Konsep Gas Ideal

Hukum gas ideal

PV = nRT

P : tekanan gas [=]bar,kPa,psia
V : volume [=]L, m3,cuft
n : mol [=] kmol,lbmol
T : suhu [=] K, R
R : konstanta gas ideal

- R = 8,314 kJ/kmol.K
  = 8,314 kPa.m3/kmol.K
  = 0,08314 bar.m3/kmol.K
  = 1,9859 Btu/mol.R
  = 10,7316 psia.cuft/lbmol.R
  = 1545,37 ft.lbf/lbmol.R
  = 0,08205 L.atm/mol.K

$$p_1V_1 = nRT_1$$
$$p_2V_2 = nRT_2$$

$$\frac{p_1V_1}{p_2V_2} = \frac{T_1}{T_2}$$

- Pada kondisi standar (0 ° C, 1 atm) :

Volume of 1 gram-mole S.C. = 22.41 liters
Volume of 1 pound-mole S.C. = 359 cubic feet

STANDARD CONDITIONS

Temperature	*Pressure*
0°Centigrade	1 atmosphere
273°Kelvin	760 mm of mercury
32°Fahrenheit	29.92 in. of mercury
492°Rankine	14.70 lb per sq in.

$$R = 10.73 \frac{\text{cu.ft.psia}}{\text{lb.mol.}^{\circ}\text{R}}$$

P	V	T	n	R
psia	cu ft	°R	lb - mole	10.73
atm	cu ft	°K	lb - mole	1.3145
atm	cc	°K	gm - mole	82.06
atm	litre	°K	gm - mole	0.08206
atm	cu ft	°R	lb - mole	0.730
mm Hg	litre	°K	gm - mole	62.37
in.Hg	cu ft	°R	lb - mole	21.85

Units of Pressure	Units of Volume	*R*
Per gram-mole (temperatures: Kelvin)		
Atmospheres	Cubic centimeters	82.06
Per pound-mole (temperatures: Rankine)		
Pounds per square inch	Cubic inches	18,510
Pounds per square inch	Cubic feet	10.71
Atmospheres	Cubic feet	0.729

Densitas gas ideal

- Densitas gas dinyatakan sebagai berat gas dalam volume 1 L.
- Pada kondisi standar, densitas udara = 1,293 g/L = 0,0807 lb/cuft.

The *specific gravity* of a gas is usually defined as the ratio of its density to that of air at the same conditions of temperature and pressure.

$$\frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2}$$

- Pada penerapan hukum gas ideal, perbandingan tekanan atau suhu harus > 1 bila perubahan tekanan atau suhu tsb menyebabkan kenaikan volume.

- Perbandingan suhu atau tekanan tsb harus < 1 bila perubahannya menyebabkan penurunan volume.

Contoh-contoh dari Hougen-Watson :

Illustration 1 (*Volume Unknown*). Calculate the volume occupied by 30 lb of chlorine at a pressure 743 mm of Hg and 70°F.

Basis: 30 lb of chlorine or 30/71 = 0.423 lb-mole.

Volume at S.C. = 0.423 × 359 = 152 cu ft.

$$V_2 = V_1 \frac{p_1}{p_2} \times \frac{T_2}{T_1}$$

70°F = 530°Rankine.

Volume at 743 mm Hg, 70°F $= 152 \times \frac{760}{743} \times \frac{530}{492} = 167$ cu ft.

Illustration 2 (*Weight Unknown*). Calculate the weight of 100 cu ft of water vapor, measured at a pressure of 15.5 mm of Hg and 23°C.

