MT - 405

B6a

MULTI - COMPONENT DISTILLATION

OBJECTIVES :

- To perform multi-component distillation of methanol - ethanol - butanol in a laboratory - scale distillation column.
- To calculate minimum no. of trays (stages) via Fenske's Equation.

THEORY :

DISTILLATION - method of separating components from a liquid mixture based on the difference in boiling points of the individual components and the distribution of the components between a liquid and a gas phase in the mixture.

The vaporisation process changes liquid to gaseous state. At equilibrium, the rates of the two processes are the same. Pressure exerted by the vapor at the equilibrium state is called the VAPOR PRESSURE of the liquid.

The following methods can be used to calculate vapor pressure :

a) <u>CLAUSIS - CLAPEYRON</u> EQ.N

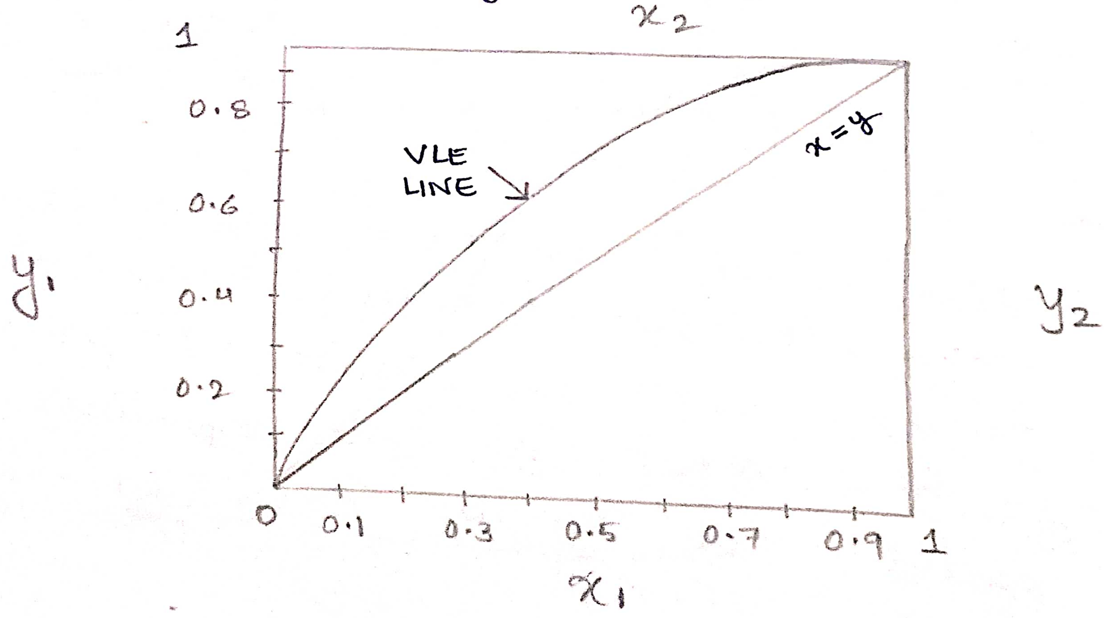
$$\ln\left(\frac{P^v}{P_1^v}\right) = \frac{\lambda}{R}\left(\frac{1}{T_1} - \frac{1}{T}\right)$$

λ: molar latent heat of vaporization

b) <u>ANTOINE</u> EQ.N

$$\ln(P^v) = A - \frac{B}{T+C}$$

<u>RELATIVE VOLATILITY</u> is the measure of difference in volatility between components, & hence, their boiling points.



<u>VAPOR- LIQUID EQUILIBRIUM PLOT</u>

$$\text{Reflux Ratio (R)} = \left(\frac{\text{Flow returned on reflux}}{\text{Flow of top product removed}} \right)$$

