The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

(0905211) Chemical Engineering Principles

Instructor : Prof. Naim M. Faqir
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Duration : 60 minutes

Section: يوم الأحد

First Semester - 2017/2018

First Midterm Exam (Closed Book)

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ID #

Question #	Gained points	Full points
1	10	10
2	10	10
3	11	15
4	15	15
Total		50

46/50 Excellent

Question 1: [15 points]

The following data are taken for the concentration of reactant A, C_A(g/L), as a function of time, t(min)

t(min)	0	36	65	100	160	∞
C_A(g/liter)	0.1823	0.1453	0.1216	0.1025	0.0795	0.0495

mean $\quad C_{A0} \quad C_{A0} \quad C_{Ae}$

The concentration, C_A(g/L), varies with time, t(min), according to the formula:

$$\ln\left(\frac{C_A - C_{A0}}{C_A - C_{Ae}}\right) = -kt$$

ln y = kt
y = e^{kt}
y = a x
y = a e^{b x}
ln y = b ...

البداية والنهاية

1. Determine the parameter k
2. Estimate the concentration of A after 2 hours.

$$\boxed{\bar{C}_A = \frac{\sum C_A}{N} = 0.1135\ g/L}$$

$$k = -\ln\left(\frac{0.1135\ g/L - 0.1823\ g/L}{0.1135\ g/L - 0.0495\ g/L}\right)$$

ووشطولها

$$y_1 = \frac{0.1135 - 0.1823}{0.1135 - 0.0495} = -1.075$$

لا يصح بالسالب ؟؟

$$y_2 = \frac{0.1135 - 0.1025}{0.1135 - 0.0495} = 0.171$$

Q ① $e^{\ln\left(\frac{C_A - C_{A0}}{C_A - C_{Ae}}\right)} = e^{-kt}$

y

$$\frac{C_A - C_{A0}}{C_A - C_{Ae}} = e^{-kt}$$

assum $\frac{C_A - A_0}{C_A - C_{Ae}}$ $\boxed{t = x}$

$$y = e^{-kt}$$

$$\ln y = -kt$$

$y_2 = 0.171\,g/L$, $t_2 = 100$ min

$y_1 = 1.075\,g/L$, $t_1 = 0$ min

slop $k = \frac{\ln y_2 - \ln y_1}{t_2 - t_1}$

$k = \frac{\ln(y_2/y_1)}{t_2 - t_1} \rightarrow k = \ln($

$k = \frac{\ln(0.171/1.075)}{100 - 1}$

$k = -\text{slop} = -(-0.0185) = \boxed{0.0185}$

$\ln\left(\frac{C_A - C_{A0}}{C_A - C_{Ae}}\right) = -(0.0185)\,t$ at $t = 2h \times \frac{60\,min}{1h}$

$\boxed{t = 120\,min}$

$$\frac{C_A - 0.1823\,g/L}{C_A - 0.0492\,g/L} = e^{-0.0185(120)\,min}$$

$$\frac{C_A - 0.1223\,g/L}{C_A - 0.1823\,g/L} = 0.1086$$

$$C_A - 0.1823 = 0.1086\,C_A - 0.0197$$

$$0.8914\,C_A = 0.1626$$

$$\boxed{C_A = 0.1824\,g/L}$$

10

Question 2: [15 points] Mw 46.07 g/mol 88.10

A mixture contains 10.0 mole% ethyl alcohol, 75.0 mole% ethyl acetate ($C_4H_8O_2$), and 15.0 mole% acetic acid. Calculate the mass fractions of each compound. What is the average molecular weight of the mixture? What would be the mass of the mixture (kg) of a sample containing 25.0 kmol of ethyl acetate?

