length upon the dangers incurred in using fatigued metals in construction, which would ultimately give way and perhaps entail the loss of hundreds of lives. The idea, he says, at present in view, is to have a bill passed to appropriate the necessary amount; a commission appointed, consisting of mining, civil, and mechanical engineers, who, under different condition, from those of the other commission, thoroughly exhaust the matter by conclusive investigations.

MEETING, APRIL 8.

Psychological explanation of the Salem witchcraft excitement, and the practical lessons derived therefrom.—By Dr. Geo. M. Beard.

Dr. Beard gave a full history of the details of the excitement in Salem in 1648, and of the trials of the twenty persons there and twelve others in other places, and their execution. This, it is said, in relation to the half million who had been executed on the other side of the Atlantic, was comparatively small, but nevertheless sufficient to arouse all persons in this country and especially New England.

The theory held by the perpetrators of these excitements was that it was a treaty which a person had made with the devil which placed the person in his power. Through him were all the evidences shown of his existence, as when brought near a slightly demented person, known as afflicted children, they were thrown down in convulsions, or saw strange phenomena. Dr. Beard showed how easy this was provoked, and, as an illustration, had two boys with him whom he made in one case to fall down in convulsions on seeing Dr. Newberry, and the other one see a yellow bird on his head and a hawk at his feet. Dr. Beard showed how this was produced, by the easy picturing of these things on an unsound brain. Dr. Beard then discussed at considerable length the Guiteau, Whittaker, and other cases in this connection, and the responsibility of demented persons.

AMERICAN CHEMICAL SOCIETY.

SESSION OF APRIL 7.

On the estimation of copper.—By P. Casamajor.

The author discussed the great indistinctness of the end reaction of Pelouze's method—that is, of dissolving the copper in ammoniacal solution and titrating with sulphide of sodium until the discharge of the blue color. He then showed his process, which was of dissolving the alkaline tartrate solution of Fehling's solution, the copper salt, and then titrating this with sulphide of sodium when near the boiling point. The precipitate of sulphide of copper was agglomerated readily by stirring in presence of the alkaline tartrate. Mr. Casamajor went over the process with some of the members, and the end reaction was distinctly found. This method is also applicable with lead and just as accurate. Thus it is capable of varied determinations.

THE SECOND PAPER OF THE EVENING.

On the determination of tannic acid.—By Mr. Nelson H. Darton.

Mr. Darton's paper was to show the relative values of all the different processes of tannic acid determination. Half of the paper only was read, showing the inaccuracies in the use of Lowenthal's and Hammel's process. A few remarks were made upon it.

AN INVESTIGATION UPON THE VALUES OF THE VARIOUS METHODS USED IN THE DETERMINATION OF TANNIC ACID.*

By NELSON H. DARTON.

PART I.

THE question of which is the most accurate and at the same time convenient method of determining the values of the various tanning materials is a much vexed one, and it is because chemists generally seem to have such vague speculative ideas in regard to tannic acid, that it is with great difficulty that we can learn anything from the many researches that have been published, they being, as a rule, enshrouded with enigmas and complications, thus rendering them of little or no value in a practical consideration. Besides this, most of the papers have no originality, being, as a rule, repetitions of worn-out theories, pointing out the difficulties lying in the way of those investigations; in fact, chemists seem rather to avoid the subject of tannic acid, but are continually pointing to it and expending all their talent in this direction in trying to find different forms of tannic acid.

As the manufacture of leather has now become such an important industry, and its intellectual production necessitates a full knowledge and control of the values of the materials used for this, a proper method should be decided upon, but not without careful consideration of its trustworthiness, this paper being for that purpose.

