

cause as it used to do. Again there was no doubt that now that, instead of its accumulating as a layer between the nitroglycerin and the waste acid as it did in the old form of separator; it came up and was removed with the nitroglycerin during the separation in the new form of nitrator-separator; it gave no trouble. It no doubt resulted from the presence in the glycerin of resinous substances, fatty acids and organic impurities, but ordinary chemical tests on glycerin as delivered in bulk failed to detect more of these substances in one sample than in others. The Chairman had asked if they knew anything about di-nitroglycerin, and tetra-nitroglycerin; he could only say they had devoted themselves entirely to tri-nitroglycerin, and so far had not done any work on either of those other forms. Di-nitroglycerin might have a future in connection with explosives, and several patents had been taken out recently for its preparation and use, but as he had no experience with regard to it he hesitated to express any opinion. It appeared to him, however, that there would be some difficulty in getting pure dinitroglycerin free from other nitroglycerines. He was happy to say, in reply to Mr. Reid, that during his sixteen years at Waltham Abbey they had never had occasion to drown a charge, but they did know that their arrangements would meet the case if unfortunately it became necessary. They had tested them, and knew that the rate of drowning was fairly rapid, and they had the additional advantage that cold water was being added to the drowning tank along with the nitroglycerin and acid. As regards the average proportion of acid to glycerin being in practice 7 or $\frac{7}{4}$ to 1, their information rather tended to support the figure they had quoted of 8 to 1, which they believed was the figure used recently in most factories in this country, and in Germany. The glycerin before being used was submitted to all the usual chemical tests and to the nitration test, and that was not a laboratory one, because experience showed that laboratory nitration tests were fallacious as a guide to what would happen in manufacture. From every consignment of glycerin they received a drum was selected at haphazard and nitrated on the manufacturing scale, and only if it was satisfactory did they accept the consignment. For a long time now it had not been necessary to reject any consignment owing to its failing to pass this test. With regard to the labyrinth referred to by Mr. Guttman, they had not been able to name the authors of all their improvements. The idea of the labyrinth was certainly suggested by Mr. Guttman many years ago, though not perhaps for quite the same purpose for which it was now used at Waltham Abbey. Mr. Guttman suggested that the labyrinth should take the place of the wash water settling tank and supplied a drawing of it as used at Hayle. They had rather extended the principle and put labyrinths in after every vessel from which washing waters were run, so as to trap as much nitroglycerin as possible before it got down to the wash water settling house. He was glad to say they had not had any signs of any failure with the sponge filter.

Mr. W. RINTOUL said a paper by H. Lemaître on the analysis of nitroglycerin waste acid (*Monit. Scient.*, Dec., 1907), had recently come to his notice, in which it was suggested that the nitroglycerin present could be determined by extraction with chloroform. From the curves given in the paper, it would be seen that the result so obtained would be about 50 per cent. too low. Lemaître assumed that all the glycerin in the waste acid existed as a nitroglycerin in solution, whereas they had shown that this was not the case. The fall of the heat test of nitroglycerin on repeated filtration was probably due to the fact that the first traces of decomposition products were absorbed by the moisture and sodium carbonate present. Whatever the cause, the fact remained that, if nitroglycerin showing a high heat test was repeatedly filtered through paper, there heat test in all such cases fell, and in so regular a manner as to suggest that the heat test of pure nitroglycerin, carried out under standard conditions, was really constant, and that it was impossible to get pure nitroglycerin to stand a prolonged test.

Manchester Section.

Meeting held at Manchester on Friday, February 7th, 1908.

DR. J. F. THORPE IN THE CHAIR.

SOME APPLICATIONS OF THE "CLARIFICATION TEST" TO SEWAGE AND EFFLUENTS.

BY GILBERT JOHN FOWLER, D.SC., F.I.C.,
SAM EVANS, D.SC. (TECH.), AND ARTHUR CHADWICK ODDIE.

Introduction.—In a paper read before this Society in May, 1905,⁽¹⁾ attention was drawn to the importance of determining the proportion of the suspended matter in sewage and effluents which is present in the colloidal state, or in a state of fine division or emulsion, as this constitutes potential solid matter which has to be ultimately dealt with. Reference was made to previous work on the subject⁽²⁾ and a number of results were given, obtained by submitting samples of sewage from various sources and of sewage and septic tank effluent, to dialysis in parchment cylinders. The importance of the subject has been since fully recognised, and numerous papers⁽³⁾ have appeared dealing with various aspects of the question.

The object of the present paper is to record a number of results which have been obtained by precipitation of the colloidal and finely suspended matters by means of basic ferric acetate, a method originally suggested by Rübner,⁽⁴⁾ and mentioned by Fowler and Ardern in the paper already referred to,⁽⁵⁾ which, for the sake of brevity, is here spoken of as the "clarification test." This method has been found to yield as instructive results as the method of dialysis, while it occupies much less time, and probably, in consequence, is less liable to error.

Clarification test.—The method adopted is as follows:—To 200 c.c. of the sample in a conical flask are added 2 c.c. of a 5 per cent. solution of sodium acetate and 2 c.c. of 10 per cent. ferric ammonium alum solution, the whole shaken and placed over a Bunsen burner. Immediately the liquid begins to boil the flame is turned down and the liquid kept just on the boil for two minutes. It is then removed, cooled under the tap, and filtered, introducing as little of the precipitate on to the paper as possible. In this way a clear filtrate is obtained which, therefore, may be taken for practical purposes to contain only substances in "true" solution. The filtrate is then analysed and the results compared with those obtained before clarification.

The precise period and method of boiling were chosen after a number of trials as being those which allowed no more liquid to be evaporated than was equal to the volume of the reagents added, the concentration of the sample is thus unaffected by the clarification. A number of blank experiments showed that, at any rate in dealing with sewage and effluents, the errors introduced by the addition of reagents and by the use of ordinary filter paper were inappreciable, especially as the chief value of the test lies in its use as a rapid method of comparing a number of samples, any small error therefore being common to all.

The exact method of estimating the amount of oxidisable matter present in the unclarified and clarified sample is a matter of more importance. It was at first thought that boiling with acid permanganate and titrating with oxalic acid, generally known as the Kubel method, would

(1) G. J. Fowler and E. Ardern, "Suspended Matter in Sewage and Effluents" (this J., 1905, 483).

(2) Manchester Corporation Rivers Committee, Annual Report for Year ending March, 1901, pp. 40—41.

