Group Assignment - Creative Problem

JP Noe, Christian Paim, Amanda Siciliano

Wentworth Institute of Technology
Environmental Unit Operations
CIVE 4225

Professor Charest

Submission Date:
07 August 2020

1. Description of Unit Operations

Mass balance, also called material balance, accounts for the mass of any water quality constituents in the process where mass is conserved. The conservation of mass is a fundamental principle in the application of environmental unit operations. This principle is built on the idea that mass is conserved for any closed system, and that it is neither created nor destroyed in chemical reactions. Constituents can be transformed or manipulated in several ways, including combustion, but the mass is always conserved. Process diagrams are utilized to illustrate the reactions and movement of constituents through a system, such as the ones included in this word problem that show how streams are fed through a distillation column.

2. Environmental Engineering Topic Explanation

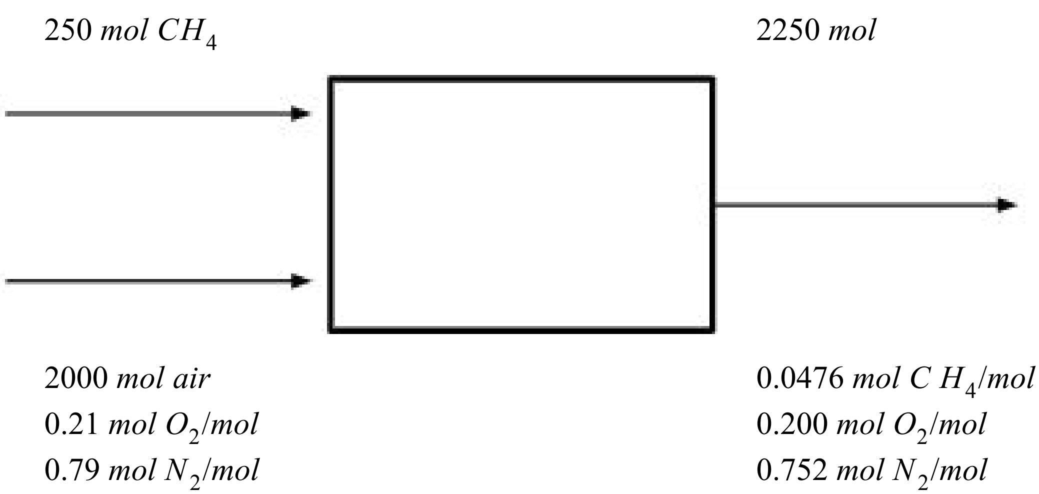
UV Disinfection

The need for water disinfection methods without the use of chemicals began around the 1980s when it was found that existing methods using chlorine and its derivatives were causing harm to people and nature (Vasilyev et al. 2018). UV disinfection has since been popular in the United States and around the world. The UV rays penetrate the water, killing bacteria and harmful pathogens. When UV light is absorbed by a microorganism, its DNA becomes corrupted and its ability to replicate becomes deactivated. The germicidal inactivation results from the nucleic acid deterioration (Dotson et al. 2012). Many water and wastewater treatment plants around the world have been implementing UV disinfection into their treatment designs. Existing water treatment plants are able to retrofit their current system to incorporate UV disinfection like in the case of the Mannheim Water Treatment Plant in Canada (Le Patourel and Smith 2003). From among three alternatives, low pressure (LP), low pressure/high output (LPHO), and medium pressure (MP) lamps, the medium pressure technology was selected in the Canadian plant for the design. It was found that retrofitting a large scale plant is possible only with careful attention to detail (Le Patourel and Smith 2003). The incorporation of UV disinfection into water treatment plants is an increasingly utilized environmental engineering technology that is an effective solution for the modern age.