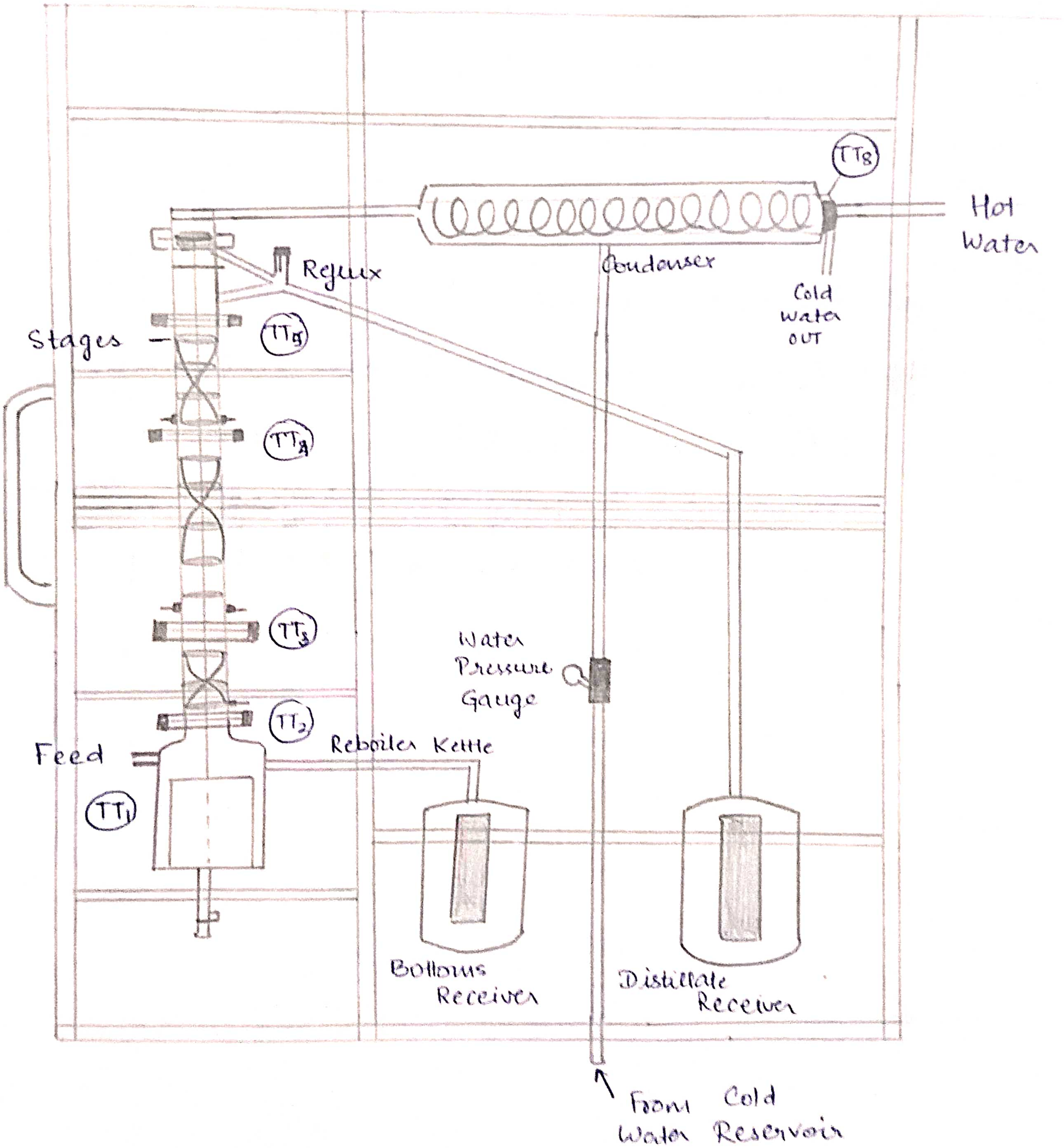
For Quantitative Analysis, Gas Chromatography is performed. It analyses different components in a sample. Gas chromatography (GC) is an analytical method utilising a gas chromatograph.

Two major relevant constituents include:

(a) Thermal Conductivity Detector (TCD)

(b) Flame Ionization Detector (FID) –
FID is a scientific instrument that measures analytes in a gas stream, and is used as a detector for GC.

EXPERIMENTAL SETUP



OBSERVATIONS :

Area : mV * min (under curve)

Observation Tables.

