Ques 1 – The heavier components of hydrocarbon gas are to be removed by absorption with oil. The feed gas enters through the bottom of the tower at a flow rate of 570 mole/hr (propane = 540 mole/hr, n-butane = 30mole/hr). The absorbent oil enters through the top of the tower at a flow rate of 165 mole/hr (n-butane = 0.83 mole/hr, oil = 164.17 mole/hr). Total number of stages is 6. Estimate the exit vapour and exit liquid flow rates and compositions by the approximate group method. Assume the effective absorption and stripping factors for each component can be estimated from the entering values of L, V. The component K – values, as listed below are based on an average entering temperature of 35 degrees Celsius.

Component	C3	nC4	Oil
K	0.584	0.195	0.0001

Repeat the problem with total number of stages as 10. What changes do you see in absorption?

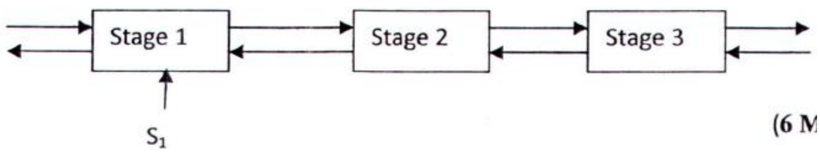
Hint : $v_1 = V_{n+1}\,\phi_A + l_0(1 - \phi_s)$ $\phi_A = (A_e - 1)/(A_e^{(N+1)} - 1)$; $\phi_S = (S_e - 1)/(S_e^{(N+1)} - 1)$; $A = L/KV$; $S = KV/L$

Ques 2 – In a gas absorption process, the solute gas A diffuses into a solvent liquid and reacts with the liquid. Assume that the concentration of A is sufficiently small such that the bulk flow is negligible and mass transfer is by steady-state unidirectional molecular diffusion. Under these conditions, the reaction is first order with respect to solute A.

i) Write only the governing equation and the boundary conditions that can lead to an expression for concentration of the solute A (as well as the flux) as a function of the distance from the interface at steady state. Write only the general solution for concentration (what you get from the governing equation), and the corresponding equation for flux.
ii) At a depth L from the liquid surface, the flux of A has fallen to one-half of the value of flux at the surface. What is the ratio of the concentration at the depth L to the concentration at the surface:
Calculate the numerical value of this ratio when $L(k_r/D)^{0.5} = 0.7$. Here, D is the molecular diffusivity and k_r is the first order rate constant.

Ques 3 – Write down the H-equation in sum rate method for absorption and stripping. Describe only the steps to solve the H-equation.

Ques 4 - The three-stage extractor is described below where the feed enters through Stage 1, and the solvent enters through Stage 3 at given flow rates. Additionally, the solvent was introduced in the first stages as S1. Draw a rough sketch of a triangular diagram with Type I envelope for miscibility, Use the material balances across stages and the tie lines to obtain the three operating points, and describe the strategy to find the flow rates of S1, if the composition of extract and raffinate from Stages 1 and 3 respectively are known.



Ques 5 - The heavier components in a slightly superheated hydrocarbon gas are to be removed by absorption at 29 bar (absolute) with oil. The feed gas enters through the bottom of the tower at a flow rate of 800 mole/hr (methane = 160 mole/hr, ethane = 370 mole/hr, propane = 240 mole/hr, n-butane = 25 mole/hr, n-pentane = 5 mole/hr).The absorbent oil enters through the top of the tower at a flow rate of 165 mole/hr (n-butane = 0.83 mole/hr, oil = 164.17 mole/hr). Total number of stages is 10. Estimate the exit vapour and exit liquid flow rates and compositions by the approximate group method. Assume the effective absorption and stripping factors for each component can be estimated from the entering values of L, V. The component K – values, as listed below are based on an average entering temperature of 35 degrees Celsius.

Component	C1	C2	C3	nC4	nC5	Oil
K	0.65	1.64	0.584	0.195	0.0713	0.0001

Repeat the problem with total number of stages as 10. What changes do you see in absorption?

