Chapter 3, Lecture 1

Process Variables

Process is defined as a set of **operations** to achieve a particular objective:

> e.g. the process of making maleic anhydride **product** via *n*-butane oxidation by air in the presence of a vanadium-phosphorus-oxide catalyst, air and *n*-butane involves 7 major operations (1) pumped, (2) mixed, (3) pre-heated to a reaction temperature (~400^{o}C), (4) introduced into the catalytic reactor; (5) effluent is passed through a water **scrubber** to remove maleic anhydride, (6) the scrubber solution is passed through a carbon filter to remove colored impurities, and (7) water is evaporated to isolate salable maleic anhydride product.

Chemical engineers are responsible for **designing** and **operating, troubleshooting,** and **de-bottlenecking** processes

These activities involve the knowledge and control of **process variables**

Mass and **Volume**

- **density** and effect of temperature on density
- **specific gravity,** $SG = \rho/\rho_{ref}$, e.g. $\rho_{H2O}(4^{o}C)=1.000$ g/cm^3

Flow Rate

- $\dot{m}$, **mass flow rate** (mass/time)
- $\dot{V}$, **volumetric flow rate** (volume/time)
- $\rho = \frac{\dot{m}}{\dot{V}}$
- **molar flow rate** (moles/time)
- measured with **flowmeters: rotameters** and **orifice meters**

Question: *come up with as many different ways to measure sugar concentration in water as possible.*

Chemical Composition

Atomic and molecular weights

- **convention:** ^{12}C atom weighs exactly 12 atomic units and atomic weight is 12 g/mol
- **gram-mole** (g-mol) and **pound-mole** (lb-mole)
- Molecular weight *M* corresponds to *M* g/mol and *M* lb_m/lb-mole
- **Avogadro's number** (1 g-mol = 6.02×10^{23})

Conversion Between Mass and Moles

- how many (1) mol N_2O, (2) mol N, (3) mol N_2, (4) mol O, (5) lb-mol N_2O, (6) g N, and (7) molecules of N_2O are in 88 g of N_2O (M = 44)?
- If N_2O is delivered at a rate of 4.4 g/min to a dental patient, what is the molar flow rate in mol/h?

Mass/Mole/Volume Fractions and Average Molecular Weight
Conversion from Mass to Molar Composition

- flue gas having the following composition: 15 vol. % CO_2, 20 vol. % N_2, 5 vol. % O_2, and 60 vol. % H_2O
- convert to mass and mole fractions
- what is its average molecular weight?

Concentration

- mass, molar concentration
- 1 M aqueous solution of maleic anhydride (MA, $C_4H_2O_3$) flows into an evaporator at a rate of 2 m^3/min. The density of the solution is 1.06 g/cm^3. Calculate (1) mass concentration of MA in kg/m^3, (2) mass flow rate of MA in kg/s, and (3) the mass fraction of MA.

Chapter 3, Lecture 2

Process Variables

Concentration (Continued)

- ppm, ppb, ppt

Pressure

- units: Pa, dynes/cm^2, lb$_f$/in^2 or psi, Torr/mm Hg, bar
- fluid pressure
- hydrostatic pressure: $P = F/A = P_o + \rho gh$
- head of particular fluid, when $P_o = 0$

Questions: does the pressure at the plug depend on the height of the opening in the tank? Does it depend on the nature of the fluid? If the pressure is given as 560 mm Hg, what is the height of the tank?

- atmospheric, absolute, and gauge pressure
- $P_{absolute} = P_{gauge} + P_{atmospheric}$
- $P_{absolute} = P_{atmospheric} - P_{vacuum}$

Fluid Pressure Measurement

- elastic-element methods (Bourdon tubes, bellows, diaphragms)
- liquid-column methods (manometers)
- electrical methods (ion and strain gauges, piezoresistive and piezoelectric transducers)
- barometers

Temperature

- measure of kinetic energy
- measuring some physical property which depends on temperature
- resistance thermometer, thermocouple, pyrometer, thermometer
- temperature scales require reference points for temperature
- definition of a degree on Celsius and Fahrenheit scales
- Kelvin and Rankine scales
- conversion factors: $1.8^oF = 1.8^oR = 1^oC = 1K$

Question: suggest different ways one could measure the temperature inside the coal-burner of Zimmer power plant located in scenic Moscow, OH.