UNIVERSITY OF EMBU

2017/2018 ACADEMIC YEAR

SECOND SEMESTER EXAMINATIONS

FIRST YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (INDUSTRIAL CHEMISTRY)

SCI 302: MATERIAL AND ENERGY BALANCE

DATE: APRIL 5, 2018 **TIME: 8:30-10:30AM**

INSTRUCTIONS:

Answer Question ONE and ANY Other TWO Questions.

Important information: ***R = 8.314 J/K/mol,*** **Na: 23, P: 31, O: 16, H: 1, K: 39, Cl: 35.4**

QUESTION ONE (30 MARKS)

a) Calculate the molar concentration of Na_2HPO_4 solution if the concentration in g/L = 21 g /L. (2 marks)

b) Differentiate between closed and open chemical system (2 marks)

c) State the first law of thermodynamics (1 mark)

d) How many ml of water should be added to 100 ml of 1M NaCl solution in order to get 0.15 M NaCl solution ('physiological saline') (3 marks)

e) An unknown sample of sulfuric acid H_2SO_4 was titrated with the known KOH solution. It was found that 12 mL of the 0.1 M KOH was needed for just complete neutralization of 10 mL H_2SO_4 unknown sample. What is the concentration of sulfuric acid in the sample? Equation: $H_2SO_4 + 2\ KOH \rightarrow K_2SO_4 + 2\ H_2O$ (3 marks)

f) The equilibrium data for CCl_4 adsorbed on activated Carbon at 34 ^{0}C are given in table 1.1.

Table 1.1. Number of moles of CCl_4 adsorbed and different pressures at constant temperature

Pressure (mm Hg)	0	1.69	3.38	6.76	8.45	11.8	20.7	32.1	40.0	84.5	104	123	133
Adsorbed CCL_4 (moles)	0	0.07	0.14	0.27	0.34	0.48	0.57	0.63	0.68	0.70	0.71	0.71	0.71

i) Plot a graph of adsorbed CCl_4 (y-axis) against pressure (3 marks)

ii) Compare the shape of your graph between (0 – 20) and 20 - 133) mm Hg (2 marks)

iii) What does the graph tell us about the adsorption process? (2 marks)

g) Define the term enthalpy and internal energy as applied to thermodynamics processes (2 marks)

h) Discuss briefly the Antoine equation as applied to vapor-liquid equilibrium calculation (2 marks)

i) What is the volume of one mole of gas at 101.325 kPa and 25 °C ? (3 marks)

j) Exposing copper metal to heat in the presence of oxygen is one process of changing the chemical composition of a substance. Comment on the mass of the new substance formed? (2 marks)

k) When water change phase from solid (ice) to liquid at 0 ^{0}C, temperature is constant but heat is absorbed. Explain this observation. (3 marks)

QUESTION TWO (20 MARKS)

a) It is required to prepare 1250 kg of a solution composed of 12 wt.% ethanol and 88 wt.% water. Two solutions are available, the first contains 5 wt.% ethanol, and the second contains 25 wt.% ethanol. How much of each solution are mixed to prepare the desired solution? (6 marks)

b) You need to prepare 1 liter of 0.1 M HCl. How many ml of concentrated HCl (12 M) do you need to take ? (3 marks)

c) Using Antoine equation, calculate the vapour pressure of acetic acid at 33 ^{0}C given the

constants A = 7.4275, B = 1558.03 and C = 224.79 (4 marks)

d) Skim milk is prepared by the removal of some of the fat from whole milk. This skim milk is found to contain 90.5% water, 3.5% protein, 5.1% carbohydrate, 0.1% fat and 0.8% ash. If the original milk contained 4.5% fat, calculate its composition, assuming that fat only was removed to make the skim milk and that there are no losses in processing. Assume 100 kg of skim milk was prepared. (7 marks)

QUESTION THREE (20 MARKS)

a) In the reaction between barium nitrate and sodium sulfate, how many grams of barium sulfate can be prepared from 10 ml of 10 % (w/v) barium nitrate when there is no loss? (Atomic weight of barium: 137.3, sulfur: 32.1, nitrogen: 14.0).

Equation: $Ba(NO_3)_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaNO_3$ (6 marks)

b) Taking into account that about 5% of the product is lost in (3 a), what is the actual grams of barium sulfate that can be prepared from 10 ml of 10 % (w/v) barium nitrate?. (3 marks)

c) An aqueous solution of sodium hydroxide contains 20 % NaOH by mass. It is desired to produce an 8% NaOH solution by diluting a stream of the 20 % solution with a stream of pure water.

i) Draw and label the flowchart of the material balance (2 marks)

ii) Calculate the ratios (H_2O feed solution) and (product solution/ feed solution) (4 marks)

iii) Determine the feed rates of 20% solution and diluting water needed to produce 2310 grams/min of the 8% solution. (5 marks)

QUESTION FOUR (20 MARKS)

a) Reaction between hydrochloric acid and solid zinc can be used to prepare hydrogen gas in the laboratory. Calculate how many grams of solid zinc and how many mL of 1 M HCl is needed

for preparation of 5 L of hydrogen gas. Take into account that about 8% of the product is lost in your apparatus. (Atomic weight of Zn: 65.4, Cl: 35.5, molar volume 24.5 L/mol).

