Cloud Physics Lab
LAB 6: Formation of Cloud Droplets – part (2)

Purpose:

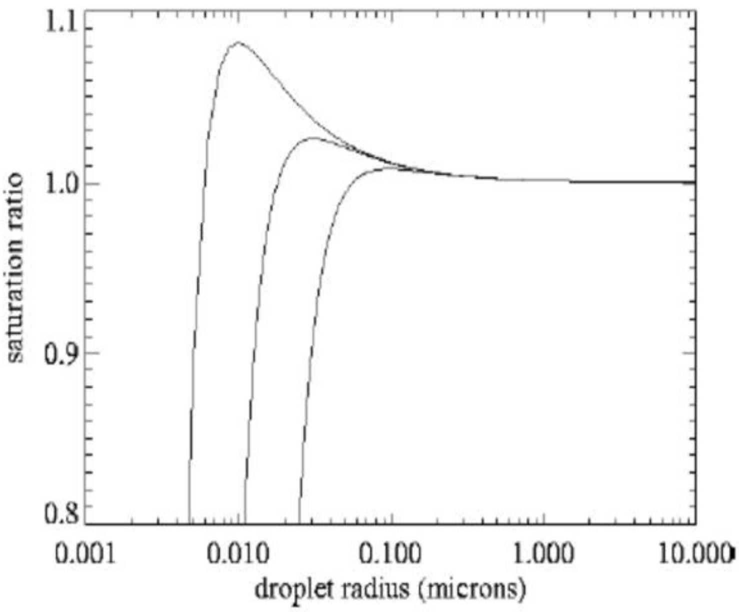
Study Kohler Curve and calculate the critical radius of cloud droplet and critical saturation ratio.

Theory:

- The curvature effect increases the saturation vapor pressure and has the greatest impact for small droplets.
- The solute effect decreases the saturation vapor pressure and also has the greatest impact for small droplets.
- Which effect "wins" depends on the droplet size and on the amount of solute present.
- The combined effects are expressed by applying the correction from equation (5) to the equilibrium saturation ratio equation (3) from lab 5 to get:

$$S_{eq} = \left[1 - \frac{b}{r^3}\right] \exp(a/r) \tag{1}$$

- A plot of S_{eq} for a solution containing three different amounts of solute (each curve differs in solute mass by a factor of 10) is shown below. The tallest curve is for the least amount of solute.



- A plot like that shown above is referred to as a Kohler curve.
- Making use of the approximation that for small x, $e^x \approx 1 + x$, we can write:

$$S_{eq} \cong 1 + \frac{a}{r} - \frac{b}{r^3} \tag{2}$$

- The radius at which the Kohler curve is a maximum can be found by taking $\partial S/\partial r$ and setting it equal to zero. This radius is called the critical radius, r^*, and the saturation ratio at this point is called the critical saturation ratio, S^*. They have values of:

$$r^* = \sqrt{3b/a} \tag{3}$$

$$S^* = 1 + \sqrt{4a^3/27b} \tag{4}$$

- The critical radius is of fundamental importance for cloud droplet growth.
- At radii below the critical radius $(r < r^*)$ the droplet are in stable equilibrium.
  If S increase the droplets will grow to a larger size and then stop.
  If S decrease the droplets will shrink to a smaller size and then stop.
  Droplets at radii below the critical radius are called haze particles.

- At radii above the critical radius $(r > r^*)$ the equilibrium is unstable, and the droplets will spontaneously grow larger. Even though S is not increasing.
  Droplets whose radius equals the critical radius $(r = r^*)$ are said to be activated.

Methodology:

1. Run the Matlab script *Kohler.m* to plot a graph of saturation ratio versus cloud droplet radius for different values of NaCl mass (ms) and calculate the critical radius and critical saturation ratio (assume cloud temperature is 0 ^oC)

Mass of NaCl, ms (g)	r^* (micron)	S^*
2e-18		
4e-18		
6e-18		

2. Run the Matlab script *Kohler.m* to plot a graph of saturation ratio versus cloud droplet radius for different values of $(NH_4)_2(SO_4)$ mass (ms) and calculate the critical radius and critical saturation ratio (assume cloud temperature is 0 ^oC).

Mass of $(NH_4)_2(SO_4)$, ms (g)	r^* (micron)	S^*
2e-18		
4e-18		
6e-18		

3. Discuss your results.