



GSJ: Volume 7, Issue 6, June 2019, Online: ISSN 2320-9186

www.globalscientificjournal.com

DESIGN OF AN EXTRACTION COLUMN (A CASE STUDY OF SEPARATION OF WATER-ACETONE-ACETIC ACID USING CHLOROFORM AS SOLVENT)

Jaja Zina

Department of Chemical/Petrochemical Engineering , Rivers State University, Port Harcourt, Rivers State , Nigeria.

E-mail : zinajajal@gmail.com (Jaja Zina, corresponding author)

ABSTRACT

An extraction column design for the separation of water –Acetic acid – A cetone using chloroform as solvent was carried out. The data for the design were obtained from Handbooks. The simulation of the column was done using Aspen Hysys version 8.6. The mass flowrate and composition of the extract and Raffinate phases were determined along with the theoretical and actual number of stages, column diameter, column height, stage efficiency and tray spacing. Stainless steel was used as the material of construction. Finally the results of the simulation was compared with hand calculation which showed a maximum devcation of 1.3

Keywords: Extract, Feed, Raffinate, Solvent, column, phase, stage, Diameter, Height.

INTRODUCTION

Extraction processes are widely used in chemical manufacturing technology .

The process involves the transfer of materials from one phase to another. It utilizes differences in vapor pressure or solubility. The driving force here is concentration gradient. The separation of the components of a liquid mixture by treatment with a solvent in which one or more of the desired components is preferentially soluble is known as liquid-liquid extraction, the process can be broken down into three stages as follows:

- (i) Bringing the feed mixture and the solvent into intimate contact
- (ii) Separation of the resulting two phases
- (iii) Removal and recovery of the solvent from each phase.

Extraction is in many ways complementary to distillation and is preferable in the following cases:

- (i) When distillation would require excessive amount of heat, such as for example when the relative volatility is near unity.
- (ii) When the components to be separated are quite different in nature.

METHODOLOGY

Material Balance

Mass balance is written from the principle of conservation of mass and is written as :

$$[\textit{Accumulation of total mass}] = [\textit{inflow of total mass}] - [\textit{outflow of total mass}] \quad (1)$$

But there is no accumulation of mass in the system, therefore equation (1) can be rewritten as:

$$[\textit{inflow of total mass}] = [\textit{outflow of total mass}] \quad (2)$$

FEED

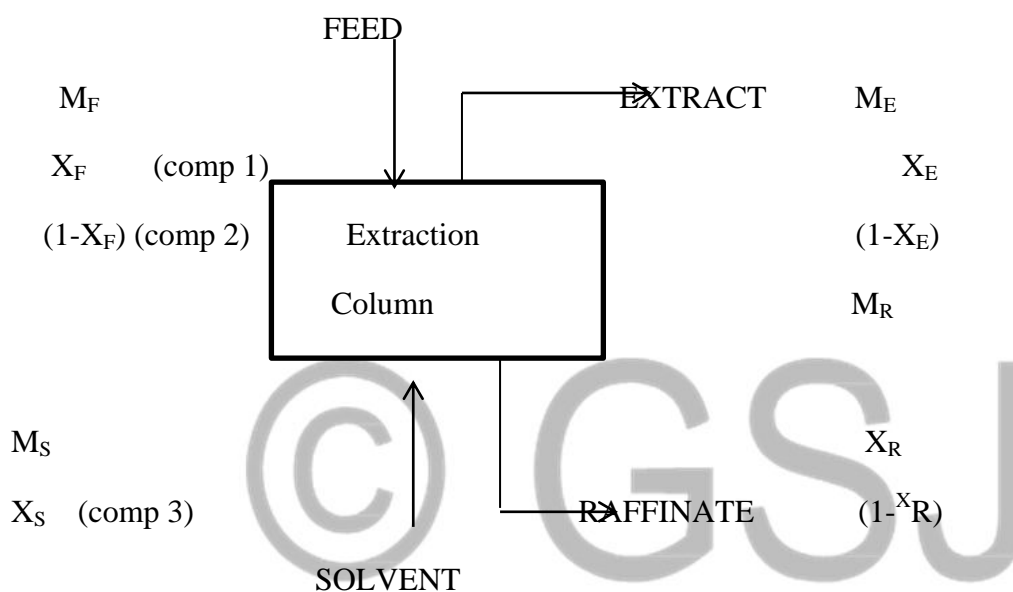


Fig 1: General schematic representation of an extraction column

Material balance of fig 1 is performed as follows:

Overall mass balance

$$M_F + M_S = M_E + M_R \quad (3)$$

Mass balance of component 1

$$M_F (X_F) = M_E (X_E) + M_R (X_R) \quad (4)$$

Mass balance of component 2

$$M_F(1 - X_F) = M_R(1 - X_R) \quad (5)$$

Mass balance of component 3

$$M_S(X_S) = M_E(1 - X_E) \quad (6)$$

Where :

