UNIVERSITY OF GHANA
FACULTY OF ENGINEERING SCIENCES
SECOND SEMESTER EXAMINATIONS, 2014/2015
LEVEL 300: BACHELOR OF SCIENCE IN ENGINEERING
FPEN 302: SEPARATION PROCESSES
TIME ALLOWED: TWO (2) HOURS

Instructions:

1. **Answer all questions**
2. **Calculators allowed**
3. **Graph paper provided on demand.**

1. In a process producing KNO_3 salt 1000kg/h of a feed solution containing 30 wt % KNO_3 is fed to an evaporator, which evaporates some water at 422K to produce a 50 wt % KNO_3 solution. This is then fed to a crystallizer at 311K, where crystals containing 96 wt % KNO_3 are removed. The saturated solution containing 37.5 wt % KNO_3 is recycled to the evaporator. Calculate the amount of recycle stream R in kg/h and the product stream of crystals P in kg/h. Give the process -flow diagram indicating clearly the components.

2. Calculate the vapour and liquid compositions in equilibrium at 95^{0}C (368.2K) for benzene-toluene using the vapour pressure from the following Table at 101.32kPa.

Temperature		Benzene (B)		Toluene (T)		x_B	y_B
K	°C	kPa	mm Hg	kPa	mm Hg		
353.3	80.1	101.32	760				
358.2	85	116.9	877	46	345		
363.2	90	135.5	1016	54	405		
368.2	95	155.7	1168	63.3	475		
373.2	100	179.2	1344	74.3	557		
378.2	105	204.2	1532	86	645		
383.8	110.6	240.0	1800	101.32	760		

Table: vapour-pressure and equilibrium Mole-fraction Data for Benzene-Toluene system

(a) Complete the table with all the values of x_B and y_B.
(b) Draw the x-y graph for benzene-toluene at 101.32kPa with the 45° line.

(c) Draw the T-x-y graph for benzene-toluene at 101.32kPa.
(d) If the mixture is 50/50 and the feed is at the bubble point, how many plates are needed if we want a product with a purity of 99% whereas the bottom contains 0.5 % of benzene? Reflux ratio: 5:1.

3. Ethylene glycol can be catalytically dehydrated to p-dioxane (a cyclic diether) by the reaction $2HOCH_2CH_2OH \longrightarrow H_2CCH_2OCH_2CH_2O+2H_2O$. Water and p-dioxane have boiling points of 100°C and 101.1°C, respectively, at 1 atm. and cannot be separated by distillation. However, liquid-liquid extraction at 25°C (298K) using benzene as a solvent is reasonably effective. Assume that 2268 kg/hour (5000lb/hr) of a 25% solution of p-dioxane in water is to be separated continuously by using 3402kg/hr (7500lb/hr) of pure benzene. Assuming benzene and water are mutually insoluble and $K_D^I = 1.5$.
   (a) Determine the effect of the number and arrangement of stages on the percent extraction of p-dioxane by considering 1 vs.3 stages in each case:
      i. the co-current arrangement,
      ii. the crosscurrent and
      iii. the countercurrent.

   (b) Draw the flowsheet of each arrangement.

4. A fuel gas containing 3.1 mol% H_2, 27.2% CO, 5.6% CO_2, 0.5%O_2, and 63.6% N_2 is burned with 20% excess air (i.e., the air over and above that necessary for complete combustion to CO_2 and H_2O). The combustion of CO is only 98% complete. For 100kg mol of fuel gas,
   (a) Write the balanced equations of the complete combustion of the compounds of the fuel.
   (b) Calculate the moles of each component in the exit flue gas.
   (c) Draw the process flow diagram clearly indicating the inflow and outflow compositions.

5. A liquid mixture of 100 kgmoles of benzene (B), 100 kgmoles of toluene (T) and 200 kgmoles of water is at equilibrium with its vapor at 52°C. Assuming that benzene and toluene follow Raoult's law, but that neither is miscible with water, calculate:
   (a) The total pressure above the mixture
   (b) The composition of the vapor assuming that Dalton's law applies.
   From the Chemical Engineer's Handbook (Perry *et al.*) you have:

$$P_a = \exp(C_1 + C_2/T + C_3 \ln T + C_4 * T^{C_5}) = \exp\left(C_1 + \frac{C_2}{T} + C_3 \ln T + C_4 * T^{C_5}\right)$$

Substance	C_1	C_2	C_3	C_4	C_5
Water	73.648	-7258.2	-7.3037	4.1653E-6	2
Toluene	80.877	-6902.4	-8.7761	5.8034E-6	2
Benzene	83.918	-6517.7	-9.3453	7.1182E-6	2