



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
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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.

VAPOR-LIQUID EQUILIBRIA IN THE TERNARY SYSTEM
ACETONE-BENZENE-CYCLOHEXANE

by

PU-SHENG TING

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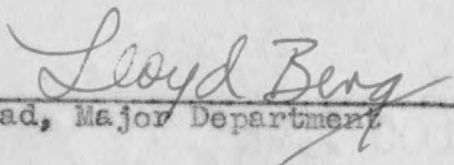
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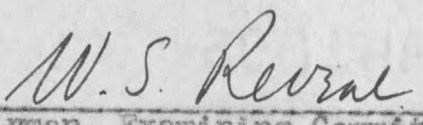
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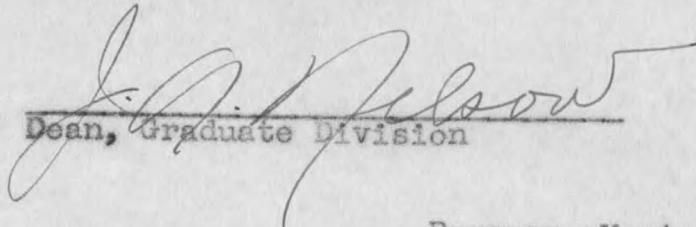
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Chairman, Examining Committee


Dean, Graduate Division

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I. Summary

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 per cent of acetone in liquid. The ternary mixture formed no azeotrope, although both the acetone-cyclohexane and the benzene-cyclohexane binary systems formed minimum azeotropes.

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 $80.103^{\circ}\text{C}.$ (13), and cyclohexane at $80.738^{\circ}\text{C}.$ (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.F., 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

coil surrounding the vapor space served to minimize heat loss from this section of the still. The stills were insulated with asbestos tape to prevent temperature fluctuations in the still due to outside influences. All heating coils were separately controlled with powerstats (Superior Electric Co.). The pressure system consisted of two five gallon surge tanks, one of which was connected through a hand valve to a nitrogen tank and served as a pressure reservoir at about 5 pounds gage. A Detroit Lubricator Co., No. 683-3, Solenoid valve was placed in the line between the surge tanks. The valve was activated by a mercury contact pressure regulator through a Fisher-Serfass electronic relay (F. S. Co. 13-991), and maintain^{ed} a pressure of 760 mm. in the second tank. Operating pressure was read from a mercury manometer connected to the system.

Vapor liquid equilibrium determinations were made according to the following procedure: A 75-120 ml. sample of either a binary or ternary mixture prepared from acetone, benzene and cyclohexane was charged to the still. The still was then slowly pressurized to 760mm. mercury. The heat was adjusted to give a distillation rate of about one drop per second. The distillations were allowed more than one half an hour to attain equilibrium. Then the powerstats were turned off and the pressure slowly dissipated. Vapor condensate and liquid samples were taken and their composition determined by refractive index in a Valentine Abbe type refractometer, capable of being

read to 0.0001. Refractive indices had previously been determined for the three binary mixtures and the ternary mixture. The refractive index data are presented in Tables I-III and VII and Figures 1 and 7. The refractive index data for the ternary system were determined at constant weight per cent of acetone. In the case of ternary mixtures, compositions were obtained from the refractive indices determined before and after water extraction of acetone from the mixtures and drying with calcium chloride. Calibrated precision thermometers were used to determine the vapor temperatures in the stills.

PERMANENT RECORD

SOUTHWORTH CO. U.S.A.

5% COTTON FIBER CONTENT

IV. Results

The vapor-liquid equilibria for the three binary systems are presented in Tables IV-VI and graphically in Figure 2. The system acetone-benzene exhibits no constant boiling mixture. Its equilibrium curve agrees closely with that given by Reinders and De Minjer (11), except its middle portion. The system acetone-cyclohexane exhibits an azeotrope containing 75.2 mole % (or 67.6 wt. %) of acetone and boiling at 53.8°C., while Lecat gave <85 wt. % at <54.0°C. (7)(9). The system benzene-cyclohexane exhibits an azeotrope containing 52.0 mole % (or 49.6 wt. %) of benzene and boiling at 76.9°C., while Lecat gave 55 wt. % at 77.5°C. (7)(9), and Richards and Hargreaves gave 51.5 mole % at 77.4°C. (12). The azeotropic points obtained in this research may be considered in good check with the literature.

Boiling points of the binary systems were plotted against composition in Figure 3. Activity coefficients were calculated with temperatures read from these curves, so as to obtain somewhat smoother curves in Figures 4-6. Vapor pressures of each pure component at various temperatures were taken from references (8)(13). All three binary equilibrium curves were checked favorably by comparison of the slopes of the activity coefficient curves with theoretical values from the Gibbs-Duhem relations (1)(2).

The vapor-liquid equilibrium data for the ternary system are presented in Table VIII in twenty two sets. Each has nearly the same amount of acetone in the liquid. The values of weight per cent of benzene in the vapor were plotted against weight per cent of benzene in the liquid for these twenty two sets, each set yielding an equilibrium curve at *constant* weight per cent acetone. The cyclohexane equilibria at constant weight per cent acetone were plotted in the same manner. In Figures 8-9, only a few sets were graphed together in order to avoid confusion and yet illustrate the general feature clearly. The end points of these curves were taken from acetone-benzene or acetone-cyclohexane equilibrium curves.

The triangular charts of Figures 10-11 were drawn from the benzene and cyclohexane equilibrium diagrams. The curved phase lines represent constant weight per cent of benzene or cyclohexane in the equilibrium vapors. The end points of these curves were taken directly from Figure 2. The compositions of the boiling liquid are represented by the coordinates of the triangle.

From these two triangular charts, equilibrium vapor compositions can be obtained for any ternary liquid mixture of acetone, benzene and cyclohexane. For example, a liquid containing 20.0 % acetone, 30.0 % benzene and 50.0 % of cyclohexane will be in equilibrium with a vapor containing 16.4 % of ben-

zene (from Figure 10), 38.3 % of cyclohexane (from Figure 11) and 45.3 % of acetone (by difference).

Boiling point data indicated no ternary azeotrope formation. All boiling points determined for ternary mixtures were higher than that of the binary azeotrope of acetone-cyclohexane.

PERMANENT RECORD

SOUTHWESTERN OIL FIELD

75% COTTON FIBER CONTENT

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TABLE I

Refractive Index at 20°C. in the Binary System
Acetone-Benzene

Weight % Acetone	Weight % Benzene	Refractive Index
0.00	100.00	1.5008
4.74	95.26	1.4941
5.00	95.00	1.4935
8.39	91.61	1.4881
9.14	90.86	1.4874
10.00	90.00	1.4860
10.93	89.07	1.4845
12.44	87.56	1.4820
14.20	85.80	1.4794
15.00	85.00	1.4784
20.00	80.00	1.4711
25.00	75.00	1.4635
25.68	74.31	1.4623
30.00	70.00	1.4560
35.00	65.00	1.4483
37.43	62.57	1.4451
40.00	60.00	1.4411
41.44	58.56	1.4388
45.00	55.00	1.4337
50.00	50.00	1.4266
55.00	45.00	1.4193
(line up) → 60.00	40.00	1.4122
65.00	35.00	1.4053
70.00	30.00	1.3983
75.00	25.00	1.3916
80.00	20.00	1.3846
85.00	15.00	1.3779
89.02	10.98	1.3728
90.00	10.00	1.3716
93.48	6.52	1.3671
100.00	0.00	1.3587

TABLE II

Refractive Index at 20°C. in the Binary System
Acetone-Cyclohexane

Weight % Acetone	Weight % Cyclohexane	Refractive Index
0.00	100.00	1.4262
5.00	95.00	1.4221
8.25	91.75	1.4200
11.54	88.46	1.4172
14.74	85.26	1.4145
15.39	84.61	1.4142
21.28	78.72	1.4095
25.00	75.00	1.4067
30.00	70.00	1.4030
35.00	65.00	1.3992
37.96	62.04	1.3976
40.00	60.00	1.3952
42.00	58.00	1.3938
45.00	55.00	1.3922
46.66	53.34	1.3906
50.00	50.00	1.3885
50.83	49.17	1.3873
54.66	45.34	1.3848
58.93	41.07	1.3816
62.51	37.49	1.3794
65.23	34.77	1.3776
68.03	31.97	1.3762
70.00	30.00	1.3750
70.87	29.13	1.3742
78.75	21.25	1.3693
78.87	21.13	1.3692
79.32	20.68	1.3690
84.62	15.38	1.3660
85.05	14.95	1.3656
87.11	12.89	1.3644
90.80	9.20	1.3626
94.17	5.83	1.3611
94.81	5.19	1.3609
95.38	4.62	1.3607
100.00	0.00	1.3587

TABLE III

Refractive Index at 20°C. in the Binary System
Benzene-Cyclohexane

Weight % Benzene	Weight % Cyclohexane	Refractive Index
0.00	100.00	1.4262
5.90	94.10	1.4292
9.84	90.16	1.4311
10.19	89.81	1.4315
10.38	89.62	1.4312
10.61	89.39	1.4316
13.87	86.13	1.4334
14.30	85.70	1.4336
14.81	85.19	1.4338
19.12	80.88	1.4366
20.35	79.65	1.4370
23.64	76.36	1.4395
27.83	72.17	1.4420
32.06	67.94	1.4448
36.20	63.80	1.4475
40.68	59.32	1.4510
44.96	55.04	1.4539
48.59	51.41	1.4567
52.90	47.10	1.4591
57.59	42.41	1.4630
61.28	38.72	1.4661
65.62	34.38	1.4698
67.71	32.29	1.4710
69.33	30.67	1.4730
72.82	27.18	1.4754
76.39	21.61	1.4800
80.99	19.01	1.4827
84.15	15.85	1.4854
86.29	13.71	1.4874
87.07	12.93	1.4881
88.27	11.73	1.4894
91.46	8.54	1.4922
95.56	4.44	1.4963
100.00	0.00	1.5008

