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THE INFLUENCE OF TEMPERATURE UPON THE RATE OF REACTION (HÆMOLYSIS, AGGLUTINATION, PRECIPITATION).[1]

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It becomes more and more evident each year, as we advance in the field of immunity, that the bodies which are concerned follow in their action the same laws as other chemical bodies, and therefore must be examined by the methods of modern chemistry. One important step toward the simplifying of this study was made by Ehrlich, when he defined substances of which the action could be measured by test tube experiments. This method allows us to vary the experimental conditions to such an extent that we have control over a whole series of different factors (temperature, dilution, medium, etc.). It is a common observation of all those workers who have investigated hæmolysis, agglutination, precipitation, etc., that these are not simple phenomena and the important bearing which such studies have upon the whole theory of immunity makes it necessary that careful investigation be carried out upon the factors which influence them. Among the factors which play a rôle in chemical reactions, few equal temperature in importance. In the study of hæmolysins and agglutinins it was very early recognized that their activity to a great extent depended upon temperature, increasing as the temperature increased, but diminishing or disappearing at low temperatures.

On account of the great theoretical and practical interest which the study of the dependence of the rate of reaction upon the temperature presents, we have carried out a series of

1 See Toxines et Antitoxines : L'influence de la température sur la vitesse de réaction. I, par Madsen et Walbum; II, par Madsen et Noguchi. *Académie Royale des Sciences et des Lettres de Danemark, Séance du 20 Mai, 1904.*

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experiments with different substances. The experiments include a certain number of hæmolysins (alkalis, acids, bacteriolysins, snake venoms) and some agglutinins and precipitins of different kinds. The ordinary physico-chemical method used for this purpose would be as follows: To determine the rate of reaction, for example, between a hæmolysin and the erythrocytes at different temperatures, and then find the relation between these rates of reaction and the corresponding temperatures. However, this method was not applicable to this investigation, since as yet we do not know the nature of the process which takes place when the hæmolysins and erythrocytes are brought together, and therefore lack the formulas which express these phenomena. For this reason it became necessary to employ another method. The procedure will perhaps be more easily understood by the detailed description of one experiment.

The object of the experiment was to determine the hæmolytic action of sodium hydrate at different temperatures. Seven water-baths with constant temperatures of 39.3°, 34.3°, 30.2°, 27°, 21.2°, 16°, 13.7° C. were prepared. Seven stands, each with six test tubes containing eight cubic centimeters of a one per cent. emulsion of erythrocytes of the horse were put in the baths. When the erythrocytes had been allowed to subside in order to avoid too quick mixture, and the fluid had obtained the surrounding temperature, the amounts of 0.2*n* sodium hydrate indicated in Table I were added as fast as possible (by three experimenters working simultaneously); the tubes were then shaken. Ten minutes afterwards all the stands were taken up at once. It was found that the degree of hæmolysis in the third tube at 39.3° C. (containing 0.06 c.c. of 0.2*n* sodium hydrate) corresponded to a stage intermediate between the second and third tube at 34.3° C. (0.1 c.c.–0.08 c.c.), but nearer the third, and it was estimated that hæmolysis in the third tube at 39.3° would correspond to that caused by .085 c.c. at 34.3° C. In a similar way it was estimated to correspond at 30.2° to 0.11 c.c., at 27° to 0.12 c.c., at 21.2° to 0.22 c.c., at 16° to 0.4 c.c., and at 13.7° to 0.55 c.c.

These results are collected in Table II under the heading 10*m*. In the first column are given the temperatures, in the second

($\frac{1}{c}$ obs.) the observed values, in cubic centimeters, producing the same degrees of hæmolysis. It is obvious that a much smaller amount of sodium hydrate is required at high than at a low temperature to produce the same effect. In the case of a great number of chemical substances, Arrhenius found that the increase of the rate of reaction with increasing temperature could be expressed by the following formula:

$$\frac{c_1}{c^2} = e^{R\left(\frac{T_1 - T_2}{T_1 T_2}\right)}$$

In the formula c_1 and c_2 indicate the concentrations (rates of reaction) at the temperatures T_2 and T_1; μ is a constant, T_1 and T_2 the absolute temperatures, and R, expressed in calories, is 2. The experiment which has been described, like most of our experiments with hæmolysins and agglutinins, can be expressed by this formula. The values calculated in this way are given in the tables under $\frac{1}{c}$ calc. Below is indicated the constant μ in calories. As a rule the observed values correspond with the calculated within the error of experiment.

The difference in the hæmolytic action at low and high temperature expressed by the constant μ is most marked immediately after the addition of the blood emulsion and decreases with increasing time. The final effect—the highest which can be obtained with the hæmolytic substance under the given conditions (medium concentration of blood corpuscles)—is the same for all temperatures; but at low temperatures a much longer time is of course required. The constant μ decreases with increasing time, following apparently a hyperbolic curve, and is zero when the final hæmolytic effect is obtained. Theoretically it would be most correctly determined for the time, zero. This being impossible it must be extrapolated from the other values.

The two *strong alkalis*, sodium and potassium hydrate, of which the degree of dissociation is about the same, act in almost the same manner (Tables II and III). On the contrary there is a marked difference in the case of ammonium hydrate (Table IV). Corresponding to the much smaller rate of reaction of this body, the value of μ is in the beginning much larger, being about double that for sodium and potassium hydrate.

The *final effect* of all alkalis is the same as is obvious from Tables V, VI, and VII. These tables present the hæmolysis produced by *equivalent* amounts of different bases and acids. The erythrocytes were suspended in physiological salt solution or in isotonic cane sugar solution. The numbers 15, 30, 60, etc., indicate the time in minutes required for the production of total hæmolysis. The rate of reaction is the same with equivalent amounts of sodium, potassium, lithium, and barium hydrates, but is much smaller with ammonium hydrate. But if the reaction is increased by shaking the tubes and keeping them some time at 37° C., the difference is diminished and the final limit between the minimal effect and no effect will be about the same. In the tables this limit is marked by a horizontal line. It is obtained after the tubes have been (1) observed six hours at the temperatures indicated in the table; (2) shaken; (3) kept twenty hours at 35.5° C.

The investigation of the hæmolysis produced by *acids* is rendered rather difficult by the strong agglutination and the considerable alteration of the hæmoglobin to which they give rise. Therefore it is difficult to get regular values, but the data given are sufficient to demonstrate the very great differences in the rates of reaction of different acids. Their final effect is nearly the same, but it is often much obscured by agglutination which causes precipitation of the erythrocytes before they are dissolved. This is perhaps one of the reasons why the limit for the "weak" acids is with a little greater amounts than with the "strong" acids. Constant shaking of the tubes with acetic acid will put the limit for this acid at a level with that of sulphuric or hydrochloric acid.

