Boiling and Condensing Points of Alcohol Water Mixtures.

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The boiling points of mixtures of alcohol and water depend on the proportions of the constituents and range from about 70° C. for pure ethyl alcohol to 100° C. for pure water. Except at a concentration of about 92 per cent. alcohol by weight (about 96 per cent. by volume) any mixture of alcohol and water when boiled gives off a vapor of different composition from the liquid, the vapor being richer or poorer in alcohol than the liquid when the latter contains respectively less or more than 92 per cent. of alcohol. The vapor has, of course, a condensing point identical with the true boiling point of the liquid from which it is given off.

The purpose of the work here reported was to ascertain experimentally the relation between the boiling point (or condensing point) and the composition of both the liquid and vapor phases, so that with the information so obtained it would be possible by observation of the corrected boiling point to learn the composition of the boiling liquid and of the condensing vapor.

PROCEDURE.

The gravity and temperature of a strong alcohol were determined with a Westphal balance, and the weight-per cent. of alcohol calculated by means of Mendelejeff's table. Five hundred cubic centimeters were placed in a one-liter distilling flask with an accurate thermometer graduated in tenths of a degree placed with its bulb just below the side-neck. The liquid was then slowly distilled at a uniform rate of about one drop per second until 15 c. c. had passed over, the distilling temperature being read when 7.5 c. c. had collected in the graduated receiver. The per cent. of alcohol in the distillate and in the residue was determined from the gravity as before.

The average of the percentages found in the liquid in the flask before and after distillation was taken as that of the liquid phase, and the percentage in the distillate as representing the vapor phase at a moment half-way through the distillation when the boiling point was observed.

The original volume of the liquid in the flask was restored by the addition of 15 c. c. of water, and the slightly more dilute mixture so obtained was used for the next experiment. Forty-three mixtures were investigated in this way, ranging from 91 to 0 per cent. of alcohol.

Corrections were introduced in the temperature readings for the barometric pressure and for the exposed column of mercury in the thermometer, assuming that the barometer effect would be the same as in the case of water —an assumption very nearly in accordance with the facts, as shown by the tables of Regnault and Classen given in Biedermann's Chemiker-Kalender.

RESULTS.

The temperature results are probably accurate within 0.2 degrees, and the concentrations within 2 per cent.

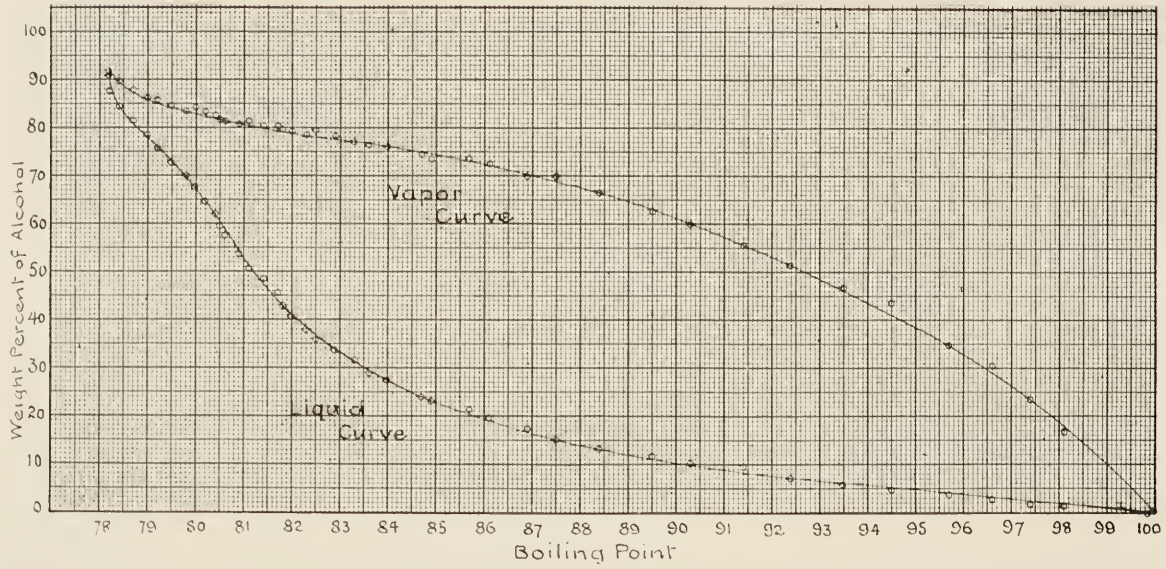
The results obtained are given in the following table:

