1. At 298.15°K the heat of mixing to obtain a 20 mol% ethanol solution is -758 J/mol, i.e.,

0.8 mol $H2O_{(l)}$ + 0.2 mol $C_2H_5OH_{(l)} \rightarrow$ 1 mol 20% solution　　$\Delta H = -758$ J/mole

The heat capacity of water and ethanol are known as:

$C_{P(H2O)} = 8.314(8.712 + 1.25\times10^{-3}T - 0.18\times10^{-6}T^2)$ and
$C_{P(ethanol)} = 8.314(33.866 - 172.6\times10^{-3}T + 349.17\times10^{-6}T^2)$ J/mole-°K.

(a) If the heat capacity of the 20 mol% solution is a constant 97.8 J/mole-°K, what is the heat of mixing at 323.15°K? **(8%)**
(b) If both water and ethanol are originally at 298.15°K and the mixing occurs adiabatically, what is the final temperature of the 20 mol% solution? **(7%)**

2. A total of 14 m^3 of liquid X is stored in a 30 m^3 tank in equilibrium with its vapor at 25°C. The vapor pressure of liquid X at the given temperature is 2.43 bar, and T_C , P_C and ω of X are 425.1°K, 37.96 bar and 0.2, respectively. Using a value of 83.14 (bar-cm^3)/(mol-°K) for the gas constant R, estimate the mass of X vapor in the tank using the generalized virial coefficient correlation:

$$Z = (1 + B^{o}\frac{P_r}{T_r}) + \omega(B^{1}\frac{P_r}{T_r})$$

where $B^0=0.083 - (0.422)/T_r^{1.6}$ and $B^1=0.139 - (0.172)/T_r^{4.2}$　**(20%)**

3. One mole of an ideal gas is compressed isothermally but irreversibly at 130°C from 2.5 bar to 6.5 bar in a piston/cylinder device. The work required is 30% greater than the work of reversible, isothermal compression. The heat transferred from the gas during compression flows to a heat reservoir at 25°C. Calculate the entropy changes of the gas, the heat reservoir, and the $\triangle S_{total}$. **(15%)**

4. A zero-order homogeneous gas reaction with stoichiometry $2A \rightarrow R$ proceeds in a constant-pressure setup, find the volume of reacting mixture (V) at t = 5 min if V = 1 m^3 at t = 0 min. Please note that the reaction temperature is kept at constant and the rate constant for the zero-order reaction is 2 mol m^{-3} min^{-1}. At t = 0 min, 30% inerts are present in the batch reactor.
(10%)

5. The desired liquid-phase reaction

$$A + B \xrightarrow{k_1} R + T \qquad \frac{dC_R}{dt} = k_1 C_A C_B^{0.5}$$

is accompanied by the unwanted side reaction

$$A + B \xrightarrow{k_2} S + U \qquad \frac{dC_S}{dt} = k_2 C_A^{0.5} C_B^{2}$$

From the standpoint of favorable product distribution, please suggest a connecting scheme of reactors in continuous flow operations. You have to suggest a reactor scheme and its operating strategy and explain why you make the selection.
(10%)

6. Suppose that the reaction

$$2A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$$

is carried out in the presence of a catalyst. If

$$B_{(g)} + S \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} B-S \qquad (1)$$

$$A_{(g)} + S \underset{k_{-2}}{\overset{k_2}{\rightleftarrows}} A-S \qquad (2)$$

$$2A_{(g)} + B-S \underset{k_{-3}}{\overset{k_3}{\rightleftarrows}} C-S \qquad (3)$$

and

$$C-S \underset{k_{-4}}{\overset{k_4}{\rightleftarrows}} C_{(g)} + S \qquad (4)$$

where *S* denotes the active site and subscript *(g)* means gas phase.

(1) Develop the rate equation for the case that step (4) is the rate controlling step. **(15%)**
(2) Also, suggest an experimental strategy for evaluating all kinetic constants in the rate equation you just developed. **(5%)**
(3) Suggest a reactor and operation method for this reaction. **(5%)**
(4) What happen on the catalyst if the step (2) becomes an irreversible reaction ($k_{-2} = 0$)? **(5%)**