## IV. "Investigations on the Spectrum of Magnesium. No. II."

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Since our last communication on this subject, we have made many additional observations on the spectrum of magnesium under various circumstances, and have arrived at some new results. Speaking generally, we find that differences of temperature, such as we get in the flame of burning magnesium, in the arc, and in the spark, produce less differences in the spectrum than we had before attributed to them. For instance, the lines which previously we had observed only in the spark discharge, we have since found to be developed in the arc also, provided the discharge occur between electrodes of magnesium.* In making these experiments we used thick electrodes of magnesium, and brought them together inside a glass globe about 6 inches in diameter, fitted with a plate of quartz in front and filled from time to time with various gases. The arc was an instantaneous flash which could not be repeated more than twice without rendering the sides of the vessel opaque with a complete coating of magnesium. It was therefore analogous to an explosion of magnesium vapour. The strong blue line λ4481, two pairs about λ3895, 3893, and λ3855, 3848, the strong pair about λ2935, 2927, and the two weaker lines of the quadruple group, namely, λ2789·9 and 2797, all come out in the arc given by a Siemens' dynamo between magnesium electrodes in air, in nitrogen, and in hydrogen. We have observed most of them also when the arc is taken in carbonic acid, in ammonia, in steam, in hydrochloric acid, in chlorine, and in oxygen. The relative intensities of these lines, as compared with one another and with the other lines of the spectrum, vary considerably under different circumstances, of which temperature is doubtless one of the most important; but none of the spark lines seem to be absent from the arc, and even the blue line λ4481, so characteristic of the spark, which we never found in the electric arc taken between carbon poles in a crucible of magnesia even on addition of magnesium, is sometimes quite as strongly shown in the arc between magnesium electrodes. There are still several lines of the arc which we have never observed in the spark, such as the series of triplets of wavelength less than 2770, but their presence may be dependent more on the large quantity of incandescent matter in the arc than upon its relative temperature. The observations, however, render doubtful

* Compare the appearance of the lines of hydrogen in the arc discharge, 'Roy. Soc. Proc.,' vol. 30, p. 157; and vol. 35, p. 75.

the correctness of the received opinion that the temperature of the spark discharge is much higher than that of the arc. The greater mass of the incandescent matter in the arc may be expected to give a greater number of lines, because the gradations of temperature will be less steep than in a smaller mass, and we shall have from the outer part of the mass the light which is emitted at comparatively low temperatures, while from the inner part we shall get those rays which are only produced by the highest temperatures. Moreover, compounds which may be dissociated in the interior of the mass may be re-formed in the outer part, and produce their characteristic emission or, in some cases, absorption spectra. Heat, however, is not the only form of energy which may give rise to vibrations, and it is probable that the energy of the electric discharge, as well as that due to chemical change, may directly impart to the matter affected vibrations which are more intense than the temperature alone would produce.

*The Bands of the Oxide.*

The set of seven bands in the green, beginning at about $\lambda 5006{\cdot}4$ and fading towards the violet side of the spectrum, which we have before attributed to the oxide of magnesium, have been subjected to further observation, and we have no reason to doubt the correctness of our former conclusion that they are due either to magnesia or to the chemical action of oxidation. On repeating our experiments with the spark of an induction coil between magnesium electrodes in different gases at atmospheric pressure, we could see no trace of these bands in hydrogen, nitrogen, or ammonia, whether a Leyden jar was used or not. Nor could we see them at all in carbonic oxide, but in this case the brightness of the lines due to the gas might prevent the bands being seen if they were only feebly developed. On the other hand, the bands come out brilliantly when the gas is oxygen or carbonic acid, both with and without the use of a Leyden jar. In air and in steam they are less brilliant, but may be well seen when no jar is used. When a jar is used they are less conspicuous, because in air the lines of nitrogen come out strongly in the same region, and in steam the F line of hydrogen becomes both very bright and much expanded.* It seems, therefore, that it is not the character of the electric discharge, but the nature of the gas which determines the appearance of the bands; and the absence of

