

THE SURFACE TENSION OF SOAP SOLUTIONS
AND
THEIR EMULSIFYING POWER

by

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THE SURFACE TENSION OF SOAP SOLUTIONS
AND
THEIR EMULSIFYING POWER.

The work on this subject was started from a special interest in the theory, as suggested in treatises of General Chemistry, especially that of Alexander Smith's, explaining the cleansing action of soap by the emulsifying power of the soap solution, the emulsifying power in turn being due to the low surface tension of the solution. Thinking on the last part of the statement, suggestions were made for experiments to establish the relation between the surface tension and the emulsifying power of the solutions.

In the history of the study of soap solutions Chevreul¹³ is credited with having been the first to study the fats and soaps and the reaction which occurs when they are acted on by water. His conclusions "that when soaps are acted on by water they are hydrolyzed to free alkali and to an acid salt", according to Hillyer, are borne out by later workers.

Many theories as to the cleansing power of soaps and soap solutions have been brought forward, among them the saponification theory in which it is claimed "that the alkali set free by the hydrolysis of the soap acts on the fat to remove it by a process of saponification". Another theory is that "alkali of hydrolysis acts in such a way as to allow contact of the water with the substance to be cleansed". A third theory "is that the alkali of hydrolysis acts as a lubricant,

making the tissues and impurities less adhesive to one another and in that way promoting the removal of the latter". A fourth theory states "that the alkali set free by hydrolysis acts on the fat by emulsifying it, and carrying it away in suspension with the other impurities"¹³. These theories are all considered in turn by Hillyer and each one is shown to be untenable. The last one he quickly nullifies by showing that both kerosene and purified cotton-seed oil easily make permanent emulsions with a deci-normal solution of sodium-oleate but are not emulsified by a deci-normal solution of an alkali. However the idea of the action of soap being due to its emulsifying power seemed plausible and Hillyer planned experiments to determine what properties a liquid should have to be a good emulsifying agent. "The great similarity between foams and emulsions in method of making and in properties, suggests the question whether any explanation given for formation and permanence of foams will not also apply to the formation and permanence of emulsions". Hillyer first confirmed the work of Quincke and Pleateau showing "in general the tendency which solutions of high viscosity and low surface-tension have^{to make} foams". In considering the question of the viscosity of the emulsifying agent being the explanation of the cause of emulsion Hillyer points out that "in the case of very thick liquids like the gum solutions used by pharmacists, it is probable that the viscosity is a very large factor in giving permanence to the separation of the oil droplets which have been formed mechanically ". But on the other hand "That even very large internal viscosity will not make an emulsion permanent is shown by the fact that 50% glycerin and 6%

gum solutions which have viscosity of a high degree will not emulsify kerosene or even a viscous oil like cotton oil. Dilute soap solutions which have not great viscosity have very great emulsifying power, and the same is true to a less degree of some other solutions. From these facts it must be decided that internal viscosity of the liquid will not account for its emulsifying power". To determine the relation of surface tension to emulsifying power, the surface tension of soap solutions was then studied by Hillyer by means of the dropping method, in which he made use of a stalagmometer. The soap solutions were allowed to flow down through oils, from the stalagmometer the tip of which dipped below the surface of the oil. Twelve different oils were used and the number of drops formed by allowing 5.35 c.cm. of each oil to flow down through a certain kerosene were noted. The same procedure was repeated allowing the liquids to flow down through a carefully purified cottonseed oil. The number of drops formed by the same amount of each liquid flowing down through the kerosene or cottonseed oil furnished a quantitative relation of the surface tensions of the liquids. Each liquid was then shaken separately with the kerosene and with the cottonseed oil to see if an emulsion were formed and by what liquids. Table No.1 shows the results of Hillyer's experiments column 1, being the liquid used, column 2, the number of drops 5.35 c. cm. of it formed in flowing down through the kerosene, column 3 shows by † and - and "Little" whether an emulsion were formed in kerosene. Columns 4 and 5 show the same for cottonseed oil respectively that 2 and 3 show for kerosene.

TABLE NO 1.

	Drops in Kerosene	Emul. in K.	Drops in Cotton- seed oil.	Emul. in oil.
Water -----	17	---	9	---
Stale beer -----	39	Little --		---
Sweet skimmed milk -----			52	+
Saponin -----			13	+
Acacia -----			14	+
Alcohol and NaOH -----	51	Little ---		---
N/640 sodium oleate -----	26	Little ---		---
N/10 sodium oleate -----	296	+	167	+
N/10 rosin soap -----	310	+	180	+
N/10 sodium chloride ---	17	---		---
N/10 sodium hydroxide --	17	---	10	---
Sodium silicate -----			15	---

From these data it is apparent at a glance that the liquids forming emulsions were those having the smaller surface tension and also in the case of the sodium oleate the more dilute solution had a larger surface tension with a smaller emulsifying power.

Bancroft² quoting Hillyer says, "the conclusion arrived at is that emulsification is due largely to the small surface tension between the oil and the emulsifying agent which allows the emulsifying agent to be spread out into thin films, separating the oil droplets. The surface tension is not strong enough to withdraw the film from between the droplets except slowly and, if the emulsifying agent has great internal viscosity or if great superficial viscosity is shown between the liquids, the thinning of the film becomes so slow that the emulsion is permanent."

Hillyer's views correspond very closely with those of Donnan, except that Hillyer lays more stress on the importance of viscosity or of surface viscosity".

While Hillyer's experiments establish the fact that there is a relation between the surface tension of a solution and its emulsifying power, the purpose of the present work was to carry out a set of experiments by another method to show the relationship more fully. The plan of the work described in detail in this paper was to secure data on the surface tensions of pure soap solutions, measured in contact with air by the rise in capillary tubes. And also to determine the emulsifying power by shaking by hand for several minutes with different oils, and recording the time of noticeable separation. Data were also to be secured for solutions of Ivory soap and for the effect of adding sugar and glycerine to the solutions. The first step was to prepare the pure soaps which was done in the following manner:--

41.16 grams of pure Palmitic acid were dissolved in 225 c.cm. of 95 percent ethyl alcohol. According to the equation, $2C_{15}H_{31}COOH / Na_2CO_3 = 2C_{15}H_{31}COONa / H_2CO_3$, a calculated slight excess of sodium carbonate was dissolved in distilled water, heated to boiling and added to the solution of alcohol and acid. This was evaporated to dryness and a portion of the residue was dissolved in another 200 c.cm. This solution was heated and filtered to remove excess sodium carbonate. The filtrate was again evaporated to dryness. The resulting residue was again dissolved in 200 c.cm. of alcohol, heated and filtered. The filtrate upon cooling formed the pure sodium

palmitate which was allowed to dry for a week at room temperature to free from alcohol.

Pure sodium stearate was made in exactly the same manner using only one-fourth the amounts used in the preparation of the sodium palmitate. The purity of the soaps was tested by the generally accepted method of determining the amount of water, fatty acid, and alkali present.

From Vol. 11¹ of the Fourth edition of Allen's Commercial Organic Analysis a method was obtained for the determination of the fatty acid present in a soap solution. Experiments were made to determine just how concentrated the solutions of these soaps might be made without becoming gelatinous upon cooling. When this was determined the solutions were made up. Beakers the correct size to hold approximately enough of the solution to yield - .2500 of a gram of the precipitated fatty acid were secured and with a glass rod stirrer were accurately marked and weighed. Gooch crucibles were prepared and weighed successively after an hour's heating each time in an electric oven at 110°C, until constant weight was obtained. The method of determination of the fatty acid present in the soap solution was to decompose the aqueous solution of the soap by adding an excess of 5 c.cm. or 10 c.cm. of Normal sulphuric acid, heating the solution, and allowing it to stand over night or until the solid fatty acid should separate. This solid fatty acid was then to be collected in the Gooch crucible by means of the suction pump and finally heated an hour at 110°C. in the electric oven. In order to secure accurate data it was necessary to know the effect of heat on the two fatty acids under consider-

ation. Duplicate trials were made for both the palmitic acid and stearic acid. A known weight of the acid was placed in a porcelain crucible (previously brought to constant weight) and heated to $110^{\circ}\text{C}.$, for hour intervals for four successive times. The following tabulated data, Table No.2, show that for palmitic acid there was an average loss per hour per .1 of a gram of .0009 of a gram. For the stearic acid the average loss per hour per .1 of a gram was .0012 of a gram.

TABLE NO.II.

