VARIABEL PROSES

PROSES :

Suatu operasi atau suatu seri operasi yang menyebabkan perubahan fisis atau kimia suatu bahan atau campuran bahan

- INPUT/FEED : bahan yang memasuki proses
- OUTPUT/PRODUCT : bahan yang keluar meninggalkan proses
- UNIT/SATUAN PROSES: peralatan di mana suatu operasi dijalankan

Suatu unit proses berhubungan satu dengan yang lain dengan suatu arus proses input dan output

1. MASSA DAN VOLUM

Densitas :

massa tiap satuan volum bahan (kg/m^3, g/cm^3, lbm/ft^3 dsb)

Specific volum :

volum yang ditempati oleh satu satuan massa bahan (m^3/kg, ft^3/lbm, dsb)

Specific gravity :

perbandingan dari densitas bahan dengan densitas suatu zat referensi, ρ_{ref}, pada kondisi tertentu.

$$SG = \frac{\rho}{\rho_{ref}}$$

The reference most commonly used for solids and liquids is water at 4.0°C, which has the following density:

$$\boxed{\begin{aligned} \rho_{H_2O(l)}(4^\circ C) &= 1.000\ g/cm^3 \\ &= 1000.\ kg/m^3 \\ &= 62.43\ lb_m/ft^3 \end{aligned}} \qquad \textbf{(3.1-2)}$$

Note that the density of a liquid or solid in g/cm^3 is numerically equal to the specific gravity of that substance. The notation

$$SG = 0.6\frac{20^\circ}{4^\circ}$$

signifies that the specific gravity of a substance at 20°C with reference to water at 4°C is 0.6.

Dalam industri, Spesific Gravity (SG) ini sering dinyatakan sebagai ^{o}API (khusus untuk industri petroleum) atau ^{o}Be (Baume)

$$^{o}API = \frac{141,5}{SG} - 131,5$$

Untuk zat cair yang lebih ringan dari air

$$^{o}Be = \frac{140}{SG} - 130$$

2. KECEPATAN ALIR

- Kecepatan alir massa (massa/waktu : kg/jam, lbm/s, dsb)
- Kecepatan alir volumetris (volum/waktu : m^3/jam, cuft/minute, dsb)
- Densitas suatu fluida dapat digunakan untuk mengubah kecepatan alir massa menjadi kecepatan alir volumetris dan sebaliknya

$$\rho = m/V = \dot{m}/\dot{V}$$

3. KOMPOSISI KIMIA

- Mol dan berat molekul

Berat atom : g/mol (= g/gmol)

Berat molekul : diperoleh dengan menjumlahkan berat atom tiap unsur dalam senyawa

Jika berat molekul suatu senyawa adalah M, maka ada sejumlah M kg/kmol atau M g/mol atau M lbm/lbmol senyawa tersebut

$$\frac{34 \text{ kg } NH_3}{} \left| \frac{1 \text{ kmol } NH_3}{17 \text{ kg } NH_3} \right. = 2.0 \text{ kmol } NH_3$$

$$\frac{4.0 \text{ lb-moles } NH_3}{} \left| \frac{17 \text{ lb}_m \text{ } NH_3}{1 \text{ lb-mole } NH_3} \right. = 68 \text{ lb}_m \text{ } NH_3$$

Fraksi massa, fraksi mol dan BM rata-rata

Mass fraction: $$x_A = \frac{\text{mass of A}}{\text{total mass}} \left(\frac{\text{kg A}}{\text{kg total}} \text{ or } \frac{\text{g A}}{\text{g total}} \text{ or } \frac{\text{lb}_m \text{ A}}{\text{lb}_m \text{ total}} \right)$$

Mole fraction: $$y_A = \frac{\text{moles of A}}{\text{total moles}} \left(\frac{\text{kmol A}}{\text{kmol}} \text{ or } \frac{\text{mol A}}{\text{mol}} \text{ or } \frac{\text{lb-moles A}}{\text{lb-mole}} \right)$$

The **percent by mass** of A is $100x_A$, and the **mole percent** of A is $100y_A$.

$$\overline{M} = y_1 M_1 + y_2 M_2 + \cdots = \sum_{\substack{\text{all} \\ \text{components}}} y_i M_i$$

% mol, % massa, % volume

- Untuk fasa padat dan cair biasa digunakan satuan % massa

- Untuk fasa gas biasa digunakan satuan % mol atau % volume

Konversi % massa ke % mol

A mixture of gases has the following composition by mass:

O_2	16%	(x_{O_2} = 0.16 g O_2/g total)
CO	4.0%	
CO_2	17%	
N_2	63%	

What is the molar composition?

