UNIT OPERATIONS – 1

RATE OF DRYING

TERMS INVOLVED:

x1, x2 = components on wet basis

X1, X2 = components on dry basis

XC = critical Moisture content

Xe = Equilibrium Moisture content

Ls/Anc = Falling rate period

T = Time

FORMULAS USED:

X1 = (x1)/(1- x1)

X2 = (x2)/(1-x2)

Xe = given percent /100

Xc = given percent /100

LS/ANC= T/[X1-Xc] +[Xc-Xe] ln([Xc-Xe]/[X2-Xe])

T = LS/Anc[X1-XC] +LS/ANC[XC-XE] ln([Xc-Xe]/[X2-Xe])

SAMPLE PROBLEM:

2. A filter cake is dryed from moisture 30 % moisture to 10 % on wet basis in 5 hrs. Calculate the time required to dry the filter cake from 30 % to 6 % on wet basis under same condition. Equilibrium moisture content is 4 % on Dry basis, Critic moist content is 14 % on Dry basis

Sol,

$x_1 = 30\% = 0.3$

$X_1 = \frac{x_1}{1-x_1} = 0.4285$

$x_2 = 10\% = 0.1$

$X_2 = \frac{x_2}{1-x_2} = 0.1111$

$X_e = 4\% = 0.04$

$X_c = 14\% = 0.14$

$\frac{5\,A N_c}{L_S} = X_1 - X_c + \frac{L_S}{AN}$

$\frac{L_S}{5 \cdot A N_c} = \frac{1}{(X_1 - X_c) + (X_c - X_e)\ln\left(\frac{X_c - X_e}{X_2 - X_e}\right)}$

$T = t_c + t_f$

$T = 5\,hr$, $T = t_c + t_f$

$$5 = \frac{L_s}{A N_c}[X_1 - X_c] + \frac{L_S}{A N_c}(X_c - X_e)\ln\left(\frac{X_c - X_e}{X_2 - X_e}\right)$$

$$5 = \frac{L_S}{A N_c}\left\{(X_1 - X_c) + (X_c - X_e)\ln\left(\frac{X_c - X_e}{X_2 - X_e}\right)\right.$$

$$\frac{L_S}{A N_c} = \frac{5}{[X_1 - X_c] + [X_c - X_e]\ln\left(\frac{X_c - X_e}{X_2 - X_e}\right)}$$

$$= \frac{5}{0.2885 + 0.1\ln\left(\frac{0.1}{0.06}\right)} \quad \frac{5}{0.3395} \quad \frac{L_S}{AN_c} = 14.727$$

Case 2 :

30 % - 6 %

$x_1 = 30\% = 0.3$

$X_1 = 0.4285$

$x_2 = 6\% = 0.06$, X_2

$x_e = 4\% = 0.04$

$x_c = 14\% = 0.14$

$\frac{L_S}{A N C} = 14.727$

$T = 14.727 [0.2885] +$

$14.727 (0.1 / 0.06)$

$4.24873 + \cancel{0.75229}$

1.4727×1.6094

$= 5.00$ $\tau \Rightarrow 6.618$ hr

$T = 14.727 [0.2885] +$

$= 14.727 (0.14 - 0.04)$

$\ln \left(\frac{0.1}{0.06 - 0.04} \right)$

1.6094

$\tau = 6.6$ hours

nont $\Rightarrow 14.727$

UNIT OPERATIONS – 1

CRYSTALLIZATION YIELD PERCENTAGE CONVERSION

"TERMS INVOLVED:

F = FEED,

Xf = Molefraction of feed

Xe = Molefraction of Evaporation

xc = Molefraction of Crystals

xm = mother liquor,

E = initial Evaporation,

M = Mother liquor,

C = Crystals

FORMULAS USED:

Xf = entered percentage /100

E = (entered percentage/100)*feed

Xe = 0

Xc = molecular weight of unhydrated salt / molecular weight of hydrated salt.

Example : Mw of Na_2CO_3 / Mw of $Na_2CO_3.10H_2O$

Xm = solubility in kg / (solubility in kg + total solvent Kg)

C value :

Overall Material Balance

F = C+M+E

F-E = C+M

M = F-E-C

Individual Material Balance

Fxf = Cxc+Mxm+Exe

Xe = 0;

Fxf = Cxc+(F-E-C)xm

Fxf = Cxc + Fxm-Exm-Cxm

Fxf-Fxm+Exm = C(xc-xm)

F(xf – xm) + Exm = C(xc – xm)

F(xf – xm)+Exm /(xc – xm) = C.

M value:

Substituting C in below equation

M = F-E-C

yield

(Cxc/Fxf) * 100

sample problem format:

QUESTION:

4.1) 1000 kg of 25% aqueous solution of Na_2CO_3 is slowly cooled from 20°c to 10°c during cooling 10% of feed solution evaporates $Na_2CO_3 \cdot 10H_2O$ is crystallizes out. Find yield.