It is interesting to note that both for acids and for alkalis the final limit is obtained with about equivalent quantities, generally a little smaller in the case of alkalis. It is evident that the action of these substances is not directly dependent on the ions. The phenomenon recalls that of the formation of a salt. Acids with a very low degree of dissociation (boric acid) have no hæmolytic action.

Measuring the hæmolytic power of the *acids*, for the above

mentioned reasons, is much more difficult than measuring that of alkalis. If to a series of test tubes, containing equal quantities of a one per cent. emulsion of erythrocytes of the horse, varying amounts of an acid (for example, sulphuric acid) be added, the following is observed: The higher doses will produce a strong brown discoloration of the erythrocytes which clump together and subside, having lost part of their color. With smaller doses total hæmolysis occurs and the color remains almost unchanged. Still further down in the series a decreasing hæmolysis and partial agglutination is observed. Smaller doses produce agglutination alone without hæmolysis.

The rate of action of the readily dissociated acids is so fast that it can hardly be measured. The organic acids generally present less difficulty. We have examined the four lowest members of the fatty acids, namely, *formic*, *acetic*, *propionic*, and *butyric acid*. From Tables VIII, IX, X, and XI, it is obvious that with these acids also the observed values correspond to the calculated. There is a marked difference between formic acid and the three other acids, the constant μ for the former being much smaller and corresponding to the greater rate of reaction. With similar results we have examined *maleinic*, *citraconic*, and *itaconic acid*. In this instance also the acid with the lowest degree of dissociation, the itaconic acid, presents the highest constant, but here too no direct proportion between the rate of reaction and the constant of dissociation is found (Tables XII, XIII, and XIV). Furthermore our investigations include some other hæmolytic bodies: *oleinic acid*, *sodium-oleate*, and *triolein*. Tables XV, XVI, and XVII show that these bodies follow the general rule.

In the above experiments the influence of the temperature has been investigated at different stages of the reaction (ten, twenty, thirty, etc., minutes after its beginning). Some experiments have been carried out, in which only a single stage, suitable for the measurement, has been taken. In this way have been examined: The dissolving effect of *streptolysin* upon the red blood corpuscles of the horse (Table XVIII); the agglutinating action of *ricin* upon rabbit blood (Table XIX); the precipitation produced by strong *sulphuric acid* in a solution of albumen

(Table XX); the agglutination of horse blood by *sublimate* (Table XXI); and the precipitating action of a *specific egg-precipitin* upon egg-albumen (Table XXII). The agglutinating action of *coli-agglutinin* is highly accelerated by increasing the temperature, as the high initial constant of Table XXIII shows. But the longer the time that elapses after the beginning of the reaction, the less the difference observed and the final effect of a given amount of agglutinin is the same at all temperatures. Table XXIV gives an example of a phenomenon which is rather often observed in experiments of this kind: The constants of the measurements, made ten, twenty, and thirty minutes after the beginning of the reaction, decreased regularly; but they subsequently increased very much in the determinations made after forty and fifty minutes. The first group of experiments were carried out in the forenoon, the last mentioned some hours later. Perhaps during this interval a considerable change had occurred in the emulsion of coli-bacilli, of such nature that the influence of the temperature had become much more important. The *agglutinin of Bacillus typhosus* seems in this respect to be quite analogous to the coli-agglutinin (Table XXV).

Among the bacterio-hæmolysins the *vibrio-lysin* (Table XXVI) seems to follow the general rule.[3] Our first experiments with *tetanolysin* seemed to indicate that this body follows the same rule within the temperatures 35.3° C. and 10.8° C. (Table XXVII). This tetanolysin was the same which had served for all the previous experiments in this Institute. In former experiments irregularities of action had never been observed, except when the lysin had become very weak. Now the greatest effect was not produced in the tubes containing the highest quantity of lysin, but in those with the lysin in much weaker concentration. Some examples of this behavior will be found in the following experiments: To twenty-seven tubes, with one per cent. horse blood amounts of lysin decreasing from 1 c.c. to 0.0025 c.c. are added (Table XXVIII). After ten minutes there is almost com-

[3] This vibrio-lysin is made with a vibrio, for which we are indebted to the kindness of Dr. Kraus in Vienna; the same is true for the staphylococcus, mentioned below.

plete hæmolysis with 0.1 c.c.; from this tube the hæmolysis decreases in the series both upwards and downwards; almost the same degree of hæmolysis is observed with 1 c.c. and with 0.07 c.c. Three and a half hours later the series presents the following result: Total hæmolysis with 0.1 c.c. and 0.07 c.c. The tubes with smaller quantities show a gradually decreasing hæmolysis. In the tubes with higher amounts of lysin the hæmolysis is strongest with 0.13 c.c. gradually decreasing to a minimum at 0.3 c.c. and 0.25 c.c.; from this point upwards the hæmolysis again increases, and with 1 c.c. almost total hæmolysis occurs. After a time all the tubes containing over 0.1 c.c. presented total hæmolysis, and therefore we would not have had any idea of these great irregularities in the rate of reaction if we had made our examination only on the following day.

These irregularities are not due to the weakness of this lysin, as we have found similar irregularities with quite fresh cultures. Thus Table XXIX shows an experiment in which hæmolysis at 90° C. and 16° C. advances regularly; H_{10}, H_{20}, H_{40} indicate the time in minutes required for total hæmolysis. But at 26 C.° is found a broad zone between 0.25 c.c. and 0.05 c.c in which total hæmolysis occurs after ten minutes, and upward and downward in the series decreasing lysis is found. At 40° C. after ten minutes total hæmolysis occurred in the tubes with 0.8, 0.5, 0.3, 0.2, 0.08 c.c. and in all the tubes from 0.04 to 0.015 c.c. In the intermediate tubes the hæmolysis was very much less.

As all the experiments with this lysin presented similar results, it was extremely difficult to compare the effect at different temperatures. There seems to exist a maximum around 31.7° C. while the action is much smaller at other temperatures. Some examples are given in Tables XXX and XXXI. In several series two values are given indicating the presence of the above mentioned irregularities.

It might be thought that the decrease of the hæmolytic action at higher temperatures, 36.5° and 41.7° C., might possibly be due to a weakening of the tetanolysin at these temperatures. However some experiments, carried out specially to settle this question, showed another curious phenomenon: in a certain

number of cases the activity of the lysin was increased considerably by a short heating to 37° C. As an example the following experiment is given. The broth medium usually employed (0.5 per cent. glucose, 2 per cent. pepton, 1 per cent. sodium chloride) was inoculated February 2 with tetanus bacilli and kept under paraffin at 35.5° C. until February 21. It was then taken from the incubator and kept at low temperature, about 4° C. Three days afterwards it was heated to 37° C. and the hæmolytic effect then tested. In Table XXXII $\frac{1}{c}$ indicates those amounts of the culture, heated to 37° C., during the time t, which have the same action. The experiments have been carried out during a series of successive days and have shown that the increase of the hæmolytic power is sometimes rather considerable. Other tetanus cultures present analogous phenomena. The experiment described by Table XXXIII shows how heating to 37° C. during ten minutes can quadruple the hæmolytic power of the culture.

