by Sir W. Thomson's statical theory, in the proportion of $1+\frac{79v^2}{150(r+g)}$ to unity, where v is the speed of the tide, and r is the quantity defined in Thomson and Tait's Nat. Phil., § 840 (28), viz., $\frac{19}{5wa^2}\times$ the coefficient of rigidity.

The last part of the paper contains a discussion of results, and a non-mathematical summary of what precedes.

IV. "On the Influence of Light upon Protoplasm." By Arthur Downes, M.D., and Thomas P. Blunt, M.A. Oxon. Communicated by J. Marshall, F.R.S., Surgeon to University College Hospital. Received October 9, 1878.

This paper is in continuation of, and supplementary to, a previous communication* in which we recorded the first part of an investigation on the effect of light upon *Bacteria* and other organisms associated with putrefaction and decay. The chief conclusions to which those observations led us were briefly as follow:—

(1.) Light is inimical to, and under favourable conditions may wholly prevent, the development of these organisms; its action on *Bacteria* being more energetic than upon the mycelial (and torulaceous) fungi which are prone to appear in cultivation-fluids.

(2.) The fitness of the cultivation-fluid as a nidus is not impaired by insolation.

We found also that tubes, containing a cultivation-fluid and plugged with cotton-wool, when removed to a dark place after exposure to the sun for a sufficient period, remained perfectly clear and free from organisms for months, and we naturally thought that the contents had been reduced to permanent sterility. The following facts, however, compel us to suspend for the present our conclusions on this point. Of the many tubes which we insolated last year we finally kept only three. Two of these—containing Pasteur solution of the composition given in our former paper—had been exposed to sunlight for three weeks in June, 1877; the third tube contained urine and had been insolated for about two months—commencing July 26th. In each case corresponding tubes which were covered with laminated lead, so as to exclude light, had swarmed with *Bacteria* in the course of two or three days, but the three tubes of which we speak not only were perfectly pellucid at the time they were removed from the light but, although kept in a warm room, remained clear all through the winter. On February 25th, 1878, however,—eight months after we had placed

* "Proc. Roy. Soc.," vol. xxvi, p. 488.

them in darkness—the two tubes of Pasteur solution each contained several tiny specks of mycelium.

One of the two was on this again exposed to sunlight, and in it the mycelial development was at once stopped; the other tube was left in the dark and the fungus gradually grew till it filled the whole space of the liquid, which on microscopical examination was found to contain no other organisms. The tube of urine remained clear till July 15th, 1878,—nearly ten months after incasement,—on which date two specks of mycelium appeared, and subsequently developed as in the previous case. No *Bacteria* could be seen on examination with an immersion $\frac{1}{12}''$. It is noteworthy that a companion tube to this which was incased after six days of insolation had developed a growth of mycelium in three or four days.

It would seem that in the three tubes above mentioned *Bacteria*, or their "germs," had been either wholly destroyed or reduced to so low a state of vitality that they were unable to develope in the fluids in question; while it is evident that the spores of the mould which at length appeared, unless they had been accidentally shaken down from the cotton-wool plugging the tubes, had undergone some change which reduced them to a condition of torpidity from which in process of time they emerged. Such a condition, we may perhaps conceive, might be brought about by any influence causing thickening of the cell-wall of the spore. We hope at a future time to offer some further evidence on this question of revival of dormant germs, which is, we think, of much interest.

From a very early period of our inquiry we have set ourselves to the task of investigating the intimate nature of the remarkable action of light upon these organisms, and we have arrived, as we believe, at a satisfactory solution of the problem, but in the first place it will be well to describe some preliminary experiments.

An interesting point to be determined was the question,—with what part of the spectrum is this property of light associated.

The observations made by us last year indicated that the rays of greatest refrangibility were the most active, but the experiments then made did not warrant any definite conclusions as to the part played by rays of lower refrangibility.

The method employed in the more recent experiments was similar to that described in our former paper:—

Small test-tubes containing the cultivation-fluid were suspended in deep narrow boxes made of garnet-red, yellow, blue, and ordinary glass respectively. Each box held about six test-tubes, and corresponding series were incased in laminated lead.

A spectroscopic examination of the glass of which these boxes were constructed showed that the yellow and blue were far from being monochromatic. The red was an excellent glass for the purpose.

The rays which were found to pass through each glass respectively are given below.

