2013-14
M.TECH. (AUTUMN SEMESTER) EXAMINATION
(CIVIL/PETRO CHEMICAL ENGINEERING)
(ENVIRONMENTAL ENGINEERING)
ENVIRONMENTAL CHEMISTRY
(CE 622 / PK- 620)

Maximum Marks: 60
Credits: 04
Duration: Three Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No.

Question

1(a) Using half reactions balance the following oxidation reduction reactions

(i) Oxidation of ammonium to nitrate and reduction of oxygen to water

(ii) Oxidation of acetate to carbon dioxide and reduction of sulphate to hydrogen sulphide

1(b) Find the pH of a 0.05M acetic acid solution. What would be the pH of the solution if 10 mL of 0.01M NaOH solution is added to 500 mL of 0.05M acetic acid solution

OR

1’ (a) Briefly explain the significance of alkalinity in water treatment processes. Calculate the hydroxide, carbonate and bicarbonate alkalinity using the following experimental results

Initial pH of sample = 11.2, volume of sample taken for titration = 100mL
mL of 0.02 N H₂SO₄ used to reach phenolphthalein end point = 8.2
mL of 0.02 N H₂SO₄ used to reach methyl orange end point = 8.4

1’ (b) Briefly explain the different units used for expressing the strength of a solution

1’ (c) Define proton balance. Illustrate your definition with a suitable example.

2 (a) Draw the logarithmic concentration diagrams for the following solutions on a graph paper.

(i) 0.01 M H₂CO₃ solution

(ii) 0.02 M H₃PO₄ solution

Contd......2
2 (b) With the help of concentration diagrams determine the pH of 0.01 M Na₂CO₃ solution and 0.02 M H₃PO₄ solution

2 (c) Calculate the activity of each ion in a solution containing 0.02 M NaCl and 0.01 M of MgSO₄

OR

2' (a) Describe in detail the procedure adopted for the determination of fluoride ion in water

2'(b) Briefly describe common ion effect. Calculate the solubility of fluoride ion in a saturated solution of sodium fluoride if the sample has already 75 mg/L of Ca⁺⁺.

3 (a) Define buffers and briefly explain their significance

3 (b) A buffer is made by combining monosodium oxalate (NaC₂O₄H) and disodium oxalate (Na₂C₂O₄) to give concentrations of 0.02 M (NaC₂O₄H) and 0.03 (Na₂C₂O₄). Take pK₁ = 1.25 and pK₂ = 4.28

(i) What is the initial pH of the buffer?
(ii) What is its buffer index?
(iii) What is the pH of the buffer after addition of 0.001 M of HCl?

3 (c) Briefly explain the criteria of selection of weak acid system for the preparation of buffer solution.

3 (d) Briefly explain the significance of buffer index

4 Using logarithmic concentration diagrams determine the optimum pH and minimum soluble concentration of Cadmium in a wastewater solution treated with lime. Take the value Kₛₚ for Cd(OH)₂ = 2 x 10⁻¹⁴ and the values of formation constants for cadmium hydroxide complexes as follows:

Log K₁ = 6.08, Log K₂ = 2.62, Log K₃ = -0.32 and Log K₄ = 0.04

5 Discuss any three of the following:

(i) Different types of surfactants and their significance in environmental engineering
(ii) Different pesticides used in agricultural practices in India.
(iii) Chlorophenols and their structures
(iv) Pollutants found in Petroleum Refinery Wastewater
Consider a series of \( m \) CSTRs in which an irreversible liquid phase reaction: \( A \rightarrow B \) \((-r_A = kC_A^n)\), is taking place. Flow control valves are installed on the outlet of each reactor and follow the relationship \( F_i = f(V_i) \), where \( F_i \) is the volumetric flow rate from \( i^{th} \) reactor and \( V_i \) is the holdup in \( i^{th} \) reactor. The process is isothermal, however, the holdup in each CSTR is varying depending on the net flow in the reactor. Develop the dynamic model of this system and specify the assumptions used.

