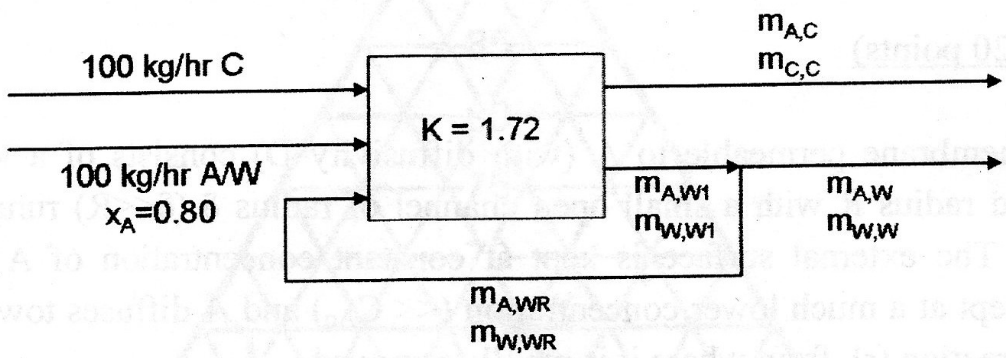
Problem 3 (30 points)

An extraction process to remove acetone (A) from water (W) involves mixing 100 kg/hr chloroform (C) with 100 kg/hr of an A/W mixture containing 80wt% A at 25°C. A recycle stream sends half of the exiting W/A mixture back into the extractor. W and C are essentially immiscible, and K = 1.72 ($x_{A,\text{C-Rich Phase}}/x_{A,\text{W-Rich Phase}}$) for A/W/C systems at 25°C. The process is depicted below, where unknown mass flow rates are labeled below:



a) Set up but do not solve an equation to determine the amount of A extracted into the C phase in kg/hr ($m_{A,C}$). The only variable in the equation should be $m_{A,C}$. (12 points)
b) If instead of using 100 kg/hr of C, we use 100 kg/hr of methyl isobutyl ketone (MIBK), will we be able to extract more or less acetone from the A/W mixture? (8 points)
c) Suppose that unknown amounts of W, A, and MIBK are mixed at 25°C and 1 atm, and the resulting mixture forms two liquid phases in equilibrium.
   1) Use Gibbs Phase Rule to determine how many equilibrium mass fractions must be measured in order to determine the rest. (5 points)
   2) Use the tertiary phase diagram to justify your answer to part 1 **(in two lines or less)**. (5 points)

Problem 4 (30 points)

An ideal liquid mixture of benzene and n-hexane at 30°C at 1 atm contains 54.5 mol% benzene. The mixture is fed to a heater at a rate of 100 mol/s where it is heated to a temperature of 75°C (and remains at 1 atm). The resulting vapor and liquid phases are in equilibrium and leave the heater as separate streams.

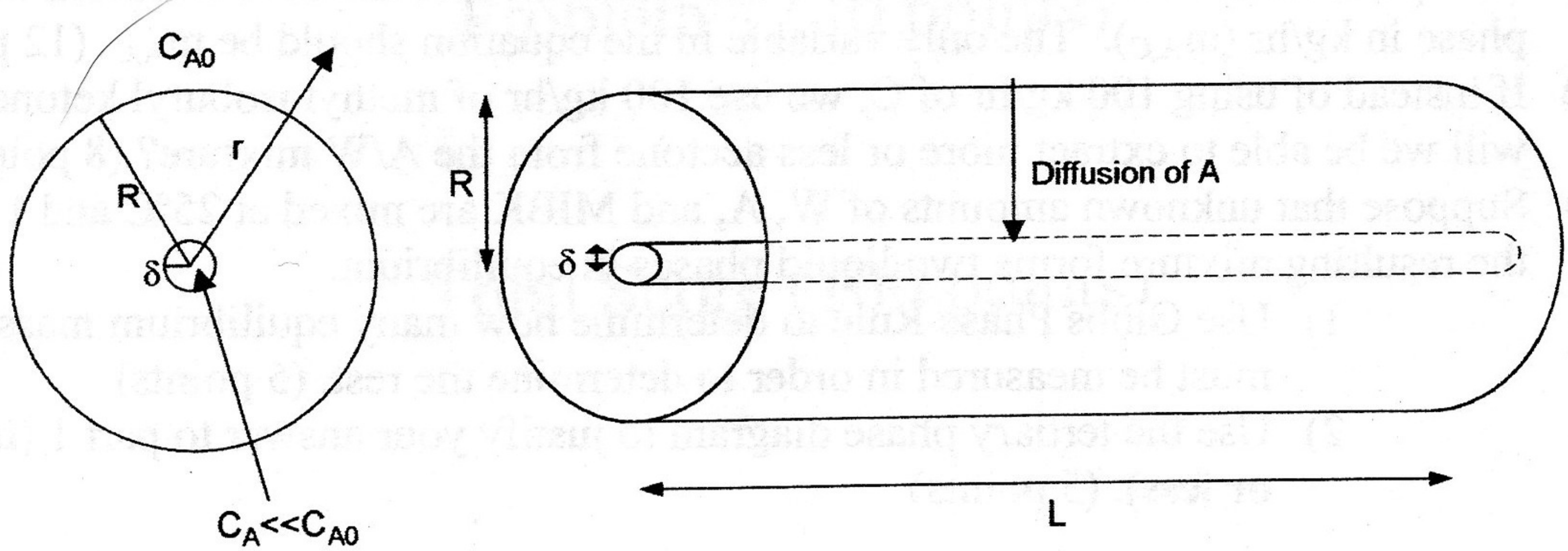
a) Calculate the molar flow rates of the vapor and liquid discharge streams. (15 points)
b) Calculate the heat supplied by the heater in kW for this process. (15 points)

Assume heat capacities are constant with respect to temperature:
$(C_P)_{\text{benzene(vapor)}}$=0.0741 kJ/mol°C
$(C_P)_{\text{benzene(liquid)}}$=0.1265 kJ/mol°C
$(C_P)_{\text{n-hexane(vapor)}}$=0.1374 kJ/mol°C
(C_P) =0.2163 kJ/mol°C

Calculate the compressibility factor, z, of superheated steam at 500 bar and 500°C using data in the steam tables. Now determine z for the same conditions using a compressibility chart (T_c=347°C, P_c=221.2 bar). Compare the two values. (20 points)

Problem 2 (20 points)

A porous membrane permeable to A (with diffusivity D) consists of a very long cylinder of length L and radius R with a small open channel of radius δ ($\delta \ll R$) running axially along its centerline. The external surface is kept at constant concentration of A (C_{Ao}) and the inner channel is kept at a much lower concentration ($\ll C_{Ao}$) and A diffuses towards the centerline in the radial direction (r), from where it is rapidly removed.



Derive the equation for the diffusion flux of A (molar rate/area) in the radial direction. Solve the