Solubility data:

21.5 kg of Na_2CO_3 in 100 kg of H_2O

SOLUTION:

Sol

$F = 1000\ Kg$

$x_f = 25\% = 0.25$

$E = 10\%$ of F

$= \frac{10}{100} \times 1000 = 100\ Kg$

$x_e = 0$

$x_c = \frac{\text{MW of unhydrated Salt}}{\text{MW of hydrated salt}}$

$= \frac{\text{MW } Na_2CO_3}{\text{MW of } Na_2CO_3 . 10H_2O}$

$= 0.37$

$x_m = \frac{21.5}{100+21.5} = 0.18$

$1000 = C + M + 100$

$C + M = 900 \longrightarrow (1)$

$250 = 0.37C + 0.18M$

$250 = 0.37(900 - M)$

$= 250 = 0.37 \times 900 - 0.37M + 0.18M$

$250 - 333 = 0.19M$

$83 = 0.19m$

$M = \cancel{436.8}\ \ 427.83 \sim 430 \quad \sim 70\%$

$C = 470 \quad \text{Yield} = \frac{C x_c}{F x_F} \times 100 = \frac{470 \times 0.37}{250} = 69.8\%$

UNIT OPERATIONS – 5

DIFFUSION

TERMS AND FORMULAS USED:

DIFFUSIVITY TEMPERATURE FOUNDER:

T1 – TEMPERATURE OF COMPONENT 1

T2 – TEMPERATURE OF COMPONENT 2

$(Dab)_{T1}$ – Diffusivity at Temperature 1

$(Dab)_{T2}$ – Diffusivity at Temperature 2

FORMULAS FOR FINDING DIFFUSIVITY AT T2:

$(Dab)_{T1}/(Dab)_{T2} = (T1/T2)^{1.5}$

Sample Problem:

Type 4 :

1) The diffusivity at 25 °C, 1 atm is 0.206 cm^2/sec. What is diffusivity at 75 °C, 1 atm

$$\frac{(D_{AB})_{25^\circ C}}{(D_{AB})_{75^\circ C}} = \left(\frac{25 + 273}{75 + 273}\right)^{3/2} = \left(\frac{T_1}{T_2}\right)^{3/2}$$

$$\frac{0.206}{(D_{AB})_{75^\circ C}} = \left(\frac{298}{348}\right)^{3/2} = (0.856)^{3/2}$$

$$\frac{0.206}{(D_{AB})_{75^\circ C}} = 0.7919$$

$$= 0.2601 \ cm^2/sec$$

2). The diffusivity at 25 °C, 1 atm is 0.206 cm^2/sec. What is diffusivity at 25 °C, 5 atm

sol:

$$\frac{(D_{AB})_{1\,atm}}{(D_{AB})_{5\,atm}} = \left(\frac{5}{1}\right) = \left(\frac{P_2}{P_1}\right)$$

$$= \frac{0.206 \ cm^2/s}{5} = (D_{AB})_{5\,atm}$$

$$= 0.0412 \ cm^2/s$$

UNIT OPERATIONS

CRYSTALLIZATION YIELD PERCENTAGE COMPARISON

"TERMS INVOLVED:

F = FEED,

Xf = Molefraction of feed

Xe = Molefraction of Evaporation

xc = Molefraction of Crystals

xm = mother liquor,

E = initial Evaporation,

M = Mother liquor,

C = Crystals

FORMULAS USED:

Xf = given parts /100 + given parts in feed

Xm = given parts / 100 + given parts in mother liquor

CASE 1:

Pure component assumed as 1

F = Given feed value / mole fraction of feed

C value :

Overall Material Balance

F = C+M+E

F = C+M

M = F-C

Individual Material Balance

Fxf = Cxc+Mxm+Exe

Xe = 0;

Fxf = Cxc+(F-C)xm

Fxf = Cxc + Fxm-Cxm

$Fxf-Fxm = C(xc-xm)$

$F(xf – xm) = C(xc – xm)$

$F(xf – xm)/(xc – xm) = C$.

M value :

Substituting C in below equation

$M = F-C$

Yield :

$Cxc / Fxf *100$

CASE 2 :

E = (given percentage / 100) * feed

C value 1:

Overall Material Balance

$F = C+M+E$

$F-E = C+M$

$M = F-E-C$

Individual Material Balance

$Fxf = Cxc+Mxm+Exe$

$Xe = 0$;

$Fxf = Cxc+(F-E-C)xm$

$Fxf = Cxc + Fxm-Exm-Cxm$

$Fxf-Fxm+Exm = C(xc-xm)$

$F(xf – xm) + Exm = C(xc – xm)$

$F(xf – xm)+Exm /(xc – xm) = C$.

