Dr. S. Rideal thought it would be interesting to be able to compare the different monetary values of oxygen, free and combined. He would therefore ask the author to give the meeting, if he could, some data as to the monetary value of oxygen as an oxidising agent. They would thus be able to judge whether bleaching as performed by hydrogen peroxide would be cheaper or dearer than when due to bleaching-powder or other oxidising agent.

Mr. Kingzett, in reply, said that the reason he had represented oxygen as either triatomic or tetratomic was that it could not possibly be diatomic. If it were diatomic the two oxygen atoms in the peroxide of hydrogen molecule would be equally associated with each atom of hydrogen, and consequently of equal stability, which was not the case, seeing that one atom only was so easily dissociated. Chemical common sense clearly showed that the two atoms could not have the same combined value in peroxide as the one atom of oxygen had in a molecule of water. It followed, therefore, that it must be either triatomic or tetratomic. He inclined to the view that it was triatomic, because it undoubtedly was so in ozone. As to the chemical equation on the slate which had been referred to in course of the discussion, he wished to disclaim all responsibility for it. It was due to the French chemist, Berthelot, and represented the analytical results of his investigation as communicated to the *Académie des Sciences*. Dr. Squire's remarks were especially valuable, because of his large experience in the manufacture of peroxide of hydrogen; and he had hit the right nail on the head when he said that the action of the ether depended largely upon how the hydrogen peroxide itself had been prepared. Therein laid the crux of the matter. If it were carelessly prepared, if it were either acid or alkaline in character, or if it contained certain impurities, no agent would prevent it from decomposing within certain limits; but if it were properly prepared, as it could be by those who understood the subject, then the substances which he had mentioned were capable of preserving it from material loss of strength for 12 months or more. With respect to the strength of hydrogen peroxide solutions he knew that there were manufacturers here, dishonest enough—he used the term advisedly, for it was dishonesty—to represent that their five-volume solutions were 10-volume solutions, relying on the quantity of oxygen as obtained by the so-called permanganate test. In America they always did so; but of course that could be got over by testing the solution with acidified iodide of potassium, and estimating the iodine thus set free in the usual manner.

Dr. Steinhart had inquired as to the specific chemical action of alcohol, and had suggested that the stability of the peroxide, as preserved by that substance, was due to the formation of acetic acid and the production thereby of an acid reaction. That could not be, for if Dr. Steinhart would refer to Table 3 he would find that in the first two experiments (which were made with standard solutions) he had added 1 per cent. of sulphuric acid to one of them on the 46th day, and it would be seen that the restraining influence of the acid reaction was expressed by the fact that on the 405th day the unprotected solution had lost 83 per cent., whereas the protected solution (which for 46 days was maintained under the same conditions) had, owing to the addition of the sulphuric acid, lost only 60 per cent. Therefore the restraining action of the sulphuric acid was about 23 per cent. It would also be seen from the same table (experiment No. 6) that acetic acid certainly exercised an even greater restraining influence than sulphuric acid; so much so, that on the 405th day the loss was only 50 per cent. Therefore it had a greater effect *per se*. Whether the effects of the sulphuric and acetic acids were to be regarded as due merely to "acid reaction," or were to be viewed in their individual characters, there could be no question but that alcohol certainly restrained very much more than did either the one acid or the other, as was revealed by the figures submitted. It was therefore absolutely incredible that the preservative effect of alcohol is due to the generation of acetic acid therefrom.

Lastly, as to the monetary value of oxygen in its various forms, he was sorry not to be able to give any exact data. Air was cheap enough, but it was not capable of producing those decolourising and oxidising effects which had to be obtained in the commercial bleaching of silk, cotton, paper, bone, hair, &c. Atmospheric oxygen, therefore, had no value in relation to such applications, nor was pure oxygen any more valuable, so far as he knew. Hydrogen peroxide, and that alone, had a distinct value for such purposes. Common air and oxygen were of no utility, either, for antiseptic purposes, whereas peroxide of hydrogen had a most pronounced value in that respect. With regard to bleaching-powder he had stated in his paper that peroxide of hydrogen was, so far as Germany and France were concerned, believed to be rapidly replacing bleaching-powder for bleaching woollen, silk, and other goods, partly in consequence of the destructive effect of chloride of lime on the tissues of such materials, and also because peroxide of hydrogen gave better results. He believed that the adoption of peroxide would follow more largely in England in time; and as to the comparative cost, the results which had been published justified him in saying that peroxide of hydrogen was not more expensive than bleaching-powder for such purposes, while its production was constantly being cheapened and its effective action increased.

