FAQs

1. Determine the rate of water evaporated from a tray full of water. Air at a velocity of 2 m/s is flowing over the tray. The temperature of water and air is 25 ^{o}C. The width of the tray is 45 cm and its length along the direction of air flow is 20 cm. The diffusivity of water vapor in air is D = 0.26 x 10^{24} m^2/s. The relative humidity of air is 50%.

{Hint: use

$$N_{Sh} = \frac{k_m L}{D_{AB}} = 0.664 (N_{Re})^{1/2} (N_{Sc})^{1/3}$$

}

Solution:

Reynolds number, N_{Re} = (2 x 0.2)/(16.14 x 10^{-6}) = 24,783
Hence it is a laminar flow

We know $N_{Sh} = \frac{k_m d_c}{D_{AB}}$ = 0.664 $(N_{Re})^{1/2}(N_{Sc})^{1/3}$

$N_{sc} = \nu/D_{AB}$ = (16.14 x 10^{-6})/(0.26 x 10^{-4}) = 0.62

(k_m x 0.2)/(0.26 x 10^{-4}) = 0.664(24783)$^{1/2}$(0.62)$^{1/3}$

k_m = 1.1587 x 10^{-2} m/s

The evaporation rate for the tray is, $\dot{m}_A = k_m A(C_{A,s} - C_{A,\infty})$

$C_{A,s}$ is the concentration under saturated conditions

$C_{A,s} = \rho_{A,s}$ = 0.02298 kg/m^3

where $C_{A,\infty}$ is the concentration of water in the free stream; since relative humidity is 50%, then

$\rho_{A,\infty}$ = (0.5)(0.02298) = 0.01149 kg/m^3

$\dot{m}_A$ = (1.1587 x 10^{-2} x 0.45 x 0.2) x (0.02298 – 0.01149)

= 1.1982 x 10^{-5} kg/s

The water evaporation rate from the tray is 0.043 kg/h.

2. Estimate the osmotic pressure of orange juice with 11% total solids at 20 ^{o}C

Solution

The Van't Hoff equation is used for computation, $\Pi = \frac{cRT}{M}$

The density of orange juice is estimated based on density of carbohydrates at 1593 kg/m^3.

$\rho = 0.11(1593) + 0.89(998.2)$
$= 1063.6$ kg/m^3

The concentration, c becomes

c = 0.11 x 1063.6 = 117 kg solid/m^3 product

$\Pi = (117 \times 8.314)/180 = 1583.5$ kPa

3. Osmotic pressures of some food materials are given below in the table

Table: Osmotic pressure of foods and food constituents at room temperature

Food	**Concentration**	**Osmotic pressure (kPa)**
Milk	9% solids-not-fat	690
Whey	6% total solids	690
Orange juice	11% total solids	1587
Apple juice	15% total solids	2070
Grape juice	16% total solids	2070
Coffee extract	28% total solids	3450
Lactose	5% w/v	380
Sodium chloride	1% w/v	862
Lactic acid	1% w/v	552

4. The concentration of whey is being accomplished by using an ultrafiltration membrane to separate water. The 10 kg/min feed stream has 6% total solids and is being increased to 20% total solids. The membrane tube has a 5-cm inside diameter, and the pressure difference applied is 2000 kPa. Estimate the flux of water through the membrane and the length of the membrane tube when the permeability constant is 4 x 10^{-5} kg water/(m^2 kPa s).

Solution

Using a mass balance on the membrane system, feed stream = water flux + concentrated product

$10 = N + N_p$

$10(0.06) = N_p(0.2)$

N_p = 3 kg/min of concentrated product

Then

N = 7 kg/min of water through membrane

Using equation $N = KA\Delta P$

A = $7/(4 \times 10^{-5} \times 2000 \times 60) = 1.46\ m^2$

Since d = 0.05 m

L = $1.46/(\pi \times 0.05) = 9.28$ m