Vapor-liquid equilibria in the ternary system acetone-benzene-cyclohexane

by Pu-Sheng Ting

A THESIS Submitted to the Graduate faculty in partial fulfillment of the requirements for the degree of Master of Science In Chemical Engineering
Montana State University

Abstract:
The purpose of this investigation was the determination of binary and ternary equilibria in the system acetone-benzene-cyclohexane. Othmer equilibrium stills were used. Vapor and liquid compositions were obtained from refractive index-composition curves for the binary and ternary systems, which had been previously determined. Data for the three binary systems were checked with those appearing in the literature. Ternary equilibrium diagrams were obtained from benzene and cyclohexane equilibria curves in the ternary system at constant weight percent of acetone in liquid. The ternary mixture formed no azeotrope, although both the acetone-cyclohexane and the benzene-cyclohexane binary systems formed minimum azeotropes.

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at

Montana State College

Approved:

Head, Major Department

Chairman, Examining Committee

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Bozeman, Montana
August, 1949

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Graduate Committee

I. Summary

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II. Introduction

Most hydrocarbons occur in nature or are produced as mixtures, and the separation of one compound from another closely boiling compound is a problem of considerable importance. At present, a number of aromatic hydrocarbons are manufactured from petroleum since the recent introduction of cyclization and hydroforming processes, in which cycloparaffins are formed as intermediate products. The economical separation of hydrocarbons thus produced becomes a significant subject in research.

In the case of mixtures of benzene and cyclohexane, the separation of benzene from cyclohexane by rectification is impossible because of their close boiling points and the formation of an azeotrope. At 760 mm. pressure, benzene boils at 80.103°C.(13), and cyclohexane at 80.738°C.(13). Azeotropic distillation with suitable entrainers usually provide favorable means of separating closely boiling pairs. Acetone is a suitable entrainer, but no data have appeared in the literature for the acetone-benzene-cyclohexane system as yet. A thorough knowledge of the vapor-liquid equilibria involved is essential in designing equipment for the azeotropic operations, and it is the purpose of this thesis to provide such data.

Acetone was chosen as the entrainer, because it forms a binary minimum azeotrope with cyclohexane only (7)(9), which is sufficiently lower than the original minimum azeotrope (3)(7)(9)(12). In addition, acetone has many other desirable properties, such as its complete solubility in benzene and cyclohexane, its ease of separation from the hydrocarbons by water extraction and distillation (8), low cost, availability, chemical stability and absence of reaction with the hydrocarbons or the column material.

III. Experimental Materials, Equipment and Procedure

Acetone (C.P., Commercial Solvents Co.) and cyclohexane (Dow Chemical Co.) were subjected to rectification in a one inch diameter, four feet long glass laboratory column, packed with 1/16" stainless steel Fenske helices and calibrating about thirty theoretical plates at total reflux. The refractive index of the acetone at 20°C. was 1.3587, compared with 1.3588 given by Hodgman (6), and that of the cyclohexane was 1.4262 as given by Rossini, et al (13). Benzene (E & A Tested Purity, Fisher Scientific Co.) was shaken three times with C. P. concentrated sulfuric acid, and washed three times with C.P. sodium bicarbonate solution. After the final acid wash, there was only a very slight tinge of coloration in the acid layer. After washing with distilled water, the benzene was dried with calcium chloride and subjected to rectification. Its purity was checked by determining the refractive index to be 1.5008, compared with 1.5009 given by Griswold and Bowden (4). Rossini, et al, give 1.5011 for pure benzene (13).

Vapor-liquid equilibrium determinations were made in two glass Othmer stills (10), which were connected to a pressure system. The stills were constructed of Pyrex glass, and each had a still pot capacity of approximately 120 ml. An external electrical heating coil surrounding the still pot provided heat for the distillation. A second external electrical heating