NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF APPLIED CHEMISTRY

UNIT OPERATIONS

SCH 2208

Second Semester Examination Paper

May 2016

This examination paper consists of **six** pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Graph paper, Steam Tables

Examiner's Name: S. Bhebhe

INSTRUCTIONS

1. Answer **ALL** questions in **SECTION A**
2. Answer **ANY THREE** questions in **SECTION B**
3. Each question carries 20 marks
4. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
A1	**20**
A2	**20**
B1	**20**
B2	**20**
B3	**20**
B4	**20**
TOTAL ATTAINABLE MARK	**100**

SECTION A

ANSWER ALL QUESTIONS

QUESTION A1

a) To ensure complete combustion, 20 per cent excess air is supplied to a furnace burning natural gas. The gas composition (by volume) is methane 95 per cent, ethane 5 per cent. Calculate the moles of air required per mole of fuel. **[4]**

b) Fig. A1 shows the main steps in a process for producing a polymer.
From the following data, calculate the stream flows for a production rate of 10,000 kg/h.
Reactor:
Yield on polymer - 100 per cent
Slurry polymerisation - 20 per cent monomer/water
Conversion - 90 per cent
Catalyst - 1 kg/1000 kg monomer
Short stopping agent - 0.5 kg/1000 kg unreacted monomer
Filter:
Filter, wash water - approx. 1 kg/1 kg polymer
Recovery column:
Yield - 98 per cent (percentage recovered)
Dryer:
Feed - approximately 5 per cent water, product specification - 0.5 per cent H_2O
Polymer losses in filter and dryer - approximately 1 per cent **[10]**

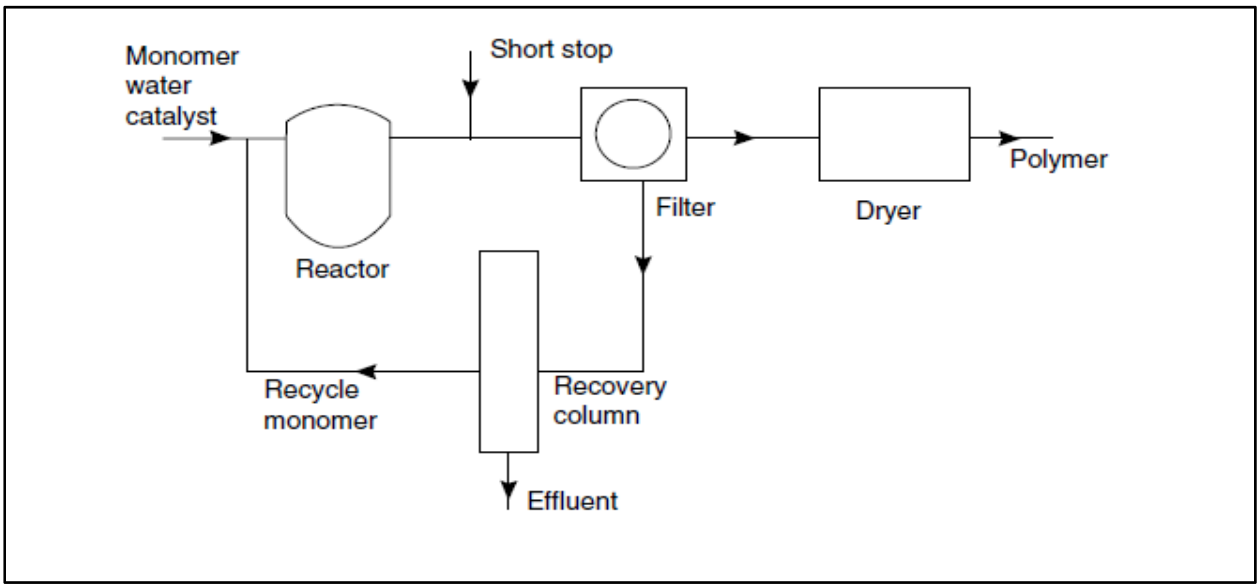

Fig. A1 Polymer production

c) The drying of materials is often the final operation in a manufacturing process, carried out immediately prior to packaging or dispatch. Describe the **four** main reasons for drying material in processing industries. **[6]**

QUESTION A2

a) Estimate the steam and the cooling water required for the distillation column shown in Fig. A2.

