XLIV. THE ABSORPTION OF WATER BY GELATIN.

PART III. THE SULPHATE SYSTEM.

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IN two previous papers [Jordan-Lloyd and Pleass, 1927, 1928] the absorption of water by gelatin in the chloride and nitrate systems has been described. The present paper deals with a system containing hydrogen, hydroxyl, sodium and sulphate ions and thus considers the specific effect of the bivalent sulphate ion. The water absorption has again been measured by the percentage change in weight, calculated on the air dry weight at 100°, of pieces of purified leaf gelatin when immersed in the experimental solutions, usually for a period of 3 days. The experimental material and method are the same as previously described with the exception of the important advantage of the use of the glass electrode for the determination of the p_H values. This has markedly decreased the magnitude of the errors occurring in the alkaline zone.

The influence of the three variables, p_H value, temperature (t) and concentration of sodium sulphate (M), on the water absorption of gelatin was investigated and the results are presented graphically.

It will be convenient again to consider separately the behaviour of the gelatin in the four zones of hydrogen ion concentration, centring respectively on p_H 2.6 (acid zone), p_H 10 (alkaline zone), p_H 5 (isoelectric zone), and p_H 7 (neutral zone).

When immersed in distilled water electrically neutral (isoelectric) gelatin absorbs water by imbibition. This water of imbibition may be regarded as penetrating through the system, forming a solid solution in the gelatin gel. It has been shown previously [Jordan-Lloyd and Pleass, 1928, p. 1013] that reduction of the water of imbibition leads to coagulation of the gel. In both acid and alkaline solutions, the gelatin, acting as a weak base or a weak acid, combines with the electrolyte present to form ionisable salts with a non-diffusible ion. This leads to the production of an internal osmotic pressure within the gel which induces further water absorption. This type of swelling is referred to as osmotic swelling. In solutions of salts at about p_H 5 gelatin absorbs more water than the water of imbibition. In these conditions the water absorption occurs by a different mechanism. Both positive and negative

ions of the salt are apparently absorbed equally by the gelatin, causing hydration of the gelatin. This type of swelling is referred to as lyotropic or salt swelling. In solutions of salts at about p_H 7 the absorption of water appears to be influenced both by osmotic swelling and lyotropic swelling.

THE ACID SWELLING ZONE (p_H 1-4).

The water absorption of gelatin at 18° , after immersion in solutions of sodium sulphate from 0 to 1.0 M concentration, plotted against the final p_H of the solution is shown in Fig. 1. When no sodium sulphate is present a curve for the swelling of gelatin in sulphuric acid solutions is obtained which is in many respects similar to the corresponding ones for hydrochloric and nitric acids, but which shows marked differences. Hydrochloric and nitric acids induce a maximum swelling of 6500 and 7000 % respectively on the dry weight of the gelatin at p_H 2.6, while the maximum in sulphuric acid is only about 5100 % and occurs at p_H 3.0.

Fig. 1. p_H varying, t constant at 18° , M constant over a series of concentrations from zero to 1.0 M .

It is interesting to observe that from p_H 5.0 to 3.2 the curves for all three acids are similar, that is to say, in dilute solutions at any particular concentration up to 0.001 N the water absorption of gelatin will be the same in solutions of all three acids. At greater concentrations, however, the specific nature of the acids becomes apparent. The most arresting observation is that the p_H value of the position of maximum swelling is determined by the anion of the acid. Callow [1925], when measuring the rate of ice crystallisation in a gelatin gel, obtained p_H curves which he compares with Loeb's curves for the swelling of gelatin. The maxima of his ice crystallisation curves occur at p_H 2.5 in hydrochloric acid and at p_H 3.0 in sulphuric acid. Previously it has been stated [Loeb, 1922] that bivalent acids induce swelling which at the maximum is only half as great as that produced by univalent acids. This is not true in the conditions under investigation. The maximum swelling in

sulphuric acid is about $4/5$ of the maximum swelling in hydrochloric or nitric acids. At p_H 2.5, however, the increase in swelling above that due to the water of imbibition is about twice as great in hydrochloric and nitric acids as it is in sulphuric, but it must be remembered that this is a comparison at one arbitrary p_H value and not a comparison of the magnitude of the swelling at the various maxima. Kuhn [1922] has measured the increase in volume of powdered commercial gelatin in solutions of hydrochloric, nitric and sulphuric acids. He finds that the maximum in solutions of nitric acid is slightly greater than the maximum in solutions of hydrochloric acid and considerably greater than the maximum in solutions of sulphuric acid. Also

Fig. 2. The water absorption of collagen in lactic, acetic, hydrochloric and sulphuric acids at p_H values between 1 and 5.

