

13047
49

*

OO

NUCLEATION OF PURE AND MIXED VAPORS
IN DUST - FREE AIR.

- * * _ * * _ * * -
_ * * _ * * _ * * -

" THESIS SUBMITTED TO THE FACULTY OF THE GRADUATE
SCHOOL OF THE UNIVERSITY OF MINNESOTA

B Y

EDWARD X. ANDERSON

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE, JUNE 19TH, 1909".

- * * _ * * _ * * _ * * -
_ * * _ * * _ * * _ * * -

OO

UNIVERSITY OF
MINNESOTA
LIBRARY

MON
Am 2

- INTRODUCTION -

It is generally known to be a well established fact that dust-free air saturated with water vapor, when adiabatically expanded beyond certain λ value, gives a precipitation of the excess vapor in the form of rain, the drops forming around the natural nuclei present in the air. This phenomenon was first observed and carefully studied by C. T. R. Wilson.*

The results Wilson obtained are recorded in the following table where V_2/V_1 is the ratio of the initial to the final pressure in the expansion apparatus:-

G A S.	Rain-like condensation.		Cloud-like condensation.	
	Expansion V_2/V_1	Supersaturation.	Expansion V_2/V_1	Supersaturation.
Air	1.252	4.2	1.38)	
Oxygen	1.257	4.3	1.383)	7.9
Nitrogen	1.262	4.4	1.38)	
Hydrogen	-----	---	1.38)	
Carbon dioxid	1.365	4.2	1.535	7.3
Chlorin	1.3	3.4	1.45	(5.9)

* Phil. Trans., A, 189, P. 265 (1897)

UNIVERSITY OF
MINNESOTA
LIBRARY

86310

AUG 12 1910 6-70

It was concluded from the size and number of the nuclei producing the cloud-like condensation that they were small aggregates of water molecules.

Using a large apparatus, constructed of brass, Wilson* sometime later showed, in the absence of (artificial) external ionising rays and of an electric field, that rain-like condensation took place in air saturated with water vapor at an expansion of 1.247, while, with an electrical field, no drops were produced, even by an expansion of 1.27.

Hence, at expansions of 1.25, the natural ions must act as condensation nuclei. The number of natural nuclei present per cubic centimetre deduced from the number of drops is in accordance with the number obtained by other methods.

*'Phil. Mag.,' June 1904. P. 681.

It appears from Wilson's experiments that there are three kinds of nuclei concerned in condensation. Nuclei of the first kind are naturally present in dust-free air, oxygen, nitrogen, (hydrogen?), carbon dioxide and chlorine; they are increased in numbers by Röntgen and Becquerel rays, ultra-violet light acting on a negatively charged zinc plate, and they are electrically charged and produce condensation in water vapor when it is supersaturated at least 4.3 times; in other words, these nuclei are ions. Nuclei of the second type are unchanged and are probably aggregates of water molecules, as previously stated. Lastly, nuclei of the third kind are present near the surface of zinc, lead and amalgamated zinc plates, are unchanged and act as nuclei when the supersaturation is not less than 4.5.

Wilson* showed in 1899, using air and water vapor, that the negative ions are more efficient in producing condensation than the positive, for he found that expansions greater than 1.247 caught the negative ions,

* 'Phil. Mag.,' June 1904, P. 681.

while both the positive and negative were caught by expansions greater than 1.31. The latter figure cannot be as accurately determined as the former.

Donnan* obtained results as shown, with the following substances:-

Substance.	Rain-point expansion.	Fog-point.	Temperature of cloud chamber.
Water	1.29	1.42	20.5-20.8 c
Methyl alcohol	1.32	1.42	16.8
Ethyl alcohol	1.20	1.25	17.2 - 17.5
Carbon tetrachlorid	1.89	Not observed.	16.5
Carbon disulfid	1.05	1.08	16.5
Chlorobenzene	1.48	1.60	16.3
Benzene	1.53	1.78	18.---18.5

The above results tend to show that the vapors of non-ionizing solvents require a larger expansion to produce nucleation than do the ionizing solvents, which point Donnan emphasizes in his article.

* ' Phil. Mag.,' Vol. 3, 1902, P. 305.

K. Przibram* has worked along the same line of investigation, using organic vapors in ionized air. He used the general method of Wilson in his experiments, but used paraffin oil instead of mercury for the piston seal, which might vitiate results in the case of vapors soluble in the oil.

Przibram's results:-

	Ionized air. Rain-point.	Ionized air. Fog-point.
Methyl alcohol	1.251	1.304
Ethyl "	1.203	1.194
Propyl "	1.20	1.201
Iso-butyl	1.22	1.223
Chloroform	1.57	Not observed.

Laby, who worked on several organic acids and esters, obtained the following results, using air saturated with the vapor and ionized by Röntgen Rays.

* 'Sitzungsber. d. kais. Akad. d. Wissen. in Wien, ' Math. - naturw. Kl., Band 115 (1906).

* 'Phil. Trans., ' A, 208, P. 455.

VAPOR.	Expansion without X Rays.	Expansion using X Rays.
Ethyl acetate	1.528	1.486
Methyl butyrate	1.364	1.334
Methyl iso-butyrate	1.387	1.347
Propyl acetate	1.334	1.310
Ethyl propionate	1.438	1.410
Iso-amyl alcohol	1.210	1.182
Formic acid	1.865	1.782
Acetic "	1.508	1.441
Propionic acid	1.369	1.343
N-butyric "	1.463	1.380
Iso-but ^r ic "	1.256	1.220
Water	1.256	1.236

Laby concluded from his results that there is no relationship between the constitution of the above vapors and the corresponding expansion ratios. The expansion, with some exceptions, decreases with increase of molecular weight. However, if the supersatura-

tion be calculated, which exists in the vapor at the moment before condensation takes place, more regular relationships will be evident, as may be seen in the following:-

ESTERS.	Supersaturation.	Alcohols.	Supersaturation.
$\text{CH}_3\text{-COOC}_2\text{H}_5$	8.9	CH_3OH	3.12
$\text{C}_3\text{H}_7\text{COOCH}_3$	5.3	$\text{C}_2\text{H}_5\text{OH}$	2.56
$(\text{CH}_3)_2\text{CH-COOCH}_3$	5.2	$\text{C}_3\text{H}_7\text{OH}$	3.03
$\text{CH}_3\text{COOC}_3\text{H}_7$	5.1	$(\text{CH}_3)_2\text{CHCH}_2\text{OH}$	3.66
$\text{C}_2\text{H}_5\text{COOC}_2\text{H}_5$	7.8	HOH	4.2

ACIDS.	S.
H CO OH	25.1
$\text{CH}_3\text{CO OH}$	9.3
$\text{C}_2\text{H}_5\text{CO OH}$	9.4
$\text{C}_3\text{H}_7\text{CO OH}$	15.0
$(\text{CH}_3)_2\text{CH CO OH}$	13.3
$(\text{CH}_3)_2\text{CHCH}_2\text{CO OH}$	6.0

Upon examination of the above results, it will be seen that the presence of the carbonyl group is associated with a large value for S, and the presence of alkyl groups is associated with a relatively small supersaturation.

