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CHEMICAL ENGINEERING REFRESHER PROGRAM

MASS TRANSFER

DIFFUSION

For 1-2: For the diffusion of solute A through a layer of gas to an absorbing liquid, with $y_A = 0.20$ and $y_{Ai} = 0.10$:

1. Calculate the transfer rate for one-way diffusion compared to that for equimolal diffusion. (in terms of percentage)
 - a. 16.2%
 - b. 18.0%
 - c. 15.3%
 - d. 20.0%
2. What is the value of y_A halfway through the layer for one-way diffusion?
 - a. 0.1212
 - b. 0.1716
 - c. 0.1515
 - d. 0.1155
3. Ammonia (A) being absorbed from air (B) into water is an example of
 - a. steady state equimolal diffusion
 - b. steady state diffusion in multicomponent mixtures
 - c. unsteady state equimolal diffusion
 - d. steady state unicomponent diffusion
4. The diffusivity of water in air at 100°F and 1atm in cm²/sec is?
 - a. 0.256
 - b. 0.273
 - c. 0.404
 - d. 0.581
5. The flux of A in unicomponent diffusion is greater than in equimolal diffusion because of
 - a. the molecular diffusion of A relative to a fixed point
 - b. the bulk motion of the phase
 - c. the concentration gradient of B is zero
 - d. the flux of A relative to the average molar velocity
6. Ammonia is diffusing through a stagnant gas mixture consisting of 1/3 nitrogen and 2/3 hydrogen by volume. The total pressure is 30 psia and the temperature is 30°F. The concentration of ammonia across the film which is 0.5mm thick drops from 10% to 5% ammonia by volume. Assuming the mass diffusivity of ammonia to be 0.229 cm²/sec, the rate of diffusion of ammonia expressed in lb/hr-ft² through the film is?
 - a. 8.93
 - b. 0.12
 - c. 2.83
 - d. 12.54

7. A tank containing water has its top open to air. The tank is cylindrical with diameter of 1m. The liquid level is maintained at a level 1m below the top of the tank. The diffusivity of water to air at 310K at 1atm is $0.273 \text{ cm}^2/\text{s}$. The vapor pressure of water at 310K is 10.73 kPa. How many moles of water are lost per hour at 310K if dry air is blown across the top of the tank?
- 0.165
 - 0.330
 - 0.34
 - None of these
8. It is a measure of the diffusive mobility of individual molecules in solution.
- eddy diffusivity
 - diffusion coefficient
 - mass transfer coefficient
 - thermal diffusion
9. Calculate the rate of diffusion of NaCl (in $\text{mol}/\text{m}^2\text{-s}$) across a film of water (non-diffusing) solution 1.5mm thick at 18°C when the concentrations on opposite sides of the film are 24 and 4 wt% NaCl respectively. The diffusivity of NaCl is $1.3\text{E-}5 \text{ cm}^2/\text{s}$ at 18°C . Densities of 24 and 4 wt% NaCl at 18°C are 1081 and 1027 kg/m^3 respectively.
- $3.7\text{E-}3$
 - $3.7\text{E-}4$
 - $8.2\text{E-}5$
 - $5.2\text{E-}7$
10. It represents the total mass transferred to mass transferred by molecular diffusion
- Sherwood Number
 - Schmidt Number
 - Reynolds Number
 - Nusselt Number
11. He and N_2 gas are contained in a conduit 5mm in diameter and a 0.1 m long at 298K and a uniform pressure of He at one end of the tube is 0.6 atm and 0.02 atm at the other end. Assuming equimolar countercurrent diffusion, the flux in $\text{kmol}/\text{s}\text{-m}^2$ is?
- $1.72\text{E-}5$
 - $2.44\text{E-}7$
 - $1.77\text{E-}6$
 - $1.22\text{E-}8$
12. A mixture of He and N_2 gas is confined in a pipe at 298K and 1atm total pressure which is constant throughout. At one end of the pipe at point 1, the partial pressure of He is 0.60 atm and at the other end at 0.2m is 0.20 atm. Calculate the flux of He in $\text{kmol}/\text{s}\text{-m}^2$ at steady state if the diffusivity of He in N_2 is $0.687\text{E-}4 \text{ m}^2/\text{s}$.
- $5.63\text{E-}4$
 - $5.63\text{E-}5$
 - $5.63\text{E-}6$
 - $5.63\text{E-}7$
13. Ammonia gas is diffusing at a constant rate through a layer of stagnant air 1 mm thick. Conditions are fixed so that the gas contains 50% by volume of ammonia at one boundary of the stagnant layer. The ammonia diffusing to the other boundary is quickly absorbed and the concentration is negligible at that plane. The temperature is 295 K and the pressure atmospheric, and under these conditions the diffusivity of ammonia in air is $0.18 \text{ cm}^2/\text{s}$. Calculate the rate of diffusion of ammonia through the layer.
- $5.15 \times 10^{-4} \text{ kmol}/\text{m}^2\text{-s}$
 - $6.23 \times 10^{-4} \text{ kmol}/\text{m}^2\text{-s}$
 - $2.18 \times 10^{-4} \text{ kmol}/\text{m}^2\text{-s}$
 - $4.53 \times 10^{-4} \text{ kmol}/\text{m}^2\text{-s}$
14. A rectangular tank 1 ft² in cross section and 6" depth is filled with ethyl alcohol solution in water at 50°F to within 0.75" of the top. A fan is blowing air at 50°F at 1atm over the tank. Alcohol concentration at the interface is 0.65 mole fraction. The diffusivity of ethyl alcohol is $0.417 \text{ ft}^2/\text{hr}$. How much alcohol will be lost (in lbmol/day) in one day by diffusion? Assume that alcohol level is maintained constant.
- 0.00056
 - 0.4517
 - 10.45
 - 31.24

