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

(0905211) Chemical Engineering Principles	Second Semester – 2015/2016
First Midterm Exam	
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Dear students:

Answer all questions to the best of your ability and knowledge.

Start with the easiest question to you. Use only the available space.

Don't waste your time on the questions that you are not confident about.

You know that cheating is not accepted and you would not need it anyway!

Good Luck!

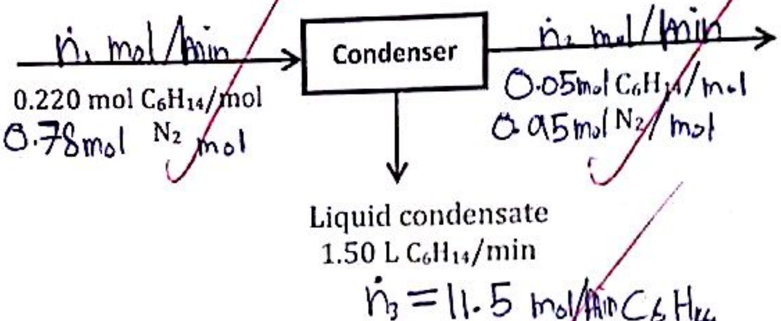
Question #	Gained points	Full points
1	30	30
2	20	20
Total	50	50

Wow!! Great Job

Question 1: [30 points]

(a) **[20 pts]** A gas stream contains 22.0 mol % hexane, C_6H_{14} (SG = 0.659 $\frac{20°}{4°}$, MW = 86.17) and the balance nitrogen (MW = 28.02). The stream flows to a condenser, where some hexane is liquefied. The hexane **mass fraction** in the gas stream leaving the condenser is 0.140 g hexane/g. Liquid hexane condensate is recovered at a rate of 1.50 L/min.

20



1- Complete labeling the flowchart and do degree-of-freedom analysis.
2- What is the flow rate of the gas stream leaving the condenser in **mol/min**?
3- What percentage of the hexane entering the condenser is recovered as a liquid (mol liquid hexane/mol hexane in feed)?

ρ = 659 Kg/m³

basis 100g

14g hexane → 0.162 mol → 0.05
86g N_2 → 3.06 mol → 0.95
3.222

$m = \frac{659\ Kg}{m^3} \cdot 1.50\ L \cdot \frac{1\ m^3}{1000\ L}$
= 988.5g

① DoF = 2 − 2 = 0
($\dot{n}_1$, $\dot{n}_2$; C_6H_{14}, N_2)

③ $\frac{11.5}{14.14} * 100\% = 81.3\%$

② Over all $\dot{n}_1 = 11.5 + \dot{n}_2$

C_6H_{14} b $0.220\dot{n}_1 = 11.5 + 0.05\dot{n}_2$

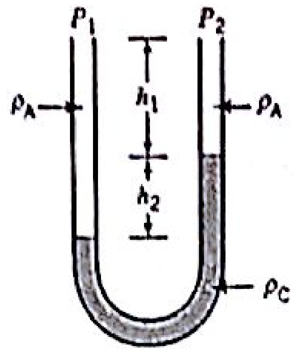
$0.220(11.5 + \dot{n}_2) = 11.5 + 0.05\dot{n}_2$

$2.53 + 0.22\dot{n}_2 = 11.5 + 0.05\dot{n}_2$

$0.17\dot{n}_2 = 8.97$ $\boxed{\dot{n}_2 = 52.76\ mol/min}$

$\boxed{\dot{n}_1 = 64.26\ mol/min}$

[10 pts] The differential manometer shown below is used to measure the pressure drop between points 1 and 2 (i.e. $P_1 - P_2$) in a process line containing methanol ($SG = 0.792 \frac{20°}{4°}$). The monometer fluid, C, has a specific gravity of $1.37 \frac{20°}{4°}$.
If $h_1 = 40.0$ cm and $h_2 = 24.0$ cm, calculate the pressure drop ($P_1 - P_2$) in mm Hg.



10

$$\frac{1360.37 \text{ N}}{\text{m}^2} \bigg| \frac{760 \text{ mmHg}}{1 \text{ atm}} \bigg| \frac{1 \text{ atm}}{1.01325\times}$$

$$= 10.2036 \text{ mmHg}$$

$$P_1 + \rho_A g(h_1+h_2) = P_2 + \rho_B g(h_1) + \rho_f g h_2$$

$$P_1 + \rho_A g h_1 + \rho_A g h_2 = P_2 + \rho_B g h_1 + \rho_f g h_2$$

$$P_1 - P_2 = \rho_B g h_1 - \rho_A g h_1 + \rho_f g h_2 - \rho_A g h_2$$

$$P_1 - P_2 = \rho_A g(h_1 - h_1) + g h_2(\rho_f - \rho_A)$$

$$P_1 - P_2 = g h_2(\rho_f - \rho_A) \qquad \rho_f - \rho_A = 1.37 - 0.792 = 0.578 \text{ g/cm}^3$$

$$= \frac{980.66 \text{ cm}}{\text{s}^2} \bigg| 24 \text{ cm} \bigg| \frac{0.578 \text{ g}}{\text{cm}^3}$$