Crucible no.	I	II	III	IV.
Weight	7.9860gr.	8.9615gr.	6.7640gr.	6.1875gr
Wgt.of cruc. and $\text{C}_{15}\text{H}_{31}\text{COOH}$	8.2282gr.	9.2310gr.		
Wgt.of cruc. and $\text{C}_{17}\text{H}_{35}\text{COOH}$			6.9790gr.	6.7528gr
Wgt.after 1 hr. at $110^{\circ}\text{C}.$	8.2258gr.	9.2205gr.	6.9746gr.	6.7486gr
Wgt.after 1 hr. more at $110^{\circ}\text{C}.$	8.2220gr.	9.2198gr.	6.9684gr.	6.7288gr
Wgt.after 1 hr. more at $110^{\circ}\text{C}.$	8.2167gr.	9.2194gr.	6.9612gr.	6.7280gr
Wgt.after 1 hr. more at $110^{\circ}\text{C}.$	8.2155gr.	9.2172gr.	6.9604gr.	6.7172gr

Tabulated data for the results of fatty acid determinations for two separate trials for both sodium palmitate and sodium stearate follow. Table No.III shows results for the 1st.trial and Table No.IV shows the results of 2nd. trial.

TABLE NO. III.

Number	I	II	III	IV
Sol. used.	Sodium palmitate	Sodium palmitate	Sodium stearate	Sodium stearate
Gr. per 100 c. cm.	.2509gr.	.2509	.2571	.2571
Am't. of Sol. used.	100c. cm.	100c. cm.	100c. cm.	100c. cm.
Excess of N.H ₂ SO ₄ used	10c. cm.	10c. cm.	10c. cm.	10c. cm.
Wgt. of fatty acid found.	.2222gr.	.2205gr.	.2303gr.	.2867gr.*
Wgt. of fatty acid calculated.	.2303gr.	.2303gr.	.2386gr.	.2386gr.

*Discarded.

TABLE NO. IV.

Number	I	II	III	IV
Sol. used.	Sodium palmitate	Sodium palmitate	Sodium stearate	Sodium stearate
Gr. per 100c. cm.	.1323	.1323	.1260	.1260
Am't of sol. used.	50c. cm.	50c. cm.	50c. cm.	50c. cm.
Excess of N.H ₂ SO ₄ used.	5c. cm.	5c. cm.	5c. cm.	5c. cm.
Wgt. of fatty acid found.	.0285gr.	.0287gr.	.0565gr.	.0600gr.
Wgt. of fatty acid calculated.	.0609gr.	.0609gr.	.0584gr.	.0584gr.

The difference in value between the weight of fatty acid calculated and the weight of fatty acid found is due to the

moisture content of the soap. By means of this determination the exact weight of sodium palmitate or of sodium stearate used in making solutions from these samples is easily calculated.

To determine the alkali present the filtrates were saved in each case of fatty acid determination, and the excess of normal sulphuric acid not neutralized by the alkali present was titrated back against .987 normal sodium hydroxide. The results are shown in Tables No.V and No. VI.

TABLE NO. V.
Trial No.I.

Number	I	II	III	IV	
*					*Titrated with .987 normal NaOH.
C.Cm. to titrate	9.15	9.26	9.20	9.20	
C.Cm. total alkali	.98	.871	.931	.931	

TABLE NO. VI.
Trial No. II.

Number	I	II	III	IV	
*					*Titrated with .987 normal NaOH.
C.Cm. to titrate	5.00	5.10	4.90	4.90	
C.Cm. total alkali	.0655		.1655	.1655	

With no alkali present the 10c.cm. of normal sulphuric in the first four cases would have used 10.131c.cm. of .987 normal sodium hydroxide. Also in the last four cases the amount of .987 normal sodium hydroxide needed would have been 5.0655c.cm. The difference in each case represents the total

alkali present.

The surface tension of the soap solutions was measured by the rise in capillary tubes, the solution being in contact with air. By means of a cathetometer accurate measurements of the distance between the lowest part of the meniscus in the tube and the surface of the solution to be measured, were secured.

The surface tension is measured in dynes per centimeter, the formula for making the calculations being

$\frac{r h d g}{2} =$ surface tension, where

$r =$ radius of the capillary tube,

$h =$ height to which the liquid rises,

$d =$ density of the solution at the temperature of measurement,

$g =$ gravitational acceleration in $\frac{\text{cm.}}{\text{sec}^2}$

These calculations give correct results only if the meniscus shows an even curvature and is hemispherical, forming thus an angle of 0° with the walls of the tube. If this condition is not realized, if the angle made by the last portions of the liquid and the walls is θ , then $\frac{r h s}{2} = y \cos \theta$, according to Bigelow's Theoretical Physical Chemistry. In these measurements correction for the angle made by the liquid and the wall of the vessel was made by adding $\frac{r}{3}$ to the height in each reading because the volume occupied by the meniscus (estimated by means of a meniscus drawn on cross section paper and counting the number of squares) occupies approximately one third the entire volume of the tube between the highest and lowest portions of the meniscus. Since in an ideal or hemispherical meniscus the height would equal the radius, $\frac{r}{3}$, being known, was used instead of

$\frac{h}{3}$ which would have had to be determined in each case.

For these experiments, capillary tubing of six different sizes was secured. Three tubes approximately four inches in length were cut from each size of tubing and marked as set I, set II, etc, up to and including set VI. Then each tube of each set was marked again with one, two, or three marks identifying each tube definitely, for example as number two of the second set or as number two of the fourth set.



No. 2 of the second set.

No.2 of the fourth set.

The diameters of the capillary tubes were next measured by means of a micrometer microscope. A table was made out and the measurement, for example, of the top of tube two of the second set was recorded, then the measurement of the bottom of the same tube was recorded and the average calculated and recorded also. This was done for each of the eighteen tubes.

The micrometer microscope was first calibrated by making several trials of the number of turns of a transverse screw near the upper end, to move the cross hairs, (carried inside the microscope by the screw) across the distance between the divisions on the image of a scale divided into half millimeters. Since it would be confusing to attempt counting the actual number of turns of the screw to move the cross hairs over a half millimeter image the following method was used.

A comb-like arrangement, with its notches so spaced that exactly one turn of the screw moves the cross-hairs one notch, is placed inside the microscope in the same plane as the cross hairs. For convenience every fifth notch is deeper than the others.

The circular head of the transverse screw is divided so as to show hundredths of a turn. By adjustment the screw may be placed at zero when the cross hairs are on any notch. Then by taking the deepest notch at the left of the comblike arrangement as zero and placing the cross hairs on the first image of the scale the number of notches, that is, the number of whole turns of the screw the scale division is from the zero point may be instantly read off and recorded as a whole number, and the number of hundredths may be read from the circular head of the screw and recorded as the decimal part of the number. Turning the screw until the cross-hairs are on the next image of the scale the second reading is made and recorded and so on as far across the scale as possible. This was repeated four times and the average was recorded for the first scale reading, for the second etc. Finally the differences of the average readings for the first and second divisions, for the second and third divisions etc., each gave a determination of the number of turns necessary to move the cross-hairs over the image of one half a millimeter. The average of the determinations multiplied by two gives the calibration constant of the micrometer microscope, which was fourteen for this microscope.

The measurements of the diameters of the capillary tubes

were made by placing the tubes on end on the base of the micrometer microscope having the bore exactly vertical. The microscope was focused on ^{the} top of the tube and readings of the number of notches between the positions of the cross-hairs when they were at opposite ends of an exact diameter of the tubes were recorded in the table mentioned. The opposite end of the tube was measured in the same way. The average of these two readings was calculated and recorded, this average divided by the calibration constant of the micrometer microscope gave the diameter of the tube in millimeters. Table No. VII shows an actual record of the measurements of diameters of tubes used in these experiments:

TABLE NO. VII.

	Top	Bottom	Average	Diameter
Tube No. I				
Ist. Set.	10.02	10.58	10.30	.735
2nd. Set.	20.58	28.08	27.83	1.98
3rd. Set.	29.655	30.25	29.95	2.14
4th. Set.	42.16	42.609	42.384	3.027
5th. Set.	45.619	45.14	45.374	3.24
6th. Set.	10.49	10.17	10.33	.736
Tube No. II.				
Ist. Set.	10.13	10.11	10.12	.721
2nd. Set.	27.80	27.37	27.565	1.968
3rd. Set.	30.32	29.97	30.145	2.153
4th. Set.	42.36	42.684	42.52	3.037
5th. Set.	46.41	46.71	46.56	3.325
6th. Set.	10.56	10.75	10.655	.761

TABLE NO.VII.

Continued.