TABLE IV

(close up)

Analysis and Equilibrium Data in the Binary System Acetone-Benzene

Refractive Index, 20° C.		Mole % Acetone		Boiling Point, °C.		Activity Coefficient	
Liquid	Vapor	Liquid	Vapor	Observed	Corrected	Acetone	Benzene
1.4962	1.4861	4.0	12.9	77.2	77.2	1.657	0.994
1.4918	1.4747	7.9	22.2	74.9	74.8	1.555	0.998
1.4862	1.4622	12.8	31.8	72.0	72.2	1.487	1.005
1.4750	1.4433	22.0	45.8	68.6	68.6	1.390	1.006
1.4733	1.4442	23.2	45.2	68.5	68.5	1.304	1.037
1.4556	1.4237	36.6	59.1	65.0	65.0	1.215	1.057
1.4506	1.4194	40.4	62.0	64.5	64.3	1.179	1.071
1.4340	1.4067	52.2	70.1	62.1	62.3	1.098	1.122
1.4263	1.4023	57.5	73.2	61.6	61.5	1.070	1.164
1.3988	1.3846	75.3	84.4	59.2	59.2	1.020	1.264
1.3797	1.3720	87.2	92.0	57.8	57.7	1.007	1.423
1.3666	1.3645	95.1	96.6	57.2	56.7	1.003	1.512
1.3623	1.3614	97.7	98.6	56.9	56.4	1.004	1.341

TABLE V

Analysis and Equilibrium Data in the Binary System Acetone-Cyclohexane

Refractive Index, 20°C.		Mole % Acetone		Boiling Point, °C.		Activity Coefficients	
Liquid	Vapor	Liquid	Vapor	Observed	Corrected	Acetone	Cyclohexane
1.4256	1.4237	1.0	4.4	78.2	77.7	2.230	1.061
1.4255	1.4233	1.1	5.0	78.1	77.4	2.318	1.066
1.4253	1.4202	1.4	10.5	76.9	76.7	3.918	1.023
1.4249	1.4155	2.3	18.3	74.4	74.4	4.447	1.019
1.4237	1.4063	4.4	33.0	69.2	69.2	5.106	1.007
1.4204	1.3961	10.2	48.2	62.2	62.2	3.883	1.046
1.4152	1.3895	19.0	57.4	58.9	58.3	2.828	1.084
1.4074	1.3847	31.2	64.0	56.0	56.0	2.077	1.174
1.3973	1.3822	46.4	67.3	54.7	54.7	1.531	1.431
1.3896	1.3804	57.3	69.5	54.2	54.2	1.301	1.707
1.3871	1.3799	60.6	70.2	54.0	54.0	1.249	1.819
1.3792	1.3774	71.3	73.4	54.4	53.8	1.118	2.244
1.3748	1.3755	76.8	75.8	53.7	53.8	1.073	2.526
1.3698	1.3725	83.7	79.8	53.9	53.9	1.033	2.992
1.3673	1.3710	87.0	81.9	53.8	54.1	1.014	3.339
1.3668	1.3704	87.6	82.7	54.0	54.2	1.015	3.336
1.3658	1.3692	89.2	84.3	54.2	54.3	1.012	3.463
1.3617	1.3641	95.2	91.6	55.1	55.0	1.003	4.044
1.3611	1.3631	96.2	93.1	55.3	55.3	1.001	4.170
1.3605	1.3621	97.0	94.5	55.4	55.4	1.001	4.180
1.3603	1.3613	98.8	97.8	56.0	55.8	1.003	4.112
1.3592	1.3596	99.3	98.6	56.2	55.9	1.005	4.432

TABLE VI

Analysis and Equilibrium Data in the Binary System Benzene-Cyclohexane

Refractive Index, 20°C.		Mole % Benzene		Boiling Point, °C.		Activity Coefficient	
Liquid	Vapor	Liquid	Vapor	Observed	Corrected	Benzene	Cyclohexane
1.4277	1.4286	3.5	5.2	80.0	80.2	1.481	1.001
1.4290	1.4301	6.1	8.2	79.8	79.9	1.351	1.003
1.4296	1.4307	7.2	9.5	79.8	79.7	1.335	1.008
1.4313	1.4327	10.5	13.5	79.4	79.3	1.317	1.031
1.4314	1.4328	10.7	13.7	79.2	79.3	1.311	1.011
1.4329	1.4347	13.8	17.0	78.9	79.0	1.272	1.015
1.4358	1.4379	19.1	22.7	78.6	78.5	1.248	1.035
1.4389	1.4412	24.3	28.0	77.6	78.0	1.229	1.035
1.4392	1.4414	24.7	28.5	78.0	78.0	1.230	1.035
1.4477	1.4492	37.6	40.0	77.3	77.3	1.160	1.070
1.4505	1.4515	41.7	43.4	77.1	77.1	1.144	1.087
1.4551	1.4554	48.3	48.9	77.1	77.0	1.115	1.110
1.4612	1.4603	57.0	55.8	77.0	77.0	1.079	1.155
1.4702	1.4678	68.4	65.4	77.1	77.1	1.409	1.225
1.4797	1.4763	79.2	75.3	77.5	77.5	1.031	1.312
1.4882	1.4847	88.1	84.5	78.2	78.2	1.016	1.410
1.4974	1.4959	97.0	95.6	79.1	79.1	1.016	1.542
1.4985	1.4975	98.1	97.0	79.3	79.3	1.013	1.651
1.4997	1.4990	99.0	98.4	79.4	79.5	1.011	1.661

TABLE VII

Refractive Index at 20°C. in the Ternary System Acetone-Benzene-Cyclohexane

		Weight % Acetone					
		10		20		30	
Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index
5.56	1.4219	6.25	1.4137	7.15	1.4063		
11.11	1.4243	12.50	1.4166	14.29	1.4092		
16.67	1.4276	18.75	1.4201	21.43	1.4126		
22.22	1.4294	25.00	1.4233	28.57	1.4159		
27.78	1.4336	31.25	1.4265	35.71	1.4197		
33.33	1.4366	37.50	1.4304	42.86	1.4229		
38.89	1.4404	43.75	1.4330	50.00	1.4267		
44.44	1.4442	50.00	1.4370	57.14	1.4298		
50.00	1.4474	56.25	1.4404	64.29	1.4340		
55.56	1.4513	62.50	1.4445	71.43	1.4381		
61.11	1.4558	68.75	1.4484	78.57	1.4420		
66.67	1.4592	75.00	1.4532	85.71	1.4462		
72.22	1.4617	81.25	1.4575	92.85	1.4511		
77.78	1.4677	87.50	1.4612				
83.73	1.4719	93.75	1.4659				
88.89	1.4768						
94.44	1.4806						

TABLE VII (Contd.)

Weight % Acetone					
40		50		60	
Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index
8.33	1.3980	10.00	1.3914	6.25	1.3830
16.67	1.4019	20.00	1.3945	12.50	1.3847
25.00	1.4051	30.00	1.3982	25.00	1.3884
33.33	1.4083	40.00	1.4020	37.50	1.3919
41.67	1.4123	50.00	1.4056	50.00	1.3957
50.00	1.4159	60.00	1.4094	62.50	1.3996
58.33	1.4197	70.00	1.4033	75.00	1.4035
66.67	1.4237	80.00	1.4174	87.50	1.4079
75.00	1.4278	90.00	1.4219	93.75	1.4096
83.33	1.4320				
91.67	1.4362				

TABLE VII (Contd.)

70		Weight % Acetone		90	
Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index	Wt. %, Benzene in Hydrocarbons	Refractive Index
8.33	1.3764	6.25	1.3700	6.25	1.3641
16.67	1.3785	12.50	1.3708	12.50	1.3644
25.00	1.3802	25.00	1.3710	25.00	1.3654
33.33	1.3821	37.50	1.3745	37.50	1.3663
50.00	1.3861	50.00	1.3764	50.00	1.3673
66.67	1.3897	62.50	1.3784	62.50	1.3683
75.00	1.3917	75.00	1.3806	75.00	1.3695
85.33	1.3939	87.50	1.3823	87.50	1.3699
91.66	1.3953	93.75	1.3831	93.75	1.3708

