140 Midterm 2 Solutions

Problem 1 Solution:

Steam Table Data:

$$z = \frac{P\hat{V}}{RT} = \frac{500bar(.003882m^3/kg)(1000L/1m^3)(18kg/1000mol)}{.08314Lbar/molK(773K)}$$

$$z = 0.544kg$$

Compressibility Chart:

$$T_r = \frac{T}{T_c} = \frac{773K}{(347+273)K} = 1.25$$

$$P_r = \frac{P}{P_c} = \frac{500bar}{221.2bar} = 2.26$$

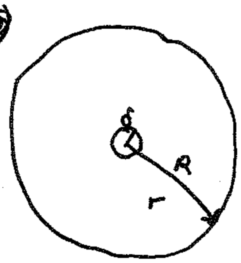
*credit was also given for using T_c=647K (value given in book)

z=0.625

Compare: Value from compressibility chart is greater. Compressibility chart gives a value closer to ideal gas than steam table.

Problem 2

(a)



• balance on cylindrical shell

$$-D(2\pi r L)\frac{dC_A}{dr}\bigg|_r - \left(-D(2\pi r L)\frac{dC_A}{dr}\bigg|_{r+\Delta r}\right) = 0$$

$$\frac{d}{dr}\left(r\frac{dC_A}{dr}\right) = 0 \Rightarrow r\frac{dC_A}{dr} = A_1 \quad (1)$$

integrating once more

$$\int dC_A = C_A = A_1\int\frac{dr}{r} = A_1 \ln r + A_2$$

applying the two boundary conditions

$C_A = 0$ at $r = \delta$ $\qquad 0 = A_2 + A_1 \ln\delta$

$C_A = C_{A0}$ at $r = R$ $\qquad C_{A0} = A_2 + A_1 \ln R$

subtracting gives. $C_{A0} = A_1 \ln R/\delta$

$$A_1 = \frac{C_{A0}}{\ln R/\delta}$$

Now

$$J_A = -D\frac{dC_A}{dr}\bigg|_{r=R} = -D\frac{A_1}{r}\bigg|_{r=R} = -D\frac{A_1}{R} = -\frac{D C_{A0}}{R\ln R/\delta}$$

from (1) $\qquad$ why negative

... a more dangerous way to do it

$\dot{n}_A \neq f(r)$ because $\dot{n}_A$ same at each point by mass balance

$$\text{flux} = \frac{\dot{n}_A}{2\pi r L} = -D\frac{dC_A}{dr}$$

$$\frac{\dot{n}_A}{2\pi L}\int_{\delta}^{R}\frac{dr}{r} = -D\int_{C_A=0}^{C_{A0}} dC_A$$

$$\frac{\dot{n}_A}{2\pi L}\cdot \ln R/\delta = -D\,C_{A0}$$

$$J_A = \frac{\dot{n}_A}{2\pi R L} \quad \text{so} \quad J_A \cdot R \cdot \ln R/\delta = -D\,C_{A0}$$

$$J_A = \frac{-D\,C_{A0}}{R \ln R/\delta}$$

Problem 3 Solution:

a) Extractor Balances:
100 kg/hr = $m_{C,C}$ = 100 kg/hr
0.2(100 kg/hr) + 0.5*$m_{W,W1}$ = $m_{W,W1}$ → $m_{W,W1}$= 40 kg/hr
0.8(100 kg/hr) + 0.5*$m_{A,W1}$ = $m_{A,C}$ + $m_{A,W1}$ → $m_{A,W1}$= 160 kg/hr – 2$m_{A,C}$

Using K:

$$\frac{m_{A,C}/(m_{A,C}+100)}{m_{A,W1}/(m_{A,W1}+40)} = 1.72 \rightarrow \frac{m_{A,C}/(m_{A,C}+100)}{(160-2m_{A,C})/(200-2m_{A,C})} = 1.72$$

b) Overall mass fractions:
x_A=80/200=0.4
x_M=100/200=0.5
x_W=0.1

From tertiary phase diagram, two phases are formed, where one is MIBK rich and one is H_2O rich. The acetone compositions are:
$x_{A,M}\approx0.4$, $x_{A,W}\approx0.29$
K=0.4/0.29=1.4 (compared to 1.72), so **LESS** acetone will be extracted.

c) 1) 2+3-2=3 intensive variables
Since T and P are specified, only **1 mass fraction** must be specified.
2) If one mass fraction is specified, one point on the semi-circle on the tertiary phase diagram is known. The tie line gives the second point.

Problem 4 Solution:

a)Raoult's Law:

x_b*p*(benzene, 75C)=y_b*P

(1-x_b)*p*(n-hexane, 75C)=(1-y_b)*P

x_b*647.75=y_b*760

(1-x_b)*921.343=(1-y_b)*760

y_b=0.50, x_b=0.59

y_h=0.50, x_h=0.41

Mass balances:

Benzene: 54.5 mol/s=0.50*m_v+0.59*m_l

n-Hexane: 45.5 mol/s=0.50*m_v+0.41*m_l

m_v=50 mol/s

m_l=50 mol/s

a)$\Delta H_{hex,v}$=25 mol/s * [(68.74-30 C)*0.2163 kJ/mol + 28.85 kJ/mol + (75-68.74 C)*0.1374 kJ/mol] = 952.24 kW

$\Delta H_{hex,l}$=20.5 mol/s * [(75-30 C)*0.2163 kJ/mol] = 199.54 kW

$\Delta H_{ben,v}$=25 mol/s * [(80-30 C)*0.1265 kJ/mol + 30.765 kJ/mol + (75-80 C)*0.0741 kJ/mol] = 917.99 kW

$\Delta H_{ben,l}$=29.5 mol/s * [(75-30 C)*0.1265 kJ/mol] = 167.93 kW

Total = 2237.69 **kW**