Blue.—Violet, blue, some green, broad band in yellow-green, very narrow band in ultra-red.

Yellow.—The whole spectrum, except violet and about half the blue.

Red.—Red, orange-red. All other rays entirely absorbed.

The mean of a number of observations as to temperature showed that, at the point at which we worked, viz., 70°—80° F., the thermometer in the red box stood about 2° F. higher than in the lead-incased tubes; between the blue, yellow, and ordinary glass boxes there was but little difference, the blue being about half a degree warmer than the last named.

We showed in our former communication that by increasing the density of our cultivation-liquid the development of *Bacteria* could be proportionately delayed. In this way we have been able to accentuate the differences in the behaviour of the solutions under varying conditions of light. Without detailing all the experiments, we may say that the first tubes to become turbid were the lead-incased; the next, usually in from 24—48 hours subsequently, the red, followed shortly by the yellow;* white and blue surviving.

The organisms which first appeared in the lead-incased and red were always *Bacteria;* in the yellow, usually *Torula*, or mycelium, with more or less *Bacteria*,—rarely *Bacteria* alone; if organisms appeared in the blue or ordinary glass they were torulaceous.

Although the blue and yellow glasses were not monochromatic, we think that these results give important indications. That the action is chiefly dependent on the blue and violet rays is shown by the great difference, as compared with those in the blue box, in the behaviour of the tubes in the yellow, in which, as we have already stated, the only rays of the spectrum not admitted were the violet and part of the blue.

Moreover, the fact that when the cultivation-fluid is of sufficient concentration the red (although the warmer) survives the lead-incased shows, we think, that the red and orange-red rays are not altogether inactive.

It is probable therefore that, if the phenomena were represented by a curve, the maximum elevation would be found in or near the violet, a rapid descent occurring in the blue or green, after which the line of the curve is maintained more or less as far as the visible red.

The experiments next to be detailed bear upon the part played by the cultivation-fluid in the phenomena under consideration. We had

* The only instance out of a large number of observations, in which yellow broke down before red, happens to be the experiment described in our former communication.

shown, in our previous paper, that the liquid in tubes which under insolation had remained barren was, nevertheless, not impaired as a nidus for development, for, on removing them to a dark place and inoculating with a drop of ordinary water, they soon teemed with vigorous bacterial life; the same experiment showing that the survival of the spores of mycelial fungi, as compared with *Bacteria*, was not due to any change in the cultivation-fluid rendering it noxious to the latter, but not to the former. At the same time, though this was not probable, there might have been a temporary and transient action dependent on some constituent of the cultivation-fluid. We determined, therefore, to render the conditions as simple as possible.

It is well known that all ordinary water, even distilled, teems with the "germs"—actual or potential—of various forms of life. We wished to ascertain whether or no sunlight would impair the vitality of, or destroy, "germs" existing in ordinary distilled water.

Fig. 1.

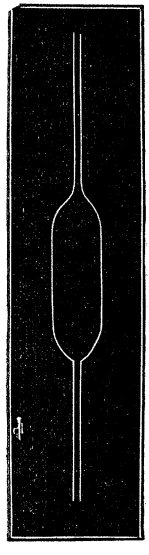
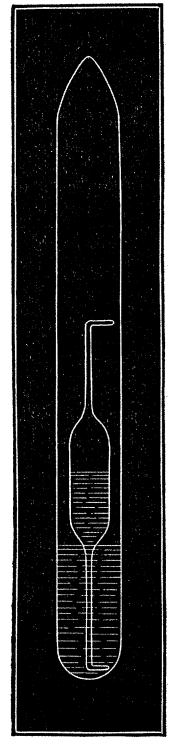


Fig. 2 (reduced).



Sealed ends of bulb bent at right angles to facilitate subsequent fracture.

We made a number of glass bulbs, of the shape shown in fig. 1, into each was introduced a measured quantity of a very concentrated

Pasteur solution, previously boiled; one end of each was then sealed. They were then placed in a water-bath, with the unsealed end projecting above the water, and after prolonged and repeated boiling this end also was sealed. The sealed bulbs were then thoroughly washed with distilled water, to remove all traces of Pasteur solution from their external surfaces, and were each finally sealed up in a tube (fig. 2) containing distilled water in such proportion that, when the bulbs were subsequently broken, the mixture produced a fluid of the ordinary strength. Four were incased in laminated lead and five insolated.