Hint : v1 = Vn+1 ϕA + lo(1 – ϕs)   ϕA = (Ae – 1)/(Ae^(N+1) – 1); ϕS = (Se – 1)/(Se^(N+1) – 1); A = L/KV; S = KV/L

Ques 6 - Air containing a water-soluble vapor is flowing up through a vertical hollow cylinder (referred as column) of inner diameter as 10 cm, while the water is flowing down over the inner wall of the column. The thickness of the water film is 0.07 ern, and the average velocity of water is 3 cm/s. The diffusion coefficient of the absorbed vapor in water is 1.8xlO-5cm2/s. The gas phase is well-mixed right up to the interface. You may assume a correlation for mass transfer coefficient at a distance y from the top as k = 0.69{Du/y}^0.5,where u is the average velocity.

(a) How long a column is needed to reach a gas concentration in water that is 10% of saturation?
(b) How will you approach the same problem, if the gas reacts with water in accordance with first order rate expression with rate constant as 20 S^(-1). You may assume that
C/Ci = sinh[(√(k1/D))(l-z)]/sinh[(√(k1/D))l]

Ques 7 – Write down an algorithm to derive the concentrations and quantities in multistage multicomponent counter current liquid-liquid extraction.

Ques 8 – A bubble of oxygen, originally 0.1 cm in diameter is injected in well-stirred water at atmospheric pressure and 25 degrees Celsius. As oxygen gets absorbed, the bubble size decreases continuously with time. After 7 minutes, the bubble is 0.054 cm in diameter. Oxygen concentration at saturation in water is 1.5 X 10^(-6) moles/cc under similar conditions. The bulk concentration of oxygen in water will be negligible.

a) Equate the rate of reduction in oxygen content in the bubble with rate of mass transfer through the liquid film around the bubble to calculate the liquid side mass transfer coefficient.
b) How will you modify the mass transfer coefficient, if oxygen reacts with a solute, dissolved in water as per pseudo first order rate equation?

Ques 9 - Density of ice is less than that of water. This helps in saving lot of flora and fauna, and fishes in the mountain lakes. During winter, the cold air causes the water to freeze at the surface of the lake. The frozen layer insulates the water to maintain higher temperature at deeper part of the lake for the fishes to survive. The replenishment of oxygen occurs only in spring after ice melts, and water comes in contact with the oxygen in air. At one such instance, before the diffusion of oxygen sets in, the concentration of oxygen in water all over the lake was 3 x 10-5 kgmol/m^3. Write Fick's second law in one dimension and the applicable boundary conditions to determine the concentration of oxygen at a depth of 0.06 m due to diffusion after (a) I day and (b) 3 days. Also, determine the penetration distance of oxygen (the depth, up to which the concentration is greater or equal to the initial value) after 30 days of diffusion. Assume that the concentration of oxygen at the surface in equilibrium with air is 3.08 x 10^(-4) kgmol O2/m^3 of solution, the depth of the lake is infinite, and diffusivity of oxygen in water is 1.58 x 10^(-9) m2/s

x	erf x	Si(x)	ci(x)	x	erf x	Si(x)	ci(x)
0.0	0.0000	0.0000	∞	2.0	0.9953	1.6054	−0.4230
0.2	0.2227	0.1996	1.0422	2.2	0.9981	1.6876	−0.3751
0.4	0.4284	0.3965	0.3788	2.4	0.9993	1.7525	−0.3173
0.6	0.6039	0.5881	0.0223	2.6	0.9998	1.8004	−0.2533
0.8	0.7421	0.7721	−0.1983	2.8	0.9999	1.8321	−0.1865
1.0	0.8427	0.9461	−0.3374	3.0	1.0000	1.8487	−0.1196
1.2	0.9103	1.1080	−0.4205	3.2	1.0000	1.8514	−0.0553
1.4	0.9523	1.2562	−0.4620	3.4	1.0000	1.8419	0.0045
1.6	0.9763	1.3892	−0.4717	3.6	1.0000	1.8219	0.0580
1.8	0.9891	1.5058	−0.4568	3.8	1.0000	1.7934	0.1038
2.0	0.9953	1.6054	−0.4230	4.0	1.0000	1.7582	0.1410