Problems

1. In a reaction as **A → Products** if the reaction rate is proportional with the nth order of A it is said that the reaction is nth order. If the r_A is the mole number that react at a unit time and at a unit volume then,

r_A(mole/liter.s)=kC_A^n

Here C_A(mole/liter) is the concentration of A and k is the proportionality constant and it is called as reaction rate constant. The reaction that its rate given by the above equation is called nth order reaction. Rate constant k, is a function of temperature while it's independent of concentration.

a) Assume that a first order reaction (n=1) is formed in an isothermal batch reactor. If we write a component balance according to A, determine that **$C_A=C_{A0}.exp(-kt)$**.

b) The reaction **SO_2Cl_2 → SO_2 + Cl_2** occurs in gas-phase, isothermal constant volume. The concentration of **SO_2Cl_2** with respect to time is measured as given below :

c)

t(min)	4.0	20.2	40.0	60.0	120.0	180.0
C_A(mole/L)	0.0158	0.0152	0.0144	0.0136	0.0116	0.0099

According to this, show graphically that the given data is suitable for 1^{st} order reaction. What is the value of k and its unit?

2. A balloon at 25°C and including 350g benzene is heated with a, 40.2 W constant heat. The heat capacity of liquid benzene can take constant as 1.77 J/g°C.

a) How much time does it take that the temperature of benzene reaches to 40°C?
b) After boiling begins, if we assume that all the given heat is used for vaporization, find the amount of liquid benzene in balloon after 40 minutes.

3. A steam coil is immersed in a stirred heating tank. Saturated steam at 7.50 bar inlets the coil and after it condensed it exits the coil at same temperature. A solvent which has 2.30 kJ/kg heat capacity is fed to tank at 25 °C with 12 kg/min constant flow rate and it exits the tank with same flowrate. Initially the tank is at 25 °C temperature and includes 760 kg solvent. At t=0 both the heating steam and solvent are feed to the tank. Heat transfer from steam to the solvent is given by the equation **Q(kJ/min) = UA(Tsteam-T)** Here UA is the product of total heat transfer coefficient and transfer surface and it is equal to 11,5 kj/min °C.

Assume that the tank is well stirred and the temperature of the exit stream is equal to the solvent temperature in the tank.

a) Write the differential energy balance for tank content.
b) Get a simple form for the balance that you get at part a and at steady-state find the exit temperature.
c) How can the required time evaluated to increase the solvent temperature to T (any temperature) ?
d) What will be the temperature of solvent after 40 minutes?

4. A liquid mixture that include %70 n-pentane and %30 n-hexane is vaporized in a semi-batch distiller. The equilibrium mole fraction balance between the liquid and vapor is **y=ax/(x+b).** Here x and y are respectively the mole fractions of n-pentane at liquid and vapor phase.

a) If x=1 then what is the value of y? Find the relationship between a and b?

b) At 46 °C a liquid phase including %70 n-pentane and %30 n-hexane is at equilibrium with its vapor phase. Then find the vapor mole fraction of n-pentane by using Rault's law and Anotine equation. Also determine the coefficients a and b for the relations of x and y.

c) Find the relationship between the remaining liquid in distiller(L) and mole fraction of pentane that in liquid. (x_f)

d) If 75% of liquid evaporates find the value of x_f ?

5. A tracer substance is used to determine the mixing degree of a continuously stirred tank. Water inlets the tank with Q (m^3/min) flow rate and exits from the tank with same flow rate. There is contamination in the inside surface of the tank because of the sedimentation so the real inside volume of the tank is unknown. At t=0, m_0 (kg) traces substance is injected to the tank and outlet concentration C is measured. It is assumed that at t=0 all of the tracer substance is in the tank.

a) Assuming the tank is well stirred write the differential balance for traces rubstance as a function of V, Q and C.

b) Show that **$C(t)=(m_0/V)\exp(-Qt/V)$**

c) According to $Q=30m^3$/min and by using the following data find V.

Injection time, t(min)	1	2	3	4
$Cx10^3(kg/m^3)$	0.223	0.050	0.011	0.0025

6. Water is added to in a 300 lt tank with variable flow rates. When the exit valve opens, the flow rate from there is proportional with the height of the liquid in the tank (or volume in the tank). The flow rate to the tank is slowly increased. At steady-state it (flow rate) reaches the value 60 lt/min and the tank gets completely full, but there isn't a overflow. Then the flow rate of the feed is suddenly decreased to 20 lt/min.

a) Write the relationship between the exit flow rate q and water volume V and using this relationship determine the volume at steady-state when the inlet flow rate is 20 lt/min.

b) Write the differential balance for water from the time that flow rate is decreased to the time passed for the volume reached to the steady-state value. (The equation must be in the form of dV/dt = …)

c) Integrate the relationship that is got from part b to find the required relationship for V(t).

7. A 40 ft^3 oxygen tent initially includes air at 68 °F and 14.7 psi. At time t=0 a mixture of gas that include 35% oxygen and %65 nitrogen by volume is fed to the tent at 68°F and 1.3 psig with 60 ft^3/min flow rate. The mole number of the gas exits from the tent is equal to the inlet mole number and it is at 68°F and 14.7 psi.

a) Write the required differential mole balance for O_2 as a function of total mole and oxygen mole fraction X.

b) Find the required time to the mole fraction of O_2 reaches to 27%.

8. 80 ft^3 pressurized air tank is filling. Before the filling process the tank was open o the atmosphere. During the filling the pressure indicator shows a rise from 0.0 psi to 100 psi at 15 seconds. The temperature is 72 °F and pressure is 1 atm.

a) Let **n(t)** is the mole number at any time. By observing q (lb-mole/sec) is feed flow rate to the tank write the differential balance between q and n(t).

b) Determine q, and determine the lb-mole number of O_2 that in the tank after 2 min

(at the end of 2 min)

9. 90 kg $NaNO_3$ is solved in 110 kg water in a well-stirred tank. At time t=0 distilled water is fed to the tank with q (kg/min) mass flow rate. Also the flow rate of the exit stream from the tank is q.

a) At any time find the mass fraction of $NaNO_3$ as a function of q and t.

b) If q=100 kg/min how many time does it require to flow out with drawn the 90% of $NaNO_3$ from the tank? Find the required time for some process for withdrawn 99% and 99.9% of $NaNO_3$.

10. Methanol is withdrawn from a 5 m^3 storage tank with a flow rate which increase linearly with time. While the withdrawn process is continue at any time the amount of methanol in the tank is 750 kg and the withdrawn flow rate is 750 kg/h. After 5 hours the withdrawn flow rate increase to 1000 kg/h. Methanol is fed to the tank with a flow rate of 1200 kg/h to complete the reduced amount.

a) Calculate the average flow rate $\mathbf{q_w}$ in the tank.

b) Calculate the amount of methanol in the tank after 5 hours (at the end of 5 hours).

c) How many time does pass for increase of the methanol level in the tank to maximum? At this condition what is the percent of tank that is full?

d) Determine the required time to empty the tank completely?