* Neither the arc of a Siemens' dynamo, nor that of a De Meritens' magneto-electric machine, when taken in a crucible of magnesia, shows these bands, even if metallic magnesium be dropped into it. A stream of hydrogen led into the crucible with a view to cool it does not elicit them. When the arc is taken in the open air, and metallic magnesium dropped through it, the bands appear momentarily, but that is probably the result of the burning of the magnesium vapour outside the arc.—May 23.

the bands in the absence of oxygen, and their increased brilliance in that gas, leave little room for doubt that they are due to the oxide, or to the process of oxidation. It may be assumed that at a sufficiently high temperature magnesia will be decomposed, but magnesia is a very stable compound, a great amount of heat is developed in its formation, and it probably requires a temperature far above that of burning magnesium for its complete dissociation. This is consistent with the appearance of the bands in the spectrum of the flame of the burning metal, as well as in the condensed spark when the other conditions are favourable for the formation of the oxide, or for its stability when formed. In our earlier observations, we obtained in the *visible* region nothing but a continuous spectrum from magnesia heated with the oxyhydrogen blowpipe; neither the *b* group, nor λ4570, nor the triplet near L appeared, but at the same time λ2852 was not only strong, but was strongly reversed. We now find that this result, so far as it was negative, was a consequence of using too large a mass of magnesia to be adequately heated by the flame. If the piece of magnesia is very small, such as a fragment of the ash of burnt magnesium ribbon, most of the spectrum of burning magnesium is developed in the flame for a short distance from the piece of magnesia. It was not very easy to make these experiments successfully. About 3 inches of magnesium ribbon were burnt in air, and the ash carefully heated in the upper part of the oxyhydrogen flame to render it dense. The thread of magnesia so obtained was held horizontally with its end projecting into the oxyhydrogen flame so as to approach the boundary of the inner cone, and if the current of gas were not too strong all that was further necessary was to move up the thread horizontally as the end was worn away. When the magnesia was placed as described, the whole upper part of the flame was of a fine azure-blue colour. Under these circumstances, the flame shows the *b* group and the magnesium-hydrogen series close to it, the bands in the green, the triplet near L, the triplet near M of the flame of burning magnesium, with the group of bands in that region, and the line λ2852. It is remarkable that the proportions in which the oxygen and hydrogen are mixed affect the relative intensities of different parts of the spectrum. In general, both the metallic lines of the *b* group and the bands of the oxide are easily seen; but if the oxygen be in excess the bands of the oxide come out with increased brightness, while the *b* group fades or sometimes becomes invisible. On the other hand, if the hydrogen be in excess the bands fade, and the *b* group shows increased brilliance. There can hardly be much difference in the temperature of the flame according as one gas or the other is in excess, but the excess of oxygen is favourable to the formation and stability of the oxide, while excess of hydrogen facilitates the reduction of magnesium and

its maintenance in the metallic state. As regards temperature, it should be observed that while substances merely heated by the flame, and not undergoing chemical change, are not likely to rise to a temperature above the average temperature of the flame, it will be otherwise with the materials of the flame itself and other substances in it which are undergoing chemical change, and have at the instant of such change the kinetic energy due to the change.

In a recent communication to the Society, "Researches on the Spectra of Meteorites," Mr. Lockyer has directly connected the appearance in nebulæ of these bands, namely, "the magnesium fluting at 500" with the temperature of the Bunsen burner ('Roy. Soc. Proc.,' vol. 43, p. 133). That the bands are persistent through a large range of temperature there is no doubt, but we cannot help thinking that Mr. Lockyer is mistaken in supposing them to be produced at the temperature of a Bunsen burner. It does not follow because the bands are seen when magnesium is burnt in a Bunsen burner that the molecules which emit them are at the temperature of the flame. In the combustion of the magnesium the formation of each molecule of magnesia is attended with a development of kinetic energy which, if it all took the form of heat and were all concentrated in the molecule, must raise its temperature to very nearly the point at which magnesia is completely dissociated. The persistence of the molecule of magnesia when formed will depend upon the dissipation of some of this energy, and one of the forms in which this dissipation occurs is the very radiation which produces the bands. The character of the vibration depends on the motions of the molecules, which in the case in question are not derived from the heat of the flame, but from the stored energy of the separated elements, which becomes kinetic when they combine. The temperature of complete dissociation of magnesia is very far higher than any temperature which can reasonably be assigned to the Bunsen burner.