We have, however, obtained several times tetanus cultures without these irregularities and the influence of the temperature has conformed to the usual rule.

Another lysin, *staphylolysin*, showed the peculiar phenomenon described above, the highest hæmolytic effect not occurring at the highest temperature. A given quantity produced the maximal action between 20° C. and 30° C., the effect being considerably smaller at higher or lower temperatures (Table XXXIV).

With another body, which has played an important rôle in the hæmolytic experiments of recent years, *lecithin*, hæmolytic action does not seem to depend very much on temperature. Table XXXV presents observations after 20, 30, 50, 60, 90, 140, and 330 minutes at four different temperatures, namely, 0.1°, 11.1°, 24.05°, and 36.7° C. The figures in columns indicate hæmolysis in percentages.[4] The process proceeds rather regularly; the effect seems to be about the same at 0.1° C. and 36.7° C. and a little less at the intermediate temperatures.

In the case of *cobra venom* there is a little increase of hæmolysis

[4] Arrhenius and Madsen: Physical Chemistry Applied to Toxins and Antitoxins, Festskrift ved Indvielsen af Statens Seruminstitut, Copenhagen, 1902.

at higher temperature; a minimum seems to exist between 14° C. and 24° C. (Table XXXVI). On the contrary hæmolysis by the venom of *Ancistrodon piscivorus* (water moccasin) is considerably greater at low than at high temperature (Table XXXVII). It is interesting to remember that this venom is used by the water moccasin to poison chiefly cold-blooded animals.

The experiments which have been communicated must be considered only as preliminary steps into a field which has not yet been investigated; owing to the great errors of experiment and to our still very incomplete methods of measurement the data cannot be definitive. A striking feature is, that among a number of experiments which have corresponding results are found irregular series, which do not follow the usual course. In such instances it seems reasonable to think that influences of catalytic nature have had a part, increasing or decreasing the rate of reaction.

Our experiments show that hæmolysis, agglutination, and precipitation by a great many different substances increase with increasing temperature, following the same formula, which applies to other chemical phenomena:

$$\frac{c_1}{c_2} = e^{\frac{\mu}{R}\left(\frac{T_1 - T_2}{T_1 T_2}\right)}$$

This is true for the hæmolysis by the hydrates of sodium, potassium, and ammonia, by formic, acetic, propionic, butyric, maleinic, citraconic, itaconic, and oleinic acids, by sodium oleate and by triolein, and furthermore by streptolysin and vibrio-lysin. It is true for the agglutination of the erythrocytes by ricin and mercuric chloride, for the precipitation of albumen by sulphuric acid and by specific precipitin; and also for the bacterial agglutination by the agglutinins of Bacillus coli and Bacillus typhosus. Still the increase of the action with the temperature can only reach a certain limit, partly owing to the destruction of the medium (erythrocytes, bacteria), partly owing to the weakening of the active body itself (bacteriolysin, agglutinin).

On the contrary, the tetanolysin showed peculiarities, for example, a maximum activity at 32° C.; staphylolysin showed

a maximum activity between 20° C. and 30° C.; with lecithin and cobra venom hæmolysis at low and high temperature seems to proceed with about equal rapidity and to be more rapid than at the intermediate temperatures; the venom of the water moccasin acts most strongly at low temperatures.

TABLE I.

ACTION OF 0.2*n* NaOH UPON 1 PER CENT. EMULSION OF HORSE BLOOD AT DIFFERENT TEMPERATURES.

	39.3°	34.3°	30.2°	27.°	21.2°	16°	13.7°
1	0.1 c.c.	0.13 c.c.	0.2 c.c.	0.2 c.c.	0.3 c.c.	0.8 c.c.	0.8 c.c.
2	0.08 "	0.1 "	0.17 "	0.17 "	0.25 "	0.6 "	0.6 "
3	0.06 "×	0.08 "×ℓ	0.13 "	0.13 "×*	0.2 "×ℓ	0.5 "	0.5 "
4	0.05 "	0.06 "	0.1 "×ℓ	0.1 "	0.17 "	0.4 "	0.4 "
5	0.04 "	0.05 "	0.08 "	0.08 "	0.13 "	0.3 "	0.3 "
6	0.03 "	0.04 "	0.06 "	0.06 "	0.1 "	0.25 "	0.25 "

* Corresponds to an amount between two that are given but nearer the larger.

× Corresponds to an amount midway between two that are given.

ℓ Corresponds to an amount between two that are given but nearer the smaller.

TABLE II.

0.2 *n* NaOH.

10*m*			20*m*			30*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
39.3	0.06	0.057	39.3	0.055	0.054			
34.3	0.085	0.084	34.3	0.07	0.069	34.3	0.06	0.057
30.2	0.11	0.12	30.2	0.085	0.086	30.2	0.07	0.071
27.0	0.12	0.155	27.0	0.1	0.1	27.0	0.065	0.083
11.2	0.22	0.26	21.2	0.13	0.14	21.2	0.115	0.116
26.0	0.4	0.4	16.0	0.185	0.184	16.0	0.15	0.15
13.7	0.55	0.5	13.7	0.26	0.21	13.7	0.19	0.17
μ = 15190			μ = 9486			μ = 9441		

40*m*			50*m*			60*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
39.3	0.04	0.04	38.5	0.043	0.042			
34.3	0.05	0.05	34.3	0.048	0.049	34.3	0.045	0.045
30.2	0.1	0.063	30.8	0.07	0.057	30.8	0.055	0.052
27.	0.07	0.073	26.8	0.065	0.067	26.8	0.065	0.061
21.2	0.1	0.1	21.1	0.07	0.085	21.1	0.07	0.077
16.0	0.13	0.13	15.8	0.1	0.107	15.8	0.09	0.096
13.7	0.17	0.15	14.6	0.115	0.112	14.6	0.1	0.12
μ = 9210			μ = 7415			μ = 7185		

80*m*			100*m*			180*m*		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
38.5	0.035	0.038	38.5	0.04	0.045	38.5	0.04	0.04
34.3	0.045	0.044	34.3	0.05	0.05	34.3	0.04	0.045
30.8	0.055	0.05	30.8	0.06	0.058	30.8	0.057	0.05
26.8	0.055	0.059	26.8	0.07	0.067	26.8	0.06	0.057
21.1	0.085	0.074	21.1	0.085	0.081	21.1	0.07	0.068
15.8	0.07	0.091	15.8	0.085	0.098	15.8	0.07	0.081
14.6	0.1	0.095	14.6	0.1	0.1	14.6	0.085	0.085
μ = 6907			μ = 6263			μ = 5663		

TABLE III.