M_F = mass flow rate of the feed in kg/h

M_S = mass flow rate of the solvent in kg/h

M_E = mass flow rate of the extract in kg/h

M_R = mass flow rate of the raffinate in kg/h

X_F = composition of solute in component 1

$(1 - X_F)$ = composition of solute in component 2

X_S = composition of solvent

X_E = composition of solute in extract in component 1

$(1 - X_E)$ = composition of solute in extract in component 3

$(1 - X_R)$ = composition of solute in raffinate in component 2

CALCULATION PROCEDURE

Determination of theoretical number of stages

$$N = \frac{\ln \left[\left(\frac{X_f - Y_{s/m}}{X_r - Y_{s/m}} \right) \left(1 - \frac{1}{\varepsilon} \right) + \frac{1}{\varepsilon} \right]}{\ln \varepsilon} \quad (7)$$

Equation (7) applies only when $\varepsilon \neq 1$ if $\varepsilon = 1$ equation (7) becomes

$$N = \left(\frac{X_f - Y_{s/m}}{X_r - Y_{s/m}} \right) - 1 \quad (8)$$

Where:

N = theoretical number of stages

X_f = solute concentration in the feed

X_r = solute concentration in the raffinate

Y_s = concentration of solvent

ε = extraction factor

M = slope of the equilibrium line

Determination of Column Diameter

$$D_c = \sqrt{\frac{4Q_c}{0.4\pi V_{cf}}} \quad (10)$$

Where:

D_c = Column diameter

Q_c = Volumetric flow rate of the continuous phase

V_{cf} = velocity of the continuous phase

Determination of Column Height

$$Z_c = \frac{HETS}{N} \quad (11)$$

Where:

Z_c = Height of Column

$HETS$ = Height equivalent to a theoretical stage

N = theoretical number of stages

The Height can also be computed as

$$Z_c = \frac{H_{or}}{N_{or}} \quad (12)$$

Where:

H_{or} = Height of a transfer unit based on raffinate phase composition

N_{or} = Number of transfer unit

Alternatively

$$Z_c = [\text{Actual number of stages}] [\text{Tray spacing}] \quad (13)$$

Where

$$\text{Actual number of stages} = \frac{\text{theoretical number of stages}}{\text{Efficiency}} \quad (14)$$

SIMULATION PROCEDURE

Table 1: Operating data of feed conditions

Parameters	Value/Unit
Temperature	50°C
Pressure	130Kpa
Molar flow rate	1000Kgmol/h

Table 2: Feed Composition data

Component	Value
Water	0.3
Acetone	0.2
Acetic acid	0.5
chloroform	0

Table 3: solvent conditions data

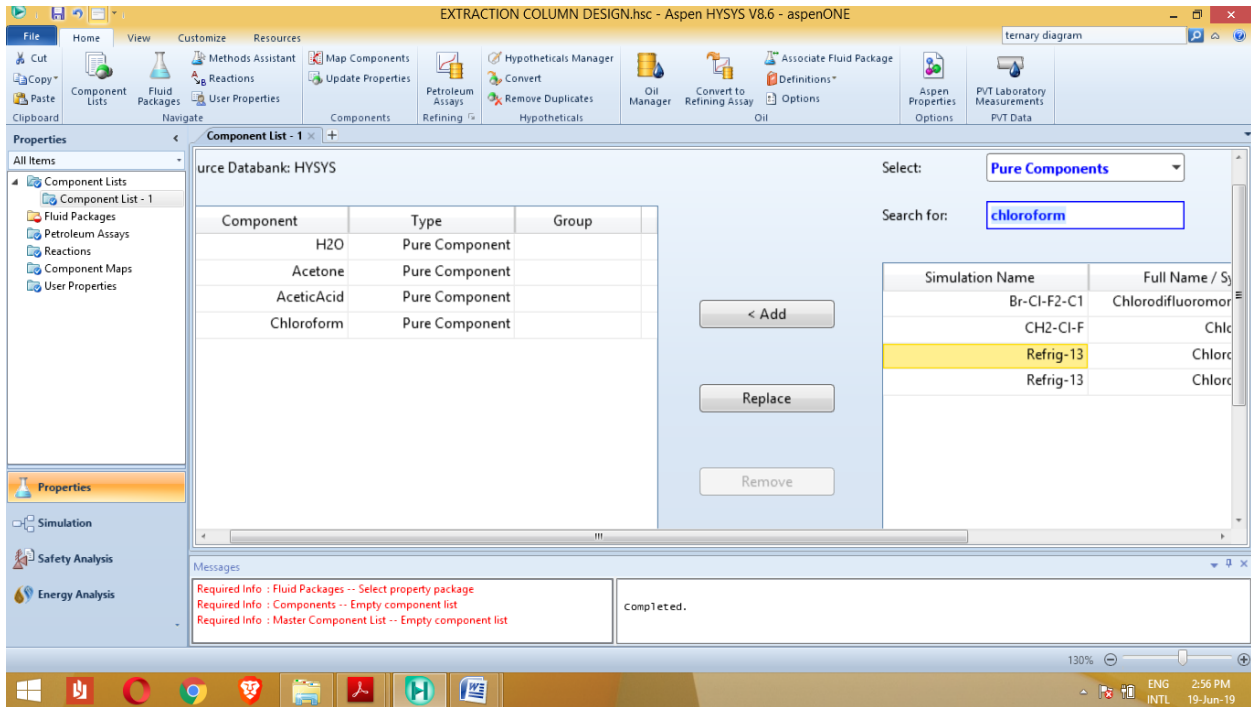
Parameter	Vaule/unit
Temperature	50°C
Pressure	130Kpa
Molar flow rate	3000Kgmol/h

