ENV-413: Thermodynamics of the Earth systems

Exercise session for Lecture 10

4. Consider a two-component system consistent of H_2O and NaCl. Write the Gibbs phase rule for this two-component system.

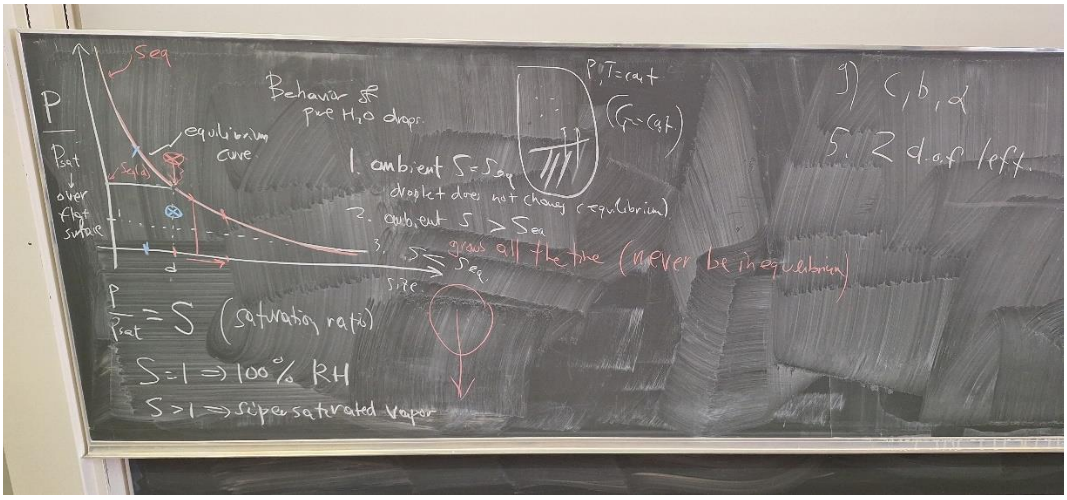
5. To conveniently represent the phase diagram on a graph, we can eliminate one degree of freedom if we examine the system only at constant pressure. For the two-component system at constant pressure, what is the maximum number of thermodynamic degrees of freedom for this system?

9. Matching:

________________	latent heat of fusion	a. 677 cal g^{-1}
________________	latent heat of vaporization	b. 597.3 cal g^{-1}
________________	latent heat of sublimation	c. 77.7 cal g^{-1}

10. During a phase change from liquid to vapor, state whether the following variables increase, decrease, or remain the same

Temperature	______________________
Pressure	______________________
Specific Volume	______________________
Entropy	______________________
Enthalpy	______________________
Gibbs energy	______________________



1. Nucleation of a pure phase of one component is referred to as
a) homogeneous
b) heterogeneous

2. Most of the nucleation processes in the atmosphere is:
a) homogeneous nucleation
b) heterogeneous nucleation

Surface tension work

3. Write an expression for surface tension work

$dW = \sigma dA$

4. What are the units for surface tension?

energy / surface $(J\,m^{-2})$ or $(N\,m^{-1})$

5a. The effect of surface tension on the internal energy of a droplet is (greater than, less than, the same) for a smaller drop.

As drop becomes larger → surface tension effect on u(arg) is smaller.

6a. How much work is required to break a 1 cm cube of water into drops with radius 10 μm? (use surface tension 0.076 N m^{-1}.) → $\Delta W = \sigma \Delta A$ ← difference in droplet area before and after splitting.

Surface area of 10μm drop: $4\pi r^2 = 4\pi (10\times10^{-6})^2 = 1.256\times10^{3}\times10^{-12} =$
$= 1.256\times10^{-9}\, m^2$

Surface area of cube 1cm3 $= 6\times1\,cm^2 = 6\times(10^{-2})^2 = 6\times10^{-4}\, m^2$

Volume of 10μm drop $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(10\times10^{-6}\right)^3 = 4.18\times10^{3}\times10^{-18} =$
$= 4.18\times10^{-15}\, m^3$

# of drops: $\frac{10^{-6} m^3}{4.18\times10^{-15}} = 2.392\times10^{8}$

$dW = \sigma \times dA$ ~ $\Delta W = \sigma\Delta A = 0.076\times(2.392\times10^{8}\times1.256\times10^{-9} - 6\times10^{-4}) = 2.28\times10^{-2} J$

16. Refer to Fig. 5.3, which is a graph of Kelvin's equation

$$r^* = \frac{2\sigma_{lv}}{\rho_l R_v T \ln S} \quad (5.14a)$$

see (*)

a) Has a drop with radius 1 x 10^{-3} μm and S=1.5 been activated (i.e. will it grow spontaneously)?

$r^* = \frac{1.10\times10^{-9}}{0.4} = 2.75\times10^{-9} m = 2.75\times10^{-3} \mu m$ $r < r^* \Rightarrow$ no growth.

b) Has a drop with radius 1 x 10^{-3} μm and S=4 been activated (i.e. will it grow spontaneously)?

$r^* = \frac{1.10\times10^{-9}}{1.38} = 0.8\times10^{-9} m = 0.8\times10^{-3} \mu m$ $r > r^* \Rightarrow$ spontaneous growth

17. The formation of pure water droplets requires a vapor pressure that is (less than, equal to, greater than) the saturation vapor pressure over a plane surface of pure water

18. If the relative humidity of the air is 100%, droplets of pure water will
a) evaporate b) grow further by condensation c) remain the same size

19. Are values of S=1.5 and S=4 observed in the atmosphere? What is a realistic maximum value of S that is observed in the atmosphere? No. realistic S = 1.001 − 1.01