CHEMICAL ENGINEERING

Paper – I

*Time Allowed : **Three** Hours*	*Maximum Marks : **200***

Question Paper Specific Instructions

Please read each of the following instructions carefully before attempting questions :

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*

*Questions no. **1** and **5** are **compulsory**. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections A and B.*

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary, and indicate the same clearly.

Neat sketches may be drawn, wherever required.

*Answers must be written in **ENGLISH** only.*

SECTION A

Q1. (a) What do you know about the terms 'priming' and 'cavitation' in pumping operation ? How do you avoid cavitation ? *8*

(b) (i) For the diffusion of solute A through a layer of gas to an absorbing liquid with $y_A = 0{\cdot}20$ and $y_{Ai} = 0{\cdot}10$, calculate the transfer rate for one way diffusion compared to that of equimolal diffusion.

(ii) What is the value of y_A half way through the layer for one way diffusion ? *8*

(c) Describe "Optimum Reflux Ratio" with a neat sketch. *8*

(d) What are the assumptions made in case of free settling velocity equation ? How do you relax these assumptions for hindered settling velocity equation ? *8*

(e) Compare multiple effect evaporator with single effect evaporator in terms of steam economy and capacity. *8*

Q2. (a) A vacuum leaf filter gives a total volume of 10 m^3 of filtrate in 30 minutes. Assuming that the resistance of filter cloth is negligible, find the time taken for the collection of 20 m^3 and 30 m^3 of filtrate. *10*

(b) A methanol (A) – water (B) solution containing 50 wt% methanol at 26·7°C is to be continuously rectified at 1 std atm pressure at a rate of 5000 kg/h to provide a distillate containing 95% methanol and a residue containing 1·0% methanol (by weight). The feed is to be preheated by heat exchange with the residue, which will leave the system at 37·8°C. The distillate is to be totally condensed to a liquid and the reflux returned at a bubble point. The withdrawn distillate will be separately collected before storage. A reflux ratio of 1·5 times the minimum will be used. Determine (i) quantity of product, (ii) enthalpy of feed and of product, (iii) minimum reflux ratio, and (iv) minimum number of theoretical trays. *15*

Given :

$t_o = 19{\cdot}69°C$

x = 0·3 mass fraction (m.f.) methanol

y = 0·665 m.f. methanol

For saturated liquid :

Heat capacity of methanol = 3852 J/kg.K

Heat of solution = 3055 kJ/kmol methanol

For saturated vapours :

y = 0·665 m.f. of methanol

Dew point = 78·3°C

Latent heat of methanol = 1046·7 kJ/kg

Latent heat of water = 2314 kJ/kg

Heat capacity of methanol = 2583 J/kg.K

Heat capacity of water = 2323 J/kg.K

$t_F = 58{\cdot}3°C$ temperature at which feed enters

Take :

Bubble point of residue = 99°C

Heat capacity of residue = 4179 J/kg.K

Heat capacity of feed = 3852 J/kg.K

For feed $\Delta H_S = -902{\cdot}5$ kJ/kmol

Take at : Δ_{D_m}, $Q_m = 62570$ kJ/kmol

$H_{G1} = 38610$ kJ/kmol

Take : Theoretical stages = 4·9 including reboiler.

Note : Refer graphs for required values, if any.

