UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Chemical Eng E866: Introduction to Chemical Engineering

COURSE CODE : **CENGE866**

UNIT VALUE : **0.50**

DATE : **04-MAY-04**

TIME : **14.30**

TIME ALLOWED : **3 Hours**

04-C0194-3-70

Answer FOUR questions. All questions carry a total of 25 marks each, distributed as shown [ ]. Show all workings and state all assumptions.

All pressures are absolute unless otherwise stated.
$R = 8.314\ J\ mol^{-1}\ K^{-1}$. 1 atm = 760 mm Hg. 1 bar = 100 kPa.

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 cooler unit contains 2.30 mole% H_2O. In the cooler, 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 air entering the process and the moles of dehumidified air recycled. [25]

2.

A gas stream consisting of 100 kmol/h of an SO_2-air mixture containing 45 mole% SO_2 is contacted with liquid water in a continuous absorber at 30 °C. The liquid leaving the absorber is analysed and found to contain 2.00 g of SO_2 per 100 g of H_2O. Assuming that the gas and liquid streams leaving the absorber are in equilibrium at 30 °C and 1 bar, calculate the fraction of the entering SO_2 absorbed in the water and the required water feed rate. [25]

Data: $p_{H_2O} = 31.6$ mm Hg at 30 °C, $p_{SO_2} = 176$ mm Hg at 30 °C,
Atomic masses: H = 1; O = 16; S = 32.

3.

A 10.0 m^3 tank contains steam at 275 °C and 15.0 bar. The tank and its contents are cooled until the pressure drops to 1.2 bar. Some of the steam condenses in the process.

(a) How much heat was transferred from the tank. [10]

(b) What is the final temperature of the tank contents? [5]

(c) How much steam condensed (kg)? [10]

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4.

(a)

(i) Centrifugal pumps operate at constant speed and the capacity (flow rate), Q, depends upon the total head, H, the design and the suction conditions. For a pump at a particular speed, what are the curves represented in Figure 1 known as? Explain also what they represent. [2]

(ii) Define the "duty point" of a pump and report it graphically in Figure 1. Attach a copy of the graph to be submitted with the answer. [3]

(iii) If a pump is capable of being operated at variable speeds, explain how the capacity, head and horsepower of the pump will change if the pump was operated at higher speed. For this case, draw a new set of curves in Figure 1, showing also the new duty point of the pump. [5]

(b)

A process fluid is to be cooled from 130 °C to 80 °C by using water in a counter – current flow double-pipe heat exchanger. Water flows through the inner tube at a rate of 0.5 kg s^{-1}, entering the tube at 25 °C and leaving at 50 °C. The inner tube has a 20 mm internal diameter and a 23 mm external diameter and it is made from steel with a thermal conductivity k_s = 45 W m^{-1} K^{-1}. The heat transfer coefficient of the process fluid side film is 72.5 W m^{-2} K^{-1}. The heat transfer coefficient for the water side film can be calculated using the following equations:

Turbulent flow: $Nu = 0.023\, Re^{0.8}\, Pr^{0.4}$

where:

$Nu = \dfrac{hd}{k}$, Nusselt number

$Pr = \dfrac{\mu c_p}{k}$, Prandtl number

Re is the Reynolds number, h is the heat transfer coefficient of the water side film and d is the internal diameter of the inner tube.

(i) Determine the overall heat transfer coefficient. [8]

(ii) Neglecting the tube wall curvature, calculate the required area for heat exchange. [7]

The following values can be used for the properties of water:
density ρ = 990 kgm^{-3}, viscosity μ = 0.6 mPa s,
thermal conductivity k = 0.637 W m^{-1} K^{-1}, specific heat c_p = 4180 J kg^{-1} K^{-1}.

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5.

Benzene and chlorobenzene are to be separated by a continuous distillation in a fractionation column operating in conjunction with a total condenser and a partial reboiler. The feed to the column is saturated liquid with 40 mol% benzene and flowrate 100 kmol h^{-1}. The required products are the distillate with 95 mol% benzene and a bottoms product with 5 mol% benzene.

