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

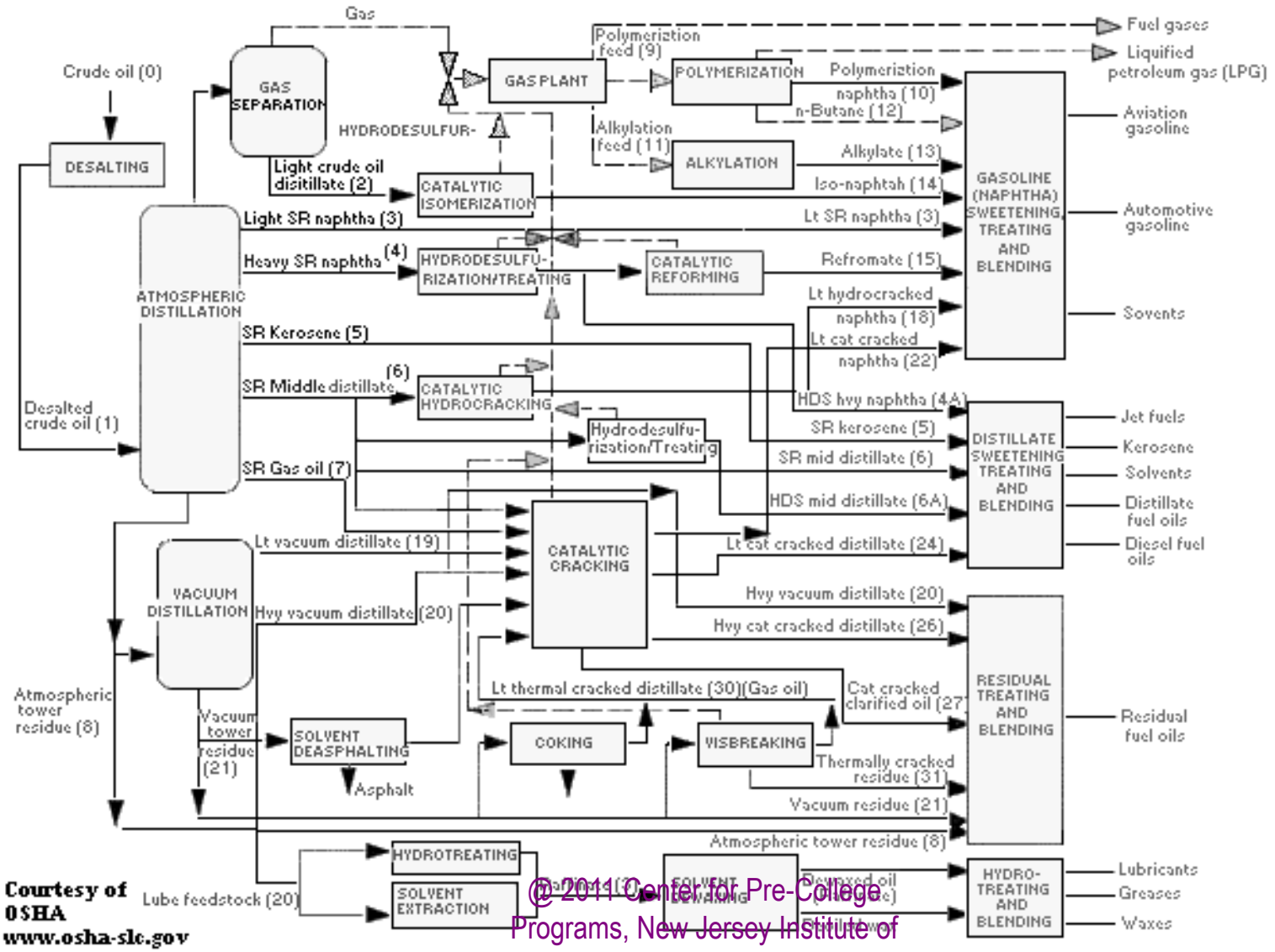
Process: batch and/or continuous

- Physical processes
  - Mixing and separation
  - Phase changes
- Chemical processes
  - Reactive processes: new products

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

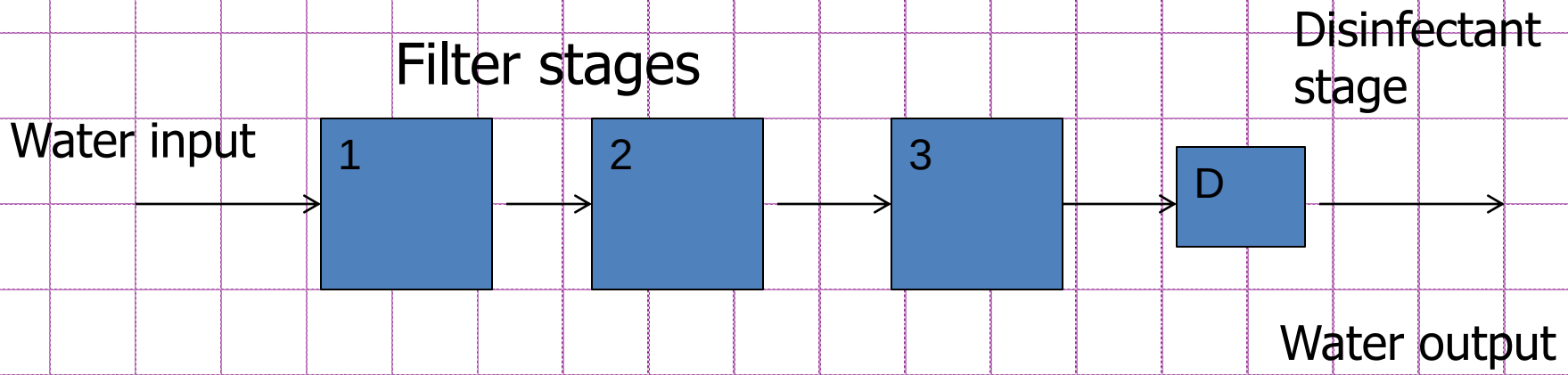
Crude Oil – what happens at the refinery