Nor do the observations we have made on magnesia in the oxy-hydrogen flame appear to us to be inconsistent with the conclusion that the spectrum of the oxide is produced only at a high temperature, as we have a decomposition of magnesia by the hydrogen at the highest temperature of the blowpipe flame, and when hydrogen is in excess little but the metallic lines is visible, because the re-formation of magnesia is, for the most part, the reversal of the former action, and occurs in the cooler part of the flame by the interchange of oxygen between steam and magnesium with scarcely any rise of temperature. On the other hand, when the oxygen is in excess the reduced magnesium carried up into the flame combines for the most part directly with oxygen, and individual molecules thereby acquire a motion of far greater intensity than they could derive from the average heat of the flame.

In fact, when chemical changes are occurring in a flame it cannot be taken for granted that the temperatures of the molecules are all alike, or that the vibrations which they assume are the result of heat alone. On the other hand, the temperature of the metal separated from magnesia by the oxyhydrogen flame cannot, we suppose, be at a temperature higher than that of the hottest part of the flame. We are therefore inclined to think that the metallic lines (*b*) are manifested at a lower temperature than the bands of the oxide; and the appearance of a line in the position of the first band without any trace of the second band (which is nearly as bright as the first), and without any trace of the *b* group, is quite sufficient to create a suspicion of mistaken identity when Mr. Lockyer ascribes the sharp green line in the spectrum of nebulæ to this band of magnesia. This suspicion will be strengthened when it is noticed that the line in question is usually in the nebulæ associated with the F line of hydrogen, if it be borne in mind that the spark of magnesium in hydrogen does not give the bands, and that the oxyhydrogen flame hardly produces them from magnesia when the hydrogen is in excess.

In Mr. Lockyer's map of the spectrum of the nebula in Orion (*loc. cit.*, p. 134), he has represented three lines in the position of the edges of the first three of these bands. If these three lines were really seen in the nebula, there would be less room to doubt the identity of the spectra; but the authorities quoted for the map (*loc. cit.*, p. 142) mention only a single line in this position.

When the flame of burning magnesium is viewed with a high dispersion these bands are resolved into series of fine, closely set lines. Seven such series may be counted, beginning at the approximate wave-lengths 5006·4, 4995·6, 4985·4, 4973·6, 4961·6, 4948·6, 4934·4, respectively. When a condensed spark is taken between magnesium electrodes in oxygen mixed with a little air, the pair of strong nitrogen lines may be seen simultaneously with the bands, and lying within the first band, the bright edge of the band being somewhat less refrangible than the less refrangible of the two nitrogen lines.

When the bands are produced by the spark discharge between magnesium electrodes in oxygen or other gas, we have not been able to resolve them into lines, but the whole amount of light from the spark is small compared with that from the flame, and besides it is possible that the several lines forming the shading may be expanded in the spark, and thus obliterate the darker spaces between them.

*Triplet near M and adjacent Bands.*

Our former account of the spectrum of the flame of burning magnesium included a description of a triplet near the solar line M, and a series of bands extending from it beyond the well-known triplet near

L. As we had not observed these features in the spectrum of the spark or arc, and could not trace their connexion with any compound, we concluded that they were produced by magnesium only at the comparatively low temperature of the flame. We have since found that they are not produced by the metal at that temperature only, but are exhibited as strongly, or even more strongly, in the arc between electrodes of magnesium. In the latter case they appear concurrently with the line at 4481 and other lines which seem to belong to high temperatures. We must therefore regard them as not only produced at the temperature of flames, but as persistent at temperatures very much higher.