0.2*n* KOH.

10*m*			20*m*			30*m*		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
38.8	0.11	0.1	38.1	0.065	0.076	38.1	0.1	0.096
35.7	0.14	0.12	35.9	0.085	0.084	35.9	0.13	0.11
28.8	0.17	0.18	28.5	0.17	0.12			
25.4	0.21	0.23	25.4	0.15	0.14	25.4	0.17	0.17
19.5	0.33	0.34	19.4	0.2	0.195			
15.3	0.45	0.45	15.2	0.225	0.245	15.2	0.25	0.28
13.4	0.5	0.52	14.1	0.275	0.26	14.1	0.3	0.29
μ = 11710			μ = 9210			μ = 8288		

40*m*			60*m*			120*m*		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
38.6	0.06	0.06	38.1	0.07	0.076			
			35.9	0.085	0.081	35.6	0.05	0.053
28.6	0.085	0.09	28.5	0.1	0.1	28.4	0.065	0.064
25.4	0.12	0.11	25.4	0.13	0.12	25.3	0.07	0.07
19.4	0.13	0.14	19.4	0.1	0.14	19.4	0.09	0.084
15.2	0.17	0.17	15.2	0.17	0.17	15.1	0.09	0.095
13.7	0.18	0.18	14.1	0.17	0.173	14.5	0.1	0.097
μ = 7968			μ = 6078			μ = 5164		

180*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.8	0.04	0.04
35.6	0.037	0.044
29.3	0.05	0.051
25.6	0.06	0.055
20.3	0.065	0.062
15.3	0.07	0.07
13.8	0.07	0.073

μ = 4145

TABLE IV.

0.5*n* NH_4OH.

10*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.5	0.04	0.043
34.8	0.085	0.083
29.7	0.17	0.17
25.9	0.3	0.3
21.0	0.60	0.64

μ = 26760

20*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.2	0.03	0.029
34.8	0.05	0.05
30.2	0.085	0.081
25.7	0.19	0.17
21.0	0.3	0.32
15.7	0.55	0.69

μ = 24360

30*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.5	0.0275	0.0225
34.8	0.035	0.039
29.7	0.07	0.072
25.9	0.13	0.12
21.0	0.25	0.225
15.2	0.5	0.5
11.0	0.7	0.89

μ = 23020

40*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.1	0.02	0.019
34.6	0.03	0.031
30.7	0.05	0.048
25.9	0.085	0.086
21.3	0.17	0.15
16.1	0.3	0.3
12.2	0.45	0.49

μ = 21640

60*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.2	0.019	0.014
34.8	0.024	0.022
30.2	0.035	0.035
25.7	0.05	0.056
21.1		
15.7	0.17	0.17
12.2	0.26	0.26

μ = 19150

80*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.2	0.025	0.02
34.8	0.03	0.03
30.2	0.04	0.046
25.7	0.07	0.069
21.1	0.1	0.11
15.7	0.18	0.18
12.2	0.3	0.26

μ = 16660

100*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.1	0.02	0.018
34.6	0.025	0.025
30.7	0.025	0.034
25.9	0.045	0.051
21.3	0.06	0.075
16.1	0.115	0.12
12.2	0.17	0.17

μ = 14920

120*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.1	0.017	0.017
34.6	0.0225	0.0225
30.7	0.0275	0.029
25.9	0.04	0.04
21.3	0.06	0.055
16.1	0.1	0.079
12.2	0.17	0.1

μ = 13720

180*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.0	0.015	0.015
34.7	0.0185	0.0185
30.9	0.0225	0.0225
25.9	0.03	0.029
21.5	0.04	0.037
16.1	0.05	0.05

μ = 9441

TABLE V.

BLOOD OF HORSE 1% (0.9% NaCl). Temperature 16.2°.

Amount in c.c.	Hydrochloric acid $\frac{m}{1}$	Sulphuric acid $\frac{m}{2}$	Formic acid $\frac{m}{1}$	Acetic acid $\frac{m}{1}$	Butyric acid $\frac{m}{1}$	Oxalic acid $\frac{m}{2}$	Succinic acid $\frac{m}{2}$	Lactic acid $\frac{m}{1}$	Tartaric acid $\frac{m}{2}$	Ammonia $\frac{m}{1}$	Sodium hydrate $\frac{m}{1}$	Potassium hydrate $\frac{m}{1}$	Lithium hydrate $\frac{m}{1}$	Amount in c.c.	Barium hydrate $\frac{m}{4}$
0.25				15†						60				0.5	
0.2														0.4	
0.17							15							0.34	
0.13										120				0.26	
0.1														0.2	
0.07				30§				15		210	15	15	15	0.14	15
0.05				60§			30 60§		15†		30	30	30	0.1	30
0.04	15*			120				30			60	60	60	0.08	60
0.03		15†	15			15†	120†	60	30§	450†				0.06	
0.025	30*	30	30	450		30 60	450†	120†	60		120	120	120	0.05	120
								450							
0.02	60*	60	60			450			120		210	210	210	0.04	
	120§	120*	120†			120§							450†		210†
0.017	450	450	450						450		450	450		0.034	450
0.013														0.026	
0.01														0.02	
0.007														0.014	
0.005														0.01	

* Corresponds to an amount between two that are given, but nearer the larger.
† Corresponds to an amount midway between two that are given.
§ Corresponds to an amount between two that are given but nearer the smaller.

TABLE VI.

BLOOD OF HORSE 2.5% (0.9% NaCl). Tp. 15.2°.

Amount in c.c	Hydrochloric acid $\frac{m}{1}$	Sulphuric acid $\frac{m}{2}$	Acetic acid $\frac{m}{1}$	Mono- $\frac{m}{1}$	Di-chlor-acetic acid $\frac{m}{1}$	Tri- $\frac{m}{1}$	Oxalic acid $\frac{m}{2}$	Succinic acid $\frac{m}{2}$	Lactic acid $\frac{m}{1}$	Citric acid $\frac{m}{3}$	Ammonia $\frac{m}{1}$	Sodium hydrate $\frac{m}{1}$
1.0			5 15†									
0.7											30	
0.5								15 30				
0.4			30						5		60	
0.3												
0.25										60†	120	
0.2												
0.17												5
0.13							5	60 120	15 30			
0.1	5 15 30	5 15 30		5			15 30					15
0.07			60	15	5							30
			120§	30	15†	5 15				120		
0.05	120† 60	120† 60		120† 60	60† 30	60† 30	60† 120		60 120			60
0.04					120	120						120
0.03												
0.025												
0.02												
0.017												
0.013												
0.01												
0.007												

For explanation of signs *, †, and § see Table V.

TABLE VII.

BLOOD OF HORSE 1% (7.8% CANE SUGAR). Tp. 14.6°. 0.9% NaCl.

