

## MOLECULAR WEIGHTS OF SOME CARBON COMPOUNDS IN SOLUTION

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This paper gives some data concerning the molecular weights in solution of the same substances in the same solvents whose heats of solution were given some time ago.<sup>1</sup>

I wished to find the molecular weights at the ordinary temperature, 25°–35°. I tried the method of Walker<sup>2</sup> and that of Loeb<sup>3</sup> but could not get satisfactory results in either case.

The only method I found available was the boiling point method in a partial vacuum. Some of the results were so unexpected that I thought it best to make determinations at several temperatures intermediate between the boiling point under the atmospheric pressure and the boiling point under the lowest pressure obtainable by the water pump.

The apparatus was essentially that of Orndorff and Cameron.<sup>4</sup> As a partial vacuum of about 50 mm Hg was needed, mercury seals were used wherever the joints had to be broken in cleaning and charging the apparatus. Stationary joints could be made tight with rubber tubing and asphalt varnish. The boiling tube, *c*, held from the bottom up to *a* down to *g* about 350 cc. It was all in one piece. As recommended by Orndorff and Cameron a quantity of scrap platinum, about fifty grams, was used; no platinum wire was fused through the bottom at all. At the neck of the boiling tube is a mercury seal, the thermometer being held in place, of course, by cork or rubber. I could not detect a trace of injury.<sup>5</sup> At *a*, where

<sup>1</sup>Jour. Am. Chem. Soc. **18**, 146 (1896).

<sup>2</sup>Zeit. phys. Chem. **2**, 602 (1882).

<sup>3</sup>Zeit. phys. Chem. **2**, 606 (1882).

<sup>4</sup>Am. Chem. Jour. **17**, 517 (1895).

<sup>5</sup>Cf. Fuchs. Zeit. phys. Chem. **22**, 72 (1897).

connection is made with the water pump, a rubber cork and mercury seal are used. The pump gave a partial vacuum of about 44 mm. The tube, *e*, contained the substance to be introduced into *c* in the form of small weighed pellets. They were successively pushed in by a small glass pusher, *f*, which floated on mercury. The height of the mercury could be adjusted by raising or lowering *j*. To prevent air from entering through the rubber tubes, a trap, *h*, was used. The tube, *i*, with tap was convenient in letting out the trapped air. The connection between boiling tube and mercury was made at *g* by a thick rubber tube, sealed with mercury. A glass demijohn, 18 liters capacity, was circuited between the pump and *a*. Ice water circulated through the condenser *b*. When boiling under atmospheric pressure, the boiling tube was separated at *a* and *g* and used alone, the substance being introduced at *a*.

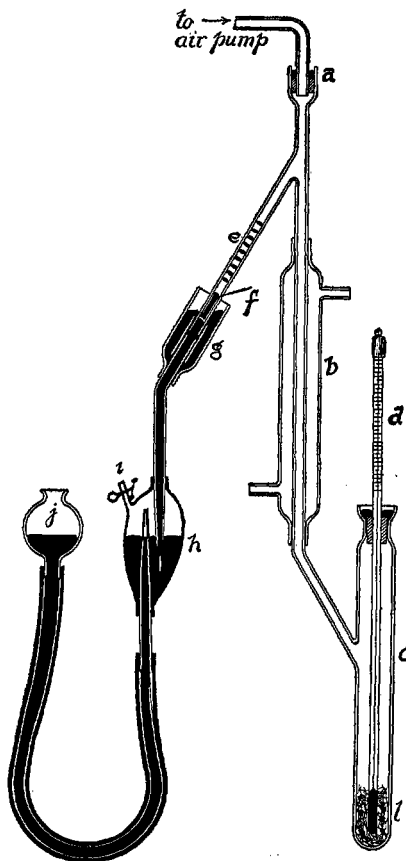


FIG. 1

Under atmospheric pressure, the time used for solution was one and a half minutes or less, and the thermometer was so steady that no correction was needed.

Under less than atmospheric pressure, the boiling temperature was often so low that a considerable time was needed for solution and the thermometer was not so steady as it was under atmospheric pressure. A correction was therefore needed. It was computed in this way. The average change in the thermometer per minute for five minutes before solution and the average change per minute for five minutes after solution were added together, the sum divided

by two, and this quotient multiplied by the number of minutes needed for solution. This, as a correction, was subtracted or added as the case might be, from the observed rise in the thermometer, to get the corrected rise. The thermometer was a Beckmann one divided into  $1/100^\circ$  and was estimated in reading to  $1/1000^\circ$ .

No corrections were made for the change in volume of the bulb of the thermometer due either to the temperature or to the pressure.

The gas was somewhat unsteady but did not give serious trouble. There was some difficulty once in a while with foaming which sometimes necessitated a lowering of the flame during a series of measurements, to prevent the solution from foaming out of the boiling tube and uncovering the bulb of the thermometer.

The correction due to the quantity of solvent which filled the boiling tube as vapor is easily calculated, at least approximately. But the quantity which trickled down the side of the boiling tube from the condenser can not be so calculated and the molecular weights are to this extent a trifle too low. This error is not more than one-half of one percent, if so much.

Experiments showed that no solvent passed the condenser tube.

The solutes and solvents have already been described.<sup>1</sup> When any substance gave out, some more was prepared according to the method previously used and identified by melting point or by boiling point.

The constant,  $K$ , for each solvent at the boiling point under atmospheric pressure was taken from Beckmann,<sup>2</sup> except for toluene. That solvent is not listed. How its constant was determined is described further on. The constants given by Beckmann are the mean of several different methods of determination and so it seemed better to use them than to determine the constants again. Under reduced pressure, they had to be determined in one of the following ways:—

1. Trouton's rule,  $Q/T = \text{constant}$ , where  $Q$  is the molecular heat of vaporization and  $T$  is the absolute temperature of vaporisation, is not available for this purpose for the constant is different at different temperatures, even for the same substance, for as  $T$  falls,

<sup>1</sup>Jour. Am. Chem. Soc. **18**, 146 (1896).

<sup>2</sup>Zeit. phys. Chem. **18**, 473 (1895).

