Important Formulas in Distillation Mass Transfer Operation PDF

Formulas
Examples
with Units

List of 20
Important Formulas in Distillation Mass Transfer Operation

1) Boil-Up Ratio Formula

Evaluate Formula

Formula

$$R_v = \frac{V}{W}$$

Example with Units

$$1.8667 = \frac{11.2\,\text{mol/s}}{6\,\text{mol/s}}$$

2) Equilibrium Vaporization Ratio for Less Volatile Component Formula

Evaluate Formula

Formula

$$K_{LVC} = \frac{y_{LVC}}{x_{LVC}}$$

Example

$$0.192 = \frac{0.12}{0.625}$$

3) Equilibrium Vaporization Ratio for More Volatile Component Formula

Evaluate Formula

Formula

$$K_{MVC} = \frac{y_{MVC}}{x_{MVC}}$$

Example

$$1.9733 = \frac{0.74}{0.375}$$

4) External Reflux Ratio Formula

Evaluate Formula

Formula

$$R = \frac{L_0}{D}$$

Example with Units

$$1.5476 = \frac{6.5\,\text{mol/s}}{4.2\,\text{mol/s}}$$

5) Feed Q-Value in Distillation Column Formula

Evaluate Formula

Formula

$$q = \frac{H_{v\text{-}f}}{\lambda}$$

Example with Units

$$0.6061 = \frac{1000\,\text{J/mol}}{1650\,\text{J/mol}}$$

6) Internal Reflux Ratio Formula

Evaluate Formula

Formula

$$R_{Internal} = \frac{L}{D}$$

Example with Units

$$2.5 = \frac{10.5\,\text{mol/s}}{4.2\,\text{mol/s}}$$

7) Minimum Number of Distillation Stages by Fenske's Equation Formula

Evaluate Formula

Formula

$$N_m = \left(\frac{\log10\left(\frac{x_D \cdot (1 - x_W)}{x_W \cdot (1 - x_D)} \right)}{\log10(\alpha_{avg})} \right) - 1$$

Example

$$2.0266 = \left(\frac{\log10\left(\frac{0.9 \cdot (1 - 0.2103)}{0.2103 \cdot (1 - 0.9)} \right)}{\log10(3.2)} \right) - 1$$

8) Mole Fraction of MVC in Feed from Overall and Component Material Balance in Distillation Formula

Evaluate Formula

Formula

$$x_F = \frac{D \cdot x_D + W \cdot x_W}{D + W}$$

Example with Units

$$0.4943 = \frac{4.2\,\text{mol/s} \cdot 0.9 + 6\,\text{mol/s} \cdot 0.2103}{4.2\,\text{mol/s} + 6\,\text{mol/s}}$$

9) Moles of Volatile component Volatilized by Steam with Trace amounts of Non-Volatiles Formula

Evaluate Formula

Formula

$$m_A = m_S \cdot \left(\frac{E \cdot Pvapor_{vc}}{P - (E \cdot Pvapor_{vc})} \right)$$

Example with Units

$$1.1613\,\text{mol} = 4\,\text{mol} \cdot \left(\frac{0.75 \cdot 30000\,\text{Pa}}{100000\,\text{Pa} - (0.75 \cdot 30000\,\text{Pa})} \right)$$

10) Moles of Volatile component Volatilized by Steam with Trace amounts of Non-Volatiles at Equilibrium Formula

Evaluate Formula

Formula

$$m_A = m_S \cdot \left(\frac{Pvapor_{vc}}{P - Pvapor_{vc}} \right)$$

Example with Units

$$1.7143\,\text{mol} = 4\,\text{mol} \cdot \left(\frac{30000\,\text{Pa}}{100000\,\text{Pa} - 30000\,\text{Pa}} \right)$$

11) Moles of Volatile component Volatilized from mixture of Non-Volatiles by Steam Formula

Evaluate Formula

Formula

$$m_A = m_S \cdot \left(\frac{E \cdot x_A \cdot Pvapor_{vc}}{P - E \cdot x_A \cdot Pvapor_{vc}} \right)$$