	Top	Bottom	Average	Diameter
Tube No.III				
1st.Set.	9.635	10.22	9.927	.709
2nd.Set.	27.33	27.77	27.55	1.967
3rd.Set.	30.38	30.47	30.425	2.173
4th.Set.	42.635	42.64	42.637	3.045
5th.Set.	45.04	45.029	45.035	3.216
6th.Set.	10.48	10.22	10.35	.739

To obtain the data for the comparative emulsifying power several trials were made attempting to secure the emulsion by a stirring motion. It was difficult to keep the stirring motion uniform and it was finally decided that shaking by hand for a specified time would be the best method. In the literature it was found that at least two ^{9 2} different experimenters had used mechanical shakers for makings emulsions. Twenty cubic centimeter graduated cylinders fitted with rubber stoppers were used for the containers. Three trials were made for each soap solution of which the surface tension had been measured. Ten cubic centimeters of the solution were placed in the cylinder and two cubic centimeters of linseed oil added. The mixture was then shaken by hand for five minutes and the time of noticeable separation observed and recorded. The trials were repeated using five cubic centimeters of the linseed oil instead of two. The same procedure was repeated for the experiment using two and five cubic centimeters of kerosene in the place of the linseed oil. The surface tension and specific gravity of

both the linseed oil and the kerosene had been measured.

In order to test the accuracy of the tube measurements and to insure that all of the apparatus for the measurements of the surface tensions was satisfactory, several liquids (which wet the surface of capillary tubes dipped into them) were measured in contact with air and the capillary rise recorded.

Table No. VIII shows the surface tensions calculated from this data compared with data by other observers.

TABLE NO. VIII.

Liquid	H ₂ O	99.5% C ₂ H ₅ OH	CHCL ₃	C ₃ H ₅ (OH) ₃	CH ₃ COCH ₃
Temp.	27.5° C.	23.° C.	20.5° C	25.° C.	24.5° C.
Density		.788	1.483	1.226	.795
No. of trials	4	2	3	2	8
Ave. Surf. tension.	72.00	21.74	28.20	55.27	22.80
Other values.	71.4	21.7	26.7	65.2	23.3
Temp.	30.° C.	20.° C.	20.° C	18.° C	17.6° C.
Observer	Smith-sonian tables.	Smith-sonian tables.	Magie	Cantor	Jaeger.

Three solutions of pure soap were made, one solution, E, contained 1.0120 grams of sodium palmitate in six hundred c.cm. of water. The second solution, F, contained .6212 grams of sodium stearate in four hundred c.cm. of water, and the third solution, G, contained .5075 grams of sodium palmitate in four hundred c.cm. of water. Solutions E₁, E₂, E₃, and E₄, were made from solution E as a basis making each just one-half as

concentrated as the preceding one. In the same manner solutions, F_1 , F_2 , F_3 , and F_4 , and solutions G_1 , G_2 , G_3 , and G_4 were made.

The measurement of the surface tension of each solution was made using nine of the capillary tubes for each solution, the temperature being kept as nearly at 25°C , as possible, a twentieth degree thermometer ranging from 16°C to 34°C . standing always in the solution being measured.

The data for each series of solutions both for surface tension and for emulsifying power arranged in tabular form appear on separate sheets in the order named, with accompanying graphs on the next sheet. In the case of surface tension data, concentration of the solution is shown as abscissae plotted against surface-tension as ordinates. In the case of emulsifying power data, the concentration of the solution is again plotted as abscissae against the time of noticeable separation as ordinates.

Table No. IX shows the data for the surface tensions of solutions of Sodium stearate, Series F.

TABLE NO. IX

Sol. used.	F	F_1	F_2	F_3	F_4
Temperature	25°C .	25°C	25°C	25°C	25°C .
Grs. per 100 c.cm.	.1553	.07765	.0388	.0194	.0097
Density	1.00038	1.00030	1.000256	1.00020	1.00017
No. of trials	8	9	8	8	6
Average Surf-tens.	21.978	26.283	30.658	34.985	39.339

Graph for Table No.IX

Surface-
tension,
in dynes
per cm.

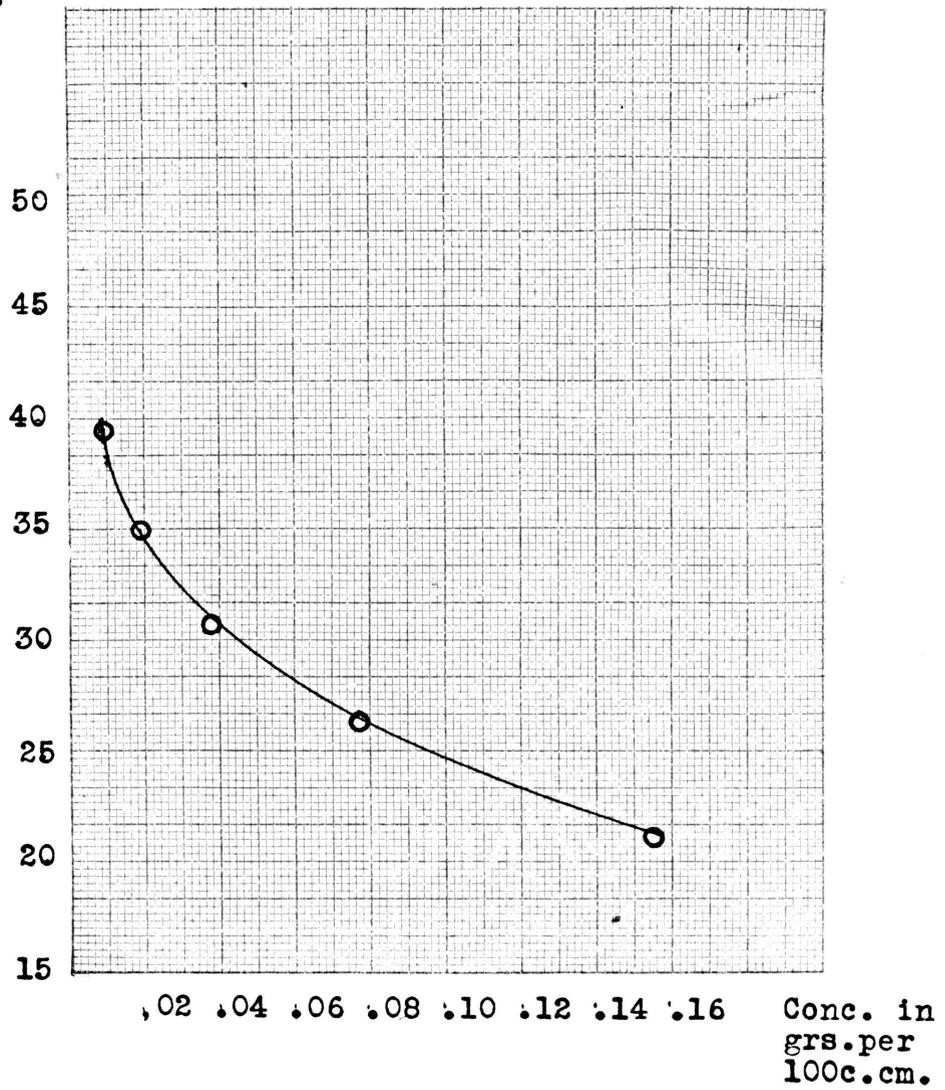


Table No.X shows the data for the surface tensions,
of solutions of Sodium palmitate, Series E.

Table No. X

Sol. used.	E	E ₁	E ₂	E ₃	E ₄
Temperature.	25 ^o C.	25 ^o C.	25 ^o C.	25 ^o C.	25 ^o .
Grs. per 100c.cm.	.16866	.08433	.04216	.02108	.01054
Density.	1.0004	1.00023	1.00017	1.00013	1.00010
No. of trials.	9	8	8	8	7
Average Surf-tens.	20.223	26.869	31.977	43.230	49.694

Graph for Table No.X

Surface-tension,
in dynes
per cm.