Equation: $Zn(s) + 2HCl \rightarrow H_2(g) + ZnCl_2$ (5 marks)

(c) The extraction process is able to recover the Streptomycin due to the fact that Streptomycin has a greater affinity for dissolving in the organic solution than in the aqueous solution. Figure 4.1 shows the overall process where organic solvent flow into the extraction process at the rate of 10 L/min while aqueous solution flows at the rate of 200 L/min. Given the density of the aqueous solution is 1 g/cm^3 and the density of the organic solvent is 0.6 g/cm^3 and that 10 g of Streptomycin dissolved in aqueous solution flows into the extraction process while 0.2 g flows out of the process in aqueous solution. The flow rates of the entering fluids equal the flow rates of the exit fluids.

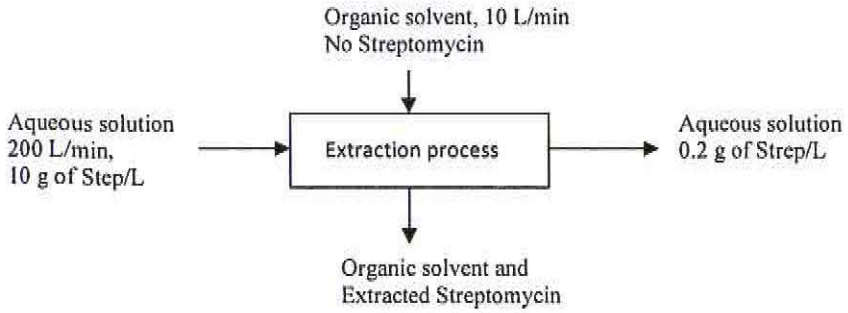

Figure 4.1. Extraction process of Streptomycin from aqueous solution.

(i) Calculate the amount of extracted Streptomycin per litre of the organic solvent (6 marks)

(ii) Determine the mass fraction of Streptomycin in the exit organic solvent assuming that no water exits with the solvent and no solvent exits with the aqueous solution (5 marks)

(d) Calculate how many g of $KClO_4$ is needed for preparation of 250 ml of 0.1 M solution (4 marks)

QUESTION FIVE (20 MARKS)

(a) A mixture containing 45% benzene (B) and 55% toluene (T) by mass is fed to a distillation column. An overhead stream of 95 wt% B is produced, and 8% of the benzene fed to the column leaves in the bottom stream. The feed rate is 2000 kg/h, determine the overhead flow rate and the mass flow rates of benzene and toluene in the bottom stream. (8 marks)

(b) Membranes represent a relatively new technology for the separation of gases. One use that has attracted attention is the separation of nitrogen and oxygen from air. Figure 5.1 illustrates a nanoporous membrane that is made by coating a very thin layer of polymer on a porous graphite supporting layer. If this is an open, steady-state process without chemical reaction, what is the composition of the waste stream if the waste stream amounts to 80% of the input stream?

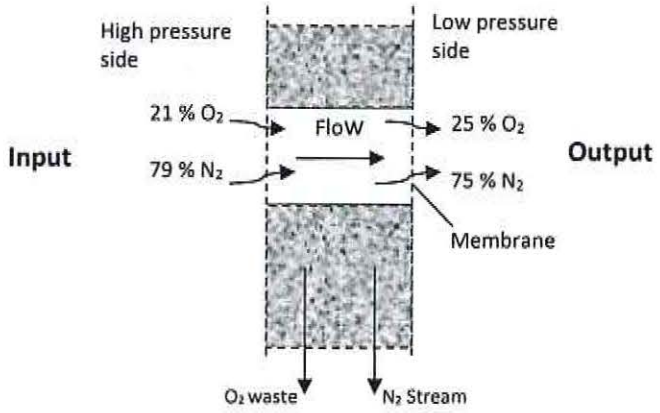

Figure 5.1. Separation of oxygen and nitrogen using a membrane.

Assuming you have 100x moles of total input gas (oxygen + nitrogen) determine the,

i) Total moles of the waste gas (oxygen + nitrogen) (2 marks)

ii) Number of moles of oxygen and nitrogen in the input gas (2 marks)

iii) Number of moles of oxygen and nitrogen in the output gas (2 marks)

iv) Number of moles of oxygen and nitrogen in the waste gas (4 marks)

v) Mole fraction of oxygen and nitrogen in the waste gas (2 marks)

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