O. Kröhnke and W. Blitz, *Hygien. Rundschau*, 1904, 9. Ber., 1904, 1745. (This J. 1904, 619.)

(3) A. S. Jones and W. O. Travis, *Proc. Inst. Civil Eng.*, 1905—1906, Paper No. 3500. F. R. O'Shaughnessy and H. W. Kinnerley, this J., 1906, 719. J. H. Johnston, *J. Roy. Sanitary Inst.*, 1906, 648. J. W. Eisma and J. F. Snell, *Zeits. angew. Chem.*, 1906, 35. W. Blitz and O. Kröhnke, *Cer. Ing.*, 1907, 350. (This J. 1907, 711.) W. O. Travis, *Contract J.*, Dec. 11 and 18, 1907.

(4) M. Rübner, "Das Städtische Siewasser und seine Beziehung zur Flussverunreinigung," *Archiv. für Hygiene*, 14.

(5) *Loc. cit.*

result in a saving of time. A number of experiments varying the proportion of reagents to sample, time of boiling, &c., showed that, if concordant results were to be obtained, the amount of permanganate used must be carefully proportioned to the amount of oxidisable matter present, and consequently time is occupied in preliminary estimations of this proportion. The ordinary 4 hours' test was finally chosen as being the most satisfactory determination for the purpose. At the same time, it is possible if the utmost rapidity is important, to obtain useful comparative results if shorter periods are taken for the action of the permanganate, e.g. 1 hour or even 3 minutes. In all cases if appreciable quantities of nitrites are present in solution, these must be allowed for by heating the clarified solution with acid and urea, redetermining the oxygen absorbed, and correcting accordingly. Further information as to the nature of the organic matter in solution and suspension is afforded by the determination of the albuminoid ammonia or Kjeldhal nitrogen before and after clarification. This

colloidal character or not. As a matter of fact, as Zsigmondy (?) has pointed out, no absolute distinction can be drawn between substances in suspension, in colloidal solution, and in crystalloidal solution.

In the following and other tables the figures given, unless otherwise stated, are those representing the oxygen absorption, or the albuminoid ammonia due either to colloids or crystalloids, these figures being calculated as follows :

In the case of the clarification method :—X=oxygen absorbed in 4 hours by *unclarified* sample ; and y=that absorbed by the *clarified* sample ; then x-y=oxygen absorbed by the *colloids* and y=that absorbed by the *crystalloids*.

In the case of the dialysis method :—X=oxygen absorbed in 4 hours by liquid *outside* dialyser ; and y=that absorbed by liquid *inside* dialyser ; then x-y=oxygen absorbed by the *colloids*, and 2y=that absorbed by the *crystalloids*.

The figures throughout are in parts per 100,000.

TABLE I.
Comparative dialysis and clarification tests (average results.)

Sample.	Clarification Test.					Dialysis.			
	4 Hours' oxygen absorption.		Ammoniacal nitrogen.	Albuminoid nitrogen.		4 Hours' oxygen absorption.		Albuminoid nitrogen.	
	Crystalloids.	Colloids.		Crystalloids.	Colloids.	Crystalloids.	Colloids.	Crystalloids.	Colloids.
Sewage, Withington Works (average 5 samples) ..	1.26	3.05	2.16	0.09	0.11	1.38	2.19	0.08	0.19
Sewage, Davyhulme Works	5.14	3.10	—	—	—	4.42	3.32	—	—
Effluent from septic tanks, Davyhulme Works ...	4.87	2.69	—	—	—	3.94	2.69	—	—

is especially valuable where sulphides are likely to be present, as these are either oxidised or precipitated by the hydrated oxide of iron, and therefore are not included in the estimation of crystalloids, but may, on the contrary, be included in the unclarified samples as colloids.

Comparison of dialysis and clarification method.—It was of interest, in the first place, to determine how far the results given by the clarification test were comparable with those given by dialysis. A number of comparative analyses were therefore made by the clarification and dialysis method, both at the Davyhulme works, where much trade effluent is present in the sewage, and at the Withington works, which receives only domestic sewage. The method used for dialysis was the same as described in Fowler and Ardern's paper. (6) In all cases, unless specially stated, the samples were examined after 2 hours' settlement. This procedure is, of course, quite empirical, but for practical purposes it is sufficient to distinguish between those matters which settle readily and are consequently eliminated after 2 hours' standing, and those which still remain in suspension, whether of a strictly

An examination of the table shows that although the oxygen absorption figures by the two methods, dialysis and clarification, are not identical, yet the relation between the samples as regards matters in true solution and in fine suspension respectively is of the same order in both cases. It will be seen, however, that if a sample contains a large proportion of "colloids" the dialysis method tends to give rather low oxygen absorbed figures for these. On the other hand, if the proportion of "crystalloids" is large, lower results for these are given by the dialysis than by the clarification method. This is to be expected in view of the fact that the dilution necessary for dialysis and the time required for equilibrium to be set up is likely to have a greater proportionate effect on whichever class of oxidisable matter is present in greater amount. This supposition is upon the whole confirmed by the results recorded in Table II. The samples were tested at once, after 24 hours standing alone, and after 24 hours standing after mixing with an equal volume of water. The figures for Davyhulme sewage are the average of seven analyses, which, owing to the presence of trade-effluents, &c., showed considerable variation among themselves.

TABLE II.
To show effect on various samples of standing in presence of air before and after dilution, to compare with dialysis experiment.

January, 1908.	4 Hours' oxygen absorption.					
	Original sample.		Original sample after standing 24 hours in contact with air.		Mixture of 1 vol. sample and 1 vol. water after standing 24 hours in contact with air.	
	Crystalloids.	Colloids.	Crystalloids.	Colloids.	Crystalloids.*	Colloids.*
Sewage, Withington	0.63	1.80	0.60	1.60	0.29	0.72
Tank effluent.....	0.77	1.74	0.50	1.03	0.27	0.79
Primary filtrate	0.40	0.67	0.34	0.65	0.20	0.29
Secondary filtrate	0.34	0.36	0.24	0.40	0.17	0.14
Sewage, Davyhulme	5.20	3.04	4.71	3.05	2.70	1.64

* Figures in these columns to be doubled for comparison with the other results.
(6) Loc. cit.
(7) "Zur Erkenntniss der Colloide," Fischer, Jena.

In the case of the Withington sewage samples some comparative determinations of albuminoid nitrogen are given in Table I. These agree well as regards the matters in true solution, but show considerable variation in respect to the colloidal matters. In presence of suspended matter it is, however, well known that the albuminoid nitrogen figure is somewhat indeterminate.