The different circumstances under which we have observed this triplet are as follows:—

In the oxyhydrogen flame when a very small piece of magnesia is held in it. In this case the outer two lines of the triplet are much stronger than the middle line (λ3724 about), which in some of our photographs does not show at all. It should be noticed that the least refrangible of the three lines (λ3730 about) is in general more diffuse and not quite so bright as the two more refrangible lines. Magnesia in the oxyhydrogen flame also gives rise to some bands close to and more refrangible than the triplet, and to another still more refrangible but less bright triplet, in which the lines are set at nearly equal distances from each other, with the approximate wave-lengths 3633·7, 3626·2, 3620·6. These additional bands and triplets are not really absent from the flame spectrum, for traces of them may be seen in some of our photographs of the magnesium flame, but they seem relatively brighter in the oxyhydrogen flame with magnesia, and the longer exposure of the photographic plate in the latter case helped to bring them out. They seem to come out more strongly under the conditions which make both the green bands of the oxide and the *b* group show well.

The triplet near M is also produced when magnesium oxychloride and when magnesium chloride is substituted for magnesia in the oxyhydrogen flame, and in the former case the more refrangible triplet is developed as well.

When carbonic oxide and oxygen are substituted for hydrogen and oxygen, both triplets are developed in the part of the flame near the magnesia, and in this flame the middle line of the triplet near M (λ3724 about) is as strong as it is in the flame of burning magnesium.

The proper adjustment of the thread of magnesia in this flame is a much more delicate matter than in the oxyhydrogen flame. In fact, we made many experiments which were failures before we succeeded in getting satisfactory results; and latterly, in order to be certain of success, we had to fill a gas-holder with a mixture of carbonic oxide

and half its volume of oxygen and burn the gases as they issued from the holder.

We have not noticed the more refrangible triplet (λ3633·7 to 3620·6 about) under other circumstances, but the triplet near M is produced when magnesia is held in the flame of cyanogen burning in oxygen, in the flash of pyroxylin with which magnesium filings have been mixed, or which has been treated with an alcoholic solution of magnesium chloride.

It is not only very strongly developed, but shows strongly reversed on our photographic plates, in the spectrum of the arc from a Siemens' dynamo taken between electrodes of magnesium in oxygen; and most of the accompanying ultra-violet bands of the magnesium flame spectrum are at the same time reversed. It is less strongly, but distinctly, reversed in the spectrum of the same arc taken in air, in carbonic acid gas, and in sulphurous acid gas. It appears also if the arc is taken in ordinary nitrogen unless great precautions are taken to exclude all traces of oxygen or carbonic acid, when it completely disappears. It is developed also in the flash produced when a piece of magnesium ribbon is dissipated in air by the discharge through it of the current from 50 cells of a storage battery. Also in the spark in air at atmospheric pressure between magnesium electrodes connected with the secondary wire of an induction coil when the alternating current of a De Meritens' magneto-electric machine is passed through the primary.

In two cases, but only two, we have found this triplet, or what looks like one or both of the more refrangible of its lines, developed in vacuous tubes. In both tubes the gas was air. One had platinum electrodes and a strip of magnesia from burnt magnesium disposed along the tube; the other had fragments of the Dhurmsala meteorite attached to the platinum electrodes. The discharge was that of an induction coil worked in the usual way without a Leyden jar. In each case it is only in one photograph of the spectrum that the lines in question appear. In other photographs taken with the same tubes they do not show.

On the other hand, this triplet does not make its appearance in the arc from a dynamo between magnesium electrodes in hydrogen, coal gas, cyanogen,* chlorine, hydrochloric acid, or ammonia; nor in the

* In taking the arc in this way in cyanogen our photographs show the whole of the five bands of cyanogen between K and L well reversed. We have before noticed ('Roy. Soc. Proc.,' vol. 33, p. 4) the reversal of the more refrangible three of these bands against the bright background of the expanded lines of magnesium when some of that metal was dropped into the arc between carbon electrodes, but in taking the arc between magnesium electrodes in an atmosphere of cyanogen the bright wings of the expanded magnesium lines near L extend beyond the cyanogen bands, and the whole series of the latter are well reversed.—May 23.

arc from a De Meritens' machine in hydrogen or nitrogen. It does not show in the spark between magnesium electrodes of an induction coil used in the ordinary way, either with or without a Leyden jar, in hydrogen or in air at atmospheric pressure; nor in the glow discharge in vacuous tubes with magnesium electrodes when the residual gas is either air, oxygen, hydrogen, carbonic acid gas, or cyanogen. Nor does it appear, except in the one instance above mentioned, in the glow discharge in highly rarefied air in a tube containing either magnesia or a strip of metallic magnesium.