Of late, in my intimate connection with the tanning industry, I have fully weighed these considerations, and having in vain sought out, through what has been already published, to find the method in view, have taken the matter in hand myself, although very busy otherwise, and have made as far as possible, with the means at hand, a thorough investigation, the results of which I will detail in this paper. Before I give them, however, I wish to have it distinctly understood that I do not doubt the accuracy of what Proctor and some others have written, but as they claim that they were not the best attainable, I claim that mine are, and thus some discordances, but as the other papers gave few figures or demonstration, these are few and will hardly bear consideration. The investigations were to determine the relative accuracy of the following methods: Lowenthal's modification of his old method; Hammel's skin and specific gravity processes; Carpeni's zinc method as modified by Barberi; the gelatine or Watt's process, highly refined; Allan's lead method, modified by Sanford, and my own method, a radical modification of Lowenthal's.

Before considering the investigations, I would like to state that every evidence that I can bring to bear shows that there exists but *one tannic acid*, that is as I define it, a peculiar organic principle, ten parts of which unite with six parts of the component parts of the skin by weight, to form sixteen parts of leather. It occurs in many different conditions in nature, but only as regards admixture with glucosides, so called, extractive and coloring matters, etc., with which chemists have confounded it, and thus the many formulas advanced and nearly as many different ones as there are materials containing it. So when I mention tannic acid throughout this paper, I refer to this principle in a state of absolute purity in the above relations to leather, which is the only practicable way as yet of expressing it. Subsidiarily I divide it in two classes: The first, gallo-tannic acid when associated

with oak and hemlock bark, etc., and which from nutgalls we can obtain in a state of absolute purity, although I have also obtained it from oak bark so pure as to have the same formula as that from the nutgalls; but as I am here intruding upon the subjects of another subsequent paper, yet unfinished, to prove that there is but one tannic acid; then I consider another association, that is with gums—kino and catechu and rhatany root, etc., from whence the impure substance, the so-called catechu tannin, has been obtained. This mixture unites very peculiarly, owing to the peculiar extractive matter, etc., present, and from which as yet we have not separated the tannic acid so as to secure it. The reactions which distinguish them from the last is the tannate of copper; is somewhat soluble in ammonia solutions in which this before contaminating extractive matter, etc., is dissolved; and also the tannate of copper contains in this case some of this matter. This is, however, strictly peculiar to these materials. The tannic acid will in all cases, however, combine with the skin in the pure state, as I have readily shown, or at least, after the washing and scrubbing, which is positively necessary, as I will show below.

For the purpose of standardizing the numerous solutions to be used, an absolutely pure tannic acid in relation to leather formation and practical theory, as noticed above, was prepared and examined. In every respect it was prepared thus: A fair quantity of coarsely-ground Aleppo nutgalls was taken and treated with ether and water after the method of the U. S. P.

The product thus obtained was then thoroughly washed with absolute alcohol dissolved in absolutely pure ether, and this repeatedly agitated with water until all of the gallic and considerable of the tannic acids were abstracted. It was then separated from the ethereal solution by gentle evaporation and dried in a vacuum. It was then dissolved in 80 per cent. alcohol, this solution filtered, and from thus separated as above. After drying at a gentle heat in the air bath, and over sulphuric acid in a current of pure dry carbon dioxide, a portion was burned and twice yielded the proper formula. This whole treatment is necessary to obtain the pure tannin, as it frees it from the one coloring matter soluble in alcohol, the other soluble in ether alone. A solution of this was prepared containing two grammes to a liter; this solution was kept in a colored bottle and out of contact with the air by carbon dioxide, when not in use. For greater precaution, the bottles were placed in the dark; no change, however, occurred in their relation to the permanganate solution or oxalic acid.

Pure gallic acid from nutgalls was procured, carefully recrystallized, and obtained pure. A solution was made containing two grammes to a liter of water, and carefully kept. Pure English gelatine (Nelson's) was used after further purification, and a solution of it prepared immediately before use by dissolving 25 grammes to a liter of a 10 per cent. solution of sodium chloride.

The permanganate of potassium solution contained 1.5 grammes to a liter, and was frequently renewed during the investigations.