TABLE VIII

Analysis and Equilibrium Data in the Ternary System Acetone-Benzene-Cyclohexane

n_D^{20}		n_D^{20}		Weight Per Cent Composition						Wt. % Acetone Plotted
Ternary System		Hydrocarbons		Liquid			Vapor			
Liquid Vapor		Liquid Vapor		Acetone	Benzene	Cyclohexane	Acetone	Benzene	Cyclohexane	
1.4751	1.4636	1.4771	1.4727	1.7	73.5	24.8	8.0	64.0	28.0	
1.4871	1.4770	1.4896	1.4860	1.8	87.1	11.1	6.9	79.0	14.1	
1.4515	1.4365	1.4537	1.4533	2.5	43.8	53.7	17.3	36.6	46.1	
1.4647	1.4522	1.4677	1.4646	2.9	61.6	35.5	12.3	52.1	35.6	
1.4758	1.4593	1.4797	1.4741	3.2	75.3	21.5	12.2	62.6	25.2	2.9
1.4361	1.4250	1.4381	1.4395	3.3	20.8	75.9	17.3	19.4	63.3	
1.4640	1.4459	1.4678	1.4649	3.5	61.3	35.2	17.3	49.5	33.2	
1.4473	1.4322	1.4506	1.4506	3.6	39.0	57.4	19.5	32.6	47.9	
1.4424	1.4276	1.4453	1.4464	3.6	31.6	64.8	20.8	27.2	52.0	
1.4376	1.4216	1.4418	1.4424	5.1	26.1	68.8	29.0	20.2	50.8	
1.4710	1.4512	1.4771	1.4723	5.2	70.9	23.9	17.8	56.7	25.5	
1.4851	1.4664	1.4926	1.4889	5.4	87.0	7.6	16.5	73.5	10.0	
1.4371	1.4213	1.4418	1.4424	5.6	24.0	70.4	26.0	21.6	52.4	
1.4370	1.4184	1.4417	1.4423	5.6	25.8	68.6	27.2	20.5	52.3	
1.4813	1.4619	1.4887	1.4841	5.6	82.9	11.5	16.9	68.7	14.4	
1.4386	1.4149	1.4376	1.4383	5.9	19.2	74.9	27.8	15.8	56.4	
1.4283	1.4091	1.4328	1.4331	6.0	11.8	82.2	29.8	9.1	61.1	
1.4444	1.4252	1.4499	1.4490	6.1	37.1	56.8	25.1	28.6	46.3	6.2
1.4838	1.4601	1.4926	1.4885	6.3	86.3	7.4	20.8	69.4	9.8	
1.4665	1.4454	1.4738	1.4686	6.4	66.4	27.2	20.0	51.6	28.4	
1.4637	1.4404	1.4712	1.4660	6.9	63.0	30.1	22.7	47.3	30.0	
1.4439	1.4210	1.4501	1.4490	6.9	37.0	56.1	30.3	26.6	43.1	
1.4827	1.4615	1.4926	1.4890	7.0	85.6	7.4	20.0	70.6	9.4	
1.4521	1.4303	1.4597	1.4561	7.3	49.1	43.6	25.3	36.0	38.7	
1.4602	1.4384	1.4684	1.4634	7.6	59.4	33.0	22.8	44.8	32.4	

TABLE VIII (Contd.)

n_D^{20}		n_D^{20}		Weight Per Cent Composition						Wt. % Acetone Plotted
Ternary System		Hydrocarbons		Liquid			Vapor			
Liquid	Vapor	Liquid	Vapor	Acetone	Benzene	Cyclohexane	Acetone	Benzene	Cyclohexane	
1.4521	1.4298	1.4605	1.4566	8.1	49.6	42.3	26.1	36.1	37.8	
1.4406	1.4191	1.4481	1.4469	8.5	33.8	57.7	29.7	24.7	45.6	
1.4682	1.4431	1.4787	1.4738	8.6	70.1	21.3	25.2	53.0	21.8	
1.4744	1.4496	1.4858	1.4804	8.7	77.3	14.0	24.1	59.6	16.3	
1.4454	1.4213	1.4537	1.4512	8.8	40.9	50.3	30.4	28.7	40.9	
1.4446	1.4221	1.4532	1.4506	9.2	40.1	50.7	29.5	28.7	42.0	9.2
1.4297	1.4053	1.4371	1.4371	9.4	18.1	72.5	37.7	12.5	49.8	
1.4461	1.4252	1.4559	1.4527	10.0	43.1	46.9	29.6	30.6	39.8	
1.4599	1.4332	1.4715	1.4651	10.3	61.2	28.5	28.0	43.2	28.8	
1.4777	1.4489	1.4924	1.4866	10.6	81.9	7.5	28.0	61.6	10.4	
1.4393	1.4135	1.4501	1.4470	11.8	35.9	52.3	35.9	22.6	41.5	
1.4571	1.4282	1.4714	1.4638	12.4	59.6	28.0	31.9	39.8	28.3	
1.4271	1.4011	1.4374	1.4364	12.6	17.6	69.8	42.0	10.8	47.2	
1.4554	1.4279	1.4681	1.4624	13.1	55.5	31.4	31.5	38.7	29.8	
1.4626	1.4328	1.4795	1.4711	13.4	67.1	19.5	32.4	45.8	21.8	13.2
1.4496	1.4202	1.4639	1.4572	13.4	50.7	35.9	35.5	32.1	32.4	
1.4679	1.4384	1.4860	1.4789	13.6	73.4	13.0	32.2	52.8	15.0	
1.4523	1.4230	1.4679	1.4616	13.9	54.8	31.3	35.6	35.8	22.6	
1.4573	1.4270	1.4750	1.4666	14.3	62.0	23.7	34.6	40.5	24.9	
1.4455	1.4161	1.4635	1.4562	16.4	48.5	35.1	38.9	29.5	31.6	
1.4690	1.4353	1.4932	1.4874	17.1	76.7	6.2	38.5	53.1	8.4	
1.4505	1.4188	1.4723	1.4620	18.4	56.5	25.1	39.6	33.8	26.6	17.7
1.4564	1.4254	1.4811	1.4722	19.1	64.2	16.7	39.2	42.0	18.8	

TABLE VIII (Contd.)

n_D^{20}		n_D^{20}		Weight Per Cent Composition						Wt. % Acetone Plotted
Ternary System		Hydrocarbons		Liquid			Vapor			
Liquid	Vapor	Liquid	Vapor	Acetone	Benzene	Cyclohexane	Acetone	Benzene	Cyclohexane	
1.4183	1.3952	1.4391	1.4362	24.6	17.5	57.9	49.1	9.3	41.6	
1.4448	1.4132	1.4750	1.4616	24.7	54.5	20.8	44.8	30.6	24.6	
1.4398	1.4100	1.4691	1.4588	25.2	48.7	26.1	46.4	27.8	25.8	
1.4561	1.4222	1.4930	1.4857	26.1	68.3	5.6	47.7	44.2	8.1	26.0
1.4408	1.4110	1.4727	1.4592	26.4	51.3	22.3	45.7	22.4	25.9	
1.4392	1.4042	1.4572	1.4494	26.8	36.4	36.8	47.5	20.4	32.1	
1.4270	1.4012	1.4542	1.4471	27.0	33.2	39.8	49.2	18.0	32.8	
1.4462	1.4153	1.4917	1.4702	27.3	52.2	14.5	46.6	35.5	17.9	
1.4401	1.4102	1.4745	1.4634	22.1	51.6	20.3	48.4	29.9	21.7	
1.4257	1.3994	1.4563	1.4460	29.6	34.0	36.4	50.4	16.8	32.8	29.1
1.4374	1.4069	1.4739	1.4591	29.8	49.8	20.4	49.5	26.4	24.1	
1.4490	1.4152	1.4922	1.4864	30.7	63.4	5.9	53.4	39.8	6.8	
1.4399	1.4104	1.4801	1.4699	31.4	53.7	14.9	51.1	32.3	16.6	31.6
1.4 230	1.3977	1.4564	1.4465	32.0	32.9	35.1	52.7	16.4	30.9	
1.4363	1.4058	1.4762	1.4631	32.1	50.1	17.8	52.6	27.3	20.1	
1.4330	1.4031	1.4743	1.4584	33.8	47.4	18.8	52.9	24.1	23.0	
1.4099	1.3911	1.4396	1.4346	34.5	15.7	49.8	53.0	7.3	39.7	
1.4205	1.3975	1.4563	1.4422	34.7	31.6	33.7	54.5	12.8	32.7	
1.4271	1.4004	1.4669	1.4532	34.8	40.6	24.6	53.3	20.7	26.0	
1.4291	1.4021	1.4701	1.4566	34.8	43.3	21.9	53.1	22.9	24.0	
1.4176	1.3957	1.4521	1.4445	35.0	27.8	37.2	58.5	13.1	28.4	35.6
1.4361	1.4079	1.4833	1.4727	35.9	52.5	11.6	54.5	31.6	13.9	
1.4306	1.4017	1.4753	1.4583	36.3	46.3	17.4	54.3	23.4	22.3	
1.4417	1.4107	1.4937	1.4878	36.7	58.8	4.5	57.5	36.9	5.6	
1.4077	1.3888	1.4396	1.4346	37.1	15.1	47.8	56.0	6.9	37.1	
1.4188	1.3952	1.4581	1.4417	37.5	31.8	30.7	52.8	12.9	34.3	

TABLE VIII (Contd.)