Example with Units

$$0.878\,\text{mol} = 4\,\text{mol} \cdot \left(\frac{0.75 \cdot 0.8 \cdot 30000\,\text{Pa}}{100000\,\text{Pa} - 0.75 \cdot 0.8 \cdot 30000\,\text{Pa}} \right)$$

12) Moles of Volatile component Volatilized from mixture of Non-Volatiles by Steam at Equilibrium Formula

Evaluate Formula

Formula

$$m_A = m_S \cdot \left(x_A \cdot \frac{Pvapor_{vc}}{P - x_A \cdot Pvapor_{vc}} \right)$$

Example with Units

$$1.2632\,\text{mol} = 4\,\text{mol} \cdot \left(0.8 \cdot \frac{30000\,\text{Pa}}{100000\,\text{Pa} - 0.8 \cdot 30000\,\text{Pa}} \right)$$

13) Murphree Efficiency of Distillation Column Based on Vapour Phase Formula

Evaluate Formula

Formula

$$E_{Murphree} = \left(\frac{y_n - y_{n+1}}{yn^* - y_{n+1}} \right) \cdot 100$$

Example

$$53.5 = \left(\frac{0.557 - 0.45}{0.65 - 0.45} \right) \cdot 100$$

14) Overall Efficiency of Distillation Column Formula

Evaluate Formula

Formula

$$E_{overall} = \left(\frac{N_{th}}{N_{ac}} \right) \cdot 100$$

Example

$$37.7358 = \left(\frac{20}{53} \right) \cdot 100$$

15) Relative Volatility using Equilibrium Vaporization Ratio Formula

Evaluate Formula

Formula

$$\alpha = \frac{K_{MVC}}{K_{LVC}}$$

Example

$$7.4333 = \frac{2.23}{0.3}$$

16) Relative Volatility using Mole Fraction Formula

Evaluate Formula

Formula

$$\alpha = \frac{\frac{y_{Gas}}{1 - y_{Gas}}}{\frac{x_{Liquid}}{1 - x_{Liquid}}}$$

Example

$$0.4118 = \frac{\frac{0.3}{1 - 0.3}}{\frac{0.51}{1 - 0.51}}$$

17) Relative Volatility using Vapour Pressure Formula

Evaluate Formula

Formula

$$\alpha = \frac{Pa^{Sat}}{Pb^{Sat}}$$

Example with Units

$$0.6667 = \frac{10\,\mathrm{Pa}}{15\,\mathrm{Pa}}$$

18) Total Feed Flowrate of Distillation Column from Overall Material Balance Formula

Evaluate Formula

Formula

$$F = D + W$$

Example with Units

$$10.2\,\mathrm{mol/s} = 4.2\,\mathrm{mol/s} + 6\,\mathrm{mol/s}$$

19) Total Pressure using Mole Fraction and Saturated Pressure Formula

Evaluate Formula

Formula

$$P_T = \left(X \cdot P_{MVC} \right) + \left(\left(1 - X \right) \cdot P_{LVC} \right)$$

Example with Units

$$153250\,\mathrm{Pa} = \left(0.55 \cdot 250000\,\mathrm{Pa} \right) + \left(\left(1 - 0.55 \right) \cdot 35000\,\mathrm{Pa} \right)$$

20) Total Steam Required to Vaporize Volatile Component Formula

Evaluate Formula

Formula

$$M_s = \left(\left(\left(\frac{P}{E \cdot Pvapor_{vc}} \right) - 1 \right) \cdot \left(m_{Ai} - m_{Af} \right) \right) + \left(\left(P \cdot \frac{m_c}{E \cdot Pvapor_{vc}} \right) \cdot \ln\left(\frac{m_{Ai}}{m_{Af}} \right) \right)$$

Example with Units

$$33.9858\,\text{mol} = \left(\left(\left(\frac{100000\,\text{Pa}}{0.75 \cdot 30000\,\text{Pa}} \right) - 1 \right) \cdot \left(5.1\,\text{mol} - 0.63\,\text{mol} \right) \right) + \left(\left(100000\,\text{Pa} \cdot \frac{2\,\text{mol}}{0.75 \cdot 30000\,\text{Pa}} \right) \cdot \ln\left(\frac{5.1\,\text{mol}}{0.63\,\text{mol}} \right) \right)$$

Variables used in list of Important Formulas in Distillation Mass Transfer Operation above

