IV

ON AN EFFECT OF ULTRA-VIOLET LIGHT UPON THE ELECTRIC DISCHARGE

(*Sitzungsberichte d. Berl. Akad. d. Wiss.*, June 9, 1887. *Wiedemann's Ann.* **31**, p. 983.)

In a series of experiments on the effects of resonance between very rapid electric oscillations which I have carried out and recently published,[1] two electric sparks were produced by the same discharge of an induction-coil, and therefore simultaneously. One of these, the spark *A*, was the discharge-spark of the induction-coil, and served to excite the primary oscillation. The second, the spark *B*, belonged to the induced or secondary oscillation. The latter was not very luminous; in the experiments its maximum length had to be accurately measured. I occasionally enclosed the spark *B* in a dark case so as more easily to make the observations; and in so doing I observed that the maximum spark-length became decidedly smaller inside the case than it was before. On removing in succession the various parts of the case, it was seen that the only portion of it which exercised this prejudicial effect was that which screened the spark *B* from the spark *A*. The partition on that side exhibited this effect, not only when it was in the immediate neighbourhood of the spark *B*, but also when it was interposed at greater distances from *B* between *A* and *B*. A phenomenon so remarkable called for closer investigation. The following communication contains the results which I have been able to establish in the course of the investigation :—

[1] See II., p. 29.

1. The phenomenon could not be traced to any screening effect of an electrostatic or electromagnetic nature. For the effect was not only exhibited by good conductors interposed between *A* and *B*, but also by perfect non-conductors, in particular by glass, paraffin, ebonite, which cannot possibly exert any screening effect. Further, metal gratings of coarse texture showed no effect, although they act as efficient screens.

2. The fact that both sparks *A* and *B* corresponded with synchronous and very rapid oscillations was immaterial. For the same effect could be exhibited by exciting two simultaneous sparks in any other way. It also appeared when, instead of the induced spark, I used a side-spark (this term having the same significance as in my earlier paper). It also appeared when I used as the spark *B* a side-discharge (according to Riess's terminology), such as is obtained by connecting one pole of an induction-coil with an insulated conductor and introducing a spark-gap. But it can best and most conveniently be exhibited by inserting in the same circuit two induction-coils with a common interruptor, the one coil giving the spark *A* and the other the spark *B*. This arrangement was almost exclusively used in the subsequent experiments. As I found the experiment succeed with a number of different induction-coils, it could be carried out with any pair of sets of apparatus at pleasure. At the same time it will be convenient to describe the particular experimental arrangement which gave the best results and was most frequently used. The spark *A* was produced by a large Ruhmkorff coil (*a*, Fig. 18), 52 cm. long and 20 cm. in diameter, fed by six large Bunsen cells (*b*) and provided with a separate mercury-break (*c*). With the current used it could give sparks up to 10 cm. long between point and plate, and up to about 3 cm. between two spheres. The spark generally used was one of 1 cm. length between the points of a common discharger (*d*). The spark *B* was produced by a smaller coil (originally intended for medical use) of relatively greater current-strength, but having a maximum spark-length of only $^1/_2$-1 cm. As it was here introduced into the circuit of the larger coil, its condenser did not come into play, and thus it only gave sparks of 1-2 mm. length. The

sparks used were ones about 1 mm. long between the nickel-plated knobs of a Riess spark-micrometer (*f*), or between brass knobs of 5 to 10 cm. diameter. When the apparatus thus arranged was set up with both spark-gaps parallel and not too far apart, the interruptor set going, and the spark-micrometer drawn out just so far as to still permit sparks to pass regularly, then on placing a plate (*p*) of metal, glass, etc., between the two sparks-gaps *d* and *f*, the sparks are extinguished immediately and completely. On removing the plate they immediately reappear.

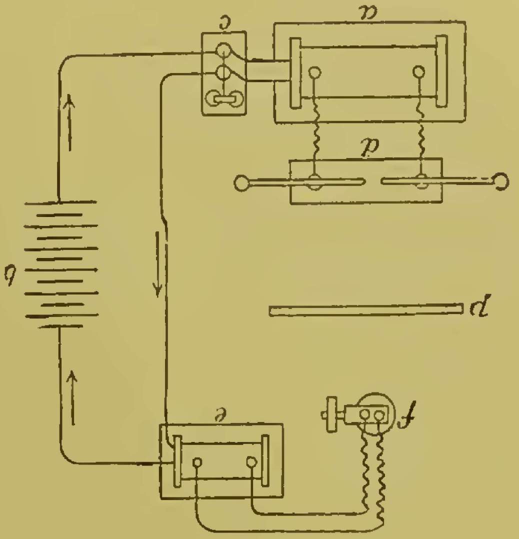

Fig. 18.