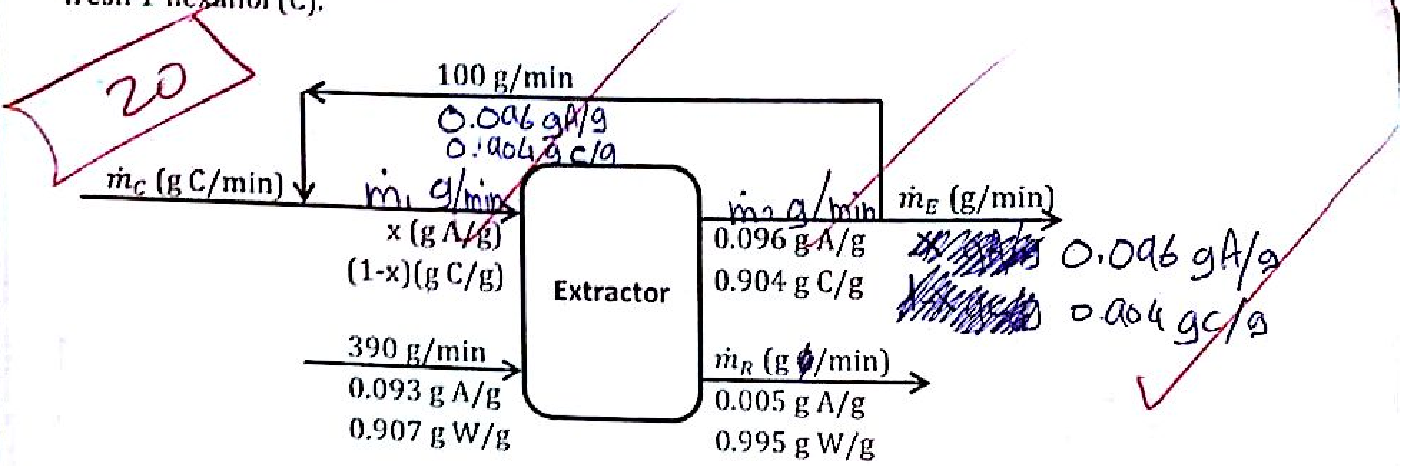
$$= 13603.7 \text{ g/cm.s}^2$$

$$= \frac{13603.7 \text{ g}}{\text{cm.s}^2} \bigg| \frac{1 \text{ kg}}{1000 \text{ g}} \bigg| \frac{100 \text{ cm}}{1 \text{ m}} \bigg| \frac{1 \text{ N s}^2}{1 \text{ kg m}}$$

$$= 1360.37 \text{ N/m}^2$$

Question 2: [20 points]

Shown below is a flowchart of a liquid extraction process in which acetic acid (A) is extracted from a mixture of acetic acid and water (W) into 1-hexanol (C), a liquid immiscible in water. To save the solvent C, 100 g/min of the extract (C-rich) stream is recycled and mixed with the fresh 1-hexanol (C).



(a) Complete labeling the flowchart.

(b) By doing an *overall DOF analysis*, show that you can find the unknown flowrates $\dot{m}_C$, $\dot{m}_R$, and $\dot{m}_E$.

(c) Find the mass flowrates: $\dot{m}_C$, $\dot{m}_R$, and $\dot{m}_E$.

(d) Find the mass fraction of A in the solvent mixture fed to the extractor (x).

(b) DOF = 3 − 3 = 0

$\dot{m}_C / \dot{m}_E / \dot{m}_R$; A/C/W

(c) W balance $0.907 * 390 = 0.995\ \dot{m}_R$

$\dot{m}_R = 355.5$ g/min

Overall $\dot{m}_1 + 390 = \dot{m}_2 + 355.5$

C balance $(1-x)\dot{m}_1 = 0.904\ \dot{m}_2 \rightarrow \dot{m}_1 - x\dot{m}_1 = 0.904\ \dot{m}_2$

$\dot{m}_1 - 9.6 = 0.904\ \dot{m}_2$

A balance $x\ \dot{m}_1 = 9.6$

$\dot{m}_1 = 0.904\ \dot{m}_2 + 9.6$

$\dot{m}_1 = 424.9$ g/min

$$0.904\,\dot{m}_2 + 9.6 + 390 = \dot{m}_2 + 355.5$$

$$44.1 = 0.096\,\dot{m}_2$$

$$\dot{m}_2 = 459.375 \text{ g/min}$$

Overall

$$459.4 = \dot{m}_E + 100$$

$$\boxed{\dot{m}_E = 359.4 \text{ g/min}}$$

Overall

$$100 + \dot{m}_c = 424.9$$

$$\boxed{\dot{m}_c = 324.9 \text{ g/min}}$$

(d)

$$x\,\dot{m}_1 = 9.6$$

$$x = \frac{9.6}{424.9}$$

$$= \boxed{0.0225 \text{ gA/g}}$$

Useful information:

$$\rho_{H_2O(l)}(4°C) = 1.000 \frac{g}{cm^3} = 1000. \frac{kg}{m^3} = 62.43 \frac{lb_m}{ft^3}$$

$$g = 9.8066\ m/s^2 = 980.66\ cm/s^2 = 32.174\ ft/s^2$$

$$\frac{1.8°F}{1°C}, \frac{1.8°R}{1\ K}, \frac{1°F}{1°R}, \frac{1°C}{1\ K}$$

$$T(K) = T(°C) + 273.15$$

$$T(°R) = T(°F) + 459.67$$

$$T(°R) = 1.8T(K)$$

$$T(°F) = 1.8T(°C) + 32$$

$$\bar{M} = \sum_{\substack{all \\ components}} y_i M_i$$

$$\frac{1}{\bar{M}} = \sum_{\substack{all \\ components}} \frac{x_i}{M_i}$$

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 L = 28,317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482×10^5 dynes
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325×10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486×10^{-4} Btu/s = 1.341×10^{-3} hp