ON A NEW METHOD OF COLOUR ANALYSIS BY MEANS OF THE TINTOMETER.

BY J. W. LOVIBOND.

I have to-night to describe and illustrate by a series of experiments a new instrument for the analysis and registration of colour.

I do not now propose to discuss the theoretical laws which govern the question of colour, having endeavoured as far as possible to keep myself free in my experiments from any undue bias to any particular theory.

The instrument and method to which I refer is a new means of impartially judging the various colours; for recording the factors of colour which combine to form any given colour; and a system for registering the same, even in the most complicated combinations, and the most delicate shades as well as in the deepest tints which exist in nature.

The illustrations which I propose to submit will represent work already done, and those cases where the application is commercial, have already become routine in the industries to which they apply.

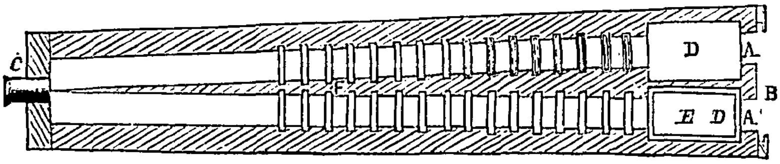
Description of Apparatus.—The apparatus which is before you now on the table may be divided into two essential parts.

First, an optical instrument which gives two fields of view under equal optical conditions free from errors arising from unequal side lights, from the influence of adjacent bodies, and from any difference of colour-perception, which may exist between the right and left eye of the observer. The grave extent of error arising from the last cause will be seen on reference to the first set of columns in Table No. 3 on "Neutral Gray," where out of nine observers, only No. 1 has the colour-perception practically equal for both eyes; No. 2 equal for red and blue, but varies in yellow as 10·0 to 7·5; No. 3 varies in red as 10·0 to 9·0; in yellow, 10·0 to 7·5; in blue, 10·0 to 14·0; whilst No. 6 pronounced six observations as tinged with green; these are equally divided between the yellow and blue columns.

The second part is the standard scale, of which I shall speak presently.

The instrument consists of two tubes, A, A, side by side, divided by a central partition B, terminating at the centre of the eye-piece C in a knife edge, which, being inside the range of vision, is not noticed, so that light, entering the openings D D at the opposite end, passes in equal quantities up each tube to the eye of the observer, giving a clear view of any opaque bodies which may be placed outside, or of transparent bodies inside the tubes.

The sides and central partition are grooved in order to hide the edges of the measuring glasses, and of the gauged vessels for containing fluids. Stops are placed at convenient distances to cut off light reflected from the sides, and the size and shape of the apertures D can be altered by means of diaphragms to suit small or irregularly shaped samples.



The Standard Scale.—The second essential part is the standard scale, which consists of sets of coloured glass slips, all the glasses of each set being of the same colour, but each glass differing in depth of colour, the difference being in degrees of equal value throughout the scale.

In all comparisons of a single colour, the starting point has been taken as a pure white. The standard white used as a background for the glasses is pure lime sulphate for small surfaces, and for large surfaces, as for the reflectors, the smooth side of Messrs. Chance's opal glass, but whichever is used should be quoted.

I may here say that a comparison of pressed lime sulphate against snow shows no free colour in the lime sulphate, which is only ·25 of a degree of neutral gray less white than the snow itself.

Colour Scale.—The relative positions of two-tenths, one degree, ten degrees, and twenty degrees are marked on the colour scale of primaries before you.

The equality of the scale can be tested in the lantern by placing a single glass of 20 degrees value on each side, and then making 20 degrees by any combinations from other parts of the scale as 12 + 7 + 1 equals 3 + 8 + 9.

The Unit.—In the early days of the instrument, before the extent of its application for analytical purposes was fully realised, the necessity of dividing the colour scale into degrees of equal value before reliable work could be done, was evident. The starting point and value of these degrees were questions of the greatest importance and anxiety.

It was decided to fix upon as a starting point a definite degree of colour, the addition of which should be perceptible in the deeper shades, and dividing this degree into tenths and hundredths for the lighter shades, where the perception is keener, thus building up the scale by successive additions of equal value.