$Q$  rises, in so far as  $Q$  refers to heat needed for vaporisation, not the heat needed to dissociate complex molecules, Ramsay.<sup>1</sup>

2. If  $K_0$  is the constant at  $T_0$ , and  $q_0$  is the heat of vaporisation at  $T_0$ , then the constant  $K$ , at  $T$ , at which  $q_0$  becomes  $q$ , is

$$K = K_0 \frac{0.02 T^2}{T_0^2} \frac{q_0}{q}.$$

The chief objection to this formula is want of sufficient data for  $q$ . Only data for chloroform, methyl alcohol, and water, that were at all sufficient for the purpose, could be found. In the case of chloroform, the results were satisfactory but in the case of methyl alcohol and water, the results were suspicious. For instance, the following table gives the data for acetanilid in methyl alcohol. Weight of acetanilid =  $w$ , weight of solvent corrected =  $W$ , both in grams, rise in boiling point corrected =  $\Delta t$ , correction which has been made for  $\Delta t$  in percent of observed  $\Delta t = \text{cor.}$ ,  $K = \text{constant}$  from Beckmann (B) or calculated by the above equation. Assumed molecular weight =  $M_0$ , observed molecular weight =  $M$ .

Temp. = 66°		W = 32.80					
K(B) = 8.8		M <sub>0</sub> = 135					
$w$	$\Delta t$	Cor.	M				
0.672	0.133	0%	136	1.929	0.325	"	127
1.208	0.242	"	134	2.621	0.434	"	129
1.938	0.385	"	135	3.284	0.532	"	132
2.643	0.517	"	137	3.947	0.627	"	134
3.338	0.648	"	138				
4.037	0.772	"	140				

Temp. = 25°		W = 33.13					
K(B. calc.) = 6.40		M <sub>0</sub> = 135					
$w$	$\Delta t$	Cor.	M				
0.490	0.084	2 %	113				
0.888	0.153	0 "	112				
1.300	0.231	3 "	108				
1.735	0.299	3 "	112				
2.111	0.368	3 "	111				

Temp. = 43.5°		W = 34.55					
K(B. calc.) = 7.37		M <sub>0</sub> = 135					
$w$	$\Delta t$	Cor.	M				
0.705	0.122	0%	123				
1.290	0.225	"	122				

The constant for the first case is taken directly from Beckmann and the somewhat high values are to be attributed to association of the solute.

<sup>1</sup>Zeit. phys. Chem. **15**, 108 (1894).

In the second case, however, the constant seems to be too low and in the third case this is markedly so. In the second case the corrections are zero and the error in reading the thermometer at most two percent of the reading. In the third case, the corrections are three percent and the error in reading the thermometer at most three percent, making a maximum error of six percent which will not account for the low values of  $M$ . A similar drop in  $M$  as  $T$  decreases was found for most of the other substances in all the solvents.

3. Another method is to select a substance of constant molecular weight and deduce the constant from this.

The advantage of this method is that it seems applicable to all solvents at all temperatures, whereas the data needed for the other two methods are not known for all solvents. Besides, any uncertainty due to loss of solvent by vaporisation and loss by clinging to the sides of the boiling tube, and any uncertainty due to expansion of the bulb of the thermometer, all these are eliminated.

The disadvantage is the uncertainty as to whether the solute has the molecular weight in solution that it is supposed to have. This uncertainty can be partly eliminated by selecting a solute whose molecular weight is the same at different dilutions. Then its molecular weight may be considered to be the simplest possible one, for complex molecules seem to decompose into simpler ones as dilution increases. But even in this case great discretion must be used.<sup>1</sup> Notwithstanding these disadvantages, this method was used whenever a solute could be found which seemed to have a constant normal molecular weight.

In the following table,  $K(B)$  means that the constant has been taken from Beckmann's tables;  $K(\text{urea})$  means that the constant has been computed from experiments with the substance named in the brackets, in this case urea;  $K(\text{calc.})$  means that the constant has been calculated by the formula given on page 769. The necessary data for  $K$  were obtained from Landolt and Börnstein's tables unless otherwise stated. Under percent is given parts of solute in 100 parts of *solvent*. The other symbols have been defined

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<sup>1</sup>See table for urethane in water.

## Water

## Urea

Temp. 100°      W = 44.19  
 $K(B) = 5.1$        $M_o = 60.$

w	$\Delta t$	Cor.	%	M
0.494	0.090	0 %	1.1	63.6
0.985	0.176	"	2.2	64.9
1.485	0.269	"	3.4	63.9
1.885	0.342	"	4.3	63.9
2.276	0.414	"	5.1	63.7
2.746	0.496	"	6.2	64.1

Temp. = 75°      W = 44.06  
 $K(\text{urea}) = 4.32$        $M_o = 60$

w	$\Delta t$	Cor.	%	M
0.978	0.159	0 %	2.2	60.4
1.971	0.318	"	4.5	60.0
2.846	0.458	"	6.5	60.1
3.862	0.619	"	8.8	60.4
4.365	0.705	"	9.9	59.9

Temp. = 54.8°      W = 44.22  
 $K(\text{urea}) = 4.05$        $M_o = 60$

w	$\Delta t$	Cor.	%	M
0.702	0.108	0 %	1.6	59.6
1.446	0.221	"	3.3	60.0
2.172	0.330	"	4.9	60.3
2.928	0.446	"	6.6	60.2

Temp. = 35.5°      W = 41.19  
 $K(\text{calc.}) = 3.72^1$        $M_o = 60$

w	$\Delta t$	Cor.	%	M
0.552	0.081	0 %	1.3	62.5
1.229	0.189	"	2.9	58.1
1.606	0.261	"	3.8	54.4
1.915	0.317	"	4.5	53.3

## Resorcinol

Temp. = 100°      W = 44.86  
 $K(B) = 5.1$        $M_o = 110$

w	$\Delta t$	Cor.	%	M
0.854	0.090	0 %	1.9	108
1.743	0.169	"	3.9	117
2.637	0.247	"	5.9	122
3.539	0.318	"	7.9	127

Temp. = 75°      W = 40.59  
 $K(\text{urea}) = 4.32$        $M_o = 110$

w	$\Delta t$	Cor.	%	M
1.146	0.143	0 %	2.8	85.4
2.575	0.264	"	6.3	104
3.908	0.368	"	9.6	113

Temp. = 54.8°      W = 44.31  
 $K(\text{urea}) = 4.05$        $M_o = 110$

w	$\Delta t$	Cor.	%	M
0.949	0.112	0 %	2.1	77.4
1.822	0.156	"	4.1	84.6
2.724	0.206	"	6.1	121
3.690	0.266	"	8.3	127

Temp. = 36°      W = 40.14  
 $K(\text{calc.}) = 3.73$        $M_o = 110$

w	$\Delta t$	Cor.	%	M
0.932	0.185	0 %	2.3	46.6
1.936	0.243	"	4.8	74.6
2.791	0.326	"	6.9	79.8

<sup>1</sup>4.05 (308.5/327.8)<sup>2</sup>(568/554) = 3.72.