(a) Sketch and *label* a simple flow diagram to show the arrangement of the column, condenser and reboiler and the approximate location of the feed. [5]

(b) Calculate the flowrates (kmol h^{-1}) of the product streams. [5]

(c) Assuming constant molar overflow and with the aid of the diagram supplied, which must be attached inside your answer book, use a graphical method to estimate the minimum reflux ratio for the separation and the number of equilibrium stages required inside the column if the reflux ratio used is 1.5 times the minimum. [15]

Data: Diagram (Figure 2) supplied showing the vapour-liquid equilibrium curve for the benzene-chlorobenzene system.

6.

(a) A solution containing reactant A with concentration C_{Ao} mol m^{-3}, flows through a tubular reactor of volume V m^3 at a flowrate of υ m^3 s^{-1}. Assuming the liquid is in plug flow, the reaction is homogeneous and isothermal with no change in volume and the rate of reaction is second order in A with reaction rate constant of k m^3 mol^{-1} s^{-1}, derive an expression for the fraction of A unconverted at the reactor outlet. [15]

(b) Use the derived expression to calculate the volume of such a tubular reactor needed to give an 80% conversion of reactant with an inlet flowrate of 0.01 m^3 s^{-1}, inlet concentration 2 mol m^{-3} and a reaction rate constant of 0.1 m^3 mol^{-1} s^{-1}. [10]

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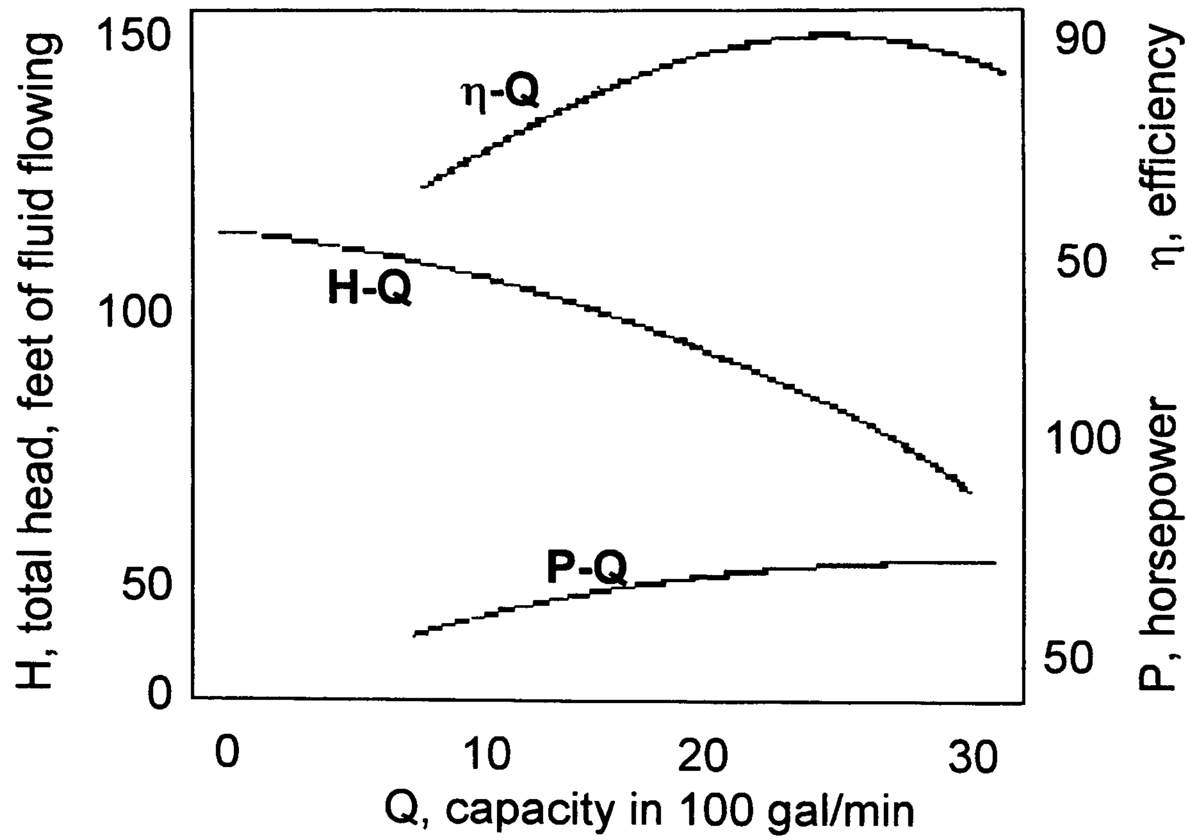