Konsentrasi

- Konsentrasi massa :

massa senyawa dalam campuran per satuan volum campuran (g/cm^3, lbm/ft^3, dsb)

- Konsentrasi molar :

jumlah mol senyawa dalam campuran per satuan volum campuran (kmol/m^3, dsb)

- Molaritas larutan :

mol solut per 1 liter larutan

$$\text{ppm}_i = y_i \times 10^6$$

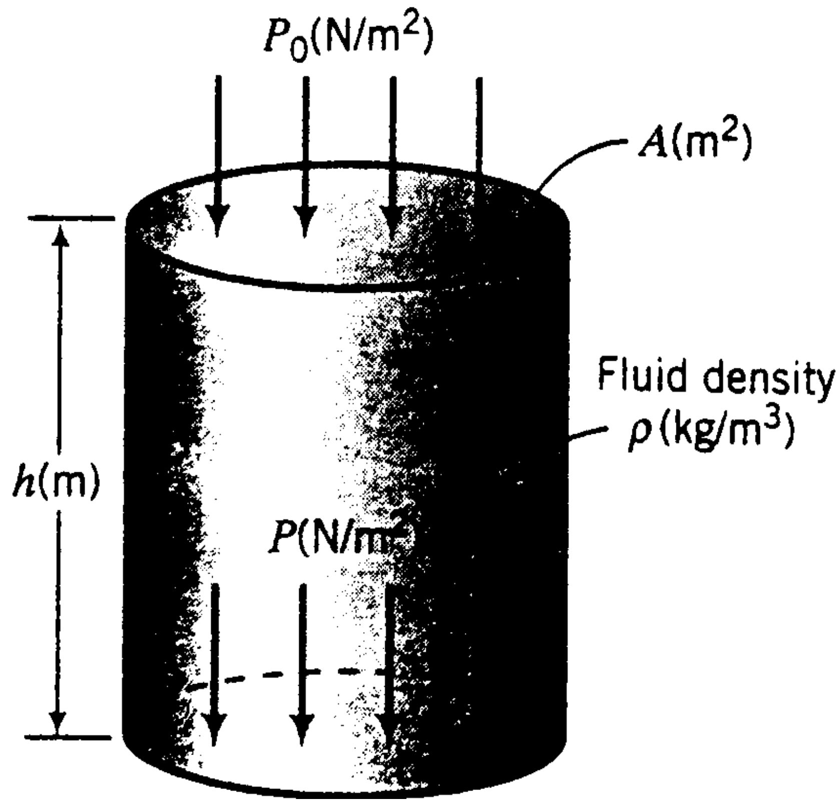
$$\text{ppb}_i = y_i \times 10^9$$

- ppm : parts per million (bagian per satu juta)
- ppb : parts per billion (bagian per satu milyar)

4. TEKANAN

- Gaya yang bekerja per satuan luas bidang penampang yang tegak lurus dengan arah gaya tersebut
- Tekanan fluida di dasar tangki :

$$P = P_0 + \rho g h$$



Satuan tekanan :

$$\frac{\mathrm{N}}{\mathrm{m}^2} = \mathrm{Pa}, \frac{\mathrm{dyne}}{\mathrm{cm}^2}, \frac{\mathrm{lb_f}}{\mathrm{in}^2}$$

Tekanan fluida dapat dinyatakan sebagai head dari suatu fluida tertentu

$$P\left(\frac{\text{force}}{\text{area}}\right) = \rho_{\text{fluid}}\, g\, P_{\text{h}}(\text{head of fluid})$$

Contoh :

Calculation of a Pressure as a Head of Fluid

Express a pressure of 2.00×10^5 Pa in terms of mm Hg.