Amount in c.c.	Hydrochloric acid m/1	Sulphuric acid m/2	Formic acid m/1	Acetic acid m/1	Di-chlor-acetic acid m/1	Tri-chlor-acetic acid m/1	Butyric acid m/1	Oxalic acid m/2	Succinic acid m/1	Lactic acid m/2	Tartaric acid m/2	Citric acid m/3	Ammonia m/1	Sodium hydrate m/1	Hydrochloric acid m/1	Ammonia m/1	Sodium hydrate m/1
1.5									5			14	•				
1.3									14		5						
1.0									60† 30		14	30	90*	5			
0.7									90		30	60		14			
0.5									240			90†				30	
0.4				5†							60			30			
0.3				60* 14							90	240				60	
0.25				240									240§	60			
0.2										5† 14						90	
0.17	5									30* 60				90			
0.13	14		14† 5							90†	240						5
0.1			60											240§		240	14
0.07	30	14†	240†					5 14							5		30
0.05		30						30§							14		
0.04	60 90	60						60							30		60
0.03	240	90			5 14	30		240							60		90*
0.025		240			90 240	240									90		240
0.02																	
0.017																	
0.013																	
0.01																	
0.007																	
0.005																	
0.004																	
0.003																	
0.0025																	
0.002																	
0.0017																	

For explanation of signs *, †, and § see Table V.

TABLE VIII.

FORMIC ACID (0.1 *n*).

10*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
37.0	0.17	0.16
34.5	0.175	0.18
29.9	0.185	0.227
24.5	0.32	0.3
20.0	0.4	0.364
15.0	0.45	0.483
10.45	0.6	0.62

μ = **8841**

20*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
37.0	0.13	0.128
34.5	0.13	0.142
29.9	0.17	0.17
24.5	0.21	0.214
20.0	0.225	0.26
15.0	0.35	0.33
10.45	0.4	0.405

μ = **7598**

30*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
37.0	0.13	0.13
34.5	0.13	0.135
29.9	0.17	0.15
24.5	0.185	0.173
20.0	0.19	0.194
15.0	0.225	0.221
10.45	0.25	0.252

μ = **4310**

40*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
37.0	0.13	0.132
34.5	0.13	0.136
29.9	0.15	0.146
24.5	0.17	0.157
20.0	0.175	0.168
15.0	0.18	0.181
10.45	0.19	0.195

μ = **2578**

50*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
37.0	0.13	0.128
34.5	0.13	0.133
29.9	0.14	0.142
24.5	0.16	0.156
20.0	0.18	0.168
15.0	0.18	0.183
10.45	0.185	0.198

μ = **2901**

180*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
37.0	0.12	0.12
34.5	0.125	0.122
29.9	0.125	0.125
24.5	0.125	0.129
20.0	0.13	0.132
15.1	0.135	0.132
10.4	0.14	0.14

μ = **921**

TABLE IX.

ACETIC ACID. $\frac{1}{1}n$

10*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
40.2	0.025	0.0209
34.7	0.035	0.0405
30.1	0.065	0.073
24.7	0.145	0.147
19.6	0.30	0.29
15.1	0.45	0.532

μ = **23580**

15*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
40.2	0.02	0.0175
34.7	0.03	0.033
30.1	0.04	0.057
24.7	0.1	0.11
19.6	0.225	0.212
15.1	0.4	0.375

μ = **22240**

20*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
40.2	0.02	0.0152
34.7	0.025	0.0251
30.1	0.035	0.0364
24.7	0.055	0.067
19.6	0.115	0.115
15.1	0.25	0.183
10.2	0.3	0.316

μ = **18050**

40*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
40.2	0.017	0.0131
34.7	0.02	0.0203
30.1	0.025	0.0298
24.7	0.033	0.047
19.6	0.065	0.074
15.1	0.13	0.11
10.2	0.17	0.18

$\mu = 15520$

50*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
40.2	0.017	0.013
34.7	0.02	0.0203
30.1	0.025	0.0274
24.7	0.03	0.0417
19.6	0.05	0.063
15.1	0.1	0.091
10.2	0.13	0.141

$\mu = 14230$

60*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
40.2	0.017	0.0114
34.7	0.017	0.0164
30.1	0.0225	0.0229
24.7	0.03	0.0338
19.6	0.04	0.0467
15.1	0.075	0.07
10.2	0.1	0.105

$\mu = 13210$

90*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
40.5	0.017	0.0134
35.15	0.017	0.017
30.4	0.0225	0.0213
24.7	0.0285	0.0281
19.6	0.035	0.0364
14.5	0.04	0.047
10.1	0.06	0.06

$\mu = 8752$

120*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
35.15	0.017	0.0164
30 4	0.02	0.02
24.7	0.025	0.0253
19.6	0.03	0.03
14.5	0.033	0.0392
10.1	0.05	0.0481

$\mu = 7459$

210*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc
40.5	0.015	0.0147
35.15	0.016	0.0169
30.4	0.02	0.0193
24.7	0.024	0.0226
19.6	0.0275	0.0262
14.5	0.03	0.03
10.1	0.033	0.0352

$\mu = 5112$

TABLE X.

PROPIONIC ACID. $\frac{I}{I}$ *n*.

10*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.15	0.0275	0.0267
35.25	0.04	0.0455
28.45	0.09	0.112
23.6	0.275	0.35
19.35	0.4	0.4

$\mu = 24860$

20*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.15	0.025	0.0176
35.25	0.0275	0.0253
28.45	0.04	0.0483
23.6	0.07	0.079
19.35	0.14	0.11
14.9	0.30	0.20
7.8	0.40	0.44

$\mu = 18050$

30*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.2	0.02	0.0172
35.15	0.022	0.0238
28.45	0.04	0.042
23.45	0.05	0.067
19.55	0.09	0.095
14.8	0.20	0.149
7.7	0.30	0.30

$\mu = 15890$

40*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.2	0.017	0.0152
35.15	0.02	0.0207
28.45	0.033	0.0353
23.45	0.043	0.055
19.55	0.065	0.076
14.8	0.15	0.116
7.7	0.25	0.226

$\mu = 15060$

60*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.2	0.017	0.0116
35.15	0.02	0.0153
28.45	0.025	0.025
23.45	0.03	0.037
19.55	0.04	0.0505
14.8	0.06	0.078
7.7	0.185	0.136

$\mu = 13720$

90*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.1	0.017	0.0164
35.15	0.02	0.0192
28.8	0.025	0.025
23.4	0.027	0.0317
19.35	0.04	0.0379
14.9	0.042	0.047
8.0	0.085	0.0775

$\mu = 7690$

120*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.1	0.017	0.017
35.15	0.02	0.02
28.8	0.025	0.0227
23.4	0.025	0.0265
19.35	0.03	0.03
14.9	0.033	0.034

$\mu = 5065$

180*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
39.1	0.017	0.017
35.15	0.017	0.019
28.8	0.0225	0.0223
23.4	0.025	0.0258
19.35	0.033	0.029
14.9	0.035	0.033
8.0	0.04	0.04

$\mu = 4789$

TABLE XI.