3. The effect becomes more marked as the spark *A* is brought nearer to the spark *B*. The distance between the two sparks when I first observed the phenomenon was 1½ metres, and the effect is, therefore, easily observed at this distance. I have been able to detect indications of it up to a distance of 3 metres between the sparks. But at such distances the phenomenon manifests itself only in the greater or less regularity of the stream of sparks at *B*; at distances less than a metre its strength can be measured by the difference between the maximum spark-length before and after the interposition of the plate. In order to indicate the magnitude of the effect I give the following, naturally rough, observations which were obtained with the experimental arrangement shown in Fig. 18 :—

Distance between the Sparks in cm.	Length of Spark *B* in mm. before and after inserting the Plate.		Difference.
∞	0·8	0·8	0
50	0·9	0·8	0·1
40	1·0	0·8	0·2
30	1·1	0·8	0·3
20	1·3	0·8	0·5
10	1·5	0·8	0·7
5	1·6	0·8	0·8
2	1·8	0·8	1·0

It will be seen that, under certain conditions, the sparking distance is doubled by removing the plate.

4. The observations given in the table may also be adduced as proofs of the following statement which the reader will probably have assumed from the first. The phenomenon does not depend upon any prejudicial effect of the plate on the spark *B*, but upon its annulling a certain action of the spark *A*, which tends to increase the sparking distance. When the distance between the sparks *A* and *B* is great, if we so adjust the spark-micrometer that sparks no longer pass at *B*, and then bring the spark-micrometer nearer to *A*, the stream of sparks in *B* reappears; this is the action. If we now introduce the plate, the sparks are extinguished; this is the cessation of the action. Thus the plate only forms a means of exhibiting conveniently and plainly the action of the spark *A*. I shall in future call *A* the active spark and *B* the passive spark.

5. The efficiency of the active spark is not confined to any special form of it. Sparks between knobs, as well as sparks between points, proved to be efficient. Short straight sparks, as well as long jagged ones, exhibited the effect. There was no difference of any importance between faintly luminous bluish sparks and brilliant white ones. Even sparks 2 mm. long made their influence felt to considerable distances. Nor does the action proceed from any special part of the spark; every part is effective. This statement can be verified by drawing a glass tube over the spark-gap. The glass does not allow the effect to pass through, and so the spark under these conditions is inactive. But the effect reappears as soon as a short bit of the spark is exposed at one pole or the other, or in the middle. I have not observed any influence due to the metal of the pole. And in arranging the experiment it is not of importance that the active spark should be parallel to the passive one.

6. On the other hand, the susceptibility of the passive spark to the action is to a certain extent dependent upon its form. I could detect no susceptibility with long jagged sparks between points, and but little with short sparks

between points. The effect was best displayed by sparks between knobs, and of these most strikingly by short sparks. It is advisable to use for the experiments sparks 1 mm. long between knobs of 5-10 mm. diameter. Still I have distinctly recognised the effect with sparks 2 cm. long. Perhaps the absolute lengthening which such sparks experience is really as great as in the case of shorter sparks, but at all events the relative increase in length is much smaller; and hence the effect disappears in the differences which occur between the single discharges of the coil. I have not discovered any perceptible influence due to the material of the pole. I examined sparks between poles of copper, brass, iron, aluminium, tin, zinc, and lead. If there was any difference between the metals with respect to the susceptibility of the spark, it appeared to be slightly in favour of the iron. The poles must be clean and smooth; if they are dirty, or corroded by long use, the effect is not produced.