A review of all the circumstances under which the triplet near M and its associated bands appear, and of those under which they fail to appear, leads pretty conclusively to the inference that they are due not to merely heated magnesium but to the oxide, or to vibrations set up by the process of oxidation.

With reference to this triplet, Mr. Lockyer (*loc. cit.*, p. 122) has referred to us as his authority for the statement that at the temperature of a Bunsen burner as ordinarily employed the ultra-violet line visible is that at 373. We do not agree to this as a statement of observed fact, and we cannot imagine how the passage to which Mr. Lockyer refers ('Roy. Soc. Proc.,' vol. 32, p. 202) can be supposed to warrant it. The flame we mention in that passage is not that of a Bunsen burner but that of burning magnesium, which may be very different from the former even when the magnesium is burning in the air which is mixed with coal gas in the Bunsen burner. Moreover, whatever the temperature of the flame may be, we have never observed the triplet at λ3730 unaccompanied by other ultra-violet lines. In the flame of burning magnesium, as we state (*loc. cit.*, p. 189), "photographs show, besides, the well-known triplet in the ultra-violet between the solar lines K and L sharply defined, and the line for which Cornu has found the wave-length 2850 very much expanded and strongly reversed."

We have expended a vast amount of time and trouble over vacuous tubes, and our later experiments do but confirm the opinion which we had previously formed that there is an uncertainty about them, their contents and condition, which makes us distrustful of conclusions which depend on them. Photographs of the ultra-violet spectra given by such tubes tell tales of impurities as unexpected as they are difficult to avoid. Every tube of hydrogen which we have examined exhibits the water spectrum more or less, even if metallic sodium has been heated in the tube or the gas dried by prolonged contact with phosphoric oxide. Indeed the only tubes which do not show the water spectrum have been filled with gases from anhydrous materials contained in a part of the tube itself; and even when tubes have been filled with carbonic acid gas from previously fused sodium carbonate and boracic anhydride the water spectrum is hardly ever

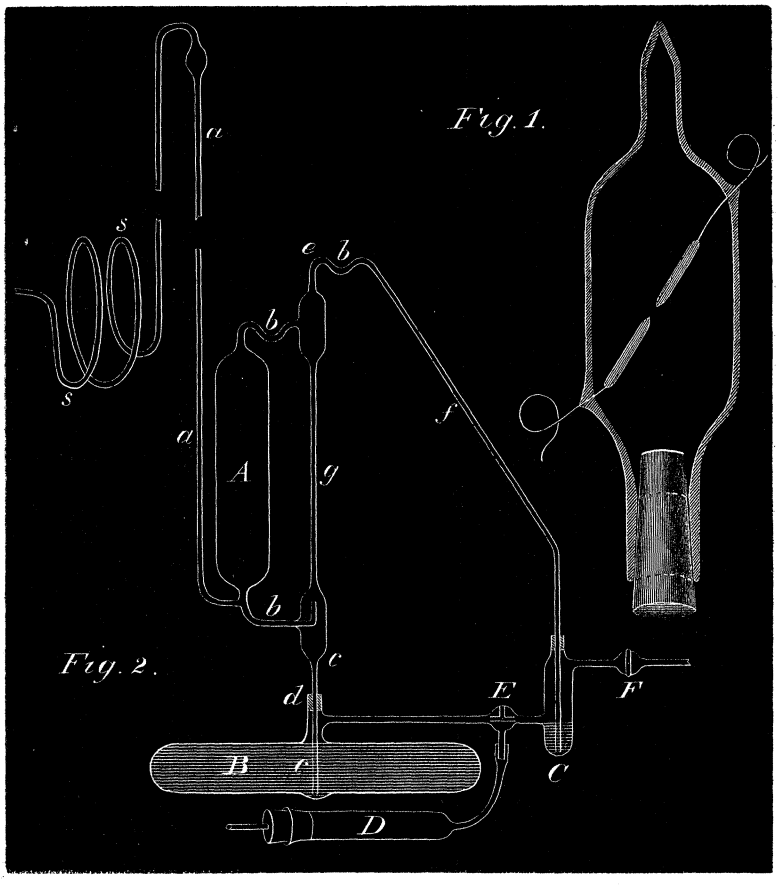
absent. The last traces of the ultra-violet bands of nitrogen are almost as difficult to be rid of with certainty. Frequently unknown lines or bands make their appearance, and the same tube will at different times exhibit wholly different spectra. This is especially the case with tubes of rarefied gases which oppose much resistance to the passage of the electric discharge such as oxygen.

