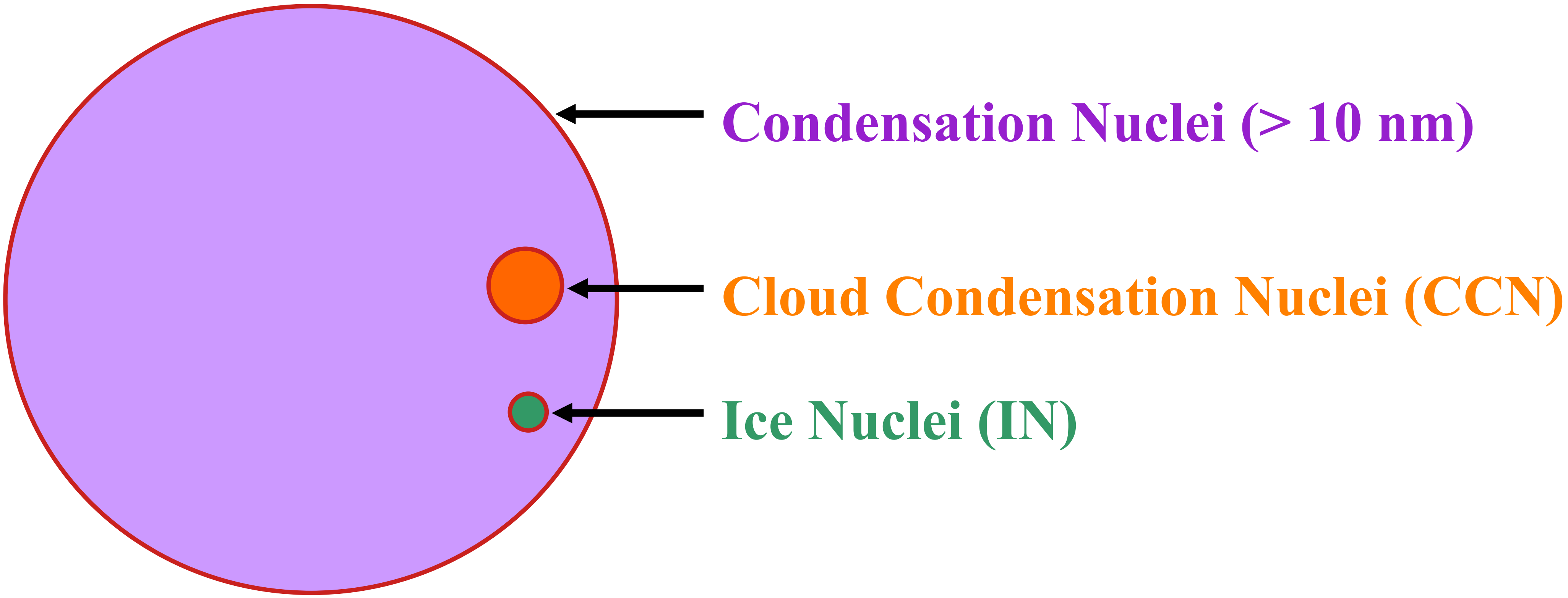


24 particles / 1 cm^3 = 24 cm^{-3}

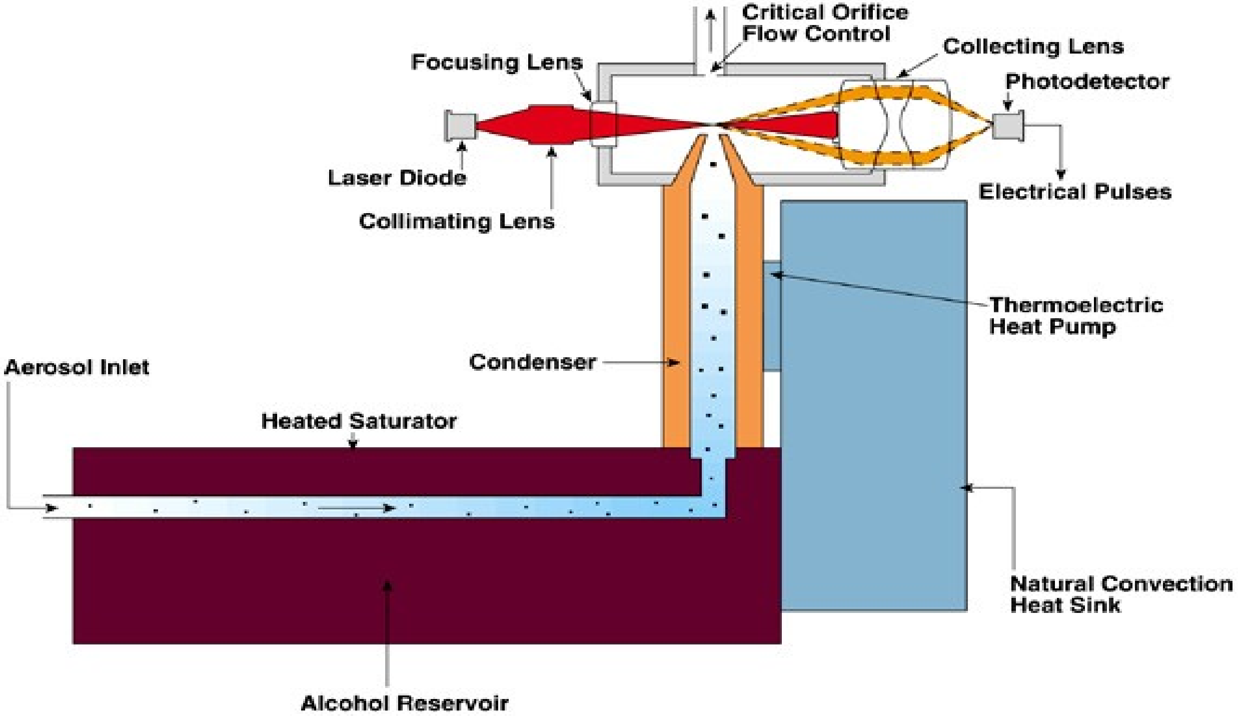
+



Relative Concentrations

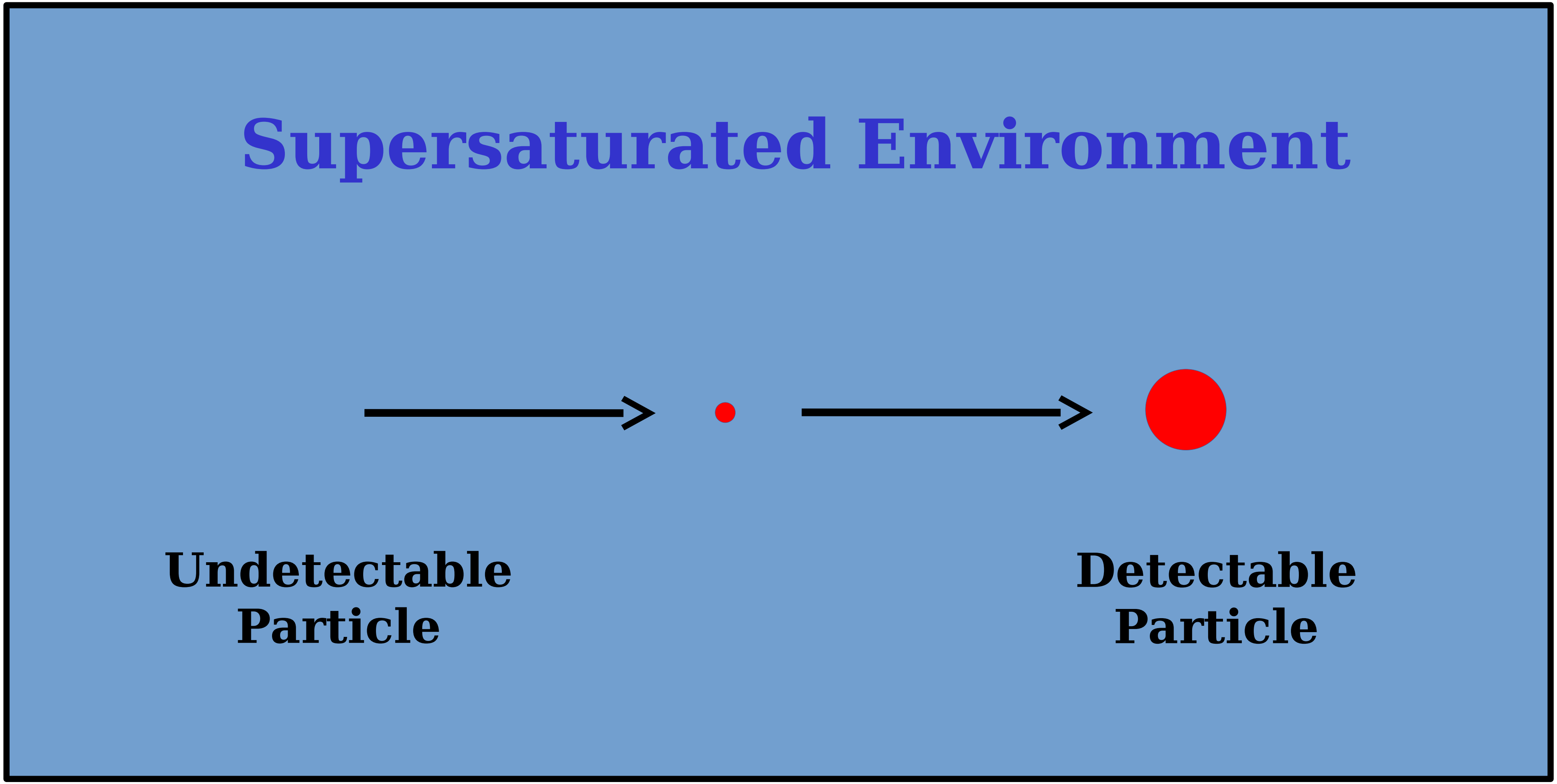


Condensation Nucleus Counter



Alcohol vapor condenses onto particles which create droplets large enough to be detected one at a