n_D^{20}		n_D^{20}		Weight Per Cent Composition						Wt. % Acetone Plotted
Ternary System		Hydrocarbons		Liquid			Vapor			
Liquid	Vapor	Liquid	Vapor	Acetone	Benzene	Cyclohexane	Acetone	Benzene	Cyclohexane	
1.4362	1.4066	1.4901	1.4798	39.1	54.4	6.5	53.3	32.5	9.2	
1.4136	1.3935	1.4539	1.4437	40.0	27.1	32.9	55.9	13.4	30.7	40.3
1.4151	1.3937	1.4576	1.4442	40.3	29.8	29.4	55.9	13.7	30.4	
1.4255	1.3996	1.4765	1.4614	41.5	43.6	15.1	57.9	23.3	18.8	
1.4240	1.3995	1.4781	1.4636	43.2	43.2	13.6	58.7	24.0	17.3	
1.4271	1.4008	1.4342	1.4704	43.4	46.9	9.7	60.0	26.6	13.4	
1.4189	1.3943	1.4698	1.4552	43.8	37.1	19.1	60.0	18.8	21.2	44.3
1.4054	1.3873	1.4470	1.4331	44.2	19.7	36.1	59.5	8.7	31.8	
1.4153	1.3939	1.4672	1.4507	45.5	34.2	20.3	58.8	16.8	24.4	
1.4010	1.3864	1.4409	1.4346	45.5	14.2	40.3	59.0	6.4	34.6	
1.4151	1.3943	1.4705	1.4532	47.3	35.3	17.4	59.7	17.8	22.5	
1.4076	1.3898	1.4563	1.4455	47.7	25.3	27.0	61.1	12.9	26.0	
1.3967	1.3846	1.4393	1.4343	49.4	11.8	38.8	61.1	5.8	33.1	49.1
1.4246	1.3986	1.4943	1.4890	49.4	47.7	2.9	67.4	23.7	3.9	
1.4034	1.3884	1.4523	1.4429	49.6	31.7	28.7	61.3	11.3	27.4	
1.3952	1.3841	1.4399	1.4338	51.4	11.8	36.8	61.7	5.4	32.9	
1.4101	1.3904	1.4759	1.4576	53.8	33.9	12.3	65.5	17.4	17.1	
1.4043	1.3886	1.4683	1.4520	54.1	29.4	16.5	65.0	14.9	20.1	
1.3931	1.3832	1.4417	1.4331	55.0	12.2	32.8	62.2	4.9	32.9	54.7
1.3920	1.3826	1.4405	1.4338	55.7	11.3	33.0	63.5	5.2	31.3	
1.3943	1.3838	1.4542	1.4410	60.0	18.3	21.7	66.0	8.9	25.1	
1.4009	1.3855	1.4750	1.4543	61.6	27.8	10.6	69.6	14.1	16.3	60.8
1.3844	1.3796	1.4377	1.4332	63.5	7.7	28.8	67.2	4.3	28.5	
1.3847	1.3792	1.4396	1.4322	64.1	8.5	27.4	67.3	3.7	29.0	64.1
1.3901	1.3812	1.4552	1.4420	64.8	16.5	18.7	69.5	8.5	22.0	

TABLE VIII (Contd.)

n_D^{20}		n_D^{20}		Weight Per Cent Composition						Wt. % Acetone Plotted
Ternary System		Hydrocarbons		Liquid			Vapor			
Liquid	Vapor	Liquid	Vapor	Acetone	Benzene	Cyclohexane	Acetone	Benzene	Cyclohexane	
1.3935	1.3812	1.4795	1.4593	68.3	24.6	7.1	75.3	12.9	11.8	
1.3970	1.3832	1.4782	1.4588	68.8	23.7	7.5	73.2	13.9	12.9	
1.3822	1.3779	1.4452	1.4347	69.7	9.9	20.4	70.5	4.7	24.8	69.3
1.3798	1.3768	1.4402	1.4324	70.3	7.4	22.3	70.6	3.4	26.0	
1.3890	1.3787	1.4816	1.4621	73.6	21.1	5.3	78.7	12.0	9.3	
1.3769	1.3750	1.4421	1.4324	75.0	7.0	18.0	73.2	3.1	23.7	74.3
1.3749	1.3736	1.4402	1.4332	77.0	5.8	17.2	75.9	3.1	21.0	
1.3826	1.3747	1.4802	1.4599	78.7	16.7	4.6	82.3	9.2	8.5	77.9
1.3728	1.3719	1.4433	1.4336	80.5	5.8	13.7	78.7	3.0	18.3	
1.3731	1.3716	1.4443	1.4352	80.6	6.2	13.2	79.6	3.4	17.0	80.6
1.3782	1.3717	1.4830	1.4615	82.8	14.0	3.2	85.8	7.9	6.3	
1.3707	1.3694	1.4463	1.4355	84.2	5.4	10.4	82.9	3.0	14.1	83.5
1.3680	1.3673	1.4456	1.4360	87.5	4.2	8.3	86.2	2.5	11.3	
1.3717	1.3676	1.4832	1.4622	88.5	9.4	2.1	90.4	5.4	4.2	88.0
1.3644	1.3639	1.4467	1.4343	92.4	2.6	5.0	91.0	1.4	7.6	92.4

(close up)

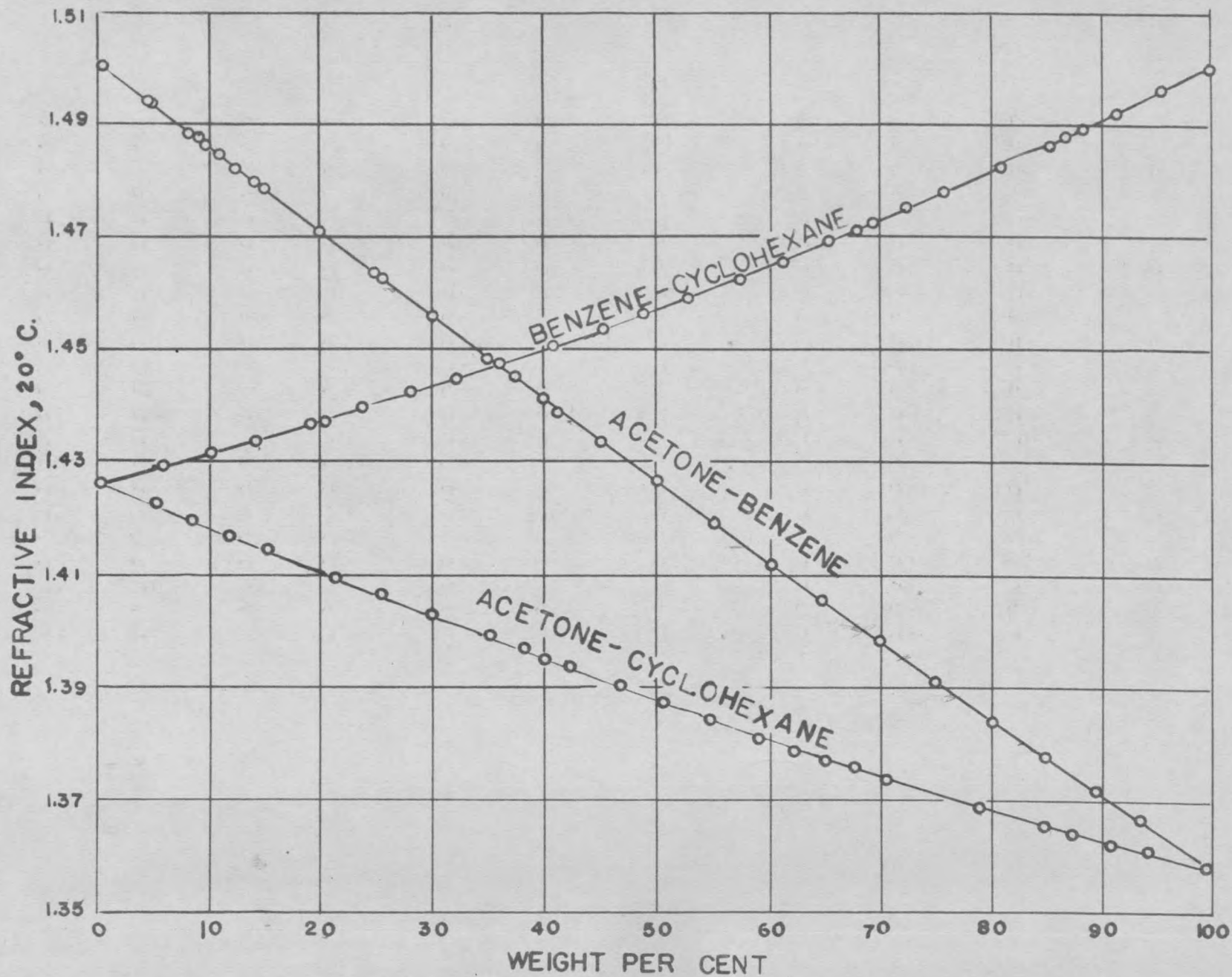


Figure 1. Refractive Index at 20°C. in the Binary Systems.