To prove that the water employed was capable of setting up bacterial or other development, a number of tubes containing Pasteur solution sterilised by repeated boiling and plugged with cotton wool were divided into two series; to each tube of the one set a few drops of the water were added with a superheated pipette; to the second series no water was added, but, in order to place them under the same conditions, the superheated pipette was successively dipped into each. All of the series inoculated with water speedily teemed with *Bacteria*; the second series remained clear.

The experiment commenced on April 3rd. About the end of May, the bulb in one of the insolated tubes was accidentally broken, so that the concentrated Pasteur solution of the bulb mingled with the distilled water of the tube. In a few days the mixture became turbid with *Bacteria* and *Torula*. We shall again refer to the behaviour of this tube.

The remaining bulbs were broken towards the close of July by jerking them against the ends of the tubes. The result was that, with one exception, the mixture in the tubes which had been insolated has remained clear to the date of writing (September 1st), but in each instance the incased tubes became turbid with organisms.

In the single insolated tube which broke down nothing could be seen on careful examination with $\frac{1}{12}''$ but round-celled *Torula*; there was a complete absence of all bacterioid life. The incased tubes all contained *Torula*, *Bacilli*, *Bacteria*, in active movement, and, in two instances, a number of short, squarish, highly refractive particles.

It is evident, therefore, that light is injurious to "germs," even when contained in ordinary distilled water. There is, however, an important fact in connexion with this which must not pass unnoticed. We have described how a tube in which the bulb had accidentally been broken after exposure to sunlight for six or seven weeks, in April and May, speedily teemed with *Bacteria*. It happens that, during portions of this time, we had insolated tubes, containing ordinary Pasteur solution, with the result that all bacterial development was prevented by a few days' exposure to the sun, and organisms, if they appeared after the tubes had been incased, were torulaceous or mycelial. There

appears, therefore, to be a remarkable difference in the rate of action of light on the germs of *Bacteria* in water, as compared with its effect on corresponding "germs" in the cultivation-fluid; insolation of, say a week, accomplishing, in the latter case, what nearly two months failed to do in the former.

The most reasonable explanation to our minds is the following:—In water destitute of organic matter the "germs" are deprived of the nourishment essential for their growth and development—they are starved; under these conditions their protoplasm reverts to a state of rest and stability, contrasting with that condition of instability which the exhibition of vital energy implies. Possibly they become encysted, the outer portion of the protoplasm being devitalised and protecting the central speck, which may be said to exist rather than to live. When, however, the "germ" finds suitable nourishment, the protoplasm takes on a higher state of activity and, therefore, of instability, and we believe that this instability of protoplasm favours the action upon it of light, but that in a condition of dormant vitality it is less susceptible.

Numerous other observations of similar character, which we need not here detail, gave the same results, and the following simple experiment, repeatedly confirmed, indicates the germicidal action of light when no water, other than the ordinary moisture in air, is present:—

April 15*th*. Four test-tubes are rinsed out with tap-water, inverted to allow the moisture to drain off, and plugged with cotton-wool. Two are covered with laminated lead, and two insolated in the usual way. (Corresponding tubes, charged with Pasteur solution previously sterilised by boiling, speedily became turbid with *Bacteria*.)

May 1*st*. The four tubes are charged with sterilised Pasteur solution.

In about a fortnight the lead-incased tubes both became turbid,* but the liquid in the insolated tubes was still clear on July 16th.

We now proceed to give an account of experiments which bear more directly on the intimate nature of the action under consideration.

From an early stage in the investigation we felt that the best way of approaching the problem was by examining the behaviour of organic bodies generally when exposed to sunlight. Taking, in the first instance, the comparatively simple molecule of oxalic acid as the subject of our experiment, we found that a decinormal solution (·63 per cent.) was entirely decomposed by sunlight. It was obviously important to ascertain what was the nature of the decomposition, *i.e.*, whether it were a *disintegration* of the molecule into water, carbonic acid, and

* Subsequent microscopical examination showed that this was due in the one case to a species of *Sarcina*, in the other to *Bacteria*, which did not, however, take on a very vigorous development.

carbonic oxide, or an *oxidation* resulting in water and carbonic acid alone.