time by an optical particle counter. Upon entering the instrument, the air sample passes through a saturation block where alcohol evaporates saturating the flow. The air sample next enters a condenser tube which cools the air sample. Cooling of the air sample creates a supersaturated environment and the alcohol condenses onto particles, regardless of particle composition.

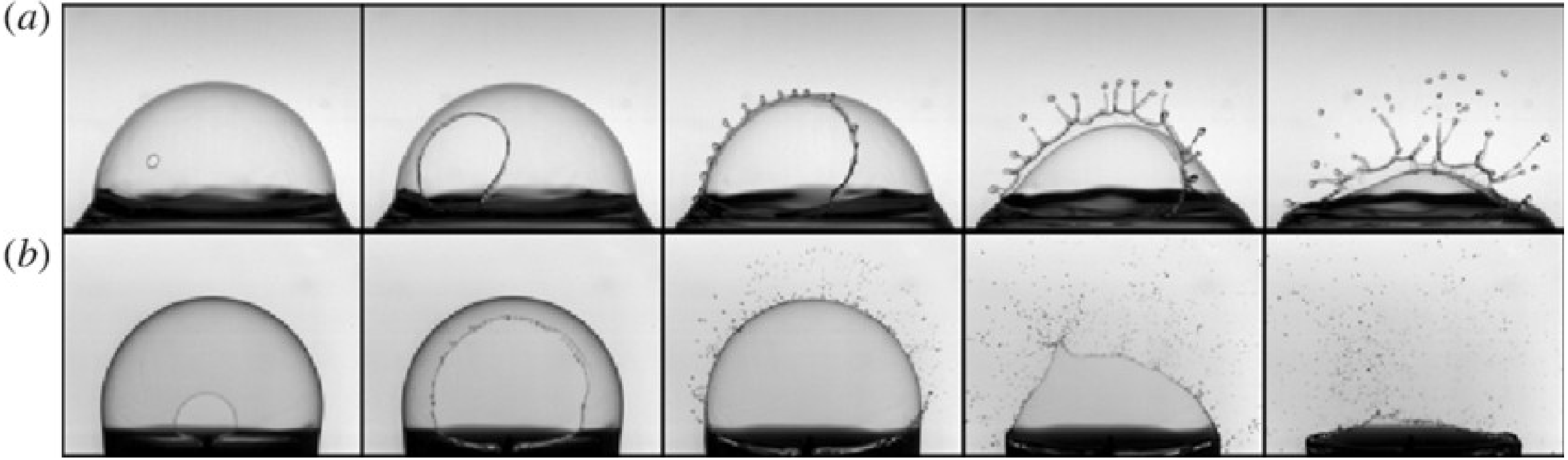
Grow Small (>10 nm) Aerosols to Detectable Size



Cloud Condensation Nuclei (CCN)

- Hygroscopic substances such as sodium chloride or ammonium sulfate make good CCN.
- Larger particles are generally better CCN than small ones.