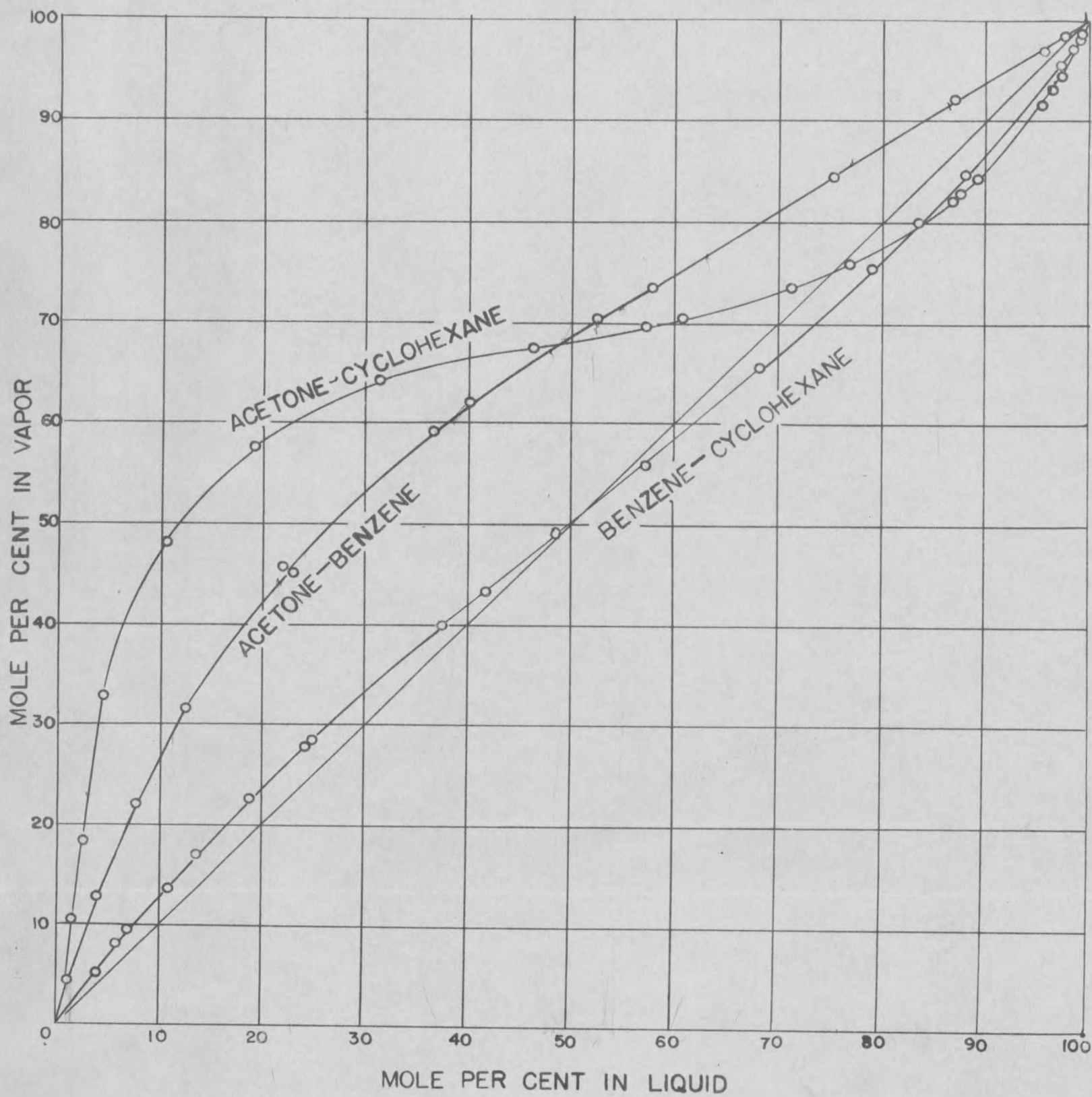


Figure 2. Vapor-Liquid Equilibrium Diagrams of the Binary Systems.

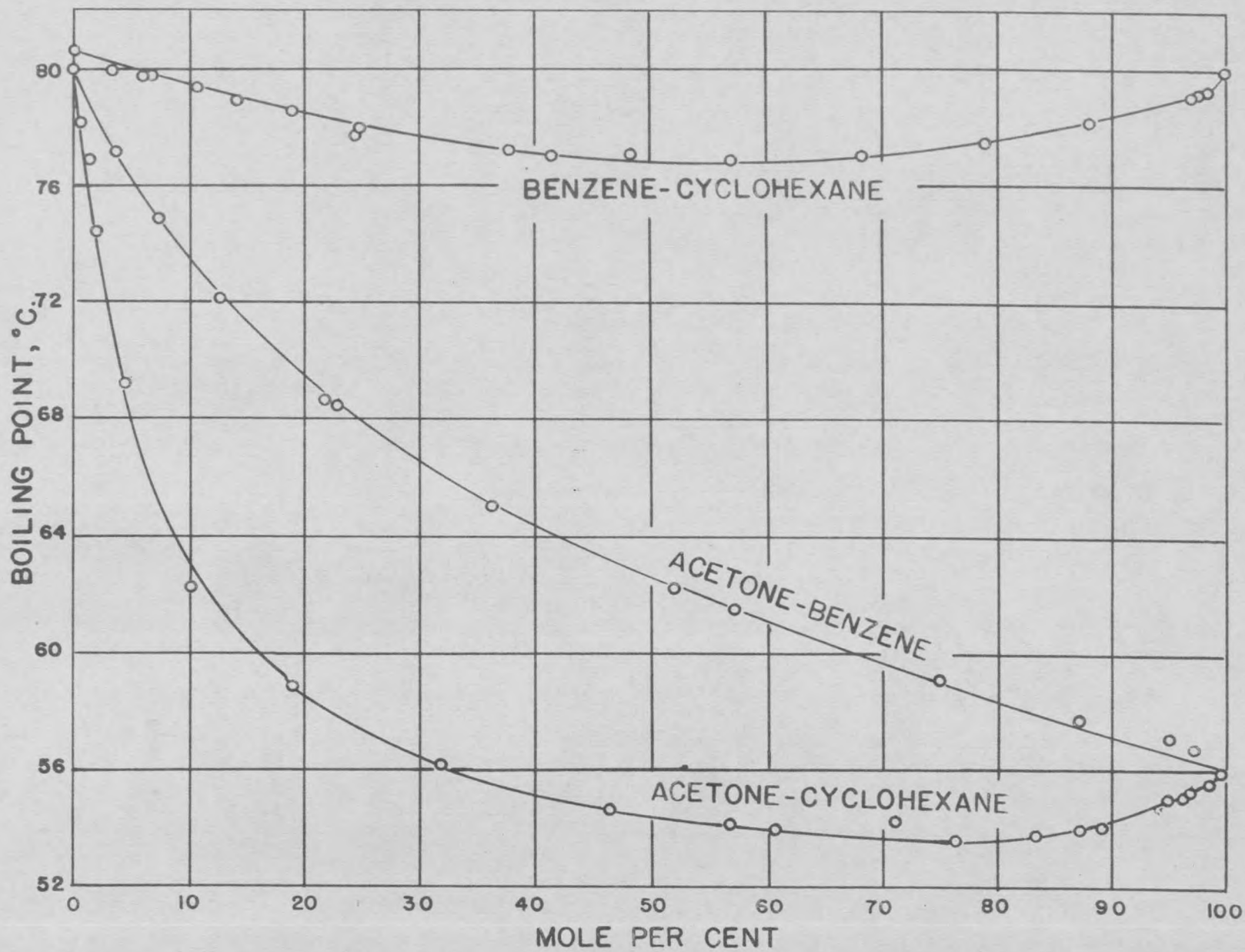


Figure 3. Boiling Points in the Binary Systems.

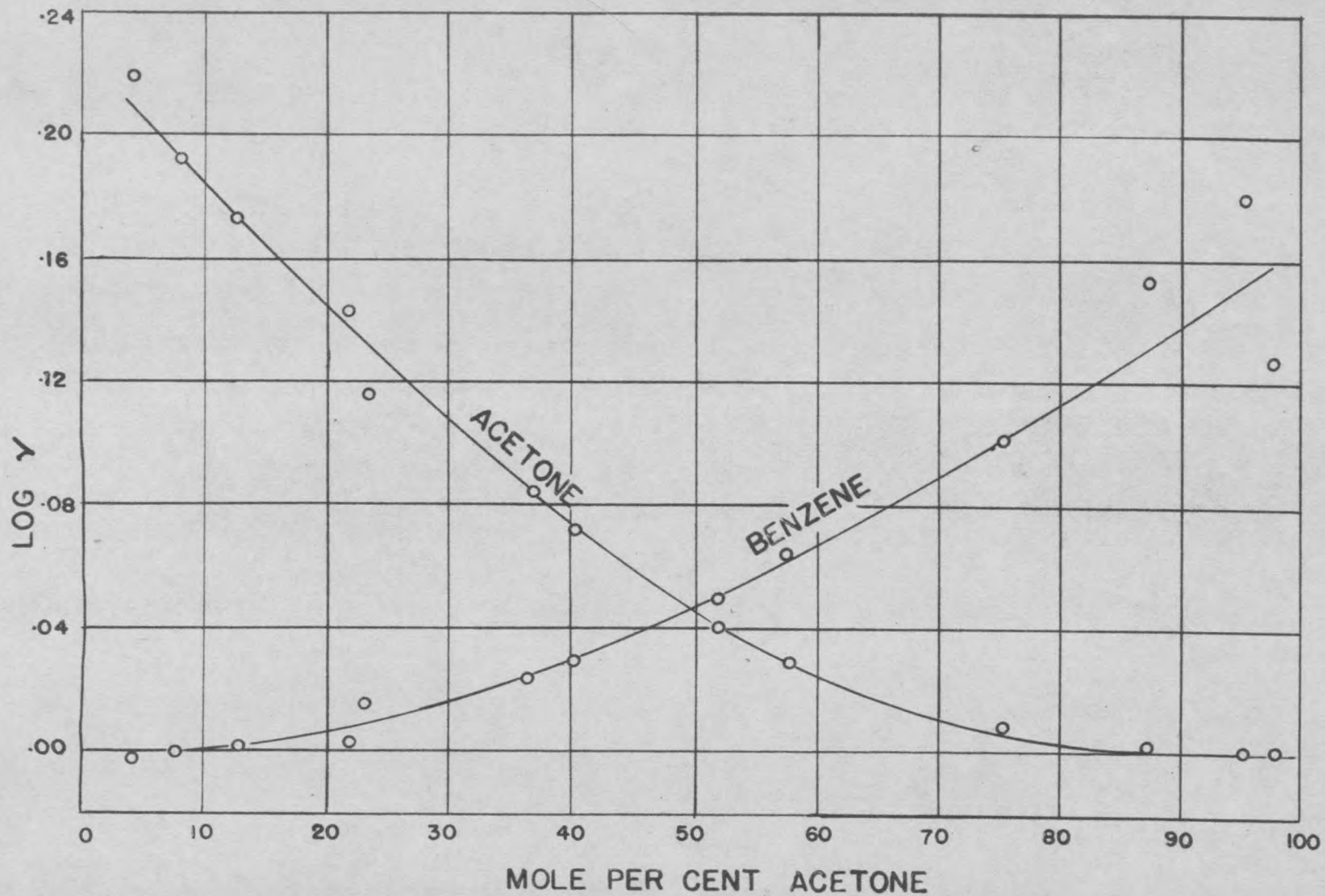


Figure 4. Activity Coefficients in the Acetone-Benzene System.

