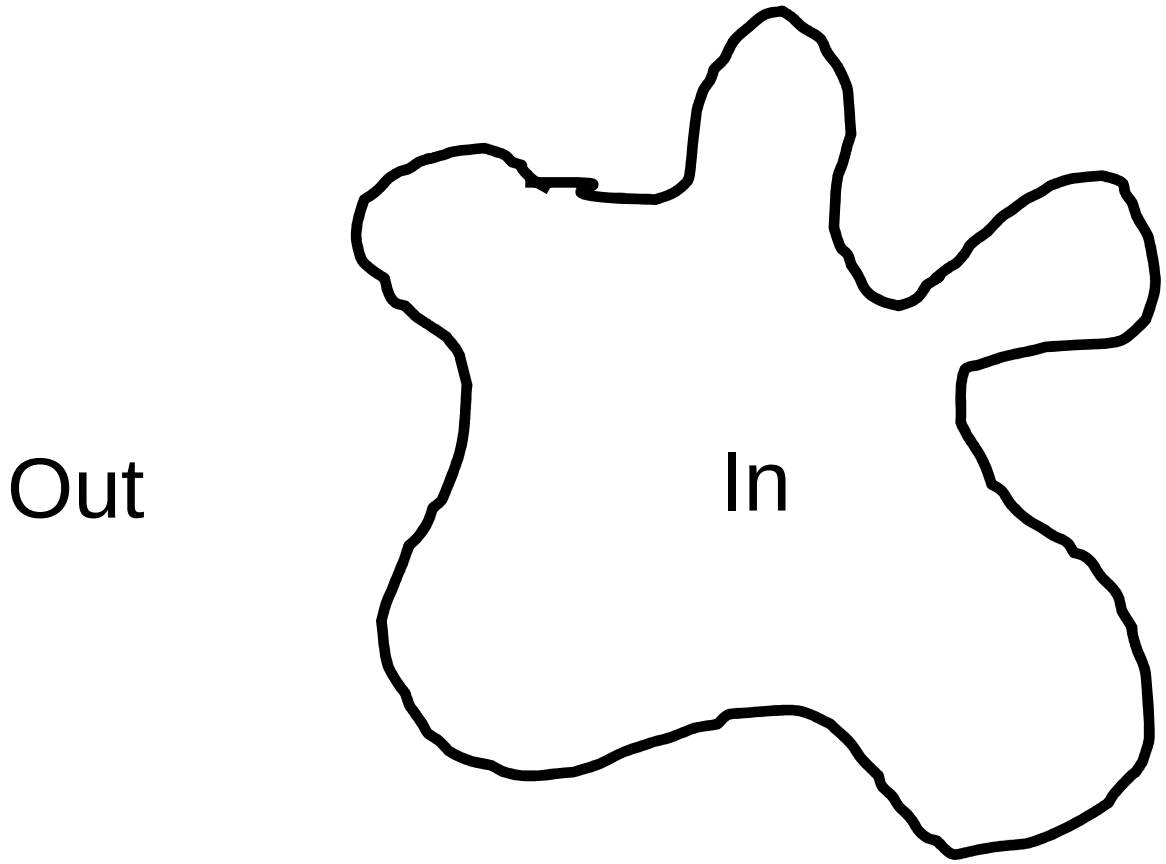
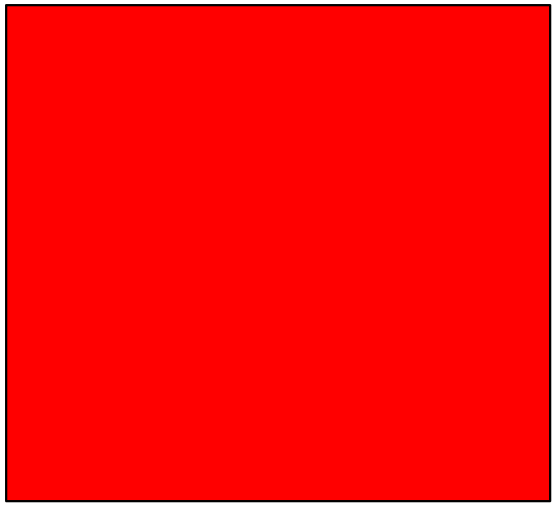
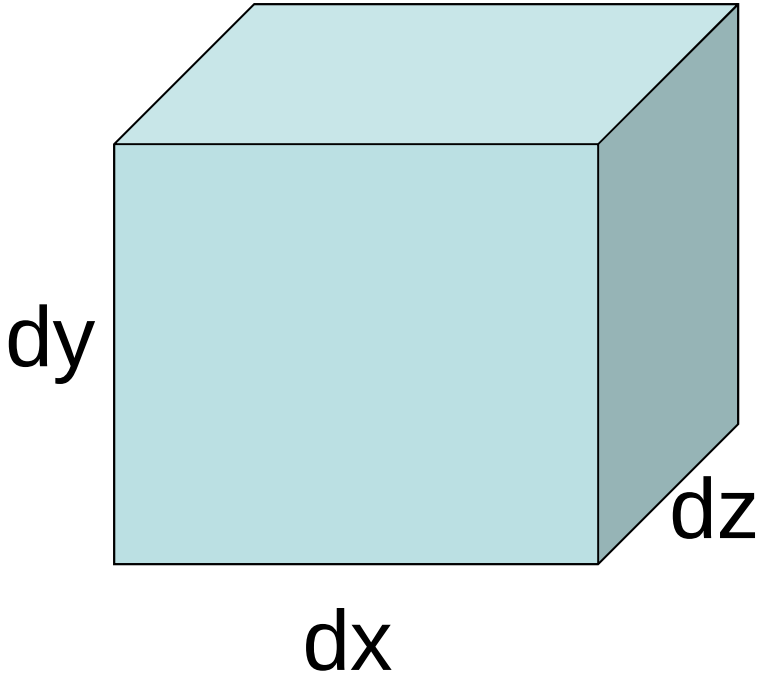
ABE 201
Biological Thermodynamics 1

