Vapour Liquid Equilibrium Study of Binary Azeotrope of Aromatic and Aliphatic Compounds at Atmospheric Pressure

Ishan Dave[1], Dr. Sachin P. Parikh[2], Piyudh Gadhiya[3]
[1, 2, 3] Department of Chemical Engineering
[1, 2, 3] V.V.P. Engineering college

Abstract- *Aromatic and aliphatic hydrocarbon used in petrochemical industry, easily form azeotrope with each other. One such type of azeotropic mixture chosen here is mixture of cyclohexane and benzene. For the separation of this mixture using special processes such as extractive distillation, azeotropic distillation the analytical description of VLE data of extractive solvent and compounds to be separated is required. To find out the effect of extractive solvent on the isobaric VLE data of chosen system the VLE data of the system without solvent is required. Here in this work the isobaric VLE data of benzene and cyclohexane is carried out which serves as a precursor for the selection of the suitable separation process. This data is then compared with the data given in the literature.*

I. INTRODUCTION

Aromatic and aliphatic hydrocarbon compounds are very important raw chemical in petrochemical industry. They are used mainly used in the manufacturing of different synthetic fibres, plasticizers, dyes, explosives, etc. one such aliphatic compound is cyclohexane. Cyclohexanone and cyclohexanol are formed by oxidizing cyclohexane, which are used for makindadipic acid and caprolactum- they are used as precursors of nylon 6 & nylon 6/6, respectively [1, 5, and 6]. For the making of nylon 6 and nylon 6, 6 about 90% of the cyclohexane, produced worldwide is used.

There are many ways of cyclohexane production but out of that the benzene hydrogenation to cyclohexane is most widely practised.

$$C_6H_6 + 3H_2 \leftrightarrow C_6H_{12}$$

Hence it is important to recover unreacted benzene from the mixture of benzene and cyclohexane. However, it forms an azeotrope with the cyclohexane. Thus the isobaric VLE data of benzene and cyclohexane is required. On the basis of this data the selection of the suitable separation process can be made[15].

II. LIST OF DIFFERENT SEPARATION PROCESSES FOR AZEOTROPE SEPARATION AND SELECTION CRITERIA

Different separation processes for azeotopre sepration are listed below.

A. Extractive distillation
B. Liquid liquid extraction
C. Pressure swing distillation
D. Azeotropic distillation
E. Membrane adsorption

Out of these special separation processes commonly used processes for such kind of azeotropic separation are: extractive distillation, liquid liquid extraction, and azeotropic distillation. All these processes are suitable and economical when the aromatic content in the feed mixture is 20 to 100%.

Depending on the aromatic content of an azeotrope the choice of the separation processes are tabulated below.

Suitable process	Aromatic content
Liquid extraction	20% to 55%
Extractive distillation	55% to 90%
Azeotropic distillation	More than 90%

Table 1: suitable separation processes for different aromatic contents [7].

III. EXPERIMENTAL SECTION

3.1 Apparatus and Chemicals

Benzene was delivered by the LOBA chemicals with the purity min. 99%, non volatile matter less than 0.002% and water content less than 0.1%.Cyclohexane was delivered by Fisher scientific with the purity min. 99%, non volatile matter less than 0.005% and water content less than 0.1%. The apparatus used here in this work to carry out the isobaric VLE data is modified Raal and Muhlbauer apparatus [10]. The apparatus used for the composition analysis is the ebbe's refractometer.

3.2 Experimental procedure

Feed with known volume and composition of the benzene and cyclohexane is fed to the round bottom flask, heating is started and meanwhile the flow of water is also started into the condenser.

After sometime vapour will start forming which will get condensed by the condenser and the liquid is collected into the distillate collector. The condensed vapour is then recycled back to the round bottom flask.

After providing enough time, eventually equilibrium is reached, this is indicated by the achievement of constant temperature, when temperature of both vapor and liquid will be same. The composition of liquid and vapor condensate is then measured by ebbe's refractometer. Plot Temperature v/s. x-y diagram and x v/s y diagram.

Change the feed composition in the bottom flask and repeat the above procedure for another point on VLE curve.

IV. RESULTS AND DISCUSSION

Isobaric Vapour liquid equilibrium data were carried out at atmospheric pressure 101.325 Kpa, amount of vapour phase & liquid phase were measured at constant value of temperature.