Experiment re-aeration of contact beds.—An interesting application of the clarification test was afforded in an experiment done at the Withington works to determine some of the conditions of effective aeration of contact beds. This inquiry arose in connection with certain experiments with reference to the working of automatic gear, where it was necessary to reduce the capacity of certain of the second contact beds by holding up the effluent within them to the depth of about 9 inches by means of a weir board at the exit. It was thought not unlikely that this might exert a prejudicial effect on the aeration of the bed, and consequently on the purification effected by it. The opportunity was therefore taken of carefully testing the point, and the results of the clarification test are given in the following table. They bring out quite clearly the superior results obtained when the bed is allowed to empty itself completely. The appearance of the samples confirmed the results of the analyses in showing that defective aeration increased the amount of colloidal matter present. The inference appeared to be that a certain amount of circulation

of air must take place through the exit valves, and consequently these should be kept open during a period of rest and the bed allowed to drain freely.

TABLE III.

Aeration of contact beds.—Secondary bed No. 3, without weir board: completely emptied. Secondary bed No. 4, with weir board: about 9 inches of water held in bed.

Average filtrate, Nov. 12 to 15, 1906.	4 Hours' oxygen absorption.		Albuminoid nitrogen.	
	Crystal- loids.	Colloids.	Crystal- loids.	Colloids.
Secondary bed, No. 3	0.00	0.04	.025	.015
Secondary bed, No. 4	0.70	0.20	.025	.045

SYSTEMATIC APPLICATION OF THE CLARIFICATION TEST AT DAVYHULME.

The foregoing results and other investigations with widely varying sewages to be recorded later led to the adoption of the "clarification test" as a routine method at the Davyhulme works, and the following tables give the result of determinations continued during the last 6 months of 1907. Average figures only are given for each month.

TABLE IV.

Clarification test (Davyhulme Works). 4 hours' oxygen absorption test. Results in parts per 100,000.

Source of sample.	Original sample I.	After 2 hours' settlement unclarified. II.	Heavy suspended matter. I.—II.	Clarified sample "crystalloids." III.	Fine suspended matter "colloids." II.—III.
<i>July and August.</i>					
Raw sewage.....	8.73	6.13	2.60	3.44	2.69
Effluent from septic tanks.....	0.79	0.03	0.76	3.17	2.86
Effluent from primary contact beds—					
Series I.....	3.17	2.86	0.31	1.77	1.09
Series II.....	2.36	1.91	0.45	1.11	0.80
Series III.....	3.33	3.07	0.26	1.77	1.30
Effluent from secondary bed.....	0.91	0.91	nil.	0.49	0.42
<i>September.</i>					
Raw sewage.....	11.44	8.07	3.37	5.33	2.74
Effluent from septic tanks.....	8.57	7.60	0.97	4.74	2.86
Effluent from primary contact beds—					
Series I.....	3.87	3.56	0.31	2.53	1.03
Series II.....	2.94	2.60	0.25	1.70	0.99
Series III.....	4.09	3.77	0.32	2.36	1.41
Effluent from secondary bed.....	1.03	1.00	0.03	0.59	0.41
<i>October.</i>					
Raw sewage.....	11.11	8.10	3.01	5.31	2.79
Effluent from septic tanks.....	8.12	7.27	0.86	4.87	2.40
Effluent from primary contact beds—					
Series I.....	3.61	3.24	0.37	2.13	1.11
Series II.....	2.83	2.51	0.32	1.50	1.01
Series III.....	4.14	3.89	0.25	2.43	1.46
Effluent from secondary bed.....	0.90	0.90	nil.	0.59	0.37
<i>November.</i>					
Raw sewage.....	11.43	8.31	3.12	5.20	3.11
Effluent from septic tanks.....	8.13	7.52	0.60	4.94	2.50
Effluent from primary contact beds—					
Series I.....	4.20	3.83	0.37	2.74	1.09
Series II.....	3.43	3.10	0.33	2.10	1.00
Series III.....	4.27	4.07	0.20	2.50	1.48
Effluent from secondary bed.....	1.27	1.21	0.06	0.73	0.48
<i>December.</i>					
Raw sewage.....	11.84	8.31	3.53	5.20	3.11
Effluent from septic tanks.....	8.65	7.70	0.95	5.03	2.67
Effluent from primary contact beds—					
Series I.....	4.16	3.80	0.36	2.57	1.23
Series II.....	3.40	3.09	0.40	2.60	0.93
Series III.....	5.10	4.73	0.37	2.51	2.22
Effluent from secondary bed.....	1.51	1.41	0.10	0.97	0.44

A study of these tables reveals several points of interest. *Sewage and septic tanks.*—In the first place, it will be seen that during the warmer months of July, August, and September there is a greater proportion of colloidal matter in the effluent from the septic tanks than in the raw sewage, whereas during the last 3 months the reverse is the case. The lower figures for the total oxidisable matters in the sewage in July and August are due entirely to the less proportion of oxidisable matter in solution. This is partly accounted for by the lessened production of certain trade effluents (mainly ammonia-recovery liquor) during this period, and partly by the greater rainfall. The figure for the total oxidisable matter in September is, however, almost identical with those of the following months. Consequently, it would appear that the increase in the colloidal matter in the effluent over that in the sewage during the first 3 months must be due almost entirely to the higher temperature, and consequently greater fermentative activity of the tanks. It is a curious fact that, although the sewage was certainly more dilute in July and August than in September, the oxygen absorption due to colloids is the same in both cases. This is confirmed by experiments quoted later, which suggest that on mixing solid sewage matter with increasing quantities of water a proportionately greater quantity of colloids are disseminated through the liquid. In time of rain the lighter organic solids are also probably more thoroughly separated from the heavier mineral matters. The substances in true solution are apparently merely diluted. There is a distinct reduction in the oxygen absorbed by crystalloidal substances in the tank effluent as compared with the raw sewage, especially during the warmer months. As there is almost always an increase in ammoniacal nitrogen after the sewage has passed through the septic tanks, the decrease in the oxygen absorption figures would indicate the breaking up of nitrogenous compounds into substances absorbing less oxygen. This receives confirmation from experiments with Withington sewage to be quoted later, and also is in harmony with results obtained some years ago in the laboratory at Davyhulme, (8) where a distinct decrease in the actual weight of dissolved organic matter originally present in the sewage, as determined by evaporation, was found to take place in the septic tank.