The acetate of lead solution for use in Allan's method contained a decinormal quantity of pure acetate of lead.

The solution of indigo carmine was prepared by dissolving three grammes of pure indigo carmine to a liter of water and boiling for some time. It was carefully kept airtight, and did not change its relation to the permanganate solution a fraction of a cubic millimeter.

The other solutions were all prepared extemporaneously with every care and precaution.

For the objects of the determinations decoctions were prepared of hemlock, oak and chestnut barks, Aleppo nutgalls, sumac leaves, and of the so-called catechu tannins of gums, catechu, kino and rhatany root. As they were all made under the same conditions, I will only detail the mode of extraction of the first and most important one, hemlock. To a liter of the decoction in view, 20 grammes of the coarsely-ground select inner bark of the hemlock was taken. This was extracted by carefully treating it with water in a current of carbon dioxide, allowing the decoction thus formed to cool, and then filtering through four thicknesses of filtering paper. A very small amount of dilute sulphuric acid was then added to the solution, and it was again filtered. The excess of acid is neutralized by adding just sufficient baryta water and the precipitate filtered off. The decoction was thus freed from much of the so-called extractive matter and elagic acid, formerly held in solution, and contained but little more than tannic and gallic acid. This decoction was preserved in small flasks with carbon dioxide. The solutions from the catechu, etc., were prepared and kept in a similar manner, but still retained considerable extraneous matter. These last solutions, I may add, are much less liable to change, owing to the peculiar principles present. Tannic acid, prepared from the solutions by a process used for the nutgalls, the pure tannin from the latter, and the contaminated from the former, had widely differing formulas, but, at the same time, very valuable ones, showing that the method must be varied to obtain the catechu tannins, so called, in a nearly pure solution like the others.

The preliminaries now being adjusted, we will consider the results of the researches, commencing with Lowenthal's new modification, published in Fresenius' "Zeitschrift," 1877, pp. 33-101. So much has been written in favor of this method by Proctor and others, that I would fain have examined it; but in working with it for only a few hours I immediately noticed discordances with its own and also with working results, and my control method, which I will detail further on.

Ten portions each of the different decoctions were taken, and the analysis conducted in strict accordance with Lowenthal's directions. For the avoidance of misunderstanding, I will detail my exact mode of procedure to obtain the results noticed as No. 1 of the hemlock on the table, with approximate figures, however, the same decoctions being used for each column throughout the table, to make the results comparable.

Twenty c. c. of the indigo solution was first titrated with the permanganate; it required exactly 8.4 c. c. The bulk of the solutions during the titration, which was conducted in a porcelain dish, was always kept equal; the volume decided upon was three-quarters of a liter. A fixed amount of dilute sulphuric acid was always present—10 c. c.

Ten c. c. of the standard tannic solution was then taken; 20 c. c. of indigo solution and the acid was then added, and these together titrated as before, requiring 13.7 c. c., which, less the 8.4 c. c. for the indigo present, = 5.3 c. c. for the tannin. In this connection the relation with oxalic acid was also ascertained.

The same operation was then repeated, using the same quantity of the decoction as of the tannin. Before, 15.3 c. c. were used, less 8.4 for the indigo, equals 6.9 c. c. for the decoction.

100 c. c. of the decoction was then taken, placed in a flask with 50 c. c. of the gelatine solution and 100 c. c. of a saturated sodium chloride solution containing besides, to a liter 25 c. c. of sulphuric and 50 c. c. of hydrochloric acids. Between the additions the mixture is well agitated. It was allowed to stand over night and a perfectly clear filtrate taken off the next morning. To save calculations and fulfill similar conditions as those above, 25 c. c. was taken, equaling 10 c. c. of the undiluted decoction. It was titrated as above, using 11.45 c. c. of permanganate, or 3.05 c. c. for the impurities, etc., titrated before and not tannin. Reducing the amount 6.9 c. c. by this deduction to 3.85 c. c., we have the equation—

