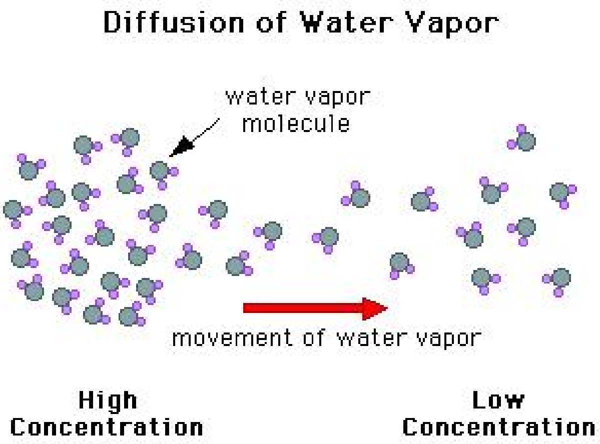
Cloud Physics Lab
LAB 7: Droplet Growth by Diffusion - Part(1)

Purpose:

Calculate the growth rate of cloud droplets by diffusion.

Theory:

The continued growth of a cloud droplet, once condensation has started, is initially governed by the diffusion of the water vapor molecules toward the droplet. Diffusion is the process of molecules moving from regions of higher concentrations to regions of lower concentrations. At the surface of a droplet, water vapor is simultaneously condensing and evaporating. When the concentration of water vapor molecules is higher some distance from the droplet than it is at the droplet surface, the water vapor in the air diffuses toward the droplet, condenses onto the droplet, and the net effect is droplet growth. Two phenomena which influence the growth that occurs by diffusion are the curvature effect and the solution effect.



- A somewhat simplified, though not as accurate, set of growth rate equations is**:**

$$R\frac{dR}{dt}=\frac{\left(S-1-\frac{a}{R}+\frac{b}{R^3}\right)}{F_k+F_d} \qquad (1)$$

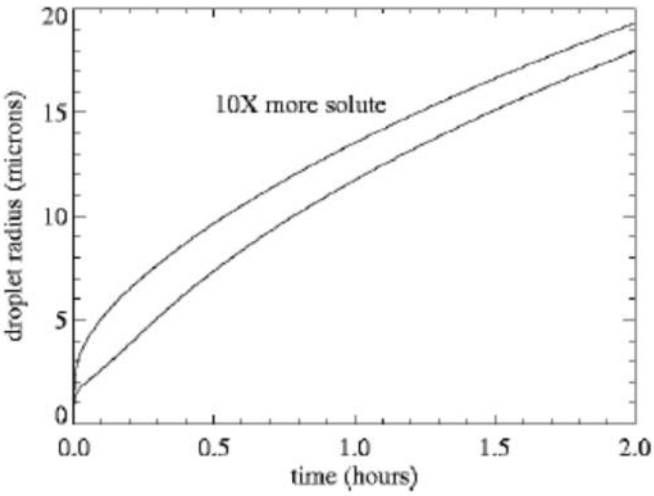
where:

$$F_k = \left(\frac{L}{R_v T} - 1\right)\frac{L\rho_L}{KT} \qquad (2)$$

$$F_d = \frac{\rho_L R_v T}{D e_s(t)} \qquad (3)$$

Note: These equations were developed in the physics of cloud, by maxson (1971).

- The figure below shows droplet radius as a function of time calculated using equation (1) for a droplet of initial size of 0.75µm with NaCl as the solute. The curves are for a temperature of 273K. the bottom curve is for a solute mass of 10^{-14} grams, and the top curve is for a solute mass of 10^{-13} grams.



- The droplet with more solute initially grows at a faster rate; however, later the growth rates become comparable.
- Note how slow this diffusional growth is.
    - It would take approximately 12 hours to grow a 50 µm droplet.
    - It would take approximately 44 hours to grow a 100 µm (0.1mm) droplet, which is the minimal size for a droplet to be able to fall and reach the ground without evaporating.

Evaporation of droplets

- Once a droplet falls from a cloud it enters an unsaturated environment $(S < 1)$. In this case, the droplet will begin to evaporate**.**
- The shrinking of the droplet is also governed by equation (1):

$$\frac{dR}{dt} = \frac{1}{R}\frac{\left(S - 1 - \frac{a}{R} + \frac{b}{R^3}\right)}{F_k + F_d} \qquad (4)$$

Only now S is less than 1 so that dR/dt is negative.

- A small droplet will evaporate very quickly and disappear.
- Larger droplets will last longer.
- Droplets larger than 0.1 mm in radius have a good chance of reaching the ground, while those that are smaller will likely evaporate. Therefore, the cutoff between cloud droplets and precipitation is taken as $r = 0.1mm$.

Methodology:

1. Runthe Matlab script *droplet.m* to plot the growth rate of cloud droplet for different values of saturation rate assuming the following cases:

Solute Type	Mass (x10^{-16}g)	Cloud temperature (ºC)
Sodium Chloride (NaCl)	2	0
	4	0
Ammonium Sulfate $(NH_4)_2(SO_4)$	2	0
	4	0
Sodium Chloride (NaCl)	2	5
	4	5
Ammonium Sulfate $(NH_4)_2(SO_4)$	2	5
	4	5

Note : enter the mass just as a number (2 or 4).

2. Discuss your results.