We found that whether oxygen was removed by exhaustion at the Sprengel pump, or by boiling the solution and inverting in mercury without access of air, decomposition was alike prevented. It was evident, therefore, that *oxygen* was the agent of destruction under the influence of sunlight, for of course the nitrogen of the air may be put out of the question.

We next experimented on a representative of a most interesting class of bodies, which in the complexity of their composition probably approach protoplasm itself. We refer to the so-called soluble or indirect ferments, of which we selected *zymase*, the soluble ferment of yeast, as a type.

We noticed last year that sunlight had no retarding effect on the action of this class of ferments, but we did not then investigate the effect of prolonged insolation on the ferment itself. Accordingly, on June 25th, some water in which a fragment of yeast had been macerated was thrice passed through double layers of the finest filtering paper. Examined under the microscope, the liquid, which was quite clear, was found to contain no trace of *Torula*. Salt was then added to saturation, in order to avoid putrefaction, and the solution was divided between two series of test-tubes, one series being insolated, and the other incased in the usual way.

On July 19th about three drachms of freshly made syrup was placed in each of a number of *éprouvettes*. These were divided into two sets; to one set was added five grain-measures of the insolated *zymase* solution, and to the other a corresponding quantity from the incased tubes; a watch-glass was placed over each, and they were left for some hours. At the end of this time, five grain-measures of the syrup to which *zymase* from the incased tubes had been added completely reduced an equal quantity of a Fehling's solution, while no perceptible change was caused by the syrup which had been treated with insolated *zymase*.

It is clear, therefore, that sunlight destroys the specific power of this ferment for hydrating cane-sugar.

We next experimented on *zymase* in vacuo. On August 16th a solution of the ferment, prepared in the same way as before, was divided between eight tubes, two of which were insolated and two incased. The remaining four were simultaneously* exhausted at the Sprengel pump and sealed. The contents gave a sharp "water-hammer" click, bearing testimony to the excellence of the vacuum. Two of these tubes were insolated and two incased.

On September 5th, eight *éprouvettes* of fresh syrup were inoculated with liquid from each tube as before, and allowed to stand overnight, a

* See Appendix.

corresponding quantity of uninoculated syrup being kept to ascertain if any hydration occurred spontaneously.

September 6th.—The uninoculated syrup has no perceptible reducing action on Fehling's solution, but the contents of all the vacuum-tubes, whether insolated or incased, have produced hydration of the cane-sugar, and there is no practical difference between their effect—as measured by Fehling's solution—and that of the non-Sprengelised *zymase* preserved in the dark. At the same time the corresponding solutions of *zymase* insolated without previous exhaustion have very feeble action indeed. We conclude, therefore, that, as in the case of the oxalic acid, the destructive action of light is by oxidation, for, while the *zymase* exposed to light and air was greatly enfeebled, a similar solution in vacuo, although equally insolated, retained its energy apparently unimpaired.*

In proceeding to investigate the nature of the action of light upon living organisms, we were met by difficulties, arising from the relation of these organisms to oxygen, which for some time baffled our research; but these difficulties we have, we believe, sufficiently overcome to be enabled to indicate the fundamental identity of the action of light upon living organisms and upon the typical non-vitalised organic substances selected for our previous experiments.

In a postscript appended to our previous communication we stated that in sealed tubes containing urine, which had been exhausted at a Sprengel pump, organisms appeared in incased and insolated tubes alike.

We have made many repetitions of these experiments, and we have invariably found that, whenever organisms appeared in the incased exhausted tubes, they were simultaneously present in equal amount and vigour in the insolated, contrasting with the difference in behaviour between corresponding insolated and incased non-exhausted tubes.

It seemed, therefore, that in absence of an atmosphere, light (notwithstanding the manifest enfeeblement of life brought about by the

* It was our original intention to examine a large number of organic bodies, and to ascertain to what extent this phenomenon of oxidation under sunlight occurred in different classes of organic compounds. The recent researches of M. Chastaing ("Ann. de Chim. et de Phys.," [5], t. xi) have anticipated us in this. M. Chastaing experimented on such organic compounds as essence of turpentine, essence of lemon, ether, oils, &c., all of which were oxidised in sunlight, the oxidation occurring in all parts of the visible spectrum, but having a maximum in violet and a minimum in red. It is noteworthy to observe how this distribution of the function of oxidation of these substances in the spectrum, according to M. Chastaing, corresponds with that assigned by ourselves on entirely independent grounds to the destructive action of light on *Bacteria*. We should have stated, also, that, according to our experiments, the oxidation of oxalic acid was very active behind blue glass, but feeble behind red.

withdrawal of air) failed entirely to produce any effect on such organisms as were able to appear.*

Experiments in which nitrogen was admitted into the exhausted tubes before they were sealed gave similar results.