Küntzel [1926] has measured the swelling of fibrous collagen by the contraction in length that occurs when the tendons from rats' tails are immersed in acid solutions. He states that nitric acid causes slightly greater maximum swelling than hydrochloric acid, sulphuric acid considerably less. The ratios of the magnitude of maximum swelling in sulphuric, hydrochloric and nitric acids are given in Table I. It is interesting to observe that results obtained by three very different methods indicate that although these monobasic acids induce greater swelling of proteins than sulphuric acid, the ratio of the

Table I. *The ratio of maximum swelling attained in sulphuric, hydrochloric and nitric acids.*

	H ₂ SO ₄	HCl	HNO ₃
Increase in weight of pure leaf gelatin (Jordan-Lloyd and Pleass)	1	1.27	1.37
Increase in volume of powdered commercial gelatin (Kuhn)	1	1.17	1.20
Contraction in the tendons of rats' tails (Küntzel)	1	1.26	1.33

maxima is, in every case, much less than 2. The results also confirm the fact that the swelling in nitric acid is only slightly, yet quite definitely, greater than that in hydrochloric acid. This difference in the degree of swelling is probably not due to the valency of the acid but to the nature of the anion.

Jordan-Lloyd and the author (unpublished results) have investigated the swelling of collagen in hydrochloric, sulphuric, lactic and acetic acids (Fig. 2). The experimental material was ox hide which had been limed to remove hair, albumins, globulins and mucoids and then, after neutralisation and washing free from mineral matter, had been dehydrated with acetone. Maximum swelling of collagen in the form of a fibrous tissue occurs in acid solutions at lower p_H values than that of gelatin in similar solutions. The degree of swelling is also much less [Jordan-Lloyd and Kaye, 1924]. The graphs show clearly that not only does the magnitude of the four maxima vary from 420 to 510 % on the dry weight, but that the p_H value at the maximum is specific for each acid. The maximum water absorption of collagen occurs at p_H 2.4 in sulphuric acid and at p_H 1.9 in hydrochloric acid solution. The curves indicate that in solutions of p_H values between 5.0 and 2.8 the water absorption in the presence of both hydrochloric and sulphuric acids is similar. In acetic and lactic acid solutions, however, the curves, even in this p_H range, are slightly removed from those for the inorganic acids, but as here the experimental error is much greater than in the gelatin systems this apparent difference may not be significant. Ostwald, Kuhn and Böhme [1925], when working with powdered gelatin in solutions of organic acids, obtained swelling curves which even for dilute solutions showed marked differences from one another. They state that swelling does not depend on the valency of the acid and that there is no correlation between the volume of maximum swelling in any acid and its ionisation constant.

Isgarischev and Pomeranzeva [1926] have measured the swelling of powdered caseinogen in $N/20$ solutions of 25 organic acids. No record is given of the p_H value of the solutions and the differences observed are certainly partially due to the variation in strengths of the acids. They state that there is no simple numerical relationship between the magnitude of the ionisation constant of the acid and the magnitude of the swelling of the caseinogen and suggest that the predominating factor is the nature and structure of the anion of the acid. In this connection probably one of the most important properties of the acid is its affinity for water. If the acid has a great affinity for water it is very probable that less water will be available for absorption by the gelatin. Fig. 2 shows that lactic acid, which has a tendency to form an anhydride at higher temperatures, *i.e.* an acid which has a negative affinity for water, induces a high degree of swelling, while sulphuric acid, which has a great affinity for water, especially at low p_H values, is, by some mechanism, preventing the gelatin from absorbing the water to so great an extent as in hydrochloric and nitric acid solutions. This view of the factors influencing swelling is supported by the influence of the presence of sodium sulphate,