Up to this point, so far as can be determined from literature, ~~that~~ only pure vapors have been investigated. It, therefore seemed of interest to take up the investigation of binary mixtures.

Liquids used.

Water:-The water used was some which had been especially prepared for work in water analysis.

Ethyl alcohol. Kahlbaum's absolute alcohol was subjected to the following process of purification.

It was first treated with quick lime and reflux and, until the liquid assumed a yellowish color, then distilled, the first tenth was saved separately, the next two-fifths were collected and tested with kerosene for critical temperature of solution value (C.T.S.) (Andrews) 5 c.c. of each being used. This gave a

C. T. S. value of 7.0^oc. The next two-fifths gave a value of 6.5^occ. The last tenth was saved as alcohol residue.

The fraction (C. T. S. 6.5^oc) was treated with lime and refluxed for several hours and then distilled in 30-60 c.c. portions.

The C. T. S. value of each fraction was taken and recorded as follows:-

Fraction..	C. T. S.
1	8.0 ^o c
2	7.2
3	6.9
4	6.7
5	6.6
6	6.6
7	6.5
8 (last)	6.2

All these fractions were put with first two-fifths fraction (C. T. S. 7.0^o c) and refluxed over lime for eight hours and then distilled in about eight fractions.

The first C.T.S. value was 6.8c. The values of the subsequent fractions decreased to 6.4c which was the C.T.S. obtained for the lost portion. All the remaining fractions were combined and treated with 1-2 gms. of Na⁰ and refluxed for a half hour. Then distilled the first fraction gave a C.T.S. of 7.3c; the last gave 6.4c.

Thus, by the last process of purification with metallic Na⁰, the purity of alcohol was not increased, hence, it is safe to conclude that the alcohol was free from water.

Andrews obtained a C.T.S. value of 4.0c for 100% alcohol, but he evidently used a kerosene containing more of the lighter oils, a conclusion drawn from the following tests:-

100% Ethyl C.T.S. 6.4c (Kerosene) gave with Petroleum ether (B.P. 40⁰-50⁰) ac. T.S. value below 0⁰c.
Petroleum ether (B.P. 50⁰-66⁰) also gave a value below 0⁰c. Refractive index determined for the pure alcohol was 1.35940 \pm 5 at 25⁰c R. I.

given by Andrews* is 1.3594 08 ~~±~~.00001 at 25°c.

Methyl alcohol. Kahlbaum's absolute methyl was treated with quick lime, refluxed till liquid took on a yellowish tint and distilled.

The main distillate gave a C.T.S. value of 17.2c 2 c.c. of the alcohol and 2 c.c. of Petroleum ether were used. (B.P. 40.5-61.°) The second treatment was made with metallic sodium, refluxed for a short time, and distilled.

Fraction.	C.T.S.
1	9.3 c
2	9.9
3	9.6
4	9.6
5	9.6
Remainder	13.2

The last fraction was treated with Na^o refluxed and distilled.

First fraction gave C.T.S. 8.°5.

Second " " " " " 11.°9.

* J. Am. Chem. Soc. Mar.1908, p. 357.

The second portion was treated with Na° and distilled using a Glyuski fractionating column.

First 200 c.c. gave C.T.S. value of 7.7°c . Collected a small sample from the condenser and obtained a value of 7.7° . Stopped distillation, took B.P. of the 7.7 fraction, making all corrections and obtained 64.071°c for the B.P. at 760 mm. barometric pressure. B.P. of methyl alcohol, 64.070 (Young and Fortey).*

The following mixtures of alcohol and water were employed:-

Ethyl, alcohol and water, by weight, 60%, 40% and 20%, all of which were made up by weighing sufficiently close to warrant accuracy within the limits of observational error.

Methyl alcohol.

80%, 60%, 40% and 20%. Made up in same manner as the ethyl alcohol mixtures and with same accuracy.

* J. C. S. London. Trans. Vol. 81, p. 722, 1902.

Apparatus used and method of working.

R_2 is a mercury reservoir to level the mercury in the manometer by means of the stop-cocks, X and Y. The three way cock B being open to the air thru the tube T at the beginning of the investigation, X and you turned the mercury in the expansion chamber. E is then levelled up to the fine wire pointer R by means of the levelling Reservoir R_1 . The stop-cock D is then closed and the three way cock B is turned so that the cloud chamber K, containing the liquid to be experimented with. L, is open to the manometer and closed to the atmosphere. It is illuminated by a Welsbach burner with a concentrating lens attached, to give maximum illumination. The manipulator observes thru a lens of long focus at a slight angle to the incident rays. The work was carried on in a darkened room, thus insuring greatest accuracy in observing the small rain drops.

The mercury in the expansion chamber is now lowered to some such point as J, F closed and the eye set in the most convenient position to observe the clouds,

D is then turned with as great rapidity as feasible.

Repeated small expansions are made until no condensation takes place and then a steady increase in the expansion is made, the pressure being read on the manometer scale (checked up by a standard scale) immediately after each expansion. The expansion at which the faintest shower is observed is taken as the rain-point.

A Thermometer was placed in close proximity to the cloud chamber. The connection C was made with thick-walled tubing. The cloud chamber was fastened to the expansion chamber by means of rubber tubing. The two edges were ground to insure a close connection, thus exposing a minimum amount of rubber to the action of the vapors.

Between determinations, the apparatus was dried out by running air thru it for several hours. The vaseline on the stop-cocks, together with the alcohol vapors, caused some of the mercury to assume the finely divided form, thus necessitating cleaning of the apparatus with strong nitric acid.