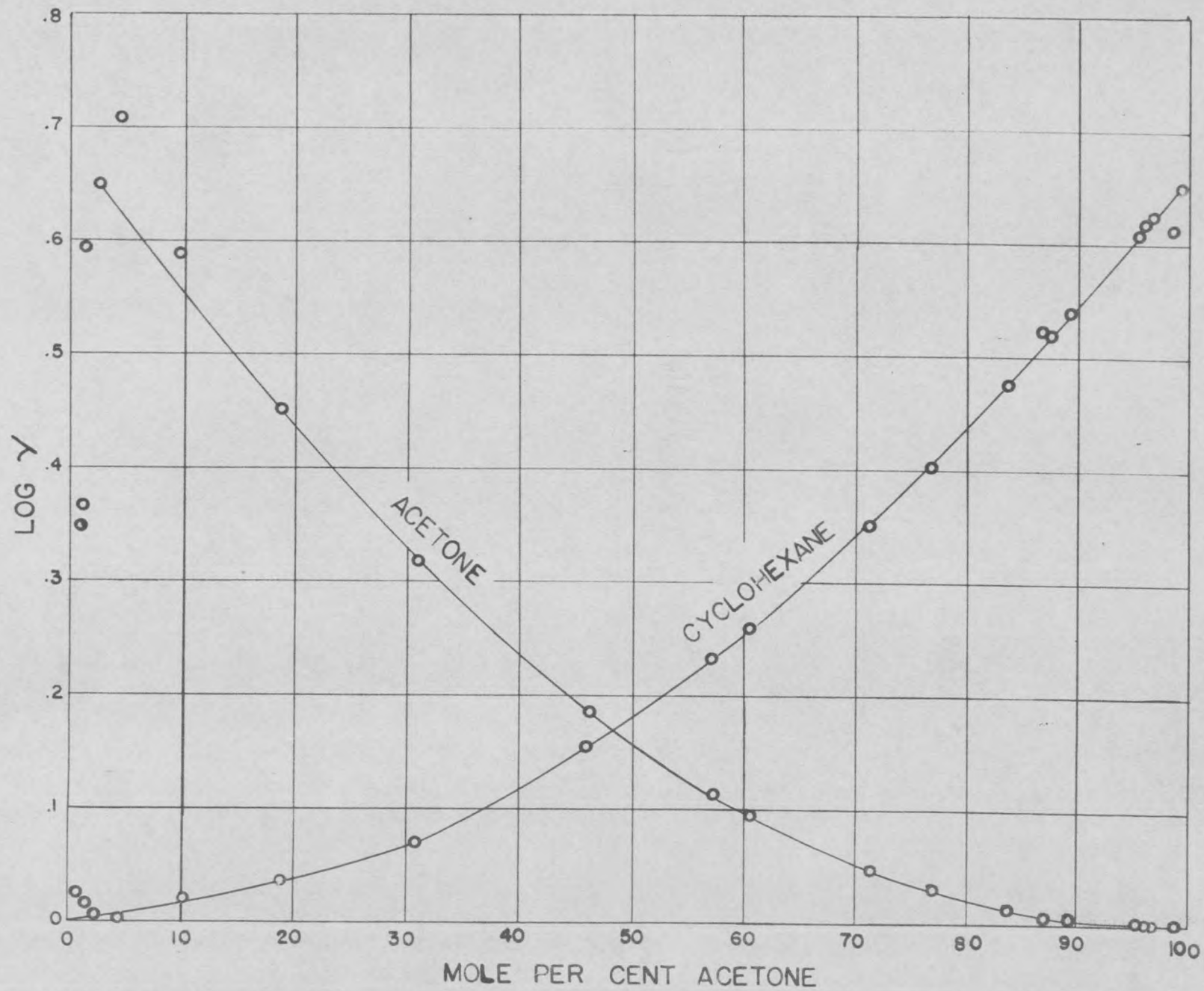


Figure 5. Activity Coefficients in the Acetone-Cyclohexane System.

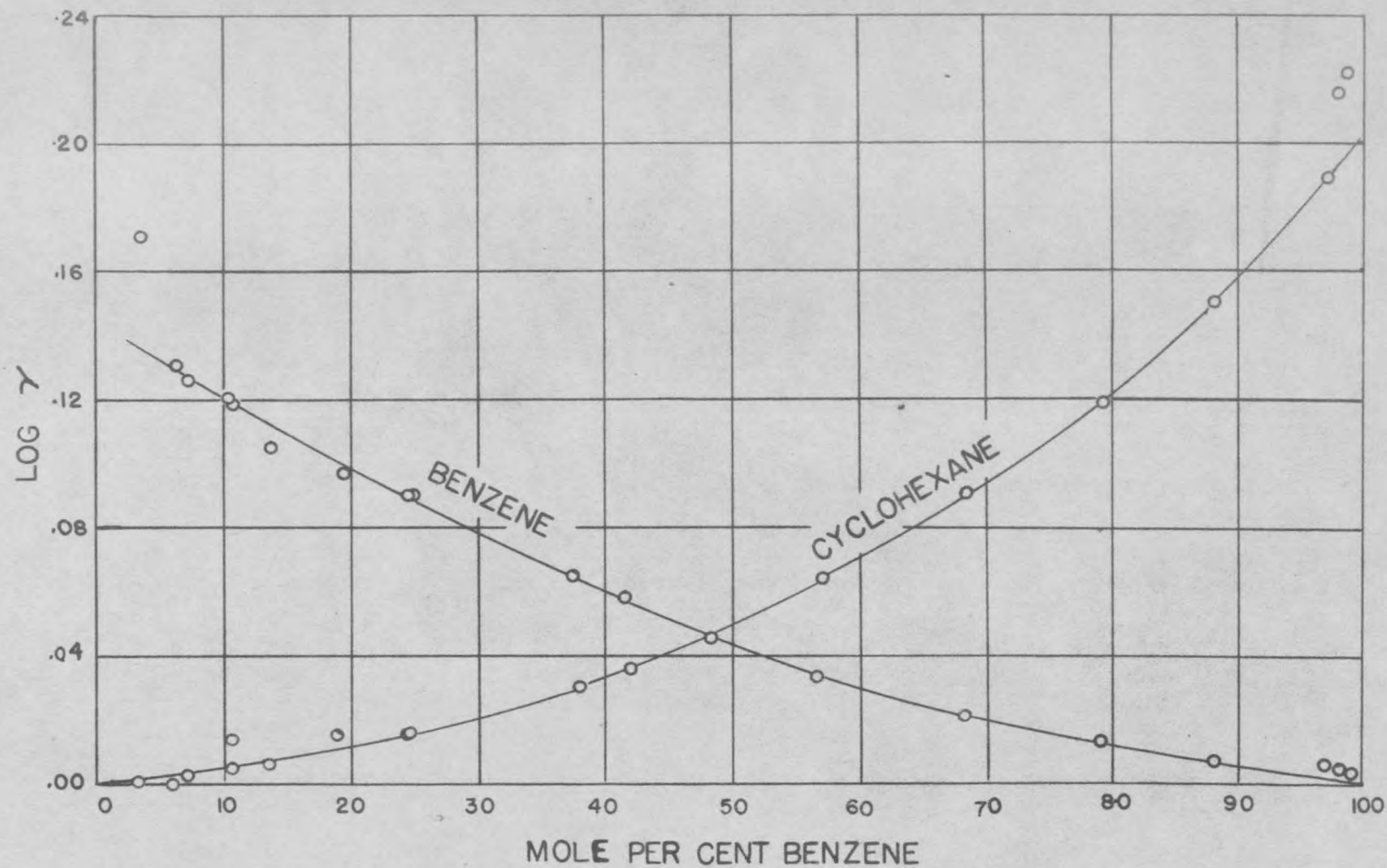


Figure 6. Activity Coefficients in the Benzene-Cyclohexane System.