which also in the anhydrous condition has a great affinity for water. The suppression of the acid swelling due to the presence of 0.01 *M* sodium sulphate is far greater than the corresponding suppression in the chloride and nitrate systems. When the concentration of the sulphate is increased to 0.5 *M* all acid swelling is completely suppressed and at greater concentrations of sodium sulphate the gelatin is coagulated to a high degree (see Figs. 1 and 9). This coagulation by sulphuric acid and sodium sulphate is much more intense and far more independent of the reaction of the solution than coagulation in either the chloride or nitrate systems. The pieces of gelatin on removal from *M* sodium sulphate solutions at all p_H values from 1–12 were very thin and brittle and rapidly dried in air, developing a surface efflorescence of sodium sulphate crystals. This suggests that the nature of the anion in both the pure acid solutions and in the salt solutions plays a very important part in determining the magnitude of the swelling. Also, in the sulphate system (see Fig. 9), when the water absorption at constant p_H values is plotted against the logarithm of the concentration of the sodium sulphate there is a point of inflexion on the curves at the point where the water absorption of the gelatin is equal to that in distilled water. This point corresponds to Loeb's theoretical deduction of the limiting value of the suppression of the swelling when the internal osmotic pressure is zero [Loeb, 1922].

The swelling of gelatin in all concentrations of sulphuric acid becomes greater as the temperature is increased (see Fig. 4). The influence of temperature on the water absorption of gelatin in acid solutions of varying concentrations of sodium sulphate at p_H 3.5 is shown in Fig. 3. It is of importance to note that the temperature coefficient of swelling becomes smaller as the salt concentration is increased. It may also be observed that, as in the chloride and nitrate systems, at all salt concentrations the temperature coefficient of water absorption is much greater above 12° than below this temperature; as this is true of the behaviour of the gelatin in the chloride nitrate and sulphate systems it strongly suggests that it is due to some inherent property of the gelatin and gives support to the theory of the transformation of the gel form (gelatin A) to the sol form (gelatin B), a change which begins at about 15° [Smith, 1919]. In sulphuric acid in the absence of inorganic salts and at reactions more acid than p_H 3.5 the gelatin dissolves at about 22°. Fig. 3 indicates that addition of increasingly large quantities of sodium sulphate not only decreases the swelling but also increases the temperature at which complete solution of the gelatin takes place.

THE ALKALINE SWELLING ZONE (p_H 8–13).

At 18° the maximum swelling of gelatin in solutions of sodium hydroxide is 4700 % of its dry weight and occurs at p_H 10.0. As the alkalinity of the solution is decreased there is a rapid decrease in the water absorption until in solutions of p_H values between 8 and 7 the water absorption is nearly

constant and then in solutions of lower p_H value it more rapidly decreases again to reach the minimum at p_H 5.

In the alkaline zone the suppression of the swelling caused by the presence of sodium sulphate is much more pronounced than that caused by the presence of sodium chloride or sodium nitrate (see Fig. 1). Even a concentration of sodium sulphate as low as 0.01 M reduces the swelling at the alkaline maximum to 3000 % and 0.1 M completely masks the effect of the p_H value of the solution in the entire alkaline zone. In the two previous studies it was observed that sodium chloride reduced alkaline swelling, but at no concentration

Fig. 3. p_H constant at 3.5, t varying from 0° to 25°, M constant at 5 values varying from 0 to 0.30 M .

Fig. 4. t varying, M constant at zero, p_H constant at 2.0, 3.6, 5.0, 7.0 and 10.0.

up to 2 M was this salt able to suppress it completely, and that the influence of sodium nitrate was found to present a marked contrast. In solutions of concentrations of 0.1 M or less, the swelling was reduced although not entirely suppressed, but above this concentration sodium nitrate, by virtue of its solvent action, caused an increase in the water absorption until at concentrations of nitrate greater than 1.0 M the gelatin completely dissolved in solutions at all alkaline reactions. In the sulphate system, however, yet a

third type of salt behaviour is observed. Increasing the concentration of the sodium sulphate leads to a proportionate increase in the suppression of the swelling until at concentrations of sulphate greater than $0.7\text{ }M$ coagulation is induced and is intensified as the salt concentration is increased. In molar solutions of sodium sulphate the gelatin is highly coagulated, but not to quite such a high degree as in the corresponding acid solutions. The influence of the addition of sodium sulphate to solutions at p_H 10 on the water absorption of gelatin is shown in Fig. 9. Between values of 0.01 and $0.5\text{ }M$ the water absorption is inversely proportional to the logarithm of the salt concentration. At about $0.5\text{ }M$ there is a point of inflexion on the curve after which the swelling decreases much more rapidly and coagulation occurs.

The property of sodium sulphate of causing coagulation in moderately concentrated solutions is also accompanied by a reduction in the solvent action of the sodium hydroxide solutions. In pure sodium hydroxide solutions complete solution of the gelatin occurs at p_H 12.1, while in $0.1\text{ }M$ sulphate solutions the gelatin dissolves at p_H 12.6 and in $1.0\text{ }M$ solutions the gelatin has not dissolved even at p_H 13.1.