It will be seen that the starting point for each colour was arbitrary, that the value of the degree in each scale was equal throughout its entire length; but the impure colour in the glass then available made the fixing of a unit of common value for each primary colour almost hopeless.

A better quality glass, and more recent work, has, however, developed a possible basis for equalising the value of the unit for the three primary colours, red, yellow, and blue, and which are alone found necessary for most analytical work, and even holds out a hope of constructing a colour nomenclature with some degree of scientific accuracy.

I am aware that the colour in my primary standards, red, yellow, and blue, are not pure, but as they are the purest yet obtainable, and as by their means most of the colours in nature are measurable, I will ask that, for the purpose of illustration only, they may be considered as the three primary colours in glass.

The Neutral Gray.—The new departure is founded on the fact that neutral gray under certain known conditions is always made by a combination of 1 red, 1·2 yellow, and 2·4 blue in the original scales, and these proportions hold good at all depths. Then, by assuming these combining values of red, yellow, and blue to be the units of their respective colours, a simple relationship of equality between these three primaries is established, at least so far as the production of neutral gray is concerned.

Having established this common equivalent as a unit of colour in reference to neutral gray, by removing the yellow equivalent a normal purple is left, made up of one equivalent of red and one of blue. By removing the blue equivalent a normal orange is left, made up of one equivalent of red and one of yellow. By removing the red equivalent a normal green is left, made up of one equivalent of yellow and one equivalent of blue.

Further, by placing 10 normal orange on each side of the screen, and adding a single degree of red to one side, and a single degree of yellow to the other, we have a 10 normal orange + 1° red, and a 10 normal orange + 1° yellow. Test this further with higher differences, as 5 on each side, and also with normal purple and normal green.

If binary colour is taken to be the sum of any two colours composing it, then any departure from the normal towards either primary can be accurately measured and described.

When a colour is composed of the three primaries, the units of neutral gray may be deducted as such, and the balance looked upon as free colour. Let us see how this works out by matching a sombre colour, such as brown paper, on the screen, by, say, 5 red, 6·3 yellow, and 4·4 blue. The equation may be written thus:—

	R.		Y.		B.		N.G.		R.		Y.
Brown paper	5	+	6·3	+	4·4	=	4·4	+	0·6	+	1·9 ;

the latter part of the equation, 4·4° neutral gray, ·6° of free red, and 1·9° free yellow, is an accurate description, and conveys an intelligible idea and record of the colour itself in this particular brown paper. Test this further by separating the free colour from the neutral gray. The method is available for the measurement of all sad-coloured bodies.

It also follows that, by the constant addition of neutral gray tints, a scale of equal degrees, ranging from white to black, may be established, and available for measuring the penetrating power of light.

Some precautions are necessary in selecting the proportion of primary colours for the composition of a true neutral gray; for instance, a person whose sight is abnormally strong or weak, even for a single primary, would never agree with an average selection, and this difficulty is increased when the abnormal condition applies to one eye only, as then each eye gives a distinctly different reading. The colour of the light must also be considered, as that from a blue sky, a dull sky, or a white cloud gives different results. The angle at which the daylight is taken has also an influence, the light gaining in red as the instrument or reflector declines from the perpendicular to the horizontal.

The proportions of primary colours for the neutral gray standard I have been dealing with is the result of observations taken in the open air, under a dull gray sky, with light as nearly perpendicular as possible, reflected from Messrs. Chance's opal glass, and is the average of 324 observations made by nine persons of my own staff, none of whom are colour-blind in the ordinary sense of the word, but all have more or less abnormal perceptions for one or more primaries in one of their eyes. I have not, however, removed any of the observations from the table of averages on this account.

A reference to the Table No. 3 will show that of the 324 observations, 130 were pronounced neutral gray, 91 slightly tinged with yellow, 80 with blue, and 23 with red. In no case had the observer a knowledge of what he was judging, and the judgments were frequently checked up and down for truth. But it is quite possible that more extended averages may alter the proportions given.

The difficulty in fixing on a standard of absolutely neutral gray arises from having to work up to a theoretically perfect neutral gray by means of daylight of a variable quality.

Range of Daylight available for Uniform Readings.—These observations were made on a clear winter day after a heavy fall of snow; the liquid used for measuring was sherry in the 1-in. vessel, and the glass standards were from Colour Series No. 52, which is a bright amber.