Temp. = 35°		W = 43.46		
K (calc.) = 3.71		M <sub>0</sub> = 110		
w	Δ t	Cor.	%	M
0.661	0.243	0%	1.5	23.1
1.336	0.328	"	3.1	34.7
2.166	0.411	"	5.0	43.9
2.436	0.466	"	5.6	43.8

*Succinimid*

Temp. = 100°		W = 42.02		
K(B) = 5.1		M <sub>0</sub> = 99		
w	Δ t	Cor.	%	M
0.894	0.103	0%	2.1	105
1.951	0.231	"	4.6	102
2.877	0.342	"	6.8	102
3.935	0.470	"	9.4	102
5.349	0.621	"	12.7	105

Temp. = 75°		W = 42.65		
K(urea) = 4.32		M <sub>0</sub> = 99		
w	Δ t	Cor.	%	M
1.106	0.120	0%	2.6	93.3
2.325	0.240	"	5.5	98.3
3.508	0.340	"	8.2	105

Temp. = 54.4°		W = 44.02		
K(urea) = 4.04		M <sub>0</sub> = 99		
w	Δ t	Cor.	%	M
1.077	0.114	0%	2.4	86.7
2.133	0.166	"	4.8	118
3.170	0.241	"	7.2	122
4.336	0.323	"	9.8	124

In the first measurement violent foaming. Flame lowered in succeeding measurements. Hence high values(?)

Temp. = 54.6°		W = 45.14		
K(urea) = 4.04		M <sub>0</sub> = 99		
w	Δ t	Cor.	%	M
2.538	0.204	0%	5.6	113

Temp. = 36°		W = 40.21		
K (calc.) 3.73		M <sub>0</sub> = 99		
w	Δ t	Cor.	%	M
0.914	0.100	0%	2.3	84.5
2.046	0.140	"	5.1	135
3.324	0.170	"	8.3	180

Temp. = 36°		W = 39.11		
K (calc.) = 3.73		M <sub>0</sub> = 99.		
w	Δ t	Cor.	%	M
0.581	0.086	10%	1.5	64.3
1.974	0.156	29 "	5.0	125
2.642	0.222	14 "	6.8	114
3.343	0.295	10 "	8.5	107

Temp. 35°		W = 43.08		
K (calc.) = 3.71		M <sub>0</sub> = 99		

0.563 grams dropped in at outset. To be subtracted from given figures.

w	Δ t	Cor.	%	M
1.500	0.059	0%	3.5	136
2.542	0.111	"	6.0	152
4.100	0.199	"	9.5	152

*Mannite*

Temp. = 100°		W = 42.55		
K(B) = 5.1		M <sub>0</sub> = 182		
w	Δ t	Cor.	%	M
1.221	0.079	0%	2.9	189
1.829	0.121	"	4.3	185
2.667	0.179	"	6.3	182
3.554	0.233	"	8.2	186

Temp. = 75°		W = 43.62		
K(urea) = 4.32		M <sub>0</sub> = 182		
w	Δ t	Cor.	%	M
1.054	0.061	0%	2.4	171
2.094	0.120	"	4.8	173
3.083	0.173	"	7.1	177
4.287	0.242	"	9.8	176

Temp. = 54° W = 43.62  
K(urea) = 4.03 M<sub>0</sub> = 182

w	Δ t	Cor.	%	M
1.065	0.066	0%	2.4	149
2.164	0.129	"	5.0	155
3.225	0.170	"	7.4	176
4.333	0.226	"	9.9	177

Temp. = 35.5° W = 40.93  
K(calc.) = 3.72 M<sub>0</sub> = 182

w	Δ t	Cor.	%	M
0.843	0.053	0%	2.1	155
1.976	0.143	"	4.8	124
2.839	0.207	"	6.9	123

Temp. = 36° W = 41.31  
K(calc.) = 3.73 M<sub>0</sub> = 182

w	Δ t	Cor.	%	M
1.065	0.095	0%	2.6	101
2.216	0.017	"	5.4	169
3.228	0.189	"	7.8	154

### Urethane

Temp. = 100° W = 43.77  
K(B) = 5.1 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.489	0.031	0%	1.1	184
1.227	0.081	"	2.8	176
2.091	0.141	"	4.8	173
2.581	0.171	"	5.9	176
3.089	0.203	"	7.0	177

Temp. = 75° W = 43.44  
K(urea) = 4.32 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
1.961	0.181	0%	4.5	108
2.993	0.243	"	6.9	123
4.062	6.303	"	9.4	133
4.667	0.333	"	10.8	139

Oily streaks observed on sides of boiling tube showing urethane volatilized.