While it is hardly conceivable that substances in true crystalloidal solution can become converted into the colloid condition in the septic tank, yet these results certainly do not favour the view that any large proportion of the solid matters in the sewage are, in the strict sense, dissolved in the septic tank under the conditions at Davyhulme. The disappearance of undissolved organic matter would appear to be chiefly accounted for by its escape in the form of colloids and as gas. At higher

of washing operations, the beds on Series II. having all been completely renewed with washed material by the beginning of the year, and an increasing number of beds in Series I. in the course of the six months in question. The superiority of the washed beds shows itself in the earlier months more in the capacity of oxidising the dissolved matter, but later rather in the reduction in the oxygen absorbed by the colloidal matter. The lessened oxidation of dissolved matter may be due in part to the greater activity of nitrification in the warmer months. At the same time, it must be remembered that the actual quantity of nitrates emerging in the effluent from contact beds is the balance left over after a certain amount has been taken up in oxidising organic matter during the period of contact. The character of the dissolved matter in the septic tank effluent in the two periods may also affect nitrification, apart from the actual temperature of the liquid as it passes on to the beds. Probably, however, the increased rate of working the beds on Series II. during the later months is the chief factor in causing a greater proportion of dissolved matter to pass through unoxidised. (9)

The figures for colloids indicate that retention, oxidation, and granulation of colloidal matter is probably a process largely independent of nitrification; other researches have, in fact, shown that the oxidation of retained organic matter is due in part to the activity of worms and other higher organisms. These latter are unable to live in any portion of a bed which is permanently water-logged. Any undigested colloids will also tend to re-dissolve in the effluent. Further, the power of "absorption" exerted by the gelatinous film has been shown by the experiments of Dunbar (10) to be reduced rapidly in absence of adequate aeration. All these factors will tend to increase the proportion of colloids in the effluent from a badly aerated bed. On the other hand, if a bed is well aerated the colloids continue to be retained or oxidised, even when the oxidation of dissolved matter is diminished.

With regard to the secondary bed, the larger amount of oxygen absorbed by the crystalloidal matter during the later months is obviously conditioned by the amount present in the primary effluents. The colloidal matter is practically independent of the amount in the primary filtrate.

The above results indicate how the "clarification test" may serve as a routine method for controlling the work of septic tanks and contact beds.

It may find equally useful application in the control of percolating filters. The following examples are taken from a number of results obtained in the course of experiments in the purification of latrine effluents on fine-grained percolating filters. The sewage under treatment

TABLE V.—Treatment of latrine tank effluent on fine-grained percolating filter.

Tank effluent.			Filter effluent.			
Oxygen absorption, 4 hours.		Ammoniacal nitrogen.	Oxygen absorption, 4 hours.		Ammoniacal nitrogen.	Nitrous and nitric nitrogen.
Crystalloids.	Colloids.		Crystalloids.	Colloids.		
·00	2·26	—	1·12	·27	1·04	3·48
·06	1·45	4·72	0·36	·36	1·08	2·37
1·28	1·20	5·08	0·88	nil.	1·33	2·00

* Figures corrected for nitrites. The samples were not allowed to settle before analysis, but the amount of sedimentary matter was practically negligible.

temperatures or longer periods of fermentation, evidence will be brought forward to show that with domestic sewage at any rate true solution of organic matter does take place.

Contact beds.—Turning to the purification effected by the bacteria beds, a point which comes out quite clearly is the better purification effected by the beds of Series II. over those of Series I. and III., and of Series I. over Series III. This is no doubt due to the progress

(9) Quantities dealt with by bacteria beds—Series II. and Secondary bed. (Gallons per cubic yard per day.)

Series II.		Secondary bed.	
July and August....	110	July and August....	180
September	100	September	100
October	125	October	140
November	125	November	180
December	160	December	180

(8) Annual Report of the Manchester Rivers Committee, 1901, p. 37.

(10) Zur Beurtheilung der biologischen Abwasserreinigungsmethoden. Ges. Eng., 1903, Nos. 33 and 34.

was mainly derived from a rice-eating population in the tropics. They are of interest as showing that even when excellent nitrification of the ammonia was being effected the work of the filter largely consisted in removal of the colloidal and suspended matters in the tank effluent. These matters are evidently much more affected than those in solution other than the ammonia.

How far the difference between the oxidisable colloidal matter in the effluent from the tank and the filter respectively indicates a mere retention of this matter by the filter, or how far it indicates actual oxidation, can only be determined after a filter has been at work a considerable time. General experience points to the fact that considerable retention does take place, and that the oxidation of this retained matter proceeds much more slowly than the nitrification change. The rapid increase of colloidal matter in the effluent if the aeration of a bed is impeded is one evidence of this storage. The "clarification test" gives a rapid measure of the quantity of this retained oxidisable matter which has to be dealt with.

It is of interest to note that the drop in the oxidisable matters in solution after filtration is less on the whole than is given by the Davyhumle contact beds. This may be due partly to the fact that the character of the dissolved matters are such that they do not cause reduction of nitrates or denitrification changes to the same extent as those present in the Davyhumle tank effluent. This is likely to be the fact, owing to the much more complete hydrolysis taking place at the high temperature of the experiment than is the case in the Davyhumle tanks. It is obvious that the clarification test will afford a simple means of determining how much of the organic matter passing away from coarse-grained percolating filters is in the colloidal and therefore incompletely oxidised condition. Recent experiments by the Massachusetts State Board of Health (11) on the mechanical filtration, after

coagulation by chemicals, of effluents from open percolating filters would indicate that the amount of colloidal matter present in these effluents is appreciable.

FURTHER INVESTIGATION OF THE ANAEROBIC DECOMPOSITION OF SEWAGE.

Effect of varying periods of time.—As the anaerobic decomposition of albuminoid organic matter consists in the progressive resolution into substances of a colloidal and finally crystalloidal character, it appeared likely that the clarification test would afford a useful means of determining how far these changes go on in the septic tank, and possibly of throwing some light on the question of so-called "over-septicisation," which involves the practical issue of the right size of septic tanks. A series of experiments was carried out in the following manner at the Withington sewage works, where only domestic sewage is dealt with. A sample of sewage after settlement was divided among a number of bottles, which were completely filled, and allowed to stand for varying periods of time, after which a portion was carefully decanted off and taken for analysis. A similar series was made up, only half filling the bottles, and thus allowing the sample to stand the presence of air. The results of the analysis are given in Table VI. with a note as to the proportion of hydrogen-sulphide present. The figures are somewhat indeterminate, owing to the uncertainty as to the effect of the proportion of soluble sulphide on the oxygen absorption test, but taken together they indicate pretty clearly that little advantage and certainly a greater liability to nuisance is incurred by constructing tanks of a capacity greater than sufficient to hold one day's flow. In presence of air the oxidisable matter, both colloidal and in solution, is certainly reduced to a greater extent than under anaerobic conditions, the ammoniacal nitrogen is also less, but the albuminoid nitrogen does not appear to be affected to the same extent.

