L. NOTES ON SOME PROPERTIES OF DIALYSED GELATIN.

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I. *Material.*

THE gelatin on which the following observations were made was purified by dialysis at the iso-electric point ($p_H = 4.6$) and subsequent precipitation in strong alcohol. Details have been published in a previous paper [Jordan Lloyd, 1920]. The dry gelatin contained 0.06 to 0.00 % of ash. It was obtained as a snow white, fibrous and brittle solid, with a low solubility. In one specimen the maximum solubility was 1.5 % in boiling distilled water. In others 2–2.5 % could be dissolved under the same conditions, but in no case was it possible to dissolve more than 2.5 % of the pure fibrous gelatin in pure boiling water. This agrees with the observations of Dheré [1910] and Dheré and Gorgolewski [1913] that prolonged dialysis is accompanied by diminished ash content and decreased solubility. The hot water solutions were clear and colourless. On cooling to 15°, if the concentration were above 0.9 % the sol set to a turbid white gel in 24 hours, below 0.9 % but above 0.6 %, gelation took from 2–5 days. At a concentration of 0.6 % or less, the clear hot sols cooled to form turbid white sols at 15°, the turbidity decreasing with decreasing gelatin content. The gelatin in these sols is not precipitated by ferric, mercuric or lead salts, nor by ferrocyanides, dichromates or tannic acid. Gels formed under these conditions are not stable, the gelatin separating from the water [see Jordan Lloyd, 1920; Smith, 1921]. The solubility of dialysed gelatin is, as would be anticipated, immediately increased by the addition of acid or alkali. Gels formed in the presence of free acid or base are glassy clear, colourless and stable.

II. *The influence of hydrochloric acid, sodium hydroxide and sodium chloride on the gelling power.*

“Gelling power” is a difficult phrase to define precisely, and the property which it purports to describe is equally difficult to measure accurately. The following notes do not claim to set out any satisfactory measurement or definition of gelling power, the differences described between the experimental fluids being purely comparative, and observed under conditions kept as

uniform as possible. The solutions of gelatin used for this comparative work were made by dissolving dialysed gelatin in hot water, raising to boiling point, and then allowing to stand for 48 hours at 15°. The minimum concentration of gelatin required to produce a gel under these conditions was assumed to give an inverse measure of the gelling power. A fluid was taken as gelled when it remained in its place in an inverted test-tube. The influence of hydrochloric acid and sodium hydroxide was examined in the absence of sodium chloride and in the presence of 0.1 *N*, 0.4 *N* and *N* sodium chloride. The reactions of the 1 % gelatin solutions were measured electrometrically and also by adding a few drops of indicator at the time of mixing, and comparing the colours with suitable standards at the end of the experiment. It is well known that the addition of sodium chloride to a solution containing hydrochloric acid increases the concentration of hydrogen ion but Harned [1915] has shown that the increase is not great. In the present case it will be well within the experimental error. The measurements of reaction are accurate to $\pm 0.2 p_H$. The results of the experiment are summarised in Tables II, III, IV and V, and a diagram, in which the minimum concentration that will cause gelling is plotted against reaction, is given in Fig. 1. Areas above the curves are sols, those below are gels.

Fig. 1.

Abcissae = p_H .

Ordinates = Minimum concentration per cent. at which gel forms. 15° and 48 hours.

● — ● = 0.0 *N* NaCl
 × — × = 0.1 *N* NaCl

○ — ○ = 0.4 *N* NaCl
 * — * = 1.0 *N* NaCl

Pure gelatin under the given conditions (48 hours' standing at 15°) requires a minimum concentration of 0.8 % to form a gel, and will only form gels at 1 % concentration from $p_H = 12-3$, and again rather surprisingly between p_H 2 and 0.7. The disappearance of the power of gelation in acid solutions and its temporary reappearance in stronger acids is a phenomenon which has not previously been described. The conditions necessary to observe it are rather restricted, temperature being an important factor as is shown in Table I.

