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	:	**02-MAY-06**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

06-C0227-3-80

TURN OVER

*Answer **FOUR** questions. All questions carry a total of 25 marks each, distributed as shown [ ]. Show all workings and state all assumptions. Only the first FOUR answers will be marked.*

All pressures are absolute unless otherwise stated.
R = 8.314 J/mol K. 1 atm = 760 mm Hg. 1 bar = 100 kPa.

1.

Methane and oxygen react in the presence of a catalyst to form formaldehyde. In a parallel reaction, methane is oxidized to carbon dioxide and water:

$$CH_4 + O_2 \rightarrow HCHO + H_2O$$
$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

The feed to the reactor contains equimolar amounts of methane and oxygen. Assume a basis of calculation of 100 mol feed/s.

a) Draw and label a flowchart. Use a degree-of-freedom analysis based on extents of reaction to determine how many process variable values must be specified for the remaining variable values to be calculated. [10]

b) Derive expressions for the product stream component flow rates in terms of the two extents of reaction, $\dot{\xi}_1$ and $\dot{\xi}_2$. [5]

c) The fractional conversion of methane is 0.900 and the fractional yield of formaldehyde is 0.855. Calculate the molar flowrates of the individual components in the output stream and the selectivity of formaldehyde production relative to carbon dioxide production. [10]

2.

The oxidation of nitric oxide

$$NO + \tfrac{1}{2}\,O_2 \leftrightarrow NO_2$$

takes place in an isothermal batch reactor. The reactor is charged with a mixture containing 20.0 volume percent NO and the balance air (79% N_2, 21% O_2) at an initial pressure of 380 kPa.

a) Assuming ideal gas behaviour, determine the composition of the mixture (component mole fractions) and the final pressure (kPa) if the conversion of NO is 90%. [12]

b) Suppose the pressure in the reactor eventually equilibriates (levels out) at 360 kPa. What is the equilibrium percent conversion of NO? [10]

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c) Calculate the reaction equilibrium constant at the prevailing temperature, K_p [$\{kPa\}^{-0.5}$], defined as:

$$K_p = \frac{(p_{NO_2})}{(p_{NO})(p_{O_2})^{0.5}}$$

where p_i (kPa) is the partial pressure of species i (NO_2, NO, O_2) at equilibrium. [3]

3.

Five hundred kilograms 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 10^4 kcal/h. Calculate the specific enthalpy change associated with the process.

Note: 1 J = 0.23901 cal and the potential energy of an object with mass m at a height h in Earth's gravitational field is given by $E_p = m\,g\,h$ where $g = 9.81$ m/s^2.

[25]

4.

Butane and pentane are to be separated by continuous distillation in a fractionation column operating in conjunction with a total condenser and a partial reboiler. The feed to the column is 40 mol% butane as saturated liquid with a flowrate of 200 kmol/h. The required products are the distillate with 95 mol% butane and a bottoms product with 5 mol% butane.

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) of the product streams. [5]

c) Assuming constant molar overflow and with the aid of the diagram supplied (Figure 1), 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. The figure is a graph of the equilibrium curve with the x-axis representing the liquid composition in terms of butane mole fraction and the y-axis the vapour composition, again in terms of butane mole fraction. [15]

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5.

a) A flat wall of uniform, homogeneous material having constant thermal conductivity "k", thickness "x" and surface area "A" is exposed to a hot fluid at temperature "T_h" on one side and to a cold fluid at temperature "T_c" on the other side. Derive an expression for the overall heat transfer coefficient "U". Use "h_h" and "h_c" to denote the heat transfer coefficient of the hot and cold fluid respectively. [10]

b) Consider two fluids between which heat is being exchanged in a double pipe heat exchanger. Both inlet and outlet temperatures of each fluid are given:

Hot fluid: T_{hi}=180 °C and T_{ho}=130 °C ;
Cold Fluid: T_{ci}=60 °C and T_{co}=100 °C

Draw the temperature profiles for both parallel and counter flow heat exchanger types and calculate the log mean temperature difference (ΔTlm) for both parallel and counter flow. [8]

For a given amount of heat exchanged, q, and assuming that U is the same for parallel and counter flow heat exchangers, calculate and compare the heat transfer area required in both cases. [7]

6.