TABLE VI.—Effect of varying periods of time on anaerobic decomposition.

Series I.—Analyses of samples of raw sewage after settlement.

Time standing at the temperature of laboratory	4 Hours' oxygen absorption.				Ammoniacal nitrogen.		Albuminoid nitrogen.				Sulphide in absence of air.
	In absence of air.		In presence of air.		In absence of air.	In presence of air.	In absence of air.		In presence of air.		
	Crystal- loids.	Colloids.	Crystal- loids.	Colloids.			Crystal- loids.	Colloids.	Crystal- loids.	Colloids.	
0	1.83	2.07	—	—	2.03	—	.11	.10	—	—	trace
24 hours	1.80	2.54	1.23	2.88	3.05	2.04	.00	.13	.08	.17	trace
48 "	1.43	2.80	1.11	2.38	2.62	2.23	.06	.14	.08	.19	fair
120 "	1.80	3.51	1.31	1.52	2.71	2.47	.03	.11	.05	.14	large

Series II.—Analyses of samples of raw sewage after shaking.

Time standing at the temperature of laboratory	4 Hours' oxygen absorption.				Ammoniacal nitrogen.		Albuminoid nitrogen.				Sulphide in absence of air.
	In absence of air.		In presence of air.		In absence of air.	In presence of air.	In absence of air.		In presence of air.		
	Crystal- loids.	Total un- dissolved matter.	Crystal- loids.	Total un- dissolved matter.			Crystal- loids.	Total un- dissolved matter.	Crystal- loids.	Total un- dissolved matter.	
0	3.00	7.20	—	—	5.52	—	.27	.80	—	—	nil
18 hours	1.71	8.12	1.60	9.00	5.85	5.04	.10	.04	.16	.88	trace
24 "	1.71	8.00	1.43	9.06	5.04	5.18	.11	.09	.11	.74	fair
42 "	1.71	7.72	1.31	8.79	5.58	6.00	.13	.72	.11	.93	v. fair
66 "	1.77	8.20	1.43	9.57	6.23	5.88	.08	.82	.08	.85	v. good
90 "	1.83	8.80	1.40	10.21	6.23	5.70	.07	.56	.07	.65	large
114 "	1.04	9.55	1.60	8.80	6.82	6.00	.08	.59	.08	.87	large

(11) State Board of Health, Massachusetts, Annual Report, 1906, p. 283.

A second series of experiments, where the samples were analysed after shaking, thus including the settled solids in the precipitated matter, led to pretty much the same conclusion. The decrease in oxidisable matter in solution under anaerobic conditions, which was noted in the case of the Davyhulme observations is here emphasized.

Additional anaerobic treatment of effluent from septic tanks.—An interesting application of the clarification test was afforded in the case of an installation where a considerable extent of anaerobic contact bed, which remained constantly full of liquid, had been provided between the septic tank proper and the aerobic percolating filters. Average samples were carefully taken before and after this anaerobic bed and tested by the clarification method, 1 hour being allowed for the oxygen absorption in this case, and the samples being allowed to settle before analysis. The following results were obtained:—

	Oxygen absorption, 1 hour.	
	Colloids.	Crystalloids.
Before anaerobic tank.....	1.00	1.00
After anaerobic tank	1.05	0.95

These figures reveal, therefore, practically no difference, and complete analyses showed that the weight of actual solids in solution was practically identical in the two cases, and consequently that the only effect of the anaerobic beds was to retain a certain quantity of the suspended solids escaping from the septic tank. In this case the septic tank alone held nearly two days' flow and the anaerobic bed provided another 12 hours' storage. Much less provision than this would have been sufficient for a mere mechanical straining, which was all apparently that the bed was effecting. The bearing of the results of the clarification test on the economical design of works is thus apparent.

Effect of dilution on rate of change under anaerobic conditions.—An important and difficult point to decide in the design of works, especially of anaerobic tanks, is the right proportion between the concentration of the sewage and the holding capacity of the tank. It is generally considered that 24 hours' storage is enough for practical purposes, and this general rough and ready estimate is probably sufficiently correct in a large number of cases. It is evident, however, that 24 hours' storage for a sewage of, say, 5 gallons per head concentration means a much less tank capacity per head of population than if a 24 hours' storage is to be given to a volume of sewage amounting to, say, 40 gallons per head from the same population. The same amount of organic matter, however, passes through both tanks. Of this the heavier portion will settle out in a few hours in both cases, and its fermentation continues over a long period of time. The question is really confined to the matters in colloidal and crystalloidal solution, and it is important to find out what effect dilution has upon their course of change. On general principles it would be expected that within limits enzymic hydrolysis would be more rapid and complete the more dilute the solution.

Much work remains to be done in this direction in connection with the various fermentations occurring in the anaerobic tank. The following experiments show the results obtained in two cases by the application of the clarification test. In the first case a sample of crude sewage (5 gallons per head strength) in a very fresh state from a rice-eating population, was diluted in varying proportions with tap-water and the mixtures allowed to stand 24 hours and then analysed, the whole of the solids, however, were included in the portion tested before clarification. The figures for the ammoniacal and albuminoid nitrogen are also given.

TABLE VII.—Effect of dilution on rate of anaerobic change. Series I.

Ratio of volume of sample to volume of tap-water.	Nitrogen.		Oxygen absorption, 4 hours.	
	Ammoniacal.	Albuminoid.	Total suspended solids, including colloids.	Crystalloids.
1:1	1.07	2.36	7.94	2.71
1:3	0.79	1.23	3.00	2.30
1:5	0.61	0.61	1.70	2.01
1:7	0.36	0.41	0.93	1.77

Series II.