The obvious inference that the presence of oxygen is essential to this action of light is confirmed by the following experiment—many times repeated—showing that the effect is in direct relation to the proportion of free oxygen :—

A Pasteur solution of half the strength given in our former paper, and therefore, for reasons stated in that paper, difficult to sterilise by insolation, was divided between six tubes.

Two of these were simply sealed, and therefore contained an atmosphere of ordinary air.

Two were exhausted at the Sprengel pump till the gauge stood at a height of 22 inches, when, by means of the apparatus described in the Appendix, nitrogen was admitted, and the tubes being sealed, consequently only contained about one-twentieth of oxygen in their atmospheres. The remaining two tubes were exhausted thoroughly and pure oxygen admitted in the same manner as the nitrogen.

One tube of each series was incased in laminated lead, the companion tube being insolated.

In two days all the incased tubes were equally turbid with *Bacteria*.

In two days more the insolated tube, with $\frac{1}{20}$th oxygen atmosphere, was turbid with *Torula* and *Bacteria*.

Next day after this, the insolated tube, with an atmosphere of ordinary air, became hazy with *Bacteria*.

The tube, with an atmosphere of pure oxygen, remained unchanged for some days later, when a deposit of *Torula* commenced to form at the bottom.

We conclude, therefore, both from analogy and from direct experiment, that the observed action on these organisms is not dependent on light *per se*, but that the presence of free oxygen is necessary; light and oxygen together accomplishing what neither can do alone: and the inference seems irresistible that the effect produced is a gradual oxidation of the constituent protoplasm of these organisms, and that, in this respect, protoplasm, although living, is not exempt from laws which appear to govern the relations of light and oxygen to forms of matter less highly endowed.† A force, which is indirectly absolutely

* The commonest form of organism in these exhausted tubes consisted of filaments of varying length, ranging perhaps from $\frac{1}{5000}''$ to $\frac{1}{500}''$, often curvilinear, composed of minute spherules in linear series, with motion usually vibratory and undulating, frequently progressive.

† That the amount of free oxygen present need not be large to produce a definite action upon *Bacteria* is shown by the fact that tubes containing Pasteur solution with a supernatant layer of vaseline, excluding all air, except that previously dissolved in the solution, if encased, in a few days become turbid, but may be kept clear for

essential to life as we know it, and matter, in the absence of which life has not yet been proved to exist, here unite for its destruction.

The organisms (*Bacteria*) on which we have mainly experimented, in their ordinary conditions of structure and development, afford an example of protoplasm in a simple and uncomplicated form, but it would be unreasonable to suppose that this protoplasm is so essentially different in its fundamental constitution from all other protoplasm that here, and here only, is this special effect of light to be found. There are, indeed, many facts which prove the contrary, and indicate that we are dealing, not with a special and fortuitous phenomenon, but with a general law.

But protoplasm may be very differently circumstanced in its relations both to light and oxygen, it may be protected. Such protection may be afforded by :—

1. Thickened, or opaque, cell-walls or envelopes.
2. Special colouring matters, which filter out the more injurious rays.
3. Aggregation of cells, whether free or combined into tissue, the inner being protected by the external.
4. Relation of the protoplasm itself to oxygen.

The first three are sufficiently obvious, but, as regards the last-named condition of protection, a few words of explanation are necessary.

Protoplasm in its relation to oxygen varies widely. In the vast majority of cases, oxygen in its free gaseous state, appears to be absolutely essential for the development and reproduction of protoplasmic life, but the labours of Pasteur have sufficiently demonstrated the power of some organisms, living in absence of free oxygen, to take it from certain of its combinations. During the present summer we have been continually troubled in our investigation by the fact, that either our materials, or the air in which we worked, had become infected with a species of small *Torula*. Solutions exposed to sunlight would remain clear for a few days—their incased companions in the meantime becoming turbid with ordinary *Bacteria*—but slowly and gradually a deposit would form at the bottom of the solution, which, on examination, would prove to be the *Torula* in question.