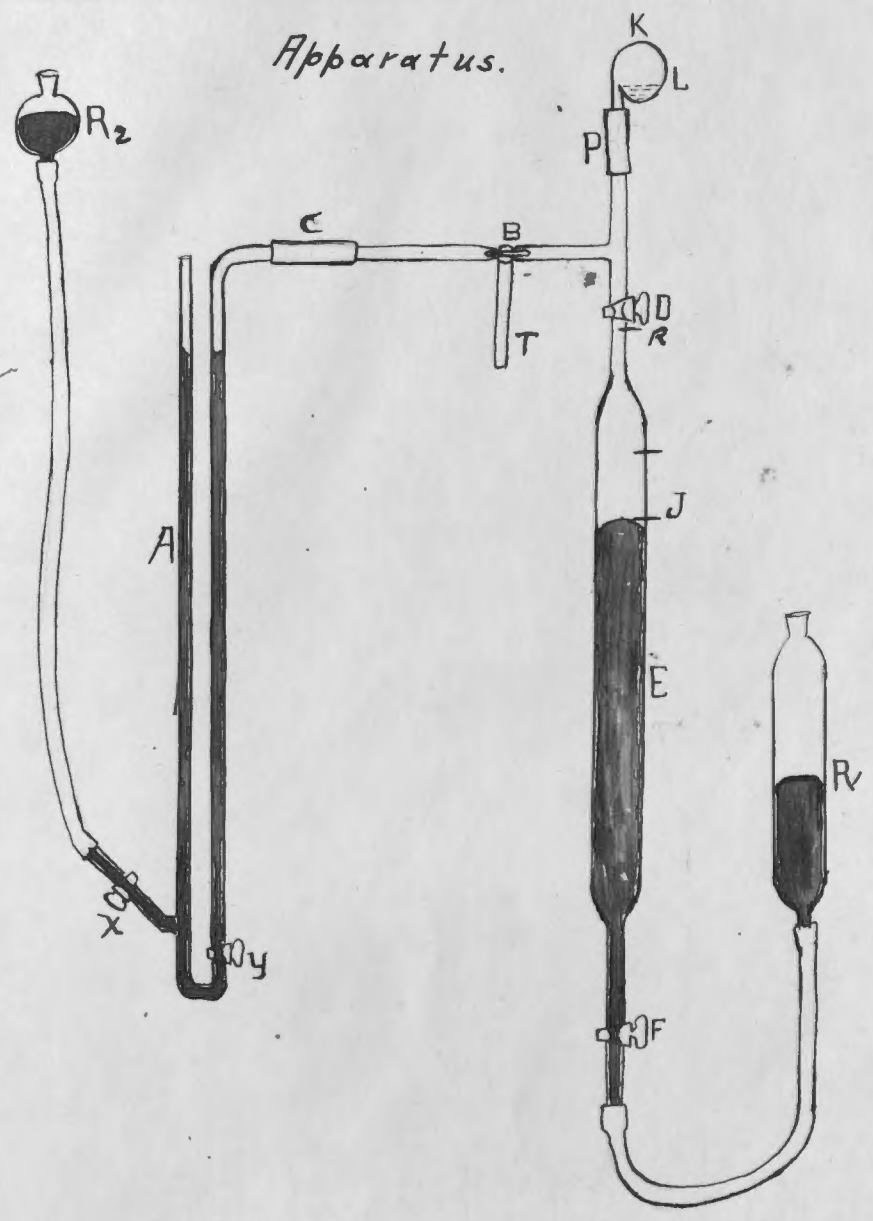
Method ^{of} calculating results.

The manometer reading, corresponding to the point at which nucleation was just perceptible, was taken as the diminution in pressure necessary to produce condensation, and was subtracted from the barometric reading (no correction for temperature was made on the mercury column), thus giving the final pressure after expansion.

The initial over the final pressure gives the expansion ratio or rain-point. The fog-points, which required a larger expansion, were calculated in precisely the same way. They are less accurately determined than the rain points, however.

Before making an expansion, the air and vapor in the cloud chamber were brought to atmospheric pressure by opening stop-cock D. Due to the heating up of the apparatus, air was let out but in no case let in.

Apparatus.



Sample determination. - Absolute methyl alcohol.

Pressure read on manometer.	Result.
183 mm.	0
185.5 "	0
186 "	0
188 "	0
189 "	0
189 "	2-3 drops.
194 "	5-6 drops.
199 "	Rain.

189 taken as rain-point.

B. R. 745.5 Temp. of cloud chamber 24.^o2

Temp. of mercury = 22.^o5

$$\frac{745.5}{556.5} - \frac{745.5}{556.5} = 1.340 \text{ expansion ratio.}$$

Fog-point on the same sample:-

Pressure.	Result.
248	Rain.
252	Rain. (Continued)

(Concluded)

Fog-point on the same sample:-

Pressure.	Result.
256	Rain.
257	Rain.
259	Colors (fog)
261	Colors (fog)
261	Colors (fog)

Results obtained.

The first experiments were made using an apparatus with a comparatively small stop-cock D. This factor would tend to give high results, due to a retardation of the expansion, which doesnot seriously alter the relative results.

With the apparatus having a large stop-cock D, the following expansion ratios were obtained:-

Ethyl alcohol and water.

% alcohol by vol.	% alcohol by weight.	expansion ratio.
0	0	1.38
10.3	8.29	1.240
20.3	16.51 (continued)	1.190

(Concluded)

Ethyl alcohol and water.

% Alcohol by vol.	% Alcohol by weight.	Expansion ratio.
30.4	25.0	1.159
41.1	34.33	1.153
51.1	43.50	1.141
62.0	54.2	1.139
71.8	64.37	1.137
81.5	75.23	1.142
90.7	86.58	1.178
99.8	99.68	1.240

From the curve the following results were read off:-

% Alcohol.	Expansion ratio interpolated.
0	1.38
10	1.227
20	1.174
30	1.155
40	1.147
50	1.140
60	1.139
70	1.138 (Continued)

(Concluded)

From the curve the following results were read off:-

% Alcohol.	Expansion ratio interpolated.
80	1.152
90	1.192
100	1.244

On comparing the above results with Wilson's & Przibram's results for water and alcohol and the later result for fifty per cent ethyl alcohol, it appears that all are too high, due to the fault of the apparatus.

A curve for apparatus correction may be constructed by means of which the above results may be converted into absolute results.

Correction curve obtained as follows:-

Taken as absolute values.

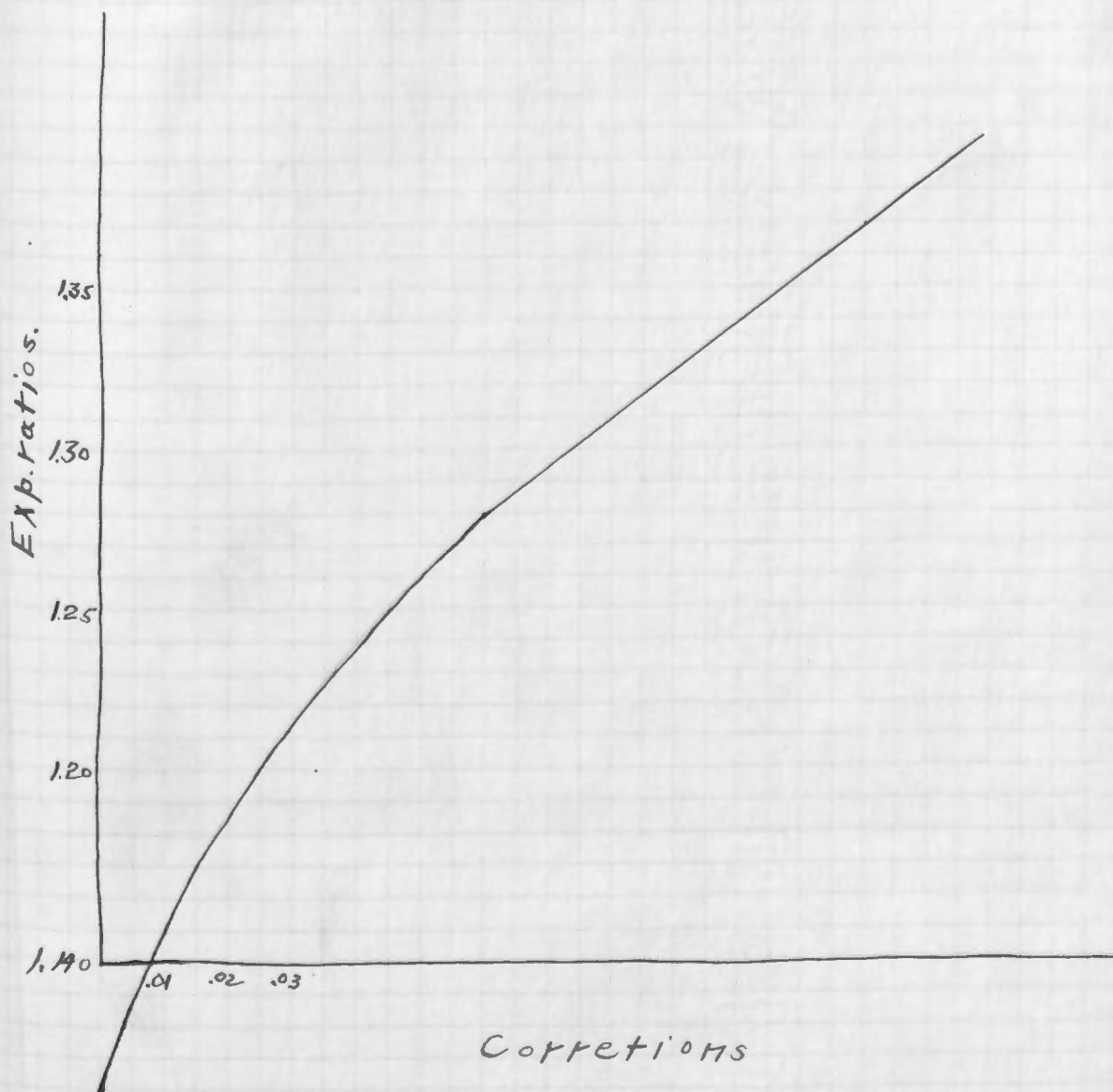
Water	1.252	(Wilson)
Ethyl alcohol	1.203	(Przibram)
50% ethyl	1.134	(Later result)