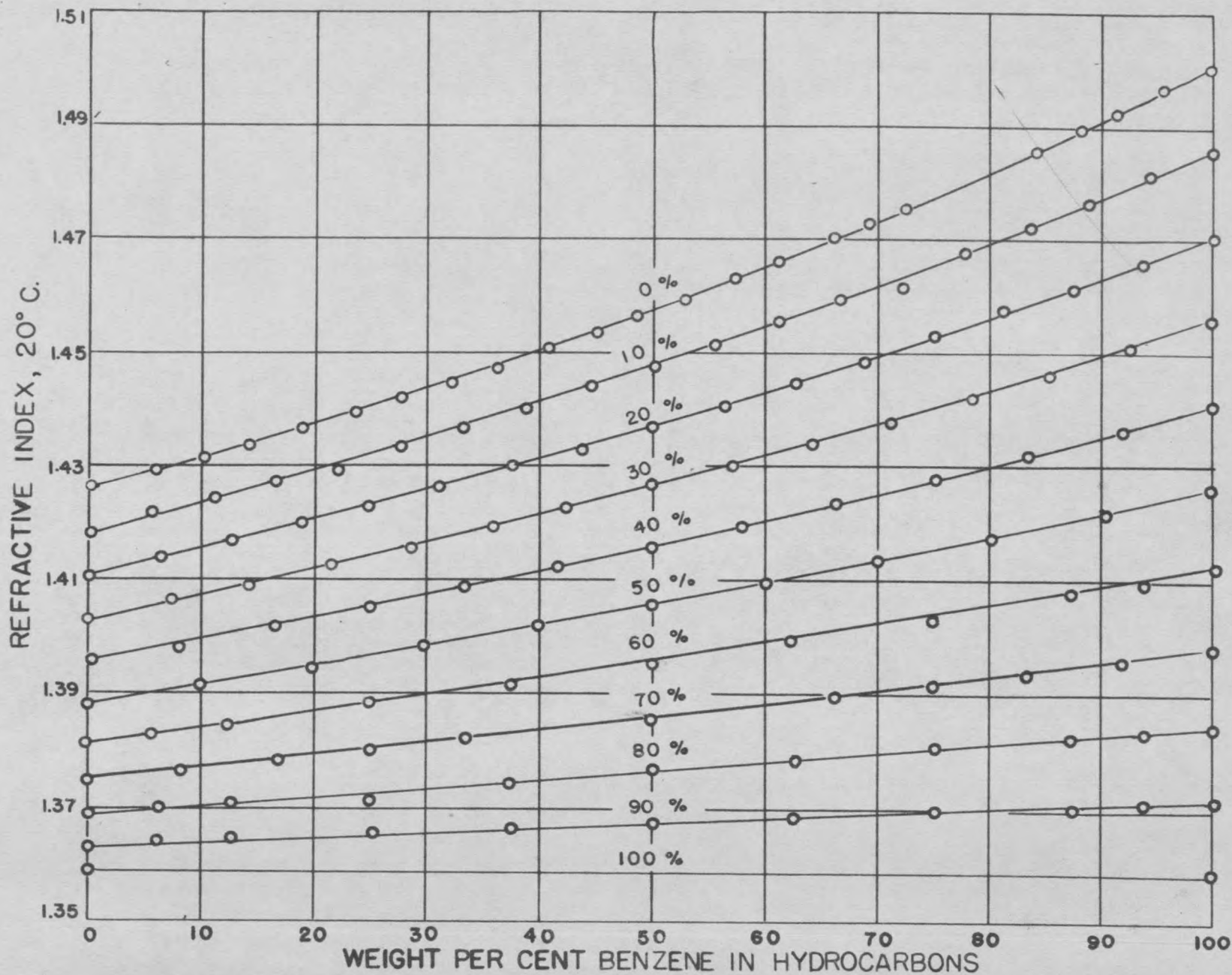


Figure 7. Refractive Index at 20°C. in the Ternary System Acetone-Benzene-Cyclohexane at Constant Weight Per Cent Acetone.

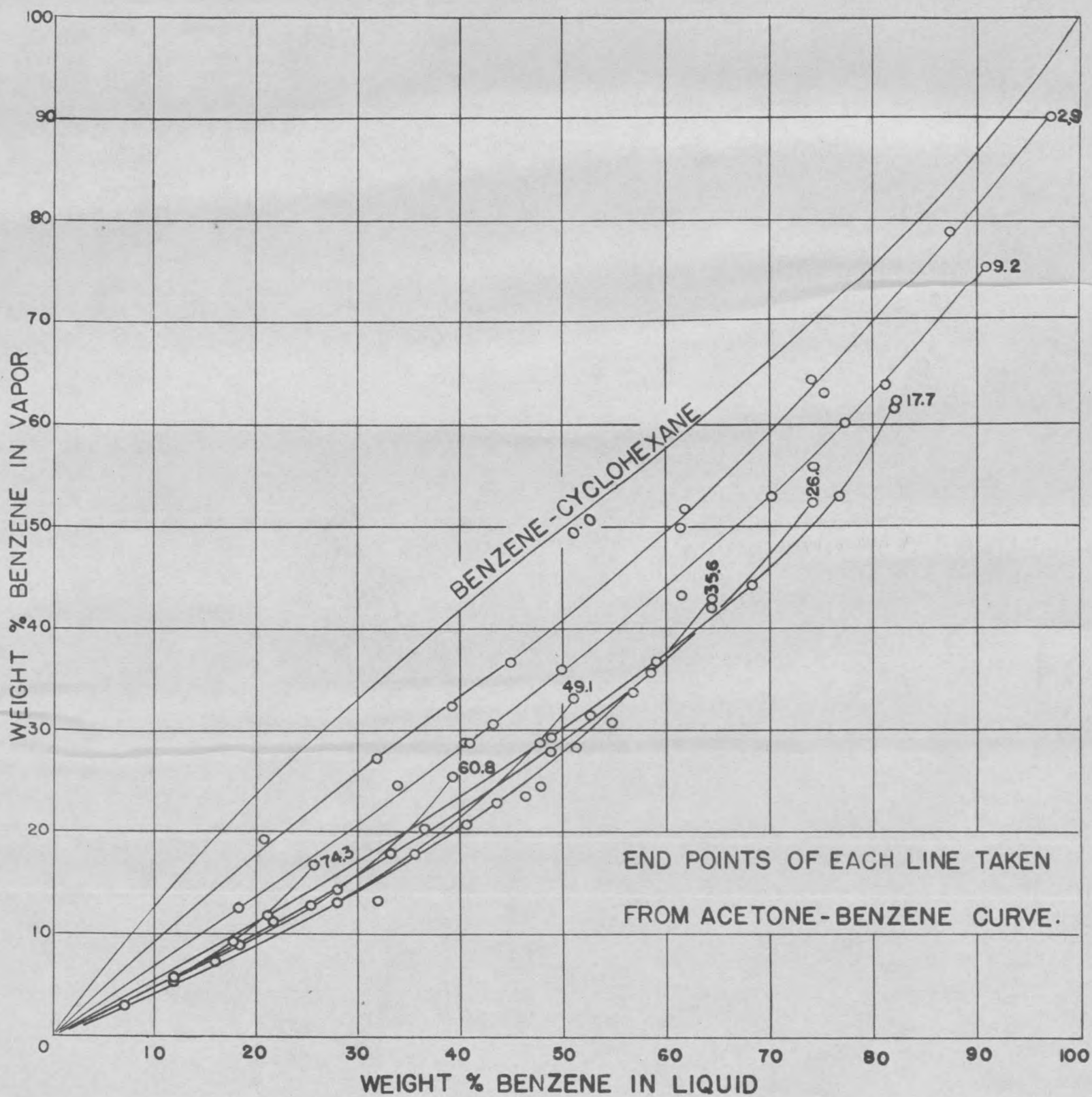


Figure 8. Benzene Equilibria in the Ternary System Acetone-Benzene-Cyclohexane at Constant Weight Per Cent Acetone in the Liquid.