BUTYRIC ACID. $\frac{I}{I}n$.

10*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.0	0.03	0.03
34.4	0.033	0.04
30.7	0.07	0.062
24.35	0.13	0.13
19.5	0.25	0.25
15.9	0.28	0.38

$\mu = 21550$

20*m*

Tp.	$\frac{I}{I}$ obs.	$\frac{I}{c}$ calc.
34.4	0.025	0.025
30.7	0.04	0.038
24.35	0.065	0.076
19.5	0.15	0.13
15.9	0.20	0.2

$\mu = 19890$

30*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.0	0.02	0.018
34.4	0.0225	0.0225
30.7	0.025	0.031
24.35	0.048	0.052
19.5	0.08	0.08
15.9	0.1	0.11
10.3	0.2	0.19

$\mu = 15190$

40*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.0	0.018	0.016
34.4	0.020	0.02
30.7	0.022	0.027
24.35	0.03	0.043
19.5	0.065	0.065
15.9	0.10	0.086
10.3	0.13	0.14

$\mu = 14000$

50*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.0	0.017	0.016
34.4	0.019	0.019
30.7	0.025	0.025
24.35	0.028	0.04
19.5	0.045	0.058
15.9	0.085	0.076
10.3	0.12	0.12

$\mu = 13210$

TABLE XII.

MALEINIC ACID. $\frac{I}{I}n$.

10*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.5	0.014	0.014
34.7	0.017	0.017
29.9	0.03	0.0235
24.7	0.04	0.034
19.3	0.05	0.05
15.8	0.065	0.065
12.2	0.07	0.086

$\mu = 12670$

20*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.5	0.014	0.013
34.7	0.015	0.0145
29.9	0.017	0.018
24.7	0.022	0.024
19.3	0.03	0.032
15.8	0.04	0.038
12.2	0.045	0.047

$\mu = 9118$

30*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.5	0.013	0.012
34.7	0.013	0.013
29.9	0.017	0.016
24.7	0.018	0.021
19.3	0.025	0.027
15.8	0.03	0.032
12.2	0.04	0.038

$\mu = 8281$

TABLE XIII.

CITRACONIC ACID. $\frac{1}{1}$ *n*.

10*m*			20*m*			50*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
35	0.017	0.017	35	0.013	0.012	38	0.0115	0.0115
30.2	0.02	0.025	30.2	0.017	0.017	35	0.013	0.012
23.7	0.04	0.04	23.7	0.025	0.026	30.2	0.015	0.015
20.3	0.05	0.051	20.3	0.03	0.032	23.7	0.017	0.016
15.6	0.085	0.076	15.6	0.047	0.045	20.1	0.017	0.017
9.8	0.1	0.098	9.8	0.065	0.068	15.6	0.019	0.019
μ = 13490			μ = 11690			μ = 4375		

TABLE XIV.

ITACONIC ACID. $\frac{1}{1}$ *n*.

15*m*			20*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
29.8	0.03	0.03	29.8	0.025	0.024
24.2	0.05	0.051	24.2	0.0375	0.039
17.8	0.085	0.096	17.8	0.05	0.069
14.6	0.15	0.13	14.6	0.09	0.093
10.7	0.2	0.2	10.7	0.135	0.135
μ = 17040			μ = 15560		

TABLE XV.

OLEINIC ACID. $\frac{1}{10}$ *n*.

10*m*			22*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
39.4	0.035	0.035	39.1	0.03	0.03
36.7	0.06	0.05	36.2	0.035	0.042
31.4	0.1	0.1	31.3	0.08	0.079
23.9	0.3	0.3	24.1	0.2	0.2
μ = 25780			μ = 23480		

TABLE XVI.

OLEATE OF SODIUM. $\frac{1}{100}$ *n*.

10*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
36.3	0.125	0.125
31.4	0.14	0.14
24.1	0.18	0.16
15.9	0.19	0.19
12	0.2	0.21
4	0.25	0.25

μ = 3776

TABLE XVII.

TRIOLEIN. $\frac{1}{100}$ *n*.

15*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
38.9	0.22	0.22
35.7	0.25	0.25
30.9	0.27	0.36
24	0.6	0.6

μ = 13810

50*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
38.9	0.17.	0.17
35.7	0.2	0.2
30.9	0.32	0.26
24	0.4	0.4

μ = 10590

TABLE XVIII.

STREPTOLYSIN.

20*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
36.1	0.08	0.08
31.1	0.20	0.21
25.8	0.40	0.54
22.9	1.30	1.15

μ = 31880

TABLE XIX.

RICIN.

c. 30*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
36.2	0.05	0.05
27.9	0.12	0.11
15.6	0.33	0.37
10.1	0.70	0.66
0.9	1.30	1.80

μ = 17220

TABLE XX.

10 *n* H_2SO_4.

2% EGG ALBUMEN.

90*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
35.8	0.1	0.11
29.7	0.16	0.16
25.4	0.225	0.21
19.9	0.3	0.29
14.5	0.4	0.41

μ = 11050

TABLE XXI.

0.1 *n* $HgCl_2$

RED COKPUSCLES OF HORSE.

45*m*

Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
35.8	0.085	0.085
30.9	0.15	0.15
25.9	0.25	0.24
21.9	0.55	0.36
16.1	0.6	0.65
12.3	1.0	0.98
10.8	1.0	1.15

μ = 17860

TABLE XXII.

PRECIPITIN.

73*m*

Tp.	$\frac{I}{c}$ obs	$\frac{I}{c}$ calc.
36.1	0.25	0.25
30.1	0.3	0.306
20.0	0.45	0.44
13.9	0.55	0.55

$\mu = 6284$

TABLE XXIII.

COLI-AGGLUTININ.