From the above table it will be noticed that the following corrections must be made:-

Water.)	Absolute values.	Observed values.	Correction.
)	1.252	1.380	.128
Ethyl alcohol	1.203	1.244	.041
50% ethyl	1.134	1.140	.006

Using these corrections and plotting them against the absolute expansion ratios, the following curves were obtained.

Apparatus correction curve
(small stopcock gas flame)



258 taken as fog-point expansion.

Play of colors was taken as indicative of a fog.

$$\begin{array}{r} 22.^{\circ}5 \\ \text{B. R. } 745.5 \\ \underline{258} \\ 487.5 \end{array} \quad \text{Temp. cloud chamber } 24.^{\circ}2$$
$$\frac{745.5}{487.5} = 1.529 \text{ Fog-point.}$$

Table giving absolute results:-

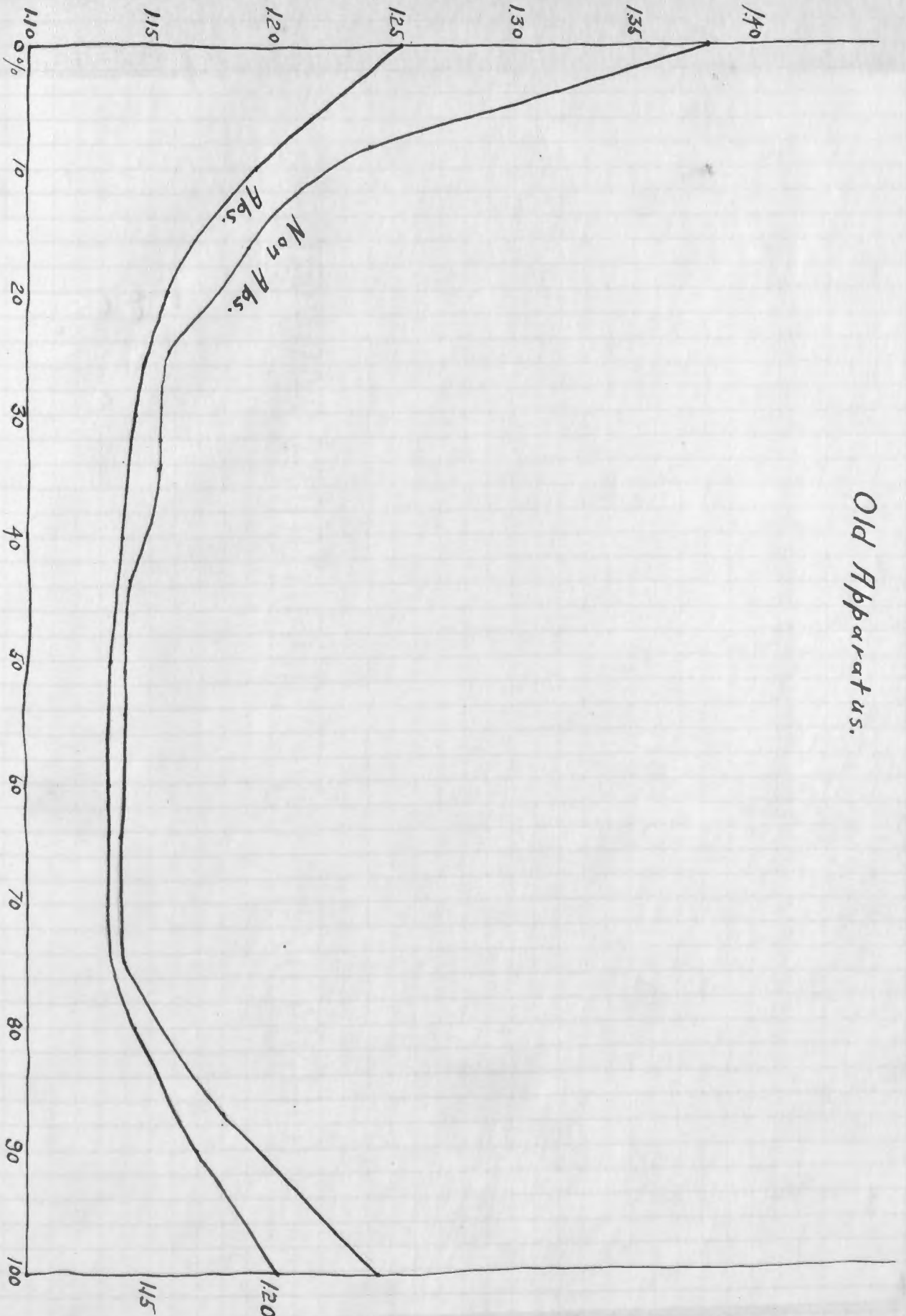
% Ethyl alcohol. Ex. ratio in- Correction. Abs.Result.
terpolated.

0	1.38	.128	1.252
10	1.227	.035	1.192
20	1.174	.016	1.158
30	1.155	.011	1.144
40	1.147	.008	1.139
50	1.140	.006	1.134
60	1.139	.005	1.134
70	1.138	.005	1.133
80	1.152	.009	1.143
90	1.192	.022	1.170
100	1.244	.041	1.203

These absolute values plotted will be found on Graph 1.