Table I.

p_H	Concentration of HCl or NaOH	1 % gelatin after 48 hours		
		0° C.	15° C.	20° C.
0.7	.25 N HCl	—	Clear fluid	—
0.8	.20	Transparent fluid	„ very soft gel	Clear fluid
0.9	.15	„ „	„ soft gel	„ „
1.1	.10	„ „	„ gel	„ „
1.5	.05	„ soft gel	„ „	„ „
1.6	.04	—	„ soft gel	—
1.7	.03	—	„ „	—
2.0	.02	—	„ fluid	—
2.8	.01	Transparent fluid	„ „	Clear fluid
3.8	.005	„ soft gel	„ soft gel	„ „
	.002	Gel with ice crystals	—	„ gel
	.0025	—	Clear gel	—
	.0015	Very faintly turbid gel	—	Clear gel
	.0010	Faintly turbid gel	—	Faintly turbid gel
	.0005	Turbid gel; hysteresis	—	Turbid gel
5.1	Distilled water	Opaque white gel	Opaque white gel	„ „
	.0005 N NaOH	Faintly turbid gel	—	Very faintly turbid gel
	.0010	Very faintly turbid gel	—	Clear gel
	.0015	„ „	—	„ „
	.002	„ „	—	„ „
10.4	.005	Clear gel	Clear gel	„ fluid
11.7	.01	„ viscous fluid	„ „	„ „
12.15	.02	—	„ very soft gel	—
12.4	.03	—	„ viscous fluid	—
12.5	.04	—	„ fluid	—
12.6	.05	Clear fluid	„ „	—
12.9	.10	„ „	„ „	Clear fluid
13.1	.20	„ „	„ „	„ „

At concentrations of 0.1 N, and 0.4 N, sodium chloride lowers the minimum concentration of gelatin required to produce gelation, except at reactions more alkaline than $p_H = 12.2$ where in no instance was a gel obtained. At normal concentration sodium chloride may either increase or decrease the gelling power, according to the value of the hydrogen ion concentration of the solution under investigation. Its influence is most marked from $p_H = 5$ to $p_H = 1.5$, *i.e.* at the range where pure gelatin gels least readily. It is interesting that this range is immediately on the acid side of the iso-electric point. The relationship between sodium chloride content and gelling power is obviously not a simple one and requires further study. One clear point however emerges from the study of Fig. 1, *i.e.* the greater the concentration of neutral salt, the less the influence of the hydrogen ion.

If gelation is regarded as a function of viscosity, the influence of sodium chloride as found by the experiments described here, does not agree with previous work by Möerner [1889] and Freundlich [1909].

The inhibition of setting in strongly acid solutions both in presence and absence of salt can be shown to be due to the hydrogen ion since on neutralisation with sodium hydroxide the gelling power is restored. Neutralisation does not restore gelling power to the strongly alkaline sols. The gelling power in this case is permanently destroyed.

III. *The influence of hydrochloric acid, sodium hydroxide and sodium chloride on the turbidity of sols and gels.*

The observations on turbidity were made in all cases on solutions of gelatin of 1 % or weaker, and refer only to their condition at 15°. 1 % gels of gelatin in water are turbid under these conditions; in 0.1 *N* sodium chloride they are less turbid, in 0.4 *N* sodium chloride they are again slightly less turbid than in 0.1 *N* salt and in normal sodium chloride they are only faintly opalescent. In acid solutions the influence of sodium chloride is reversed. In the absence of sodium chloride the 1 % gelatin solutions in hydrochloric acid are generally clear. A slight turbidity develops on standing if the acid concentration does not exceed 0.005 *N* [Jordan Lloyd, 1920]. The addition of sodium chloride in concentrations of 0.1 *N*, 0.4 *N* and 1.0 *N* causes the clear gels to become turbid. In the last case the gels containing 0.01–0.008 *N* HCl are actually cloudier than those with salt alone. In dilute alkaline solutions (0.002 *N* or less) the addition of sodium chloride causes the clear gels to become turbid. In stronger alkaline solutions (0.05 *N* or more) the addition is without effect, but evidence from other sources shows that the gelatin is actually destroyed at this reaction.

The influence of acid, alkali and salt is summarised in Tables II, III, IV and V. Miss Laing has very kindly examined the turbid water gels for me by means of the ultra-microscope and finds that they contain long fibres similar to the fibres in soap curds.

The relations of the turbidity or “degree of dispersion” of the gelatin to acid, alkali and salt form a close parallel to those for globulin described by Hardy [1905].

Table II.

48 hours at 15°. Salt concentration = 0.00.

