NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF APPLIED CHEMISTRY

UNIT OPERATIONS

SCH 2208

Supplementary Examination Paper

July 2016

This examination paper consists of **five** pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Graph paper, Steam tables

Examiner's Name: S. Bhebhe

INSTRUCTIONS

1. Answer **ALL** questions
2. Each question carries 20 marks
3. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
1	**20**
2	**20**
3	**20**
4	**20**
5	**20**
TOTAL ATTAINABLE MARK	**100**

ANSWER ALL QUESTIONS

QUESTION 1

a) 2000 kg of a 5 % slurry of calcium hydroxide in water is to be prepared by diluting a 20% slurry. Calculate the quantities required. The percentages are by weight. **[4]**

b) 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. **[8]**

c) The composition of a gas derived by the gasification of coal is, volume percentage: Carbon dioxide 4, carbon monoxide 16, hydrogen 50, methane 15, ethane 3, benzene 2, balance nitrogen. If the gas is burnt in a furnace with 20 per cent excess air, calculate:
(i) The amount of air required per 100 kmol of gas,
(ii) The amount of flue gas produced per 100 kmol of gas,
(iii) The composition of the flue gases, on a dry basis.
Assume complete combustion. **[8]**

QUESTION 2

a) 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 per cent 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. **[5]**
(ii) The number of transfer units required. **[3]**

b) A liquid containing four components, **A**, **B**, **C** and **D**, with 0.3 mole fraction each of **A**, **B** and **C**, is to be continuously fractionated to give a top product of 0.9 mole fraction **A** and 0.1 mole fraction **B**. The bottoms are to contain not more than 0.5 mole fraction **A**. Estimate the minimum reflux ratio required for this separation, if the relative volatility of **A** to **B** is 2.0. **[4]**

c) In a mixture to be fed to a continuous distillation column, the mole fraction of phenol is 0.35, *o*-cresol is 0.15, *m*-cresol is 0.30 and xylenols is 0.20. A product is required with a mole fraction of phenol of 0.952, *o*-cresol 0.0474 and *m*-cresol 0.0006. If the volatility to *o*-cresol of phenol is 1.26 and of *m*-cresol is 0.70, estimate how many theoretical plates would be required at total reflux. **[8]**

QUESTION 3

a) In the production of ammonia from hydrogen and nitrogen the conversion, based on either raw material, is limited to 15 per cent. The ammonia produced is condensed from the reactor (converter) product stream and the unreacted material recycled. If the feed contains 0.2 per cent argon (from the nitrogen separation process), calculate the purge rate required to hold the argon in the recycle stream below 5.0 per cent. Percentages are by volume. **[4]**

b) The composition of a gas derived by the gasification of coal is:
carbon dioxide 4% v/v, carbon monoxide 16% v/v, hydrogen 50% v/v, methane 15% v/v, ethane 3% v/v, benzene 2% v/v, balance nitrogen% v/v. If the gas is burnt in a furnace with 20 per cent excess air, calculate:
(i) The amount of air required per 100 kmol of gas,
(ii) The amount of flue gas produced per 100 kmol of gas,
(iii) The composition of the flue gases, on a dry basis.
Assume complete combustion. **[8]**

c) An acetone–air mixture containing 0.015 mole fraction of acetone has the mole fraction reduced to 1 per cent of this value by counter-current absorption with water in a packed tower. The gas flowrate G' is 1 kg/m^{2}s of air and the water flowrate entering is 1.6 kg/m^{2}s.
For this system, Henry's law holds and $ye = 1.75x$, where ye is the mole fraction of acetone in the vapour in equilibrium with a mole fraction x in the liquid. How many overall transfer units are required? **[8]**

QUESTION 4

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 per cent 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]**

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 5

a) A single-effect evaporator is used to concentrate 7 kg/s of a solution from 10 to 50 per cent of solids. Steam is available at 205 kN/m^2 and evaporation takes place at 13.5 kN/m^2. If the overall heat transfer coefficient is 3 kW/m^2.K, calculate the heating surface required and the amount of steam used if the feed to the evaporator is at 294 K and the condensate leaves the heating space at 352.7 K. The specific heat capacity of a 10 per cent solution is 3.76 kJ/kg.K; the specific heat capacity of a 50 per cent solution is 3.14 kJ/kg K. **[8]**

b) 1 Mg of dry mass of a non-porous solid is dried under constant drying conditions in an air stream flowing at 0.75 m/s. The area of surface drying is 55 m^2. If the initial rate of drying is 0.3 g/m^2s, how long will it take to dry the material from 0.15 to 0.025 kg water/kg dry solid? The critical moisture content of the material may be taken as 0.125 kg water/kg dry solid. If the air velocity were increased to 4.0 m/s, what would be the anticipated saving in time if the process were surface-evaporation controlled? **[8]**

c) Carbon dioxide is added at a rate of 10 kg/h to an air stream and the air is sampled at a sufficient distance downstream to ensure complete mixing. If the analysis shows 0.45 per cent v/v CO_2, calculate the air-flow rate. **[8]**

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