FIGURE 1

* Material from "Elementary principles of chemical processes", 3rd edition by R M Felder and R W Rousseau, Wiley

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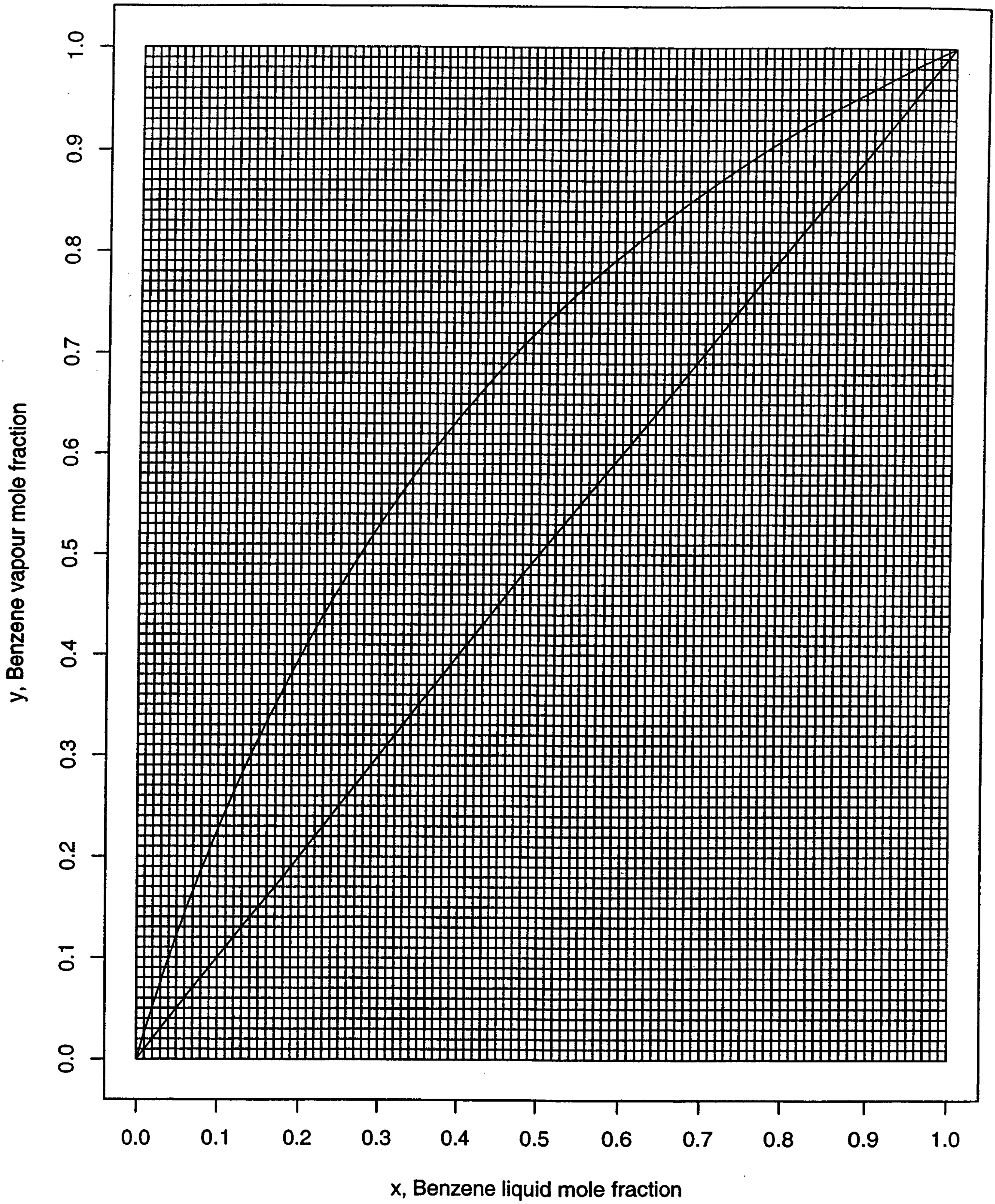
Figure 2: Benzene/Chlorobenzene Equilibrium curve



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