		Concentration of gelatin				
Reaction		1.0 %	0.9 %	0.8 %	0.7 %	0.6 %
·25 <i>N</i> HCl $p_H = 0.7$		Clear fluid	—	—	—	—
·20 <i>N</i>	0.8	„ soft gel	Clear gela- tinous fluid	—	—	—
·15 <i>N</i>	0.9	„ „	„ „	—	—	—
·10 <i>N</i>	1.1	„ gel	„ „	—	—	—
·05 <i>N</i>	1.5	„ „	„ „	—	—	—
·04 <i>N</i>	1.6	„ soft gel	„ „	—	—	—
·03 <i>N</i>	1.7	„ „	„ „	—	—	—
·02 <i>N</i>	2.0	„ fluid	Clear fluid	—	—	—
·01 <i>N</i>	2.5	„ „	„ „	—	—	—
·005 <i>N</i>	3.8	„ soft gel	„ „	—	—	—
·0025 <i>N</i>	4.4	„ „	Clear gela- tinous fluid	—	—	—
Water	5.0	Firm opaque gel	Turbid soft gel	Turbid soft gel	Turbid gela- tinous fluid	Turbid fluid
·005 <i>N</i> NaOH	10.4	Clear gel	Clear gel	Clear gela- tinous fluid	Clear fluid	—
·01 <i>N</i>	11.7	„ „	„ „	„ „	„ „	—
·02 <i>N</i>	12.1	Clear very soft gel	„ fluid	—	—	—
·03 <i>N</i>	12.4	Clear fluid	—	—	—	—
·04 <i>N</i>	12.5	„ „	—	—	—	—
·05 <i>N</i>	12.6					
·10 <i>N</i>	12.9					

Table III.

48 hours at 15°. Salt concentration = 0.10 *N*.

Concentration of gelatin

Reaction	1.0 %	0.9 %	0.8 %	0.7 %	0.6 %	0.5 %
Hydrochloric acid						
$p_H = 0.8$	Faintly turbid gelatinous fluid	—	—	—	—	—
$p_H = 1.1$	Faintly turbid gel	Faintly turbid soft gel	Clear fluid	—	—	—
$p_H = 1.5$	" "	" "	" "	—	—	—
$p_H = 2.7$	" "	Faintly turbid gel	Faintly turbid soft gel	Clear gel	Clear gelatinous fluid	Clear fluid
$p_H = 3.8$	" "	" "	Faintly turbid gel	" "	Clear soft gel	" "
Water						
$p_H = 5.1$	Turbid gel	Turbid gel	" "	Faintly turbid gel	Faintly turbid soft gel	Faintly turbid fluid
Sodium hydroxide						
$p_H = 10.4$	Faintly turbid gel	" "	" "	Faintly turbid soft gel	Faintly turbid fluid	—
$p_H = 11.8$	" "	" "	" "	Faintly turbid gel	" "	—
$p_H = 12.6$	Clear fluid	—	—	—	—	—
$p_H = 13.0$	" "	—	—	—	—	—

Table IV.

48 hours at 15°. Salt concentration = 0.40 *N*.

Concentration of gelatin

Reaction	1.0 %	0.9 %	0.8 %	0.7 %	0.6 %	0.5 %
Hydrochloric acid						
$p_H = 0.8$	Faintly turbid fluid	—	—	—	—	—
$p_H = 1.1$	Turbid gel	Turbid soft gel	Faintly turbid soft gel	Clear fluid	—	—
$p_H = 1.5$	" "	" "	" "	Faintly turbid gelatinous fluid	Faintly turbid fluid	—
$p_H = 2.7$	" "	Turbid gel	Faintly turbid gel	" "	Faintly turbid gelatinous fluid	Clear fluid
$p_H = 3.8$	" "	" "	" "	" "	" "	" "
Water						
$p_H = 5.1$	" "	" "	" "	Faintly turbid gel	" "	Faintly turbid fluid
Sodium hydroxide						
$p_H = 10.4$	Turbid gel	" "	" "	Clear soft gel	" "	Clear fluid
$p_H = 11.8$	" "	" "	Faintly turbid soft gel	Clear gelatinous fluid	Clear fluid	—
$p_H = 12.6$	Clear fluid	—	—	—	—	—
$p_H = 13.0$	" "	—	—	—	—	—

Table V.