Table 4: Solvent composition data

Component	Value
Water	0
Acetone	0
Acetic acid	0
chloroform	1

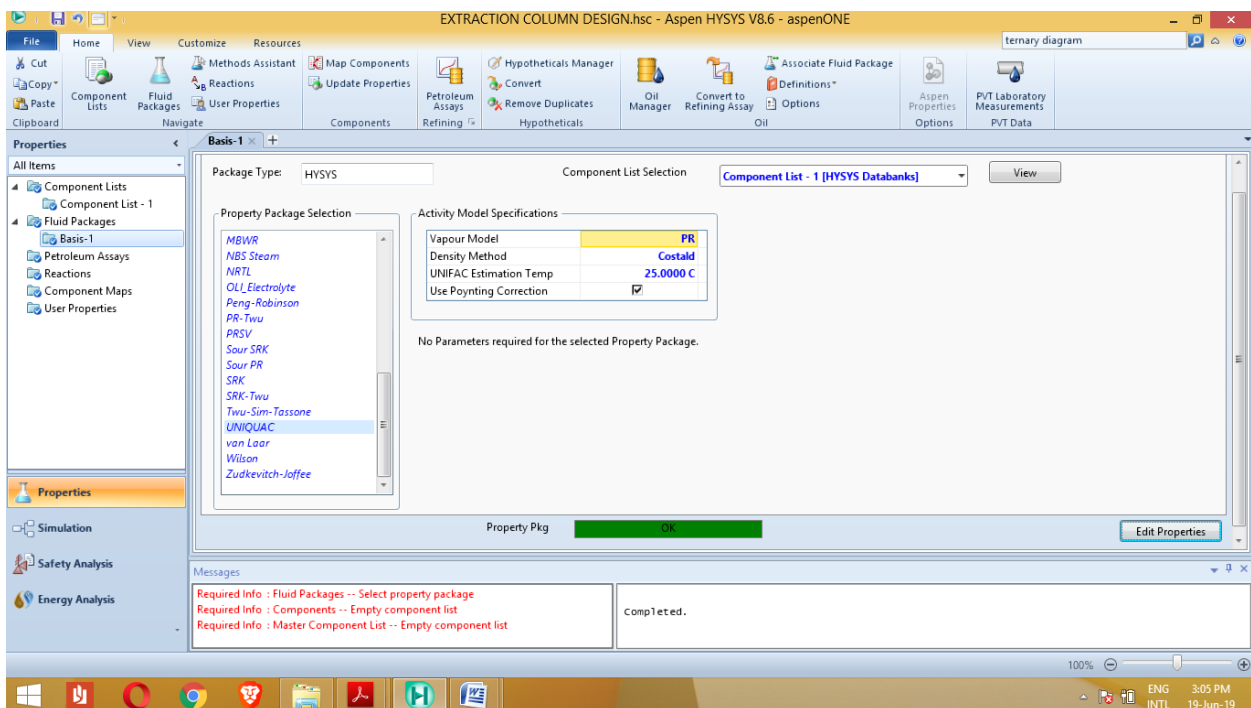
selection of components :

Open a new case in Aspen Hysys and select the components: Water, Acetone, Acetic acid and Chloroform as shown below.