Original sample.	Colloids.	Crystalloids.
1:1	2.64	2.26
1:3	2.04	1.43
1:5	1.73	1.11
1:7	1.30	0.83

These figures show very clearly the greater conversion of complex nitrogenous matters into simpler forms, the albuminoid figures decrease in much greater proportion than the dilution, while the ammoniacal nitrogen is proportionately increased. Corresponding with this there is a very considerable increase in the oxygen absorption due to crystalloids, and a corresponding decrease in the amount absorbed by the insoluble matters. There is clear evidence here of true solution of organic colloidal matter, and this solution evidently takes place more rapidly the more dilute the solution. These results are confirmed by experiments in this country, the experimental conditions being somewhat modified. The sewage contained a thick sediment of faecal matter; this was shaken up thoroughly on dilution, but even when 7 volumes of tap water were added, to 1 of sewage much sediment remained. The samples were incubated for 7 days at 26° C., and the supernatant liquid carefully decanted off and the oxygen absorbed in 1 hour determined before and after clarification.

Table VII, Series II., shows the progressive increase in colloids and crystalloids, with increase of dilution, the figures being much greater than they would have been had simple dilution taken place.

The fact that considerable evolution of hydrogen sulphide took place hardly affects the conclusion that the rate of decomposition increases with the dilution, as in any event any oxygen absorbed by the hydrogen sulphide would only affect the figure due to colloids, and if the rate of decomposition were equal throughout should be proportionately less with the greater dilution. Moreover, the total sulphur in European sewage of 5 gallons per head strength has been found by one of us not to exceed 4 parts per 100,000.⁽¹²⁾ Still, some portion of the increase in the oxygen apparently absorbed by the colloids may be due to hydrogen sulphide, and no doubt a purely mechanical disintegration of heavy solids into colloidal matter takes place on dilution as mentioned earlier in connection with Davyhulme sewage. The results, however, bear out the general conclusion that when sewage ferments under anaerobic conditions some proportion of the heavy solids assume the colloidal condition, and the colloids progressively are converted into complex crystalloidal compounds, and these suffer further change in composition with final production of simple ammonia derivatives. The relative rate at which these various changes take place will depend on the character of the sewage, the temperature, and the dilution. Much further work is needed before these points can be worked out in detail. Thus examination by the clarification test of a sample of Withington sewage after incubation at about 26° C. for 4 days and after standing for the same time at laboratory temperature shows a greater amount of colloids and of crystalloids in the incubated sample.

⁽¹²⁾ Fowler "Treatment of Sewage under Tropical Conditions," International Congress of Hygiene and Demography, Berlin, Sept., 1907.

TABLE VIII.—Effect of temperature on anaerobic changes.—Raw sewage, Withington.

Temperature conditions.	Oxygen absorption.				Chlorine.	Hydrogen Sulphide.
	4 hours.		3 minutes.			
	Crystalloids.	Colloids.	Crystalloids.	Colloids.		
Incubated at 26° C.01	1.38	.46	.45	3.6	Fair amount
Laboratory temperature00	1.08	.29	.45	3.6	trace

FURTHER STUDY OF THE CHANGES TAKING PLACE IN SEWAGE UNDER AEROBIC CONDITIONS.

It becomes now of interest to endeavour to follow the changes taking place under aerobic conditions of various kinds and certain observations may be quoted in reference to preliminary aerobic treatment in contact beds of very open structure.

The following table (Table IX.) shows the average effect

TABLE IX.—Preliminary aerobic treatment (tropical conditions).

Description of sample.	Oxygen absorption, 4 hours.	
	Crystalloids.	Colloids.
Raw sewage.....	2.77	6.69
Preliminary aerobic contact bed .	3.10	6.10
Secondary ditto	0.00	2.51

of such treatment on native sewage (10 gallons per head dilution) in the tropics. The sewage was taken in an almost absolutely fresh condition. Unfortunately no distinction was made between heavy solids and colloidal matters, the oxygen absorbed by both of these being given in one column. As a matter of fact with a 10 gallon dilution most of the oxidisable matter was obviously colloidal. There is a slight decrease in the oxygen absorbed by the insoluble and colloidal matters, and a slight increase in the amount absorbed by the crystalloids. On passing the liquid on to a fine contact bed a great decrease takes place in both. With a concentration of 5 gallons per head, later experiments showed that a greater difference was exhibited in the total purification effected by the open contact bed.

The following observations were made in the course of an investigation of Mr. Dibdin's slate bed process at Devizes, High Wycombe, and Coombe Malden. At Devizes the sewage is highly offensive and concentrated, at High Wycombe it is very dilute, and at Coombe Malden the sewage is of average strength, and the object of the test in the latter case was to compare the effect of the slate bed with chemical treatment. The oxygen absorption figures were in this investigation determined by the Kubel method, the amount of permanganate used being roughly proportional to the oxidisable matter present. The colloids were not determined separately from the total suspended matters except in the case of Devizes where the figures for colloids are given in brackets. The results obtained were as follows:—

TABLE X.

Preliminary aerobic treatment (English conditions) (Kubel test).

	Oxygen absorbed (Kubel test) by	
	Total suspended solids.	Crystalloids.
Devizes—		
Crude sewage	30.3 (0.3)	10.7
Slate-bed effluent	21.1 (9.0)	15.4
Fine-bed	3.5	8.5
High Wycombe—		
Sewage	13.5	5.5
Slate-bed effluent	3.0	0.9
Coombe Malden—		
Effluent from chemical treatment	5.00	1.0
Slate-bed	3.00	0.8

Both under tropical and European conditions the main effect of holding the sewage in contact with such surfaces for an hour or two appears to be retention of the heavier suspended solids which are subsequently slowly oxidised. The effect on the remaining colloidal and crystalloidal substances is much less marked and will depend to some extent no doubt on dilution and temperature. It is worthy of remark, however, that the effluents after preliminary aerobic treatment are more quickly nitrified on mixing with aerated tap-water than is untreated sewage.

Changes accompanying nitrification in solutions of organic matter.—The clarification test may be usefully employed in studying the changes taking place when mixtures of nitrogenous organic matter and aerated tap-water are kept under conditions favouring nitrification. It thus supplements the methods of examination so successfully used by Adeney in his classical researches.⁽¹³⁾ It may find a specially useful application in studying the conditions of successful treatment of complex trade-effluents.