Temp. 54.5° W = 44.60  
K(urea) = 4.04 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.771	0.170	0%	1.7	41.1
1.598	0.210	"	3.6	69.0
2.400	0.261	"	5.4	83.4
3.202	0.304	"	7.2	95.4
4.014	0.349	"	9.0	104

Temp. = 35° W = 41.82  
K(calc.) = 3.71 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.784	0.250	0%	1.9	27.8
1.556	0.307	"	3.7	44.8
2.053	0.333	"	4.9	54.5
2.508	0.355	"	6.0	62.4
3.057	0.398	"	7.3	68.1

Temp. = 36° W = 39.57  
K(calc.) = 3.73 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.853	0.139	0%	2.2	54.6
1.774	0.204	"	4.5	81.7
2.599	0.256	"	6.6	95.5

### Methyl Alcohol

#### Urethane

Temp. = 66° W = 34.22  
K(B) = 8.8 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.749	0.209	0%	2.2	92.2
1.155	0.320	"	3.4	92.7
3.273	0.880	"	9.6	95.6
4.109	1.098	"	12.0	96.2
5.103	1.340	"	14.9	97.9
6.142	1.592	"	18.0	99.2



Temp. = 44° W = 33.35  
K(urethane) = 7.55 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.534	0.130	0%	1.6	93.1
1.047	0.269	"	3.1	88.2
1.580	0.409	"	4.7	87.5
2.124	0.546	"	6.4	88.1
2.704	0.692	"	8.1	88.5
3.265	0.831	"	9.8	89.0

Temp. = 35.4° W = 44.89  
K(urethane) = 7.55 M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.560	0.125	0%	1.7	88.1
1.124	0.258	"	3.3	85.9
1.667	0.385	"	4.9	85.3
2.203	0.508	"	6.5	85.5
2.742	0.621	"	8.1	85.8
3.733	0.826	"	11.0	89.0

*Acetanilid*

Temp. = 66° W = 32.80  
K(B) = 8.8 M<sub>0</sub> = 135

w	Δ t	Cor.	%	M
0.672	0.130	0%	2.0	136
1.208	0.242	"	3.7	134
1.938	0.385	"	5.9	135
2.643	0.517	"	8.1	137
3.338	0.648	"	10.2	138
4.037	0.772	"	12.3	140

Temp. = 43.5° W = 34.55  
K(urethane) = 7.52 M<sub>0</sub> = 135

w	Δ t	Cor.	%	M
0.705	0.122	0%	2.0	126
1.290	0.225	"	3.7	125
1.929	0.325	"	5.6	130
2.621	0.434	"	7.6	132
3.284	0.532	"	9.5	135
3.947	0.627	"	11.4	137

Temp. = 25° W = 33.13  
K(urethane) = 5.65 M<sub>0</sub> = 135

w	Δ t	Cor.	%	M
0.490	0.084	2%	1.5	117
0.888	0.153	0 "	2.7	116
1.300	0.231	3 "	3.9	112
1.735	0.299	3 "	5.2	116
2.111	0.368	3 "	6.4	115

*Acenaphthene*

Temp. = 66° W = 34.12  
K(B) = 8.8 M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.776	0.112	0	2.3	179
1.568	0.234	"	4.6	173
2.326	0.344	"	6.8	174
3.332	0.456	"	9.8	188

Temp. = 43.4° W = 34.27  
K(urethane) = 7.52 M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.683	0.095	--	2.0	158

23 mins. for solution. Value for M uncertain. Not corrected.

Temp. = 43.4° W = 34.26  
K(urethane) = 7.52 M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.339	0.067	--	1.0	111
0.799	0.135	--	2.3	130
1.129	0.205	--	3.3	120

14 to 28 minutes for solution. Values for M uncertain. Not corrected.

Temp. = 24.8° W = 34.62  
K(urethane) = 6.64 M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.333	0.071	12%	1.0	90.0
0.681	0.113	58 "	2.0	115

Trace of acenaphthene undissolved.

*Naphthalene*

Temp. = 66°      W = 35.35  
K(B) = 8.8      M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.560	0.103	10%	1.6	133
1.058	0.187	"	3.0	141
1.586	0.270	"	4.5	146
2.087	0.349	"	5.4	149
2.604	0.423	"	7.9	153
3.551	0.560	"	10.1	158

Temp. = 43.5°      W = 34.39  
K(urethane) = 6.66      M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.407	0.070	0%	1.2	128
0.850	0.146	"	2.5	128
1.275	0.213	"	3.7	131
1.655	0.282	"	4.8	129
2.018	0.352	"	5.9	126
2.357	0.423	"	6.8	121

Temp. = 25.2°      W = 34.11  
K(urethane) = 6.66      M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.475	0.080	5%	1.4	115
1.441	0.233	3"	4.2	120
1.927	0.323	15"	5.7	116

*Ethyl Alcohol**Urea*

Temp. = 78°      W = 33.72  
K(B) = 11.7      M<sub>0</sub> = 60

w	Δ t	Cor.	%	M
0.773	0.404	0%	2.3	62.9
1.198	0.639	1"	3.6	65.1
1.696	0.877	0"	5.0	67.1
2.158	1.086	0"	6.4	68.9
2.682	1.306	0"	8.0	71.3
3.251	1.528	1"	9.6	73.8

Temp. = 52.2°      W = 34.03  
K(calc.) = 9.60<sup>1</sup>      M<sub>0</sub> = 60

w	Δ t	Cor.	%	M
0.556	0.277	10%	1.6	56.6
1.104	0.525	11"	3.2	59.4
1.731	0.776	10"	5.1	62.8
2.381	1.031	9"	7.0	65.1

Temp. = 25° Not soluble enough.

<sup>1</sup>11.7(325.2/351)<sup>2</sup>(204.6/214.2) = 9.60.  
Temp. = 25°. Too insoluble.

*Urethane*

Temp. = 78°      W = 34.94  
K(B) = 11.7      M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.495	0.187	0%	1.4	88.7
0.951	0.341	"	2.7	93.4
1.495	0.532	"	4.3	94.1
2.051	0.722	"	5.5	95.1
2.608	0.909	"	7.9	96.1
3.177	1.094	"	9.1	97.2

Temp. = 52.2°      W = 33.24  
K(B) = 9.60      M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.565	0.189	9%	1.7	86.4
1.154	0.381	"	3.5	87.6
1.704	0.552	"	5.1	89.3
2.793	0.872	"	8.4	92.5
3.388	1.074	"	10.2	93.5

Temp. = 27.6°      W = 33.32  
K(calc.) = 7.80<sup>1</sup>      M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.568	0.175	0%	1.7	76.0
1.166	0.345	0"	3.5	78.7
1.759	0.515	0"	5.3	79.8
2.302	0.660	2"	6.9	81.6
2.868	0.812	3"	8.6	82.6
3.457	0.960	2"	10.4	84.2

<sup>1</sup>11.7(300.6/351)<sup>2</sup>(204.6/225.2) = 7.80.