Now, if we consider the rapidity with which *Torula* removes dissolved oxygen from water,* and the comparative slowness with which

a considerable period by insolation. This fact, as well as others, shows, by the way, that the action does not depend on ozone formed, as Gorup v. Besanez believes ("Ann. Chem. Pharm.," clxi, 232) is invariably the case when water evaporates. We have, we may observe, never been able to detect the formation of active oxygen as ozone, or peroxide of hydrogen, in cultivation solutions or in water exposed to sunlight.

* Schützenberger, "Fermentation," pp. 107 and 134.

water dissolves that gas, we shall at once see that the *Torula*, deriving its respiratory oxygen from the sugar of the solution, is all this time living comparatively in absence of free oxygen, and we understand how the relations of protoplasm to oxygen, by enabling it in some forms to be largely independent of the uncombined gas, may prove a source of protection against the oxidising action of light.

In some cases, indeed, the affinity of organisms for oxygen would appear to be so great that, when presented to them in its gaseous and uncombined state, it acts, not as a source of vital energy, but as a poison, and we think that protoplasm will be found to possess varying degrees of tolerance of excess or deficiency of this element. To some forms of life, if Pasteur be right, oxygen is injurious even when diluted as in ordinary air, to others it is hurtful only when oxidation is quickened by some adjuvant force, as, for example, by light. Finally, since light here acts as an oxidiser, it is conceivable that there may exist sluggish forms of protoplasm, whose oxidising processes, and, therefore, general growth and development, may be *favourably* augmented by a modified degree of light. We are not of our present knowledge, however, able to point to such.*

In connexion with the subject of this paper, it is an interesting speculation whether any one of the constituent elements of organic bodies is specially subject to oxidation under light. We seem to have obtained some glimpse of a possible answer to this question by a few experiments upon the oxalates. If the constitutional formula of oxalic acid be rightly represented thus, $\begin{matrix} C—O—O—H \\ \| \\ C—O—O—H \end{matrix}$, a mode of approach to the problem seems to be opened, for should we find on substituting some other element for the hydrogen that decomposition is no longer produced by light, the conclusion would seem inevitable that the destruction of the molecule of oxalic acid was effected through the oxidation of the hydrogen.

On July 26th a solution of neutral oxalate of potash of decinormal strength was divided between a number of test-tubes, some of which we incased while some were insolated in the usual way. At the same time a decinormal solution of oxalic acid was similarly treated.

August 26th. The insolated oxalic acid solution is completely decomposed, but the incased oxalic acid solution is unaffected. The solutions of oxalate of potash, both incased and insolated, remain quite unchanged, and are still neutral to test-paper.

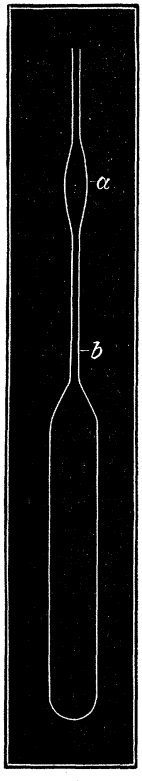
* From what we have said, it would follow that the organisms most injuriously affected by light would be found to be those whose protoplasm is "unprotected," having high affinities for oxygen, but yet for the most part requiring it uncombined, and at the same time being so minutely particulate as to offer in point of surface the greatest facility for access both of light and of oxygen, all of which conditions are exemplified by the ordinary forms of *Bacteria*.

We are justified, therefore, in concluding that, in this case at least, the destruction of an organic body in light is due to the oxidation of its hydrogen.

Appendix.

Vacuum Apparatus.—In conducting our experiments in vacuo, or in a modified atmosphere, obtained by means of the Sprengel pump, it was necessary to ensure that the tubes compared should be under exactly similar conditions with regard to pressure; and it seemed desirable, therefore, to exhaust the pairs, or double pairs, at one operation. With this object an *adapter* was contrived, which, though simple in its construction, proved so efficient that it may be worth while to describe it in detail.

Fig. 3.—*a*, "shoulder." *b*, the point of sealing after exhaustion.