<u>Sources</u>



- Dust
- Smoke
- Gas to Particle Conversion

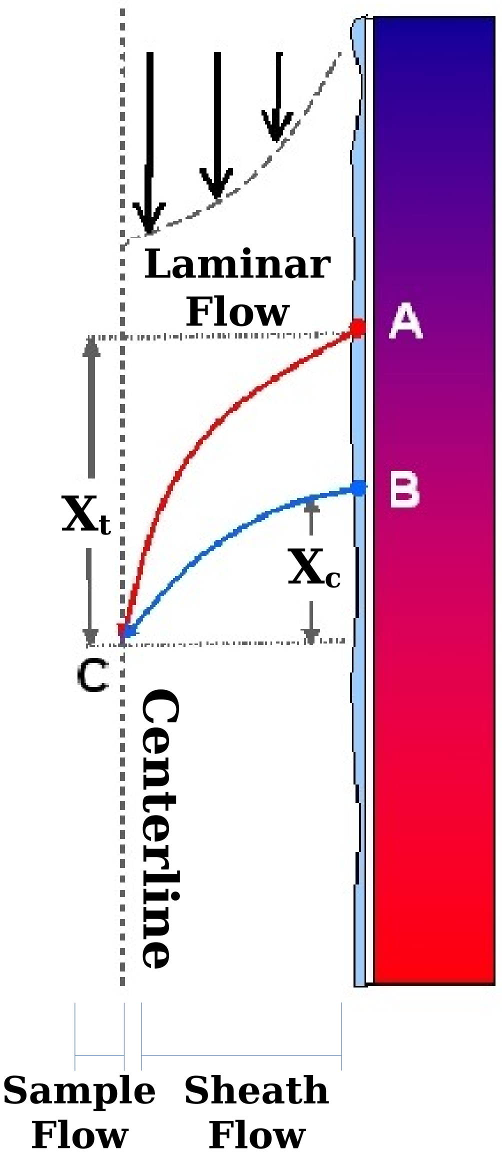
Cloud Condensation Nuclei Measurement

- Expansion Chambers
- Gradient Diffusion Chambers

Water vapor diffuses from the chamber walls inward more quickly than heat.

The unit operates at a single supersaturation, because the temperature and water vapor gradient along the wetted walls are approximately constant.

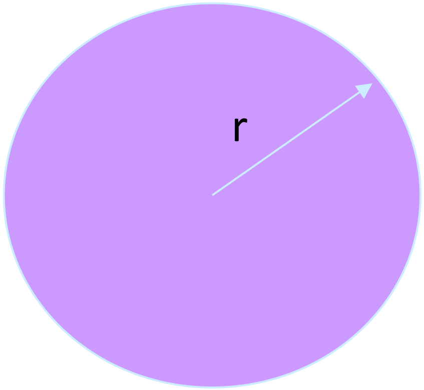
The centerline supersaturation depends on the temperature difference between the top and bottom of the column, the flow rate and the absolute pressure in the column.



Growth of Droplets

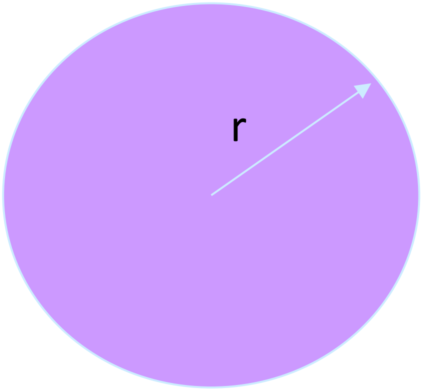
- In order to get condensation, the air must be slightly supersaturated with respect to the surface upon which the condensation will occur.
- We know what that equilibrium value is if the surface is flat and the water is pure (Clausius-Clapeyron relationship).

- Curvature Effect
  - Water molecules at surface can escape more easily
- Solute Effect



Effect of Curvature

- Effect of curvature is to enhance the equilibrium vapor pressure by a factor of 1/r.
- Small droplets have a difficult time to keep from evaporating.
- This is the primary reason for the fact that large aerosols make better CCN.