60.05

Assume mixture 100 mol

mixture → 0.1 mol ethylalcohol/mol
→ 0.75 mol acetate /mol
→ 0.15 mol acetic /mol

mol alcohol = (0.1 mol alcohol/mol)(100 mol) = 10 mol alcohol * Mw (40.07 g/mol alcohol) = $\boxed{400.7 \text{ g alcohol}}$

mol acetate = 75 mol acetate * 88.10 g/mol = $\boxed{6607.5 \text{ g acetate}}$

mol acetic = 15 mol acetic * 60.05 g/mol = $\boxed{900.75 \text{ g acetic}}$

Total mass = 400.7 g alcohol + 6607.5 g acetate + 900.75 g acetic

$\boxed{\text{Total} = 7908.95 \text{ g mixture}}$

$X_{alcohol} = \dfrac{400.7 \text{ g alcohol}}{7908.95 \text{ g mix}} = 0.05 \text{ g alcohol/g}$

$X_{acetate} = \dfrac{6607.5 \text{ g acetate}}{7908.95 \text{ g mix}} = 0.835 \text{ g acetate/g}$

$X_{aceticacid} = \dfrac{900.75 \text{ g acetic}}{7908.95 \text{ g mix}} = 0.113 \text{ g acetic/g}$

Q2) average Mw

$$\bar{M} = y_{acetic} M_{acetic} + y_{acetate} M_{acetat} + y_{alcohol} M_{alcohol}$$

$$= \left(\frac{0.15\ mol\ acetic}{mol}\right)\left(\frac{60.05\ g\ acetic}{mol\ acetic}\right) + \left(\frac{0.75\ mol\ acetate}{mol}\right)\left(\frac{88.10\ g\ acet}{mol\ acet}\right)$$

$$+ \left(\frac{0.1\ mol\ alcohol}{mol}\right)\left(\frac{46.07\ g\ alcohol}{mol\ alcohol}\right)$$

$$\boxed{\bar{M} = 79.68\ g/mol}$$

kg mixture / contain 25 kmol ethyl acetate

$$\frac{25\ kmol\ acetate}{} \left| \frac{kmol}{0.75\ kmol\ acetate} \right| \frac{79.68\ kg}{kmol}$$

$$\boxed{mass\ mixture = 2656.3\ kg}$$

10

Question 3: [15 points]

The following equation of state of an ideal gas relates the specific volume of a gas to its temperature and pressure:

$$p = \frac{RT}{\hat{V}}$$

Where: P: pressure (atm)
T: temperature (K)
V: specific volume (L/mol)
R: The gas constant

1. What are the units of R?
2. Derive a formula for P(N/m²) as a function of T(K) and V(m³/mol)? The units of R should be in (J/mol.K).
3. If R= 0.80206 (L.atm/mol.K), what is the value of R from the derived formula in (J/mol.K)

formula − $9.9\times10^{-6}\, p'(\frac{N}{m^2}) = \frac{(10^{-3})(R')(T)}{1000\, \hat{V}(L/mol)}$

R'

② $p'(\frac{N}{m^2}) = \frac{0.10\ R(J/mol.K)\ (T)(K)}{\hat{V}(L/mol)}$

R

1). $P = \frac{(R)T}{\hat{V}} \rightarrow \frac{P\hat{V}}{T} = R$

$\frac{atm \cdot \frac{L}{mol}}{K} = \boxed{atm.L / mol.K}$

③ R = 0.80206 L.atm/mol.K

R' = R (1000)

R' = 802.06 J/mol.K

−4

2) p' (N/m²)

$P(atm) = p'(\frac{N}{m^2})\left(\frac{1\ atm}{1.01\times10^5\ N/m^2}\right) =$

$\boxed{P(atm) = 9.9\times10^{-6}\ p'(N/m^2)}$

$\hat{V}$ (m³/mol) =

$V(L/mol) = \frac{\hat{V}\ m^3}{mol} \Big| \frac{1000\ L}{1\ m^3} = 1000\,\hat{V}(L/mol)$

R' (J/mol.K)

$R\left(\frac{atm.L}{mol.K}\right) = p' \left(\frac{J}{mol.K}\right) \Big| \frac{1\ N.m}{1\ J}$