Mixture of azeotropic system was taken total 700 ml of pure benzene for the first experiment, and then all the other data were generated for different amounts of benzene and cyclohexane by adding different amount of cyclohexane to the feed.

4.1 Experimental result

Table 2: Experimental Isobaric VLE data of benzene (1) and cyclohexane (2) at atmospheric pressure, 101.325 kPa.

Sr No.	T (K)	X_1exp	Y_1exp
1.	353.25	1.00000	1.00000
2.	352.15	0.96561	0.96561
3.	351.55	0.76679	0.73736
4.	350.05	0.66912	0.65708
5.	**350.05**	**0.55807**	**0.55405**
6.	349.65	0.52596	0.51391
7.	349.65	0.48180	0.48716
8.	349.75	0.35871	0.37477
9.	349.85	0.25033	0.26907
10.	351.25	0.09781	0.11119
11.	352.65	0.00415	0.00415
12.	353.89	0.00000	0.00000

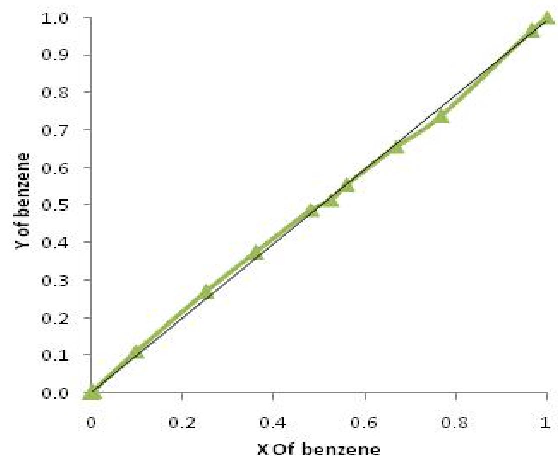

Fig 1: Experimental X v/s Y diagram for benzene (1) and cyclohexane (2) system.

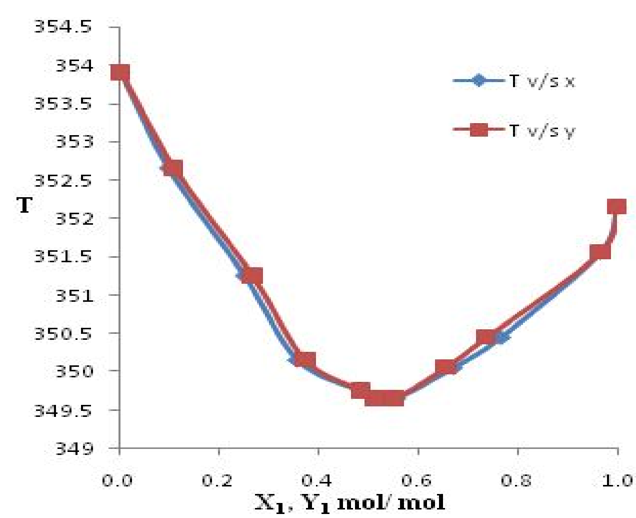

Fig. 2: Experimental T v/s X, Y diagram for benzene (1) and cyclohexane (2).

4.2 Comparison with the literature data[8]

T [K]	X_1 [mol/mol]	Y_1 [mol/mol]
353.9	0	0
352.7	0.101	0.131
352.1	0.171	0.211
351.6	0.256	0.293
351	0.343	0.376
350.7	0.428	0.445
350.6	**0.525**	**0.529**
350.6	0.571	0.564
350.8	0.665	0.645
351.1	0.759	0.728
351.4	0.81	0.777
351.8	0.863	0.834
352.5	0.945	0.926
353.3	1	1

Tabel 3: Isobaric VLE data of benzene (1) and cyclohexane (2) at atmospheric pressure, 101.325 kPa from literature [8].