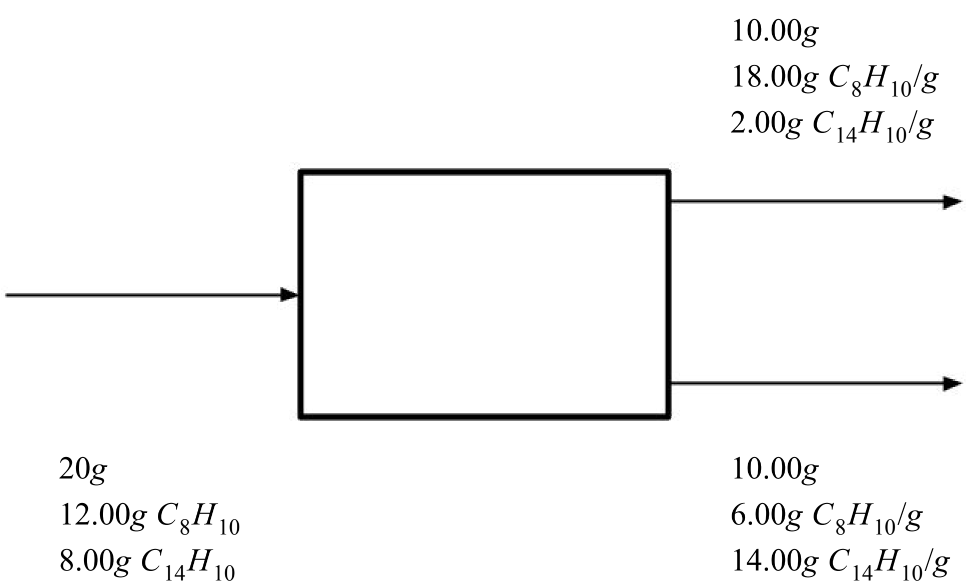
3. Word Problem

The following processes were originally balanced using advanced techniques learned in Environmental Unit Operations that include examining different streams fed through a distillation column. Using the flowcharts shown below, scale the processes and determine the product stream compositions.

a) Air mixes with $250\ mol\ methane$. Scale up the feed to $500\ mol\ methane$.

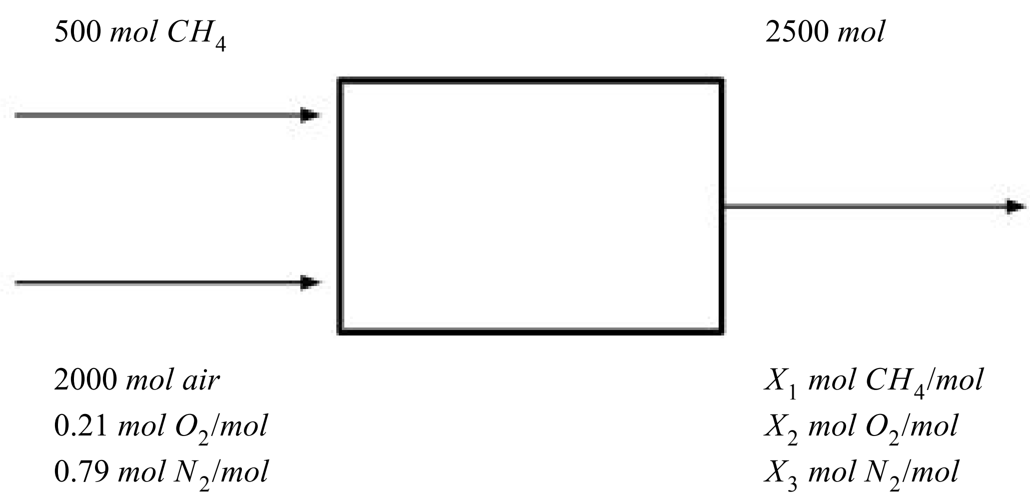


b) Distill a mixture of xylene and anthracene based on a feed of 20g and scale the end flow to 500 lbm/min.



4. Solution

(a) The following diagram shows a scaled up version, using a goal of $500\ mol\ methane$, of the original distillation process.