M value 1:

Substituting C in below equation

$M = F-E-C$

yield

(Cxc/Fxf) * 100

Sample problem:

4.4 2500 kg of KCl, salt present in a saturated solution of 80°C. The solution is cooled to 20°C. The solubilities of KCl at 80°C and 20°C are 55 parts and 35 parts per 100 parts of H_2O.

a) Calculate yield of crystal Neglecting loss of evaporation

b) Calculate yield if 5% ~~of~~ weight on solution is loss by evaporation.

sol/

salt = $F x_f$ = 2500 kg

$$x_f = \frac{55}{100+55} = 0.354$$

$$x_m = \frac{35}{100+35} = 0.259$$

$x_c = 1$ [pure KCl]

$x_e = 0$

$F x_f = 2500$

F = ~~7062.146~~ kg

7042.253 kg

Case 1) :

$E = 0$

$F = C + M$

$C = F - M$

$F x_f = C x_c + M x_m$

$C =$ kg

$M =$ kg

$7042.14 \times 0.354 = C + M \times 0.254$

$2499.99 = (7062.25 - M) + M(0.25$

$2499.99 - 7062.25 = -M + M(0.25$

$\boxed{2500}$

$4562.26 = M(-1 + 0.254)$

$= 0.746$

$M = 6129.6 \quad 912.36$

$C = \cancel{946.55}$

yield = %

$\frac{C x_c}{F x_F} = \frac{\cancel{946.55 \times 1}}{\cancel{2499.99}} \quad \frac{912.36}{2500}$

$= \cancel{37.8}$ %

$= 36.5$ %

Case 2 :

$E = 5$ % of F

$= \frac{5}{100} \times 7062.14$ kg $= 353.107$ kg

$F = C + M + E$

$F x_f = C x_c + M x_m + (E \overset{0}{x_e})$

$F = C + M + 353.107$

$\cancel{F = 6709.03}$

$6689.14 = C + M$

$6689.14 - C = M$

$7042.25 \times 0.355 = C \times 1 + (6689.14 - C)\, 0.259$

$2499.99 = C + 1732.48 - 0.259C$

$767.51 = C - 0.259C = C(1 - 0.259)$

$767.51 = C(0.741)$

$C = 1035.776$

$M = 5653.36$

$= \frac{1035.776}{2499.99} = 41.4$ %

UNIT OPERATIONS

CRYSTALLIZATION – EVA 0 %

"TERMS INVOLVED:

F = FEED,

Xf = Molefraction of feed

Xe = Molefraction of Evaporation

xc = Molefraction of Crystals

xm = mother liquor,

E = initial Evaporation,

M = Mother liquor,

C = Crystals

FORMULAS USED:

Xf = given percentage /100

E = 0

Xe = 0

Xc = Molecular wt of component / Molecular wt of hydrated molecule

Example :

Mw of NaCl/ Mw of NaCl.10H_2O

Xm = solubility of component / solvent

C value :

Overall Material Balance

F = C+M+E

F = C+M

M = F-C

Individual Material Balance

Fxf = Cxc+Mxm+Exe

Xe = 0;

$Fxf = Cxc+(F-C)xm$

$Fxf = Cxc + Fxm-Cxm$

$Fxf-Fxm = C(xc-xm)$

$F(xf – xm) = C(xc – xm)$

$F(xf – xm)/(xc – xm) = C.$

M value :

Substituting C in below equation

$M = F-C$

Yield:

(Cxc/Fxf**) *100**

Sample problem:

4.2. A crystallizer is charged with 10,000 kg of 30% Na_2SO_4 solution Glauber salt ($Na_2SO_4 \cdot 10H_2O$) crystallizes out during this process no loss of H_2O by evaporation, E = 0 solubility data 19.4 g in 100 g of water sol^n

$F = 10{,}000\ kg$

$x_f = 30\% = 0.3$

$E = 0$

$x_E = 0\%$

$$x_c = \frac{MW\ Na_2SO_4}{MW\ (Na_2SO_4\ 10H_2O)} = \frac{142}{322} = 0.440$$

$= 0.440$

$$x_m = \frac{19.4}{19.4 + 100}\ g$$

$$x_m = \frac{19.4}{119.4} = 0.1624$$

$10{,}000 = C + M$

$F x_f = C x_c + M x_m \ \ -1\ 0$

$10{,}000 \times 0.3 = C \times 0.440 + M \times 0.162$

$$3{,}000 = (10{,}000 - M) \times 0.440 + 0.162\,M$$

$$3{,}000 = 4400 - 0.440M + 0.162\,M$$

$$3{,}000 - 4400 = 0.278\,M$$

$$1400 = 0.278\,M$$

$$M = 5035.97$$

$$C = 4964.03$$

$$C = \frac{C \times c}{A \times F} = \cancel{5035.9} \frac{4964.03 \times 0.440}{10{,}000 \times 0.3}$$

$$C = 72.8\,\%$$