0% Ethyl Alcohol

Exp. ratios.



Old Apparatus.

100% Ethyl Alcohol.

Results with apparatus having a larger stop-cock
and gas flame used for illumination.

Ethyl alcohol and water.

Mixture.	Exp. ratio.	t° c	Fog point.	t° c	Date.	Mean.
100%	1.211	25.1			5/24/09	1.211
80%	1.755	----	1.203	---	---	---
60%	(1.131	26.°0	----	----	6/3/09	1.134
	(1.139	26.°2	----	----	"	
	(1.132	26.°2	1.187	26.°0	"	
40%	(1.138	25.°5	----	----	6/2/09	1.138
	(1.138	25.°5	----	----	"	
20%	(1.164	25.°0	----	----	"	1.164
	(1.164	25.°0	1.235	22.°0	"	
	(*1.023	25.°0	----	----	"	
0%	(1.350	27.°0	----	----	4/20/09	1.331
	(1.32	----	----	----	4/19/09	
	(1.308	----	----	----	5/17/09	
	(1.335	25.°0	----	----	5/21/09	
	(1.328	----	----	----	"	
	(1.342	----	----	----	"	
	(1.373	26.°0	1.52	25.°0	6/10/09	
		1.596	26.°0		F.P. 1.558	

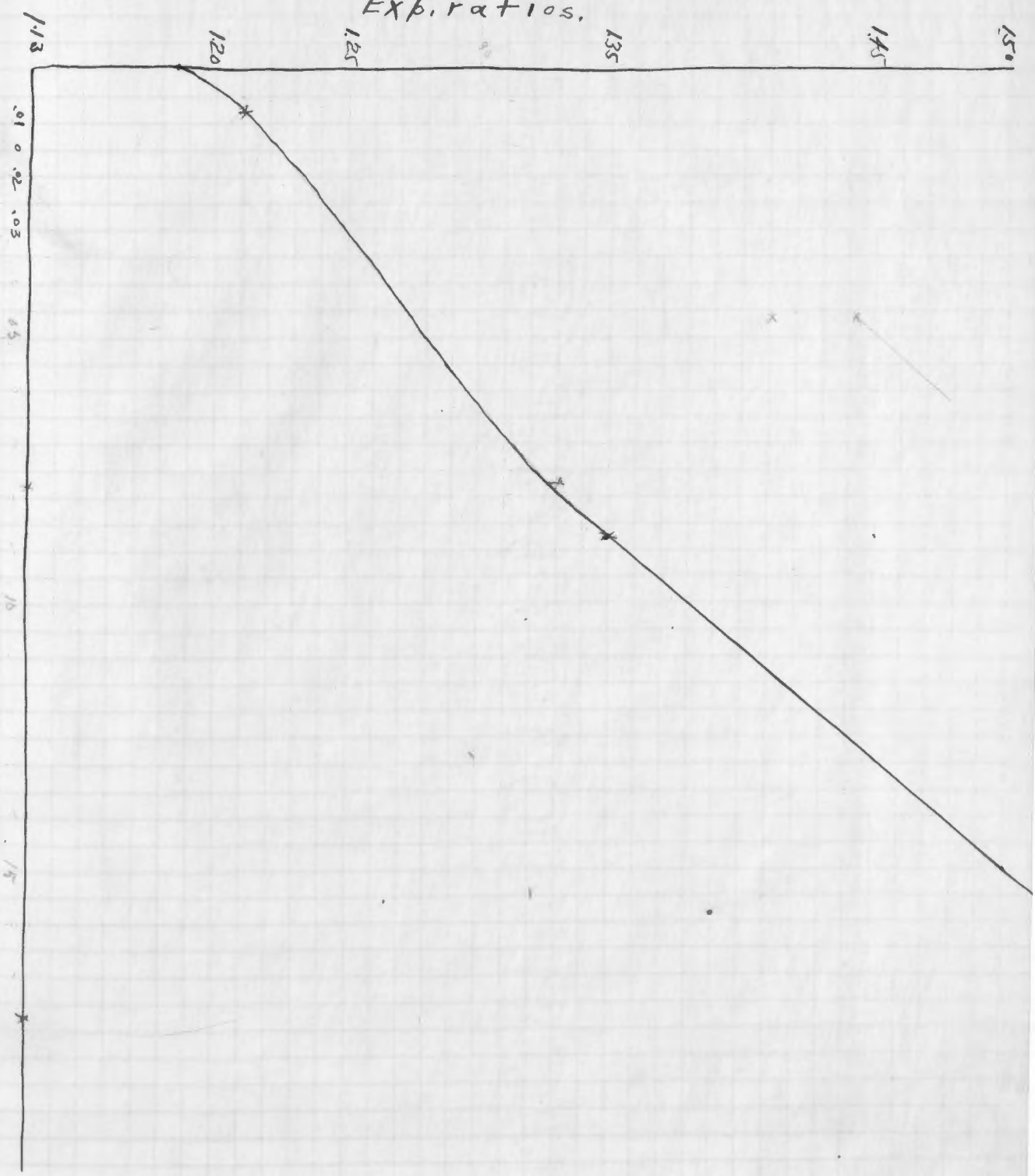
* X Rays used, and determination made within ten
minutes after rays were shut off.

Methyl alcohol and water.

Mixture.	Exp. ratio.	t ^o	Fog point.	t ^o c	Date	Mean Exp.ratio.	Mean F.P.
100%	(1.370	26. ^o 0	-----	-----	6/3/09	1.362	1.538
	(+ 1.376	29. ^o 0	1.547	29. ^o 0	6/4/09		
	0 1.340	24. ^o 2	1.529	24. ^o 2	6/10/09		
80%	(* 1.205	28. ^o 3	----	----	5/5/09	1.189	-----
	(1.174	27. ^o 5	----	----	"		
	(----	----	1.275	27. ^o 0	"		
60%	1.155	25. ^o 0	1.217	25. ^o 0	"	1.155	1.217
50%	1.160	----	----	----	----		
40%	(1.149	24. ^o 0	1.233	24. ^o 0	6/7/09	1.159	1.234
	(1.171	27. ^o 1	----	----	"		
	(1.160	27. ^o 1	1.226	27. ^o 1	"		
	(1.160	27. ^o 1	1.233	24. ^o 0	"		
(----	----	1.242	24. ^o 0	"			
20%	(1.212	28. ^o 0	1.279	27. ^o 1	6/8/09	1.209	1.278
	(1.206	28. ^o 0	1.274	27. ^o 1	"		
	(1.208	26. ^o 0	1.281	26. ^o 0	6/9/09		
50% ethyl & methyl.	1.287	27. ^o 0	1.435	27. ^o 0	6/11/09		

* Used gas flame for illumination.

Expirations.



Corrections for late apparatus.

By examining the above tables a variation from the results of Przibram and Wilson is still apparent.