THE ISOELECTRIC ZONE (p_H 4–6).

Minimum water absorption of gelatin occurs at p_H 5.0 if the solution is free from salts. The presence of sodium sulphate in fairly dilute solution causes an increase in the water absorption of gelatin in the isoelectric zone. As in the chloride and nitrate systems previously investigated, the salt swelling is proportional to the logarithm of the sodium sulphate concentration at concentrations between 0.01 and $0.1\text{ }M$ (see Fig. 9). In more concentrated solutions, however, the three systems exhibit marked differences from one another. In concentrated solutions of sodium chloride the logarithmic relationship continues to be mathematically exact up to $2\text{ }M$ concentration. Bechhold [1912] states that there is a maximum swelling induced in isoelectric sodium chloride solutions at $2.4\text{ }M$ concentration. In solutions of sodium nitrate more concentrated than $0.1\text{ }M$ lyotropic swelling increases more rapidly and is proportional to the nitrate concentration until in molar solutions the gelatin is on the verge of solution. In the sulphate system, however, it will be seen from Figs. 6 and 10 that as the concentration of sodium sulphate is increased from 0.1 to $0.5\text{ }M$ the swelling is practically constant, *i.e.* almost independent of the sulphate concentration, but at greater concentrations the swelling is inversely proportional to the salt concentration. Thus in the isoelectric range also, the magnitude of water absorption has been reduced to below that of the water of imbibition and coagulation is again encountered.

The influence of temperature on the water absorption of gelatin in solutions at p_H 5 is shown in Figs. 5 and 6. In the absence of salts, the water absorption increases gradually to a maximum as the temperature is increased from 0° to 12° . Above 12° the water absorption again decreases. In $0.01\text{ }M$

sodium sulphate solution the water absorption increases regularly with temperature but as the sulphate concentration is increased to 0.1 *M* the temperature coefficient becomes increasingly larger at temperatures above 18°. In 0.3 *M* and 0.5 *M* solutions the temperature coefficient of water absorption is quite small. The curve of water absorption in molar sodium sulphate solution shows that less swelling occurs at higher temperatures. It should be noted, however, that the sodium sulphate is much less soluble at low temperatures and that a considerable quantity of the salt has crystallised out at 0°, leaving a solution which is less concentrated than molar.

Fig. 5. *t* varying, *p_H* constant at 5.0, *M* constant at 7 values varying from 0 to 1.0 *M*.

At a temperature of 25° there is a clearly defined maximum of lyotropic swelling in 0.1 *M* sodium sulphate, greater concentrations strongly suppressing the swelling and causing coagulation of the gelatin (Fig. 6). At 0°, 12° and 18°, the maxima are not pronounced, the magnitude of the swelling at each temperature only varying slightly between 0.01 and 0.3 *M* sodium sulphate concentration.

THE NEUTRAL ZONE (*p_H* 6–8).

It can be seen from Figs. 1 and 8 that at 18° the swelling of gelatin in dilute solutions of sodium hydroxide of *p_H* value between 6 and 8 is reduced by the addition of sodium sulphate in concentrations up to 0.02 *M*. Unlike its behaviour in similar solutions of the chloride or nitrate systems, the gelatin absorbs slightly more water as the sulphate concentration is increased

to 0.3 M after which further increase in the salt concentration leads to rapid decrease in the water absorption and coagulation. The influence of temperature on the water absorption at p_H 7.0 and 7.3 is illustrated by Figs. 7 and 8. In sodium sulphate solutions of concentration greater than 0.02 M , the curves in Figs. 6 and 8 show great similarity at temperatures of 0°, 12° and 18°, indicating that the magnitude of the swelling is similar in corresponding solutions at p_H 5 and 7. At 25°, however, the curve for swelling in solutions at p_H 7 does not exhibit a maximum at 0.1 M sodium sulphate concentration as does the curve for solutions at p_H 5. The water absorption of gelatin in

Fig. 6. M varying, p_H constant at 5.0, t constant at 0°, 12°, 18° and 25°.

solutions of varying concentration of sodium sulphate at p_H 7.3 plotted against the temperature is shown in Fig. 7. The maximum of water absorption, which occurs at about 15° in sodium hydroxide solutions of p_H 7.3, is absent when any sodium sulphate is present. The curves relating to all concentrations of sulphate from 0.01 to 0.3 M lie close together and show a gradually increasing temperature coefficient as the temperature is increased. In molar solutions increase in temperature causes decrease in water absorption by the gelatin. This increase in water absorption of gelatin at low temperatures may be affected to some extent by the decreased solubility of the sodium sulphate. In moderately concentrated solutions the sodium sulphate produces the predominating effect.

