UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. M.Eng.

Chemical Eng E877: Introduction to Bioprocess Engineering

COURSE CODE	:	**CENGE877**
UNIT VALUE	:	**0.50**
DATE	:	**07-MAY-03**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

03-C0200-3-60

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Answer ***FOUR QUESTIONS.*** **Only the first four answers given will be marked.**
ALL questions carry a total of ***25 MARKS*** *each, distributed as shown* [ ]

All pressures are absolute unless otherwise stated.
R=8.314 J/mol K. 1 atm = 760 mm Hg. g = 9.81 m/s^2.

1.

Fresh air containing 4.00 mole% water vapour is to be cooled and dehumidified to a water content of 1.70 mole% H_2O. A stream of fresh air is combined with a recycle stream of previously dehumidified air and passed through the cooler. The blended stream entering the unit contains 2.30 mole% H_2O. In the air conditioner, some of the water in the feed stream is condensed and removed as liquid. A fraction of the dehumidified air leaving the cooler is recycled and the remainder is delivered to a room. Taking 100 mol of dehumidified air delivered to the room as a basis of calculation, calculate the moles of fresh feed, moles of water condensed and moles of dehumidified air recycled. [25]

2.

Methane is burned with air in a continuous steady-state combustion reactor to yield a mixture of carbon monoxide, carbon dioxide and water. The reactions taking place are:

$$2\,CH_4 + 3\,O_2 \rightarrow 2\,CO + 4\,H_2O$$
$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

The feed to the reactor contains 7.80 mole% CH_4, 19.4% O_2 and 72.8% N_2. The percentage conversion of methane is 90.0% and the gas leaving the reactor contains 8 mol CO_2/mol CO. Carry out a degree-of-freedom analysis on the process and calculate the molar composition of the product stream. [25]

3.

Five hundred kilogramme per hour of steam drives a turbine. The steam enters the turbine at 44 atm and 450 °C at a linear velocity of 60 m/s and leaves at a point 5 m below the turbine inlet at atmospheric pressure and a velocity of 360 m/s. The turbine delivers shaft work at a rate of 70 kW and the heat loss from the turbine is estimated to be 4 x 10^7 J/h. Calculate the specific enthalpy change associated with the process. [25]

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4.

A fluid having density "ρ" and velocity "u" flows in a pipeline of length "l" in which bends and control valves are also present. Explain what is meant by "equivalent pipe length, l_e" and its significance in the calculation of the total frictional losses in the pipeline. [6]

Write the expression for the total frictional losses "ΔP_f" in the pipeline for turbulent flow. Use "c_f" and "d" to denote the Fanning friction coefficient in the pipeline and the pipe internal diameter respectively. [4]

2.32 $m^3 h^{-1}$ of water is pumped in a 35 mm internal diameter pipe through a distance of 125 m in a horizontal direction and then up through a vertical height of 12 m. The friction loss in the 90° square elbow may be taken as equivalent to 60 pipe diameters. Also in the line there is a control valve and frictional losses may be taken equivalent to 200 pipe diameters. Calculate the total head "H" to be delivered by the pump. You may neglect entrance and exit effects. You may assume that for this pipe $c_f=0.079Re^{-0.25}$. Assume the water to flow in turbulent regime through the pipe. Density and viscosity of water in the pipe are 1000 kg m^{-3} and 0.65 mN s m^{-2} respectively. [8]

Under these conditions, calculate also the power "P" required by the pump to deliver "H". [7]

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5.

A liquid mixture of methanol and water at its bubble point containing 45 mole percent of methanol is to be separated by continuous distillation. The column is a fractionation column operating in conjunction with a total condenser and a partial reboiler.

The requirements of the column are that 500 kmol/h of 95 mol% methanol is to be produced as distillate and that the residue is 5 mol% methanol.

a) Calculate both the flowrate (kmol/h) of the feed required to meet the production rate and the flowrate of the residue. [4]

b) Assuming constant molar overflow and with the aid of the diagram supplied, *which must be attached inside your answer book*, use the McCabe-Thiele method to estimate:

i) The minimum reflux ratio, R_{min}, for the separation. [4]

ii) The number of theoretical stages for a reflux ratio $R=(L/D) = 1.5\ R_{min}$. [12]

c) Assuming constant molar overflow and $R = 1.5R_{min}$, calculate the internal liquid and vapour flowrates (kmol/h) above and below the feed tray. [5]

Data:
Diagram supplied showing vapour-liquid equilibrium curve for methanol and water.