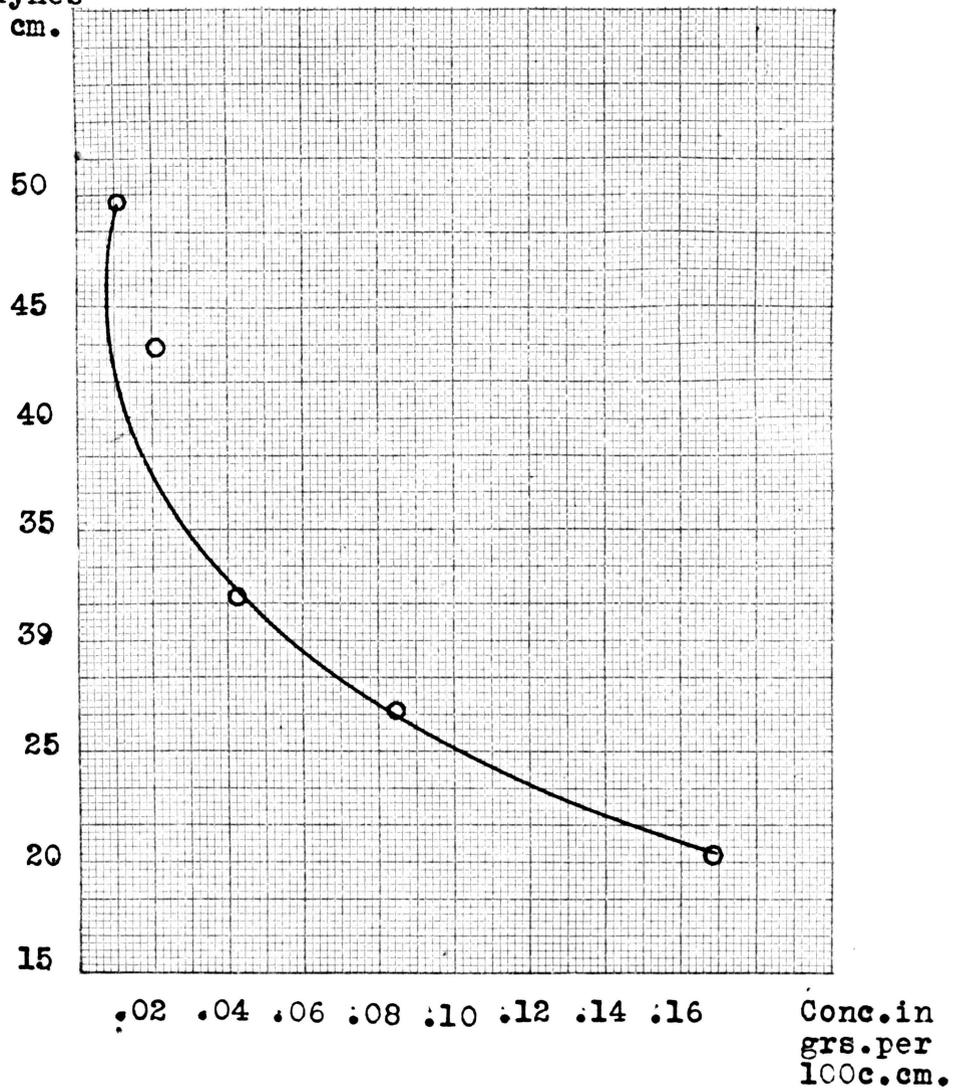


Table No, XI shows the data for the surface tensions of solutions of Sodium palmitate, Series G.

Table No. XI

Sol. used.	G	G ₁	G ₂	G ₃	G ₄
Temperature.	25 ^o C.	25 ^o C.	25 ^o C.	25 ^o C	25 ^o C.
Grs. per 100c.cm.	.1269	.06345	.03172	.0158	.0079
Density.	1.00032	1.00026	1.00019	1.00014	1.00010
No.of trials.	7	5	6	6	7
Average Surf-tens.	21.307	29.142	34.609	38.707	46.438

Graph for Table No. XI

Surface-tension,
in dynes
per cm.

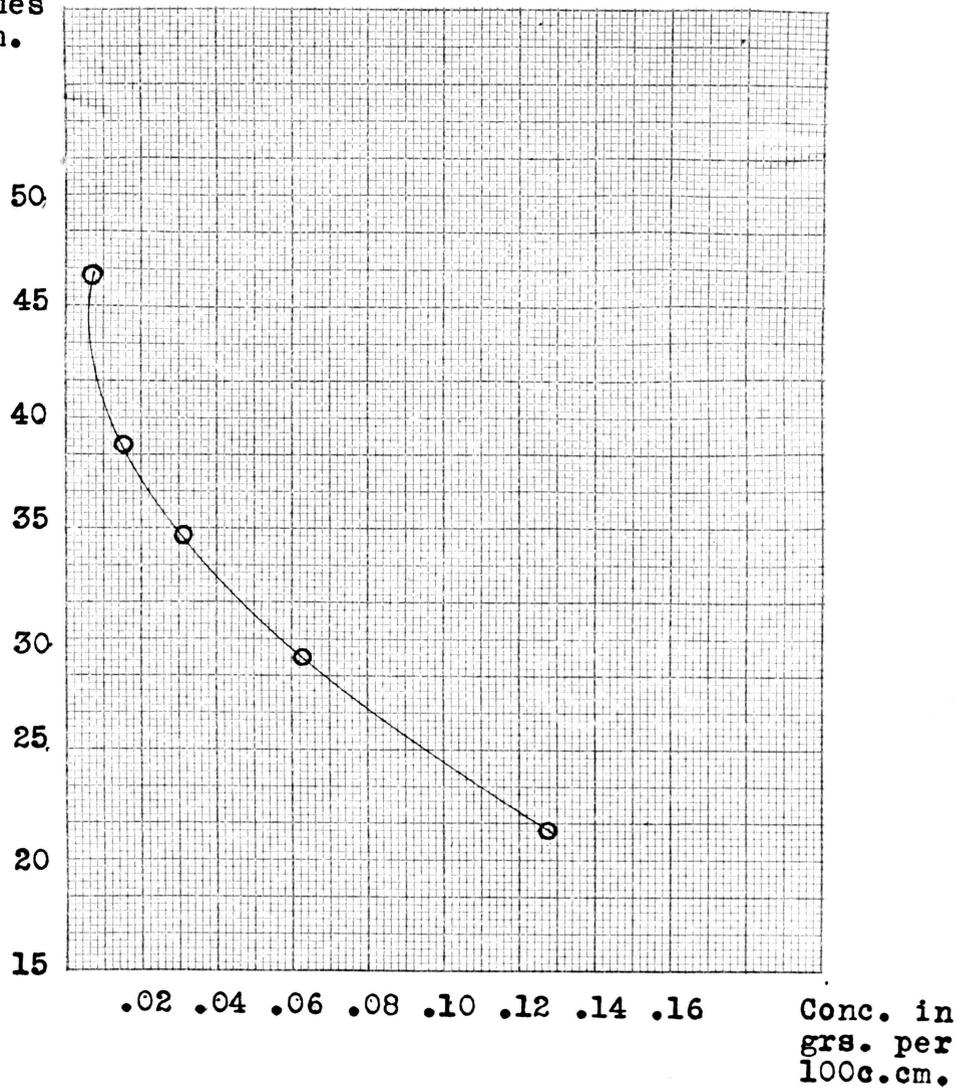


Table No. XII shows the data for the Emulsifying power of solutions of Sodium stearate, shaken with two cubic centimeters of kerosene, specific gravity .813.

Table No. XII

Sol. used.	F	F ₁	F ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1553	.07765	.0388
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	* 18.02 min.	* 10.85 min.	* 1.66 min.

* Average of three readings.

Graph for Table No. XII

Time of
noticeable
separation
in minutes.