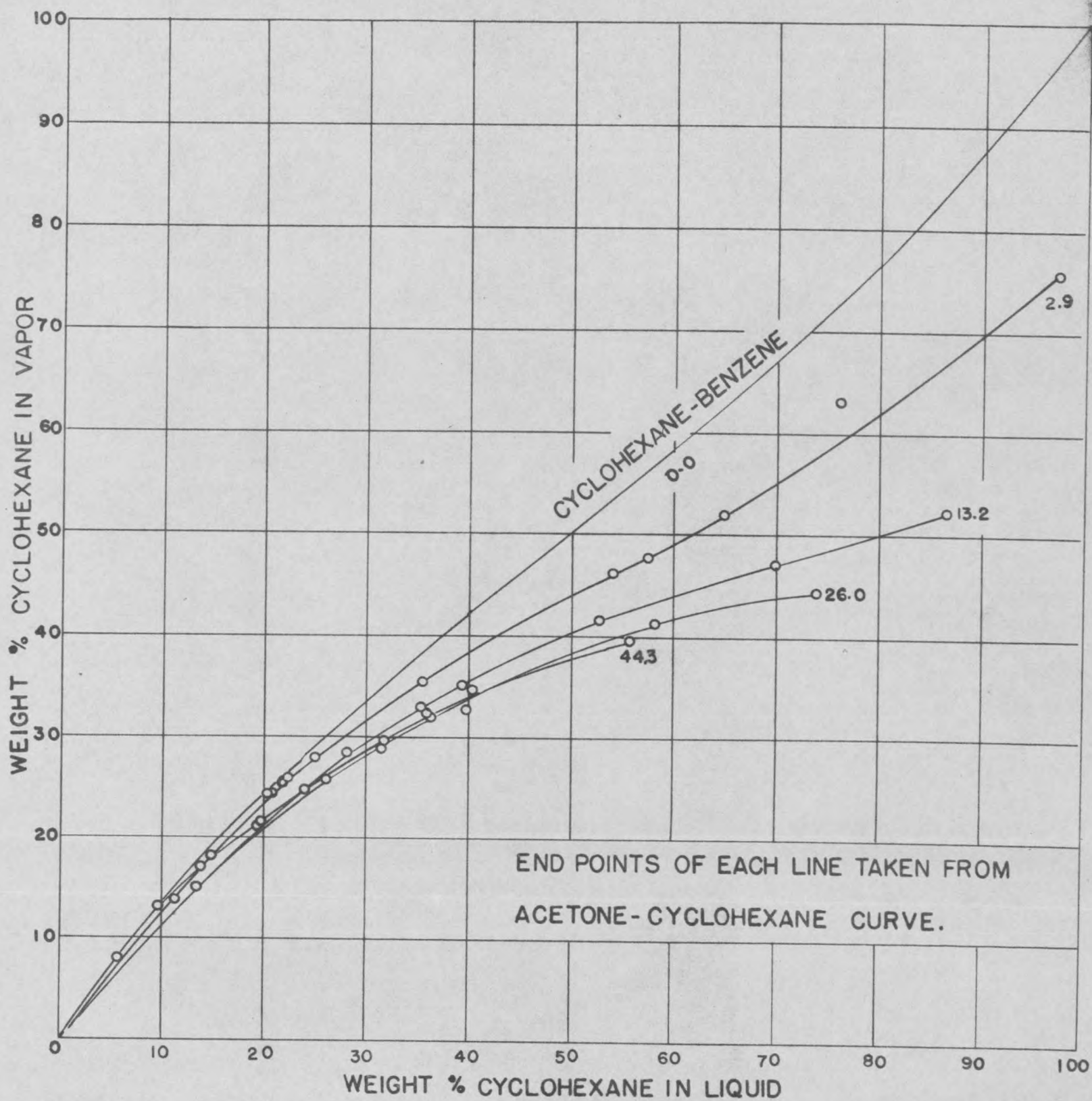


Figure 9. Cyclohexane Equilibria in the Ternary System Acetone-Benzene-Cyclohexane at Constant Weight Per Cent Acetone in the Liquid.

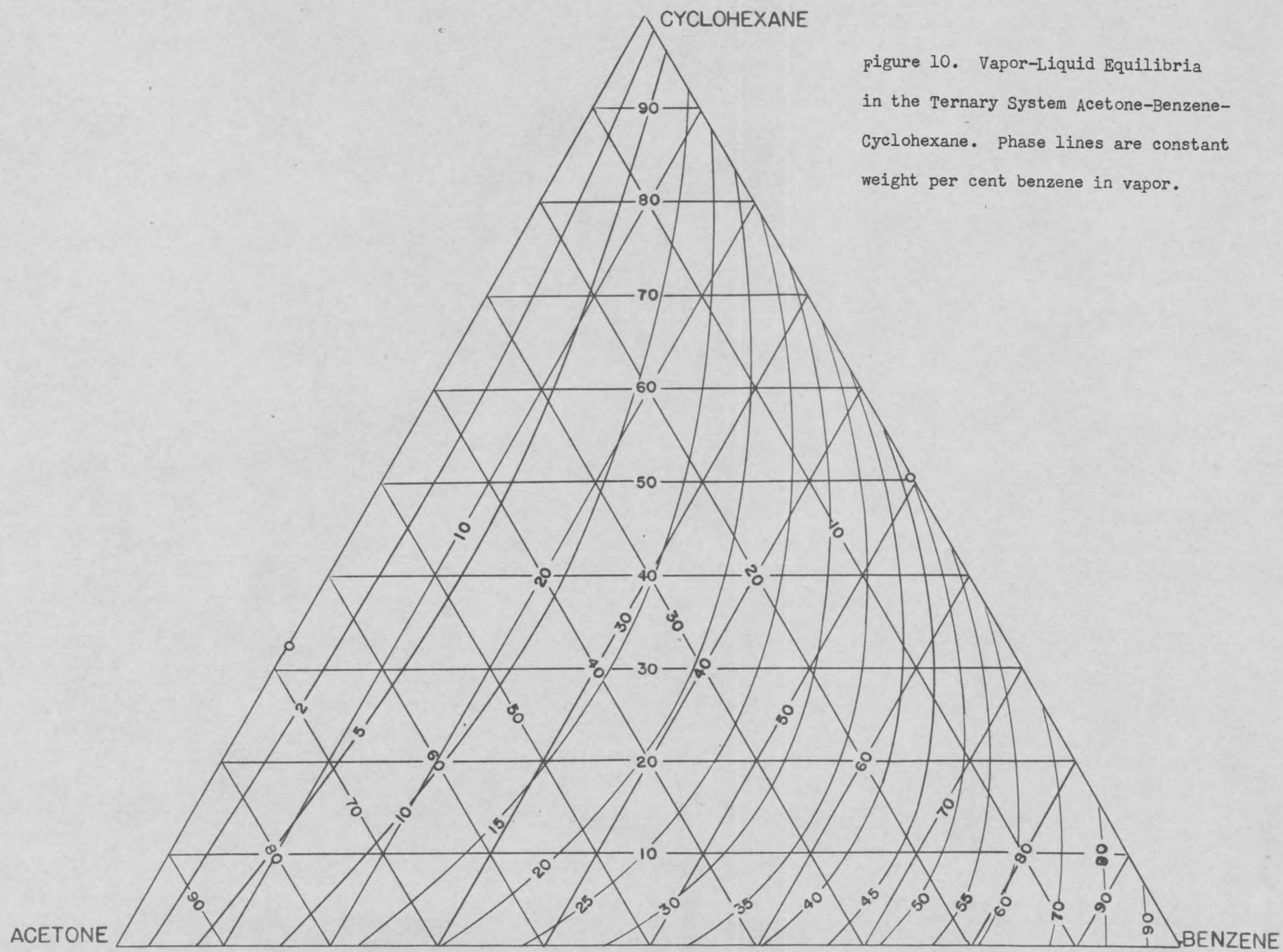
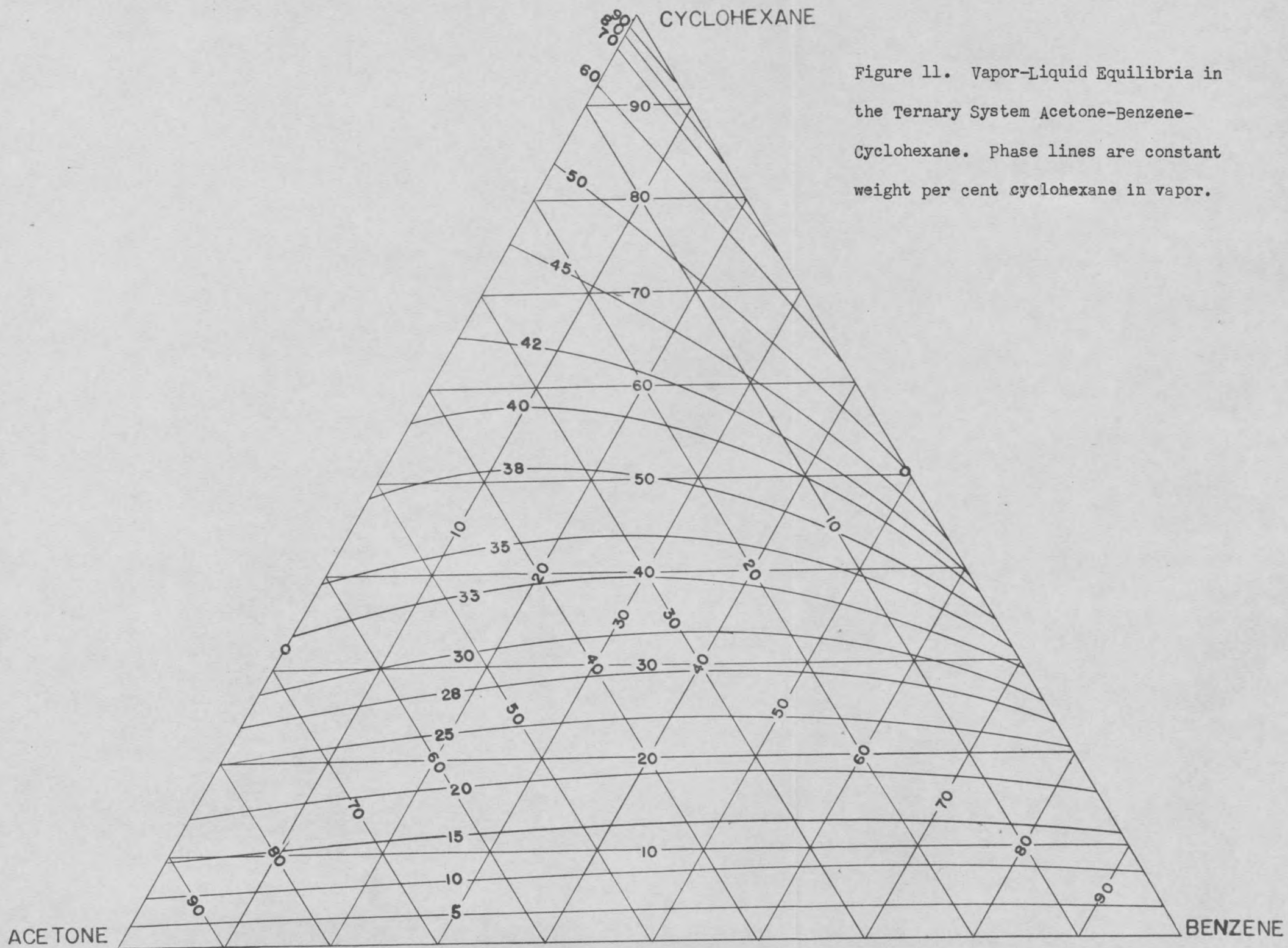


figure 10. Vapor-Liquid Equilibria
in the Ternary System Acetone-Benzene-
Cyclohexane. Phase lines are constant
weight per cent benzene in vapor.



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