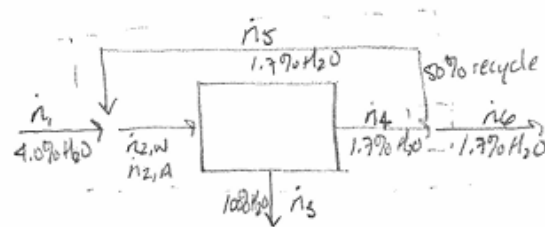


## Problem statement

Fresh air containing 4.0% mol H<sub>2</sub>O is to be cooled and dehumidified to 10°C and 1.7% mol H<sub>2</sub>O using an air conditioner. The fresh air is combined with a recycle stream of previously dehumidified air then passed through the cooler. Some water is condensed in the cooler and removed as a liquid, and half of the air leaving the cooler is recycled. The unit produces 2 L/s of dehumidified air at atmospheric pressure. Determine all molar flow rates in the process.

[Adapted from Example 4.5-1 of R.M. Felder, R.W. Rousseau, and L.G. Bullard. *Elementary Principles of Chemical Processes*, 4th ed. (Wiley, 2016).]



Assume steady state, no reaction

$$0 = \dot{n}_{in} - \dot{n}_{out} \rightarrow \dot{n}_{in} = \dot{n}_{out}$$

Unknowns:  $\dot{n}_1, \dot{n}_{2,w}, \dot{n}_{2,A}, \dot{n}_3, \dot{n}_4, \dot{n}_5, \dot{n}_6 \leftarrow 7$

Equations Overall - air  $0.96 \dot{n}_1 = 0.983 \dot{n}_6 \quad (1)$

Overall - total  $\dot{n}_1 = \dot{n}_3 + \dot{n}_6 \quad (2)$

Recycle point - total  $\dot{n}_4 = \dot{n}_5 + \dot{n}_6 \quad (3)$

Recycle ratio  $\dot{n}_5 = 0.5 \dot{n}_4 \quad (4)$

Cooler - air  $\dot{n}_{2,A} = 0.983 \dot{n}_4 \quad (5)$

Cooler - total  $\dot{n}_{2,w} + \dot{n}_{2,A} = \dot{n}_3 + \dot{n}_4 \quad (6)$

Ideal gas law  $P\dot{V} = \dot{n}_6 RT \quad (7)$

Solution strategy: Get  $\dot{n}_6$  from (7),  $\dot{n}_1$  from (1),  $\dot{n}_3$  from (2),  $\dot{n}_4$  and  $\dot{n}_5$  from (3) + (4) simultaneously,  $\dot{n}_{2,A}$  from (5), and  $\dot{n}_{2,w}$  from (6).

Use ideal gas law for product

$$\dot{n}_6 = \frac{P \dot{V}}{RT} = \frac{1 \text{ atm} \cdot 2 \text{ L} \cdot \cancel{\text{mol}} \cdot \cancel{\text{K}}}{8.314 \text{ J} \cdot 283.15 \text{ K} \cdot 1 \text{ atm} \cdot 10^3 \text{ L}} = 0.0861 \text{ mol/s}$$

Solve (1) for  $\dot{n}_1$

$$\dot{n}_1 = \frac{0.983 \dot{n}_6}{0.96} = \frac{0.983}{0.96} (0.0861 \text{ mol/s}) = 0.0882 \text{ mol/s}$$

Solve (2) for  $\dot{n}_3$

$$\dot{n}_3 = \dot{n}_1 - \dot{n}_6 = 0.0882 \text{ mol/s} - 0.0861 \text{ mol/s} = 0.0021 \text{ mol/s}$$

Solve (3) + (4) for  $\dot{n}_4$  and  $\dot{n}_5$

$$\dot{n}_4 = 0.5 \dot{n}_4 + \dot{n}_6$$

$$0.5 \dot{n}_4 = \dot{n}_6 \quad \rightarrow \quad \dot{n}_4 = 2 \dot{n}_6 = 0.1722 \text{ mol/s}$$

$$\dot{n}_5 = 0.5 \dot{n}_4 = \dot{n}_6 = 0.0861 \text{ mol/s}$$

Solve (5) for  $\dot{n}_{2,A}$

$$\dot{n}_{2,A} = 0.983 (0.1722 \text{ mol/s}) = 0.1693 \text{ mol/s}$$

Solve (6) for  $\dot{n}_{2,W}$

$$\dot{n}_{2,W} = \dot{n}_3 + \dot{n}_4 - \dot{n}_{2,A}$$

$$= 0.0021 \text{ mol/s} + 0.1722 \text{ mol/s} - 0.1693 \text{ mol/s} = 0.0050 \text{ mol/s}$$