Table No. 1.

	Sherry in 1-in. Vessel.		Colour Series 52.
North light from opal reflector, 2 ft. from instrument	1	matched by	11·75
North light from white blotting paper, 2 ft. from instrument	1	„	11·75
Sunlight from drab wall, 30 ft. from instrument	1	„	11·75
Sunlight from yellow wall, 30 ft. from instrument	1	„	11·75
Direct light from cloud over the sun	1	„	11·75 to 11·50
Sunlight reflected from white blotting paper	1	„	11·38
Sunlight reflected through white blotting paper	1	„	10·38
Sunlight from snow 3 ft. from instrument	1	„	10·38
North light from snow 10 ft. off	1	„	10·75

This table shows, in common with Table No. 2, and also accords with general experience, that all kinds of ordinary daylight between the first approach of twilight and direct rays from the sun are available for ordinary work, so that variations in the colour of daylight within wide limits do not alter the readings where the same light is used for both sides.

The Measurement of Incandescent Bodies.—For the measurement of colour or intensity in incandescent bodies, whether from a naked flame, molten metal in a furnace, or the sun itself, one tube must command the object either directly or by reflection, while the other tube similarly commands the standard light, to which glasses are added until equal to the object. But if the object is more brilliant or of purer colour than the standard light, glasses are added to the object side, reducing its light or colour to equal the standard light; in either case the glasses are indices of the difference.

The following table is a measurement of sunlight against a blue sky made on June 26th, 1889. The sun was brilliant, and the sky unusually blue, both lights were reflected from Messrs. Chance's opal glass, and the standard glasses were necessarily added to the sunlit side until equality was obtained.

Table No. 2.—Comparison of Sunlight against a Blue Sky, both Reflected from Messrs. Chance's Opal Glass.

June 26th, 1889.	Primary Glass Standards.			
	Red.	Yellow.	Blue.	Total.
9 a.m. Blue sky sunlight	·5	·42	3·1	4·02
12 m. „ „	·75	·54	3·6	4·89
7 p.m. „ „	·37	·42	2·83	3·62

Amongst the apparatus on the table is one mounted for showing the colour in 6 ft. of water drawn from the service tap of this building; one showing the contrast between 2 ft. of water-white paraffin and 2 ft. of distilled water.

The colour-blind measuring apparatus employed in preparing a part of Table No. 3.

The arrangements for measuring ordinary opaque and transparent substances and liquids are also on the table.

An adaptation for measuring the difference of colour between two lights, also one for measuring the colour in stars; this latter is adapted to a telescope belonging to the Rev. Canon Hutchins of Alderbury, and has been kindly lent me by him for this occasion.

Measurements of Transparent Commercial Colours.

		Series 52.				Total Colour in Degrees.
No. 1 caramel, 1 per cent. solution in ¼-in. vessel		58·0		..		58
No. 2 „ „ „ „		31·0		..		31
		200 Red.		510 Yellow.		
No. A Anatto, 1 per cent. solution in 1-in vessel		1·5	+	16·6	=	18·1
No. B „ „ „ „		1·15	+	8·3	=	9·45
		500 Yellow.				
White mineral oil	1-in. vessel	5·		..	=	5·0
		500.				
Sp. Gr. ·890	1 „	43		..	=	43·0
		200 Red.		510 Yellow.		
Water-white paraffin	24 „	2·9	+	0·510	=	3·41
		52 Series.				
No. 1 glycerin	12 „	6·0		..	=	6·0
		52.		500 Yellow.		
No. 2 glycerin	12 „	9·0	+	0·75	=	9·75
		500 Yellow.				
Syrups from charcoal purifier No. 1,	⅛ „	1·5		..	=	1·5
2,	⅛ „	2·75		..	=	2·75
3,	⅛ „	8·0		..	=	8·0
4,	⅛ „	12·0		..	=	12·0

Table of Colour Measurements of Commercial Substances.