20*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
41.2	0.0025	0.0023
36.6	0.004	0.0042
31.4	0.0115	0.0086
25.8	0.030	0.019
19.4	0.05	0.05
15.6	0.06	0.092
12.3	0.085	0.15

$\mu = 25960$

30*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
41.2	0.0007	0.00063
36.6	0.001	0.0011
31.4	0.001	0.0021
25.8	0.0017	0.0044
19.4	0.012	0.011
15.6	0.018	0.018
12.3	0.026	0.029

$\mu = 23850$

50*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
41.2	0.0004	0.00035
36.6	0.0005	0.00056
31.4	0.0005	0.00098
25.8	0.0007	0.00184
19.4	0.002	0.0038
15.6	0.0055	0.0061
12.3	0.01	0.0093

$\mu = 20030$

65*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
40.9	0.00018	0.000175
36.7	0.0002	0.00022
30.7	0.0005	0.00038
25.9	0.0005	0.00062
19.4	0.0008	0.00116
15.9	0.002	0.0017
12.0	0.002	0.0025

$\mu = 17080$

80*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
41.5	0.0002	0.000115
36.7	0.00013	0.00015
30.8	0.00025	0.00023
25.9	0.0002	0.00031
19.5	0.00045	0.00049
15.8	0.0007	0.00064
12.1	0.0017	0.00085

$\mu = 12200$

100*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
41.5	0.0001	0.0001
36.7	0.000085	0.000125
30.8	0.000185	0.00017
25.9	0.00019	0.00022
19.5	0.00035	0.00031
15.8	0.0004	0.00039
12.1	0.00045	0.00047

$\mu = 9486$

120*m*

Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
41.9	0.000085	0.000084
36.7	0.0001	0.0001
30.7	0.00018	0.00014
25.9	0.0002	0.00017
19.4	0.000225	0.00023
15.9	0.000275	0.00027
12.0	0.00033	0.00033

$\mu = 8288$

TABLE XXIV.

COLI-AGGLUTININ.

10*m* I			10 *m* II			20*m* I			20*m* II			30*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
38.6	0.005	0.0036	38.6	0.005	0.005	39.5	0.0015	0.0013	39.5	0.001	0.001	38.5	0.001	0.00088
34.9	0.0055	0.0057	34.9	0.0055	0.0088	35.7	0.002	0.002	35.7	0.0015	0.0017	35.0	0.0012	0.0012
30.9	0.01	0.011	30.9	0.02	0.016	31.5			31.5	0.003	0.003	30.7	0.00175	0.0018
24.0	0.04	0.035	24.0	0.05	0.05	24.1	0.01	0.0084	24.1	0.01	0.0088	24.0	0.007	0.0034
21.2	0.045	0.057	21.2	0.085	0.08	20.5	0.0125	0.013	20.5	0.007	0.015	21.6	0.007	0.0044
13.2	0.25	0.25	12.7	0.35	0.35	14.1	0.03	0.039	14.1	0.04	0.041	12.7	0.01	0.011
									10.5	0.048	0.074	9.6	0.015	0.015
μ = 30950			μ = 29340			μ = 22820			μ = 26380			μ = 17180		

40*m* I			40*m* II			50*m*			5*h*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
38.5	0.0007	0.0007	38.5	0.0006	0.00065	38.5	0.0007	0.00062	38.5	0.0002	0.00018
35	0.00085	0.0012	35.0	0.00125	0.00125	35.0	0.001	0.0011	35.0	0.0002	0.0002
30.7	0.002	0.0022	30.7	0.006	0.0037	30.7	0.002	0.0022	30.7	0.0002	0.00024
24	0.008	0.0063	24.0	0.007	0.0057	24.0	0.009	0.0069	24.0	0.0003	0.00031
21.6	0.011	0.0093	21.6	0.035	0.035	21.6	0.01	0.01	21.6	0.00042	0.00033
12.7	0.04	0.04	12.7	0.04	0.044				12.7	0.00052	0.00049
									9.6	0.00052	0.00055
μ = 29030			μ = 28320			μ = 30630			μ = 6907		

TABLE XXV.

B. TYPHOSUS-AGGLUTININ.

10m			40m			120m		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
38.2	0.002	0.002	38.6	0.0013	0.00126	37.8	0.0006	0.0006
35.2	0.006	0.0036	34.9	0.00225	0.0024	35.2	0.0008	0.00079
31.1	0.007	0.0083	19.6	0.04	0.04	31.3	0.00115	0.00115
27.4	0.02	0.018	16.1	0.1	0.079	27.4	0.0014	0.0018
19.2	0.13	0.09	11.4	0.15	0.2	15.8	0.006	0.006
15.9	0.2	0.2						
11.5	0.5	0.55						
	$\mu = 37160$			$\mu = 33010$			$\mu = 18690$	

180m		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
37.8	0.0007	0.0007
35.2	0.0009	0.00083
31.3	0.001	0.00107
27.4	0.0013	0.0014
19.0	0.0017	0.0025
11.6	0.0045	0.0044
	$\mu = 8511$	

TABLE XXVI.

VIBRIO-LYSIN.

20m			40m		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc
35.3	0.17	0.1	35.3	0.115	0.078
29.8	0.25	0.25	29.8	0.17	0.17
26.3	0.4	0.4	26.3	0.22	0.27
20.6	1.0	1.0	20.6	0.6	0.6
	$\mu = 27330$			$\mu = 24410$	

100m			180m		
Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.	Tp.	$\frac{I}{c}$ obs.	$\frac{I}{c}$ calc.
40.1	0.0275	0.0275	39.8	0.03	0.03
35.3	0.05	0.044	35.4	0.042	0.043
29.5	0.07	0.08	29.3	0.07	0.073
26.0	0.1	0.117	25.3	0.1	0.104
20.4	0.25	0.215	20.1	0.17	0.17
16.1	0.42	0.394	15.6	0.3	0.25
	$\mu = 19340$			$\mu = 15840$	

TABLE XXVII.

TETANOLYSIN.

60*m*			65*m*		
Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.	Tp.	$\frac{1}{c}$ obs.	$\frac{1}{c}$ calc.
30.4	0.4	0.37	35.3	0.45	0.45
25.6	0.5	0.53	31.1	0.58	0.58
21.9	0.8	0.66	24.9	0.8	0.83
15.4	1.0	1.0	10.8	2.0	2.1
12.1	1.3	1.27			
μ = 10860			μ = 10860		

TABLE XXVIII.

1.0 c.c.	0.1 c.c.	0.01 c.c.
0.7	0.07	0.007
0.5	0.05	0.005
0.4	0.04	0.004
0.35	0.035	0.0035
0.3	0.03	0.003
0.25	0.025	0.0025
0.2	0.02	
0.17	0.017	
0.13	0.013	

TABLE XXIX.

TETANOLYSIN.

Amount in c.c.	40°	26°	16°	9°
1.3				H_{10}
1.0				
0.8	H_{10}			
0.6				
0.5	H_{10}			
0.4				H_{20}
0.3	H_{10}			
0.25			H_{10}	
0.2	H_{10}			H_{40}
0.17				
0.13		H_{10}		
0.1			H_{20}	
0.08	H_{10}			
0.06			H_{40}	
0.05				
0.04	H_{10}			
0.03				
0.02				
0.015				

TABLE XXX.

TETANOLYSIN.

25*m*		
Tp.		$\frac{1}{c}$
41.7		0.25
36.5		0.6
31.7		0.03
25.7	or	0.07 or 0.2
21.2		0.17
14.9		0.2
6.7	or	0.4 or 0.8

TABLE XXXI.