*Resorcinol*

Temp. = 78°      W = 33.16  
 K(B) = 11.7      M<sub>0</sub> = 110

w	Δt	Cor.	%	M
0.634	0.218	0%	1.9	103
1.268	0.434	"	3.8	103
1.753	0.612	"	5.3	101
2.441	0.865	"	7.4	99.6
3.058	1.100	"	9.2	98.1
3.723	1.360	"	11.2	96.6

Temp. = 52.3°      W = 32.90  
 K(calc.) = 9.60      M<sub>0</sub> = 110

w	Δt	Cor.	%	M
0.579	0.172	0%	1.7	98.4
1.217	0.378	"	3.7	93.9
1.806	0.566	"	5.5	93.0
2.473	0.784	"	7.5	92.0
3.018	0.969	"	9.2	90.8
3.640	1.181	"	11.1	89.8

Temp. = 27.8°      W = 33.19  
 K(calc.) = 7.81      M<sub>0</sub> = 110

w	Δt	Cor.	%	M
0.671	0.199	3%	2.0	79.3
1.475	0.422	2"	4.4	82.2
2.344	0.672	0"	7.1	82.0
3.162	0.911	2"	9.5	81.6
3.826	1.145	0"	11.5	78.5
4.484	1.327	0"	13.5	83.3

*Benzamid*

Temp. = 78°      W = 33.36  
 K(B) = 11.7      M<sub>0</sub> = 121

w	Δt	Cor.	%	M
0.929	0.269	0%	2.8	121
1.959	0.559	"	5.9	123
2.794	0.778	"	8.4	126
3.631	0.990	"	10.9	129
4.476	1.192	"	13.4	132
5.335	1.395	"	16.0	134

Temp. = 52.2°      W = 32.82  
 K(calc.) = 9.60      M<sub>0</sub> = 121

w	Δt	Cor.	%	M
0.655	0.164	0%	2.0	116
1.276	0.305	"	3.9	122
1.991	0.464	"	6.1	125
2.557	0.584	"	7.8	128
3.018	0.694	"	9.2	127
3.607	0.824	"	11.0	128

Temp. 27.8°      W = 34.29  
 K(calc.) = 7.81      M<sub>0</sub> = 121

w	Δt	Cor.	%	M
0.648	0.168	5"	1.9	87.8
1.226	0.319	3"	3.6	87.5
1.794	0.456	3"	5.2	89.8

In the last measurement the solution was saturated and some benzamid crystallized on walls of boiling tube above the solution so result is a little too high.

*p-Toluidin*

Temp. = 78°      W = 31.97  
 K(B) = 11.7      M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.534	0.189	0%	1.7	103
1.079	0.365	"	3.4	108
1.589	0.530	"	5.0	110
2.139	0.695	"	6.7	113
2.683	0.859	"	8.4	114
3.225	1.011	"	10.1	117

Temp. = 52.2°      W = 32.85  
 K(calc.) = 9.60      M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.555	0.167	0%	1.7	97.4
1.103	0.311	"	3.4	103
1.609	0.438	"	4.9	107
2.160	0.577	"	6.6	109
2.676	0.705	"	8.1	111
3.195	0.827	"	9.7	113

Temp. = 27.5°      W = 34.79  
K. (calc.) = 7.79      M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.548	0.146	0%	1.5	84.0
1.244	0.308	3 "	3.6	90.4
2.027	0.478	1 "	5.8	94.5
2.773	0.634	0 "	7.9	98.1
3.539	0.788	0 "	10.1	101
4.301	0.930	0 "	12.3	104

*Acetanilid*

Temp. = 78°      W = 32.99  
K(B) = 11.7      M<sub>0</sub> = 135

w	Δt	Cor.	%	M
0.977	0.259	0%	3.0	134
1.449	0.382	"	4.4	134
2.150	0.557	"	6.5	137
2.882	0.733	"	8.7	139
3.689	0.921	"	11.2	142
4.836	1.178	"	14.7	145

Temp. = 52°      W = 34.05  
K. (calc.) = 9.59      M<sub>0</sub> = 135

w	Δt	Cor.	%	M
0.579	0.120	0%	1.7	137
1.225	0.257	0 "	3.6	136
1.922	0.391	0 "	5.7	140
2.573	0.523	1 "	7.6	140

Temp. = 27.7°      W = 32.94  
K. (calc.) = 7.81      M<sub>0</sub> = 135

w	Δt	Cor.	%	M
0.626	0.129	8%	1.9	114
1.300	0.253	11 "	4.0	121
1.925	0.370	2 "	5.9	123
2.563	0.485	4 "	7.8	125
3.199	0.591	8 "	9.7	128

*Acenaphthene*

Temp. = 78°      W = 31.14  
K(B) = 11.7      M<sub>0</sub> = 154

w	Δt	Cor.	%	M
1.089	0.250	0%	3.5	164
1.886	0.419	0 "	6.0	169
2.637	0.559	0 "	8.4	177
3.363	0.684	0 "	10.8	185
4.120	0.809	0 "	13.2	191
4.875	0.916	1 "	15.7	200

Temp. = 52°      W = 34.57  
K. (calc.) = 9.59      M<sub>0</sub> = 154

w	Δt	Cor.	%	M
0.480	0.099	0%	1.4	135
1.002	0.200	0 "	2.9	140
1.527	0.291	33 "	4.4	145
2.073	0.408	28 "	6.0	142
2.590	0.451	16 "	7.5	159
3.160	0.587	14 "	9.1	149

Temp. 28°. Too insoluble.

*Naphthalene*

Temp. = 78°      W = 32.49  
K(B) = 11.7      M<sub>0</sub> = 128

w	Δt	Cor.	%	M
0.826	0.215	0%	2.5	138
1.606	0.404	"	4.9	143
2.397	0.575	"	7.4	150
3.182	0.740	"	9.8	155
4.036	0.909	"	12.4	160
4.831	1.061	"	14.9	164

Temp. = 52.2°      W = 33.17  
K. (calc.) = 9.60      M<sub>0</sub> = 128

w	Δt	Cor.	%	M
0.552	0.128	0%	1.7	125
1.344	0.298	0 "	4.0	131
2.147	0.458	0 "	6.5	136
2.923	0.601	0 "	8.8	140
3.663	0.738	1 "	11.0	143
4.465	0.892	2 "	13.5	145

Temp. = 27.5° W = 33.54  
 $K(\text{calc.}) = 7.79$   $M_o = 128$

w	$\Delta t$	Cor.	%	M
0.676	0.151	4%	2.0	104
1.419	0.293	10 "	4.2	113
2.114	0.414	16 "	6.3	118
2.844	0.533	5 "	8.5	124

Naphthalene volatilized and crystallized on upper part of boiling tube so results are somewhat uncertain, in last measurement at any rate.