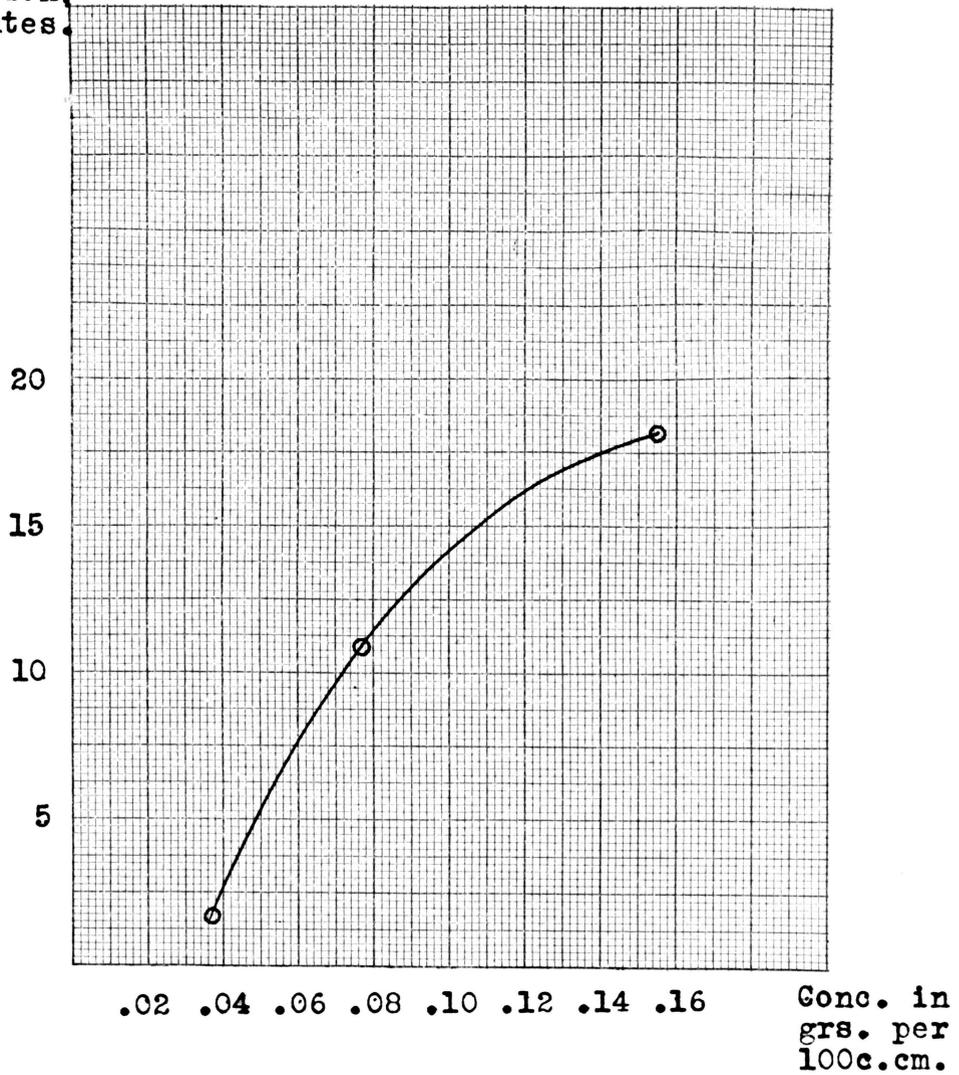


Table No. XIII shows data for the emulsifying power of solutions of Sodium palmitate, shaken with two cubic centimeters of kerosene, specific gravity.813.

Table No. XIII

Sol. used.	E	E ₁	E ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1686	.0843	.0421
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	5.11 min.*	3.90 min.*	3.10 min.*

* Average of three readings.

Graph for Table No. XIII

Time of
noticeable
separation,
in minutes.

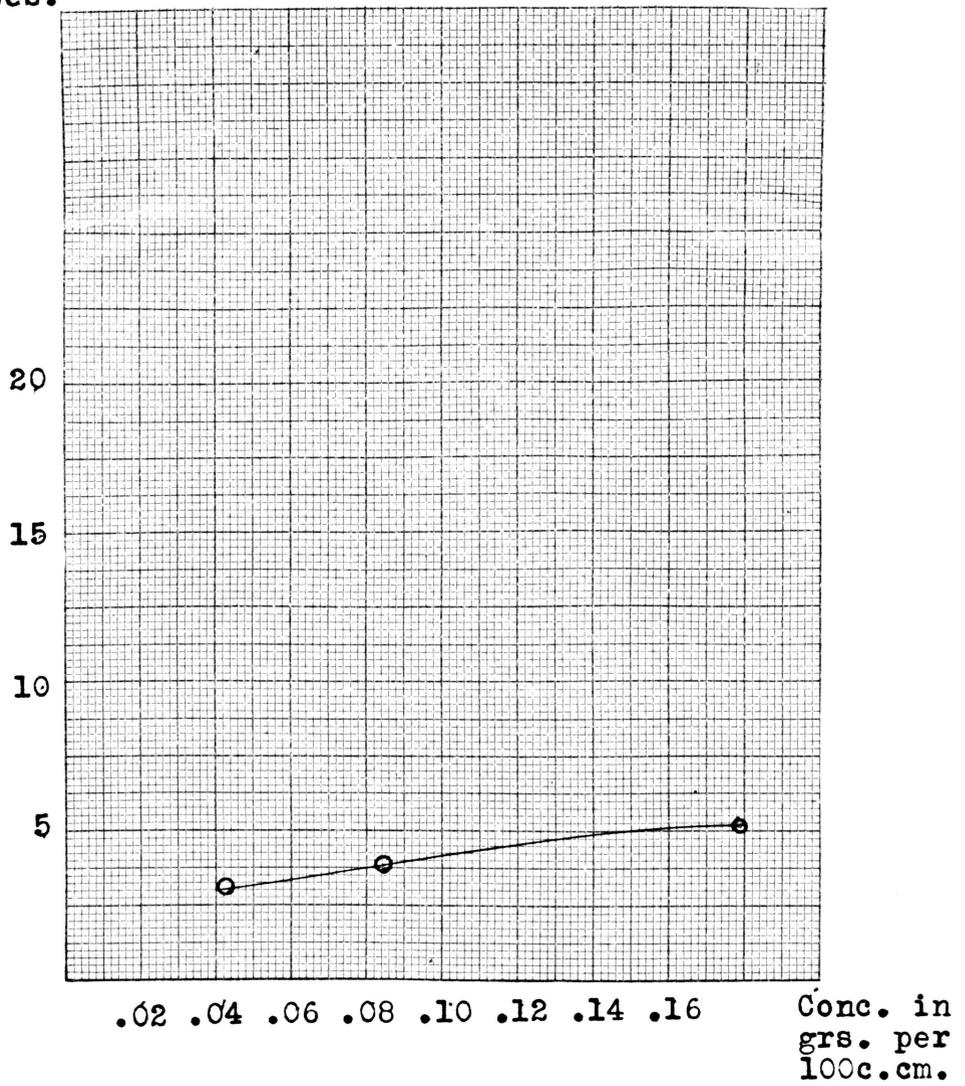


Table No. XIV shows data for the emulsifying power of solutions of Sodium stearate, shaken with five cubic centimeters of kerosene, specific gravity .813.

Table No. XIV

Sol. used.	F	F ₁	F ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1553	.07765	.0388
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	16.35 min.*	2.29 min.*	.66min.*

* Average of three readings.

Graph for Table No.XIV.

Time of
noticeable
separation,
in minutes.

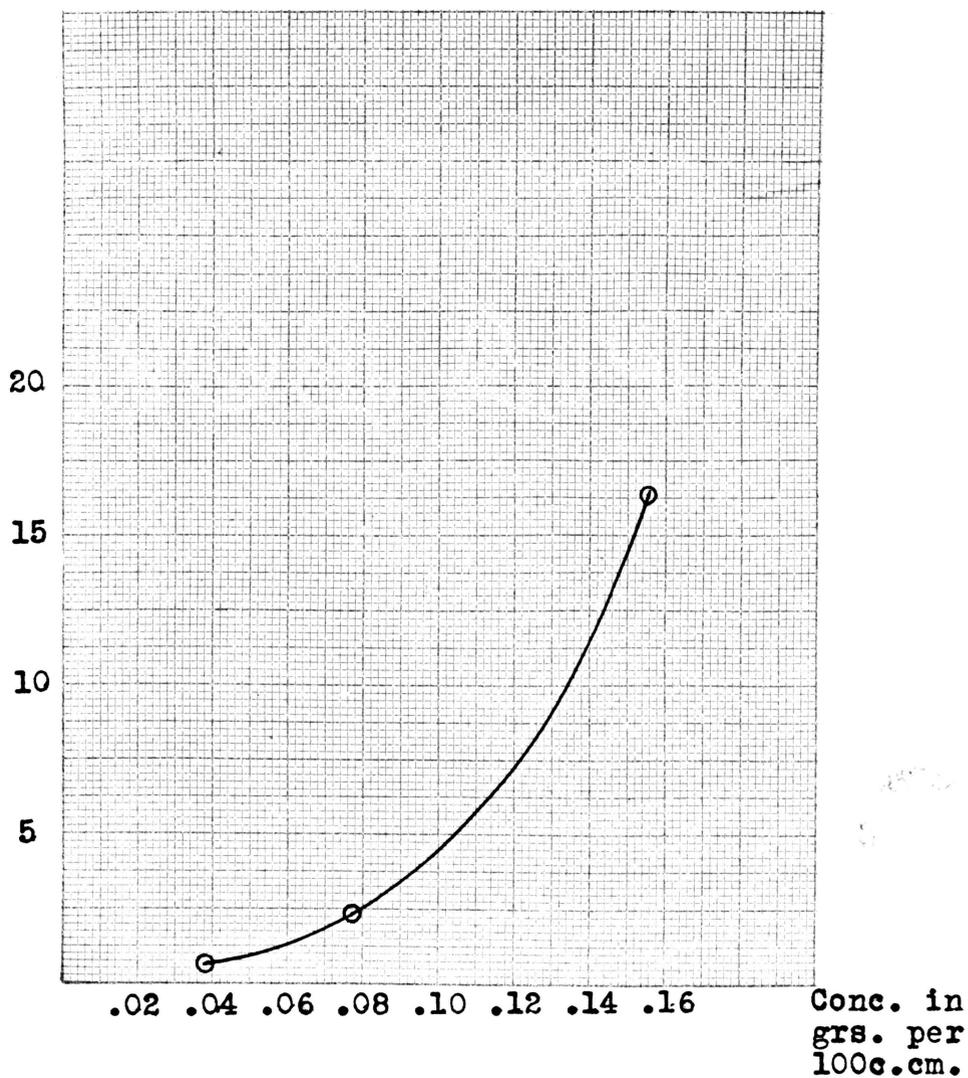


Table No. XV shows data for the emulsifying power of solutions of Sodium palmitate, shaken with five cubic centimeters of kerosene, specific gravity.813.