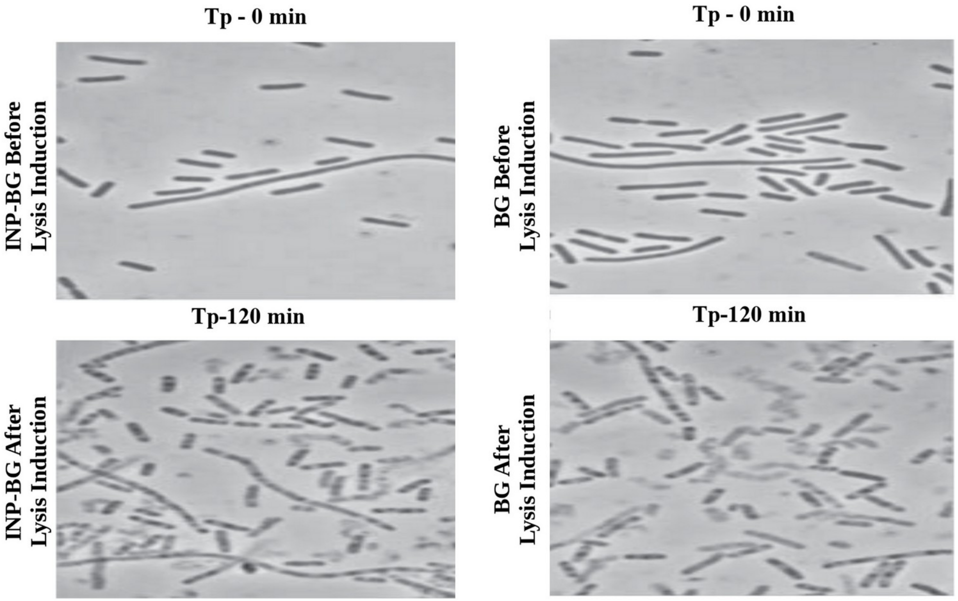


Ice Nuclei (IN)

- The freezing process requires a starting point.
- Once the starting point is established, the freezing process proceeds rapidly.
- The starting point is normally on a solid particle referred to as the “ice nucleus”.
  - High-speed imaging of ice nucleation in water proves the existence of active sites – See Videos

Sources Ice Nuclei

- Certain Types of Clay
- Certain Bacteria



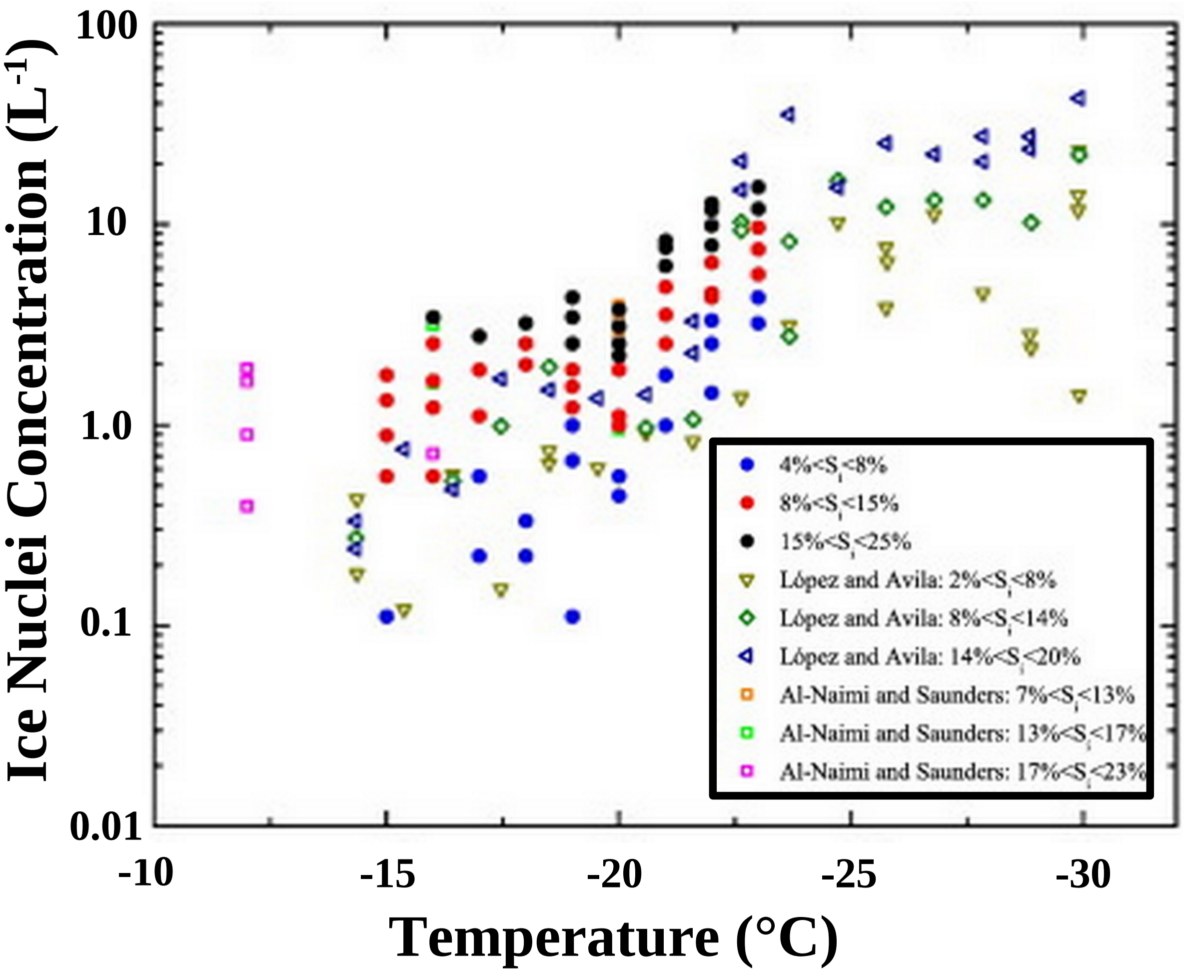
Images of the E. Coli C41 fabricated organic ice nuclei (OIN).