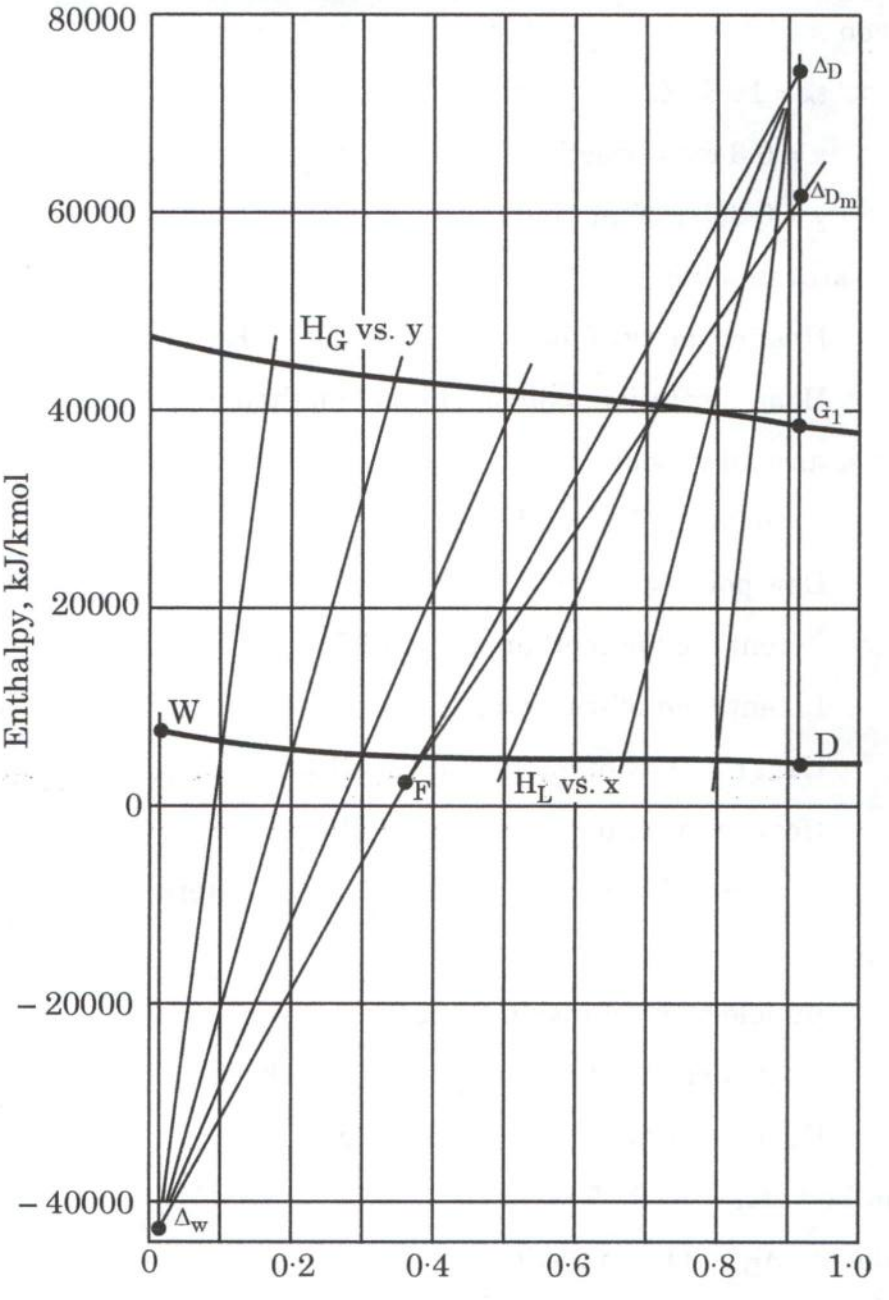


Figure : Enthalpy-concentration diagram for methanol – water system

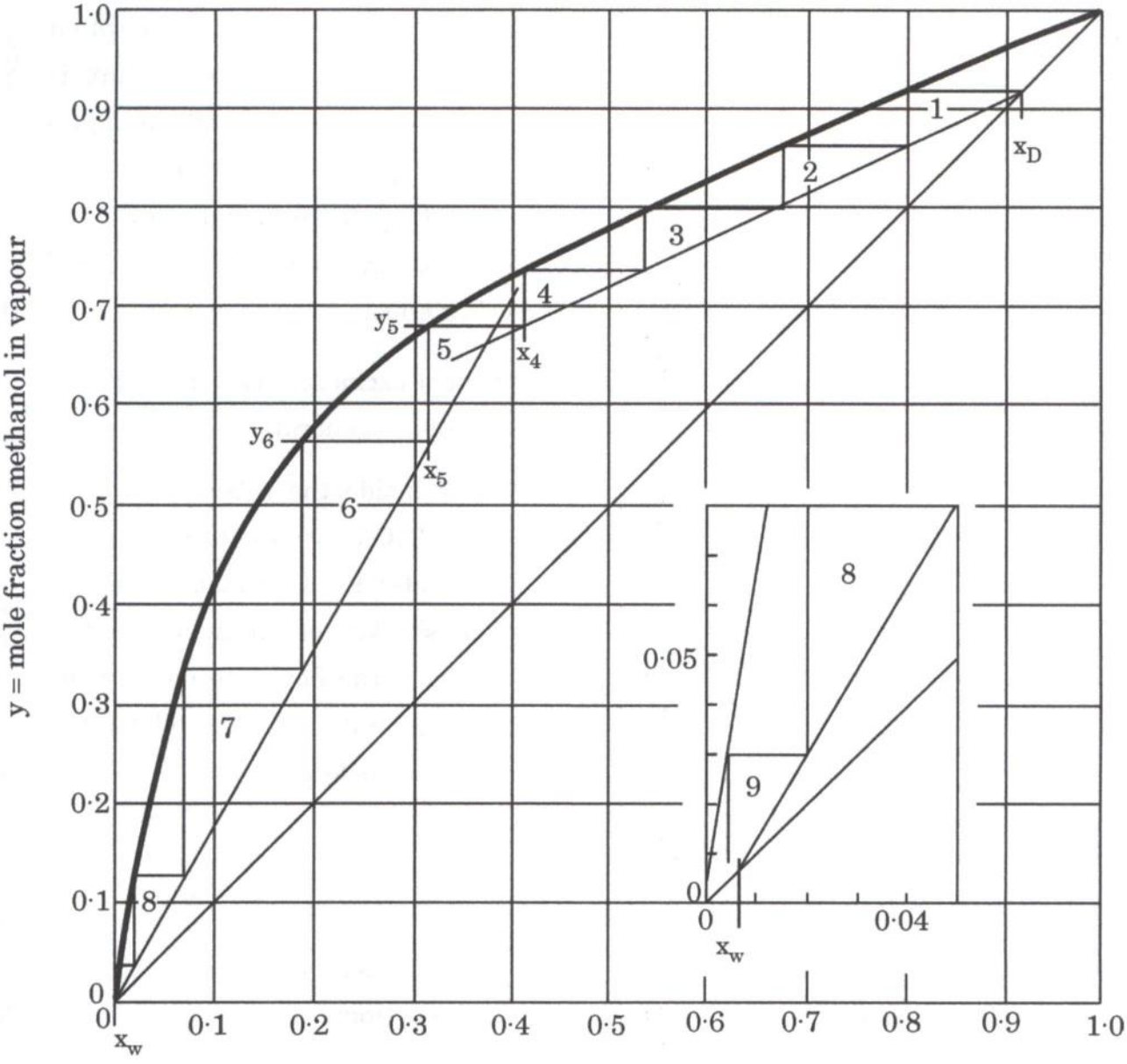


Figure : xy diagram for methanol – water system

(c) Water at the rate of 3·783 kg/s is heated from 37·78°C to 54·44°C in a shell and tube heat exchanger. On the shell side, one pass is used with water as a heating fluid, 1·892 kg/s entering the exchanger at 93·33°C. The overall heat transfer coefficient is 1419 W/m^2 °C and the average water velocity in the 1·905 cm diameter tubes is 0·366 m/s. Because of space limitations, the tube length must not be longer than 2·438 m. Calculate the number of tube passes, the number of tubes per pass and the length of the tube consistent with this restriction. *15*

Data : F = 0·88 (correction factor)

Q3. (a) Sulphur dioxide is absorbed from air into water in a packed absorption tower. At a certain location in the tower, the mass transfer flux is 0·0270 kmol SO_2 per m^2.h (i.e., 0·0270 kmol SO_2/m^2.h) and the liquid phase mole fractions are 0·0025 and 0·0003 respectively at the two-phase interface and in the bulk liquid. If the diffusivity of SO_2 in water is $1·7 \times 10^{-5}$ cm^2/s, determine the mass transfer coefficient, k_c and the film thickness neglecting the bulk flow effect. *10*

(b) Well-baffled single-shell, two-tube pass heat exchanger performance test has been carried out and the following data are generated :

