Chemical Process Industries

Chemical Process Industries = Unit operation + Unit process

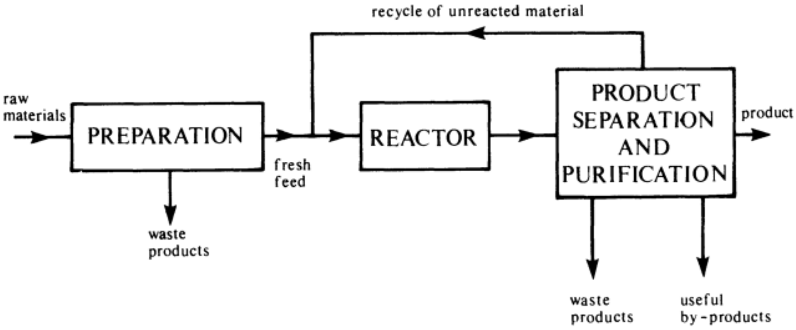

Figure 6.1 Prototype chemical process.

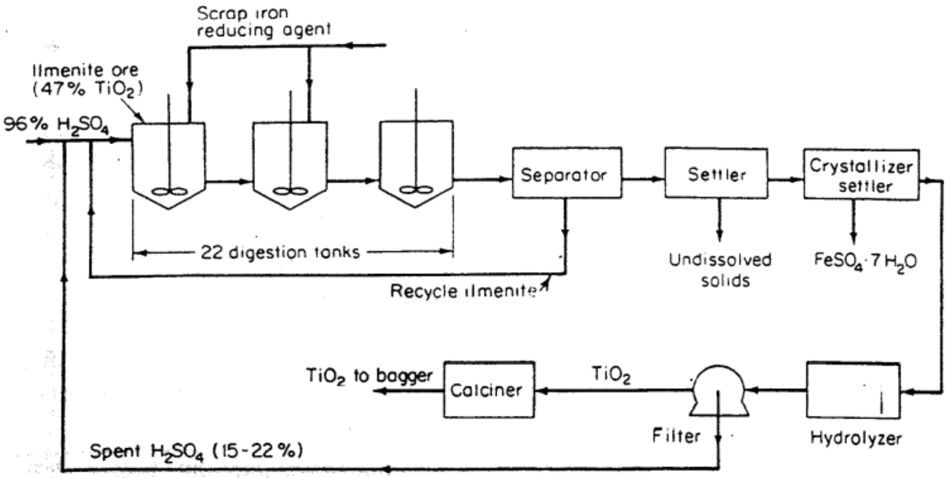

Fig. 8 .6. Titanium dioxide manufacture by two types of sulfuric acid processes.

1.2 Units and Dimensions

Lecture 2

Table 1.1: SI Units

Physical Quantity	Name of Unit	Symbol for Unit*	Definition of Unit
	Basic SI Units		
Length	metre, meter	m	
Mass	kilogramme, kilogram	kg	
Time	second	s	
Temperature	kelvin	K	
Amount of substance	mole	mol	
	Derived SI Units		
Energy	joule	J	$kg.m^2.s^{-2}$
Force	newton	N	$kg.m.s^{-2} = J.m^{-1}$
Power	watt	W	$kg.m^2.s^{-3} = J.s^{-1}$
Density	kilogram per cubic meter		$kg.m^{-3}$
Velocity	meter per second		$m.s^{-1}$
Acceleration	meter per second squared		$m.s^{-2}$
Pressure	newton per square meter, pascal		$N.m^{-2}$, Pa
Heat Capacity	joule per (kilogram - kelvin)		$J.kg^{-1}$,K^{-1}
	Alternative Units		
Time	minute, hour, day, year	min, h, d, y	
Temperature	degree Celsius	°C	
Mass	tonne, ton (Mg), gram	t, g	
Volume	litre, liter (dm^3)	L	

Table 1.2: American Engineering System Units

Physical Quantity	Name of Unit	Symbol
	Basic Units	
Length	feet	ft
Mass	pound (mass)	lb_m
Force	pound (force)	lb_f
Time	second, hour	s, hr
Temperature	degree Rankine	°R
	Derived Units	
Energy	British thermal unit, foot pound (force)	Btu, (ft)(lb_f)
Power	horsepower	hp
Density	pound (mass) per cubic foot	lb_m/ft^3
Velocity	feet per second	ft/s
Acceleration	feet per second squared	ft/s^2
Pressure	pound (force) per square inch	lb_f/in^2
Heat capacity	Btu per pound (mass) per degree F	$Btu/lb_m.{}^0F$

1.4 Conversion of Units

Table 1.3: Factors for unit conversions

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 L = 28,317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482×10^5 dynes
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325×10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486×10^{-4} Btu/s = 1.341×10^{-3} hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462\ lb_m}{1000\ g}\right)$.

1.5.6 Moles and Molecular Weight

Atomic weight is the mass of an atom of an element. *Mole* is the amount of the species whose mass in grams is numerically equal to its molecular weight. One mole of any species contains approximately 6.023×10^{23} (Avogadro's number) molecules of that species. *Molecular weight* is the sum of the atomic weights of the atoms that constitute a molecule of the compound (same as molar mass); units are of the form kg/kmol, g/mol, or lb/lbmol. Molecular weight is the conversion factor that relates the mass and the number of moles of a quantity of a substance.