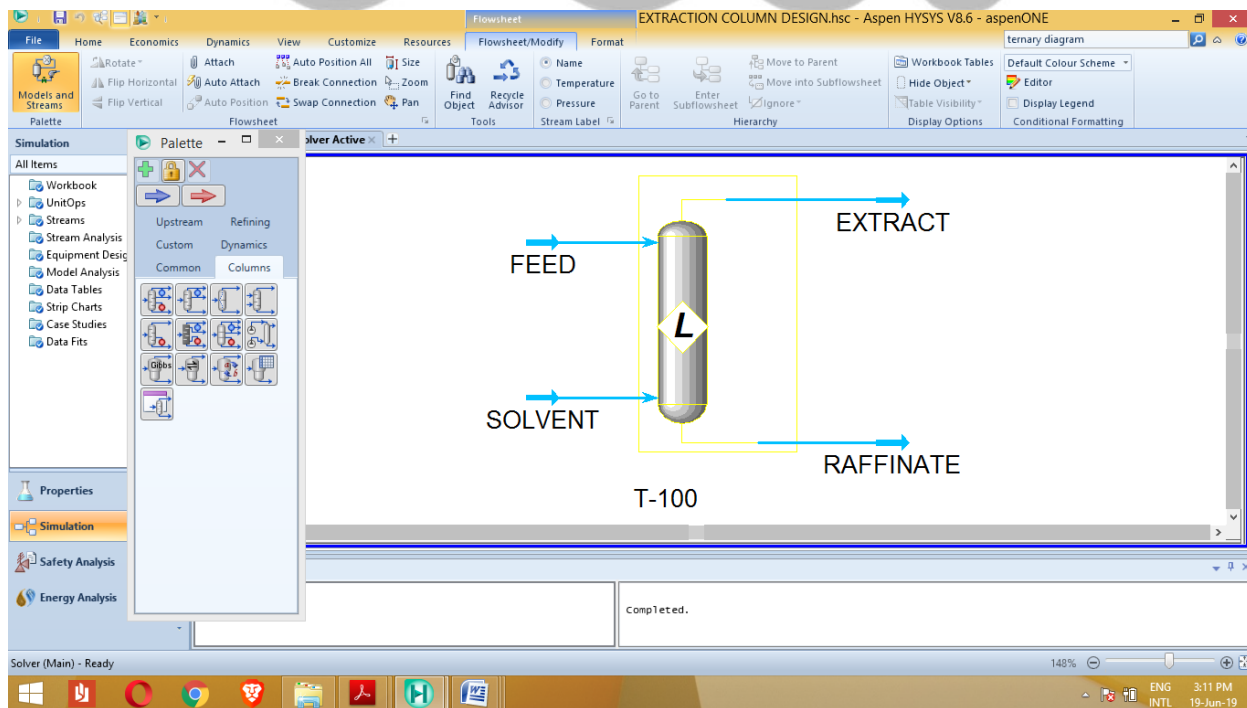
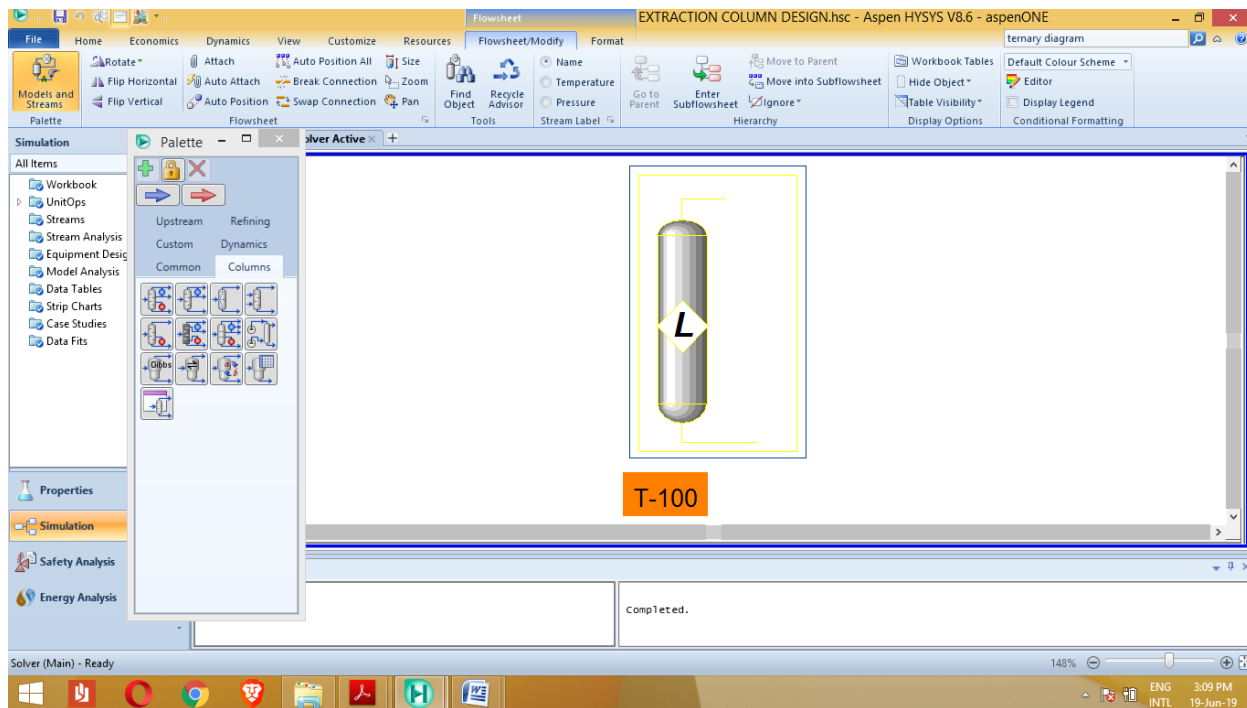


Selection of Fluid package:

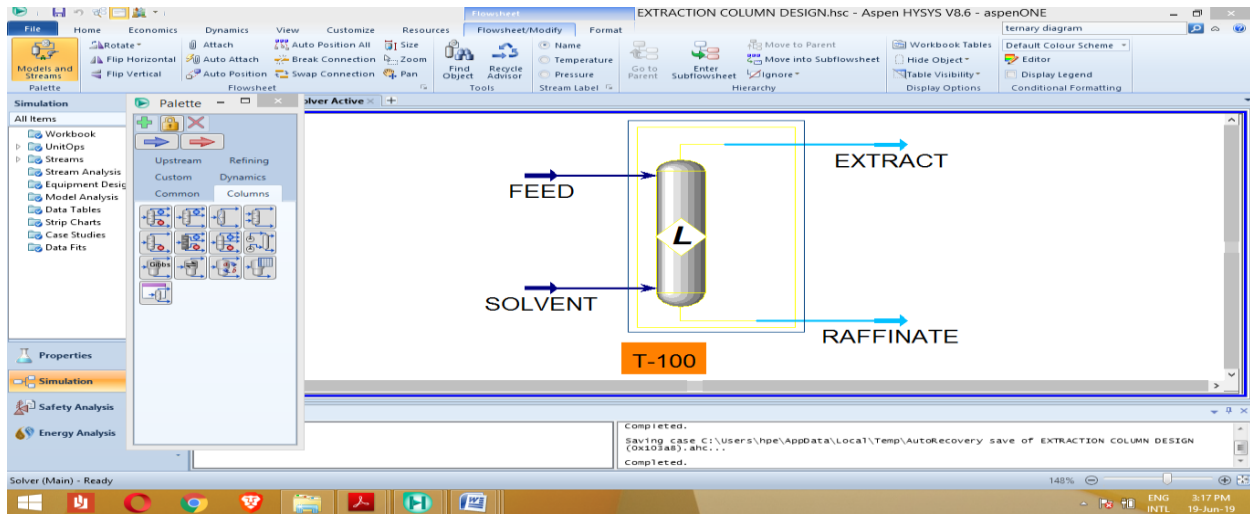
the fluid package that will be used in the simulation is UNIQUAC PR as shown below:



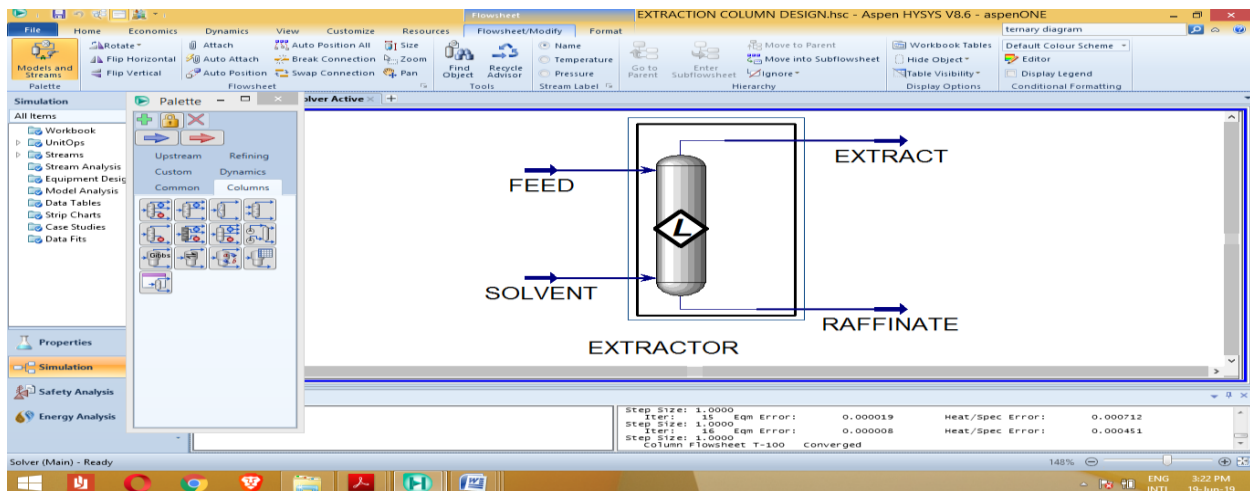
Enter the simulation environment and select the liquid-liquid extraction column and input the parameters shown in table 1



Define the feed and solvent streams so the two streams turns blue as shown



After defining all the streams name the column Extractor and run the column which should now converge as shown



RESULT AND DISCUSSIONS

Workbook: Case (Main)

Material Streams

Fluid Pkg

Name	FEED	SOLVENT	EXTRACT	RAFFINATE
Vapour Fraction	0.0000	0.0000	0.0000	0.0000
Temperature (C)	50.00 *	50.00 *	49.92	50.01
Pressure (kPa)	130.0 *	130.0 *	130.0	130.0
Molar Flow (kgmole/h)	1000 *	3000 *	3733	267.1
Mass Flow (kg/h)	4.705e+004	3.581e+005	4.004e+005	4815
Liquid Volume Flow (m3/h)	48.67	239.0	282.9	4.824
Heat Flow (kJ/h)	-3.631e+008	-3.919e+008	-6.795e+008	-7.559e+007

Compositions

Fluid Pkg

Name	FEED	SOLVENT	EXTRACT	RAFFINATE
Comp Mole Frac (H2O)	0.3000 *	0.0000 *	0.0088	0.9998
Comp Mole Frac (Acetone)	0.2000 *	0.0000 *	0.0536	0.0000
Comp Mole Frac (AceticAcid)	0.5000 *	0.0000 *	0.1339	0.0001
Comp Mole Frac (Chloroform)	0.0000 *	1.0000 *	0.8037	0.0001

Fig 1: Material and compositions streams

The screenshot shows a software interface with a 'Performance' tab selected. It displays data for three streams: 'Feeds', 'extract', and 'raffinate'. Each stream has a table showing the flow rate and composition (mole fractions) of H2O, Acetone, AceticAcid, and Chloroform.

