**UNIVERSITY OF GHANA**


B.Sc ENGINEERING RESIT EXAMINATION - 2021

**DEPARTMENT OF FOOD PROCESS ENGINEERING**

**FPEN 312: MASS TRANSFER (2 Credits)**

**INSTRUCTIONS:**

**ANSWER FOUR (4) QUESTIONS** **TIME: TWO (2) HOURS**

1.

An Arnold diffusion cell is a simple device used to measure gas diffusion coefficients. A pool of pure liquid A is maintained at the bottom of a small diameter tube. A gas B, which is insoluble in the liquid, flows across the mouth of the tube carrying away the vapors of A which diffuse through the gas space above the liquid pool. If the general differential mass balance equation is expressed in vector form as follows:

$$\frac{\partial \rho_A}{\partial t} - \nabla^2(\rho D_{AB} x_A) + \rho_A(\nabla . \tilde{v}) + \tilde{v} . \nabla(\rho_A) = r_A$$

then, under isothermal, isobaric conditions, the evaporation of A is a steady-state process.

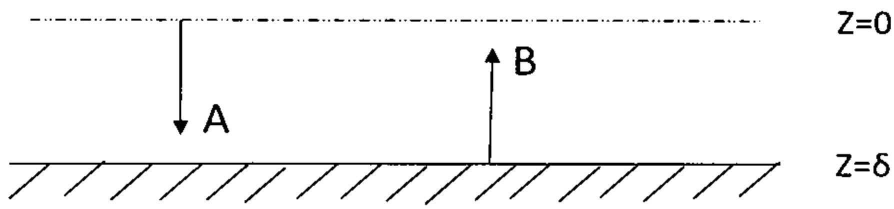
a) What is the implication of using a small diameter tube in the experiment and its effect on the mass balance equation?
b) What is the implication of gas B being insoluble in the liquid, and what word is used to describe it?
c) What is the effect of the isothermal conditions on the equation?
d) What is the effect of isothermal and isobaric conditions together on the equation?
e) Reduce the general differential equation for mass transfer to the specific differential equation which will describe this mass transfer process.

2.

The following sketch illustrates the gas-phase diffusion in the neighborhood of a catalytic surface. Component A diffuses through a stagnant film to the catalytic surface where it is instantaneously converted to B by the reaction

$$A \longrightarrow 4B$$

B diffuses away from the catalytic surface, back through the stagnant film.




a) Determine the rate at which A enters the gas film if this is a steady-state process

b) Evaluate the concentration profile, that is $y_A$ versus $z$.

(a)

Derive a relationship between the overall mass transfer coefficient based on the gas phase, $K_y$, and the individual coefficients, $k_y$ and $k_x$.

(b) Consider the one-dimensional mass transfer for a mixture of oxygen and carbon dioxide at 294 K and a total pressure of $1.519 \times 10^5$ Pa. Designate oxygen as gas $A$ and carbon dioxide as gas $B$. From the conditions: $x_A = 0.40$ and $v_A = 0.08$ m/s and $v_B = -0.02$ m/s, calculate the following:

(i) $N_A$, $N_B$ the molar fluxes of A and B with respect to stationary axes
(ii) $n_A$, $n_B$, the mass fluxes of A and B
(iii) $j_B$, the flux of B with respect to moving axes in kg/m$^2$.s
(iv) $j_B$, in mol/m$^2$.s

Use only the definitions of the concentrations, velocities and fluxes.

3.

In the desorption of component A from an aqueous solution into an air stream at a particular point in the mass transfer tower, the bulk concentration of the two streams were analyzed to be

$P_{AG}$=10 mm Hg

$C_{AL}$=0.250 kg mol/m$^3$

The overall gas coefficient, $K_G$, was equal to 0.06 kg mol A/(hr)(m$^2$) (atm). Sixty-five percent of the total mass transfer for resistance was encountered in the gas film, 45% in the liquid film. Henry's law constant was equal to 0.265 atm/(mol A/m$^3$ of solution). Determine

a) the gas-film coefficient, $k_G$
b) the liquid-film coefficient, $k_L$

c) the mass flux of A
d) the interfacial pressure, $p_{Ai}$
e) the interfacial concentration, $c_{AL}$

(1atm=760 mm Hg)

4.

A charcoal briquette, approximately spherical shaped with a 3-cm radius, has an initial moisture content of 500 $kg/m^3$. It is placed into a forced-air dryer that produces a surface moisture concentration of 1 $kg/m^3$. If the diffusivity of water in the charcoal is $1.3 \times 10^{-6}$ $m^2/s$ and the surface resistance is negligible, estimate the time required to dry the center of the briquette to a moisture concentration of 50 $kg/m^3$.

Use the unsteady state calculations graph provided in your solution.

5.

An ethyl alcohol/water vapour mixture is being rectified by contact with an alcohol/water liquid solution. Alcohol is transferred from the liquid to the vapour phase, and water is transferred in the opposite direction. Both components are diffusing through a gas film 0.004 in thick. The temperature is 203°F and the pressure is 1 atm. At that temperature, the latent heats of vaporization of the alcohol and water are 483 $Btu/lb_m$ and 976 $Btu/lb_m$, respectively. The mole fraction of the alcohol is 0.80 on one side of the film and 0.20 on the other side. Calculate the rate of diffusion of the ethyl alcohol and of water in pounds per hour through one square foot of area.

Diffusion coefficient, $D_{AW}$ = 0.579 $ft^2/s$

Gas Constant, $R$ = 0.73 $ft^3 atm$ / lb mol.R

Molecular weight ethanol, MW= 46