Solve Equation 3.4-2 for P_{h}(mm Hg), assuming that $g = 9.807\ \text{m/s}^2$ and noting that the density of mercury is $13.6 \times 1000\ \text{kg/m}^3 = 13{,}600\ \text{kg/m}^3$.

$$P_{\text{h}} = \frac{P}{\rho_{\text{Hg}}\, g}$$

$$= \frac{2.00 \times 10^5\ \text{N}}{\text{m}^2} \left| \frac{\text{m}^3}{13{,}600\ \text{kg}} \right| \frac{\text{s}^2}{9.807\ \text{m}} \left| \frac{1\ \text{kg}\cdot\text{m/s}^2}{\text{N}} \right| \frac{10^3\ \text{mm}}{\text{m}} = \boxed{1.50 \times 10^3\ \text{mm Hg}}$$

Tekanan atmosferis, tekanan absolut dan tekanan gauge

- Tekanan atmosferis pada permukaan laut , 760 mmHg, digunakan sebagai tekanan standar 1 atmosfer
- Tekanan absolut didasarkan pada vakum sempurna
- Tekanan gauge adalah relatif terhadap tekanan barometris (terbaca sbg tekanan di alat)

$$P_{\text{absolute}} = P_{\text{gauge}} + P_{\text{atmospheric}}$$

$$\frac{lb_f}{in^2} = \text{psi}$$

Psia = psig + P atmosfer

0 psig → psia = P atm

5. SUHU

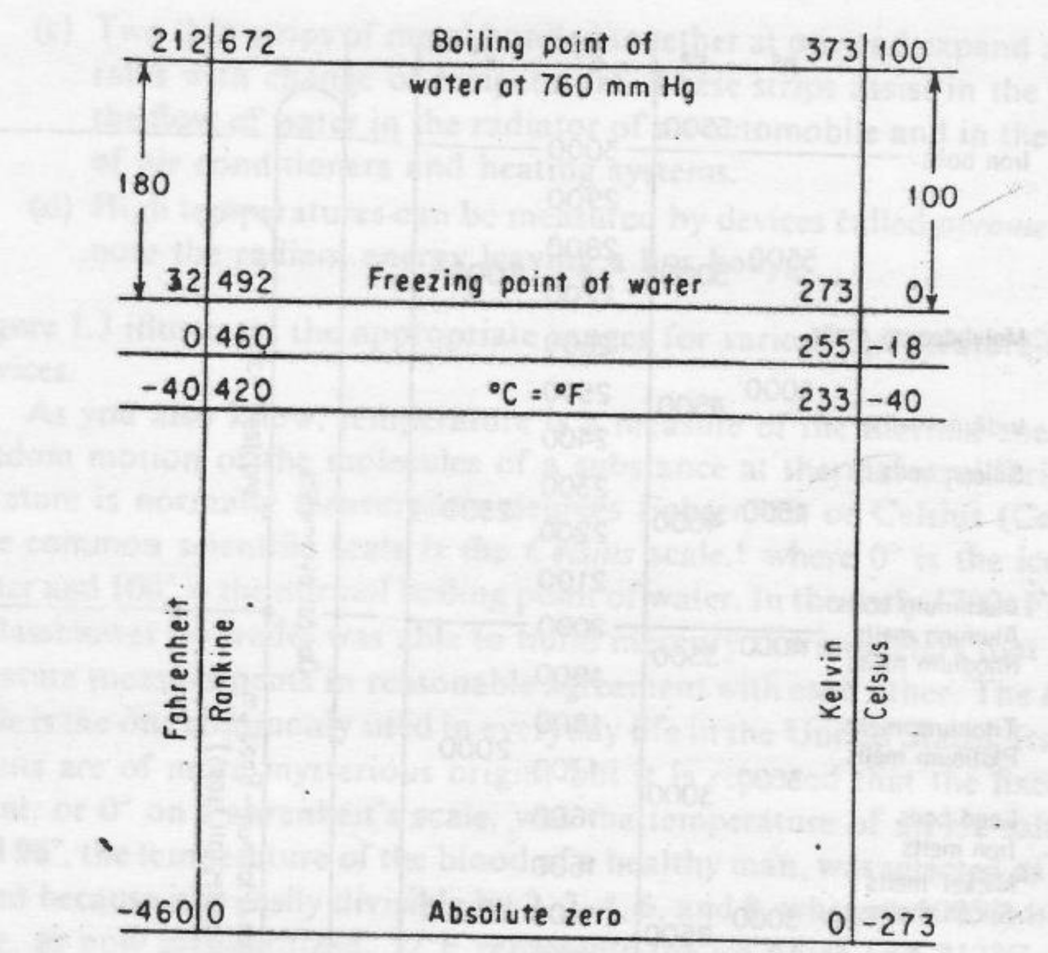


Fig. 1.4. Temperature scales.