7. The relation between the two sparks is reciprocal. That is to say, not only does the larger and stronger spark increase the spark-length of the smaller one, but conversely the smaller spark has the same effect upon the spark-length of the larger one. For example, using the same apparatus as before, let us adjust the spark-micrometer so that the discharge in it passes over regularly; but let the discharger be so adjusted that the discharges of the large coil just miss fire. On bringing the spark-micrometer nearer we find that these discharges are again produced; but that on introducing a plate the action ceases. For this purpose the spark of the large coil must naturally be fairly sensitive; and, inasmuch as long sparks are less sensitive, the effect is not so striking. If both coils are just at the limit of their sparking distance complications arise which have probably no connection with the matter at present under discussion.[1] One frequently has occasion to notice a long spark being started by other ones which are much smaller, and in part this may certainly be ascribed to the action which we are investigating. When the discharge of a coil is made to take place between knobs, and the knobs are drawn apart until the sparks cease, then it

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[1] [See Note 8 at end of book.]

is found that the sparking begins again when an insulated conductor is brought near one of the knobs so as to draw small side-sparks from it. I have proved to my entire satisfaction that the side-discharges here perform the function of an active spark in the sense of the present investigation. It is even sufficient to touch one of the knobs with a non-conductor, or to bring a point somewhat near it, in order to give rise to the same action. It appears at least possible that the function of an active spark is here performed by the scarcely visible side-discharges over the surface of the non-conductor and of the point.

8. The effect of the active spark spreads out on all sides in straight lines and forms rays exactly in accordance with the laws of the propagation of light. Suppose the axes of both of the sparks used to be placed vertically, and let a plate with a vertical edge be pushed gradually from the side in between the sparks. It is then found that the effect of the active spark is stopped, not gradually, but suddenly, and in a definite position of the plate. If we now look along the edge of the plate from the position of the passive spark, we find that the active spark is just hid by the plate. If we adjust the plate with its edge vertical between the two sparks and slowly remove it sideways, the action begins again in a definite position, and we now find that, from the position of the passive spark, the active spark has just become visible beyond the edge of the plate. If we place between the sparks a plate with a small vertical slit and move it backwards and forwards, we find that the action is only transmitted in one perfectly definite position, namely, when the active spark is visible through the slit from the position of the passive spark. If several plates with such slits are interposed behind each other, we find that in one particular position the action passes through the whole lot. If we seek these positions by trial, we end by finding (most easily, of course, by looking through) that all the slits lie in the vertical plane which passes through the two sparks. If at any distance from the active spark we place a plate with an aperture of any shape, and by moving the active spark about fix the limits of the space within which the action is exerted, we

obtain as this limit a conical surface determined by the active spark as apex and by the limits of the aperture. If we place a small plate in any position in front of the active spark we find, by moving the passive spark about, that the plate stops the action of the active spark within exactly the space which it shelters from its light. It scarcely requires to be explained that the action is not only annulled in the shadows cast by external bodies, but also in the shadows of the knobs of the passive spark. In fact, if we turn the latter so that its axis remains in the plane of the active spark, but is perpendicular to it instead of being parallel, the action immediately ceases.

9. Most solid bodies hinder the action of the active spark, but not all; a few solid bodies are transparent to it. All the metals which I tried proved to be opaque, even in thin sheets, as did also paraffin, shellac, resin, ebonite, and india-rubber; all kinds of coloured and uncoloured, polished and unpolished, thick and thin glass, porcelain, and earthenware; wood, pasteboard, and paper; ivory, horn, animal hides, and feathers; lastly, agate, and, in a very remarkable manner, mica, even in the thinnest possible flakes. Further investigation of crystals showed variations from this behaviour. Some indeed were equally opaque, *e.g.* copper sulphate, topaz, and amethyst; but others, such as crystallised sugar, alum, calc-spar, and rock-salt, transmitted the action, although with diminished intensity; finally, some proved to be completely transparent, such as gypsum (selenite), and above all rock-crystal, which scarcely interfered with the action even when in layers several centimetres thick. The following is a convenient method of testing:—The passive spark is placed a few centimetres away from the active spark, and is brought to its maximum length. The body to be examined is now interposed. If this does not stop the sparking the body is very transparent. But if the sparking is stopped, the spark-gap must be shortened until it comes again into action. An opaque substance is now interposed in addition to the body under investigation. If this stops the sparking once more, or weakens it, then the body must have been at any rate partially transparent; but if the plate produces no further effect it must have been quite opaque. The influence of the interposed bodies increases with their thickness,

and it may properly be described as an absorption of the action of the active spark; in general, however, even those bodies which only act as partial absorbers, exert this influence even in very thin layers.

