Department of Chemical Engineering King Saud University

Test 1

Roll Number

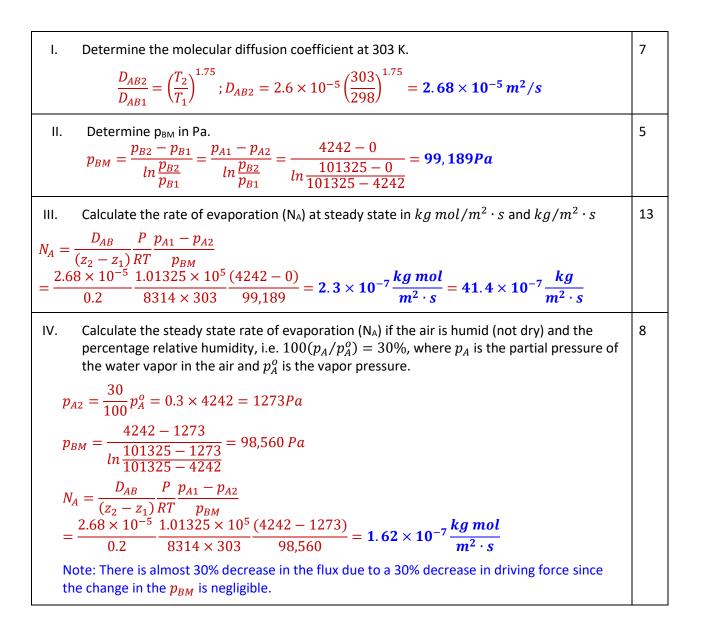
ChE 318

Time: 90 min

- <u>Carry out detailed calculations in answer sheet and provide final answer on this paper</u>
- Open book examination (No notes allowed even if written on the book)

Question 1 (33 pts):

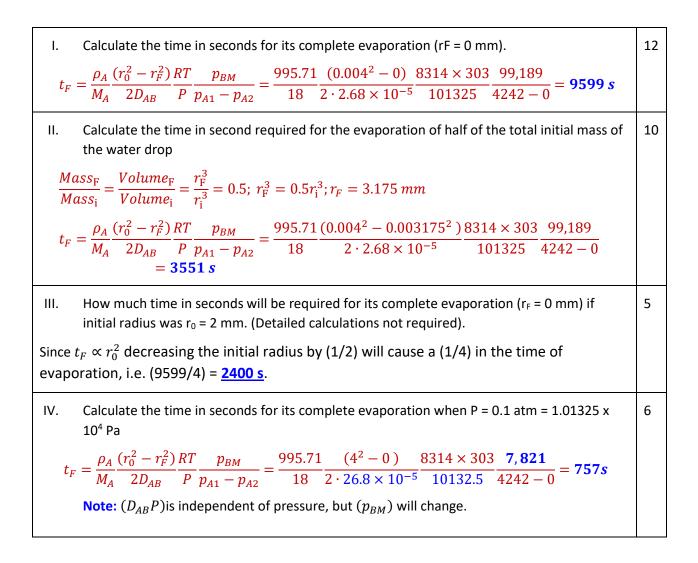
Water in the bottom of a narrow metal tube is held at a constant temperature of 303 K. The total pressure of air (assumed dry) is 1.01325×10^5 Pa (1.0 atm) and the temperature is 303 K. Water evaporates and diffuses through the air in the tube and the diffusion path ($z_2 - z_1$) is 0.2 m long. The tube diameter is 10 mm. The diagram is similar to Fig. 6.2-2a. The vapor pressure of water vapors at 303 K is 4242 Pa. The experimental value of the diffusion coefficient at 298 K is 2.6×10^{-5} m²/s.



Question 2 (33 pts):

Water drop (spherical) is suspended in still air (assumed dry) by a fine wire at 303K at 1.01325 x 10⁵ Pa (1.0 atm). Its initial radius was $r_0 = 4$ mm. The vapor pressure of water at 303 K is $p_A^0 = 4242 Pa$ and the density of water is 995.71 kg/m³. Note that

- Conditions in this problem are same as in Question 1
- Area, $A = 4\pi r^2$; Volume, $V = (4/3)\pi r^3$; Mass = ρV
- The time of evaporation can be computed using, $t_F = \frac{\rho_A}{M_A} \frac{(r_0^2 r_F^2)}{2D_{AB}} \frac{RT}{P} \frac{p_{BM}}{p_{A1} p_{A2}}$



Question 3 (34 pts):

<u>A tube is coated on the inside with naphthalene</u> and has an inside diameter of 25 mm and a length of 3.0m. Air at 318 K and an average pressure of 101.3 kPa flows through this pipe at a velocity of 2 m/s. The surface temperature of the naphthalene can be assumed to be at 318 K and its vapor pressure at 318 K is 74 Pa = $2.8 \times 10^{-5} (kg \ mol/m^3)$. Assume that the D_{AB} of naphthalene in air at 318 K is $6.92 \times 10^{-5} \ m^2/s$. For air, $\mu = 1.932 \times 10^{-5} \ Pa \cdot s$, $\rho = 1.114 \ (kg/m^3)$.

I. Compute Reynold number (N_{Re}), Schmidt number (N_{Se})
6

$$N_{Re} = \left(\frac{Dvp}{\mu}\right) = \left(\frac{0.025 \times 2 \times 1.114}{1.932 \times 10^{-5}}\right) = 2883$$
8

 $N_{Sc} = \frac{(\mu/p)}{D_{AB}} = \frac{(1.932 \times 10^{-5}/1.114)}{6.92 \times 10^{-5}} = 0.25$
2

II. What is the flow regime (laminar/turbulent)
2

Since $N_{Re} > 2100$, flow regime is turbulent
12

III. Determine k'_c using appropriate equation or figure
12

 $N_{Sh} = k'_c \frac{D}{D_{AB}} = 0.023 (2883)^{0.03} (0.25)^{0.33} = 10.84$
12

 $k'_c = 10.84 \frac{D_{AB}}{D} = 0.030 m/s$
2

IV. Compute the volumetric flow rate in m^3/s
2

Volumetric flow rate = Velocity × X-al area of tube
 $A = \frac{\pi}{4} \left(\frac{25}{1000}\right)^2$; $v \times A = 9.82 \times 10^{-4}$
2

V. Compute the total mass transfer area in $m^2 = \pi DL = 0.2356$
2

VI. Compute mean driving force if the inlet concentration, $C_{A1} = 0 \ kg \ mol/m^3$ and outlet concentration, $C_{A2} = 2.2 \times 10^{-5} \ kg \ mol/m^3$
5

 $(C_{A1} - C_{Am}) \cong \left(C_{A1} - \frac{C_{A1} + C_{A2}}{2}\right) \cong \frac{C_{A2} - C_{A1}}{\ln \frac{(C_{A1} - C_{A1})}{(C_{A1} - C_{A1})}} = 1.428 \times 10^{-5} \ kg \ mol/m^3$
5

VII. Compute mass transfer rate, N_A, in kg mol/s
5

 $N_A(kg \ mol/s) = k_c (\pi DL)(c_{A1} - c_{Am}) = 0.03 \ \frac{m}{s} \times 0.2356 \ m^2 \times 1.428 \times 10^{-5} \ \frac{kg \ mol}{m^3}$
5