It is no easy matter to prepare tubes for the observation of ultra-violet rays to which glass is opaque. Our plan is to fit a sort of stopper of quartz to an "end-on" tube (fig. 1). This stopper is a slightly conical piece of rock-crystal with the truncated ends of the cone ground plane and polished. It is first fitted to the tube by grinding and then cemented in with some vitreous substance more fusible than glass. Formerly we employed sodium metaphosphate which answered fairly, but latterly we have used fused silver nitrate which is easier to manipulate. In any case it is very difficult to prevent the tubes cracking under variation of temperature, but if the tube does not crack it is as effectually closed in this way as if it were all of one piece of glass. It is obvious that nitrogen, oxygen, and silver might be derived from silver nitrate used as cement and might add their spectra to those of the other contents of the tube. But the stopper does not lie in the direct course of the discharge, and we have not found that the silver nitrate is in general decomposed. The products of decomposition would at any rate give well-known spectra. The unknown and variable rays we are inclined rather to attribute to substances derived from the glass, either products of decomposition under the action of the electric discharge, or to matters adherent to the surface which become detached under some electric conditions, and adhere again when those conditions are changed. We have photographed the spectrum of one tube which had been filled with oxygen several times and exhausted, and which gave a well-marked spectrum containing a number of rays unknown to us. After a time other photographs of the same tube showed an entirely different spectrum, and after a further interval the spectrum was found to be again entirely changed, and finally after a further interval the original spectrum reappeared. Changes in the surface tension between the glass and some adherent film may in this case have facilitated the disengagement of the matter of the film and its after re-adherence. Whatever the cause, such changes of the spectra are none the less confusing and suggestive of caution in drawing our inferences from the phenomena of vacuous tubes.

The ultra-violet magnesium lines which we have observed in vacuous tubes with magnesium electrodes, when the induction coil, without jar, is employed, are the triplets at $\lambda$3837, and the lines $\lambda$2852, 2802, and 2795. These appear whether the residual gas be air, oxygen, hydrogen, or carbonic acid. When a jar is used we have

obtained also the triplets at P and S, the pair about λ2935 and 2927, all the quadruple group near λ2802 and the quadruple group beyond, and *in one case only*, in oxygen, the group near *s*, described below, and the flame-triplet near M. When no jar is used sometimes only λ2852 is to be seen, sometimes λ2852 and the strong pair near λ2802, and sometimes also the triplet near L. We infer, therefore, that this is the order of persistency of these lines under the circumstances.