Table No. XV

Sol. used.	E	E ₁	E ₂
Am't used.	10 c. cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1686	.0843	.0421
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	.647 min.*	.51 min.*	.44 min.*

* Average of three readings.

Graph for Table No. XV.

Time of
noticeable
separation,
in minutes.

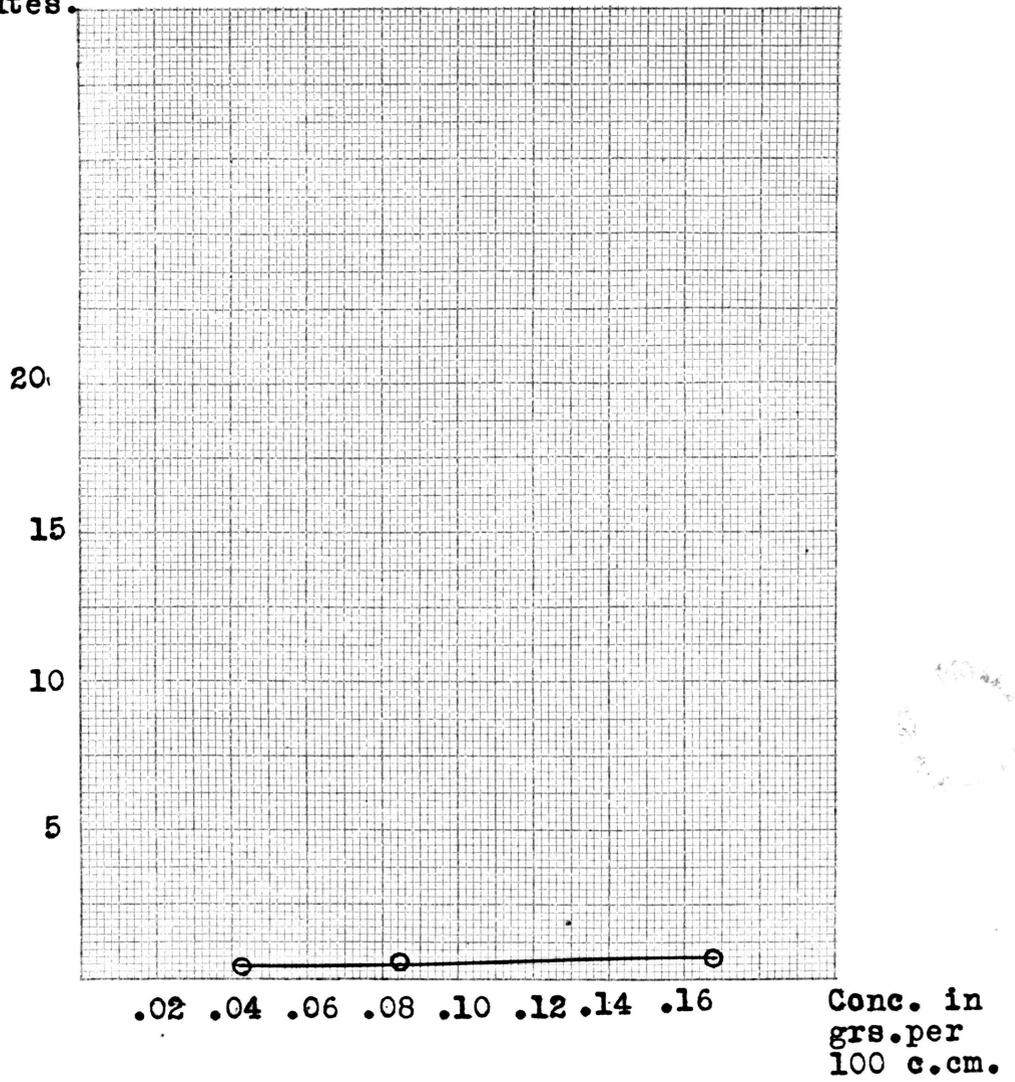


Table No. XVI shows data for the emulsifying power of solutions of Sodium stearate, shaken with two cubic centimeters of linseed oil, specific gravity .923.

Table No. XVI

Sol. used.	F	F ₁	F ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1553	.07765	.0388
Time shaken.	5 min.	5min.	5 min.
Time of noticeable separation.	9.76 min.*	5.08 min.*	1.47 min.*

* Average of three readings.

Graph for Table No. XVI

Time of
noticeable
separation,
in minutes.

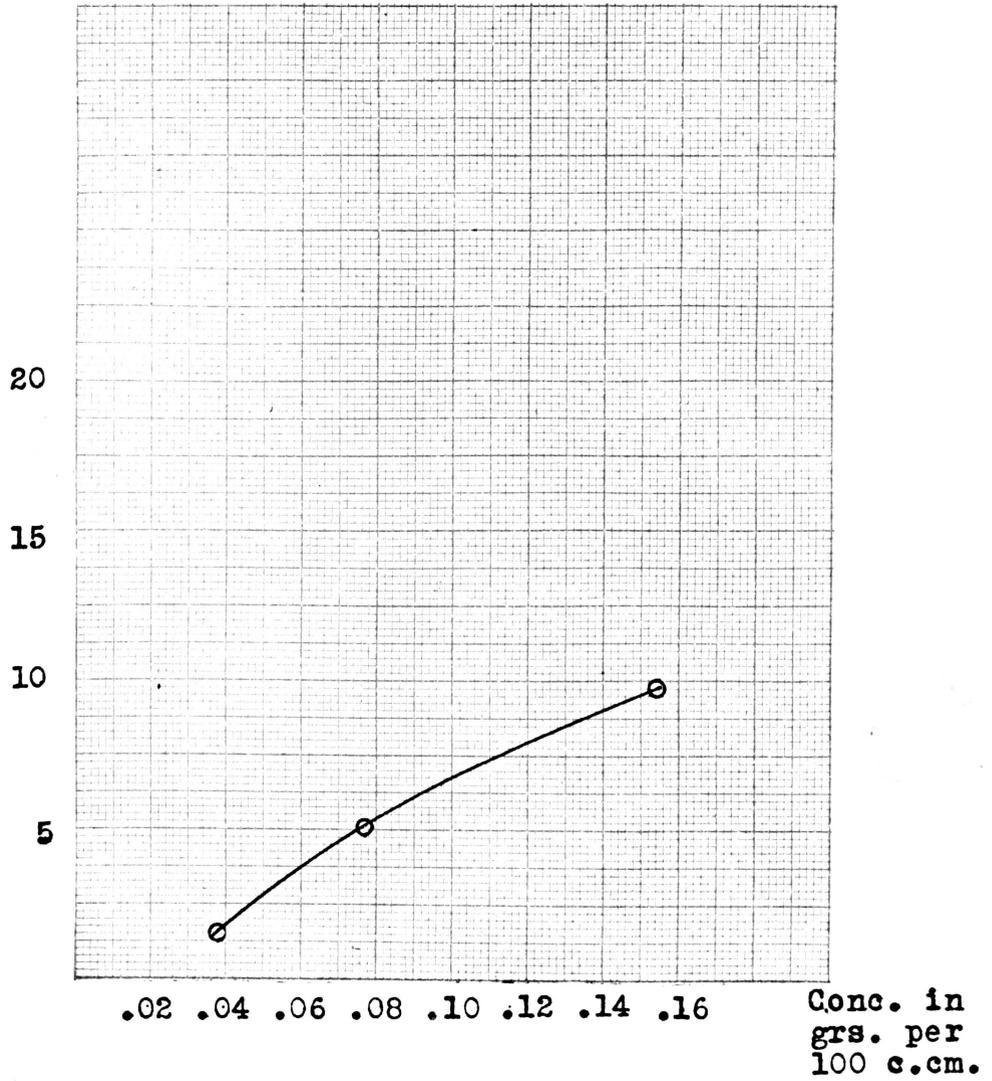


Table No. XVII shows data for the emulsifying power of solutions of Sodium stearate, shaken with two cubic centimeters of linseed oil, specific gravity.923.

Table No. XVII

Sol. used.	G	G ₁	G ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1269	.0634	.0317
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	4.51 min.*	2.22 min.*	1.77 min.*

* Average of three readings.

Graph for Table No. XVII

Time of
noticeable
separation,
in minutes.