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

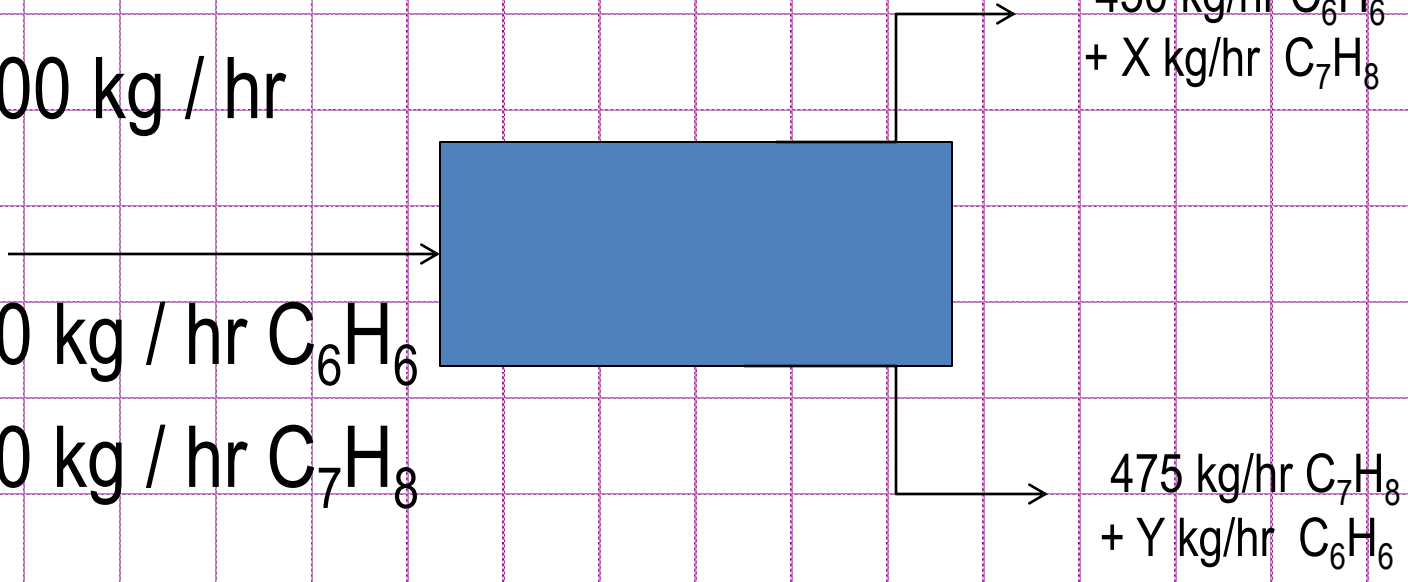
- Chemical processes are
  - **Batch:** Feed is added once, Products are removed later. No other exchange happens in between
  - **Continuous**: Inputs and outputs flow continuously during the duration of the process
  - **Semi-Batch**: Input is once with a continuous output, or the reverse, input continuous 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, C_6H_6 and toluene C_7H_8, which is 50 wt% benzene, is fed into a distiller.
- The top stream contains 450 kg/hr C_6H_6, and the bottom stream contains 475 kg/hr C_7H_8,
- 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

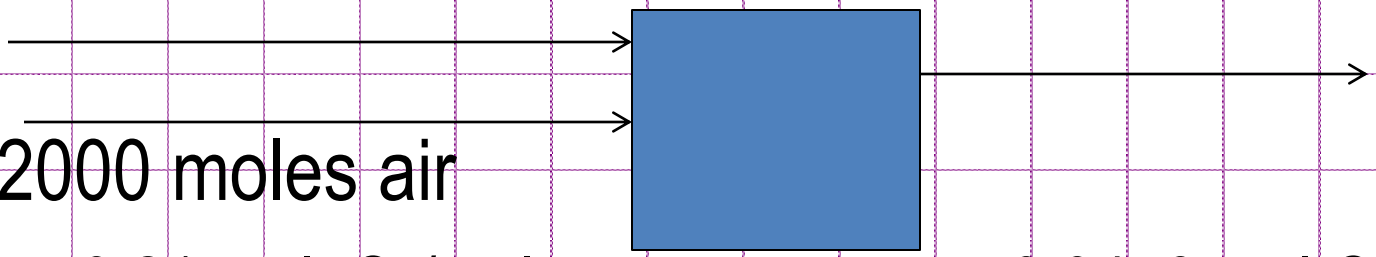


X = 25 kg/hr C_7H_8

Y = 50 kg/hr C_6H_6

Scaling a process

- 100 moles C_2H_6
- 2000 moles air
  - 0.21 mol O_2/mol
  - 0.79 mol N_2/mol



2100 mols

0.0476 mol C_2H_6/mol

0.200 mol O_2/mol

0.752 mol N_2/mol

Scale to 1000 mol C_2H_6 / hr