Basis: 100 cu ft of water vapor at 15.5 mm Hg, 23°C.

$$\text{Volume at S.C.} = 100\,\frac{15.5}{760} \times \frac{273}{296} = 1.88 \text{ cu ft.}$$

$$\text{Moles of } H_2O = 1.88 \div 359 = 0.00523 \text{ lb-mole.}$$

$$\text{Weight of } H_2O = 0.00523 \times 18 = 0.0942 \text{ lb.}$$

Illustration 3 *(Pressure Unknown).* It is desired to compress 10 lb of carbon dioxide to a volume of 20 cu ft. Calculate the pressure in pounds per square inch which is required at a temperature of 30°C assuming the applicability of the ideal gas law.

Basis: 10 lb of CO_2 or 10/44 = 0.228 lb-mole.

Volume at S.C. = 0.228 × 359 = 81.7 cu ft.

From Equation (12):

$$p_2 = p_1 \frac{V_1}{V_2} \times \frac{T_2}{T_1}$$

30°C = 303°K.

$$\text{Pressure at 20 cu ft, 30°C} = 14.7 \frac{81.7}{20} \times \frac{303}{273} = 66.6 \text{ lb per sq in.}$$

Illustration 4 *(Temperature Unknown)*. Assuming the applicability of the ideal gas law, calculate the maximum temperature to which 10 lb of nitrogen, enclosed in a 30 cu ft chamber, may be heated without the pressure exceeding 150 lb per sq in.

Basis: 10 lb of nitrogen or 10/28 = 0.357 lb-mole.

Volume at S.C. = 0.357 × 359 = 128.1 cu ft.

$$T_2 = T_1 \frac{p_2}{p_1} \times \frac{V_2}{V_1}$$

Temperature at 30 cu ft, 150 lb/sq in. =

$$273 \frac{150}{14.7} \times \frac{30}{128.1} = 652°\text{K or } 379°\text{C}$$

Hukum Dalton :

tekanan total suatu campuran gas sama dengan jumlah tekanan parsial masing-masing komponen gas

$$p = p_A + p_B + p_C + \cdots$$

Hukum Amagat :

volume total yang ditempati suatu campuran gas sama dengan jumlah volume masing-masing komponen gas murni

$$V = V_A + V_B + V_C + \cdots$$

Hukum gas ideal dapat diterapkan untuk masing-masing komponen gas dalam suatu campuran :

$$p_A = \frac{n_A RT}{V}$$

p_A = tekanan uap murni komponen A
n_A = mol komponen A
V = volume total campuran gas

$$p = (n_A + n_B + n_C + \cdots) \frac{RT}{V}$$

$$p_A = \frac{n_A}{n_A + n_B + n_C \cdots} p = N_A p$$

$$N_A = n_A / (n_A + n_B + n_C + \cdots)$$ Fraksi mol komponen A

$$pV_A = n_A RT$$

$$pV_B = n_B RT$$

$$p(V_A + V_B + \cdots) = (n_A + n_B + \cdots)RT$$

$$\frac{V_A}{V} = \frac{n_A}{n_A + n_B + \cdots}$$

$$V_A = N_A V$$

Illustration 6. Calculate the average molecular weight of a flue gas having the following composition by volume:

CO_2	13.1%
O_2	7.7%
N_2	79.2%
	100.0%

Basis: 1 gram-mole of the mixture.

CO_2 = 0.131 gram-mole or......	5.76 grams
O_2 = 0.077 gram-mole or......	2.46 grams
N_2 = 0.792 gram-mole or......	22.18 grams

Weight of 1 gram-mole = ...30.40 grams, which is the average molecular weight.

Illustration 7. Calculate the density in pounds per cubic foot at 29 in. of Hg and 30°C of a mixture of hydrogen and oxygen which contains 11.1% H_2 by weight.

Basis: 1 lb of mixture.