5.3 c. c. : 3.85 c. c. :: 2 grammes to a liter; x grammes to a liter $x = 1.45$ c. c. grammes to 20 grammes of bark, or 7.25 per cent., the value of the bark. In tannic acid this is, as I will show, lower than really is the case:

No.	20 G. to liter. Hemlock.	20 G. Oak.	20 G. Chestnut.	5 G. Nut Galls.	10 G. Sumac.	5 G. Catechu.	25 G. Kino.	3 G. Rhatany.
1	7.25	7.40	6.00	52.5	13.5	47.0	82.0	
2	7.00	7.30	6.00	56.3	12.9	51.0	82.0	
3	7.30	7.45	6.10	54.2	12.9	48.0	82.0	
4	7.20	7.25	5.90	55.0	13.3	49.0	82.5	
5	7.25	7.00	6.30	55.5	13.1	48.0	81.3	
6	7.20	7.00	6.00	53.0	12.8	50.0	83.0	
7	6.90	7.10	5.90	55.6	13.2	51.0	82.0	
8	7.25	7.30	6.20	54.4	13.25	49.0	82.0	
9	7.10	7.20	8.00	54.5	12.95	50.0	83.0	
10	7.15	7.10	6.10	52.8	13.2	48.0	81.5	About.
Average.	7.16	7.21	6.15	54.4	13.1	49.0	82.1	80.00
Real value.	7.90	8.22	7.42	61.5	16.25	40.60	72.00	34.00

All these figures together, except those of the rhatany, give an average value of 100 per cent. nearly, but as this average is of the high and low, it is not to be taken as a value. The average from the first price is about 86 per cent., and for the last two 117 per cent., or a comparative value the same as the other. These errors are incurred thus: In the first place, the tannate of gelatine is more or less soluble in a weak gelatine solution, even when chloride of sodium and the strong acids are present; in fact, although the acids facilitate the coagulation of the precipitate, and, consequently, the subsequent filtration dissolves a portion of it. It is also somewhat soluble in solutions of gallic acid. This is also shown by the figures in the nutgall column; besides this, considerable gelatine remains in solution as an excess, and as the quantity is very variable, cannot be calculated for, as it depends upon the amount of so-called extractive matter present, as I will show further on. All these errors together produce a difference of 40 per cent. at least. This is, however, partly compensated by the amount of oxidizable matter and gallic acid, which are also, when together, precipitated partly, or in greater or less proportion, with the tannate of gelatine. Considerable is also precipitated by withdrawing the tannic acid, which, acting as a solvent, holds them in solution. This is shown, besides, in some experiments in the column under rhatany, where so much matter depending on the tannic acid for the solution was precipitated as to render this determination impracticable. It is also shown in catechu and kino, but to a less extent. This is what some in good faith call a peculiar tannic acid, and even separate and ascribe to it a formula. They probably never combined an ounce of tannic acid with as much skin to make leather in their lives, or they would have known its character. Thus their ignorance is pardonable. I have not endeavored to modify this process, in the last three determinations I used little excess of gelatine and acid; but with no perceptible difference. The real values were found by the control to be detailed further on.

This part of the method surely is a very satisfactory one, as far as it goes, as it is easy to execute, and has not so many of the difficulties peculiar to the others. It, however, does not come up to my working tests on a large scale, wishing to investigate further its value, especially on the use in determining the tannic acid in spent barks and liquors, those from which the so-called *free* tannic acid has been removed by tanning with them.

These liquors contain many unknown principles derived from the skins and their treatment; and thus their accurate examination is very difficult, so that this and my own method are the only ones that can be used at all. It is of great importance to the tanner to know how his spent barks and liquors are running in strength. For the investigations the spent liquors were taken, treated with sulphuric acid, etc., as above, and the determination proceeded with as before. Five analyses were made of the spent liquors, direct from the vats, after a run with Buenos Ayres skins well cleansed and rinsed for the oak and hemlock. Liquors from sumac and catechu were taken—they had been used on fine skins, and were good samples. The results are tabulated in per cents.