#### Phenanthrene

Temp. = 78° W = 34.05  
 $K(B) = 11.7$   $M_o = 178$

w	$\Delta t$	Cor.	%	M
0.519	0.100	0 "	1.5	178
1.482	0.270	0 "	4.4	189
2.122	0.374	2 "	6.2	195
3.050	0.506	1 "	9.0	207
3.747	0.594	0 "	11.0	217
4.802	0.716	0 "	14.1	230

Temp. = 51.8° W = 33.17  
 $K(B) = 9.58$   $M_o = 178$

w	$\Delta t$	Cor.	%	M
0.488	0.099	0%	1.5	142
1.009	0.190	0 "	3.0	154
1.591	0.280	0 "	4.8	164
2.111	0.361	0 "	6.4	169
2.608	0.414	23 "	7.9	182

Temp. 28°. Too insoluble.

#### Succinimid

Temp. 78° W = 33.46  
 $K(B) = 11.7$   $M_o = 99$

w	$\Delta t$	Cor.	%	M
0.933	0.317	0%	2.8	103
1.748	0.569	"	5.2	107
2.391	0.751	"	7.1	111
3.094	0.938	"	9.2	115
4.068	1.180	"	12.1	121
5.058	1.408	"	15.1	136

Temp. 52.3° W = 35.03  
 $K(\text{calc.}) = 9.61$   $M_o = 99$

w	$\Delta t$	Cor.	%	M
0.717	0.196	4%	2.0	100
1.419	0.381	3 "	4.0	102
2.145	0.556	7 "	6.1	106
2.833	0.719	3 "	8.1	108

Temp. 28°. Too insoluble.

#### Propyl Alcohol

##### Urethane

Temp. = 97° W = 34.17  
 $K(B) = 16.09$   $M_o = 89$

w	$\Delta t$	Cor.	%	M
0.564	0.277	0%	1.7	95.8
1.151	0.557	"	3.4	97.2
1.740	0.824	"	5.1	99.3
2.297	1.076	"	6.7	100
2.878	1.328	"	8.4	102
3.462	1.574	"	10.1	103

Temp. = 64.7° W = 34.38  
 $K(\text{calc.}) = 13.40^2$   $M_o = 89$

w	$\Delta t$	Cor.	%	M
0.651	0.264	0%	1.9	95.9
1.290	0.523	"	3.8	95.9
1.946	0.780	"	5.7	97.0
2.567	1.008	"	7.5	99.0
3.186	1.224	"	9.3	103
3.837	1.452	"	11.2	103

$^{16.09(337.7/370)^2} = 13.40$ ; no data found for change of  $q$  with  $T$ .

Temp. 36.5° W = 35.70  
 $K(\text{calc.}) = 11.26^2$   $M_o = 89$

w	$\Delta t$	Cor.	%	M
0.592	0.206	0%	1.7	90.4
1.123	0.386	0 "	3.3	91.5
1.683	0.582	0 "	4.9	91.0
2.281	0.757	1 "	6.6	94.8
2.826	0.910	3 "	8.2	97.6
3.462	1.084	1 "	10.1	100

$^{16.09(309.5/370)^2} = 11.26$ .

*Naphthalene*

Temp. = 97°      W = 33.02  
K(B) = 16.09      M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.816	0.270	0%	2.5	147
1.639	0.525	"	5.0	152
2.411	0.744	"	7.3	158
3.330	0.989	"	10.1	164
4.143	1.203	"	12.6	168
4.894	1.385	"	14.8	172

Temp. = 64.1°      W = 34.18  
K(calc.) = 13.36      M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.580	0.160	2%	1.7	142
1.145	0.303	3 "	3.3	148
1.691	0.431	2 "	4.9	153
2.271	0.561	2 "	6.6	158
2.881	0.690	4 "	8.4	163
3.509	0.815	1 "	10.3	168

Temp. = 36.9°      W = 33.90  
K(calc.) = 11.29      M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.703	0.157	4 "	2.1	149
1.425	0.292	16 "	4.2	162
2.164	0.439	12 "	6.4	164
2.796	0.526	20 "	8.3	176

*Acenaphthene*

Temp. = 97°      W = 32.00  
C(B) = 16.09      M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.556	0.173	0%	1.7	162
1.114	0.326	"	3.5	172
1.635	0.469	"	5.1	175
2.160	0.607	"	6.8	179
2.871	0.787	"	9.0	183
3.226	0.875	"	10.1	185

Temp. = 63.9°      W = 33.46  
K(calc.) 13.35      M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.568	0.135	1%	1.7	167
1.181	0.274	3 "	3.5	171
1.673	0.371	3 "	5.0	179
2.218	0.476	6 "	6.6	185
2.790	0.585	6 "	8.3	189
3.333	0.688	1 "	9.9	192

Acenaphthene crystallized on cooling  
from last solution. Temp. = 36°.  
Too insoluble.