Mass Balance Fundamentals

System Definition






dy
dz
dx

Material Balances

- We can think of material balances in the same way as we think of balancing our checking accounts.

Generalized Continuity Equation

Accumulation = in – out + generation - consumption

$$\frac{\partial \varphi}{\partial t} + \nabla \cdot \vec{f} = \sigma \qquad \frac{dq}{dt} + \oiint \vec{f} \cdot dS = \Sigma$$

Definitions

- Input:
  - Mass and energy entering the system
- Output:
  - Mass and energy exiting the system
- Generation:
  - Mass and energy produced by the system
- Consumption:
  - Mass and energy being converted in the system
- Accumulation:
  - Mass and energy building up in the system

Generation and Consumption

- Chemical compounds can be generated through chemical reactions (products)
- Chemical compounds can be consumed through chemical reactions (reactants)

- Elements (C,N,P,S, etc) are neither generated nor consumed
- Total mass is neither generated nor consumed

Example: Population

- Chicago has 4 million people. Per yr. 250,000 move to the city, 200,000 leave the city, 50,000 are born and 100,000 die. What are the terms?
  - Input: 250,000 (move in)
  - Output: 200,000 (move out)
  - Generation: 50,000 (births)
  - Consumption: 100,000 (deaths)

Groundwater

- A well is measured at a level of 10” (each inch corresponds to 100 gallons). Today it rains and increases the level to 12”. The well provides water for a farm household that used 200 gallons today. What are all of the terms? What is the final level?
  - Input: (12”-10”)(100 gal/in) = 200 gal
  - Output: 200 gal
  - Accumulation = Input – Output = 200 gal – 200 gal = 0 gal, the level remains 10”

Special Terms

- Steady State
  - Accumulation = 0
  - dX/dt = 0
- Transient
  - Accumulation =/= 0
  - dX/dt =/= 0
- Non-reactive
  - Generation = Consumption = 0

Types of Processes

- Batch: No mass crosses the system boundary
- Continuous: Mass inputs and outputs exist
- Semibatch: Processes not batch or continuous, usually a stream entering (input) or a stream leaving (output) but not both, contributing to the value of the accumulation term.

Solving Mass Balance Problems

- When solving mass balance problems the proper choice of a basis for the calculations can make life easier!
- Ask yourself:
  - What do I have to start with?
  - What answer is called for?
  - What is the most convenient **basis** to use?

What type of basis?

- If compositions are given as mass fractions then choose a total mass basis.
- If mole fractions are known, choose total number of moles.
- If some amount is already given:
  - a) use it as the basis
  - b) use 100 (percentage) as the basis and then scale the answer.