It can be seen in Fig. 10 that at all p_H values and at all concentrations

of sodium sulphate solutions from 0.1 to 1.0 M the magnitude of the swelling is determined by the sulphate concentration almost independently of the p_H value of the solution.

DISCUSSION.

The behaviour of gelatin in the presence of dilute solutions of sulphuric acid and sodium sulphate is to some extent similar to its behaviour in corresponding solutions in the chloride and nitrate systems, but, even in dilute

Fig. 7. t varying, p_H constant at 7.3, M constant at 5 values varying from zero to 1.0 M

solutions and to a much greater extent in concentrated ones, marked differences are patent.

From a physico-chemical view-point the three acids and their corresponding sodium salts are similar in many respects but the sulphate ion is differentiated by its bivalent character. Sulphuric acid also is not ionised to so great an extent and is only about half as strong as nitric and hydrochloric acids and has a great affinity for water.

It should be borne in mind when comparing the effect of sodium sulphate

with that of sodium chloride and nitrate that the unit of concentration used is molecular and that equal molecular concentrations do not indicate equal ionic concentrations. This is particularly important when considering osmotic effects. The three systems which have been investigated form a very convenient triad. The hydrochloric acid, sodium chloride, sodium hydroxide system presents what may be regarded as the simplest type, *i.e.* the salt action is almost entirely confined to suppression of osmotic swelling in the acid and alkaline zones and to inducing lyotropic swelling near the isoelectric point.

Fig. 8. M varying, p_H constant at 7.0, t constant at 0°, 12°, 18° and 25°.

The behaviour of gelatin in the nitrate system is similar in dilute solutions to that in the chloride system but, as the concentration of the nitrate is increased, proportionately greater swelling is induced which becomes more and more predominant and leads to solution of the gelatin. In solutions of nitric acid the behaviour of gelatin is similar to that in hydrochloric acid, but the magnitude of the water absorption is slightly greater. The suppression of swelling by sodium nitrate in acid solutions and the induction of lyotropic swelling in solutions of 0 to 0.7 M concentration at p_H 5 are slightly greater than the corresponding effects in the chloride system. As the concentration of sodium nitrate is increased, however, this greater lyotropic swelling proves

to be the precursor of solution, which takes place in 2 M solutions at all p_H values greater than 2.5 and in molar solutions at all p_H values above 5. In the nitrate system coagulation of the gelatin may occur to a greater degree than in the chloride system but its occurrence is far more restricted by the

Fig. 9. M varying, t constant at 18° , p_H constant at 2.0, 3.0, 5.0, 7.0 and 10.0

Fig. 10. M varying, t constant at 18° , p_H constant at 1.5, 3.0, 5.0, 7.0, 8.5 and 10.0.

reaction of the solution, due to the fact that the concentrated nitrate solutions exhibit a powerful solvent action. The powerful coagulating action which occurs in sulphate solutions presents a marked contrast. In sulphuric acid solutions of p_H values of 3.0 or less, the magnitude of the swelling of gelatin

is considerably less than in the nitrate and chloride systems. As the concentration of the sodium sulphate solutions at p_H 5 is increased, the lyotropic swelling of gelatin also is suppressed by the coagulating action of the concentrated solutions and in acid solutions the suppression of the osmotic swelling is enhanced. Thus, as the sulphate concentration is increased, coagulation, which is antagonistic to both osmotic and lyotropic swelling, becomes the predominant feature at all reactions.

It has previously been suggested [Jordan-Lloyd and Pleass, 1928] that if coagulation is defined as the reduction of the concentration of water in the gel to below that characteristic of the water of imbibition of the gelatin then the degree of coagulation may be expressed numerically. If the "coagulation ratio" be defined as the ratio of the percentage weight of the gelatin in distilled water to its percentage weight in the conditions under consideration, we may compare the degree of coagulation in different systems. It should be noted that a coagulation ratio of 1 indicates that there is neither swelling nor coagulation. Numbers greater than unity indicate coagulation and less than unity, swelling. In distilled water the swelling of gelatin is 1300 %, while in molar sodium sulphate solution at p_H values from 1-4 it is 250 %. Therefore in these conditions the degree of coagulation is $1300/250 = 5.2$. Similarly, at molar concentrations at p_H 2 in the chloride and nitrate systems the coagulation ratio is 1.8 and 2.2 respectively. At p_H 2 in 2 *M* chloride and nitrate solutions the coagulation is 4.0 and 3.6 units respectively. In molar sodium sulphate solution the coagulation ratio slightly decreases as the reaction becomes more alkaline. At p_H 5 the value is 2.9 units, while at p_H values greater than 7 the coagulation is 2.6 units.