Steam is available at 25 psig (274 kN/m^2 abs), dry saturated.

The rise in cooling water temperature is limited to 30^{o}C.

Column operates at 1 bar.

Data:

Acetone - Cp (25^{0}C-35^{0}C) = 2.2 kg/kg.K Water - Cp (25^{0}C -100^{0}C) = 4.2 kg/kg.K

- Latent heat @ 56.5^{0}C = 620kJ/kg - Latent heat @56.5^{0}C = 2500kJ/kg **[8]**

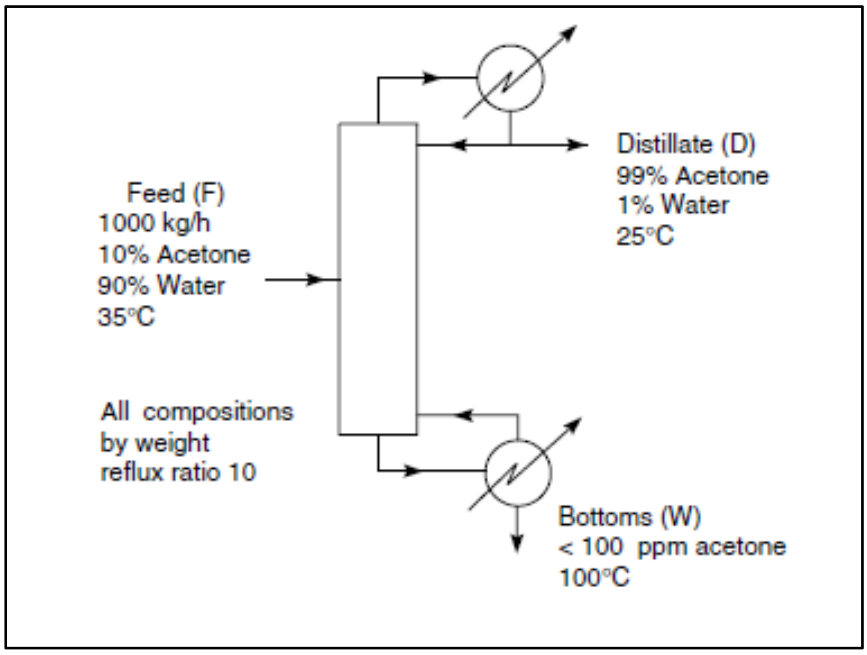

Fig. A2 Distillation column

b) Ammonia is removed from a 10 per cent ammonia–air mixture by scrubbing with water in a packed tower, so that 99.9 per cent of the ammonia is removed. What is the required height of tower? The gas enters at 1.2 kg/m^2s, the water rate is 0.94 kg/m^2s and *KGa* is 0.0008 kmol/sm^3 *(*kN/m^2*)*. **[12]**

SECTION B

ANSWER ANY THREE QUESTIONS

QUESTION B1

a) A single effect evaporator operates at 13 kN/m^2. What will be the heating surface necessary to concentrate 1.25 kg/s of 10 per cent caustic soda to 41 per cent, assuming a value of *U* of 1.25 kW/m^2 K, using steam at 390 K? The heating surface is 1.2 m below the liquid level.
The boiling-point rise of the solution is 30 K, the feed temperature is 291 K, the specific heat capacity of the feed is 4.0 kJ/kg.K, the specific heat capacity of the product is 3.26 kJ/kg.K and the density of the boiling liquid is 1390 kg/m^3. **[8]**

b) A continuous fractionating column is required to separate a mixture containing 0.695 mole fraction *n*-heptane *(*C_7H_{16}) and 0.305 mole fraction *n*-octane *(*C_8H_{18}*)* into products of 99 mole per cent purity. The column is to operate at 101.3 kN/m^2 with a vapour velocity of 0.6 m/s. The feed is all liquid at its boiling-point, and this is supplied to the column at 1.25 kg/s. The boiling-point at the top of the column may be taken as 372 K, and the equilibrium data are:

Mole fraction of heptane in vapour	0.96	0.91	0.83	0.74	0.65	0.50	0.37	0.24
Mole fraction of heptane in liquid	0.92	0.82	0.69	0.57	0.46	0.32	0.22	0.13

Determine the minimum reflux ratio required. What diameter column would be required if the reflux used were twice the minimum possible? **[12]**

QUESTION B2

a) A mixture of water and ethyl alcohol containing 0.16 mole fraction alcohol is continuously distilled in a plate fractionating column to give a product containing 0.77 mole fraction alcohol and a waste of 0.02 mole fraction alcohol. It is proposed to withdraw 25 per cent of the alcohol in the entering stream as a side stream containing 0.50 mole fraction of alcohol. Determine the number of theoretical plates required and the plate from which the side stream should be withdrawn if the feed is liquor at its boiling point and a reflux ratio of 2 is used. **[10]**

b) With the aid of a diagram, give a detailed description of a mixer settler unit used in liquid-liquid extraction. **[6]**

c) Liquid-liquid extraction is complementary to distillation. Identify and explain three cases under which liquid-liquid extraction might be the preferred method, use examples to support your argument. **[4]**

QUESTION B3

a) The selection of the equipment for an extraction process is influenced by the factors which are responsible for limiting the extraction rate. Describe these factors and explain how they affect the leaching process. **[8]**

b) Gas, from a petroleum distillation column, has its concentration of H_2S reduced from 0.03 kmol H_2S/kmol of inert hydrocarbon gas to 1 percent of this value, by scrubbing with a triethanolamine-water solvent in a counter current tower, operating at 300 K and at atmospheric pressure. H_2S is soluble in such a solution and the equilibrium relation may be taken as $Y = 2X$, where Y is kmol of H_2S kmol inert gas and X is kmol of H_2S/kmol of solvent.

The solvent enters the tower free of H_2S and leaves containing 0.013 kmol of H_2S/kmol of solvent. If the flow of inert hydrocarbon gas is 0.015 kmol/m^2s of tower cross-section and the gas-phase resistance controls the process, calculate:

(i) The height of the absorber necessary. **[4]**

(ii) The number of transfer units required. **[2]**

The overall coefficient of absorption K''_Ga maybe taken as 0.04 kmol/s.m^3 of tower volume (unit driving force in Y).

c) A mixture of 2mol % ethanol and 98 mol % water is to be stripped in a plate column to a bottom product containing not more than 0.01 mol % ethanol. Steam admitted through an open coil in the liquid at the bottom plate is to be used as a source of vapour. The feed is at its boiling point. The steam flow is at 0.2 mol per mole of feed. For dilute ethanol-water solutions, the equilibrium line is straight and is given by $y_e = 9.0\ x_e$. How many ideal plates are required? **[6]**

QUESTION B4

a) Seeds, containing 20 per cent by mass of oil, are extracted in a counter-current plant, and 90 per cent of the oil is recovered in a solution containing 50 per cent by mass of oil. If the seeds are extracted with fresh solvent and 1 kg of solution is removed in the underflow in association with every 2 kg of insoluble matter, how many ideal stages are required? **[8]**

b) If 35,000kg of whole milk containing 4% fat is to be separated in a 6 hour period into skim milk with 0.45% fat and cream with 45% fat, what are the flow rates of the two output streams from a continuous centrifuge which accomplishes this separation? **[4]**

c) An autoclave contains 1000 cans of pea soup. It is heated to an overall temperature of 100 ^{o}C. If the cans are to be cooled to 40 ^{o}C before leaving the autoclave, how much cooling water is required if it enters at 15 ^{o}C and leaves at 35 ^{o}C?
The specific heats of the pea soup and the can metal are respectively 4.1 kJ/ kg ^{o}C and 0.50 kJ/ kg ^{o}C. The weight of each can is 60g and it contains 0.45 kg of pea soup.
Assume that the heat content of the autoclave walls above 40 ^{o}C is 1.6 x 104 kJ and that there is no heat loss through the walls. **[8]**

(END OF PAPER)