Mass Balance Problems: Develop a Procedure

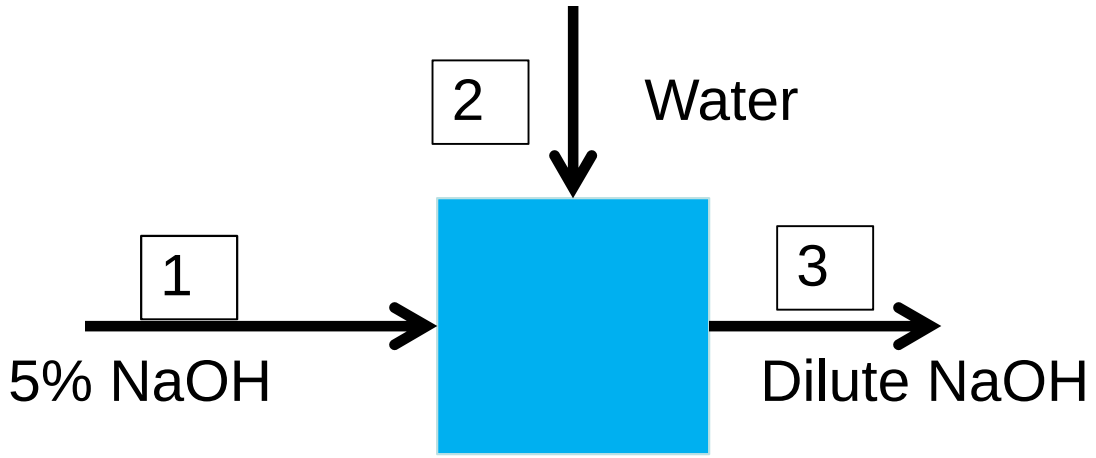
- Write down all of the information with units in an organized form, with a picture if applicable.
- Write down what you want to find and the units.
- Pick a basis if necessary.
- Do the calculations, for multiple calculations use a table format
- Check to see if the result is dimensionally correct and does it make sense, is it in the right range.

Sodium Hydroxide Example

- A 5.00% wt solution of sodium hydroxide is being diluted by a 10.0 gpm stream of pure water.

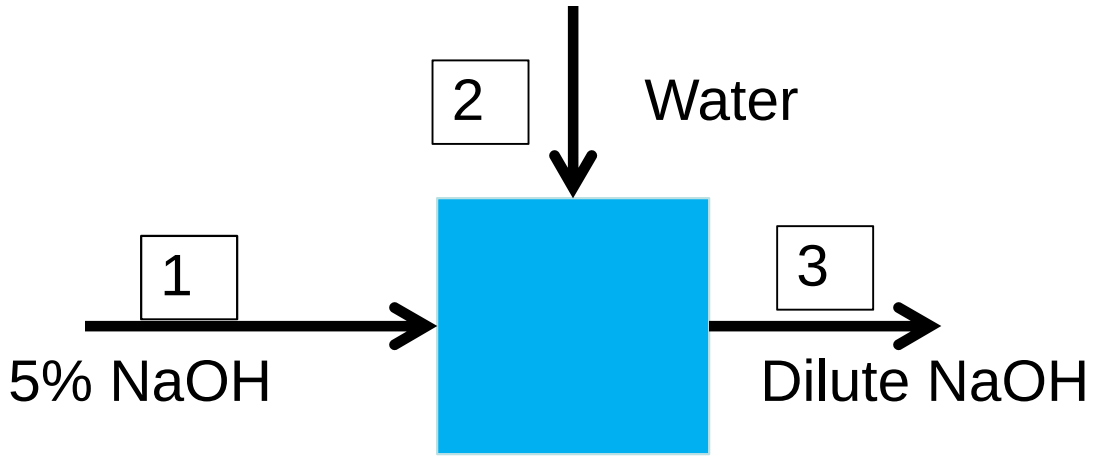
- What is the weight percent of sodium hydroxide in the stream exiting the system at 2.00×10^2 lbm/min?

- Assume steady-state conditions.



Composition	1	2	3
NaOH	0.05	0	?
Water	0.95	1	?

$$\Sigma(x\%) = 100\%$$



Composition	1	2	3
NaOH	0.05	0	?
Water	0.95	1	?

Mass	1	2	3
NaOH	?	0	?
Water	?	83.4 lbm	?
Total	?	83.4 lbm	200 lbm

ρ_{water} = 8.34 lbm/gal

Mass	1	2	3
NaOH	X1n * m1	0	X3n * m3
Water	X1w * m1	83.4 lbm	X3w * m3
Total	m1	83.4 lbm	200 lbm

Acc = In – Out + Gen - Con

Acc = 0 (Steady State)

Total Mass Balance

0 = (m1 + m2) – m3 = m1 + 83.4 - 200

m1 = 116 lbm

NaOH Mass Balance

0 = (x1n*m1 + x2n*m2) – x3n*m3

0 = (0.05*116 + 0*83.4) – x3n*(200)

X3n = 0.0290 = 2.90%

Summary

- Systems are defined by their boundary
  - A boundary is a closed loop
- Accumulation = in – out
  + generation - consumption
- Solving Material Balance Problems
  - Organize your information
  - Draw a diagram
  - Assemble your equations
  - Solve!