Feeds		extract	raffinate
Flow Rate (kgmole/h)	1.0000000e+03	3.732911e+03	267.0895
H2O	0.3000	0.0088	0.9998
Acetone	0.2000	0.0536	0.0000
AceticAcid	0.5000	0.1339	0.0001
Chloroform	0.0000	0.8037	0.0001

Fig 2: percentage recovery

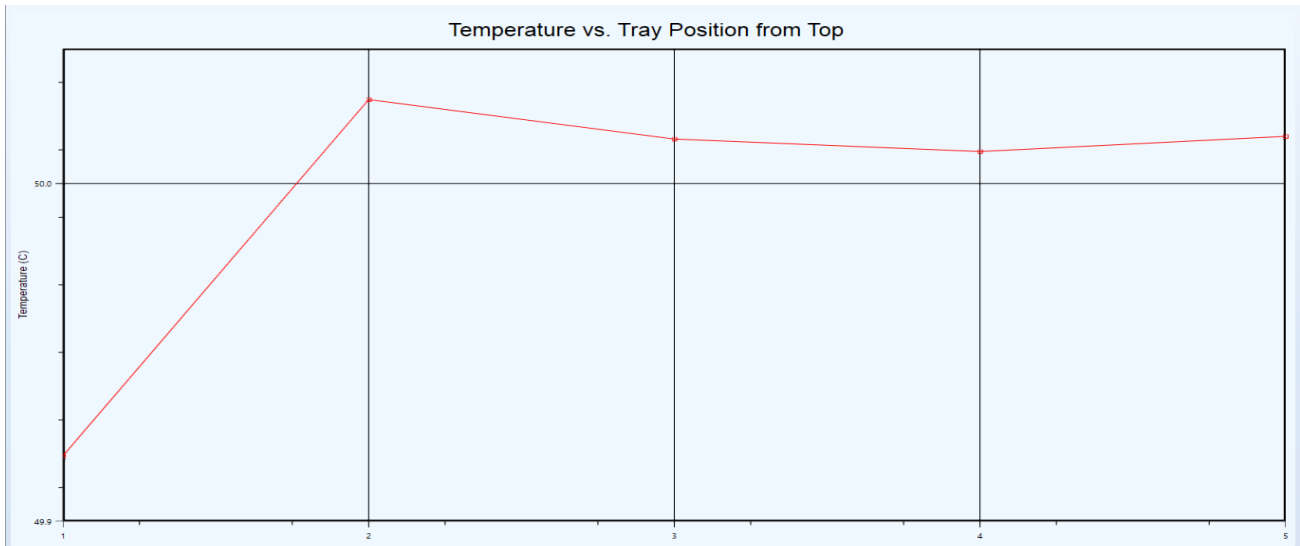


Fig 3: Temperature on each Tray from top

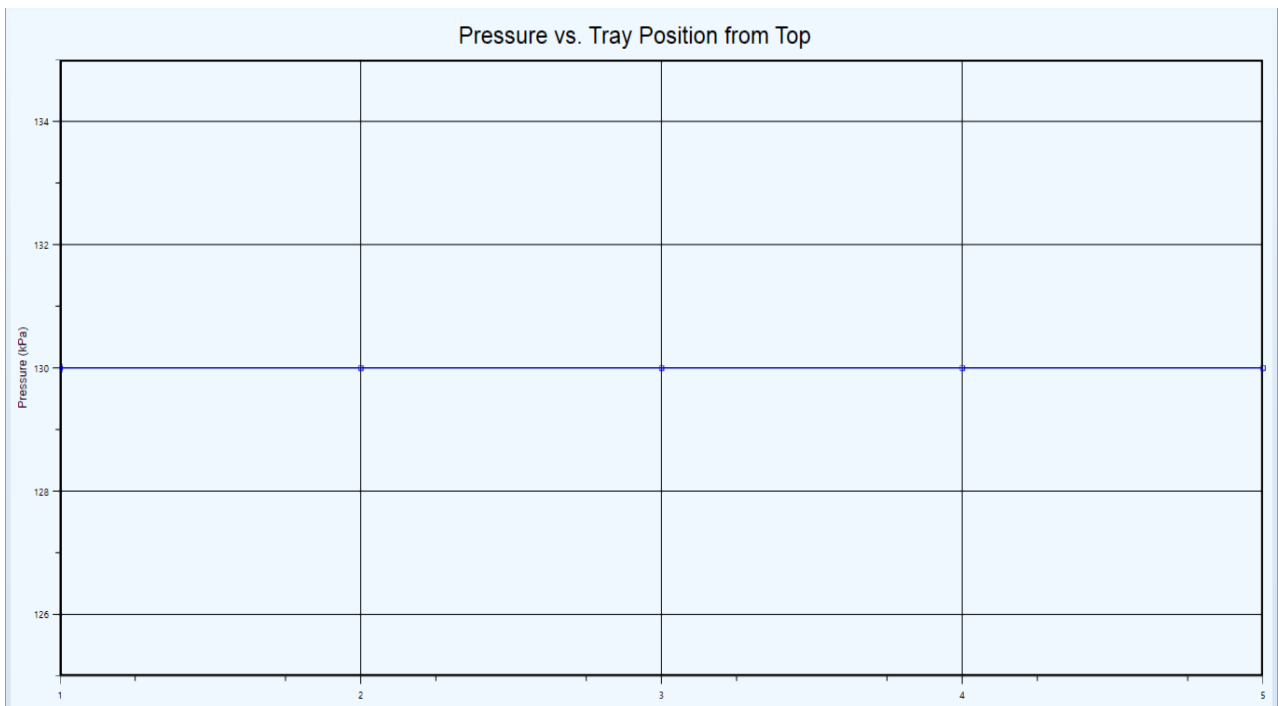


Fig 3: pressure on each tray from top

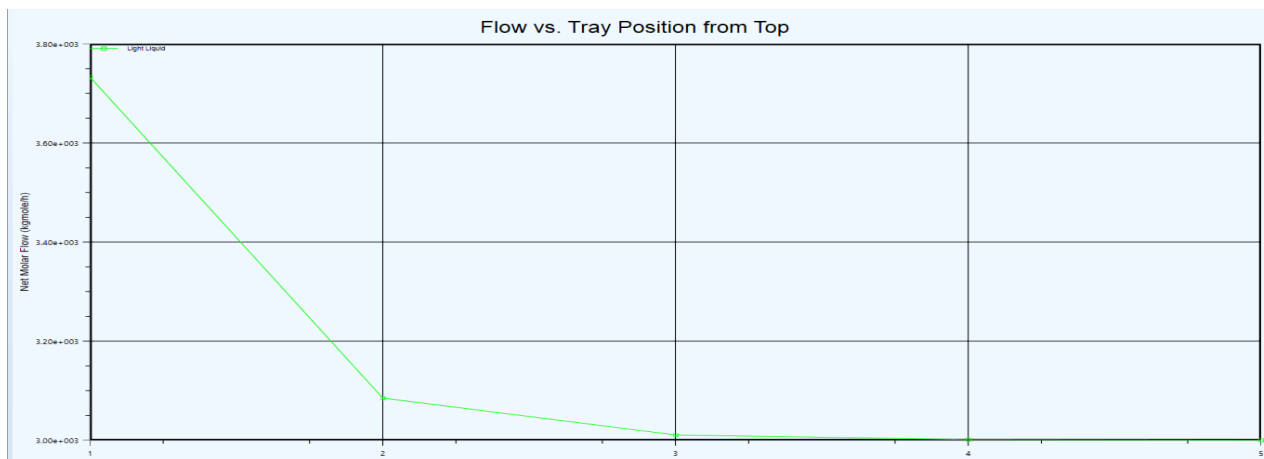


Fig 4: Molar flow rate on each tray from top

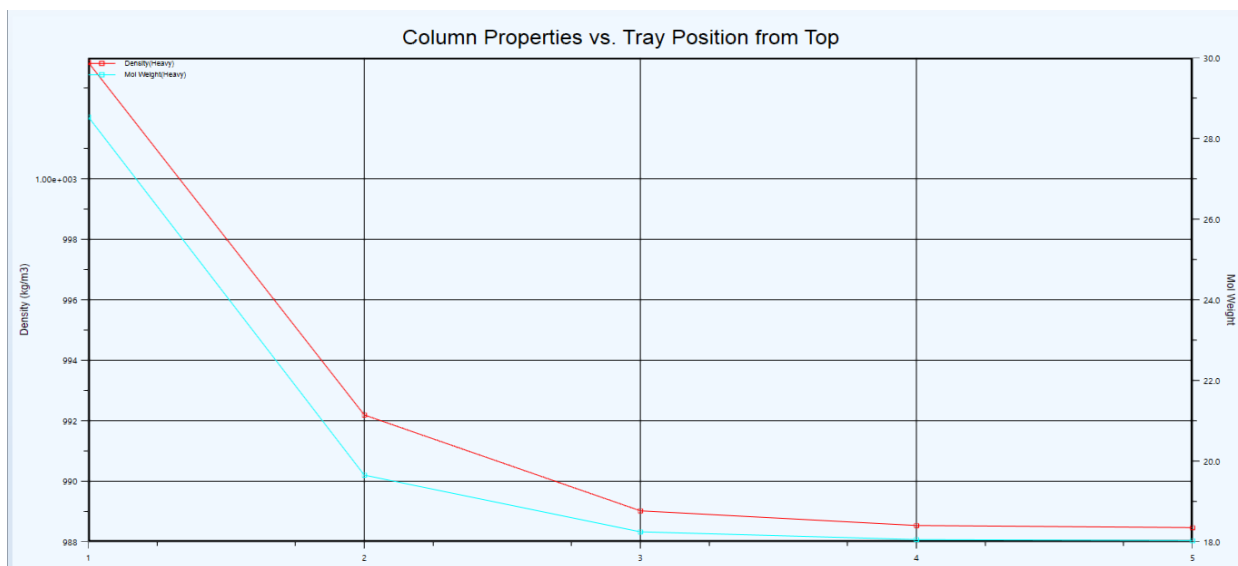


Fig 5: Density on each tray from top

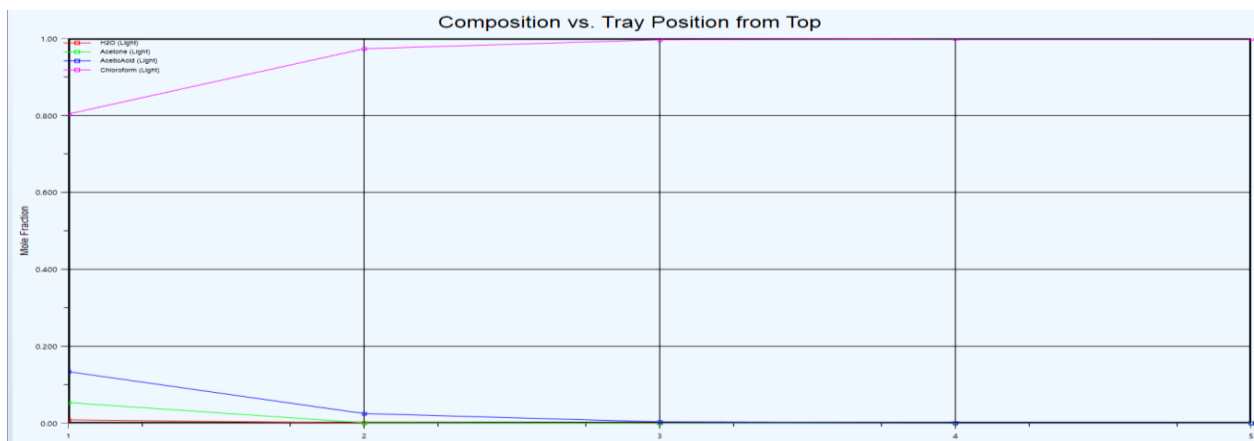


Fig 6: composition on each tray from top

The results given in the tables above reveal that although the temperature of the feed and solvent were held constant, there was a little drop in temperature in the extract phase while that of the raffinate remained constant.

There was no change in pressure in all the streams.