No.	Oak.	Hemlock.	Sumac.	Catechu.
1	0.13%	0.08%	1.95%	1.90%
2	0.14%	0.085%	1.90%	1.925%
3	0.125%	0.88%	1.95%	1.93%
4	0.16%	0.08%	1.95%	1.89%
5	0.145%	0.085%	1.925%	1.90%
Average.	0.140%	0.08%	1.90%	1.91%
Real value.	0.27%	0.21%	1.02%	1.00%

These figures are of course only approximate, but lead proportionally to the real values, which are true to the first decimal. The causes of such great errors as these are that much less matter is separated with the tannate of gelatine. A very large proportion of this last dissolves the large proportion of gallic acid, etc., and the amount of free gelatine left in solution is greater in proportion with spent bark. The results are about the same, or a little higher, in comparison.

Now the prime argument: to show the misleading results given by this method, and to show the method used, we will consider the analysis of the hemlock bark-decoction, keeping in our comparison the result obtained in No. 1. In the tables here we find the first value 7.25 per cent. tannic acid.

* Read before the American Chemical Society, April 7, 1882.

We take a cord of this bark, leach it, and obtain a measure (1,250 gals) of decoction. The spent bark is examined by this method and found to contain 0.7 per cent. of tannic acid. Leather is carefully formed from the decoction, and what is 5 per cent. of the bark found to have combined, and as I will show further on, is now tannic acid. The spent liquors' value we find to be equal to 0.5 per cent. of the bark, that is to say, as we would speak of sweet liquors, nearly all the tannin in the bark, or 6.5 per cent. of it as tannic acid, treated in this manner so as to avoid confusion. All these figures together give a result of 6.2 per cent., or 1 per cent. unaccounted for, thus showing the first result to be too low also. The tannic in the spent liquors and forming them had been kept from change by the use of a preservative, and one which I know to be complete.

Now if the spent liquors be examined by my method we find it to contain what is equivalent to 1.4 per cent., which would bring the result up to 6.9 per cent.—still too low; but by also examining the spent bark by my method we obtain 1.5 instead of 0.5, and the figure is brought up to the actual point of 7.9 by this working test, or as we will see by consulting the table under my method, my result.

According to the reasoning deduced from the figures obtained by this method we would have 6 per cent. of the bark combined with the leather, but this is proven untrue every day in actual tanning, as over 5 per cent. for hemlock, others in proportion, is never attained.

The next method in order for consideration comes Hammel's process and its modifications, which were so popularly used some time ago, and even yet among the tanners. The results obtained by it in constant use were so inaccurate and inconstant as to have it speedily set aside, and one like Lowenthal's used. The many inaccuracies have been partially shown by a number of investigators, especially Proctor, who has shown that gallic acid is thrown down with the tannic acid, etc. The method was carefully tested and examined as the other, and the results are here tabulated.

No.	Hemlock.	Oak.	Chestnut.	Nut Galls.	Sumac.	Catechu.	Kino.	Rhatany.
1	10.2	13.2	10.8	34.0	10.00			
2	6.5	6.4	0.8	43.0	1.00			
3	9.9	9.3	9.2	56.0	6.5			
4	11.4	12.4	7.4	40.0	7.6			
5	9.6	14.0	6.9	61.0	9.8			
6	6.8	4.0	11.2	53.0	6.9			
7	11.2	8.0	10.2	57.0	8.2			
8	6.9	12.5	4.9	49.5	7.4			
9	8.4	5.0	8.6	45.0	10.5			
10	10.5	10.0	9.4	56.0	6.8			
Average.	9.14	9.48	8.26	49.0	8.57			
Real value.	7.90	8.22	7.42	61.5	16.25			