*Chloroform**Urethane*

Temp. = 61.7°      W = 60.34  
K(naphthalene) = 37.86      M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.610	0.390	0%	1.0	98.0
1.205	0.731	"	2.0	103
1.736	1.003	"	2.9	108
2.322	1.287	"	3.8	110
2.940	1.570	"	4.9	116
3.544	1.821	"	5.9	122

Temp. = 42.7°      W = 59.40  
K(naphthalene) = 34.33      M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.645	0.360	0%	1.0	104
1.271	0.654	"	2.1	112
1.908	0.925	"	3.2	119
2.524	1.163	"	4.3	125
3.143	1.396	"	5.3	131
3.734	1.610	"	6.3	134

Temp. = 26.6°      W = 60.48  
K(naphthalene) = 30.09      M<sub>0</sub> = 89

w	Δ t	Cor.	%	M
0.511	0.255	0%	0.8	99.7
1.035	0.479	"	1.7	108
1.584	0.689	"	2.6	115
2.107	0.873	"	3.5	120
2.618	1.046	"	4.3	125
3.103	1.202	"	5.1	128

*Acetanilid*

Temp. = 61.7° W = 59.27  
 K(naphthalene) = 37.86 M<sub>0</sub> = 135

w	Δ t	Cor.	%	M
0.832	0.346	0%	1.4	154
1.448	0.556	"	2.4	167
2.168	0.763	"	3.7	181
2.888	0.940	"	4.9	196
3.563	1.094	"	6.0	208
4.233	1.233	"	7.1	219

Temp. = 42.3° W = 58.41  
 K(naphthalene) = 34.24 M<sub>0</sub> = 135

w	Δ t	Cor.	%	M
0.468	0.189	0%	0.8	146
0.986	0.357	"	1.7	162
1.524	0.503	"	2.6	178
2.122	0.640	"	3.6	195
2.718	0.760	"	4.6	220
3.452	0.898	"	5.9	226

Temp. = 26.3° W = 57.78  
 K(naphthalene) = 30.05 M<sub>0</sub> = 135

w	Δ t	Cor.	%	M
0.676	0.232	0%	1.2	151
1.320	0.397	"	1.3	165
2.039	0.547	"	3.5	193
2.739	0.659	"	4.7	216
3.466	0.765	"	6.0	236
3.966	0.862	"	6.9	240

*Acenaphthene*

Temp. = 61.7° W = 60.84  
 K(naphthalene) = 37.86 M<sub>0</sub> = 154

w	Δ t	Cor.	%	M
0.413	0.172	0%	0.7	150
0.769	0.323	"	1.3	148
1.115	0.470	"	1.8	148
1.460	0.610	"	2.4	149
1.780	0.743	"	2.9	149
2.412	1.000	"	4.0	150

*Naphthalene*

Temp. = 61.7° W = 60.53  
 K(naphthalene) = 37.86 M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.644	0.318	0%	1.1	127
1.256	0.621	"	2.1	127
1.845	0.914	"	3.0	127
2.468	1.210	"	4.1	128
3.037	1.488	"	5.0	128
3.620	1.769	"	6.0	128

Temp. = 42.9° W = 58.20  
 K(naphthalene) = 34.36 M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.558	0.267	0%	1.0	123
1.084	0.509	0"	1.9	125
1.643	0.769	0"	2.8	126
2.093	0.972	1"	3.6	127
2.702	1.246	1"	4.6	128
3.302	1.523	1"	5.7	128

Temp. = 26.7° W = 55.88  
 K(naphthalene) = 30.11 M<sub>0</sub> = 128

w	Δ t	Cor.	%	M
0.617	0.249	3%	1.1	133
1.197	0.503	0"	2.1	128
1.712	0.734	0"	3.1	126
2.269	0.965	0"	4.1	127
2.829	1.185	0"	5.1	129
3.419	1.439	1"	6.1	128

*p-Toluidin*

Temp. = 61.7° W = 54.71  
 K(naphthalene) = 37.86 M<sub>0</sub> = 107

w	Δ t	Cor.	%	M
0.523	0.347	0%	1.0	104
1.093	0.725	"	2.0	104
1.630	1.046	"	3.0	107
2.155	1.405	"	3.9	106
2.635	1.705	"	4.8	106
3.155	2.033	"	5.8	107

In all the measurements with *p*-toluidin, chloroform had been standing for some time and give a slight precipitate for chlorin with silver nitrate.

Temp. = 42.7°      W = 59.44  
K(naphthalene) = 34.33      M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.534	0.261	0%	0.9	118
1.034	0.533	"	1.8	112
1.564	0.815	"	2.6	111
2.094	1.082	"	3.7	111
2.648	1.356	"	4.5	112
3.164	1.630	"	5.3	112

Temp. = 26.3°      W = 61.33  
K(naphthalene) = 30.04      M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.475	0.203	0%	0.8	115
0.984	0.444	"	1.6	108
1.493	0.673	"	2.4	108
1.997	0.900	"	3.3	108
2.527	1.127	"	4.1	109
3.083	1.376	"	5.0	109

**Toluene***Urethane*

Temp. = 110.8°      W = 37.84  
K (calc.) = 33.94<sup>1</sup>      M<sub>0</sub> = 89

w	Δt	Cor.	%	M
0.546	0.197	none	1.5	247
1.030	0.378	"	2.7	244
1.582	0.577	"	4.2	245
2.111	0.768	"	5.6	246
2.556	0.927	"	6.7	242
3.901	1.363	"	10.3	254

<sup>1</sup>Beckmann does not list toluene.  
According to Ramsay and Marshall,  
q = 86.8, at 110.8° so

$$K = 0.02(383.8)^2/86.8 = 33.94$$

Temp. = 80.1°      W = 36.44  
K (calc.) = 28.71      M<sub>0</sub> = 89

$$K = 33.94(353/383.8)^2 = 28.71$$

w	Δt	Cor.	%	M
0.522	0.213	0%	1.4	194
1.042	0.416	"	2.9	197
1.818	0.689	"	5.0	207
2.672	0.950	"	7.3	221
3.553	1.190	"	9.8	235
4.016	1.310	"	11.0	242

Temp. 25.0°      W = 35.32  
K (calc.) = 25.04<sup>1</sup>      M<sub>0</sub> = 89

w	Δt	Cor.	%	M
0.641	0.242	0%	1.8	187
1.089	0.296	"	3.1	194
1.541	0.539	"	4.4	203
1.963	0.664	"	5.6	210
2.410	0.780	"	6.8	219
2.898	0.903	"	8.2	227

$$^133.94(329.7/383.8)^2 = 25.04.$$

Temp. = 34.2°      W = 36.79  
K (calc.) = 21.74<sup>1</sup>      M<sub>0</sub> = 89

w	Δt	Cor.	%	M
0.550	0.212	0%	1.5	153
1.727	0.529	"	4.7	193
2.942	0.793	"	8.0	219
3.502	0.916	"	9.5	226

$$^133.94(307.2/383.8)^2 = 21.74$$

*p-Toluidin*

Temp. = 110.8°      W = 37.13  
K (calc.) = 33.94      M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.417	0.301	0%	1.1	127
0.947	0.692	"	2.6	126
1.507	1.099	"	4.1	126
2.050	1.487	"	5.5	127
2.549	1.835	"	6.9	127
2.975	2.115	"	8.0	129