A piece of glass tubing, $1\frac{1}{2}$ inches long, $\frac{3}{4}$ inch in diameter, and open at both ends, which were slightly lipped, was fitted with two caoutchouc stoppers, one of which, pierced with a single hole, served for connexion

with the entrance tube of the pump, while the other had bored in it four holes into which the ends of the experimental tubes were pushed until the "shoulder" (see fig. 3) was firmly thrust against the india-rubber. All junctions were luted with viscid glycerine, and it was found that a good vacuum could then be produced and maintained for a considerable time.

In order conveniently to seal off the tubes they were again drawn out below the shoulder, so that when complete they had the shape given in the figure (fig. 3).

When atmospheres of special composition were required the mode of procedure was somewhat different; one of the four holes in the outer caoutchouc stopper was then appropriated to a gauge, formed of a straight piece of tubing of sufficient length, dipping under mercury: into another hole was fitted a glass tube to which was attached a piece of india-rubber tubing with a clamp. The pump was then worked until the gauge showed the required tension, when the gas was admitted from a small gasholder by attaching the stop-cock of the gasholder to the india-rubber tubing and opening the clamp.

The *nitrogen* used was prepared by removing the oxygen from atmospheric air, either by the prolonged action of alkaline solution of pyrogallic acid, or, in some instances, by the combustion of phosphorus; in the latter case the oxides of phosphorus were removed by agitating with solution of caustic potash.

Our *oxygen* was made by heating pure chlorate of potash alone in a tube of hard glass; lest any trace of ozone or chlorine should be present the gas was slowly bubbled through solution of iodide of potash; this precaution, however, appeared to be superfluous, the iodide solution remaining colourless.

Postscript. Received October 18, 1878.

The oxidation of hydrogen by light, demonstrated in the case of oxalic acid, naturally suggests an inquiry into the deportment of oxygen towards hydrogen in sunlight under other conditions.

We have not, for the present at least, an opportunity of examining this question in the detail which it demands, but we think that it may be of interest to append to our paper the following brief observations.

One of the best known facts in the chemistry of light is the combination effected between chlorine and hydrogen, and in their behaviour towards hydrogen under the influence of light the halogens form an interesting series. Thus, while chlorine and hydrogen unite explosively in sunlight, bromine and hydrogen are with difficulty, if at all, induced to combine, and iodine and hydrogen do not unite at all. Again, water may be decomposed with the aid of sunlight both by chlorine* and by

* $Cl_2 + H_2O = 2HCl + O$.

bromine,* but not by iodine. Finally, while hydrochloric and hydrobromic acid in aqueous solution each resist decomposition when insolated in the presence of free oxygen, it is known that hydriodic acid under like conditions is rapidly destroyed.† This destruction, according to our experiments, is promoted by all the rays, but is much less active behind red glass than behind blue. It occurs also, but more slowly, in the dark.

Here we appear to have a phenomenon analogous to the oxidation of the hydrogen of oxalic acid.

The question arises how far a preliminary dissociation of the constituent atoms of the molecule may influence the reaction. It has been clearly shown by M. Lemoine‡ that hydriodic acid *gas* is completely dissociated by light; but the same observer states that in aqueous solution no such dissociation in sunlight can be demonstrated—a fact observed also by M. Berthelot. It may be, however, that the phenomena of dissociation and oxidation under light may go on side by side, the presence of oxygen promoting the splitting of hydriodic acid by its determining affinity. In like manner it may be that in the decomposition of oxalic acid the oxygen plays a similar part, determining the dissociation of $C_2O_4.H_2$, and replacing the dissociated radicle C_2O_4. The analogy of chlorine, however, leads us to the belief that, in its relations to hydrogen under the influence of light, oxygen may be classed with that element; but the reactions above noted would seem to indicate that, under these conditions, its affinity for hydrogen is inferior to that of either chlorine or bromine.§

We would note also the following known reactions which occur in air and sunlight:

(1.) The decomposition of arsenamine with formation of water and deposition of arsenic.

(2.) The absorption of oxygen by and precipitation of sulphur from sulphuretted hydrogen;—reactions which, although occurring in the dark, are accelerated by sunlight.

V. "Note on the Influence exercised by Light on Organic Infusions." By JOHN TYNDALL, D.C.L., F.R.S., Professor of Natural Philosophy in the Royal Institution. Received December 17, 1878.