	200 Red Series.		510 Yellow Series.		1180 Blue Series.		Neutral Gray.		Free Red.		Free Yellow.		Free Blue.
Annatto paste A	13·6	+	11·8	+	5·	=	5·	+	8·6	+	6·8		..
„ B	15·75	+	7·25	+	2·25	=	2·25	+	13·5	+	5:		..
Paper:													
Brown paper	6·6	+	8·3	+	5·4	=	5·4	+	1·2	+	2·9		..
No. 1 writing paper	0·27	+	0·45	+	0·31	=	0·27	+	0·04		..	+	0·04
No. 2 „	0·33	+	0·51	+	0·5		0·33	+	0·18		..	+	0·17
Fabrics:													
Red sateen	28·8	+	6·1	+	5·8	=	5·8	+	23·0		..	+	0·3
Purple velvet	36·0	+	3·3	+	9·6	=	3·3	+	32·7		..	+	6·3
Light blue satin		+	1·2	+	4·1								
Paints:													
Chrome yellow on paper	2·7	+	12·0										
Orange chrome „	9·8	+	4·5										

Flour:	Amber, Series 52.		Brown, Series 50.		Gray, Series 30.
Hungarian E.O.P. No0, Lofty ground	2·0		..		..
„ „ Fine „	1·75		..		..
Spring wheat flour	..		4·75	+	0·25
English super	0·5	+	2·75		..

Candles:	Series 52.		Series 500.
Patent No. 1	1·75	+	0·375
Patent No. 3	3·5	+	·75

Conclusion.—In submitting this apparatus and method to your judgment, I am fully conscious that there must be many questions which time and more exhaustive work will elucidate, but I am not conscious of having hidden a weakness or exaggerated a strength, and feel sure that when the weaknesses are pointed out, they will act as a spur to further investigation. And in conclusion I wish gratefully to acknowledge the assistance received by me from many quarters; it will be impossible for me to enumerate all, indeed, in some instances I have no knowledge even of the names of gentlemen who have made valuable suggestions.

I am, however, specially indebted to Mr. H. Le Neve Foster, who worked out the method of quantitative estimation of carbon in steel; to Mr. T. Jobson, jun., of the Stocksbridge Works, near Sheffield, who overcame a difficulty in steel solutions of a reddish tinge; to Professor Hummel, of the Yorkshire College, Leeds, who suggested a method of bringing surfaces uneven in texture or colour to a suitable condition for comparison by throwing them out of focus with a lens at the eye-piece; to Dr. Knecht, of the Technical College, Bradford, for some comparisons in Turkey reds; to Mr. Boverton Redwood for co-operation in working out standards of colour for petroleum and cocoa-nut oils; to Dr. Munro, of the Downton College of Agriculture, for investigation into the method of making ammonia estimations, and for some special work on the colour of waters. The fine divisions in the standard scale is mainly the work of one of my daughters.

The working out of the neutral gray equation is the direct result of conversations with Professor Crookes, Professor Church, and Captain Abney, greatly aided by the brilliant lectures of the latter at the Society of Arts last session.

Discussion.

The Chairman said that the subject of the paper was one of very wide interest, and capable of most important practical application. All chemists had to do with the judging of colours, and all had a profound conviction of the perfection of their individual colour sense. Everyone present knew how delicate and difficult a matter it was to hint to a friend that his eyesight was not quite what it should be. With regard to the sense of sight, everyone considered himself perfect. He happened to have a number of relatives so far colour-blind as to be capable of imagining emeralds to be rubies, and *vice versâ*. In all his experience in this direction, however, he had never met with a colour-blind woman, and did not believe that there was one. He would appeal to Mr. Lovibond on that point.

Mr. Lovibond said that he could agree with the Chairman's experience to this extent, that the only absolutely non-colour-blind person he had ever met was a woman.

The Chairman, continuing, said it was certain that as a rule women's eyes were far more accurate than men's. We ought to recognise the fact that a great many of us were more or less colour-blind with respect to certain tints; and if chemists in particular did so they would save a great deal of inaccurate work. He believed that it was in that room that Dr. Tidy had related his experiences in testing the average eye for accuracy. He could not recall the exact figures, but he remembered that a very small percentage of those tried could, for instance, sort out twenty shades of brown with an approximation to accuracy. Nevertheless, it was possible by careful training to greatly develop the power of the eye in this respect. To do so one must have accurate instruments and methods; and in Mr. Lovibond's apparatus and his method of gauging the different depths of colour, there seemed to him to be the means of training the eye to the work which the eyes of chemists were called upon to do. The matter was one well worthy the study not only of those to whom it was a subject of special importance, as to those engaged in dyeing, but of every chemist. They had to thank the Royal Institution for the loan of the lantern, and Mr. Heath for attending to exhibit the various colours on the screen.