The following results were obtained in the course of an investigation into the treatment of woolcombers' refuse and the effect of the presence or absence of free sulphuric acid on the decomposition of the organic matter present. The following solutions were made up:—*Solution 1a.* 50 c.c. sample 1, 5 c.c. nitrifying solution, 945 c.c. tap-water (free acid present). *Solution 1b.* The same mixture neutralised with excess of magnesium carbonate. *Solution 2a.* 50 c.c. sample 2, 5 c.c. nitrifying solution, 945 c.c. tap-water (free acid present). *Solution 2b.* The same mixture neutralised with excess of magnesium carbonate. (The nitrifying solution was made by dissolving 0.25 gm. of urea in 1 litre of water, with the addition of 1 c.c. of sewage effluent, a small piece of filter paper moistened with fermenting urine, and a little magnesium carbonate. A good development of nitrites had taken place in the solution when used as above.) Solutions 1a, 1b, 2a, and 2b were transferred to Winchester bottles (which were thus more than half full of air), placed in the incubator at 26° C., and kept under observation for a considerable time (Sept. 9—Oct. 17, 1907) being well shaken at intervals. They were then examined by the clarification test, the 4 hours' oxygen absorption being used as a measure of the changes which had taken place. The following figures were obtained after deducting the oxygen absorbed by the nitrites in the neutralised samples:—

TABLE XI.

Effect of neutralisation on aerobic changes.

	Oxygen absorbed, 4 hours.	
	Total insoluble matters, including colloids.	Crystalloids.
1a (acid).....	1.53	0.01
1b (neutral)	1.31	0.94
2a (acid).....	1.00	0.61
2b (neutral)	1.27	1.40

These figures point to a greater breaking down and solutionising of organic matter in the case of the neutralised samples, and thus indicate that neutralisation is advisable at some stage of the purification process.

(13) Trans. Royal Dublin Soc., 1897; Proc. Royal Irish Academy, 1905.

Amount and character of crystalloidal and colloidal matter.—It is fully realised that the mere determination of the oxygen absorbed, though of evident value as a comparative test, does not give much information as to the actual composition or quantity of the oxidisable matters present in the different conditions, and much further research of a more detailed character is needed for a full interpretation of results. Some preliminary work has been done in this direction. Thus a number of determinations of the amount of grease present in Withington sewage have been made by extracting the basic ferric acetate precipitate with ether. The results as given in the following table do not show any special correspondence between the amount of ether extract and the other analytical figures.

TABLE XII.—Application of clarification test to determination of amount of "ether extract" in Withington sewage. (Parts per 100,000.)

Oxygen absorption, 3 minutes' test.		Albuminoid nitrogen.		Ammoniacal nitrogen.	Chlorine.	Ether extract.
Total precipitated matter.	Crystalloids.	Total precipitated matter.	Crystalloids.			
3.08	3.26	0.37	0.11	3.05	7.7	8
3.56	1.31	0.32	0.16	3.53	8.0	42
4.57	1.49	0.30	0.09	2.82	7.7	11
4.29	1.77	0.20	0.08	2.35	7.4	35
4.57	1.60	0.24	0.11	2.70	8.3	20
4.74	1.09	0.36	0.13	3.18	7.7	20

It is intended to pursue the investigation of the precipitated matter, determining, for example, the total carbon and nitrogen present, if possible, after separating fatty substances and cellulose. Further examination of the amount and nature of the crystalloidal substances and their rate of oxidation needs to be made; in fact, ample materials exist for prolonged research.

Conclusions.—The present paper, however, is intended to be suggestive rather than final. The results recorded have, at any rate, emphasised the complexity of the problem with which the sewage chemist has to deal. They have shown that the oxidisable matters in sewage are present in three states, as heavy suspended matter, as colloidal matter, and as crystalloidal matter. The rate and character of change in each of these states respectively has been shown to differ and to depend on varying factors.

For a full understanding of the process, the conditions of purification of each class of matter should be worked out separately. This evidently requires prolonged research of a refined character.

At the same time, when used as an ordinary routine method, the "clarification test" has been shown to be capable of affording the sewage works chemist, in a rapid and simple way, a deeper insight into the changes taking place in the course of the processes he is called upon to supervise. It is hoped, therefore, that it may be more generally adopted, when the accumulated observations of a number of workers should supply a valuable control upon the more detailed work of the research laboratory.

The thanks of the authors are due to the Rivers Committee of the Manchester Corporation for their ready permission to publish the results obtained at the Davyhulme and Withington works, and to Mr. Edward Arden, Resident Chemist at Davyhulme, for valuable help and criticism during the preparation of the paper.

The experiments relating to the treatment of sewage under tropical conditions were done in connection with work described in a paper on the subject read before the International Congress for Hygiene and Demography at Berlin, in September, 1907. The remaining observations were made by one of us at the Public Health Laboratories of the University of Manchester, where every facility was afforded for the carrying on of such work

DISCUSSION.

The CHAIRMAN said that some time ago, in conjunction with Mr. Ogden, the manager of the Davyhulme works, he had made experiments with regard to sewage clarification by filtration processes. He could not say whether they got rid of the colloids, but he should think not. He thought Dr. Fowler's method, in addition to being simple, was accurate. He believed it was due to the soluble colloids that the effluent, although not putrefactive itself, possessed putrefactive power when mixed with other waters which contained bacteria. He looked upon this question as one for the organic chemist more than the sewage chemist to deal with. When they considered the great number of known compounds and the

different methods adopted for their production, he thought it should be possible at the present time to attack these problems with some hope of success. With regard to the proteins, this was a problem which could not be solved by one man. Science had become so specialised that it would have to be collaborated work of the chemist, the physiologist, and the bacteriologist.

Mr. H. L. PENNY said that the clarification test would doubtless be employed when better known, in conjunction with the oxygen absorption test, by those who had sewage works under their control. Dr. Fowler had not suggested that the reagent could be employed on the large scale with a view to further reduce the objectionable colloidal matters existing in varying amounts in sewage effluents. He was specially interested in the figures given in the effluent from a percolating filter, showing as they did the conjunction of low colloidal matter and high nitrates. His experience with certain types of sprinkler filters was that with effluents containing nitric nitrogen varying from one to three grains per gallon, there was no subsequent decomposition. High nitrates seemed to indicate a low content of colloidal matters, and, consequently, the advantage of the sprinkler filter over the contact bed.

Mr. BARNES said that a more rapid method for estimating the oxygen absorbed was by using chromic acid and sulphuric acid, whereby he could quickly obtain very good results and a more complete oxidation of the organic matter than by the usual four hours' permanganate test. Moreover, certain organic substances which gave practically no results with the permanganate test gave almost theoretical results with the chromic acid test. He also found it possible by making use of the two tests to tell whether the sewage effluent was polluted with starch or gelatin, or whether it was mainly of an albuminoid character. He should like Dr. Fowler's opinion on these matters.

