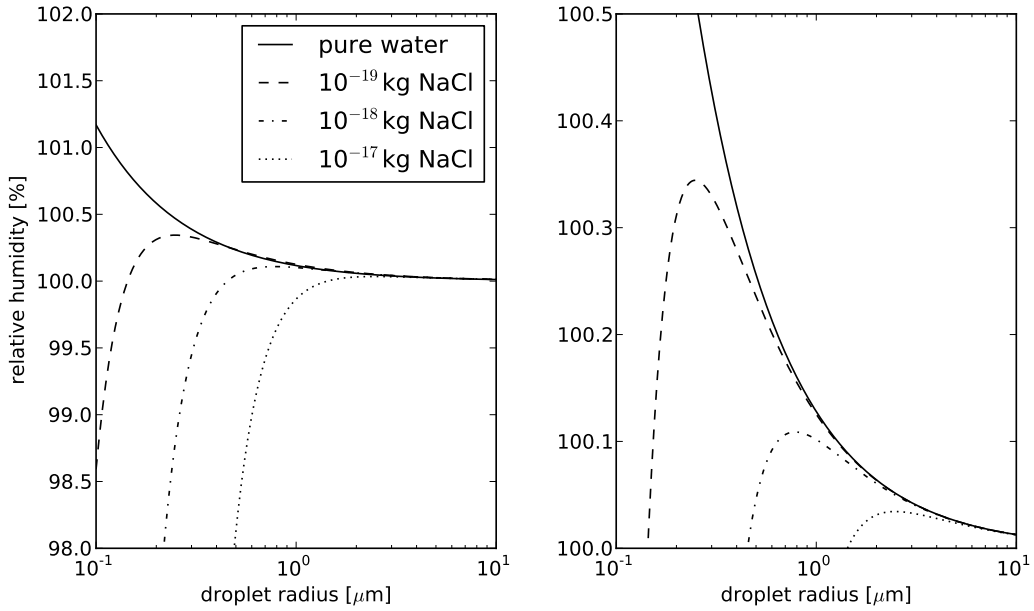
Cloud microphysics - Exercises 1

1. Use the Köhler curves shown in the figure to estimate:



   (a) The radius of a droplet that will form on a sodium chloride particle of mass 10^{-18}kg in air that is 0.1% supersaturated.

   (b) The relative humidity of the air adjacent to a droplet of 0.04 μm that contains 10^{-19}kg of dissolved sodium chloride.

   (c) The critical supersaturation required for a sodium chloride particle of mass 10^{-19}kg to grow beyond the haze state

   (d) What is the difference between the droplets formed in (a) and (b)?

2. Show that for a very weak solution droplet ($m \ll \frac{4}{3}\pi r^3 \rho' M_s$), the Köhler equation

$$\frac{e}{e_s} = \left(\exp\frac{2\sigma'}{n'kTr}\right)\left(1+\frac{imM_w}{M_s\left(\frac{4}{3}\pi r^3\rho' - m\right)}\right)^{-1}$$

   can be written as

$$\frac{e}{e_s} \approx 1 + \frac{a}{r} - \frac{b}{r^3}$$

   where $a = 2\sigma'/n'kT$ and $b = imM/\frac{4}{3}M_s\pi\rho'$.
   What is your interpretation of the second and the third terms on the right hand side of this expression? Show that in this case the peak in the Köhler curve occurs at

$$r \approx \sqrt{\frac{3b}{a}} \qquad \text{and} \qquad \frac{e}{e_s} \approx 1 + \sqrt{\frac{4a^3}{27b}}$$

3. A drop with an initial radius of 100 μm falls through a cloud containing 100 droplets per cubic centimeter that it collects in a continuous manner with a collection efficiency of 0.8. If all the cloud droplets have a radius of 10 μm, how long will it take for the drop to reach a radius of 1 mm? You may assume that the fall speed v (in m/s) of a drop of radius r (in meters) is given by $v=6\cdot10^3 r$. Assume that the cloud droplets are stationary and that the updraft velocity is negligible.

4. If a raindrop has a radius of 1 mm at cloud base, which is located 5 km above the ground, what will be its radius at the ground if the relative humidity between cloud base and ground is 60%? (Assume that G_l=700 $\mu m^2 s^{-1}$ and the same fall speed as in Ex. 3)

5. A cloud is cylindrical in shape with a cross-sectional area of 10 km^2 and a height of 3 km. All of the cloud is initially supercooled and the liquid water content is 2 gm^{-3}. If all of the water in the cloud is transferred onto ice nuclei present in a uniform concentration of 1/liter, determine the total number of ice crystals in the cloud and the mass of each ice crystal produced. If all the ice crystals precipitate and melt before they reach the ground, what will be the total rainfall produced?