- **D** Distillate Flowrate from Distillation Column *(Mole per Second)*
- **D** Distillate Flowrate *(Mole per Second)*
- **E** Vaporizing Efficiency
- $E_{Murphree}$ Murphree Efficiency of Distillation Column
- $E_{overall}$ Overall Efficiency of Distillation Column
- **F** Feed Flowrate to Distillation Column *(Mole per Second)*
- H_{v-f} Heat Required to Convert Feed to Saturated Vapor *(Joule Per Mole)*
- K_{LVC} Equilibrium Vaporization Ratio of LVC
- K_{MVC} Equilibrium Vaporization Ratio of MVC
- **L** Internal Reflux Flowrate to Distillation Column *(Mole per Second)*
- L_0 External Reflux Flowrate to Distillation Column *(Mole per Second)*
- m_A Moles of Volatile Component *(Mole)*
- m_{Af} Final Moles of Volatile Component *(Mole)*
- m_{Ai} Initial Moles of Volatile Component *(Mole)*
- m_c Moles of Non-Volatile Component *(Mole)*
- m_S Moles of Steam *(Mole)*
- M_s Total Steam Required to Vaporize Volatile Comp *(Mole)*
- N_{ac} Actual Number of Plates
- N_m Minimum Number of Stages
- N_{th} Ideal Number of Plates
- **P** Total Pressure of System *(Pascal)*
- P_{LVC} Partial Pressure of Less Volatile Component *(Pascal)*
- P_{MVC} Partial Pressure of More Volatile Component *(Pascal)*
- P_T Total Pressure of Gas *(Pascal)*
- Pa^{Sat} Saturated Vapour Pressure of More Volatile Comp *(Pascal)*

Constants, Functions, Measurements used in list of Important Formulas in Distillation Mass Transfer Operation above

- Functions: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Functions: **log10**, log10(Number)
  The common logarithm, also known as the base-10 logarithm or the decimal logarithm, is a mathematical function that is the inverse of the exponential function.
- Measurement: **Amount of Substance** in Mole (mol)
  Amount of Substance Unit Conversion
- Measurement: **Pressure** in Pascal (Pa)
  Pressure Unit Conversion
- Measurement: **Molar Flow Rate** in Mole per Second (mol/s)
  Molar Flow Rate Unit Conversion
- Measurement: **Energy Per Mole** in Joule Per Mole (J/mol)
  Energy Per Mole Unit Conversion

- **Pb^{Sat}** Saturated Vapour Pressure of Less Volatile Comp *(Pascal)*
- **$Pvapor_{vc}$** Vapor Pressure of Volatile Component *(Pascal)*
- **q** Q-value in Mass Transfer
- **R** External Reflux Ratio
- **$R_{Internal}$** Internal Reflux Ratio
- **R_v** Boil-Up Ratio
- **V** Boil-Up Flowrate to the Distillation Column *(Mole per Second)*
- **W** Residue Flowrate from Distillation Column *(Mole per Second)*
- **X** Mole Fraction of MVC in Liq Phase
- **x_A** Mole Fraction of Volatile Comp in Non-Volatiles
- **x_D** Mole Fraction of More Volatile Comp in Distillate
- **x_F** Mole Fraction of More Volatile Component in Feed
- **x_{Liquid}** Mole Fraction of Component in Liquid Phase
- **x_{LVC}** Mole Fraction of LVC in Liquid Phase
- **x_{MVC}** Mole Fraction of MVC in Liquid Phase
- **x_W** Mole Fraction of More Volatile Comp in Residue
- **y_{Gas}** Mole Fraction of Component in Vapor Phase
- **y_{LVC}** Mole Fraction of LVC in Vapor Phase
- **y_{MVC}** Mole Fraction of MVC in Vapor Phase
- **y_n** Average Mole Fraction of Vapour on Nth Plate
- **y_{n+1}** Average Mole Fraction of Vapour at N+1 Plate
- **yn^*** Average Mole Fraction at Equilibrium on Nth Plate
- **α** Relative Volatility
- **α_{avg}** Average Relative Volatility
- **λ** Molal Latent Heat of Vaporization of Saturated Liq *(Joule Per Mole)*

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