10. Liquids also proved to be partly transparent and partly opaque to the action. In order to experiment upon them the active spark was brought about 10 cm. vertically above the passive one, and between both was placed a glass vessel, of which the bottom consisted of a circular plate of rock-crystal 4 mm. thick. Into this vessel a layer, more or less deep, of the liquid was poured, and its influence was then estimated in the manner above described for solid bodies. Water proved to be remarkably transparent; even a depth of 5 cm. scarcely hindered the action. In thinner layers pure concentrated sulphuric acid, alcohol, and ether were also transparent. Pure hydrochloric acid, pure nitric acid, and solution of ammonia proved to be partially transparent. Molten paraffin, benzole, petroleum, carbon bisulphide, solution of ammonium sulphide, and strongly coloured liquids, *e.g.* solutions of fuchsine, potassium permanganate, were nearly or completely opaque. The experiments with salt solutions proved to be interesting. A layer of water 1 cm. deep was introduced into the rock-crystal vessel; the concentrated salt solution was added to this drop by drop, stirred, and the effect observed. With many salts the addition of a few drops, or even a single drop, was sufficient to extinguish the passive spark; this was the case with nitrate of mercury, sodium hyposulphite, potassium bromide, and potassium iodide. When iron and copper salts were added, the extinction of the passive spark occurred before any distinct colouring of the water could be perceived. Solutions of sal-ammoniac, zinc sulphate, and common salt[1] exercised an absorption when added in larger quantities. On the other hand, the sulphates of potassium, sodium, and magnesium were very transparent even in concentrated solution.

11. It is clear from the experiments made in air that some gases permit the transmission of the action even to con-

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[1] According to my experiments a concentrated solution of common salt is a more powerful absorbent than crystallised rock-salt. This result is so remarkable as to require confirmation.

siderable distances. Some gases, however, are very opaque to it. In experimenting on gases a tube 20 cm. long and 2·5 cm. in diameter was interposed between the active and passive sparks; the ends of this tube were closed by thin quartz plates, and by means of two side-tubes any gas could at will be led through it. A diaphragm prevented the transmission of any action excepting through the glass tube. Between hydrogen and air there was no noticeable difference. Nor could any falling off in the action be perceived when the tube was filled with carbonic acid. But when coal-gas was introduced, the sparking at the passive spark-gap immediately ceased. When the coal-gas was driven out by air the sparking began again; and this experiment could be repeated with perfect regularity. Even the introduction of air with which some coal-gas had been mixed hindered the transmission of the action. Hence a much shorter stratum of coal-gas was sufficient to stop the action. If a current of coal-gas 1 cm. in diameter is allowed to flow freely into the air between the two sparks, a shadow of it can be plainly perceived on the side remote from the active spark, *i.e.* the action of this is more or less completely annulled. A powerful absorption like that of coal-gas is exhibited by the brown vapours of nitrous oxide. With these, again, it is not necessary to use the tube with quartz-plates in order to show the action. On the other hand, although chlorine and the vapours of bromine and iodine do exercise absorption, it is not at all in proportion to their opacity. No absorptive action could be recognised when bromine vapour had been introduced into the tube in sufficient quantity to produce a distinct coloration; and there was a partial transmission of the action even when the bromine vapour was so dense that the active spark (coloured a deep red) was only just visible through the tube.

12. The intensity of the action increases when the air around the passive spark is rarefied, at any rate up to a certain point. The increase is here supposed to be measured by the difference between the lengths of the protected and the unprotected sparks. In these experiments the passive spark was produced under the bell-jar of an air-pump between adjustable poles which passed through the sides of the bell-jar. A window

of rock-crystal was inserted in the bell-jar, and through this the action of the other spark had to pass. The maximum spark-length was now observed, first with the window open, and then with the window closed; varying air-pressures being used, but a constant current. The following table may be regarded as typical of the results:—

Air-pressure in mm. of Mercury.	Length in mm. of Spark with Window Closed.	Open.	Difference.
760	0·8	1·5	0·7
500	0·9	2·3	1·4
300	1·0	3·7	2·7
100	2·0	6·2	4·2
80	very great	very great	undetermined.

