Important Formulas in Distillation Mass Transfer Operation

List of 20 Important Formulas in Distillation Mass Transfer Operation

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1) Boil-Up Ratio

Open Calculator

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

ex $1.866667 = \frac{11.2\text{mol/s}}{6\text{mol/s}}$

2) Equilibrium Vaporization Ratio for Less Volatile Component

Open Calculator

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

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

3) Equilibrium Vaporization Ratio for More Volatile Component

Open Calculator

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

ex $1.973333 = \frac{0.74}{0.375}$

4) External Reflux Ratio

Open Calculator

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

ex $1.547619 = \frac{6.5\text{mol/s}}{4.2\text{mol/s}}$

5) Feed Q-Value in Distillation Column

Open Calculator

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

ex $0.606061 = \frac{1000\text{J/mol}}{1650\text{J/mol}}$

6) Internal Reflux Ratio

Open Calculator

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

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

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

Open Calculator

fx $N_m = \left(\frac{\log 10\left(\frac{x_D \cdot (1-x_W)}{x_W \cdot (1-x_D)}\right)}{\log 10(\alpha_{avg})}\right) - 1$

ex $2.026557 = \left(\frac{\log 10\left(\frac{0.9 \cdot (1-0.2103)}{0.2103 \cdot (1-0.9)}\right)}{\log 10(3.2)}\right) - 1$

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

Open Calculator

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

ex $0.494294 = \frac{4.2\text{mol/s} \cdot 0.9 + 6\text{mol/s} \cdot 0.2103}{4.2\text{mol/s} + 6\text{mol/s}}$

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

Open Calculator

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

ex $1.16129\text{mol} = 4\text{mol} \cdot \left(\frac{0.75 \cdot 30000\text{Pa}}{100000\text{Pa} - (0.75 \cdot 30000\text{Pa})}\right)$

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

Open Calculator

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

ex $1.714286\text{mol} = 4\text{mol} \cdot \left(\frac{30000\text{Pa}}{100000\text{Pa} - 30000\text{Pa}}\right)$

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

Open Calculator

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

ex $$0.878049\text{mol} = 4\text{mol} \cdot \left(\frac{0.75 \cdot 0.8 \cdot 30000\text{Pa}}{100000\text{Pa} - 0.75 \cdot 0.8 \cdot 30000\text{Pa}} \right)$$

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

Open Calculator

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

ex $$1.263158\text{mol} = 4\text{mol} \cdot \left(0.8 \cdot \frac{30000\text{Pa}}{100000\text{Pa} - 0.8 \cdot 30000\text{Pa}} \right)$$

13) Murphree Efficiency of Distillation Column Based on Vapour Phase

Open Calculator

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

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

14) Overall Efficiency of Distillation Column

Open Calculator

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

ex $$37.73585 = \left(\frac{20}{53} \right) \cdot 100$$

15) Relative Volatility using Equilibrium Vaporization Ratio

Open Calculator

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

ex $$7.433333 = \frac{2.23}{0.3}$$

16) Relative Volatility using Mole Fraction

Open Calculator

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

ex $$0.411765 = \frac{\frac{0.3}{1-0.3}}{\frac{0.51}{1-0.51}}$$

17) Relative Volatility using Vapour Pressure

Open Calculator

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

ex $$0.666667 = \frac{10\text{Pa}}{15\text{Pa}}$$

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

Open Calculator

fx $$F = D + W$$

ex $$10.2\text{mol/s} = 4.2\text{mol/s} + 6\text{mol/s}$$

19) Total Pressure using Mole Fraction and Saturated Pressure

Open Calculator

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

ex $$153250\text{Pa} = (0.55 \cdot 250000\text{Pa}) + ((1-0.55) \cdot 35000\text{Pa})$$

20) Total Steam Required to Vaporize Volatile Component

Open Calculator

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

ex $$33.98579\text{mol} = \left(\left(\left(\left(\frac{100000\text{Pa}}{0.75 \cdot 30000\text{Pa}}\right) - 1\right) \cdot (5.1\text{mol} - 0.63\text{mol})\right) + \left(\left(100000\text{Pa} \cdot \frac{2\text{mol}}{0.75 \cdot 30000\text{Pa}}\right) \cdot \ln\left(\right.\right.\right.$$

Variables Used

- **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)*
- 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)*

Constants, Functions, Measurements used

- Function: **ln**, ln(Number)
  Natural logarithm function (base e)
- Function: **log10**, log10(Number)
  Common logarithm function (base 10)
- 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

Check other formula lists

- **Continuous Distillation Formulas**
- **Important Formulas in Distillation Mass Transfer Operation**
- **Material Balance Formulas**
- **Relative Volatility & Vaporization Ratio Formulas**

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