From Przibram's and Wilson's results, as before, we obtain the following apparatus corrections:-

Water	.178	From fog point.
Water	.079	" rain "
Ethyl alcohol	.008	
50% ethyl	.000	

Table showing corrections.

Ethyl alcohol and water.

Mixture.	Expansion ratio.	Cor.	Abs. result.	Fog-point.	Cor.	Abs. result.
100%	1.211	.008	1.203	-----		
80%	1.145		1.135	1.203	.003	1.200
60%	1.134	0	1.134	1.187	0	1.187
40%	1.138	0	1.138			
20%	1.164	0	1.164	1.235	.023	1.212
0%	1.331	.079	1.252	1.558	.178	1.380

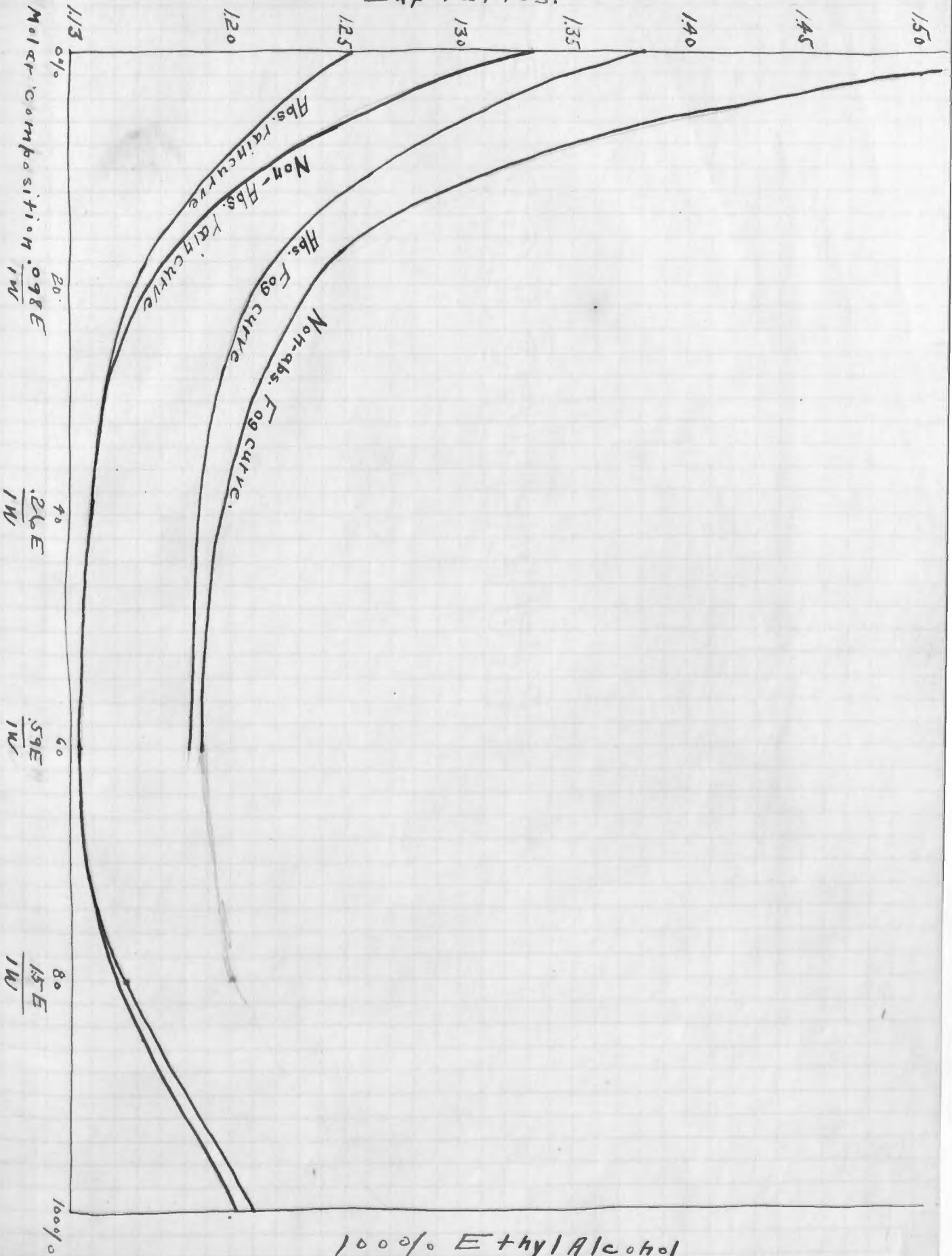
Methyl alcohol and water.

Mixture.	Expansion ratio.	Cor.	Abs. result.	Fog-point.	Cor.	Abs. result.
100%	1.362	.093	1.269	1.538	.168	1.370
80%	1.189	.005	1.184			
60%	1.155	.002m	1.153	1.217	.011	1.206
40%	1.159	.002	1.157	1.234	.023	1.211
20%	1.209	.008	1.201	1.278	.052	1.226
50% methyl & ethyl	1.287	.057	1.230*	1.435	.123	1.312

* Mean value between 100% methyl and ethyl alcohols is 1.236.