It will be seen that as the pressure diminishes, the length of the spark which is not influenced only increases slowly; the length of the spark which is influenced increases more rapidly, and so the difference between the two becomes greater. But at a certain pressure the blue glow-light (*Glimmlicht*) spread over a considerable portion of the cathode, the sparking distance became very great, the discharge altered its character, and it was no longer possible to perceive any influence due to the active spark.

13. The phenomenon is also exhibited when the sparking takes place in other gases than air; and also when the two sparks are produced in two different gases. In these experiments the two sparks were produced in two small tubulated glass vessels which were closed by plates of rock-crystal and could be filled with different gases. The experiments were tried mainly because certain circumstances led to the supposition that a spark in any given gas would only act upon another spark in the same gas, and on this account the four gases—hydrogen, air, carbonic acid, and coal-gas—were tried in the sixteen possible combinations. The main conclusion arrived at was that the above supposition was erroneous. It should, however, be added that although there is no great difference in the efficiency of sparks when employed as active sparks in different gases, there is, on the other hand, a notable difference in their susceptibility when employed as passive sparks. Other things being equal, sparks in hydrogen experienced a perceptibly greater

increase in length than sparks in air, and these again about double the increase of sparks in carbonic acid and coal-gas. It is true that no allowance was made for absorption in these experiments, for its effect was not known when they were carried out; but it could only have been perceptible in the case of coal-gas.

14. All parts of the passive spark do not share equally in the action; it takes place near the poles, more especially near the negative pole.[1] In order to show this, the passive spark is made from 1 to 2 cm. long, so that the various parts of it can be shaded separately. Shading the anode has but a slight effect; shading the cathode stops the greater part of the action. But the verification of this fact is somewhat difficult, because with long sparks there is a want of distinctness about the phenomenon. In the case of short sparks (the parts of which cannot be separately shaded) the statement can be illustrated as follows:—The passive spark is placed parallel to the active one and is turned to right and left from the parallel into the perpendicular position until the action stops. It is found that there is more play in one direction than in the other; the advantage being in favour of that direction in which the cathode is turned towards the active spark. Whether the effect is produced entirely at the cathode, or only chiefly at the cathode, I have not been able to decide with certainty.

15. The action of the active spark is reflected from most surfaces. From polished surfaces the reflection takes place according to the laws of regular reflection of light. In the preliminary experiments on reflection a glass tube, 50 cm. long and 1 cm. in diameter, was used; this tube was open at both ends, and was pushed through a large sheet of cardboard. The active spark was placed at one end so that its action could only pass the sheet by way of the tube. If the passive spark was now moved about beyond the other end of the tube it was affected when in the continuation of the tubular space and then only; but in this case a far more powerful action was exhibited than when the tube was removed and only the diaphragm retained. It was this latter phenomenon that suggested the use of the tube; of itself it indicates a reflection from

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[1] [See Note 9 at end of book.]

the walls of the tube. The spark-micrometer was now placed to one side of the beam proceeding out of the tube, and was so disposed that the axis of the spark was parallel to the direction of the beam. The micrometer was now adjusted so that the sparking just ceased; it was found to begin again if a plane surface inclined at an angle of 45° to the beam was held in it so as to direct the beam, according to the usual law of reflection, upon the passive spark. Reflection took place more or less from glass, crystals, and metals, even when these were not particularly smooth; also from such substances as porcelain, polished wood, and white paper. I obtained no reflection from a well-smoked glass plate.

In the more accurate experiments the active spark was placed in a vertical straight line; at a little distance from it was a largeish plate with a vertical slit, behind which could be placed polished plane mirrors of glass, rock-crystal, and various metals. The limits of the space within which the action was exerted behind the slit were then determined by moving the passive spark about. These limits were quite sharp and always coincided with the limits of the space within which the image of the active spark in the mirror was visible. On account of the feebleness of the action these experiments could not be carried out with unpolished bodies; such bodies may be supposed to give rise to diffused reflection.