These figures were obtained in the following manner: The decoction, filtered and treated as before, was placed in a graduated jar, and the specific gravity taken by the use of a very delicate densimeter; the skin was then taken, thoroughly cleansed, bated, and raised by appropriate treatment; it was then thoroughly washed with a solution of gallic acid, and again with acetic acid, and finally with warm water until the liquors were pure and sweet; it was then placed in contact with the decoction, and allowed to tan in the first five analyses for an indefinite period, and in the last five for the shortest possible time without difference, however, these tannings being executed without access of air. It was then taken out and scrubbed off, and rolled as far as possible without altering the bulk of the solution, the specific gravity of which was then taken, the amount of tannic acid being calculated from the difference, etc.

The details of the method were executed with much more refinement than it is generally, and the principles involved thoroughly worked out; but with this observe the results. One might reason why should not the results be identical with the practical manufacture of the leather, or 5 per cent., etc.? This I can readily show. In the first place, to obtain the decoction for the determination, or, rather, to make solutions containing all the tannic acid from the material used, we have to extract much more extraneous matter, especially in the case with rhatany, kino, and catechu, than in the imperfect leaching of the tanneries, where, in the case of the last-named material, only 50 per cent. of the tannic acid is present, and a minimum of coloring matter is extracted; thus the leather has much less matter to contaminate with. In the second place, the sample of skin is never a fair specimen in the treatment of the whole skin, and more particularly, besides this, the leather formed cannot be properly freed from the different matters besides tannic acid held mechanically in the pores, without altering the volume of the solution, it must be remembered in this connection that leather, after it is formed, is thoroughly rolled, scrubbed, and treated in such a manner as to leave nothing but leather; the skin absorbs gallic acid; and the so-called extractive matters, even before the tannic acid and also by withdrawing the tannic and partly the gallic acids from the decoctions, much other matter is deposited, as I have shown before. Part of this is deposited in the leather, the rest is set free; this by the treatments noticed above is removed before the leather is dried and weighed. Thus in our determination much matter is abstracted and accounted for, as tannic acid thus yielding too high results. Besides these considerations the densimeter employed must have extreme delicacy, and even then a small distance on the scale represents much tannic acid, and the readings being so very different after the treatment, being influenced by the above condition. Altogether I pronounce this method little better than a mere guess—in fact, a tanner can arrive at closer results by his tasting the liquors than are obtained by this method.

In the examination of spent liquors and barks this method has no value at all, as it yields very inconstant results. This is caused mainly by the putrescent matters present in the liquor and the other causes intensified. In the analysis of the spent bark, the results are like those shown in the table below:

No.	Oak.	Hemlock.	Sumac.	Catechu.
1	6.5	4.0	7.9	4.0
2	2.2	5.2	8.4	3.0
Average.	4.3	4.8	8.2	3.5
Real value.	0.27	0.21	1.62	1.9

These results together are about the same as those obtained

by the so-called tannometer; in fact Hammel's whole method, however modified, is about the same thing as this instrument, which I cannot too strongly emphasize should be done always within the tanneries, as it only shows how much tannic acid and otherwise, especially otherwise, may be held in solution.

In the use of this method, and the worthless modification of drying the skin fillings, and weighing before and after treatment, chemists and others generally obtain the results too low, but that depends upon the very nice point of understanding how to make leather. Like many other things, it is very simple to view, but requires considerable tact in that direction. Therefore the tanners, as a rule, obtain better results with it than chemists generally.

Using the calculations applied to Loewenthal's method for a control, we find thus: In the No. 1 as before, the leather, 5 per cent.; the spent liquor, 3.5 per cent.; the spent bark, 4.5 per cent.; these together, 13 per cent. This is quite far from the average value given, or 9.5 per cent. Now, giving the proper value to the spent liquor, or 1.4 per cent., the result is 10.9 per cent., or much nearer the truth—but showing the method to yield too high results, irrespective of any other method or control.