The average molecular weight based on mole fraction is

$$\bar{M}w = y_A M_{w,A} + y_B M_{w,B} \quad (1.11)$$

The average molecular weight based on mass fraction is

$$\frac{1}{\bar{M}w} = \frac{x_A}{M_{w,A}} + \frac{x_B}{M_{w,B}} \quad (1.12)$$

where

$\bar{M}w$ is the average molecular weight
x_i is the mass fraction of component i in a mixture
y_i is the mole fraction of component i in the mixture

1.6 Compositions of Streams

1.6.1 Mass Fraction and Mole Fraction

Process streams occasionally contain one substance; more often they consist of mixtures of liquids or gases, or solutions of one or more solutes in a liquid solvent. The following terms may be used to define the composition of a mixture of substances, including a species A:

$$\text{Mass fraction}: x_A = \frac{\text{mass of A}}{\text{total mass}} \quad (1.13)$$

$$\text{Mole fraction}: y_A = \frac{\text{moles of A}}{\text{total number of moles}} \quad (1.14)$$

Mass fractions can be converted to mole fractions or vice versa by assuming a basis of calculation. Remember mass and mole fractions are unitless.

1.6.2 Concentration

Concentrations can be expressed in many ways: weight/weight fraction (w/w), weight/volume fraction (w/v), molar concentration (M), and mole fraction. The weight/weight concentration is the weight of the solute divided by the total weight of the solution, and this is the fractional form of the percentage composition by weight. The weight/volume concentration is the weight of solute divided by the total volume of the solution. The molar concentration is the number of moles of the solute, expressed in moles, divided by the volume of the solution. The mole fraction is the ratio of the number of moles of the solute to the total number of moles of all species present in the solution [7].

1.7 Pressure Measurement

Pressure is defined as force per unit area. Pressure can be expressed as a relative pressure or absolute pressure. The units of pressure are

$$\text{SI unit}: \frac{N}{m^2} (\text{or Pa})$$

$$\text{CGS unit}: \frac{dyn}{cm^2}$$

$$\text{AES unit}: \frac{lb_f}{in.^2} (\text{or psi})$$

1.8 *Temperature*

Temperature is a measurement of the average kinetic energy possessed by the substance molecules. It must be determined indirectly by measuring some temperature-dependent physical properties of another substance.

The temperature conversions are:

$T(K) = T(^0C) + 273.15;$ $T(^0R) = T(^0F) + 459.67;$

$T(^0R) = 1.8\ T\ (K);$ $T(^0F) = 1.8\ T(^0C) + 32$

Figure 1.2 shows a process stream with several examples of process variables of input and output. Meanwhile ,the details about process variables are stated in table 1.4

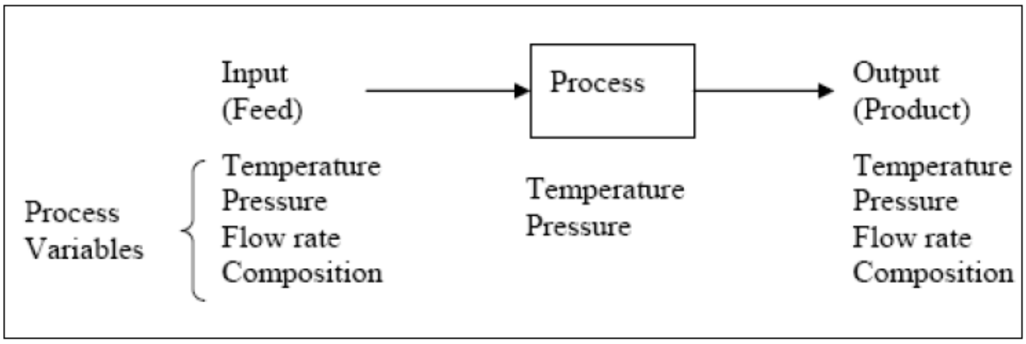

Figure 1.2: Process streams with various process variables.

Lecture 2

Table 1.4: Process variables

Quantity	Symbol	Derivation	Dimension	Standard Unit	
				SI	AES
Mass	m		M	kg	lb_m
Volume	V	$(Length)^3$	L^3	m	ft
Density	ρ	m/V	$M L^{-3}$	kg/m^3	lb_m/ft^3
Specific gravity	sp gr	ρ / ρ_{ref}			
Specific volume	$\hat{V}$	V/m	$L^3 M^{-1}$	m^3/kg	ft^3/lb_m
(Specific) molar volume	$\hat{V}$	V/n	$L^3 M^{-1}$	m^3/mol	ft^3/lb-mole
Mass flow rate	$\dot{m}$	m/t	$M \theta^{-1}$	kg/s	lb_m/s
Molar flow rate	$\dot{n}$	n/t	$M \theta^{-1}$	mol/s	lb-mole/s
Volumetric flow rate	$\dot{V}$	V/t	$L^3 \theta^{-1}$	m^3/s	ft^3/s
Temperature	T		T	K	°F
Pressure	P	F/A	$M L^{-1} \theta^{-2}$	$Pa = N/m^2$	ft-lb_f