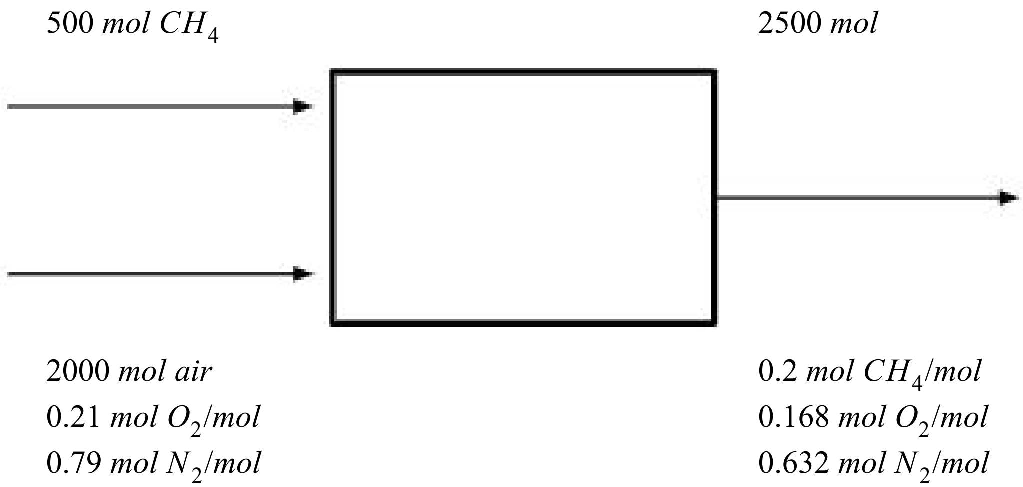
To determine the composition in the product streams, the following equations are used:

$$Composition\ X_1 = \frac{Incoming\ Flow\ CH_4}{Outgoing\ Combined\ Flow} = \frac{500\ mol\ CH_4}{2500\ mol} = 0.2\ mol\ \ CH_4\ final$$

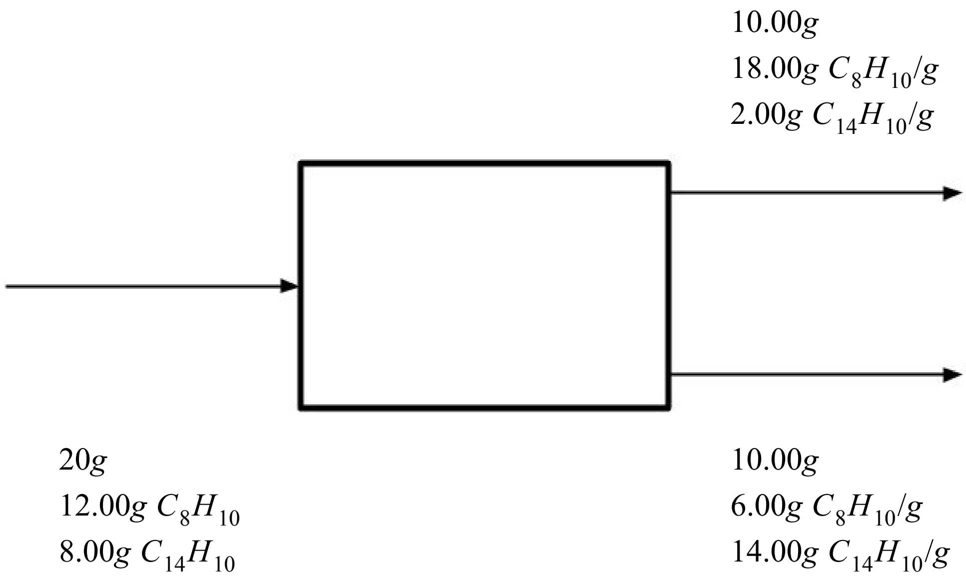
$$Composition\ X_2 = Fraction\ x\ Incoming\ Flow = 0.21\ x\ 2000\ mol\ air = 420\ mol$$
$$Composition\ X_2 = \frac{Incoming\ Flow\ O_2}{Outgoing\ Combined\ Flow} = \frac{420\ mol\ O_2}{2500\ mol} = 0.168\ mol\ \ O_2\ \ final$$

$$Composition\ X_3 = Fraction\ x\ Incoming\ Flow = 0.79\ x\ 2000\ mol\ air = 1580\ mol$$
$$Composition\ X_3 = \frac{Incoming\ Flow\ N_2}{Outgoing\ Combined\ Flow} = \frac{1580\ mol\ N_2}{2500\ mol} = 0.632\ mol\ \ N_2\ \ final$$