16. In passing from air into a solid transparent medium the action of the active spark exhibits a refraction like that of light; but it is more strongly refracted than visible light. The glass tube used in the reflection experiments served here again for the rougher experiments. The passive spark was placed in the beam proceeding out of the tube and at a distance of about 30 cm. from the end farthest from the active spark; immediately behind the opening a quartz-prism was pushed sideways into the beam with its refracting edge foremost. In spite of the transparency of quartz, the effect upon the passive spark ceased as soon as the prism covered the end of the tube. If the spark was then moved in a circle about the prism in the direction in which light would be refracted by the prism, it was soon found that there were places at which the effect was again produced. Now let the passive spark be fixed in the

position in which the effect is most powerfully exhibited; on looking from this point towards the tube through the prism the inside of the tube and the active spark at the end of it cannot be perceived; in order to see the active spark through the tube the eye must be shifted backwards through a considerable distance towards the original position of the spark. The same result is obtained when a rock-salt prism is used. In the more accurate experiments the active spark was again fixed vertically; at some distance from it was placed a vertical slit, and behind this a prism. By inserting a Leyden jar the active spark could be made luminous, and the space thus illuminated behind the prism could easily be determined. With the aid of the passive spark it was possible to mark out the limits of the space within which was exerted the action here under investigation. Fig. 19 gives (to a scale of $\frac{1}{2}$) the result thus obtained by direct experiment. The space *a b c d* is filled with light; the space *a′ b′ c′ d′* is permeated by the action which we are considering. Since the limits of this latter space were not sharp, the rays *a′ b′* and *c′ d′* were fixed in the following way:—The passive spark was placed in a somewhat distant position, about *c′*, at the edge of the tract within which the action was exerted. A screen *m n* (Fig. 19) with vertical edge was then pushed in sideways until it stopped the action. The

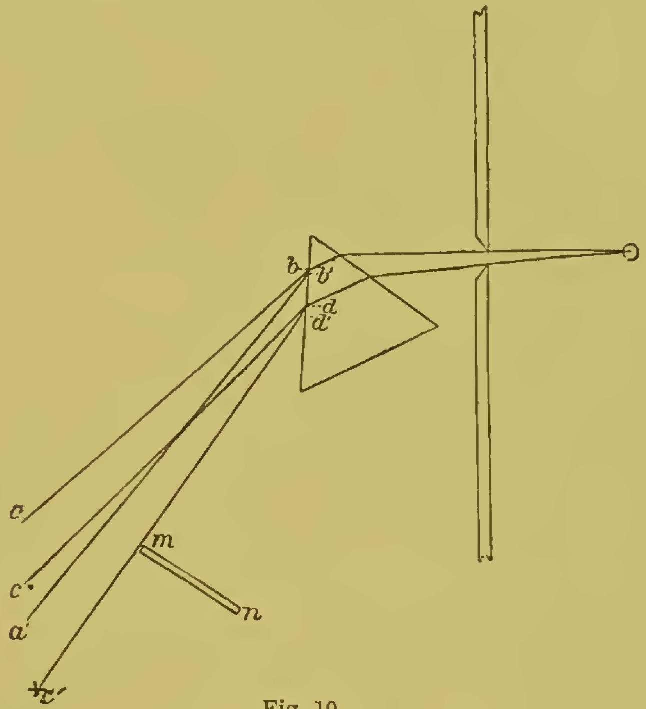

Fig. 19.

position *m* of its edge then gave one point of the ray $c' d'$. In another experiment a prism of small refracting angle was used, and the width of the slit was made as small, and the spark placed as far from it as would still allow of the action being perceived. The visible light was then spread out into a short spectrum, and the influence of the active spark was found to be exerted within a comparatively limited region which corresponded to a deviation decidedly greater than that of the visible violet. Fig. 20 shows the positions of the rays as they were directly drawn where the prism was placed, *r* being the direction of the red, *v* of the violet, and *w* the direction in which the influence of the active spark was most powerfully exerted.

Fig. 20.

I have not been able to decide whether any double refraction of the action takes place. My quartz-prisms would not permit of a sufficient separation of the beams, and the pieces of calc-spar which I possessed proved to be too opaque.[1]

17. After what has now been stated, it will be agreed (at any rate until the contrary is proved) that the light of the active spark must be regarded as the prime cause of the action which proceeds from it. Every other conjecture which is based on known facts is contradicted by one or other of the experiments. And if the observed phenomenon is an effect of light at all it must, according to the results of the refraction-experiments, be solely an effect of the ultra-violet light. That it is not an effect of the visible parts of the light is shown by the fact that glass and mica are opaque to it, while they are transparent to these. On the other hand, the absorption-experiments of themselves make it probable that the effect is due to ultra-violet light. Water, rock-crystal, and the sulphates of the alkalies are remarkably transparent to ultra-violet light and to the action here investigated; benzole and allied substances