Number.	Gravity before distillation.	Temperature during gravity determination.	Per cent. alcohol before distillation.	Gravity of residue.	Temperature during gravity determination.	Per cent. alcohol in residue.	Average per cent. alcohol in liquid.	Gravity of distillate.	Temperature during gravity determination.	Per cent. alcohol in distillate.	Observed temperature of distillation.	Barometer.	Barometer correction in boiling point.	Room temperature.	Correction for exposed mercury column.	Corrected boiling point.
1	.815	20	91.1	.812	23	91.1	91.1	.811	22	91.8	77.2	750	.4	23	.6	78.2
2	.822	22	87.7	.821	23	87.7	87.7	.815	23	90.0	77.2	750	.4	22	.6	78.2
3	.829	23	84.6	.829	23	84.6	84.6	.819	22	89.6	77.4	750	.4	22	.6	78.4
4	.836	24	81.5	.838	22	81.5	81.5	.823	22	88.0	77.6	748	.5	22	.6	78.7
5	.845	22	78.7	.843	25	78.8	78.8	.825	22	86.5	77.7	743	.7	22	.6	79.0
6	.852	22	75.8	.851	23	75.8	75.8	.827	22	85.8	77.8	740	.8	22	.6	79.2
7	.857	24	72.9	.860	21	72.9	72.9	.829	23	84.6	78.1	741	.8	22	.6	79.5
8	.864	23	70.4	.866	23	69.6	70.0	.832	22	83.8	78.4	741	.8	23	.6	79.8
9	.873	21	67.5	.873	21	67.5	67.5	.833	20	84.2	78.6	743	.7	21	.6	79.9
10	.879	21	65.0	.880	21	64.6	64.8	.835	20	83.5	78.9	743	.7	21	.6	80.2
11	.884	21	62.7	.885	23	61.4	62.0	.838	19	82.7	79.1	743	.7	21	.6	80.4
12	.891	22	59.2	.893	20	59.2	59.2	.839	20	81.9	79.5	750	.4	21	.6	80.5
13	.898	20	57.1	.899	21	57.5	57.3	.839	21	81.5	79.6	750	.4	21	.6	80.6
14	.904	21	54.1	.904	23	53.2	53.6	.839	23	80.8	80.2	757	.1	23	.6	80.9
15	.908	23	51.4	.910	22	51.0	51.2	.840	21	81.2	80.3	756	.2	22	.6	81.1
16	.915	22	48.6	.916	22	48.2	48.4	.842	21	80.4	80.5	756	.2	22	.6	81.4
17	.920	22	46.4	.923	22	45.0	45.7	.843	20	80.4	80.8	756	.2	22	.6	81.7
18	.926	23	43.8	.928	22	42.5	43.1	.844	21	79.6	81.0	756	.2	22	.6	81.8

