CHEMICAL PROCESS CALCULATIONS

(Introduction to processes and process variables)

Lecture #4: August 22, 2022

Process Classification

- Batch process
- Continuous process
- Semi-batch process

- Steady state
- Transient or unsteady-state

General Balance Equation

Input + generation = output + consumption + accumulation

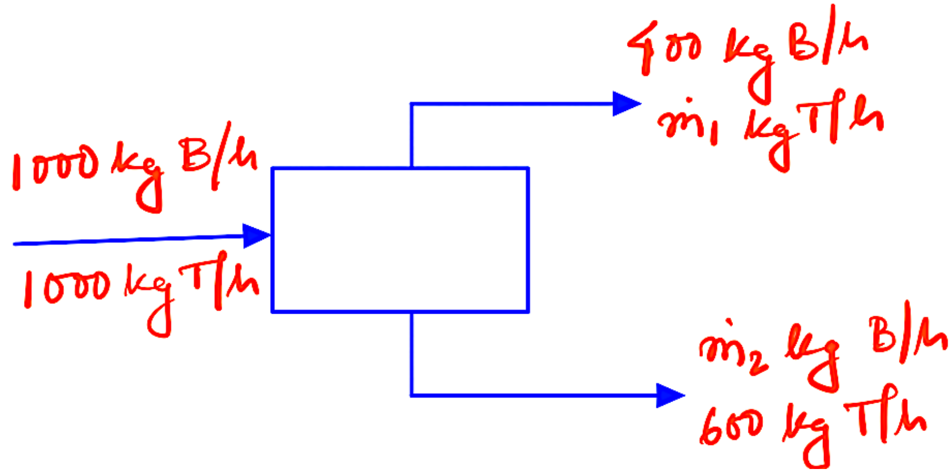
General Balance Equation

- **Differential balances (normally applied to continuous process)**
  - describe at an instant in time
  - each term represents the rate of input, rate of generation, etc.
- **Integral balances (normally applied to batch process)**
  - describe between two instants of time
  - each term represents the amount of the balanced quantity
- When balanced parameter = total mass
  - generation = 0 and consumption = 0 (except in nuclear reactions)
- When balanced parameter = nonreactive species
  - generation = 0 and consumption = 0
- When the system is at steady state
  - accumulation = 0 (always!)

Continuous Steady-State Processes

- input + generation = output + consumption
- for total mass or non-reactive species
  - input = output
- Two thousand kilograms per hour of a mixture of benzene (B) and toluene (T) containing 50% benzene by mass is separated into two fractions. The mass flow rate of benzene in one stream is 400 kg B/h and that of toluene in the other stream is 600 kg T/h. The operation is at steady state. Write balances on benzene and toluene to calculate the unknown component flow rates in the output streams.

Continuous Steady-State Processes



Input = Output

Benzene balance

$$1000 \text{ kg B/h} = 400 \text{ kg B/h} + \dot{m}_2 \text{ kg B/h}$$

$$\Rightarrow \dot{m}_2 = 600 \text{ kg B/h}$$

Toluene Balance:

$$1000 \text{ kg T/h} = \dot{m}_1 \text{ kg T/h} + 600 \text{ kg T/h}$$

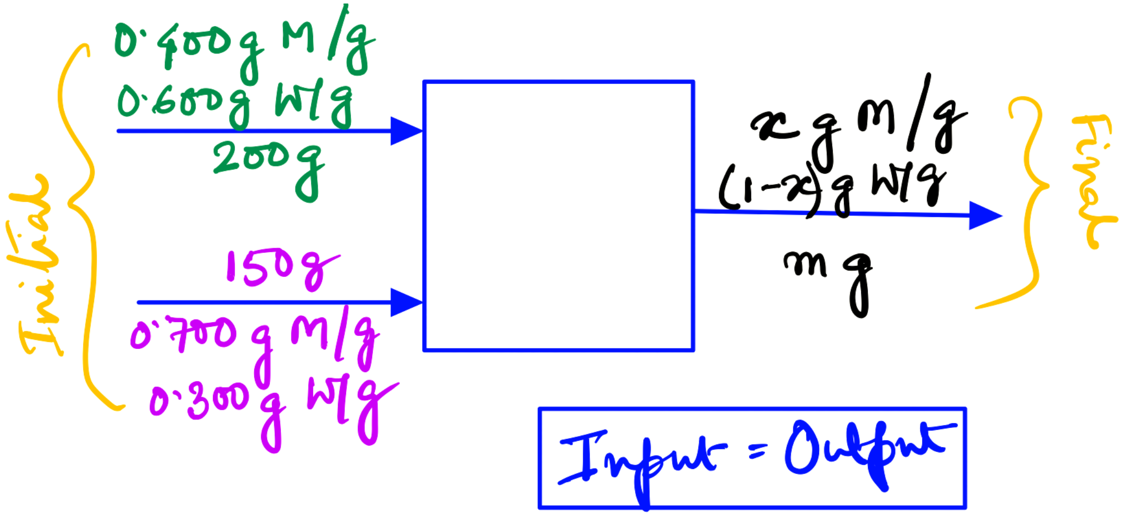
$$\Rightarrow \dot{m}_1 = 400 \text{ kg T/h}$$

Batch Processes

- accumulation = final output - initial input

  = generation - consumption
- initial input + generation = final output + consumption

There are two methanol–water mixtures in separate flasks. The first mixture contains 40.0 wt% methanol, and the second contains 70.0 wt% methanol. If 200 g of the first mixture is combined with 150 g of the second, what are the mass and composition of the product?