OR

Consider a single component vaporizer sketched in Fig. 1. The liquid is fed at a volumetric flow rate \( F_0 \) into a pressurized tank to hold the liquid level in the tank. Heat is added at a rate \( Q \) to hold the desired pressure in the tank by vaporizing the liquid at a rate \( W_p \) (mass per time). Heat losses and the mass of the tank walls are assumed negligible. Gas is drawn off the top of the tank at a volumetric flow rate \( F_v \). Develop the dynamic model of this vaporizer. Assume that the vapour phase behaves as an ideal gas and its dynamics can be neglected. The relationships between inlet flow and holdup, and the heat input and pressure are respectively given by:

\[
Q = f_1(P) \quad \text{and} \quad F_0 = f_2(V_L).
\]
2. A radial flow reactor with its inner walls coated with a catalytic agent is shown in Fig. 2. An isothermal gaseous phase first order catalytic reaction \((A \rightarrow B)\) is taking place on the inner surface of the walls. The volumetric flow rate and the reactant concentration of the feed are \(v_0\) and \(C_{A0}\), respectively. The flow between the plates is laminar, and the steady state and isothermal conditions are prevailing. Develop the model equation for this reactor along with relevant conditions. It should be noted that the velocity will not be constant along radial direction. The density of the fluid mixture may be assumed to be constant throughout the system.
3(a). Develop the maximum gradient model of a packed bed adsorber by assuming that the process of adsorption is fast and that the local equilibrium exists near the solid particles; the equilibrium relation follows a linear relationship between the solid phase composition and solute composition. Also specify the relevant ICs and BCs.

3(b). A Newtonian fluid of constant density and viscosity is contained in a very long horizontal square duct of cross sectional area $a^2$ and length $L$. Initially the fluid is at rest and at time $t=0$, a pressure gradient $(P_0-P_f)/L$ is impressed on the system. Develop the model equation describing the transient velocity profile of flowing fluid. Also state the relevant assumptions and associated conditions used.

OR

3’. Consider the steady flow of a Newtonian fluid over a sharp edged and very thin plate as shown in Fig. 3. The velocity and temperature of the fluid away from the boundary layer are denoted by $U_\infty$ and $T_\infty$, respectively. The fluid properties are assumed to be constant and the viscous dissipation can be neglected. Develop the transport phenomena based microscopic model for the flow in boundary layer. Also carry out the scaling of resultant equations and order of magnitude analysis to extract the maximum information without solving the equations.

![Figure 3: Boundary layer flow over a sharp edged thin plate](image-url)
4. Develop the mathematical models for any two of the following systems. Also state the relevant assumptions and allied conditions.

(i) Start-up operation of a double pipe heat exchanger with a counter current flow arrangement (hot fluid is flowing in the inner pipe and the cold fluid is flowing the outer pipe).

(ii) Unsteady state axial dispersion model of a tubular chemical reactor running under isothermal conditions.

(iii) Dissolution of a spherical pill inside stomach.
2013-14
M.TECH. (AUTUMN SEMESTER) EXAMINATION
PETROLEUM PROCESSING & PETROCHEMICAL ENGINEERING
PETROLEUM PROCESSING
PK 602

Maximum Marks: 60 Credits: 04 Duration: Three Hours

Answer all the questions.
Assume suitable data if missing.
All questions, and parts thereof, be started on a fresh page of the answer book(s).

Q.No. Question M.M.
1(a) Differentiate any two of the following. [3+3]
   (i) Core Bit & PDC Bit
   (ii) Drill Collar & Crossover Subs
   (iii) Aerated Mud and oil based Mud

1(b) What do you mean by ‘Trip’ & ‘Trip tanks’? Which is the first line of action against Kick? Name and discuss some basic BOP equipments. [6]

OR

1(b') Name different drill string components. Explain clearly the function of each. [6]

1(c) Explain briefly the method of conducting seismic surveys for finding petroleum reservoirs. [3]

2(a) Name various steps involved in completion of well. Discuss cementing & perforation in detail. [7]

OR

2(a') Differentiate between Primary, Secondary and Tertiary Oil recovery methods. Describe the chemical & thermal methods of enhanced oil recovery [7]

2(b) Discuss the thermodynamics & kinetic considerations of various reactions involved in catalytic reforming process. Describe any one type of catalytic reforming process with the help of suitable process flow sheet. [8]

3(a) Discuss the factors that influence the occurrence of petroleum. [6]
3(b) Explain the process of petroleum migration and accumulation. [4]
3(c) Explain the significance of Source, Reservoir and Cap rocks. [5]

OR

3(c') Define kerogen. Discuss, in brief, types of kerogen and stages of kerogen maturation. [5]

Contd......2
4(a) Describe the theories of origin of petroleum. [5]