a) Describe and give a schematic of the following reactors: fixed bed, trickle bed, fluidised bed and slurry reactor. [8]

b) Give typical particle sizes of catalysts used in the above reactors. [3]

c) Develop the equation which can be used to calculate the reaction rate for a gas-solid reaction (for example combustion of a nonporous carbon particle with first order kinetics). [10]

d) Under what conditions is the reaction in (c) under mass transfer control and under what conditions is it under kinetic control? [4]

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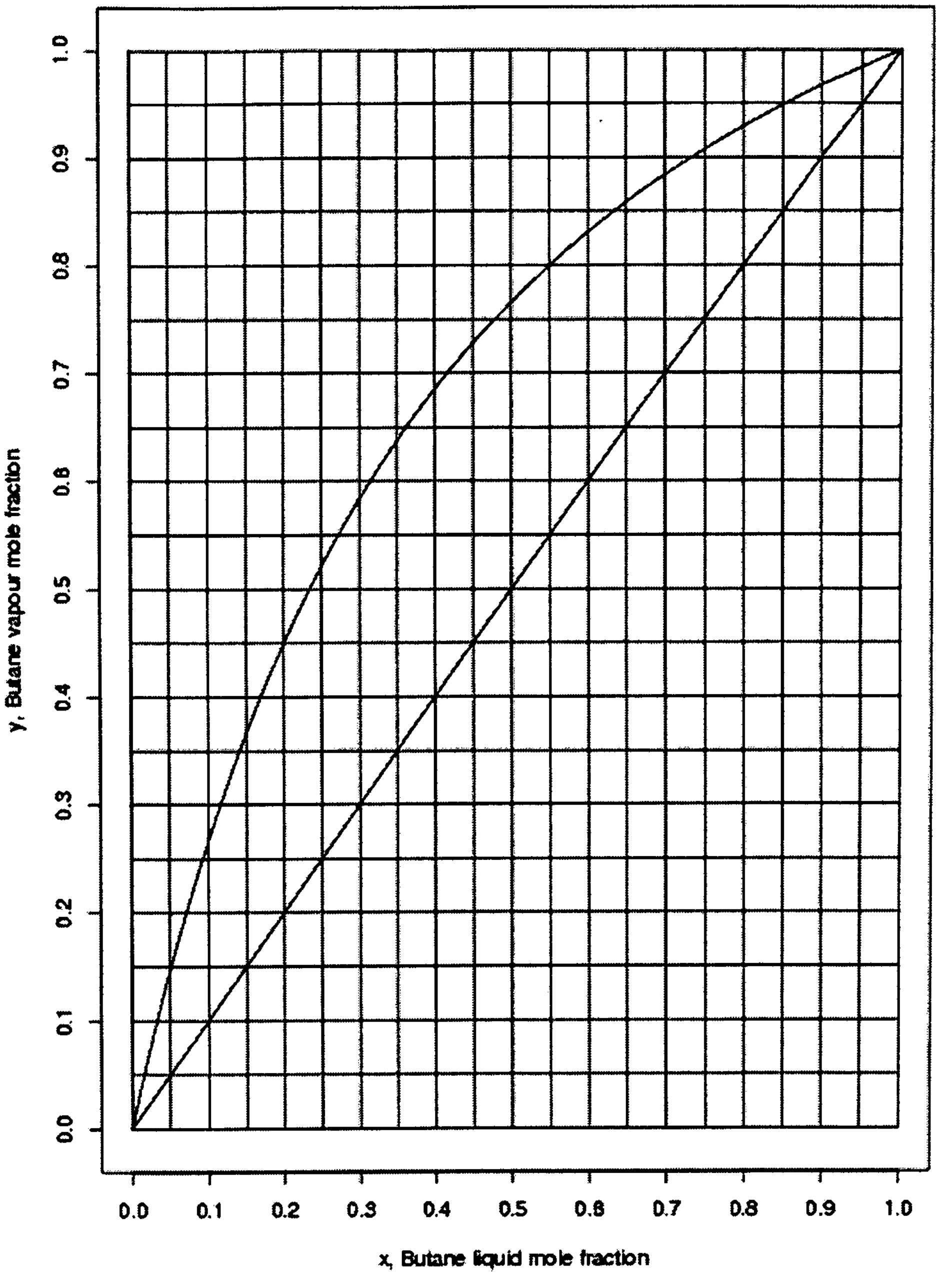
Candidate Identifier ______________

Seat Number ____________________

Figure 1: Butane/Pentane Equilibrium curve



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