Total mass balance:

$$200\,g + 150\,g = m$$

$$\Rightarrow \quad m = 350\,g$$

Methanol balance:

$$200 \times 0.400 + 150 \times 0.700 = m \times x = 350x$$

$$\Rightarrow \quad x = 0.529 \text{ g M/g}$$

$$\Rightarrow \quad 1 - x = 0.471 \text{ g W/g}$$

Flowchart

- Boxes/symbols for process units
  - reactors, mixers, separation units, etc.
- Lines + arrows for inlets and outlets
- A gas mixture containing N_2 & O_2 is combusted with propane (C_3H_8) in a batch combustion chamber. Some of the O_2 and C_3H_8 react to form CO_2 and H_2O, and then the product is cooled for condensing the water.

Flowchart

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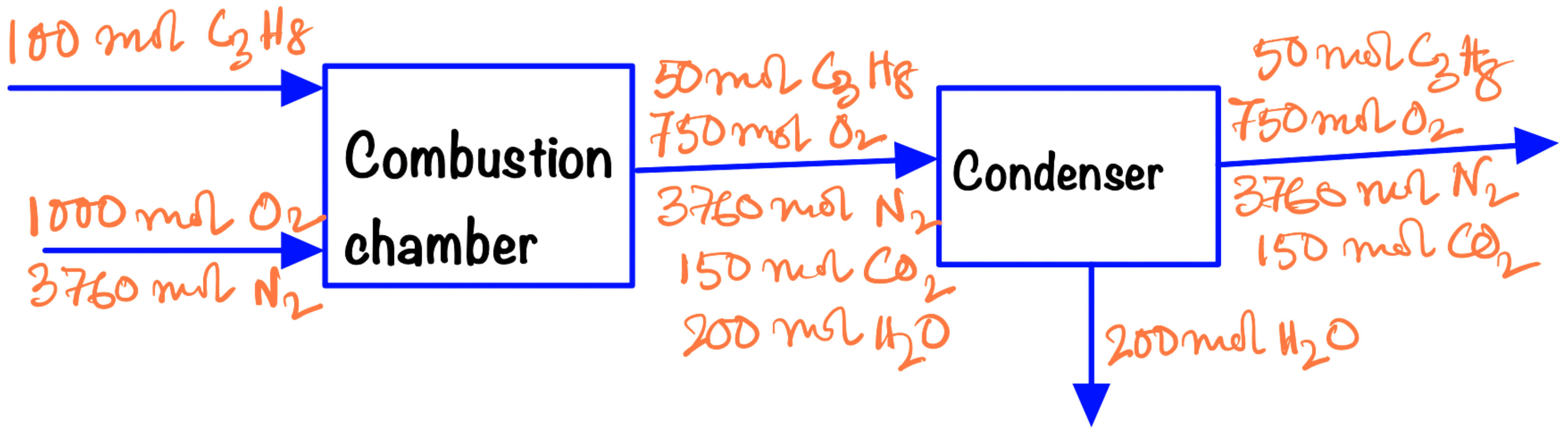

Flowchart

400 mol/h

$\longrightarrow$

0.21 mol O_2/mol

0.79 mol N_2/mol

$T = 350°C$, $P = 1.5$ atm

60 mol N_2/min

$\longrightarrow$

40 mol O_2/min

$\Longleftrightarrow$

100 mol/min

$\longrightarrow$

0.6 mol N_2/mol

0.4 mol O_2/mol

Flowchart

$\dot{n}$ (mol/h)

0.21 mol O_2/mol
0.79 mol N_2/mol
$T = 350°C$, $P = 1.5$ atm

400 mol/h

y mol O_2/mol
$(1-y)$ mol N_2/mol
$T = 350°C$, $P = 1.5$ atm

An experiment on the growth rate of certain organisms requires an environment of humid air enriched in oxygen. Three input streams are fed into an evaporation chamber to produce an output stream with the desired composition.

A: Liquid water, fed at a rate of 20.0 cm^3/min
B: Air (21 mole% O_2, the balance N_2)
C: Pure oxygen, with a molar flow rate one-fifth of the molar flow rate of stream B

The output gas is analyzed and is found to contain 1.5 mole% water. Draw and label a flowchart of the process, and calculate all unknown stream variables.