4(b) Discuss porosity and permeability as important physical properties of oil bearing rocks that are important for oil generation and production. [10]

OR

4(b') Discuss, in detail, the process of atmospheric and vacuum distillation of crude oil. [10]
Q1(a). The Liquid feed of 100 mol/h having composition in mole fraction as (n-butane \(x_A = 0.40\), n-pentane \(x_B = 0.25\), n-hexane \(x_C = 0.20\), n-heptane \(x_D = 0.15\)) is fed to a distillation tower at 405.3 kPa and is to be fractionated so that 95\% of the n-pentane (B) is recovered in the distillate and 92\% of the n-hexane (C) in bottoms. Calculate the following:

1. Moles per hour and composition of distillate and bottoms.
2. Dew point and Bubble point.

Q1(b). Following is the composition of feed to the distillation tower: (n-butane \(x_A = 0.40\), n-pentane \(x_B = 0.25\), n-hexane \(x_C = 0.20\), n-heptane \(x_D = 0.15\)). At a pressure of 405.3 kPa. Calculate the temperature and composition of both the phases when 40 \% of the feed is vaporized in a flash distillation.

Q1(c) A liquid feed at its bubble point is to be distilled in a tray tower to produce the distillate and bottoms as follows: Feed, \(x_{AF} = 0.047, x_{BF} = 0.072, x_{CF} = 0.881\); distillate, \(x_{AD} = 0.1260, x_{BD} = 0.1913, x_{CD} = 0.6827\); bottoms, \(x_{AW} = 0, x_{BW} = 0.001, x_{CW} = 0.999\). Average \(\alpha\) values to use are \(\alpha_A = 4.19, \alpha_B = 1.58, \alpha_C = 1.00\).

1. For a feed rate of 100 mol/h, calculate D and W, number of
stages at total reflux, and distribution of A in the bottoms.

2. Calculate $R_m$ and the number of stages at $1.25 \times R_m$.

3. Feed tray location

**OR**

**Q1(c').** For the distillation column shown in Figure 1, use Tridiagonal Matrix procedure to compute $x_{ij}$ for component $C_3$ (1). Use composition independent $K$-values from the Table 1.

![Diagram of distillation column](image)

**Figure 1**

**Table 1**

<table>
<thead>
<tr>
<th>Component</th>
<th>$x_{i,j}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_3$ (1)</td>
<td>0.30</td>
</tr>
<tr>
<td>$nC_4$ (2)</td>
<td>0.30</td>
</tr>
<tr>
<td>$nC_5$ (3)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Q1(d).** Explain in brief about Homogeneous Azeotropic Distillation. [03]

Contd......3
Q2(a). An aqueous feed solution of 1000 kg/h containing 23.5 wt% acetone and 76.5 wt% water is being extracted in a countercurrent multistage extraction system using pure methyl isobutyl ketone solvent at 298-299 K. The outlet water raffinate will contain 2.5 wt% acetone. Equilibrium data is given in Table 2.

1. Calculate the minimum solvent that can be used.
2. Using a solvent flow rate of 1.5 times the minimum, calculate the number of theoretical stages.

Table 2

<table>
<thead>
<tr>
<th>MIK</th>
<th>Acetone (wt%)</th>
<th>Water (wt%)</th>
<th>Water Phase (wt%)</th>
<th>MIK Phase (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>98.0</td>
<td>0</td>
<td>2.00</td>
<td>2.5</td>
<td>4.5</td>
</tr>
<tr>
<td>93.2</td>
<td>4.6</td>
<td>2.33</td>
<td>5.5</td>
<td>10.0</td>
</tr>
<tr>
<td>77.3</td>
<td>18.95</td>
<td>3.86</td>
<td>7.5</td>
<td>13.5</td>
</tr>
<tr>
<td>71.0</td>
<td>24.4</td>
<td>4.66</td>
<td>10.0</td>
<td>17.5</td>
</tr>
<tr>
<td>65.5</td>
<td>28.9</td>
<td>5.53</td>
<td>12.5</td>
<td>21.3</td>
</tr>
<tr>
<td>54.7</td>
<td>37.6</td>
<td>7.82</td>
<td>15.5</td>
<td>25.5</td>
</tr>
<tr>
<td>46.2</td>
<td>43.2</td>
<td>10.7</td>
<td>17.5</td>
<td>28.2</td>
</tr>
<tr>
<td>12.4</td>
<td>42.7</td>
<td>54.0</td>
<td>20.0</td>
<td>31.2</td>
</tr>
<tr>
<td>5.01</td>
<td>30.9</td>
<td>64.2</td>
<td>22.5</td>
<td>34.0</td>
</tr>
<tr>
<td>3.23</td>
<td>20.9</td>
<td>75.8</td>
<td>25.0</td>
<td>36.5</td>
</tr>
<tr>
<td>2.12</td>
<td>3.73</td>
<td>94.2</td>
<td>26.0</td>
<td>37.5</td>
</tr>
<tr>
<td>2.20</td>
<td>0</td>
<td>97.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OR