Nucleation

- Homogeneous Nucleation
- Heterogeneous Nucleation (Supercooled Droplets)
  - Similar in concept to supersaturation.
  - Statistical process.
  - A supercooled drop will freeze after a long enough time.

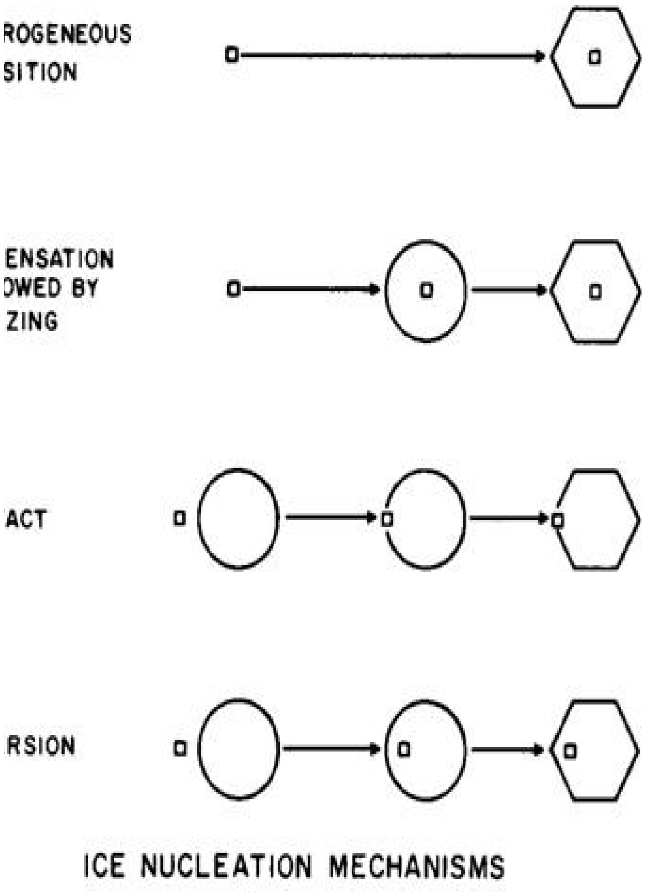
Effectiveness of Ice Nuclei

- Effectiveness is often measured by “threshold temperature”.
- Threshold temperature is when 1 in 10,000 produce an ice crystal.
- Different substances have different threshold temperatures ranging from about -5 to -40 °C.



Activation of Ice Nuclei

- Deposition (Sublimation)
- Condensation-freezing (Absorption)
- Contact Nucleation
- Immersion (Bulk Freezing)



Concentration of Ice Nuclei

- Depends upon temperature, ice nuclei concentrations are commonly measured at -20 °C.
- At -20 °C concentrations are often 10^3 m^{-3} or lower. (Cloud droplet concentrations are typically of the order of 10^8 m^{-3})
  - Important point in most weather modification programs.