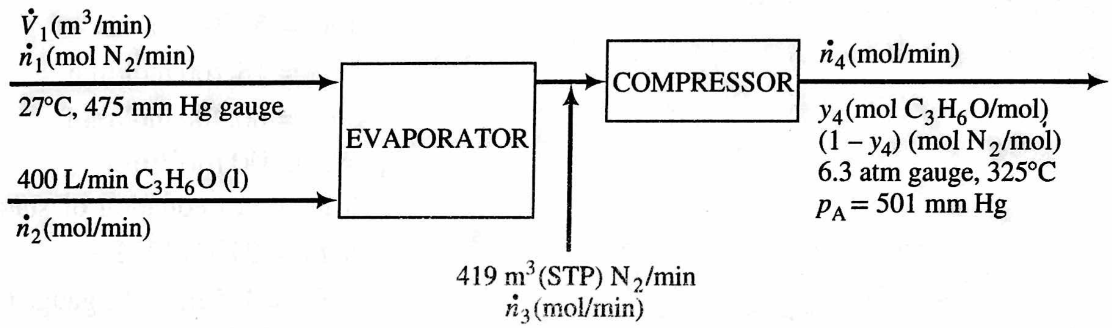
Material Balances on an Evaporator-Compressor

Liquid acetone (C_3H_6O) is fed at a rate of 400 L/min into a heated chamber, where it evaporates into a nitrogen stream. The gas leaving the heater is diluted by another nitrogen stream flowing at a measured rate of 419 m^3(STP)/min. The combined gases are then compressed to a total pressure $P = 6.3$ atm (gauge) at a temperature of 325°C. The partial pressure of acetone in this stream is $p_A = 501$ mm Hg. Atmospheric pressure is 763 mm Hg.

1. What is the molar composition of the stream leaving the compressor?
2. What is the volumetric flow rate of the nitrogen entering the evaporator if the temperature and pressure of this stream are 27°C and 475 mm Hg gauge?

Basis: Given Feed Rates

Assume ideal-gas behavior. Let $\dot{n}_1, \dot{n}_2, \ldots$ (mol/min) be the molar flow rates of each stream.



You should be able to examine the flowchart and see exactly how the solution will proceed.

1. Perform a degree-of-freedom analysis for the system and verify that the problem can be solved.
2. Calculate $\dot{n}_2$ (from the given volumetric flow rate and a tabulated density of liquid acetone), $\dot{n}_3$ (from the ideal-gas equation of state), and y_4 $(= p_A/P)$.
3. Calculate $\dot{n}_4$ (overall acetone balance), $\dot{n}_1$ (overall mass balance), and $\dot{V}_1$ (ideal-gas equation of state).

Degree-of-Freedom Analysis

$$
\begin{array}{l}
6 \text{ unknowns } (\dot{V}_1, \dot{n}_1, \dot{n}_2, \dot{n}_3, \dot{n}_4, y_4) \\
-1 \text{ specific gravity relationship } (\dot{n}_2) \\
-2 \text{ molecular balances (overall, } C_3H_6) \\
-1 \text{ ideal-gas equation of state } (\dot{V}_1) \\
-1 \text{ partial pressure relationship } (y_4) \\
-1 \text{ ideal-gas equation of state } (\dot{n}_3) \\
\hline
0 \text{ degrees of freedom}
\end{array}
$$

Calculate Molar Flow Rate of Acetone

From Table B.1 in Appendix B, the density of liquid acetone is 0.791 g/cm^3 (791 g/L), so that

$$
\dot{n}_2 = \frac{400 \text{ L}}{\text{min}} \left| \frac{791 \text{ g}}{\text{L}} \right| \frac{1 \text{ mol}}{58.08 \text{ g}} = 5450 \frac{\text{mol } C_3H_6O}{\text{min}}
$$