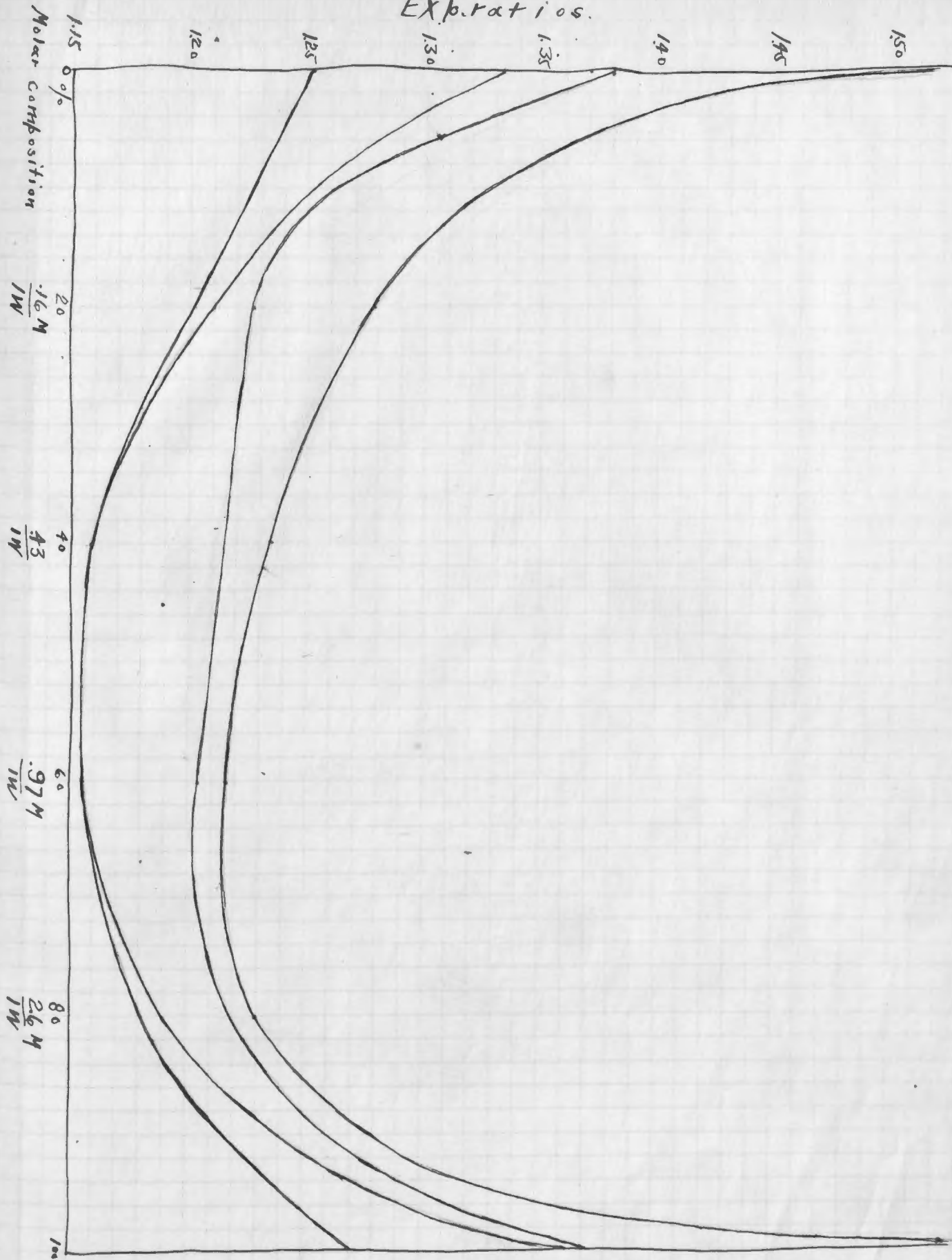
0% Ethyl Alcohol

Exp. ratios.



100% Ethyl Alcohol

0% Methyl Alcohol
Extractions.



100% Methyl Alcohol.

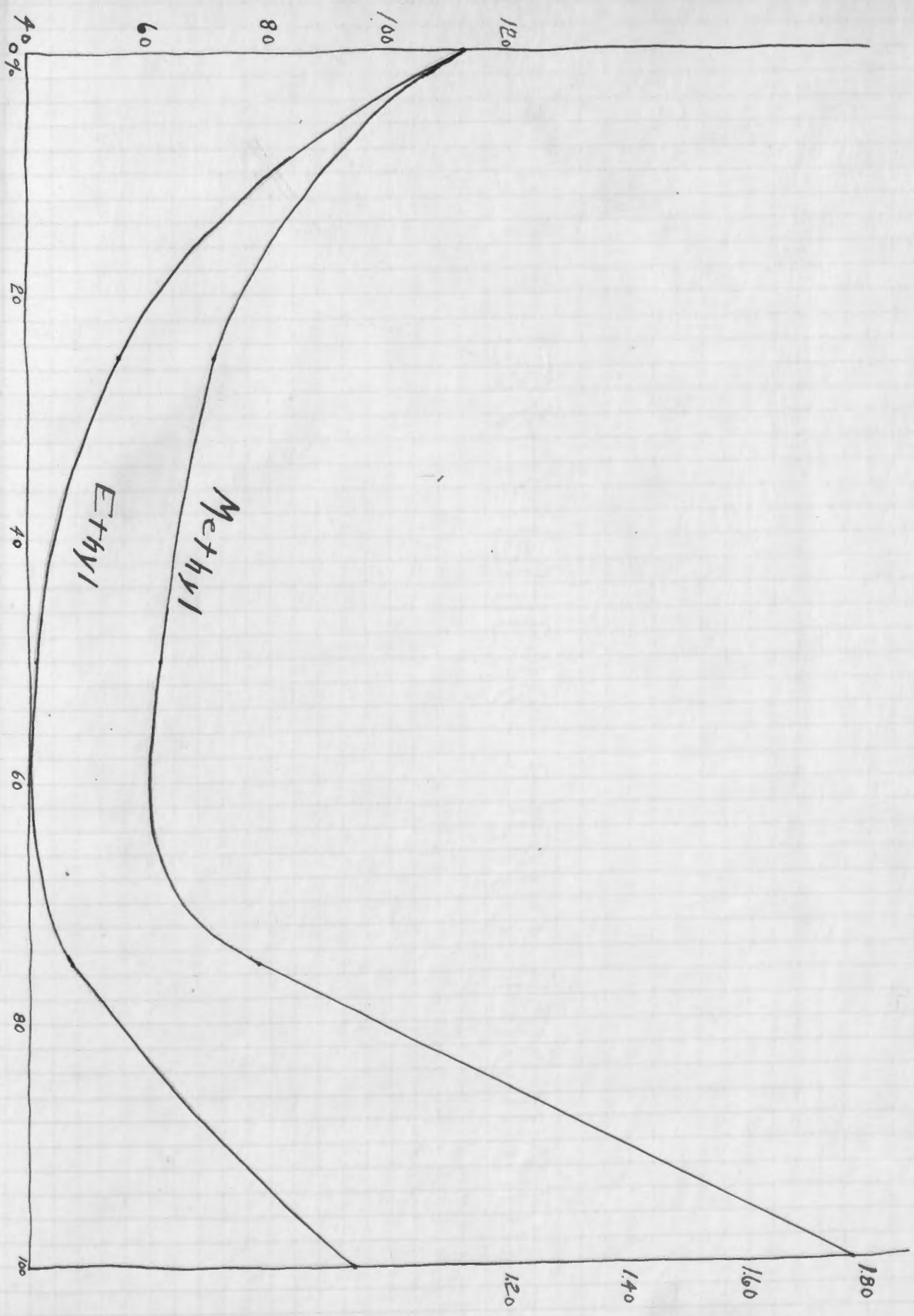
Upon examining the values given for the fluidities of methyl and ethyl alcohols and their water mixtures, (H. C. Jones and L. McMaster)*, it will be learned that the values differ apparently in the same manner that the expansion ratios differ. It would be of interest to compare the fluidity values with the corresponding expansion ratios, so the values given below have been plotted.

Fluidities at 25.°c

<u>Substance.</u>	<u>0%</u>	<u>25%</u>	<u>50%</u>	<u>75%</u>	<u>100%</u>
Ethyl alcohol	112.3	55.22	41.56	47.21	90.35
Methyl	112.3	70.94	62.04	77.92	176.70

* Paper on "The conductivity and Viscosity of Solutions of certain salts in water, methyl alcohol, ethyl alcohol, acetone and binary mixtures of these solvents".
p. p. 384 - 386.

Fluidity curves.