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[1] [See Note 10 at end of book.]

are strikingly opaque to both. Again, the active rays in our experiments appear to lie at the outermost limits of the known spectrum. The spectrum of the spark when received on a sensitive dry-plate scarcely extended to the place at which the most powerful effect upon the passive spark was produced. And, photographically, there was scarcely any difference between light which had, and light which had not, passed through coal-gas, whereas the difference in the effect upon the spark was very marked. Fig. 21 shows the extent of some of the spectra taken. In *a* the position of the visible red is indicated by *r*, that of the visible violet by *v*, and that of the strongest effect upon the passive spark by *w*. The rest of the series give the photographic impressions produced—*b* after simply passing through air and quartz, *c* after passing through coal-gas, *d* after passing through a thin plate of mica, and *e* after passing through glass.

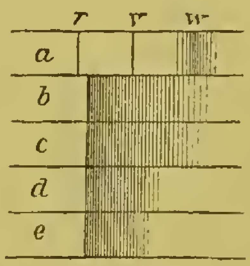

Fig. 21.

18. Our supposition that this effect is to be attributed to light is confirmed by the fact that the same effect can be produced by a number of common sources of light. It is true that the power of the light, in the ordinary sense of the word, forms no measure of its activity as here considered; and for the purpose of our experiments the faintly visible light of the spark of the induction-coil remains the most powerful source of light. Let sparks from any induction-coil pass between knobs, and let the knobs be drawn so far apart that the sparks fail to pass; if now the flame of a candle be brought near (about 8 cm. off) the sparking begins again. The effect might at first be attributed to the hot air from the flame; but when it is observed that the insertion of a thin small plate of mica stops the action, whereas a much larger plate of quartz does not stop it, we are compelled to recognise here again the same effect. The flames of gas, wood, benzene, etc., all act in the same way. The non-luminous flames of alcohol and of the Bunsen burner exhibit the same effect, and in the case of the candle-flame the action seems to proceed more from the lower, non-luminous part than from the upper and luminous part. From a small hydrogen flame scarcely any effect could be obtained. The light from

platinum glowing at a white-heat in a flame, or through the action of an electric current, a powerful phosphorus flame burning quite near the spark, and burning sodium and potassium, all proved to be inactive. So also was burning sulphur; but this can only have been on account of the feebleness of the flame, for the flame of burning carbon bisulphide produced some effect. Magnesium light produced a far more powerful effect than any of the above sources; its action extended to a distance of about a metre. The limelight, produced by means of coal-gas and oxygen, was somewhat weaker, and acted up to a distance of half a metre; the action was mainly due to the jet itself: it made no great difference whether the lime-cylinder was brought into the flame or not. On no occasion did I obtain a decisive effect from sunlight at any time of the day or year at which I was able to test it. When the sunlight was concentrated by means of a quartz lens upon the spark there was a slight action; but this was obtained equally when a glass lens was used, and must therefore be attributed to the heating. But of all sources of light the electric arc is by far the most effective; it is the only one that can compete with the spark. If the knobs of an induction-coil are drawn so far apart that sparks no longer pass, and if an arc light is started at a distance of 1, 2, 3, or even 4 metres, the sparking begins again simultaneously, and stops again when the arc light goes out. By means of a narrow opening held in front of the arc light we can separate the violet light of the feebly luminous arc proper from that of the glowing carbons; and we then find that the action proceeds chiefly from the former. With the light of the electric arc I have repeated most of the experiments already described, *e.g.* the experiments on the rectilinear propagation, reflection, and refraction of the action, as well as its absorption by glass, mica, coal-gas, and other substances.

According to the results of our experiments, ultra-violet light has the property of increasing the sparking distance of the discharge of an induction-coil, and of other discharges. The conditions under which it exerts its effect upon such discharges are certainly very complicated, and it is desirable that the action should be studied under simpler conditions, and especially without using an induction-coil. In endeavouring to make progress in this direction I have met with difficulties.[1] Hence I confine myself at present to communicating the results obtained, without attempting any theory respecting the manner in which the observed phenomena are brought about.

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[1] [See Note 11 at end of book.]