		48 hours at 15°. Salt concentration = 1.0 N. Concentration of gelatin		
Reaction		1.0 %	0.9 %	0.8 %
Hydrochloric acid				
$p_H = 0.8$	Faintly turbid fluid		—	—
$p_H = 0.9$	Faintly turbid gelatinous fluid		Faintly turbid fluid	—
$p_H = 1.1$	Faintly turbid soft gel		„ „	—
$p_H = 1.5$	Faintly turbid gel		Faintly turbid gelatinous fluid	Faintly turbid fluid
$p_H = 2.5$	Turbid gel		Faintly turbid gel	Faintly turbid gelatinous fluid
$p_H = 3.8$	„ „		„ „	„ „
Water $p_H = 5.1$	Faintly turbid gel		„ „	„ „
Sodium hydroxide				
$p_H = 10.4$	Clear gel		Clear gel	„ „
$p_H = 11.7$	„ „		„ fluid	—
$p_H = 12.1$	„ fluid		—	—
$p_H = 12.5$	„ „		—	—

IV. Optical rotation.

The rotatory power of a solution of gelatin is not a constant one but varies with temperature. This property has been examined by Trunkel [1910] and Smith [1919].

Smith considers that above 35° gelatin is converted to a form which he calls gelatin *A* which has not the property of forming gels. Below 15° Smith considers gelatin exists in a form which he calls gelatin *B*, which is the substance capable of gel formation. Between these two temperatures, a solution of gelatin is considered to be a mixture of the two isomers. The conversion of *A* to *B* is reversible. Smith, using the sodium line, gives the following values:

$$[\alpha]_D \text{ at } 35^\circ \text{ and above} = -141^\circ,$$

$$[\alpha]_D \text{ at } 15^\circ \text{ and below} = -313^\circ.$$

The rotatory power of the purified gelatin used throughout these experiments was examined in solutions of distilled water, dilute acid, or dilute alkali. The reaction of the solution in distilled water is approximately $p_H = 5$. It was found that all three solutions showed mutarotation, and that the rotatory power differed in acid, alkaline and distilled water solution. The mercury green line was used as the source of light in all experiments. $[\alpha]_{\text{Hg green}}$ is the rotation caused by a column of fluid 10 cm. in length when each cc. of solution contained 1 g. of pure gelatin. Constant values were obtained for the higher temperature by keeping the tubes for three hours at 37°: at the lower temperature by keeping the tubes for 48 hours at 10° before taking a reading. Intermediate values were not taken. All three solutions set to gels at the lower temperature, the acid and alkaline gels are clear, the water gel cloudy.

For this reason a short tube had to be used in the last case. The following experimental figures were obtained:

Solvent	0.017 $NHCl$	Water $p_H=5$	0.017 $N NaOH$
Concentration of gelatin	1.67 %	2.00 %	1.67 %
Length of polarimeter tube	18.9 cm.	9.9 cm.	20 cm.
Observed rotation at 37°	-5.03°	-2.81°	-4.97°
Observed rotation at 10°	-9.55°	-6.08°	-9.34°
$[\alpha]_{Hg}$ at 37°	-160°	-142°	-150°
$[\alpha]_{Hg}$ at 10°	-302°	-307°	-280°

These values for $[\alpha]_{Hg}$ at 10° and 37° are reversible. After several heatings and coolings, the value of the alkaline, and to a less extent of the acid tube, tends to sink. The difference in the values of the acid, alkaline and neutral solutions at 37° is a considerable one. A further investigation of the influence of temperature and reaction on the value of $[\alpha]_{Hg \text{ green}}$ is being carried out.

V. *Note on the combination of gelatin with hydrochloric acid and sodium hydroxide and on molecular structure in sols and gels.*