Mr. Boverton Redwood was glad to have an opportunity of bearing testimony to the value for certain technical purposes of the instrument which Mr. Lovibond had taken so much trouble to exhibit and explain to the meeting. In connexion with the class of products with which he had to deal, it had been his lot for 20 years past to be almost daily engaged in chromometrical determinations, and consequently when Mr. Lovibond brought the tintometer under his notice some two years ago, he examined it with great interest. He had already had the opportunity of explaining, in that room, the principles of construction of the instrument with which, in the petroleum trade, they were in the habit of determining the colours of some of their products. That instrument had certain defects; and he had never found it well adapted for the registration of the colour of such oils as were employed for lubricating purposes. He had suggested, therefore, that there was an opening in that direction for such an instrument as the tintometer, and had gladly concurred in Mr. Lovibond's proposal that they should together endeavour to arrange a scale of standards suited for commercial use in the lubricating oil trade. He might say that in his laboratory for nearly two years past they had been in the habit of testing with the tintometer and recording the colour of a two-inch stratum of every sample of lubricating oil submitted to them, and there had thus been established a numerical scale of colour which already possessed some significance. They had of course experienced difficulties at times in consequence of the variable character of the daylight available—difficulties which all who were in the habit of working in London would appreciate. He did not refer to such exceptional cases as the darkness which had recently enveloped the city; but apart from such cases as that, Londoners had to work under atmospheric conditions which would afford Mr. Lovibond food for serious study after the more transparent atmosphere of Salisbury. He had reason to hope that at no distant date some artificial light equivalent to ordinary daylight, or capable of being employed alternatively, with some definite correction, might be provided. In that case the tintometer would come more largely into use than under present conditions. The experience they had had of the use of artificial light that evening was not encouraging; and, as one who had had some experience in the use of the instrument by daylight, he was bound to say that the impressions to be derived from the demonstrations just given were less favourable than those which would result from a short use of the instrument by ordinary daylight.

Mr. W. Thorp felt grateful to Mr. Boverton Redwood for the encouragement conveyed by his concluding remarks. He had often to experience the difficulties due to the great peculiarities of what we were pleased to call daylight in London. It was no uncommon thing for a part of his work to be set aside for days, or even weeks, in consequence. Referring to the Chairman's remarks, he thought that any who had a short experience of a colour works would soon have any ideas of the perfection of their own eyesight knocked out of them. There were certain men at the works with which he was connected who had especially good eyes for certain colours, and when an examination of those particular colours was required it was done by those men. He himself had, he thought, a good eye for some colours, but there were others that he would not dream of judging. Under these circumstances the instrument before them ought to prove valuable. It would certainly be useful in giving a numerical value for depth of colour. He was not so clear as to its value for giving an exact representation of tone or tint, especially as it seemed to him, judging from the experiments just made under artificial light, that the tints produced by the mixtures of glasses were not what could be called *pure* colours. He believed, indeed, that Mr. Lovibond had referred to that point in his paper, and had said that they were not pure. It was often a matter of great importance to decide whether a colour was rich or poor, and how the instrument would deal with such a point as that he could not say. But while looking at the pieces of glass exhibited, a horrible doubt occurred to him as to their permanence, and he would be glad to know from the inventor whether he had considered that. People were very apt to think that coloured glass was permanent, yet probably most of those present had seen specimens of glass which had begun their existence as colourless, and which before long had acquired an appreciable colour. He remembered seeing some glass which in 18 months had attained an intensity which would be represented on the scale before them by at least 2 degrees. If changes increasing or diminishing in depth, or varying, were to be feared, it would be a great impediment to the application of such instruments. How such a difficulty was to be met he did not see, but it was certainly a point worthy of careful consideration.

Dr. Alder Wright said that there were one or two points upon which he would be glad to have further information. In the first place, he did not understand what was meant by one, two, or three degrees. Did it mean that the glass was, for example, tinted with one, two, or three grains respectively of some colouring material per pound? Secondly, how far were the colours which were transmitted through the glasses mono-chromatic? In other words, if the glasses were viewed through a spectroscope, would one get a single line as the absorption spectrum, or a large proportion of bands at other parts of the spectrum? If there were any considerable proportion of other colours, it would be difficult to ensure that any combinations of glasses would give even approximately pure colours. He supposed it would be almost improper to inquire what the materials were with which the glasses were tinted. But if the author could give any information which would tend to show that a scale could be reproduced with accuracy at a future period, it would be of considerable interest to all possible users of the instrument.