HUMIDIFICATION

15. $0.6 \text{ m}^3/\text{s}$ (measured at STP) of gas is to be dried from a dew point of 294K to a dew point of 277.5K. Vapor pressure of water at 294K is $2.5 \text{ kN}/\text{m}^2$. Vapor pressure of water at 277K is $0.85 \text{ kN}/\text{m}^2$. What will be the volume of the gas after drying (measured at STP)?
- $0.59 \text{ m}^3/\text{s}$
 - $2.18 \text{ m}^3/\text{s}$
 - $4.52 \text{ m}^3/\text{s}$
 - $6.78 \text{ m}^3/\text{s}$
16. The temperature at which the moisture in humid air exerts a partial pressure equal to its vapor pressure is called the
- dry-bulb temperature
 - ambient temperature
 - critical temperature
 - dew point

For 17-18: Air at 100kPa pressure and a dry-bulb temperature of 93°C and wet-bulb temperature of 35°C is fed to a dryer. In the dryer, 0.03 kmol of water evaporates per kmol of air fed to the dryer.

17. If the vaporization of water in the dryer is adiabatic, calculate the wet-bulb temperature of the air leaving the dryer.
- | | |
|---------|---------|
| a. 27°C | c. 42°C |
| b. 35°C | d. 48°C |
18. Calculate the percentage saturation of the air leaving the dryer.
- | | |
|----------|----------|
| a. 30.1% | c. 54.3% |
| b. 41.7% | d. 65.1% |
19. An indication of the moisture content of ambient air is its
- | | |
|-------------------------|---------------------|
| a. dry-bulb temperature | c. ambient pressure |
| b. wet-bulb temperature | d. vapor pressure |

For 20-22: In an air-conditioning system, 1 kg/s air at 350 K and 10 per cent humidity is mixed with 5 kg/s air at 300 K and 30 per cent humidity.

20. What is the humidity of the resultant stream?
- | | |
|-----------------|-----------------|
| a. 0.5215 kg/kg | c. 0.0125 kg/kg |
| b. 0.2125 kg/kg | d. 0.1250 kg/kg |
21. What is the enthalpy of the resultant stream?
- | | |
|-------------|-------------|
| a. 45 kJ/kg | c. 54 kJ/kg |
| b. 67 kJ/kg | d. 34 kJ/kg |
22. What is the temperature of the resultant stream
- | | |
|---------|---------|
| a. 305K | c. 309K |
| b. 317K | d. 209K |
23. The relative humidity of air at a given temperature is the
- | |
|---|
| a. pounds of water vapor in one pound of dry air |
| b. the ratio between the actual temperature of the air and its dew point |
| c. the ratio between the volume of the water vapor in the air and the humid volume |
| d. the ratio of the partial pressure of the water vapor and the vapor pressure of water |

For 24-27: Given a mixture of air and water at 85°F dry bulb temperature and 68°F wet bulb temperature, calculate the following:

24. Percent relative humidity (using humidity chart)
- | | |
|--------|--------|
| a. 30% | c. 81% |
| b. 40% | d. 42% |
25. Heat of vaporization in BTU per lb water
- | | |
|---------|---------|
| a. 850 | c. 972 |
| b. 1046 | d. 1186 |
26. Vapor pressure of water in psia
- | | |
|--------|--------|
| a. 0.1 | c. 5.1 |
| b. 3.2 | d. 0.6 |
27. Partial pressure of water in psia
- | | |
|---------|---------|
| a. 0.25 | c. 2.14 |
| b. 1.44 | d. 3.88 |