Early last June I took with me to the Alps 50 small hermetically sealed flasks containing infusion of cucumber, and 50 containing

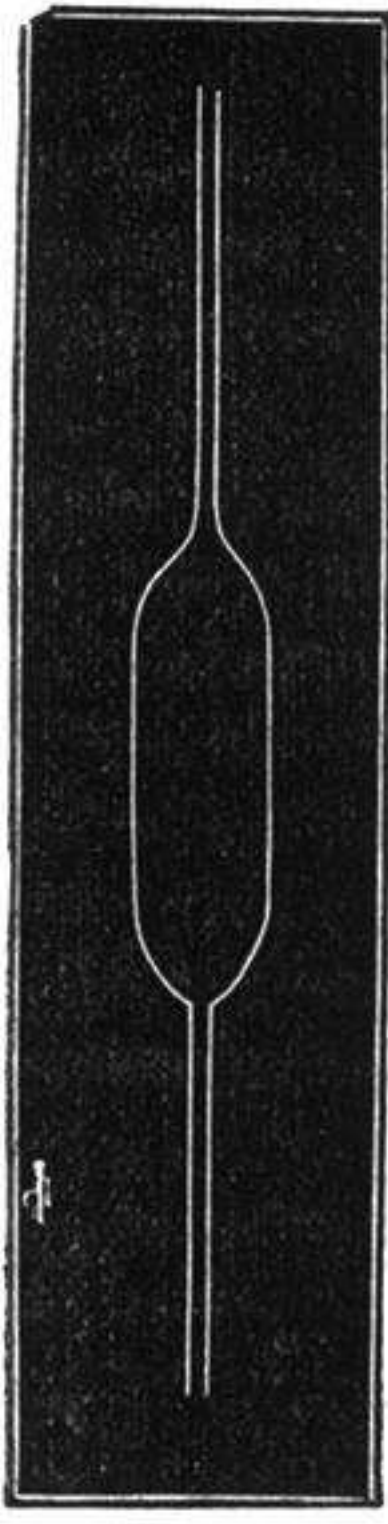
* $Br_2 + H_2O = 2HBr + O$.

† $2HI + O = I_2 + H_2O$.

‡ "Annales de Chim. et de Phys.," [5], t. xi.

§ Under ordinary conditions the direct combination of oxygen and hydrogen gases does not occur in sunlight.

FIG. 1.



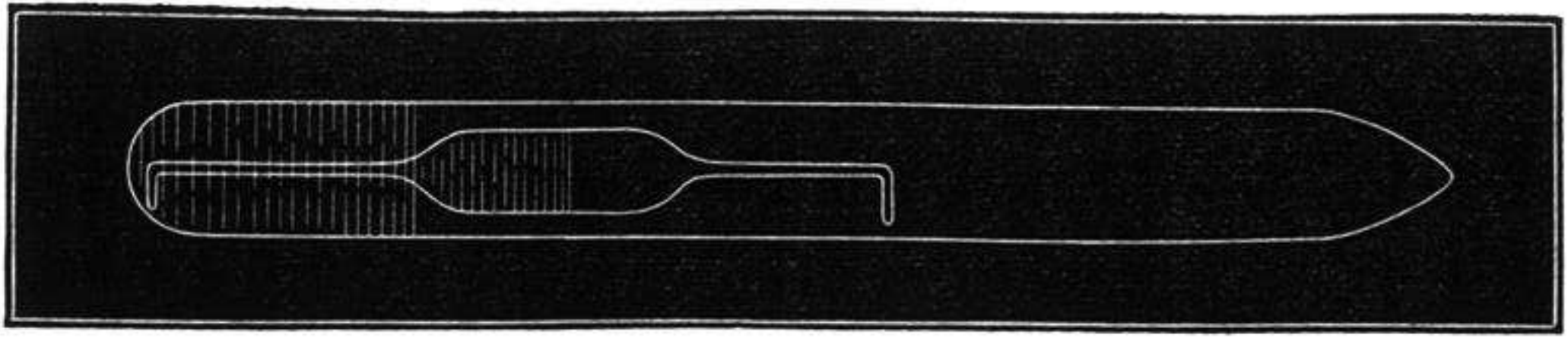


FIG. 2 (reduced).

Sealed ends of bulb bent at right angles to facilitate subsequent fracture.

FIG. 3.—*a*, "shoulder." *b*, the point of sealing after exhaustion.