Mr. Friese-Greene wished to ask the author whether he had taken into consideration the effect due to the surfaces of the glasses used. It was obvious that as he increased the number of glasses in building up his colours, he would get more surfaces and, consequently, more reflection due to the breaking up of light all along the different media. His own experience in photography led him to think that this was a point which might be of considerable importance in the case of the instrument under notice. Again, it was well known that the eye in going from one colour to another always carried with it as it were the tone of the first colour; and not only so, but there was a kind of opposition set up by the retina endeavouring to neutralise the colour. Consequently, if the eye passed quickly from one colour to another, there was produced on the retina a mixture of the first colour or tint with the second. That was a matter which ought to be taken into consideration. It might be met by the observer going into the dark until the tone was neutralised, and then looking at the colour.

Dr. L. Thorne said that he had had one of Mr. Lovibond's tintometers in practical use for some time, and could fully corroborate Mr. Redwood's remarks as to the advantages to be derived from it. He had used it for estimating colour in oils, and also with regard to the colours of more or less bleached natural products, and had found it valuable in either case. Referring to what he might call the optical part of the instrument, he considered it a great advance on the apparatus hitherto used. Getting the one absolute field split up as it were by means of the wedge-shaped division, so that with the same eye one could get at the same focus the two fields in equal physical condition, enabled one to obtain an estimation of colour much more accurately than by any other process. As to the permanency of the standard colours, no doubt Mr. Lovibond would have something to say. But assuming that point to be satisfactory, he could strongly corroborate what had been said as to their value for future work. A colour having once been matched, the standards required for it could be noted, and the colour could be reproduced with absolute accuracy at any future time. He had not had a large range of colours to work with, but those which he had tested he had found to be matchable with ease; occasionally a very bright tint would be a little awkward to match, but not often. To him the point of special novelty in the paper was the portion relating to the production of neutral grays. It was a matter of the greatest interest from the theoretical point of view that the grays could be made up from those three standard colours, and that different depths of gray would be shown by exactly the same proportions of the three colours. This led one to suppose that there was a possibility of getting what might be taken as natural standard units of tone in the different standard colours in place of the purely arbitrary units at present employed. Referring to Dr. Wright's remarks, he believed it had been mentioned that at present the scales of colours were essentially arbitrary ones. One standard—a pale colour—was taken as a unit in each tint, and the other shades were built up from that by actual trial with the glasses. So far as his own experience had gone he had found the tintometer capable of doing very good service in dealing with both liquids and solids.

Mr. J. J. Eastick said that he had had one of Mr. Lovibond's instruments in use for the last three years, and had found it simply invaluable. He had, however, experienced one or two difficulties. One was, that some of the colours of the solutions which he tested were brighter and nearer the primary colours than the glasses themselves. Another difficulty—or rather he might say a warning—was that if an observer was looking through an inch of colour in certain liquids, and the colour was, for example, 20, if he then looked through two inches of the same liquid the tint would not be 40, as might be expected. He did not know whether that was the case with all colours, but it certainly was so with several. He had heard with great pleasure the hint thrown out by Mr. Boverton Redwood as to the possibility of overcoming the difficulties of artificial light. Even if the promised light was not so perfect as the reflection from a white cloud, it would still be a boon if it was an improvement upon the present means of carrying on operations during a fog or night.

Dr. Munro desired to add a few words as to the use of the tintometer for measuring the colour of water, as he thought it likely to be especially useful to chemists in that direction. In Table 6 he had given, as an illustration, some measurements of a number of waters from one neighbourhood—all within half a mile of a common centre. It would be seen from the figures in the last column that these waters ranged from seven-tenths of a degree of colour in a 2 ft. tube to 53 degrees, which was a most extraordinary variation. He had found the instrument very useful in following certain changes in the Lisdoonvarna sulphur spas. The twin sulphur spa, as shown in the table, always had the same composition; but near it was the Gowlaun spa, from the same formation, which was subject to extraordinary variations in strength. It was to be noted that there was a certain variation in colour also; and so there was probably some connexion between the two things. That enabled them to form some idea of what went on under the ground, for the variation in strength was perhaps due to the percolation of water; and they could in that case ascertain by the variation in colour what particular water was getting in. He had had an opportunity of seeing Mr. Lovibond's neutral gray by daylight, and as far as he could judge it was free from any positive tint.