H_2 = 0.111 lb or	0.0555 lb-mole
O_2 = 0.889 lb or	0.0278 lb-mole
Total molal quantity	0.0833 lb-mole
Volume at S.C. = 0.0833×359	29.9 cu ft

$$\text{Volume at 29 in. Hg, 30°C} = 29.9 \times \frac{29.92 \times 303}{29.0 \times 273} = 34.2 \text{ cu ft}$$

$$\text{Density at 29 in. Hg, 30°C} = \frac{1}{34.2} \ldots\ldots\ldots\ldots \quad 0.0292 \text{ lb per cu ft}$$

Illustration 8. Air is assumed to contain 79.0% nitrogen and 21.0% oxygen by volume. Calculate its density in grams per liter at a temperature of 70°F and a pressure of 741 mm of Hg.

Basis: 1.0 gram-mole of air.

O_2 = 0.210 gram-mole or	6.72 grams
N_2 = 0.790 gram-mole or	22.10 grams
Total weight	28.82 grams
Volume at S.C.	22.41 liters

$$\text{Volume, 741 mm Hg, 70°F} = 22.41 \times \frac{760 \times 530}{741 \times 492} \quad 24.8 \text{ liters}$$

$$\text{Density} = \frac{28.82}{24.8} = 1.162 \text{ grams per liter (741 mm Hg, 70°F)}$$

Illustration 9. Combustion gases having the following molal composition are passed into an evaporator at a temperature of 200°C and a pressure of 743 mm of Hg.

Nitrogen	79.2%
Oxygen	7.2%
Carbon dioxide	13.6%
	100.0%

Water is evaporated, the gases leaving at a temperature of 85°C and a pressure of 740 mm of Hg with the following molal composition:

Nitrogen	48.3%
Oxygen	4.4%
Carbon dioxide	8.3%
Water	39.0%
	100.0%

(*a*) Calculate the volume of gases leaving the evaporator per 100 cu ft entering.
(*b*) Calculate the weight of water evaporated per 100 cu ft of gas entering.

Solution:

Basis: **1 gram-mole of the entering gas.**

N_2	0.792 gram-mole
O_2	0.072 gram-mole
CO_2	0.136 gram-mole

Total volume (743 mm Hg, 200°C) calculated from Equations (14) and (20):

$$p = 743/760 \text{ or } 0.978 \text{ atm}$$

$$T = 473°\text{K}$$

$$R = 82.1 \text{ cc atm per °K}$$

$$V = \frac{(n_A + n_B + n_C)\,RT}{p} = \frac{(0.792 + 0.072 + 0.136)\,82.1 \times 473}{0.978}$$

$$= \frac{1.0 \times 82.1 \times 473}{0.978} = 39{,}750 \text{ cc or } 1.40 \text{ cu ft}$$

(743 mm Hg, 200°C)

This 1.0 g-mole of gas entering forms 61% by volume of the gases leaving evaporator.

$$\text{Gases leaving} = \frac{1.0}{0.61} = 1.64 \text{ gram-moles.}$$

Water leaving = 1.64 − 1.0 = 0.64 gram-mole.

Volume of gas leaving, from Equations (14) and (20):

$$p = 740/760 = 0.973 \text{ atm}$$
$$T = 358°\text{K}$$
$$R = 82.1 \text{ cc atm per °K}$$

$$V = \frac{(0.792 + 0.072 + 0.136 + 0.64) \times 82.1 \times 358}{0.973}$$

$$= \frac{1.64 \times 82.1 \times 358}{0.973} = 49{,}500 \text{ cc or} \ldots\ldots\ldots\ldots 1.75 \text{ cu ft}$$

Volume of gas leaving per 100 cu ft entering,

$$\frac{1.75 \times 100}{1.40} \ldots\ldots\ldots\ldots\ldots\ldots \quad 125 \text{ cu ft (740 mm Hg, 85°C)}$$

Weight of water leaving evaporator = $0.64 \times 18 = 11.5$ grams or 0.0254 lb

Weight of water evaporated per 100 cu ft of gas entering,

$$\frac{0.0254 \times 100}{1.40} \quad \dots\dots\dots\dots\dots\dots\dots\dots \quad 1.81 \text{ lb}$$