Sample Problems for Reactive Systems  
CM2110 Fall 2003

1. A stream containing 50 mol % C₃H₆ and 50 mol % NH₃ is mixed with air (79 mol % N₂ and 21 mol% O₂) and fed into a reactor to undergo the reaction

\[ \text{C₃H₆} + \text{NH₃} + 1.5 \text{O₂} \rightarrow \text{C₃H₃N} + 3 \text{H₂O} \]

The effluent from the reactor was analyzed to contain 1.95 mol % O₂ and 51.30 mol % N₂. Calculate the molar composition of the feed.

2. For the process shown in Figure 1, fresh feed containing ethylene and oxygen are mixed with a recycle stream (also containing only ethylene and oxygen). The mixture is then fed to the reactor in which the following reactions occur:

\[ 2\text{C₂H₄} + \text{O₂} \rightarrow 2\text{C₂H₄O} \]
\[ \text{C₂H₄} + 3 \text{O₂} \rightarrow 2 \text{CO₂} + 2 \text{H₂O} \]

The effluent is then passed through a series of separation units and results in a product stream containing only ethylene oxide, C₂H₄O, a waste stream containing only CO₂ and water, and a recycle stream containing only C₂H₄ and O₂. The molar ratio of the product stream (P) to waste stream (W) is 1/2 (mol P/mol W). The molar recycle ratio was set to 1 (mol recycle/mol fresh feed). The feed (F) contains 50 mol % C₂H₄. Calculate the composition of the reactor effluent. (Suggestion: use a basis of 100 mol C₂H₄ in the fresh feed.)

![Figure 1](image-url)
For the process shown in Figure 2, fresh feed containing CO$_2$, H$_2$ and 40 mol % inert are mixed with a recycle stream. The feed mixture (F) contains 46.15 mol % inert, 23.08 mol % H$_2$ and 30.77 mol % CO$_2$. This mixture is then fed to the reactor in which the following reactions occur:

$$\text{CO}_2 + 3 \text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}$$

The effluent is then passed through a separator in which all the methanol CH$_3$OH and water are removed. The vapor stream from the separator are then split to a purge stream (G) and a recycle stream (R). The molar ratio of the feed stream (F) to the effluent stream was determined to be 1.04 (mol F/mol E). Calculate the percent yield of methanol, CH$_3$OH.

![Figure 2](image)

Partial Answers:

1. $y_{(P),\text{NH}_3} = 7.79$ mol %, $y_{(P),\text{H}_2\text{O}} = 23.38$ mol %
2. $y_{(E),\text{CO}_2} = 15.4$ mol %
3. percent yield of methanol = 50%