Mr. Lovibond, in reply, said that in reference to Mr. Boverton Redwood's remarks as to the bad quality of London light, it had been found a great difficulty at first, as the small surfaces commanded by the two apertures did not admit sufficient light to illuminate the object. But he had recently overcome it to a great extent by including a reflector at a low angle, so as to collect the light from a large surface and throw it into the comparatively small space. An illustration of this would be seen upon the table in the form which his assistants called the Eiffel tower. He had not as yet given much attention to the use of the instrument with artificial light, but he had no hesitation in saying that, given the said light had permanent characteristics, there would be no difficulty in establishing its relative value compared with daylight, and thus making it available with a certain constant correction. With reference to Mr. Thorp's doubt as to the exact representation of tint—that was the strong point of the instrument, and half an hour's work by daylight would completely satisfy the most sceptical on that point. As to the purity of the colours, he was very much at fault. He had only a certain material to deal with, and he made the most he could of it. He had a blue, for instance—he called it a blue, but it was really a purple; for it was a cobalt put on white glass. To seek for absolute purity of colour in glass, taking the spectrum colours as his standard, would be futile. But for ordinary colour measurement, all that was needed was to employ so much more or less red, blue, or yellow to compensate for the departure from purity in the standards. This was no real detriment to the value of the instrument for measuring commercial colours; but it would be fatal to the measurement of pure colours *directly*—though they could be measured *indirectly* by toning the pure colours down by a series of neutral grays. As to the permanence of the colours, he had the assurance of the makers, the red being oxide of gold, the yellow silver, and the blue cobalt. Under these circumstances he could not guarantee their permanence; but if any chemist would establish the value of a unit for any coloured chemical compound, he would have the power of testing for himself its permanence. As tó the value of a degree on his scale of tints, that was purely arbitrary, and it was fixed so that the difference of a degree up to 30 might be just perceptible. It started at 1; then the 2 was equal to two 1's. If he had to deal with two glasses against one, he added a white glass to the one, so as to equalise the number of surfaces on each side. As to the spectrum value of the colours, he had already said that the two were not comparable. If he had to compare his colours with the spectrum colours, he should tone the latter down to his colours and get the indices on the spectrum side. He said this to show the elasticity of the instrument to meet any question asked of it. The accuracy of the scale of colours was in the hands of the chemist; and if anyone found a scale inexact he hoped they would bring it to his notice. No real difficulty existed in grading the colours beyond the necessary labour, which was excessively trying. As to reproducing the scales, he had deposited standards at the colleges of Liverpool, Leeds, and Bradford, on the condition that anyone using the tintometer should be at liberty to take his glasses to the college and test them with the standards. With reference to Mr. Friese-Greene's remarks as to the interference of complementary colour sensations, that was a serious difficulty in judging the value of any one colour; but when judging the difference between two colours placed side by side, as in the tintometer, it counted for nothing. In matching two colours in the instrument with one eye, any interference equally affected both sides, and whatever colour impressions might be conveyed to the eye by the interference, the measuring glasses required to make a match were the same. That was proved by the diagrams which dealt with the judging of certain colours under different conditions; in which it would be seen that although the lights varied, the same results were obtained by a considerable number of persons, thus showing that the question of outside influences (arising from adjacent colours) did not apply. The observer was simply judging of two things before him; and if one observer called it a green, while another said it was a red, that made no difference when the two sides were equal. The glasses were the indices of the difference; and as the glasses were always the same, they reduced these hitherto unmeasurable differences to a matter of common understanding. He had not as yet met with any difficulty as to the reproduction of his scale. If difficulties did arise, all he could say was that they would have to be overcome. Solutions brighter than the glasses were at one time a source of difficulty which was only overcome by the discovery of the theory of the neutral grays. If the observer had a solution brighter than the glass, he would first add an equal number of glasses, and if that were not sufficient, it was evident that he was dealing with a purer colour than the glasses themselves. He would then add glasses to the pure side and bring that down to the impure. In either case the glasses required would be the indices of the difference.