Temp. = 80.5° W = 35.74  
K(calc.) = 28.81 M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.489	0.329	0%	1.4	120
0.996	0.668	"	2.8	120
1.473	0.970	"	4.1	122
1.996	1.297	"	5.6	123
2.447	1.580	"	6.9	125
3.075	1.942	"	8.6	127

Temp. = 56.7° W = 36.95  
K(calc.) = 25.04 M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.497	0.298	0%	1.3	113
0.964	0.568	"	2.6	113
1.514	0.872	"	4.1	115
2.026	1.146	"	5.5	121
2.537	1.405	"	6.9	123
3.065	1.669	"	8.3	125

Temp. = 34.6° W = 38.08  
K(calc.) = 21.84 M<sub>0</sub> = 107

w	Δt	Cor.	%	M
0.530	0.304	0%	1.4	100
0.987	0.550	"	2.6	103
1.532	0.844	"	4.0	104
2.053	1.094	"	5.4	108
2.610	1.347	"	6.8	111
3.167	1.601	"	8.3	113

### Acenaphthene

Temp. = 110.8° W = 36.62  
K(calc.) = 33.94 M<sub>0</sub> = 154

w	Δt	Cor.	%	M
0.547	0.332	0%	1.5	153
1.034	0.622	"	2.8	155
1.415	0.851	"	3.9	154
1.753	1.051	"	4.8	155
2.452	1.452	"	6.7	157
3.094	1.811	"	8.5	159

Temp. = 80.5° W = 36.48  
K(calc.) = 28.81 M<sub>0</sub> = 154

w	Δt	Cor.	%	M
0.637	0.326	0%	1.8	154
1.329	0.680	"	3.6	154
1.963	0.978	"	5.4	155
3.331	1.620	"	9.1	163
4.174	2.005	"	11.4	165

Solution foamed.

Temp. = 56.4° W = 35.35  
K(calc.) = 25.07 M<sub>0</sub> = 154

w	Δt	Cor.	%	M
0.614	0.299	0%	1.7	147
1.232	0.579	"	3.5	154
1.862	0.842	"	5.3	157
2.422	1.080	"	6.9	159
3.065	1.352	"	8.7	161
3.716	1.621	"	10.5	162

Solution foamed.

Temp. = 34.6° W = 37.36  
K(calc.) = 21.84 M<sub>0</sub> = 154

w	Δt	Cor.	%	M
0.570	0.206	0%	1.5	161
1.158	0.451	"	3.1	150
1.800	0.673	"	4.8	157
2.370	0.878	"	6.3	158
2.980	1.096	"	8.0	159
3.618	1.302	"	9.7	162

Solution foamed badly; last two values uncertain.

### Phenanthrene

Temp. = 110.8° W = 38.30  
K(calc.) = 33.94 M<sub>0</sub> = 178

w	Δt	Cor.	%	M
0.550	0.272	0%	1.4	178
1.120	0.550	"	2.9	179
1.634	0.787	"	4.3	183
2.788	1.295	"	7.3	195

Temp. = 80.5° W = 36.23  
K(calc.) = 28.81 M<sub>0</sub> = 178

w	Δt	Cor.	%	M
0.638	0.311	0%	1.8	163
1.303	0.621	"	3.6	167
1.941	0.914	"	5.4	169
2.609	1.218	"	7.2	170
3.277	1.501	"	9.0	174
3.936	1.779	"	10.9	176

Solution foamed.

Temp. = 57.0° W = 36.01  
K(calc.) = 25.14 M<sub>0</sub> = 178

w	Δt	Cor.	%	M
0.520	0.219	0%	1.4	165
1.833	0.782	"	5.1	164
2.532	1.039	"	7.0	170
3.323	1.328	"	9.2	174
4.095	1.593	"	11.4	179

Solution foamed.

Temp. = 34.3° W = 38.70  
K(calc.) = 21.74 M<sub>0</sub> = 178

w	Δt	Cor.	%	M
0.791	0.373(?)	0%	2.0	120(?)
1.418	0.198	"	3.7	179
2.091	0.398	"	5.4	184
2.794	0.598	"	7.2	192
3.459	0.792	"	8.9	191
4.072	0.962	"	10.5	193

Foamed very badly, so results are not certain. First result so different from others that it is calculated separately.

### Naphthalene

Temp. = 110.8° W = 36.55  
K(calc.) = 33.94 M<sub>0</sub> = 128

w	Δt	Cor.	%	M
0.706	0.479	0%	1.9	136
1.197	0.820	"	3.3	135
1.679	1.139	"	4.6	136
2.161	1.452	"	5.9	137
2.615	1.751	"	7.2	137
3.447	2.264	"	9.4	141

Temp. = 81.0° W = 36.15  
K(calc.) = 28.91 M<sub>0</sub> = 128

w	Δt	Cor.	%	M
0.743	0.442	0%	2.1	134
1.442	0.854	"	4.0	135
2.242	1.313	"	6.2	136
3.030	1.750	"	8.4	138
3.843	2.190	"	10.6	139
4.604	2.597	"	12.8	142

Temp. = 56.7° W = 38.62  
K(calc.) = 25.04 M<sub>0</sub> = 128

w	Δt	Cor.	%	M
0.502	0.260	0%	1.3	125
1.022	0.526	"	2.6	124
1.616	0.792	"	4.2	134
2.211	1.062	"	5.7	136
2.792	1.322	"	7.2	137
3.411	1.599	"	8.8	139

Temp. = 35.0° W = 36.76  
K(calc.) = 21.94 M<sub>0</sub> = 128

w	Δt	Cor.	%	M
0.527	0.238	0%	1.4	132
1.064	0.494	"	2.9	129
1.590	0.722	"	4.3	132
2.156	0.949	"	5.9	135
2.740	1.192	"	7.4	137
3.323	1.460	"	9.0	135

Foamed. Last value uncertain.