Oil (c_p = 2100 J/kg.K) in turbulent flow inside the tubes entered at 340 K at the rate of 1·00 kg/s and left at 310 K; water flowing on the shell side entered at 290 K and left at 300 K. A change in service conditions requires the cooling of a similar oil from an initial temperature of 370 K but at three-fourths of the flow rate used in the performance test. Estimate the outlet temperature of the oil for the same water flow rate and inlet temperature as before. *15*

Take F = 0·94

Take ξ (effectiveness factor) = 0·61

(c) Find the time taken to empty a hemispherical vessel of radius 'R' through an orifice of area 'a', located at the bottom. *15*

Q4. (a) Roasted copper ore containing the copper as $CuSO_4$ is to be extracted in a countercurrent stage extractor. Each hour a charge consisting of 10 tons of gangue, 1·2 tons of copper sulphate, and 0·5 ton of water is to be treated. The strong solution produced is to consist of 90% H_2O and 10% $CuSO_4$ by weight. The recovery of $CuSO_4$ is to be 98% of that in the ore. Pure water is to be used as a fresh solvent. After each state, 1 ton of inert gangue retains 2 tons of water plus the copper sulphate dissolved in that water. Equilibrium is attained in each stage. How many stages are required ? *15*

(b) Two perfectly black parallel plates 1·2 m by 1·2 m are separated by a distance of 1·2 m. One plate is maintained at 800 K and the other at 500 K. The plates are located in a large room whose walls are at 300 K. What is the net heat transfer between the plates ? *10*

Stefan-Boltzmann constant $\sigma = 5{\cdot}669 \times 10^{-8}$ W/m^2.K^4

F_{12} (view factor) = 0·2

(c) (i) Calculate the work index of a material, if power required to crush 100 tons/h of this material is 180 kW. 80% of the feed and product passes through 50 mm and 3 mm screen respectively.