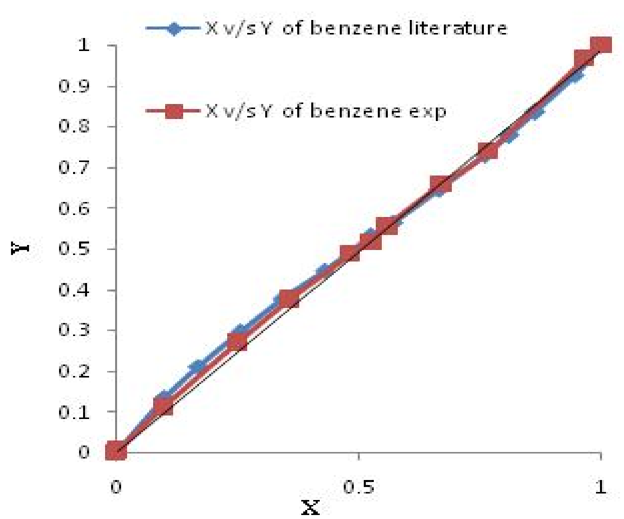

Fig 3: Comparison of X v/s Y of benzene from experiment and literature for benzene (1) and cyclohexane (2).

4.3 Discussion

The isobaric VLE data of benzene and cyclohexane found out experimentally here in this work table 2 matches very closely with the data given in the literature. The comparison of the VLE data and comparison of X v/s Y diagram shown in figure 3 indicates very negligible deviation of the VLE data of the benzene /cyclohexane system from the literature. From table 2 and Fig 1 it can be seen that the binary system of benzene and cyclohexane forms an azeotrope when the composition of benzene and cyclohexane is around 55% and 45% respectively and the corresponding temperature is around 350.5 K.

V. CONCLUSION

The comparison of the VLE data for the benzene /cyclohexane system and the X v/s Y diagram figure 3 indicate very negligible deviation from the literature, thus the isobaric VLE data for binary system of benzene and cyclohexane found in this work is valid. Since the aromatic content of the mixture is about 55% table 1 shows that the extractive distillation or liquid liquid extraction technique of separation will be more suitable and economical for the chosen azeotrope of benzene and cyclohexane compared to azeotropic distillation.

REFERENCES

[1] S. Matar, L.F. Hatch, Chemistry of Petrochemical Processes, Second ed., Butterworth-Heinemann, Boston, 2001, pp. 281–283.

[2] L.F. Hatch, Hydrocarbon Process, 1969, 48, pp. 77–88.

[3] L.F. Hatch, S. Matar, Hydrocarbon Process, 1977, 56, pp. 191– 201.

[4] N. Dachos, A. Kelly, D. Felch, E. Reis, Handbook of Petroleum Refining Processes, Second ed., McGraw-Hill, 1997, pp. 4.1–4.26.

[5] R.B. Stobaugh, Hydrocarbon Process, 1965, 44, 157–165.

[6] R.L. Marcell, H.M. Sachs, Encyclopedia of Chemical Processing and Design, 1982, 14 pp. 61–82.

[7] K. Weissermel, H.J. Arpe, Industrial Organic Chemistry, 4th ed., 2003, pp. 313–336.

[8] Nagata I, "Vapor-Liquid Equilibria for the Ternary System Methyl Acetate-Benzene-Cyclohexane", J.Chem.Eng.Data, 1962, 7, pp. 461-466.

[9] Malanowski S, "Experimental Methods for Vapour-Liquid Equilibria", Part I. Circulation Methods, Fluid Phase Equilibria, 1982, 8, pp 197-219.

[10] Raal JD and Muhlbauer AL, Phase Equilibria: Measurement & Computation; 1st Edn; Taylor & Francis, USA, 1998.

[11] Othmer DF, "Composition of Vapors from Boiling Binary Solutions." Ind. Engg. Chem. Ind. Ed. 1928, 20, 743-746.

[12] Piyush muljibhai gadhiya “vapor – liquid equilibrium studies for binary system of cyclopentyl methyl ether and cyclopentanol at atmospheric pressure”, Gujarat technological university, 2015.

[13] Gillespie DT, “Vapor-Liquid Equilibrium Still for Miscible Liquids.” Ind. Eng. Chem. Anal. Ed., 1946, 18, 575–577.

[14] Gore and Michael, “Spectrophotometry & Spectro fluorimetry”, Oxford University Press, New York, 2000.

[15] Parodi CA, Campanella EA, “Effect of vapor-liquid equilibrium data on the design of separation sequences by distillation.” Latin American applied research, 2009, 39.

[16] Smith JM, VanNess HC, and Abbott MM, Introduction to chemical engineering thermodynamics; 7th Edn; Tata McGraw Hill Education private limited, New Delhi, 2010.

[17] Bruce E. Poling ,John M. Prausnitz John P. O’Connell, Properties of gases and liquids;5th edition,2001.