If the gelling power of a gelatin solution be plotted against the reaction, in a system free from inorganic salts, as in Fig. 1, it can be seen that the former is reduced over a range of reaction immediately on the acid side of the iso-electric point, Michaelis and Grineff's [1912] figure being taken for the last point. Over this same range, the gelatin is combining rapidly with hydrochloric acid to form soluble hydrochlorides [Procter, 1914; Loeb, 1919; Lloyd and Mayes, 1922]. On the theory that gels are formed of a framework of uncombined gelatin, penetrated with a solution of soluble gelatin salts, it is possible to suppose that the loss of gelling power at these reactions is due to the reduction of the uncombined gelatin to below the minimum necessary for the formation of a rigid framework. The temporary reappearance of the gel state at higher reactions is probably due to the reduction of the active mass of the water owing to the hydration of the protein ions. At higher p_H values the gel state is again inhibited. Immediately on the alkaline side of the iso-electric point, the presence of free hydroxyl ions has very little effect. Yet it is known that the combination of gelatin with sodium hydroxide begins immediately on the alkaline side of $p_H = 4.6$, though the rate of combination is slower by about a third for bases up to a concentration of 0.01 N of free hydrogen or hydroxyl ions. At this point on the curve of "base fixed" the curve inflects and this point corresponds to a p_H value of 12 beyond which gelation cannot exist [see Lloyd and Mayes, 1922, Fig. 5]. Smith [1921] finds that the rise of osmotic pressure to a maximum is more rapid in alkaline solutions than in acid. Evidence has been given elsewhere [Lloyd and Mayes, 1922] that acids and bases combine with gelatin at different positions in the molecule and this is supported by the observations given above on the gelling power. It even seems possible that the sodium salts of gelatin may be able to build themselves into the jelly framework in the undissociated state. The loss of gelling power at $p_H = 12$ is to be attributed to actual destruction of

the gelatin molecule in the presence of the strong alkali. Patten and Johnson [1919] also found that liquefaction accompanied high alkalinity ($p_H = 8, 9$ or 10 in their experiments) but as their observations were all made in the presence of buffer salts they are not comparable with those given in this paper. The effect of sodium chloride in diminishing the minimum concentration of gelatin required to form a gel is obscure, but a possibility suggests itself that it may be due to withdrawal of water from the system by the hydration of its ions. This hypothesis is consistent with the fact that sodium chloride increases the turbidity of gelatin in acid or alkaline solution but is difficult to harmonise with the observation that sodium chloride decreases the turbidity of gels near the iso-electric point, and when in sufficient concentration also decreases the setting power. (It may be remarked in parenthesis that Dr Holker has examined the influence of sodium chloride on some of the gelatin used in this work, at a temperature of 40° . At this temperature, according to Smith, the gelatin would be entirely transformed into the non-gelling form. Dr Holker finds that at this temperature the curve of turbidity against sodium chloride content shows the characteristic sine form [Holker, 1921]. This fine variation of turbidity at 40° is however different from the coarser variations described in this paper which are more of the nature of an actual separating out of gelatin from its solutions.)

In a recent paper [Jordan Lloyd, 1920] the theory was put forward that gelatin gels consist structurally of a framework of solid iso-electric or neutral gelatin together with water, through the open meshes of which lies an aqueous solution of ionised gelatin salts, either acid or basic. The solid phase was assumed to be the seat of the elastic forces of the gels, and the liquid phase of the osmotic forces. The necessity for gelatin in both the uncombined, uncharged, and the ionised, charged condition for the formation of a stable gel, was postulated. This theory has been criticised adversely by both Procter [1920] and Laing and McBain [1920] on the grounds that the structure postulated was supposed to be of microscopic dimensions. This, however, is a misinterpretation of the position taken up by the writer. There is no need to assume that the framework, even if solid, is necessarily of an order of magnitude that would be visible under a microscope, and the existence of glass-like gels of gelatin, showing that they are free from particles of an order of magnitude greater than 10^{-6} cm. in diameter, is against this. Adam [1921] has shown that films of palmitic acid on water only one molecule in thickness may either be in the solid or the liquid state. This proves that the solid state is not incompatible with structure of molecular dimensions. The writer does not consider that there is any fundamental difference between the "molecular network" of Procter, the "exceedingly fine filamentous structure" of Laing and McBain, or the "solid framework" postulated by herself, though originally suggested by Hardy. (It is noteworthy that though Hardy made his gelatin frameworks of microscopic dimensions by the arbitrary use of alcohol, he explicitly states in his original paper [1900] that the droplets may be any size

from macroscopic to sub-microscopic according to the conditions under which they separate.) The existence of structure in both gels and sols would seem to have been proved by work on the viscosity of melted gels [see P. van Schroeder, 1903; Garrett, 1903; Levites, 1908; Gokum, 1908; Schorr, 1911; and more recently Hess, 1922], and further the anisotropic properties demonstrated by Hatschek [1921] are evidence that a part at any rate of a gel exhibits the characteristics of a solid. Bearing in mind the work of Adam already referred to, it does not seem impossible that the liquefaction and solidification of gels may be associated with a liquefaction and solidification of the framework similar to the liquefaction and solidification of a film of palmitic acid one molecule in thickness.