Number.	Gravity before distillation.	Temperature during gravity determination.	Per cent. alcohol before distillation.	Gravity of residue.	Temperature during gravity determination.	Per cent. alcohol in residue.	Average per cent. alcohol in liquid.	Gravity of distillate.	Temperature during gravity determination.	Per cent. alcohol in distillate.	Observed temperature of distillation.	Barometer.	Barometer correction in boiling point.	Room temperature.	Correction for exposed mercury column.	Corrected boiling point.
19	.923	22	40.5	.932	25	40.0	40.2	.845	20	79.6	81.2	755	.2	19	.6	82.0
20	.936	24	38.0	.938	23	37.5	37.7	.848	19	78.8	81.5	755	.2	20	.6	82.3
21	.940	24	36.0	.942	23	35.5	35.7	.846	20	79.2	81.6	755	.2	20	.7	82.5
22	.945	23	33.9	.947	22	33.3	33.6	.849	19	78.3	82.0	755	.2	20	.7	82.9
23	.949	23	31.7	.950	23	31.1	31.4	.851	20	77.1	82.4	755	.2	21	.7	83.3
24	.952	24	30.0	.955	23	28.1	29.0	.853	20	76.2	82.7	756	.2	21	.7	83.6
25	.956	23	27.5	.956	25	26.9	27.2	.853	21	75.8	82.5	748	.5	20	.7	84.0
26	.958	24	26.2	.961	22	24.7	25.4	.856	22	74.2	83.4	748	.5	22	.8	84.7
27	.962	23	23.7	.964	23	22.3	23.0	.858	19	73.7	83.7	750	.4	21	.8	84.9
28	.965	23	21.7	.966	23	21.0	21.3	.859	20	73.7	84.3	750	.4	21	.8	85.7
29	.966	23	21.0	.969	23	18.9	19.9	.860	22	72.5	84.8	747	.5	22	.8	86.1
30	.970	23	17.9	.972	22	16.7	17.3	.866	22	70.0	85.5	745	.6	23	.8	86.9
31	.973	22	15.8	.974	24	14.4	15.1	.865	23	70.0	86.2	747	.5	23	.8	87.5
32	.975	24	13.3	.977	25	12.3	12.8	.873	23	66.7	86.9	756	.6	24	.9	88.4
33	.977	25	12.3	.979	25	11.0	11 6	.882	24	62.5	88.1	748	.5	25	.9	89.5
34	.980	22	11.0	.982	23	9.3	10 1	.891	21	60.0	89 1	750	4	22	.9	90.3
35	.982	23	11.0	.984	24	7.9	9.4	.901	20	55.8	90 1	750	.4	22	.9	91 4
36	.985	22	7.9	.987	22	6 4	7.1	.910	22	51.4	91 1	750	.4	22	.9	92.4
37	.987	22	6.4	.989	20	5.0	5.7	.919	22	46.8	92.2	750	.4	23	.9	93.5
38	.990	21	4.4	.991	23	3.9	4.1	.927	22	43.7	93.1	747	.5	21	.9	94.5
39	.991	23	3.9	.992	24	2.8	3.3	.947	21	33.5	94.3	747	.5	22	.9	95.7
40	.992	24	2.8	.994	22	2.2	2.5	.953	21	30.6	95.2	747	.5	22	.9	96.6
41	.995	22	1 7	.996	21	1.1	1.4	.964	21	23.6	96.0	747	.5	22	.9	97.4
42	.996	22	1.1	.996	23	0.9	1.0	.972	22	16.7	96.8	751	.4	22	.9	98.1
43	.998	25	−0.5	.999	22	−0.3	−0.4	.999	21	−0.1	98.7	753	.3	22	.9	99.9

The last experiment (No. 43) was with water only.

The relations existing between the boiling point or condensing point and the composition of the liquid and vapor phases are shown clearly by the following plot:


Weight Percent of Alcohol
100
90
80
70
60
50
40
30
20
10
0
Vapor
Curve
Liquid
Curve
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
Boiling Point

A convenient table of results estimated from the curves is here given:

Boiling Point.	Weight Per Cent. Alcohol in		Boiling Point.	Weight Per Cent. Alcohol in	
	Liquid.	Vapor.		Liquid.	Vapor.
78.2	91	92	86.5	18	71
78.4	85	89	87.0	17	70
78.6	82	88	87.5	16	69
78.8	80	87	88.0	15	68
79.0	78	86	88.5	13	67
79.2	76	85	89.0	12	65
79.4	74	85	89.5	11	63
79.6	72	84	90.0	10	61
79.8	69	84	90.5	10	59
80.0	67	83	91.0	9	57
80.2	64	83	91.5	8	55
80.4	62	82	92.0	8	53
80.6	59	82	92.5	7	51
80.8	56	81	93.0	6	49
81.0	53	81	93.5	6	46
81.2	50	80	94.0	5	44
81.4	47	80	94.5	5	42
81.6	45	80	95.0	4	39
81.8	43	79	95.5	4	36
82.0	41	79	96.0	3	33
82.5	36	78	96.5	3	30
83.0	33	78	97.0	2	27
83.5	30	77	97.5	2	23
84.0	27	76	98.0	1	19
84.5	25	75	98.5	1	15
85.0	23	74	99.0	0	10
85.5	21	73	99.5	0	5
86.0	20	72	100.0	0	0

The information here given enables one to determine quickly the approximate concentration of any alcohol-water mixture by observation of its boiling point, with corrections for barometric pressure and exposed mercury column. The accuracy is, of course, less than by the usual and more difficult analytical method of distillation and the determination of the gravity of the distillate with a pyknometer.

It is also possible to tell the approximate composition of both liquid and vapor (or distillate) at any moment during the distillation of a mixture. This application has proved interesting in interpreting the behavior of alcohol-water mixtures during distillation and partial condensation in the writer's laboratory classes.

It is the intention to continue the experiments by examining mixtures containing over 92 per cent. of alcohol; the observations will require greater accuracy, and a differential thermometer graduated in hundredths of a degree will be employed.

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