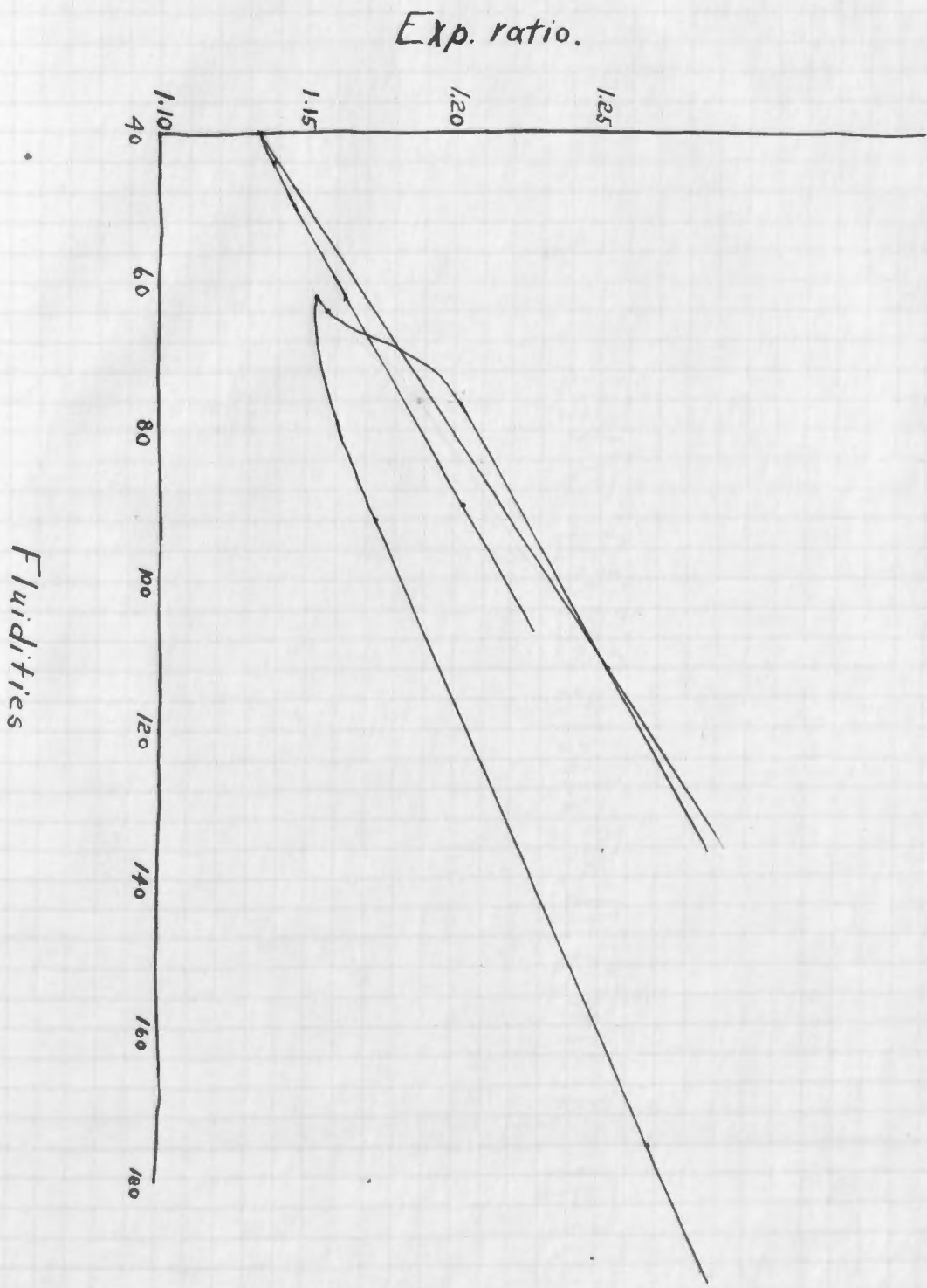


If a comparison of the two pairs of curves be made, it will be seen that there is evidently a feasible connection between the fluidity and the expansion ratio of the pure liquids and their mixtures. The curves have the same general form as the foregoing. A very noticeable and interesting feature is that the curves have a dip in the approximate vicinity of the 60% mixture.

The next plat shows the fluidity values plotted against the corresponding expansion ratio values.

<u>Ethyl alcohol.</u>		
<u>Mixture.</u>	<u>Abs. exp. ratio.</u>	<u>Fluidity.</u>
100%	1.203	90.35
80%		
60%	1.134	40*
40%	1.137	44*
20%	1.162	62*
0%	1.252	112.3

* Deduced from fluidity curve.



Methyl alcohol.

<u>Mixture.</u>	<u>Abs. Exp. ratio.</u>	<u>Fluidity.</u>
100%	1.269	176.70
80%	1.184	92. *
60%	1.153	62.5*
40%	1.157	64. *
20%	1.201	76.5*
0%	1.252	112.3

In the case of the ethyl alcohol curve, there is quite noticeably some connection between the fluidity and corresponding expansion ratio, as seems very probable from the character of the curve, since it is very nearly a straight line falling retracing itself.

In the case of the methyl alcohol, however, the relationship, if any, is not so apparent.

It is hoped that more extended work on the expansion ratios of the different alcohols will disclose closer connection between the two constants.

Discussion of results.

An inspection of the expansion ratio curves

of ethyl alcohol, methyl alcohol and their water mixtures reveals the fact that the water mixtures in both cases have a lower expansion ratio than either of the pure liquids.

The bubbling experiments of Lord Kelvin* and T.H. Laby† seem to offer at least a possible explanation of the ease of nucleation. Lord Kelvin found that, if air were bubbled thru water, the water would become positively and the air negatively charged. Laby found that the alcohols under the same conditions gave just the reversed results. Now, in the case of alcohol and water vapors, the former would be positively and the latter negatively charged.

Now, if nucleation takes place more readily when nuclei are introduced into the gas, it seems quite probable that in the case of the mixtures one or the other of the vapors furnishes nuclei for the other to condense on. And, since the vapors are oppositely charged, their nucleation is enhanced.

* 'Roy. Soc. Proc.,' 57, p. 335 (1895)

† 'Phil. Trans.,' A, 208, p. 473.

It may be that there is an equilibrium established at the minimum expansion ratio and works the turning point of the mutual nucleation referred to above.

The fact that the expansion ratio of a fifty per cent mixture of ethyl and methyl alcohols is a mean between the ratios of the pure liquids seems to show that the curve of the expansion ratios of various mixtures of these two liquids is linear. Further, work will be necessary to determine the truth or falsity of the above explanation.

It is a question whether the composition of the condensed vapor is the same as that of the vapor itself, the liquid or different from both.

A meteorological phenomenon.

It has doubtless been noticed that immediately after an electrical discharge during a rain storm, there is a marked increase of rain fall. The following seemed a reasonable explanation. As soon as the discharge takes place, there is a sudden expansion of air in the discharge field, and in turn a very rapid contraction in the

immediate vicinity, which means an adiabatic cooling:
now, wher ever the rarefaction takes place, a greater
shower would be produced. The induced electricity causes
the smaller drops of rain to combine, which would allow
the drops to fall more rapidly due to comparatively less
air friction. This would apparently enhance the shower.

I am indebted to Prof. J. Seelye for the use of valuable papers bearing on the subject.

I, also, wish to express most sincere thanks to Prof. Derby for constant attention given me thru - out the entire series of experiments.