ATM515 **Aerosol Physics**, Fall 2025

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Homework # 3 (due date Oct. 8)

1. (15 points) Consider a 0.01 μm-diameter sulfuric acid-water droplet at 60% relative humidity. (a) What is the H_2SO_4 mass fraction in the solution? (b) What is the size of the droplet if all the water were removed? (c) What is the size of this droplet at 90% RH? (d) What is the increase in the equilibrium H_2SO_4 vapor pressure over the curved droplet surface over that for the corresponding flat surface?

2. (15 points) Calculate the number of molecules in the critical clusters, size of critical clusters, and nucleation rates for water under the following temperatures (T) and supersaturation ratios (S):

   (1) T=215 K, S=2, 5, 8
   (2) T=250 K, S=2, 5, 8
   (3) T=285 K, S=2, 5, 8

   Comment on the results with regard to the efforts of T and S on nucleation rates. Attach the hardcopy of the excel sheet to show your work.

   The dependence of water vapor saturation pressure on temperature can be expressed as: $p_w = 6.1121\ e^{(18.678 - t/234.5)\,t/(257.14 + t)}$ where t is temperature in ºC and p_w is in hpa. The values of water surface tension can be assumed to be 84, 79, 74 erg/cm^2 at T=215, 250, 285 K, respectively. The volume of one water molecule is 3×10^{-23} cm^3.

3. (20 points) Based on the nucleation rate lookup tables for H_2SO_4–H_2O binary homogenous nucleation (BHN), H_2SO_4–H_2O–NH_3 ternary homogeneous nucleation (THN), H_2SO_4–H_2O-ion binary ion-mediated nucleation (BIMN), and H_2SO_4–H_2O–NH_3-ion ternary ion-mediated nucleation (TIMN) available at https://gmd.copernicus.org/articles/13/2663/2020/,

   (1) calculate and plot the dependence of BHN and BIMN rates as a function of H_2SO_4 gas-phase concentration (suggested range: 5E5 cm^{-3} to 5E8 cm^{-3}) under three typical conditions: (I) stratosphere (T=210 K, RH=0.6%, particle surface area =1 μm^2/cm^3), (II) upper troposphere (T=230 K, RH=50%, particle surface area =10 μm^2/cm^3), and (III) near surface (T=280 K, RH=80%, particle surface area =50 μm^2/cm^3). For BIMN, assume ionization rate of 10 ion-pairs cm^{-3}s^{-1}. Comment on the results regarding key parameters controlling BHN and BIMN rates in the atmosphere.

   (2) calculate and plot the dependence of THN and TIMN rates as a function of NH_3 gas-phase concentration (suggested range: 1E8 cm^{-3} to 1E12 cm^{-3}) under two typical conditions in the boundary atmosphere: (I) T=295 K, RH=80%, [H_2SO_4]=3E7 cm^{-3}, and particle surface area =50 μm^2/cm^3; (II) T=275 K, RH=80%, [H_2SO_4]=3E7 cm^{-3}, and particle surface area =50 μm^2/cm^3. For TIMN, assume ionization rate of 10 ion-pairs cm^{-3}s^{-1}. Comment on the results regarding the effect of T and [NH_3] on THN and TIMN rates in the atmosphere.