$$T(\text{K}) = T(^\circ\text{C}) + 273.15$$

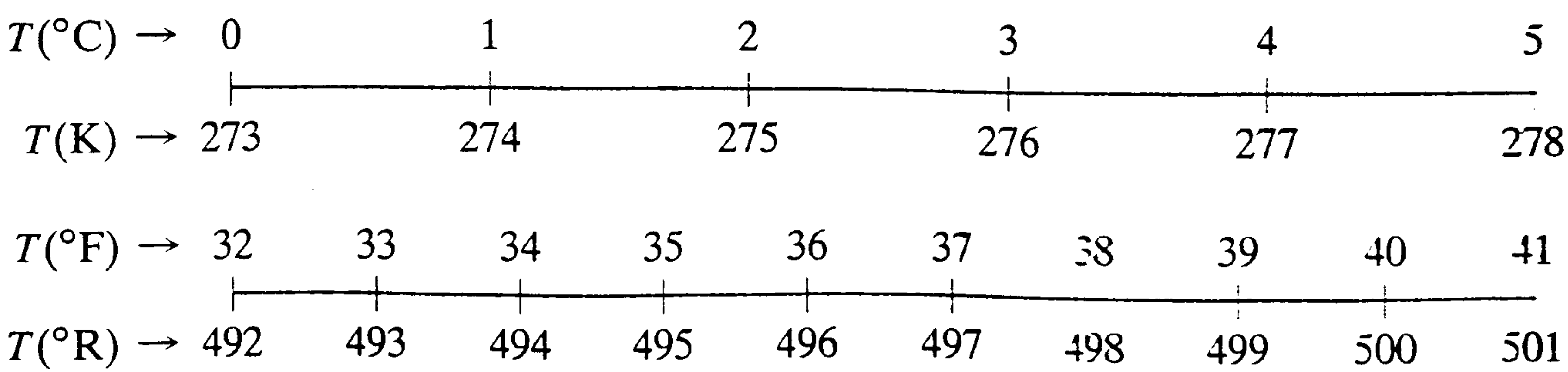
$$T(^\circ\text{R}) = T(^\circ\text{F}) + 459.67$$

$$T(^\circ\text{R}) = 1.8T(\text{K})$$

$$T(^\circ\text{F}) = 1.8T(^\circ\text{C}) + 32$$

A degree is both a temperature and a temperature interval, a fact that sometimes leads to confusion. Consider the temperature interval from 0°C to 5°C. There are nine Fahrenheit and nine Rankine degrees in this interval, and only five Celsius degrees and five Kelvin. An interval of 1 Celsius degree or Kelvin therefore contains 1.8 Fahrenheit or Rankine degrees, leading to the conversion factors

$$\frac{1.8°\mathrm{F}}{1°\mathrm{C}},\ \frac{1.8°\mathrm{R}}{1\ \mathrm{K}},\ \frac{1°\mathrm{F}}{1°\mathrm{R}},\ \frac{1°\mathrm{C}}{1\ \mathrm{K}} \tag{3.5-5}$$



Contoh :

- Kapasitas panas amonia sebagai fungsi suhu dinyatakan dalam persamaan :

$$C_p\left(\frac{\text{Btu}}{\text{lb}_\text{m}\cdot{}^\circ\text{F}}\right) = 0.487 + 2.29 \times 10^{-4}T(^\circ\text{F})$$

Ubahlah ke dalam satuan SI!

The °F in the units of C_p refers to a temperature interval, while the unit of T is a temperature. The calculation is best done in two steps.

1. Substitute for T(°F) and simplify the resulting equation:

$$C_p\left(\frac{\text{Btu}}{\text{lb}_\text{m}\cdot°\text{F}}\right) = 0.487 + 2.29 \times 10^{-4}[1.8T(°\text{C}) + 32]$$

$$= 0.494 + 4.12 \times 10^{-4}T(°\text{C})$$

2. Convert to the desired temperature interval unit using Equation 3.5-5:

$$C_p\left(\frac{\text{J}}{\text{g}\cdot°\text{C}}\right) = [0.494 + 4.12 \times 10^{-4}T(°\text{C})]\frac{(\text{Btu})}{(\text{lb}_\text{m}\cdot°\text{F})}\left|\frac{1.8°\text{F}}{1.0°\text{C}}\right|\frac{1\ \text{J}}{9.486 \times 10^{-4}\ \text{Btu}}\left|\frac{1\ \text{lb}_\text{m}}{454\ \text{g}}\right.$$

⇓

$$\boxed{C_p\left(\frac{\text{J}}{\text{g}\cdot°\text{C}}\right) = 2.06 + 1.72 \times 10^{-3}T(°\text{C})}$$

Latihan soal (Problems of Felder-Rousseau)

1.