(ii) Calculate the sphericity of a cylindrical particle of diameter 4 mm and length 4 mm. *15*

SECTION B

Q5. (a) Explain the mechanism of Electrodialysis process to separate salts from sea-water. *8*

(b) How does the concentration polarization affect the solvent (water) flux in reverse osmosis process ? Explain. *8*

(c) Describe the selection criteria for material of construction (steels) for vessels operating at elevated temperatures. Give your recommendation for material of construction for both low and high values of operating pressure. *8*

(d) Define adaptive control. With a neat diagram, explain the construction and working of adaptive control. *8*

(e) What is the relationship between pressure and liquid level measurement ? What pressure will be created by a column of liquid 5 metres high, if the density of the liquid is 5000 kg/m^3 ? *8*

Q6. (a) (i) Write various 'control system parameters'.

(ii) A velocity control system has a range of 220 mm/s to 460 mm/s. If the setpoint is 327 mm/s and the measured value is 294 mm/s, calculate the error as percentage of span. *10*

(b) A cellophane membrane dialyzer is operated at 37°C. The membrane used in the dialyzer has an area of 2·5 m^2 and thickness of 0·03 mm. The concentration of urea in the blood is 0·025 g urea per 100 mL and that in the dialyzing fluid will be assumed as zero. Calculate the flux of urea at steady state in g/h from blood. The mass transfer coefficient on the blood side is $1{\cdot}25 \times 10^{-5}$ m/s and that on the aqueous side is $3{\cdot}33 \times 10^{-5}$ m/s. The permeability of the membrane is 8×10^{-6} m/s. *15*

(c) (i) What are the factors to be considered while selecting the 'type of support' of vessels ?

(ii) What is skirt support ? Write the steps for the design of skirt support. *15*

Q7. (a) Write the advantages of supercritical fluid extraction (SFE). Why is CO_2 frequently a desirable solvent for SFE ? *10*

(b) A thermocouple has the following characteristics when it is immersed in a stirred bath :

Mass of thermocouple = 1 g

Heat capacity of thermocouple = 0·25 cal/g °C

Heat transfer coefficient = 20 cal/cm^2 h °C (for thermocouple and bath)

Surface area of thermocouple = 3 cm^2

Derive a transfer function model for the thermocouple relating the change in its indicated output T to the change in the temperature of its surroundings T_s assuming uniform temperature (no gradients in the thermocouple bead), no conduction in the leads, constant physical properties, and conversion of the millivolt-level output directly to a °C reading by a very fast meter. *15*

(c) A pressure vessel having outer diameter 1·3 m and height 3·8 m is subjected to internal pressure of 12 kg/cm^2. The vessel is fabricated as class B vessel having joint efficiency of 85%. Calculate the vessel thickness under the following conditions : *15*

Allowable stress of material = 1020 kg/cm^2

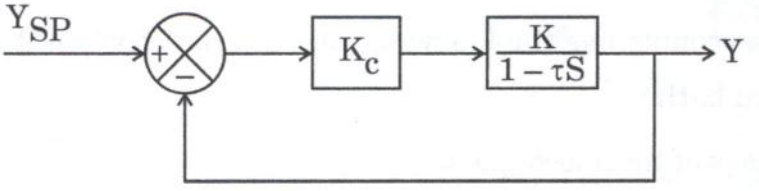
Corrosion allowance = 1 mm

Q8. (a) (i) What are permeability and permeance in membrane separation ?

(ii) Describe the mechanism for the transport of gases through dense polymeric membrane. *15*

(b) Write the parameters influencing the design of vessels. Describe each one of them in short. *10*

(c) (i) For the process and controller shown below, find the range of K_c values that yield a stable response. (Note that τ is positive)



(ii) Also check the gain of $Y(S)/Y_{SP}(S)$ to make sure that the process responds in the correct direction if K_c is within the range of part (i). *15*