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(To be continued.)

COMETS.*

PART II.

By RICHARD A. PROCTOR.

From what we have already seen, it will be manifest that the formation of comets' tails is a process of a very mar-

to think that the head may act in some way to send a beam of condensed light along the region opposite to the sun. It should hardly be necessary, however, to explain that no such beam of light could ever be seen where we see the comet's tail. The cases supposed to correspond with the formation in this way of the tail-like appendage are, in reality, of an entirely different kind. Thus, when we see a long beam extending from a bright light, we find that—first, the light has been caused to pass in that direction only (as when light is admitted into an otherwise darkened room through a hole); and secondly, there is matter along the course of the light to be illuminated. The beam is simply that long array of material particles which the light illuminates while leaving the particles in neighboring space in darkness. So understood, such a beam is seen to be utterly unlike a comet's tail; for, in the first place, we know of no matter behind the head to be illuminated; and, in the second, we know that light is falling on the regions all around the apparent array of illuminated particles, so that these surrounding regions should be as brightly lit up, which is not the case.

If any further doubt could remain as to this theory, it would be removed by—first, the circumstance that the tail of a comet is generally curved; and, secondly, the existence of several tails extending from the head of one and the same comet.

Professor Tyndall started a theory based on physical experiments, and otherwise in better accordance with scientific possibilities. Having found that certain gases, even in an exceedingly attenuated form, form a luminous cloud under the action of the electric light, he suggested that a comet's tail may be a luminous cloud of this sort, formed in the ether of space by those rays of sunlight which have passed

FIG. 6.—DONATI'S COMET, SEPTEMBER 24, 1858.

velous nature, as apparently involving forces other than those with which we are acquainted. The tail, ninety millions of miles in length, which was seen stretching from the head of Newton's comet nearly along the path which the retreating comet had to traverse (the comet thus passing away with its tail in front, instead of behind, as when it approached the sun), must, it would seem, have been formed by some force far more active than the force of gravity. The distance traversed by the comet in the last four weeks of its approach to the sun under gravity was no greater than that over which the matter of the tail, seen after the comet had circled around the sun, had been carried in a few hours. Yet we have no other evidence of any repulsive force at all

through the comet's head. The rays which, without passing through the head, fall on the ether of space, would not call into existence this visible cloud, because their heating action would destroy what their chemical or actinic action by itself would produce. And as fast as, by the comet's motion, the cloud formed behind the head came under full solar action, it would be destroyed. So the tail would always be behind the head.

It appeared to Professor Tyndall that the curvature of a comet's tail, or the existence of more tails than one, as in Donati's comet (Figs. 6 and 7), was not inconsistent with this interpretation. For he noticed that according to the gas dealt with, the luminous cloud would take a longer or

FIG. 7.—DONATI'S COMET, SEPTEMBER 26, 1858.

being exerted by the sun—at least, no evidence which can be regarded as demonstrative—and still less have we any evidence of a repulsive force exceeding in energy the sun's attracting power.

This difficulty, and the circumstance that a comet's tail lies in the direction opposite to the sun, or in the position which the shadow of the head would occupy, has led many, unfamiliar with the laws of optics, to suppose that the comet's tail may be simply the track of the luminous rays which have passed through the comet's head. They seem

shorter time in becoming visible. And he suggested that when the cloud formed slowly, the tail would be curved, the part near the head being behind the position which the head had recently passed through, while the part near the end of the tail would be behind the regions through which the comet had passed much earlier. Such luminous trails as were formed more quickly would account, he considered, for the straighter tails. He overlooked, I think, the circumstance that the shape of the luminous cloud trail would not in reality depend at all upon the length of time which the cloud might take in becoming visible. Light would pass with the same velocity through the different kinds of

* Continued from SUPPLEMENT No. 330, page 5270.