The coagulation in rather more dilute solutions of sodium sulphate is very interesting.

p_H	Coagulation ratio	
	0.9 <i>M</i>	0.7 <i>M</i> sodium sulphate
2.0	2.6	2.0
4.0	2.9	1.9
5.0	2.0	1.2
6.5	1.3	0.8
7.0	1.6	0.9
9.0	1.7	1.1
12.0	1.5	1.0

At p_H 6.5 both the curves for 0.9 and 0.7 *M* sodium sulphate show a minimum of coagulation.

The curves in Fig. 10 which indicate the influence of salt concentration at various reactions clearly show that although at salt concentrations from 0.1 to 0.5 *M* the p_H value of the solution has very little effect on the water absorption, at greater concentrations of sodium sulphate, which lead to coagulation of the gelatin, the degree of coagulation is slightly greater in acid than in neutral or alkaline solutions.

It is interesting to observe that coagulation of the gelatin increases its resistance to solution; this is true both of solution caused by increasing the

temperature and solution induced in alkaline fluids of high p_H value. This suggests that coagulation is the converse of lyotropic swelling in this respect also, for swelling appears to precede and promote solution. Thus it appears that the relative concentration of water and gelatin of the aqueous phase of the gel greatly influences the solubility of the gel in water. This suggestion is supported by the fact that dry isoelectric gelatin has a very low solubility in water, even at 100° , whereas if the same sample of gelatin be soaked in water at room temperature for 24 hours, the moist gelatin may then be melted at temperatures above 37° with the formation of quite concentrated solutions (15 % or even greater).

The investigation of the water absorption of gelatin in the sulphate system suggests that in very dilute solutions the action of sulphuric acid and sodium sulphate is very similar to the action of corresponding solutions in the chloride and nitrate systems but as the concentrations are increased the specific nature of the ions becomes more and more the dominating effect. In isoelectric solutions of sodium chloride, nitrate and sulphate as the concentrations of the salts are increased the divergence between the magnitudes of the lyotropic swelling becomes gradually more pronounced. The form of the curves, shown in this and the two previous papers indicating a high degree of swelling leading to solution of the gelatin in the case of the nitrate and coagulation of the gelatin in the case of the sulphate solutions, suggests that with increasing concentration of salt the specific influence of the anions finally overwhelms the influence of the hydrogen and of the hydroxyl ions at all values of p_H .

SUMMARY.

1. Maximum swelling of gelatin occurs in a solution of sulphuric acid at p_H 3.0.
2. Sodium sulphate in concentrations up to 0.5 *M* in the presence of sulphuric acid suppresses the osmotic swelling of the gelatin due to the acid. At greater concentrations of this salt there is coagulation of the gelatin.
3. Increasing the temperature of solutions in the acid zone causes an increased water absorption by the gelatin. The temperature coefficient of swelling is greater the higher the temperature, but is decreased by an increase in the concentration of sodium sulphate.
4. The osmotic swelling of gelatin in alkaline solutions is suppressed to a greater degree by solutions of sodium sulphate than by equal molar concentrations of sodium chloride or nitrate. At concentrations of sodium sulphate of 0.7 *M* or greater, coagulation is induced.
5. At the isoelectric point of gelatin the water absorption in solutions of sodium sulphate is proportional to the logarithm of the salt concentration up to 0.1 *M*. At greater concentrations lyotropic swelling is reduced and coagulation occurs in solutions of greater than 0.7 *M* concentration.

6. In solutions of sodium sulphate of 0.1 to 1.0 *M* concentration the magnitude of the water absorption of the gelatin is determined chiefly by the sulphate concentration almost independently of the p_H value of the solution.

7. A method of interpreting the term "coagulation" on a numerical scale is described.

8. Gelatin in the coagulated condition tends to resist the solvent action of alkaline solutions.

9. Increase in temperature generally causes greater water absorption, the temperature coefficient becoming larger as the temperature is increased.

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