DRYING

28. The portion of water in the wet solid that cannot be removed by the air in direct contact with the solid is called
- free moisture
 - final moisture content
 - equilibrium moisture content
 - critical moisture content
29. The rate of drying at constant rate period is 20 lbs/hr. 400 lbs of dry solid containing 300 lbs water enter the drier. If the critical free moisture is 0.05 (d.b.), the drying time to dry the material to 5% moisture (w.b.) is:
- 67.50 hrs
 - 14.00 hrs
 - 57.51 hrs
 - 23.67 hrs
30. Consider the drying operation with critical moisture content of 0.10 and an equilibrium moisture content of 0.005 and for a solid loading (dry basis) of 50 kg/m² with a constant drying rate of 5kg/m²-hr. The falling rate of drying is linear with moisture content. The drying time (in hrs) required to reduce an initial moisture content of 25% to a final moisture content of 2% is:
- 1.55 hrs
 - 1.75 hrs
 - 3.25 hrs
 - 4.55 hrs
31. A batch drier removes water from a solid material at a rate of 30 lb/hr during the constant rate period. Under the operating conditions, the critical free moisture content is 0.5 lb H₂O/lb dry solid, and the equilibrium moisture content is 0.04 lb H₂O/lb dry solid. The curve of drying rate versus moisture content may be assumed as a straight line during the entire falling rate period. Three hundred pounds of dry solid, containing 200 lb of water, enters the drier. How long will the total drying require if the final product contains 0.08 lb of water per lb of dry solid?
- 12.6 hrs
 - 1.27 hrs
 - 13.9 hrs
 - 19.3 hrs
32. One thousand kilograms per hour of a material with 30% moisture content (d.b.) is dried in a belt conveyor drier with a capacity of 50kg of bone-dry solid per meter of dryer. The total drying time is 5.3 hours. Estimate the length of the drier.
- 74.2 hrs
 - 81.5 hrs
 - 106 hrs
 - 98 hrs
33. The free-moisture content of the solid does not depend upon
- the vapor concentration in the gas
 - the amount of moisture in the solid
 - the nature of the solid to be dried
 - the nature by which heat is supplied
34. Wet solids are to be dried from 36% to 8% moisture in 5 hours under constant drying conditions. $X_{Tc} = 14\%$, $X_e = 4\%$. All moisture contents are on a dry basis. The additional time it will take to dry from 8% to 5.5% moisture under the same drying conditions is:
- 6.6 hrs
 - 1.6 hrs
 - 1.8 hrs
 - 5 hrs
35. The amount of water to be removed from 2,000 kg/hr of feed to be dried from 110% (d.b.) to 5% (w.b.) is ___ kg/hr.
- 998
 - 1000
 - 451
 - 910
36. Coffee extract containing 70% water is to be spray dried using air at 420 K in a 6-m diameter by 6-m high chamber with centrifugal disk atomizer. The capacity of the spray drier is ___ lb/hr of feed, if the final product will have a moisture content of 1% (w.b.).
- 20,500
 - 35,000
 - 40,500
 - 43,200
37. In drying at the falling rate period, the rate at which moisture is removed from the solid material
- increases with time
 - decreases with time
 - remains constant
 - no more drying takes place

38. Wet solids are to be dried from 40% to 10% in 5 hours under constant drying conditions. The critical moisture content is 20% and the equilibrium moisture content is 7%. All moisture contents are on a dry basis. The time needed to dry from 15% to 5% free moisture under the same drying conditions is
- | | |
|--------------|--------------|
| a. 3.42 hrs | c. 0.542 hrs |
| b. 1.846 hrs | d. 2.129 hrs |
39. 1 Mg of dry mass of a non-porous solid is dried under constant drying conditions in an air stream flowing at 0.75 m/s. The area of surface drying is 55 m². If the initial rate of drying is 0.3 g/m²s, how long will it take to dry the material from 0.15 to 0.025 kg water/kg dry solid? The critical moisture content of the material may be taken as 0.125 kg water/kg dry solid.
- | | |
|-------------|-------------|
| a. 3.04 hrs | c. 5.42 hrs |
| b. 2.46 hrs | d. 1.29 hrs |
40. A wet solid is dried from 40 to 8 per cent moisture in 20 ks. If the critical and the equilibrium moisture contents are 15 and 4 per cent respectively, how long will it take to dry the solid to 5 per cent moisture under the drying conditions? All moisture contents are on a dry basis.
- | | |
|-------------|-------------|
| a. 4.13 hrs | c. 2.84 hrs |
| b. 7.90 hrs | d. 4.82 hrs |