1. TOTAL REFLUX :

Temp. at top of column (T_{1t}) = 63.3 °C

Temp. at bottom (T_{1b}) = 76.6 °C

	wt. of CH	Area CH_4	Area C_2H_6	Area C_4H_{10}	Area CH
Distillate	5.008	10.54	15.73	0.15	75.95
Bottoms	4.997	9.00	10.25	16.71	62.77

2. R = 1.9 :

Temp. at top of column (T_{2t}) = 64.8 °C

Temp. at bottom (T_{2b}) = 79.4 °C

	wt. of CH	Area CH_4	Area C_2H_6	Area C_4H_{10}	Area CH
Distillate	5.038	36.90	2.31	0.18	42.34
Bottoms	5.025	7.37	25.72	16.65	64.11

3. R = 1 :

Temp. at top of column (T_{3t}) = 65.7 °C

Temp. at bottom (T_{3b}) = 82.3 °C

- Distillate = 250 ml

	wt. of CH	area CH_4	area C_2H_6	area C_4H_{10}	area CH
Distillate	4.996	22.15	11.54	0.29	63.58
Bottoms	5.023	5.15	11.28	18.44	65.41

- Distillate = 500 ml

	wt. of CH	area CH_4	area C_2H_6	area C_4H_{10}	area CH
Distillate	5.001	23.43	25.58	0.12	61.85
Bottoms	5.000	2.42	13.65	20.13	72.33

<u>Initial</u> (Feed) Composition :

	CH_4	C_2H_6	C_4H_{10}
weights fed (kg)	1.5	0.75	0.75

Moles (η) = Mass / Molar Mass.

$M_o\ (CH_4) = 34.04$ g/mol

$M_o\ (C_2H_6) = 46.07$ g/mol

$M_o\ (C_4H_{10}) = 74.13$ g/mol.

	CH_4	C_2H_6	C_4H_0
Moles (mol)	46.82	16.28	10.12

Total Moles $= \eta_{CH_4} + \eta_{C_2H_6} + \eta_{C_4H_{10}}$

$= \underline{\underline{73.22}}$ mol (approx.)

Mol. fraction (x) $= \dfrac{\text{moles of component } (\eta_i)}{\text{total moles } (\eta)}$

	CH_4	C_2H_6	C_4H_{10}
mol. fraction (x)	0.639	0.222	0.139

$$\text{Area Ratio} = \frac{\text{Area of component}}{\text{Area of cyclohexanone (CH)}}$$

$$\text{Weight Ratio} \equiv \text{(via Calibretion curves)}$$

$$y = m\left(\begin{matrix}\text{Area}\\\text{Ratio}\end{matrix}\right) + b$$

			M	E	B
where	m	=	1.293 ,	1.4527 ,	1.0115
	b	=	0.1829 ,	0.0604 ,	0.016

$$\text{weight of component} = [\text{weight ratio} \times \text{wt. of CH}]$$

CALCULATIONS -

- **TOTAL REFLUX :** DISTILLATE

	Area Ratio	Weight Ratio	Weight	Mol. fraction
Methanol	0.14	0.36	1.81	0.61
Ethanol	0.18	0.32	1.58	0.37
Butanol	0.00	0.02	0.09	0.01

BOTTOMS

	Area Ratio	Wt. Ratio	weight	Mole fraction
Methanol	0.14	0.37	1.84	0.51
Ethanol	0.18	0.33	1.63	0.32
Butanol	0.27	0.29	1.43	0.17

- $R = 1.9$:

DISTILLATE

	Area Ratio	Weight Ratio	Weight	Mole fraction
Methanol	0.87	1.31	6.60	0.71
Ethanol	0.49	0.77	3.86	0.29
Butanol	0.00	0.02	0.10	0.005

BOTTOMS

	Area Ratio	Weigh Ratio	weight	Mole fraction
Methanol	0.11	0.33	1.67	0.49
Ethanol	0.19	0.33	1.66	0.34
Butanol	0.26	0.28	1.40	0.18

- $\underline{\underline{R = 1}}$:

250 ml

DISTILLATE

	Area Ratio	Wt. Ratio	Weight	Mole fraction
Methanol	0.35	0.63	3.16	0.70
Ethanol	0.22	0.38	1.90	0.29
Butanol	0.00	0.02	0.10	0.01

BOTTOMS

	Area Ratio	Wt. Ratio	Weight	Mole fraction
Methanol	0.08	0.28	1.43	0.45
Ethanol	0.17	0.30	1.53	0.34
Butanol	0.28	0.30	1.51	0.21

500ml

DISTILLATE

	Area Ratio	Wt. Ratio	Weight	Mole fraction
Methanol	0.38	0.67	3.36	0.70
Ethanol	0.24	0.40	2.02	0.29
Butanol	0.00	0.02	0.09	0.01

BOTTOMS

	Area Ratio	wt. Ratio	weight	Mole fractions
Methanol	0.03	0.23	1.13	0.48
Ethanol	0.07	0.16	0.82	0.24
Butanol	0.28	0.30	1.49	0.27