Dr. F. W. SKIRROW said it has been shown by Biltz and Khrönke that the colloids in sewage had a negative polarity when suspended in water, and it had also been shown that two colloids of opposite polarity mutually precipitated one another, even in absence of electrolytes, but in order to effect this precipitation it was essential that the concentration of the colloids should be kept within certain limits, and if the concentration of the added colloid was outside these limits no precipitation was

affected. Biltz and Khrönke stated that in the precipitation of the negative colloids in sewage by ferric salts the active agent, in all probability, was the positively charged colloidal ferric hydroxide present owing to the hydrolysis of the salt. Had Dr. Fowler found it necessary to carefully regulate the concentration and amount of the basic ferric acetate added in order to effect the maximum precipitation? Biltz and Khrönke attempted to explain the bacteriological treatment of sewage by the attraction of oppositely charged colloids. The bacteria formed a gelatinous layer on the material of the bed and this layer then acted mechanically on the colloids contained in the sewage forming a so-called "absorption compound." The further oxidation of the absorbed colloid then took place quite independently by the oxygen of the air or by enzyme action. If this explanation were correct, Dr. Fowler's method was of still greater value, as the laboratory test really reproduced what was taking place on the bacteria bed, the active agent in this case being the positively charged colloidal ferric hydroxide in place of the gelatinous product of bacterial action.

Mr. E. ARDERN, as a result of considerable experience with the clarification test at Davyhulme, was able to confirm the authors' opinions in regard to its usefulness in amplifying the information gained by the usual routine analytical methods employed in the examination of sewage and sewage effluents. The results given in Table I. showed that the oxygen absorption due to crystalloids in the case of the sewage at Davyhulme was considerably greater than that due to colloids, while in the case of Withington, it was only one-third of that due to colloids. The difference in character of the two sewages was thus readily shown. The clarification test also afforded useful information in connection with the supervision of sewage purification works. Once a definite standard of working had been established for a given works, by results obtained from filter beds of known efficiency, it was possible with some degree of accuracy to ascertain by means of the tests whether any individual filter bed was in a satisfactory condition or not. Considerable care would, however, have to be exercised in the interpretation of the results obtained. Further information was required as to the relation of the amount of oxygen absorbed from permanganate by the colloidal matter to its actual weight and character. The determination of the total amount of colloidal matters (by examination of the matter precipitated by ferric acetate) appearing in the various stages of the purification process, and investigation as to the exact nature of these matters, would doubtless yield interesting information regarding the actual purification changes. Mr. Barnes had referred to the results obtained by oxidation with chromic acid as compared with those given with acidified permanganate. Under suitable conditions it was possible to obtain, by means of concentrated chromic acid, complete oxidation of the carbonaceous products present and consequent estimation of the percentage of organic carbon. In many cases this moist combustion method was very useful, especially where a combustion furnace was not available.

Dr. FOWLER, in reply, said his chief reason for reading the paper was to bring this test into general use, so that others might collect information which would be mutually helpful. The chairman had referred to the experiment of filtration through porous porcelain. He thought Dr. Thorpe was the first to work on these lines. He remembered how Dr. Thorpe filtered some sewage through a porous pot and found that the filtered liquid was very slightly putrefactive. Undoubtedly the colloidal matter was the more polluting and would be more rapidly oxidised on mixture with the stream, and afterwards they did not cause any very serious trouble by deposit. As a matter of fact, the Davyhulme effluents, if filtered through paper, were non-putrefactive. The most serious problem centred round the removal of the colloidal matters. He fully agreed with the chairman as to the necessity of the collaboration of many workers in the purely scientific investigation of these matters and he was also particularly

anxious to obtain information from the works managers, who had ordinary routine knowledge of analytical methods, which would be of great value in the scientific working out of the subject. Mr. Terry referred to the absence of colloids if nitrates were present. He (Dr. Fowler) thought that was not always the case, and referred to the Massachusetts experiments to show that such colloids were present. He was particularly anxious to obtain more information as to the character of effluents from open percolating filters. He had shown that in a fine-grain filter the colloids were removed. Whether they were removed or oxidised remained to be seen. As explained by Dr. Skirrow, the removal in the first instance was largely physical. The theory of Khrönke and Biltz threw further light on the absorption theory of Dunbar. When sewage is placed in connection with elinkers, there was no doubt that the colloids were largely removed from solution. They were not oxidised in the time taken for them to pass through the filter. The rate of oxidation depended on a variety of factors. The idea of the precipitation of the colloids by electrical means had been present in his mind for some time. Some years ago Mr. Ogden found, on experimenting, that purification was effected. He thought it was largely due to the polarising of the colloidal matter. They had tried a number of experiments, but had not obtained very good results. It was not possible with the action of the weak current to bring about any great change without a considerable extension of surface. With regard to Dr. Skirrow's reference to the proportion of ferric salts to be added, they had never had any difficulty in getting an absolutely clear solution, having always an excess of ferric salt present. The permanganate test was purely experimental. It afforded a rapid means of comparison, but it is necessary to investigate much more fully, and no doubt the chromic acid method mentioned by Mr. Barnes would be extremely useful in that respect. They could differentiate between the final cellulose, but it was very difficult to oxidise such compounds as certain derivatives of humic acid. In their further investigations they would certainly bear in mind the relative effect of these reagents. They began to collect these precipitates with a view to their complete oxidation by chromic acid owing to this differential action, but gave up the method and went on with the combustion process; that work was still in progress and further work was in contemplation.

Obituary.

F. J. SMALE.

The death of F. J. Smale, Ph.D., of Toronto, has deprived the Canadian Section of the Society of an exceedingly valuable member. He was born Sept. 20th, 1871, was educated in the public school and Collegiate Institute of Lindsay, graduated into Toronto University in 1889, won a fellowship in 1892 given for capacity in scientific research, and then proceeded to Leipzig, where he took the Ph.D. degree. On his return from Leipzig, he was at once elected a lecturer in Chemistry in the Toronto University. At the end of three years he resigned this post, to devote himself to business life. He served on the Committee of the Canadian Section of this Society as an ordinary member in 1902, became vice-chairman in 1903, and was chairman during 1904 and 1905. In 1906 he was elected an ordinary member of the Council of this Society. Smale was a man of high character, and greatly esteemed both in social and scientific circles. He died after a brief illness on Jan. 3rd, 1908.