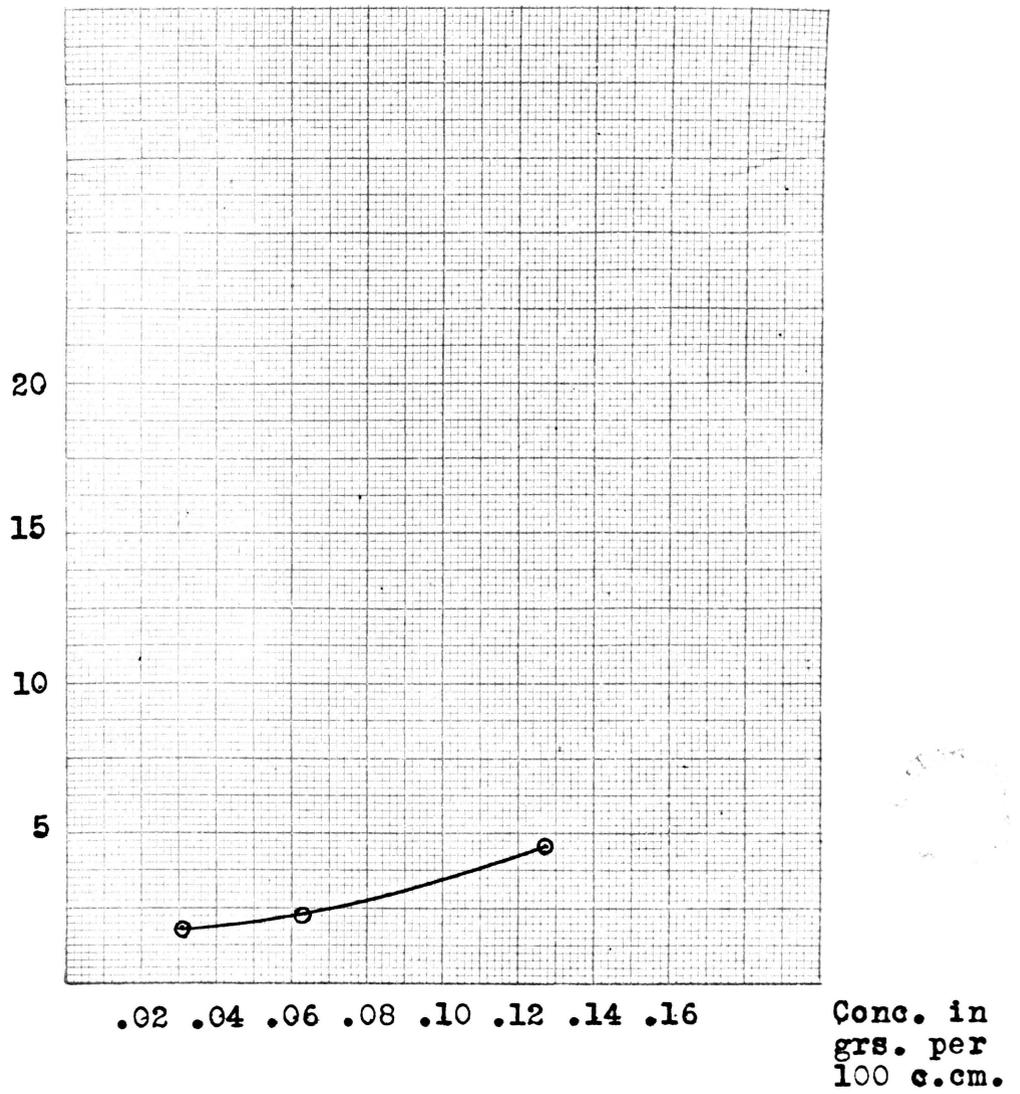


Table No. XVIII shows data for the emulsifying power of solutions of Sodium stearate, shaken with five cubic centimeters of linseed oil, specific gravity .923.

Table No. XVIII

Sol. used.	F	F ₁	F ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c. cm.	.1553	.0776	.0388
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	18 min.*	5.10 min.*	.67 min.*

* Average of three readings.

Graph for Table No. XVIII

Time of
noticeable
separation,
in minutes.

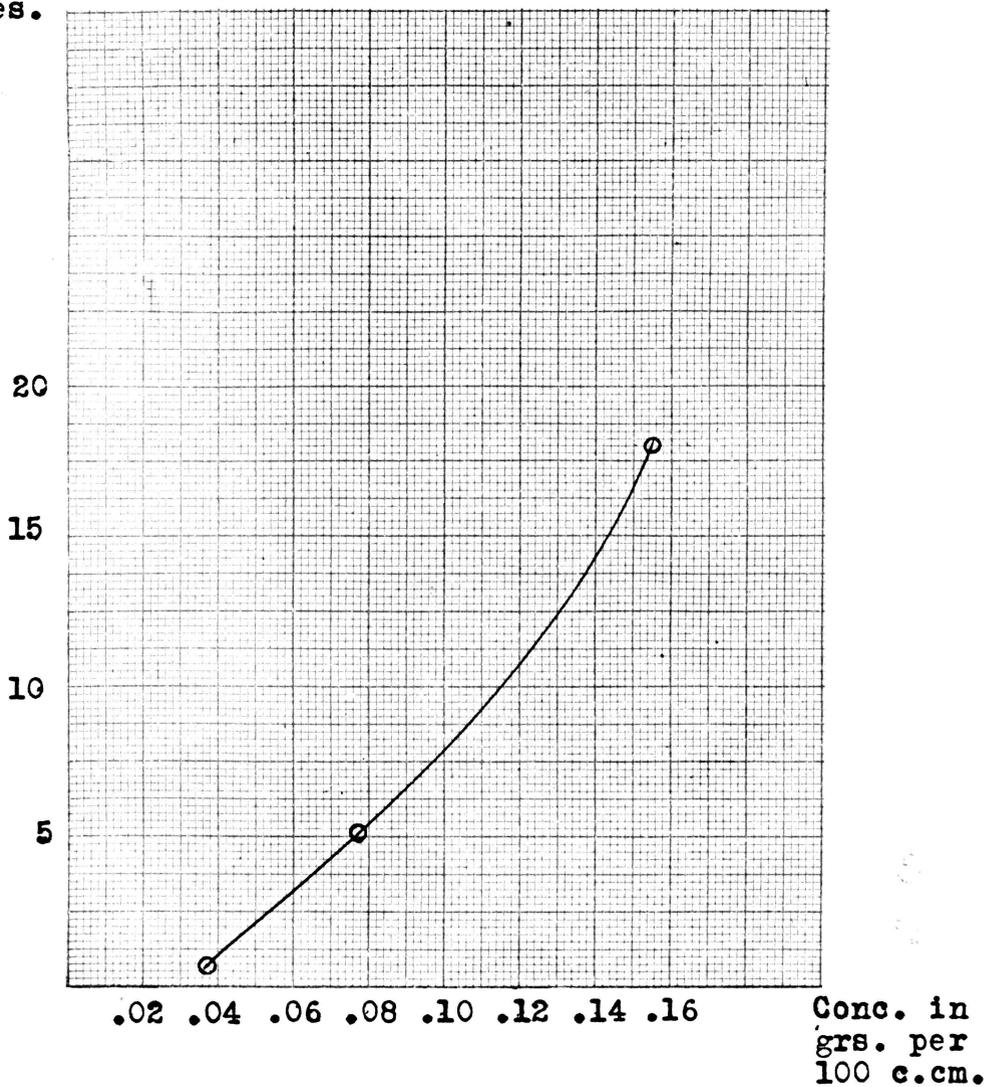


Table No. XIX shows data for the emulsifying power of solutions of Sodium palmitate, shaken with five cubic centimeters of linseed oil, specific gravity .923.