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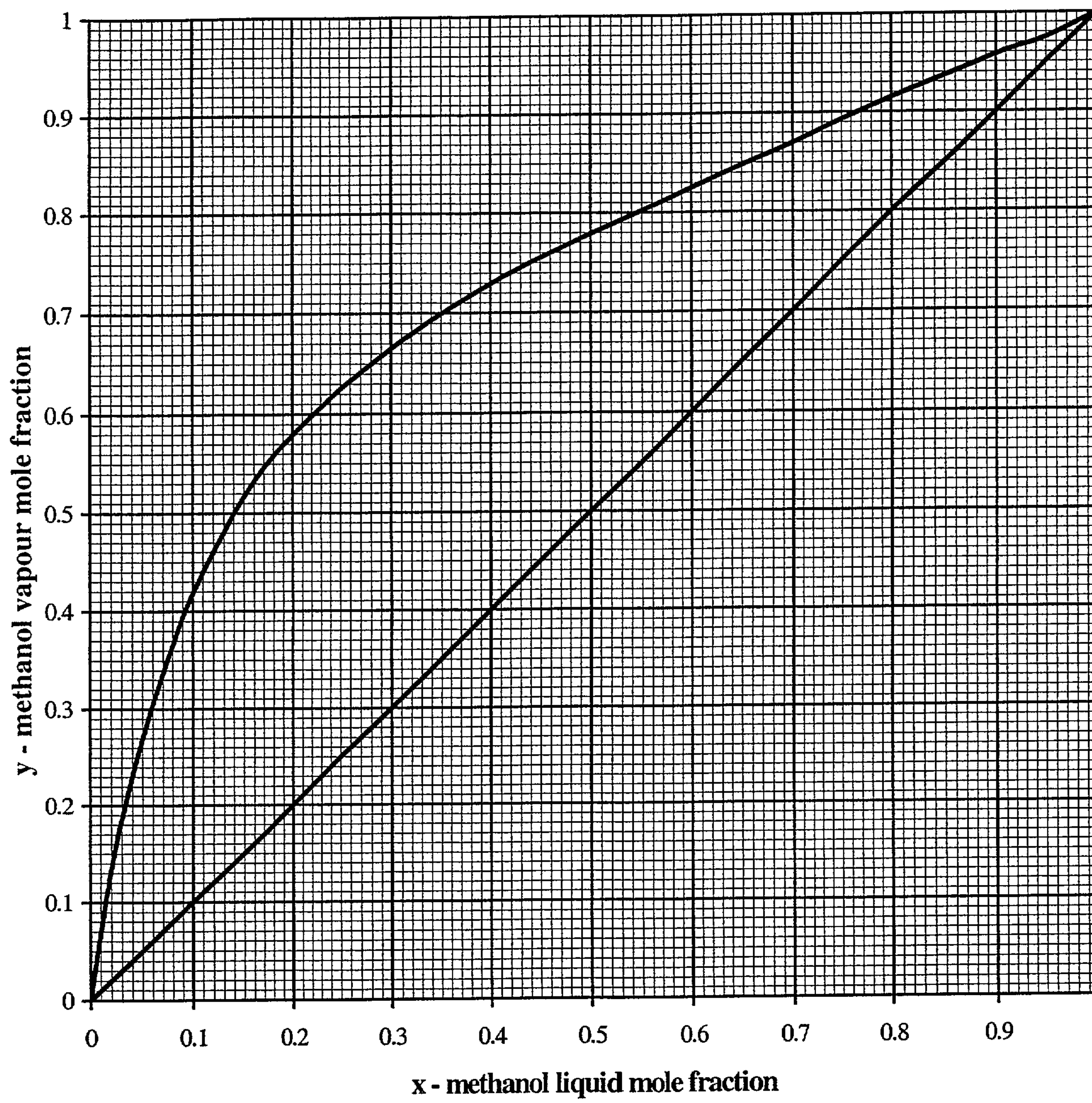
y - methanol vapour mole fraction
x - methanol liquid mole fraction
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

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6.

Antibody fragment produced by *E Coli* can be released from the cell by chemical lysis. The product is then recovered by membrane separation. 100 L lysed broth is first concentrated to 50 L which gives 20% yield of the product. It is then proposed to use diafiltration to increase the yield.

a) How much diafiltration buffer is needed to achieve a final yield of 80%? [10]

b) Please give the assumptions you have made. [5]

c) Please give an appraisal of this method of antibody fragment recovery considering that the product is to be further purified by high resolution chromatography. [10]

7.

The disk-stack centrifuge is often used in industrial solid-liquid separation due to its continuous mode of operation. You have 100 L fermentation broth which is a mixture of cells, product (a protein) and soluble contaminants. The solids carry over in the centrifuge is 5% and the dewatering level of the sediment is 50% by volume cells. The level of product recovery is not satisfactory and a washing stage has to be introduced to increase the yield. You can have two options. One is to centrifuge the 100 L broth, and then dilute the sediment using 100 L buffer, and then centrifuge again. The other is to dilute the fermentation broth by adding 100 L buffer, and then centrifuge the diluted broth.

a) Predict the composition of each stream involved in the two processes. [15]

b) Summarise the two process options. [5]

c) If the yield in the pilot plant trial is lower that you predicted, discuss the possible reasons. [5]

Background information:

Cell concentration in fermentation broth 40g dry weight/L
Cell wet to dry weight ratio ~ 3
Product concentration in fermentation broth is 0.3 g/L
Contaminants are negligible
Assume for purpose of calculation that the density of the cells and the liquor are the same as 1 kg/L

END OF PAPER