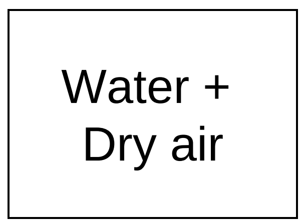
WEEK 7

Multiphase systems (cont.)

Gas-liquid systems: one condensable component

- Several components but only one can exist as a liquid at the process condition
- Two phases and two components: DF=2+2-2 = 2
- 3 intensive variables: T, P, y_{H2O}, but only two can be specified.



a) At time=0, system is at 75ºC and 760 mmHg, $p_{H2O} = 0$ (in gas phase).
b) Water molecule begins to evaporate
c) $p_{H2O} = y_{H2O}P$ increases since water molecule in gas phase increases
d) At some point, the rate at which water molecules enter the gas phase approaches zero.
e) No changes in the water composition in either phase

The gas is said to be saturated with water.

f) The water in the gas phase is referred as saturated vapor.

Raoult's law, single condensable species

- If a gas at T and P contains a saturated vapor whose mole fraction is yi (mole vapor/mole of total gas), and if this vapor is the only species that would condense if the temperature were slightly lowered , then the partial pressure of the vapor in the gas = pure component vapor pressure $p_i^*(T)$ at the system temperature.

- Raoult's law: $p_i = y_i \times P = p_i^*(T)$

- Page 250, Ex. 6.3-1

- <u>Superheated vapor</u>: $p_i = y_i \times P < p_i^*(T)$: A vapor present in a gas in less than its saturation amount is referred to as a "superheated vapor"

Raoult's law, single condensable species

- Gas has a single superheated vapor and is cooled at constant P, the temperature at which the vapor becomes saturated is referred to as the dew point of the gas:

  $$pi = yi \times P = pi^{*}(T_{dp})$$

- Difference between the temperature and dew point of a gas is called degree of superheat of the gas.

- Ex: 6-3.2 on page 251

- Page 253; Humidity

- Relative Saturation (Relative Humidity): Gas at T and P contains a vapor whose vapor pressure is $pi^{*}(T)$.

- Relative humidity (or saturation) = $S_r(or \quad h_r) = \frac{p_i}{p_i^{*}(T)} \times 100\%$

Raoult's law, single condensable species

- Molal saturation (Molal humidity):

$$S_M\,(or\quad h_M) = \frac{p_i}{P - p_i} =$$ (Moles of vapor)/(Moles of vapor-free (dry) gas)

$$S_a\,(or\quad h_a) = \frac{p_i M_i}{\left(P - p_i\right) M_{dry}} = \frac{Mass\quad vapor}{Mass\quad dry\quad gas}$$

- M_i: Molecular weight of vapor
- M_{dry}: Molecular weight of vapor-free (dry) gas

Raoult's law, single condensable species

- Percentage saturation (percentage humidity):

$$S_p(or \quad h_p) = \frac{S_M}{S_M^*} \times 100\% = \frac{\dfrac{p_i}{P - p_i}}{\dfrac{p_i^*}{P - p_i^*}} \times 100\%$$

- Page 254, ex. 6.3-3

6.4 Multicomponent gas-liquid systems

- 6.4b Raoult’s law and Henry’s law
- A is a substance in a gas-liquid system in equilibrium at T and P. Raoult’s law and Henry’s law provide a relationship between p_A (partial pressure of A in gas phase) and x_A (mole fraction of A in liquid phase): $p_A = y_A \times P = x_A\, p_A^*(T)$
- p_A^*: vapor pressure of pure liquid A at the temperature T
- y_A: mole fraction of A in a gas phase
- Raoult’s law valid when x_A is close to 1 (Liquid is almost pure A; similar substances)

6.4 Multicomponent gas-liquid systems

- Henry's law: $p_A = y_A \times P = x_A H_A(T)$
- $H_A(T)$ is the Henry's law constant for A in a specific solvent
- Henry's law valid when x_A is close to 0 (dilute solutions of A)
- Page 258, Ex. 6.4-2

Solutions of solid in liquids

- Solubility and saturation
- A solution is saturated with a particular species
- Pages 264 and 265, Ex. 6-5.1

HMK: **6.23 a, b**
6.25, 6.29