$R = \frac{P\hat{V}}{T} = \frac{(N/m^2)(L/mol)}{T} = \frac{N \cdot L}{m^2.K\ .mol} \Big| \frac{1\ m^3}{1000\ L}$

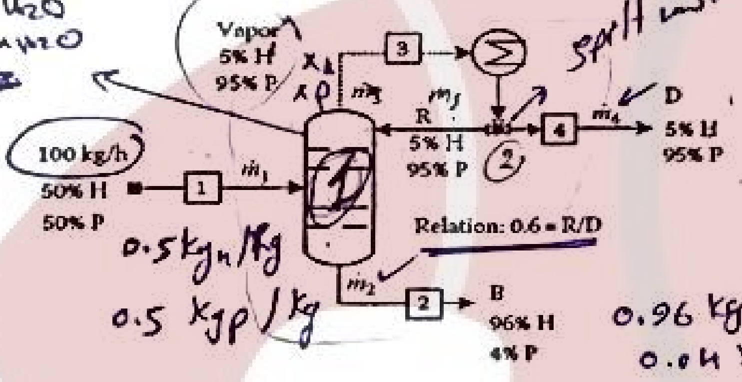
$\boxed{R = 10^{-3} R (J/K.mol)}$

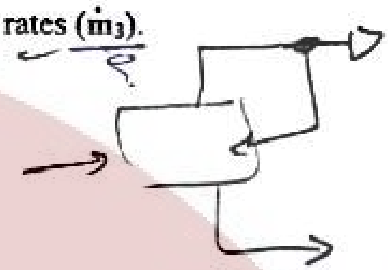
$= \frac{N \cdot m}{1000\ K.mol} \Big| \frac{1\ J}{1\ N.m} =$

Question 4: [15 points]

A mixture of Hexane (H) and pentane (P) is separated in a distillation column with a reflux ratio of 0.60 (reflux ratio = Reflux/Distillate = R/D) as shown in the following figure. If the feed contains 50 wt% hexane, the distillate (D) is 5 wt% hexane, and the bottom stream (B) is 96 wt% hexane, and the mass flow rate of the feed stream is 100 kg/h.

1. Perform a degree of freedom analysis for this system.
2. Determine the distillate, bottom, Reflux, and overhead flow rates ($\dot m_3$).





H_2O
m_{H_2O}

split unit

0.5 kg H/kg
0.5 kg P/kg

0.96 kg H/kg
0.04 kg P/kg

	# unknown	# eqn	DOF
overall	$\dot m_1$, $\dot m_4$, $\dot m_2$ (3)	2 (M.B)	zero
split unit	$\dot m_3$, $\dot m_4$, $\dot m_5$	1 (M.B) + 1 ratio	~~zero~~ 1
unit 1	$\dot m_2$, $\dot m_3$, $\dot m_5$	2 (M.B)	1

0

overall Balance M.B

(1)

$$\dot m_1 = \dot m_4 + \dot m_2$$

$$\boxed{100\ kg/h = \dot m_4 + \dot m_2}$$

Balance hexane

$$0.5\ \frac{kg\,h}{kg}\left(100\ \frac{kg}{h}\right) = \left(0.96\ \frac{kg\,h}{kg}\right)\dot m_2 + (0.05\ kg_h/kg)\,\dot m_4$$

$$D = \boxed{\dot m_4 = 50.55\ kg/h}$$

$$\boxed{\dot m_2 = 49.5\ kg/h}$$

(2) use split unite

Ratio. $\frac{R}{D} = 0.6$

$$\frac{m_R}{m_D} = 0.6$$

$$m_R = 0.6\,(50.55\ kg/h)$$

$$\boxed{m_R = 30.33\ kg/h} = \dot m_5$$

(3) Balance in split unite

overall M.B

$$\dot m_3 = \dot m_5 + \dot m_4$$

$$= 30.33\ kg/h + 50.55\ kg/h$$

$$\boxed{\dot m_3 = 80.88\ kg/h}$$