Q2(a'). A distillate containing 45 wt% isopropyl alcohol, 50 wt% diisopropyl ether and 5 wt% water is obtained from the isopropyl alcohol finishing column head. It is desired to recover ether from this stream by liquid-liquid countercurrent extraction with water as solvent which is entering at the top of the column so as to produce an ether containing no more than 2.5 wt% alcohol and to obtain the extracted alcohol at a concentration of at least 20 wt%. The unit will operate at 25 °C and 1 atm. Find how many stages are required. Is it...
possible to obtain an extract alcohol composition of 25 wt %. The equilibrium data is given in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Wt % Alcohol</th>
<th>Wt % Ether</th>
<th>Wt % Water</th>
<th>Wt % Alcohol</th>
<th>Wt % Ether</th>
<th>Wt % Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4</td>
<td>96.7</td>
<td>0.9</td>
<td>8.1</td>
<td>1.8</td>
<td>90.1</td>
</tr>
<tr>
<td>3.2</td>
<td>95.7</td>
<td>1.1</td>
<td>8.6</td>
<td>1.8</td>
<td>89.6</td>
</tr>
<tr>
<td>5.0</td>
<td>93.6</td>
<td>1.4</td>
<td>10.2</td>
<td>1.5</td>
<td>88.3</td>
</tr>
<tr>
<td>9.3</td>
<td>88.6</td>
<td>2.1</td>
<td>11.7</td>
<td>1.6</td>
<td>86.7</td>
</tr>
<tr>
<td>24.9</td>
<td>69.4</td>
<td>5.7</td>
<td>17.5</td>
<td>1.9</td>
<td>80.6</td>
</tr>
<tr>
<td>38.0</td>
<td>50.2</td>
<td>11.8</td>
<td>21.7</td>
<td>2.3</td>
<td>76.0</td>
</tr>
<tr>
<td>45.2</td>
<td>33.6</td>
<td>21.2</td>
<td>26.8</td>
<td>3.4</td>
<td>69.8</td>
</tr>
</tbody>
</table>

2(b). An inlet water solution of 800 Kg/h containing 12.0 wt % acetone is extracted with the solvent trichloroethane containing 0.5 wt % acetone in a counter-current tray tower at 25 °C. The solvents water and trichloroethane are essentially immiscible in each other up to a concentration of acetone in water of 27 wt %. The exit concentration in the water (raffinate) stream is set at 1.0 wt % acetone. The equilibrium data is given in Table 4.

1. Determine the minimum solvent rate needed.
2. Using 1.3 times the minimum rate, determine the number of steps needed.
(1123)

<table>
<thead>
<tr>
<th>Weight fraction of acetone in water</th>
<th>Weight fraction of acetone in trichloroethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0120</td>
<td>0.0196</td>
</tr>
<tr>
<td>0.0294</td>
<td>0.0476</td>
</tr>
<tr>
<td>0.0462</td>
<td>0.0741</td>
</tr>
<tr>
<td>0.0571</td>
<td>0.0909</td>
</tr>
<tr>
<td>0.0833</td>
<td>0.1304</td>
</tr>
<tr>
<td>0.1081</td>
<td>0.1666</td>
</tr>
<tr>
<td>0.1316</td>
<td>0.2000</td>
</tr>
</tbody>
</table>

2(e) Explain Mixer-settler type of extraction equipment with their merits and demerits.

Additional Data:

Equilibrium K values for light hydrocarbon systems at 405.3 kPa absolute

Contd......6
Erbar–Maddox correlation between reflux ratio and number of stages \( R_m \) based on Underwood method. [From J. H. Erbar, R. N. Maddox, Petrol. Refiner. 40 (5), 183 (1961). With permission.]