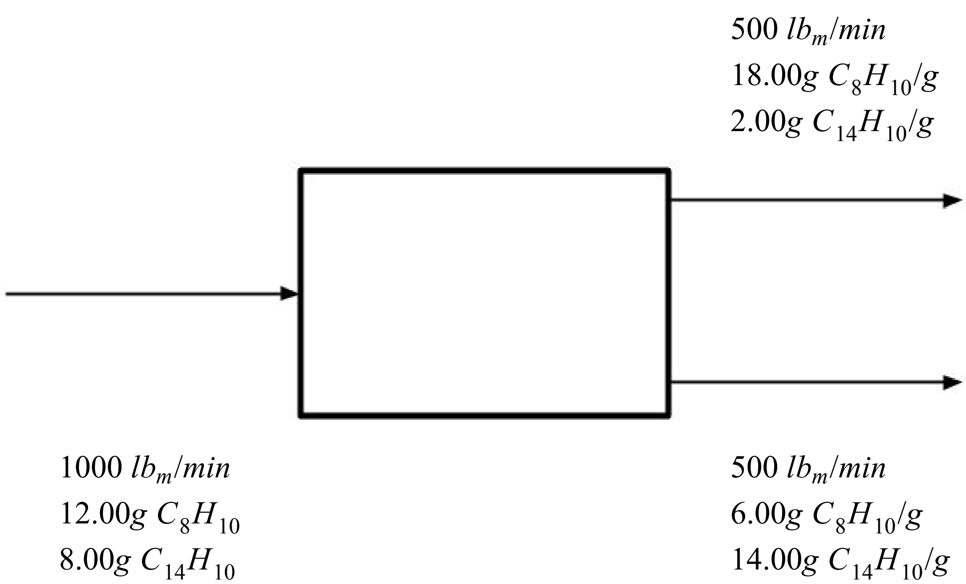
The resulting diagram is as follows:



(b) This is the diagram of the mixture of xylene and anthracene based on a feed of 20g.



In scaling the end flow rate by 500 lbm/min, the initial entering flow must then be scaled by 1000 lbm/min to account for the two exit flows. This would be the resulting diagram:



Although the flow rates have been scaled, the compositions will remain the same.

$$C_8H_{10}\ coming\ in\ = C_8H_{10}\ in\ the\ upper\ stream\ + C_8H_{10}\ in\ the\ lower\ stream$$
$$(1000\ lb_m/min) * 12\ lb_m/min = (500\ lb_m/min) * 18\ lb_m/min + (500\ lb_m/min) * 6\ lb_m/min$$
$$12,000\ = 12,000\ ✓$$

$$C_{14}H_{10}\ coming\ in\ = C_{14}H_{10}\ in\ the\ upper\ stream\ + C_{14}H_{10}\ in\ the\ lower\ stream$$
$$(1000\ lb_m/min) * 8\ lb_m/min = (500\ lb_m/min) * 2\ lb_m/min + (500\ lb_m/min) * 14\ lb_m/min$$
$$8,000\ = 8,000\ ✓$$

In this scenario, the final flow rates are 1000 lbm/min entering the system, and 500 lbm/min for both of the exiting streams. Each of the mass fractions also remained the same.

Works Cited

Dotson, A. D., Rodriguez, C. E., and Linden, K. G. (2012). "UV disinfection implementation status in US water treatment plants." *Journal (American Water Works Association),* 104(5), E318-E324.

Le Patourel, G., and Smith, F. (2003). "field report: Implementation of Primary UV Disinfection at The Mannheim Water Treatment Plant: Procurement, Installation, and Validation Challenges." *Journal (American Water Works Association),* 95(10), 57-132.

Vasilyev, A. I., Kostyuchenko, S. V., Kudryavtsev, N. N., Sobur, D. A., and Sokolov, D. V. (2018). "Uv Disinfection Technologies for Water, Air and Surface Treatment." *Light & Engineering,* 26(1), 25-31.