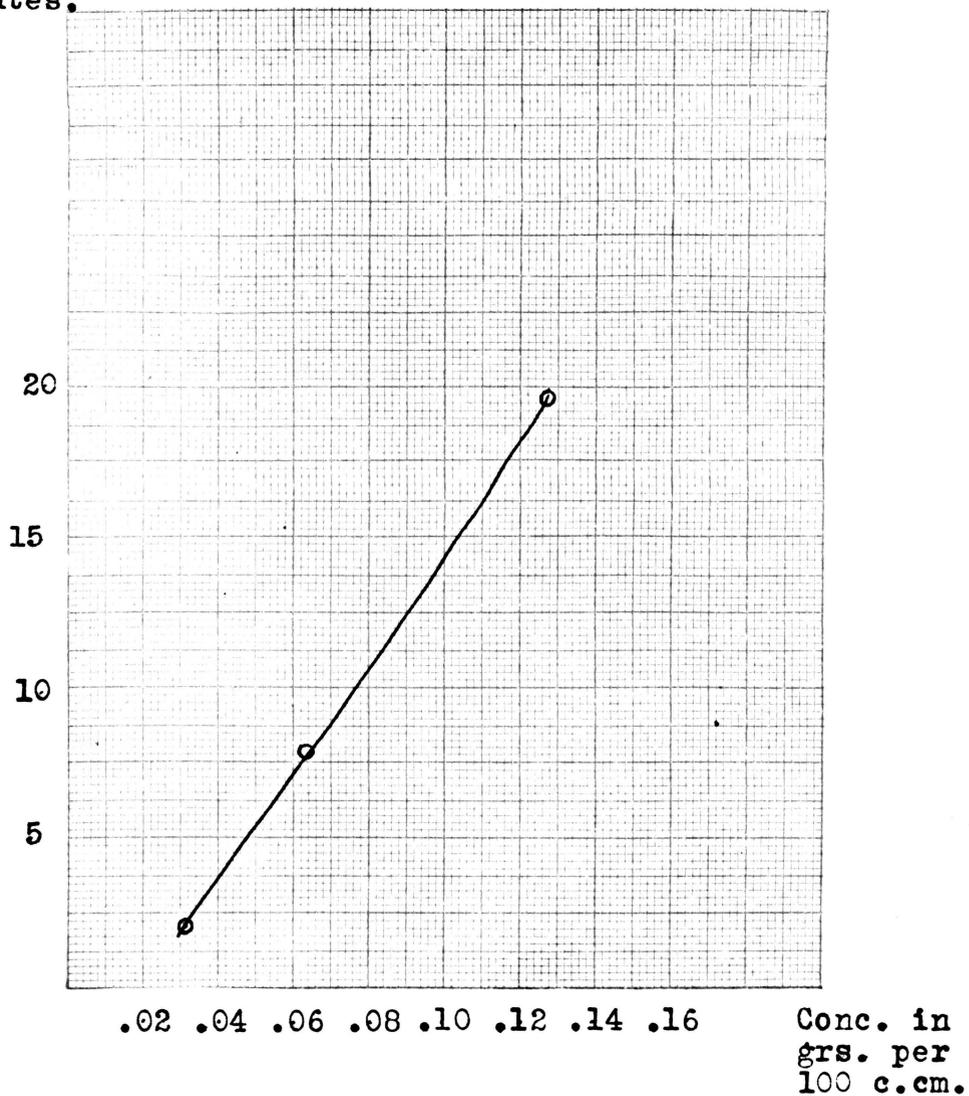
Table No. XIX

Sol. used.	G	G ₁	G ₂
Am't used.	10 c.cm.	10 c.cm.	10 c.cm.
Grs. per 100 c.cm.	.1269	.0634	.0317
Time shaken.	5 min.	5 min.	5 min.
Time of noticeable separation.	19.60 min. *	7.76 min. *	2.06 min. *

* Average of three readings.

Graph for Table No. XIX

Time of
noticeable
separation,
in minutes.



An effort was made to determine the effect of an added foreign substance such as sugar and glycerine on the surface tension of the soap solutions.

To a measured amount of solution F, whose surface tension was found to be 21.9785 was added enough sugar to make a ten per cent solution. The surface tension of the resulting solution was found to average 30.45. On the other hand solution F₁ whose surface tension was 26.2832, upon the addition of enough glycerine to form a ten per cent solution then had a surface tension of 26.0293.

The addition of enough sodium-carbonate to form a ten per cent solution (with solution F₂) produced such a strong curdling effect that no readings could be made to determine the surface tension.

A little work was done on solutions of Ivory soap to see if the data secured would be comparable to that secured from solutions of pure sodium palmitate and pure sodium stearate. A little more than thirteen grams of Ivory soap shaved into thin slices were heated in an electric oven at 65°C. for hour periods, three successive times. At the close of the first hour .3118 grs. had been lost, at the close of the second hour, .2200 grams had been lost, and at the close of the third .1434 grams had been lost.

A solution was made containing 1.0126 grams of the soap thus treated in four hundred cubic centimeters of distilled water. Determinations of fatty acid and total alkali present were then made and the results recorded in Table No. XX.

Table No. XX

	Solution No.I	Solution No.II
Am't of solution.	100c.cm.	100c.cm.
Excess of N.H ₂ SO ₄	10c.cm.	10c.cm.
Fatty acid found.	.2197grs.	.2125grs.
*C.cm. to titrate.	9.15c.cm.	9.12c.cm.
C.cm. total alkali.	.981 c.cm.	1.011 c.cm.

* Titrated with .987 normal sodium hydroxide.

The average surface tension of the Ivory soap solution was found to be 19.3930.

As in the previous work portions of the solution were emulsified by shaking by hand for five minutes with a few cubic centimeters of linseed oil and with kerosene, with the results shown in Table No.XXI.

Table No. XXI.

Am't of Kerosene	Am't of linseed oil	Am't of solution	Time shaken	Time of noticeable separation.
2c.cm.		10c.cm.	5min.	11.09 min.
5c.cm.		10c.cm.	5min.	11.14 min.
	2c.cm.	10c.cm.	5min.	11.22 min.
	5c.cm.	10c.cm.	5min.	11.45 min.

Summary:-

In this work, surface tensions of solutions of sodium palmitate and of sodium stearate in contact with air have been determined. These surface tensions were found to increase with decrease in the concentration of the solutions

of sodium-palmitate and sodium stearate.

The relative emulsifying power of solutions of sodium palmitate and of sodium stearate was determined by shaking by hand for five minutes and observing the time of noticeable separation or, in other words, noting the time of the first sign of de-emulsification. The times of noticeable separation increased with increase of the concentration of the solutions of sodium palmitate and sodium stearate.

The relation between the surface tension and the emulsifying power of the solutions studied is shown to be that with increase of the concentration of the solution there is an increase of emulsifying power with a decrease in the surface tension, or vice versa, as the surface tension increases the emulsifying power decreases.

In general it may be concluded

1. That the result of the experiments carried out in this work submits another substantiation of the theory that the cleansing power of soap is due to the power of the soap solution to form emulsions with oil and grease and to carry away the dirt in suspension.

2. That emulsions are not due to the alkali set free by hydrolysis, since that alkali exists in equilibrium with the fatty acid set free at the same time, and it has been proved by experiments that pure alkali of the same concentration as the alkali of hydrolysis has no more emulsifying power than pure water.

3. That, (since in the historical part of this work Hillyer's proof is quoted for the fact that "internal viscosity of the liquid will not account for its emulsifying power", and "that emulsification is due largely to the small surface tension between the oil and the emulsifying agent",) the surface tension of a soap solution measures the cleansing power of the soap, because this data, as well as that obtained by Hillyer by another method, proves that the emulsifying power (and therefore the cleansing power) may be determined by the measurement of the surface tension.

The writer wishes to acknowledge her indebtedness, to Doctor J.W.Marden, under whom this work was done and to express her appreciation of his interest and many helpful suggestions.

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DEPARTMENT OF THE INTERIOR

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MINING EXPERIMENT STATION, GOLDEN, COLORADO

March 15, 1919.

Dean Walter Miller,
Dean of the Graduate School,
University of Missouri,
Columbia, Missouri.

My dear Dean Miller:

Miss Mollie G. White is sending you her thesis as a partial fulfillment for the Degree of Master of Arts in the Graduate School of the University of Missouri. A part of the work done for this thesis was on the "Surface Tension of Soap Solutions and Their Emulsifying Power." Miss White did this work under my direction last summer during the summer session and I believe the work to have been accurately and carefully done. It seems to me as though her data is of value in adding proof to the fact that the cleansing power of soap is due to the emulsifying power of soap solutions.

My understanding of the matter is that Miss White has also done work with Dr. Schlundt during the present school year and that the work she did with me is to be a chapter of her thesis. I recommend, therefore, that this portion of the paper be accepted since, as I have stated, the work has scientific value and Miss White deserves much credit for the effort she has made. This portion of the work was done almost entirely by Miss White herself and I have only made occasional suggestions to help her along on methods of work in the laboratory, etc. The actual writing of the paper is entirely her work.

Let me thank you for your consideration. With
best wishes,

Very truly yours,

J.B

Miss White's thesis represents the work done with Dr. Marden. The subsequent work with me has not been incorporated,
sincerely truly,
H. Schlundt

J. W. Marden

UNIVERSITY OF MISSOURI
COLUMBIA

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF AGRICULTURAL CHEMISTRY

April 11th 1919.

Dean Walter Miller,
Graduate School,
211 Academic Hall.

My dear Dean Miller:

I have read the thesis submitted by
Mollie G. White and it is my opinion that
it meets the general standard that has been
established in the University for the Master's
dissertation.

Yours sincerely,

A handwritten signature in cursive script that reads "Robert Moulton". The signature is written in dark ink and is positioned below the typed name.

Professor Agricultural Chemistry.

CRM-H



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