Calculate densities in lb_m/ft^3 of the following substances:

(a) a liquid with density of 995 kg/m^3. Use (i) conversion factors from the table on the inside front cover and (ii) Equation 3.1-2.

(b) a solid with a specific gravity of 5.7.

2.

The specific gravity of gasoline is approximately 0.70.

(a) Determine the mass (kg) of 50.0 liters of gasoline.

(b) The mass flow rate of gasoline exiting a refinery tank is 1150 kg/min. Estimate the volumetric flow rate in liters/s.

(c) Estimate the average mass flow rate (lb_m/min) delivered by a gasoline pump.

(d) Gasoline and kerosene (specific gravity = 0.82) are blended to obtain a mixture with a specific gravity of 0.78. Calculate the volumetric ratio (volume of gasoline/volume of kerosene) of the two compounds in the mixture, assuming $V_{blend} = V_{gasoline} + V_{kerosene}$.

3.

Liquid benzene and liquid *n*-hexane are blended to form a stream flowing at a rate of 700 lb_m/h. An on-line *densitometer* (an instrument used to determine density) indicates that the stream has a density of 0.850 g/mL. Using specific gravities from Table B.1, estimate the mass and volumetric feed rates of the two hydrocarbons to the mixing vessel (in American engineering units). State at least two assumptions required to obtain the estimate from the recommended data.

Table B.1 Selected Physical Property Data[a]

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,j] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[e,j] kJ/mol	T_c(K)[f]	P_c(atm)[g]	$(\Delta\hat{H}_f^\circ)$[h,j] kJ/mol	$(\Delta\hat{H}_c^\circ)$[i,j] kJ/mol
Acetaldehyde	CH_3CHO	44.05	$0.783^{18°}$	−123.7	—	20.2	25.1	461.0	—	−166.2(g)	−1192.4(g)
Acetic acid	CH_3COOH	60.05	1.049	16.6	12.09	118.2	24.39	594.8	57.1	−486.18(l) −438.15(g)	−871.69(l −919.73(g
Acetone	C_3H_6O	58.08	0.791	−95.0	5.69	56.0	30.2	508.0	47.0	−248.2(l) −216.7(g)	−1785.7(l) −1821.4(g)
Acetylene	C_2H_2	26.04	—	—	—	−81.5	17.6	309.5	61.6	+226.75(g)	−1299.6(g)
Ammonia	NH_3	17.03	—	−77.8	5.653	−33.43	23.351	405.5	111.3	−67.20(l) −46.19(g)	−382.58(g
Ammonium hydroxide	NH_4OH	35.03	—	—	—	—	—	—	—	−366.48(aq)	—
Ammonium nitrate	NH_4NO_3	80.05	$1.725^{25°}$	169.6	5.4		Decomposes at 210°C			−365.14(c) −399.36(aq)	—
Ammonium sulfate	$(NH_4)_2SO_4$	132.14	1.769	513	—		Decomposes at 513°C after melting			−1179.3(c) −1173.1(aq)	
Aniline	C_6H_7N	93.12	1.022	−6.3	—	184.2	—	699	52.4	—	—
Benzaldehyde	C_6H_5CHO	106.12	1.046	−26.0	—	179.0	38.40	—	—	−88.83(l) −40.04(g)	−3520.0(l) —
Benzene	C_6H_6	78.11	0.879	5.53	9.837	80.10	30.765	562.6	48.6	+48.66(l) +82.93(g)	−3267.6(l) −3301.5(g)
Benzoic acid	$C_7H_6O_2$	122.12	$1.266^{15°}$	122.2	—	249.8					[illegible]
n-Hexane	C_6H_{14}	86.17	0.659	−95.32	13.03	68.74	28.85	507.9	29.9	−198.8(l) −167.2(g)	−4163.1(l) −4194.8(g)