Procter considers gelatin gels to be of the nature of solid solutions, presumably similar to glass. Laing and McBain state that "a gel is identical with a sol except for its mechanical properties." It is perhaps helpful to consider the matter in the light of the kinetic theory. According to this theory it is possible to visualise the solid state as one in which the molecules composing it are able to vibrate only round a mean position which is fixed, and the fluid state as one in which the molecules (or ions) composing it are free to migrate in any direction. If the molecules of solid are displaced from their mean position by the application of an external force, they will return towards it on the removal of the force, *i.e.* provided that the body has not been strained beyond its elastic limit. Molecules in a liquid displaced by an external force will not return to their previous position on the removal of the force. Gelatin gels are elastic solids with a modulus that has been determined [Leick, 1904], but the classical researches of Graham [1850, 1851] and Dumanski [1907] show that ions can migrate through them as rapidly as through water provided the gel be not too concentrated; *i.e.* experiments on diffusion show that part of the gel at least is fluid and that in gels not too concentrated the fluid phase is continuous. Hardy's observations on the reversal of continuity of phases in the alcohol-water-gelatin system, with increasing concentration of gelatin, have a bearing on this point. Laing and McBain have shown the similarity of gels and sols for other physical properties. The simplest theory harmonising all these facts does seem to be that in sols there is a meshwork of protein in the fluid state through which is an aqueous solution non-miscible with it; in gels the framework is not fluid but solid. The justification for this is to be found in the work of Adam on palmitic acid films. The extension of the theory to suppose that the framework was iso-electric gelatin, and the solution gelatin salts, led to the deduction that perfectly pure gelatin would be unable to form stable gels. This supposition has since been confirmed by the observations of the writer [Jordan Lloyd, 1920]; Field [1921] and Smith [1921].

SUMMARY.

1. Gelatin purified by dialysis and precipitation in alcohol is only soluble with difficulty in boiling distilled water. On cooling, if the concentration be 0.8 % or above, the solution sets to an opaque white gel; if the concentration be 0.7 % or less, the solutions on cooling become turbid fluids. The gels are not stable but show syneresis. The addition of sodium chloride in small quantities (0.4 *N*) *decreases* turbidity and *increases* gelling power, 0.6 % gelatin setting to a soft almost clear gel at 15° in 48 hours in the presence of 0.1 *N* sodium chloride: at 1.0 *N* concentration sodium chloride *decreases* turbidity and *decreases* gelling power.

2. In the presence of hydrochloric acid, gelatin becomes much more readily soluble. Sols and gels are transparent to the naked eye. Hydrochloric acid diminishes the gelling power, the degree of diminution passing through a maximum between the reactions $p_H = 2$ and $p_H = 3$, and again beyond $p_H = 0.7$ at 15°. The addition of sodium chloride in small quantities (0.1 to 1.0 *N*) *increases* turbidity and *increases* gelling power up to a p_H of 0.9. In stronger acid solutions the effect of salt is to decrease gelling power. The presence of the sodium chloride does not appreciably affect the reaction of the system.

3. In the presence of caustic soda, gelatin is more soluble than in water. Sols and gels are transparent to the naked eye. Caustic soda slightly decreases the gelling power between $p_H = 10$ and $p_H = 12$ and completely prevents gelation at concentrations above $p_H = 12$. At concentrations $p_H = 12$ and above slow hydrolysis occurs. The addition of sodium chloride in small quantities (0.4 *N*) *increases* turbidity and *increases* gelling power. In greater concentrations (1.0 *N*) gelling power is decreased. The presence of the sodium chloride is without appreciable effect on the reaction of the system.

4. Gelatin therefore can exist in the forms clear sol, clear gel, turbid sol, turbid gel, at the same temperature and the same concentration.

5. Aqueous solutions of pure gelatin are not precipitated by the salts of the heavy metals.

6. The rotatory power of gelatin is not a constant but varies (a) with temperature, (b) in acid, neutral or alkaline solutions.

7. The bearing of the above properties on the theory of gelation is discussed.

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