Tp.	10m $\frac{I}{c}$	10m $\frac{I}{c}$	20m $\frac{I}{c}$	40m $\frac{I}{c}$	60m $\frac{I}{c}$	90m $\frac{I}{c}$	120m $\frac{I}{c}$
41.7	0.35	0.4	0.185	0.1	0.07	0.05	0.06
36.5	0.55	0.5	0.2	0.1	0.07	0.07	0.045
31.71	or 0.25 / 0.06	or 0.17 / 0.025	<0.03	0.025	0.0275	0.017	0.013
25.7		0.6	0.225	0.07	0.085	0.085	0.0275
21.2	0.8		0.1	0.05		0.06	0.04
14.9	0.18		0.07		0.085	0.06	0.07
6.7	1.7	2.0	0.4	0.17	0.115	0.2	0.085

TABLE XXXII.

TETANOLYSIN.

Heating at 37°.

$^{24}/_{2}$		$^{25}/_{2}$		$^{26}/_{2}$		$^{27}/_{2}$		$^{1}/_{3}$		$^{3}/_{3}$	
t	$\frac{I}{c}$	t	$\frac{I}{c}$	t	$\frac{I}{c}$	t	$\frac{I}{c}$	t	$\frac{I}{c}$	t	$\frac{I}{c}$
0m	0.5	0m	0.7	0m	0.225	0m		0m	0.2	0m	0.07
30	0.45	30	0.5	20	0.2	5	0.03	5	0.175	10	0.07
60	0.275	60	<0.1	30	0.03	10	0.05	10	0.15	20	0.07
120	<0.2	120	0.7	40	0.33	20	0.05	20	0.1	30	0.05
		180	0.7	50	0.5	30	0.05	40	0.1	40	0.03
		240	0.7	60	0.5	40	0.07			50	0.03
				80	0.7	50	0.4			60	0.07
				100	0.55	60	0.35			90	0.1
				120	0.7	80	0.3			120	0.1
				180	0.5	120	0.3			180	0.16
				240	0.225	240	0.3			240	0.13
				360	0.3	360	0.3			300	0.06
						480	0.3			360	0.04
						600	0.3			420	<0.02
										480	<0.02

TABLE XXXIII.

NEW CULTURE.

Amount in c.c.	Heated 20 *m.* at 37°	Not heated.
1.0		H_{35}
0.7		H_{75}
0.5		H_{180}
0.4		
0.3		
0.25	$>H_{35}$	
0.2		
0.17		
0.13	H_{75}	
0.1	H_{180}	

TABLE XXXIV.

STAPHYLOLYSIN.

(Blood of Rabbit 1 %.)

15*m*		**20*m***		**45*m***		**60*m***	
Tp.	$\frac{1}{c}$	Tp.	$\frac{1}{c}$	Tp.	$\frac{1}{c}$	Tp.	$\frac{1}{c}$
36.5	0.35	36.4	0.3	36.4	0.35	28.6	0.095
29.1	0.17	28.9	0.17	28.6	0.08	24.4	0.08
24.3	0.225	24.4	0.14	24.4	0.07	19.7	0.08
19.5	0.33	18.8	0.22	19.7	0.075	11.3	0.53
13.6	1.8	12.5	1.55	11.3	0.6		

TABLE XXXV

LECITHIN. $\frac{1}{20}$ *n*.

	20*m*				30*m*				50*m*				60*m*			
	0.1°	11.1°	24.05°	36.7°	0.1°	11.1°	24.05°	36.7°	0.1°	11.1°	24.05°	36.7°	0.1°	11.1°	24.05°	36.7°
0.3	95	100	100	98	99	100	100	100	100	100	100	100	100	100	100	100
0.2	87	—	99.5	95	96	—	—	98	—	—	—	—	—	—	—	—
0.1	76	85	93	90	92	—	98	95	98	—	—	99	—	—	—	—
0.08	65	80	85	87	90	95	96	93	96	—	99	97	—	—	—	98
0.06	50	65	60	85	85	90	90	92	94	95	97	95	97	99	98	97
0.04	25	25	25	80	70	80	75	90	90	88	85	92	95	90	89	95
0.03	0	0	0	75	58	30	60	85	75	65	80	90	90	70	82	92
0.02				40	35	0	0	50	50	30	45	60	60	30	48	65
0.01				25	0			0	20	0	20	20	35	0	20	35
0.008				0					0		0	0	0		0	0

	90*m*				140*m*				330*m*			
	0.1°	11.1°	24.05°	36.7°	0.1°	11.1°	24.05°	36.7°	0.1°	11.1°	24.05°	36.7°
0.3	100	100	100	100	100	100	100	100	100	100	100	100
0.2	—	—	—	—	—	—	—	—	—	—	—	—
0.1	—	—	—	—	—	—	—	—	—	—	—	—
0.08	—	—	—	—	—	—	—	—	—	—	—	—
0.06	—	—	—	—	—	—	—	—	—	—	—	—
0.04	—	95	90	98	—	—	92	—	—	—	—	—
0.03	95	80	85	95	—	90	87	—	—	—	—	—
0.02	85	42	60	70	90	55	70	80	98	70	96	98
0.01	65	0	20	25	68	20	20	35	80	80	25	83
0.008	25		0	0	45	0	0	0	48	0	0	55
0.006	0				0				25			25
0.004									5			0
0.003									0			

TABLE XXXVI.

NAJA TRIPUDIANS.

	5*m*		10*m*		15*m*	
	$\frac{1}{c}$ obs.		$\frac{1}{c}$ obs.		$\frac{1}{c}$ obs.	
Tp.	I	II	I	II	I	II
37.3	0.4	0.3	0.275	0.225	0.275	0.225
35.3	0.4	0.3	0.3	0.25	0.275	0.225
30.8	0.4	0.33	0.35	0.26	0.3	0.25
24.1	0.5	0.33	0.4	0.35	0.4	0.3
17.7	0.4	0.3	0.45	0.35	0.45	0.3
14.2	0.6	0.45	0.5	0.38	0.35	0.25
10.8	0.5	0.4	0.45	0.3	0.3	0.25

TABLE XXXVII.

ANCISTRODON PISCIVORUS.

	5*m*		10*m*		15*m*	
	$\frac{1}{c}$ obs.		$\frac{1}{c}$ obs.		$\frac{1}{c}$ obs.	
Tp.	I	II	I	II	I	II
39.3	0.5	0.38	0.4	0.35	0.4	0.28
35.2	0.5	0.36	0.45	0.35	0.4	0.28
30.7	0.4	0.35	0.42	0.35	0.4	0.3
28.2	0.4	0.35	0.4	0.35	0.45	0.33
19.2	0.4	0.3	0.35	0.28	0.4	0.3
14.8	0.4	0.3	0.35	0.28	0.3	0.25
10.6	0.4	0.25	0.3	0.25	0.25	0.225