The molar flow rate of the extract is far greater than that of the raffinate as the solvent has extracted a large amount of the feed streams.

Acetone was completely extracted as its composition in the raffinate phase is zero.

Only a very small fraction of the Acetic acid was left in the raffinate phase.

CONCLUSION

Table 5: Comparison between Hand Calculation and Aspen Hysys

Parameter	Calculation	Hysys	Difference
Number of theoretical stages	4.5	5	0.5
Actual number of stages	6	7	1
Stage efficiency	0.7	0.7	0
Column Diameter	1.2m	1.5m	0.3
Column Height	3m	3.5m	0.5
Tray type	sieve	sieve	
Material of construction	Stainless steel	Stainless steel	
Tray thickness	0.1mm	0.1mm	0

It is observed that the less the stage efficiency the more the theoretical number of stages, hence a high stage efficiency design should be done in further research in order to reduce the number of stages for the separation.

Chloroform has a high recovery percentage for the feed mixture and should be used for large scale industrial extraction of Acetone and Acetic acid.

Acknowledgement

I wish to thank Dr. Akpa Jackson, Mrs. S.P. Oboho , Dr. K.K. Dagde , my Parents and siblings who ensured that the this work became a reality.

References

- [1] J.M. Coulson, J.F. Richardson, J.H. Harker, J.R. Backhurst, Chemical Engineering volume 2 (Butterworth-Hanemann, 2003)
- [2] J.M. Coulson, J.F. Richardson, R.K. Sinnott, Chemical Engineering volume 6 (Butterworth-Hanemann, 2005)
- [3] W.C. McCabe, J.C. Smith, P. Harriot, Unit operations of chemical Engineering (McGraw Hill, 2001)
- [4] R.H. Perry, D.W. Green, Perry's chemical Engineering Handbook (McGraw Hill,1998)
- [5] M. Sangashekan, H.G. Gilani, Solubility and Tie line Data for Ternary system of (Water-Phenol+ isobutyl acetate) at T = 308.2K, Volume 4, (issue1), 2017, pages 129-133
- [6] M.A. Nory -saith, liquid-liquid equilibrium for the design of extraction column, Volume 5, (issue 4), 2017, pages 18-36
- [7] M.J. Slater, Liquid-liquid Extraction column design, Volume 63, (Issue 6), December 1985, pages 100-105.

