Chemical Engineering

Basic Principles:
Energy and material balances
Transport Processes

- Momentum Transfer: Fluid Flow
- Energy Transfer: Heat
- Mass Transfer: mixing and separation processes
  - Physical and Chemical processes
  - Energy balance related to mass
A Systems Approach

Input = Output

• In energy and materials

Process: batch and/or continuous

• Physical processes
  • Mixing and separation
  • Phase changes

• Chemical processes
  • Reactive processes: new products

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Mapping the Process

- Each process step is a “block”
  - Inputs and outputs are at the system boundary
  - Output from one block is input to another
  - Paths between blocks are defined
- Mass and energy can be balanced around any block
- See the oil refinery block
Crude Oil - what happens at the refinery

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Courtesy of OSHA
www.osha-slc.gov
Mapping the Process

- Example: a water purification system has 3 filter stages and a disinfecting unit.
Physical Processes

• Mixing
  • Phase, gas, liquid, solid, mixed, determines the shape and operation of the mixer.
  • Miscibility determines the properties of the final mixture, heterogeneous or homogeneous

• Designing the mixer
  • Method: Stirring, beating, agitating, turning ...
  • Mixer shape: round, tube, v-shape ...
  • Mixers can be insulated from or designed for heat exchange
Physical Processes

Separation methods

• Heterogeneous mixtures
  • Settling, sifting, panning, sieving or filtering
• Homogeneous mixtures
  • Phase change
    • Chilling/freezing
    • Boiling/distillation
    • Evaporation/condensation
    • “Flash” – vapor/liquid separation based on a sudden change of pressure
• Electrostatic separation
• Filtering
• Absorption and leaching
• Chemical separation
Chemical Processes

- Designing the reactor vessel
  - Phase?
    - Solid, liquid, gas, or multiphase?
  - Batch or continuous?
    - Vessel or “slug flow” pipe?
  - Exothermic or endothermic?
    - Regulate reaction rate?
  - Catalyst required?
    - Fixed or moving bed?
  - Mixing or separation required?
Energy Balance

- Where the energy enters and leaves
- Before and after the process
  - Heat energy in the state of the materials
  - Heat capacity of the materials
  - Heat energy released or absorbed by reactions
  - Heat added or removed at the boundary
Chemical Engineering Applications

Petroleum
- Fuels and lubricants
- Fertilizers
- Plastics and chemical feedstocks

Pharmaceuticals

Food and flavorings

Cosmetics, soaps, fragrances

Sanitation and water treatment, desalination

Materials science
- Biochem and electrical/mechanical uses
- Nanotechnology

Paper processing
Material Balances

- Chemical processes are
  - **Batch**: Feed is added once, Products are removed later. No other exchange happens in between
  - **Continuous**: Inputs and outputs flow continuously during the duration of the process
  - **Semi-Batch**: Input is once with a continuous output, or the reverse, input continuous with output in batches
- Steady state or transient, (unsteady state)
  - Constant rate WRT time, or variable WRT time
Example

• A 1000 kg/hr mixture of benzene, C₆H₆ and toluene C₇H₈, which is 50 wt% benzene, is fed into a distiller.
• The top stream contains 450 kg/hr C₆H₆, and the bottom stream contains 475 kg/hr C₇H₈.
• Draw the flow diagram and solve the material balance.
• How efficient is separation?
Solution

- 1000 kg/hr
- 500 kg/hr $C_6H_6$
- 500 kg/hr $C_7H_8$

$$450 \text{ kg/hr } C_6H_6 + X \text{ kg/hr } C_7H_8$$

$$475 \text{ kg/hr } C_7H_8 + Y \text{ kg/hr } C_6H_6$$

$X = 25 \text{ kg/hr } C_7H_8$
$Y = 50 \text{ kg/hr } C_6H_6$
Scaling a process

- 100 moles $\text{C}_2\text{H}_6$

- 2000 moles air
  - 0.21 mol $\text{O}_2$/mol
  - 0.79 mol $\text{N}_2$/mol

Scale to 1000 mol $\text{C}_2\text{H}_6$ / hr

2100 mols

0.0476 mol $\text{C}_2\text{H}_6$/mol

0.200 mol $\text{O}_2$/mol

0.752 mol $\text{N}_2$/mol