We have before remarked upon the necessity of avoiding all rubber connexions in the construction of pumps employed in the exhaustion of tubes for spectroscopic observation, and we described a modification of the Sprengel pump which we had constructed for this end ('Roy. Soc. Proc.,' vol. 30, p. 499). The warnings of unexpected impurities given by photographs of the ultra-violet spectra of vacuous tubes have shown the necessity of preventing the contact of the mercury employed with the dust and moisture of the atmosphere. Hence we have used in the experiments described in this paper a mercurial pump constructed wholly of glass, and in which the same mercury is used over and over again without being exposed to any unfiltered air. For this pump we are indebted to the ingenuity and skill in glass-blowing of Mr. Lennox of the Royal Institution. The annexed figure (2) represents its construction. A is a reservoir which communicates by the tube *aa*, which ascends vertically some distance in order to prevent any mercury being driven into the exhausted tube, through the spiral tube *ss*, with the tube to be exhausted. B is the reservoir of mercury, to the bottom of which the tube *gcc* passes through the sealed joint *d*. The upper part of B can be put in communication through the three-way cock E, either with the vessel C or with the outer air through the tube D which is filled with calcium chloride. C forms a mercury valve, and at its upper part communicates through the stopcock F with an exhaust pump by which the pressure of the gas in C can be quickly reduced to a few millimetres of mercury. When this has been done, the three-way cock E is turned so as to cut off the communication between B and C and open that between B and D. The pressure of the air filtered through D forces the mercury in B up the tube *c* until it fills A and the whole apparatus, as high as the bend *e*, driving all gas before it through the tube *f* and through the mercury valve C, whence it is carried off by the exhaust. The tube *g* is very narrow so as to oppose resistance to the passage of the mercury whereby A is filled with mercury as quickly as *g*. As soon as the last bubble of gas has been driven out of *f*, the three-way cock E is turned so as to shut the communication with D and open that between B and C. As the pressure of the air on the surface of the mercury in B diminishes the mercury falls both in A and in *f*, leaving a Torricellian vacuum above it, and, as soon as it




has fallen below the end of the tube *a*, the gas in the tube to be exhausted expands into A. The same process is then gone through again and again, whereby the whole gaseous contents of A are each time removed, and if the volume of A be large compared with that of the tube to be exhausted, the pressure of the gas in the latter is very quickly reduced. The bends *bbb* retain a little mercury when A is exhausted, and prevent any diffusion from *c* into A, and from *f* into *c*. Each time the mercury fills the apparatus a small quantity flows over into C, but when it has risen above the opening of the tube connecting C and B, it passes back into B, when the cock E is turned so as to open the communication between C and B.

*Group near s.*

In their list of lines in the spectrum of magnesium ('Phil. Trans.,' 1884, p. 95) Messrs. Hartley and Adeney have given two lines, λ3071·6 and λ3046·0, which we had not heretofore observed either in the spectrum of the flame, arc, or spark of magnesium; but in our recent observations we have noticed in many cases a well-marked line which, by interpolation between neighbouring iron lines, appears to have a wave-length about 3073·5, and a pair of narrow bands sharply defined on their less refrangible sides at wave-lengths about 3050·6 and 3046·7, and fading away on their more refrangible sides.

We have little doubt that the lines we have observed are identical with those given by Messrs. Hartley and Adeney, notwithstanding that there is a much greater discrepancy between the wave-lengths assigned by them and by us than there is between the wave-lengths we have respectively found for the iron lines in the same neighbourhood.

We have noticed the occurrence of this group in the spectrum of the arc from a Siemens' dynamo between magnesium electrodes in a variety of gases, in all in fact in which we have examined the arc, except in sulphurous acid gas which is opaque to rays of this refrangibility. Also in the arc from a De Meritens' magneto-electric machine between magnesium electrodes in air, in the flash of a magnesium ribbon dissipated by the discharge of a storage battery, in the spark of an induction coil worked in the usual way in air and in hydrogen at atmospheric pressure, and in one instance in the spectrum of an oxygen vacuous tube with magnesium electrodes when a Leyden jar was connected with the secondary wire of the induction coil.

On the other hand, we do not see this group in the spectrum of other vacuous tubes with magnesium electrodes or with magnesia in the tube, nor in the spark from an induction coil in air or hydrogen at atmospheric pressure when the coil is worked with a De Meritens' machine on the primary wire, nor in the flame of burning magnesium, nor in the oxyhydrogen flame with magnesia or magnesium chloride, nor in the arc between carbon electrodes in a crucible of magnesia.

The circumstances under which this group is seen and is not seen, do not seem to indicate that its emission is connected with any particular temperatures so much as with the character of the electric discharge, and perhaps also with the density of the magnesium vapour.

*Fig. 1.*

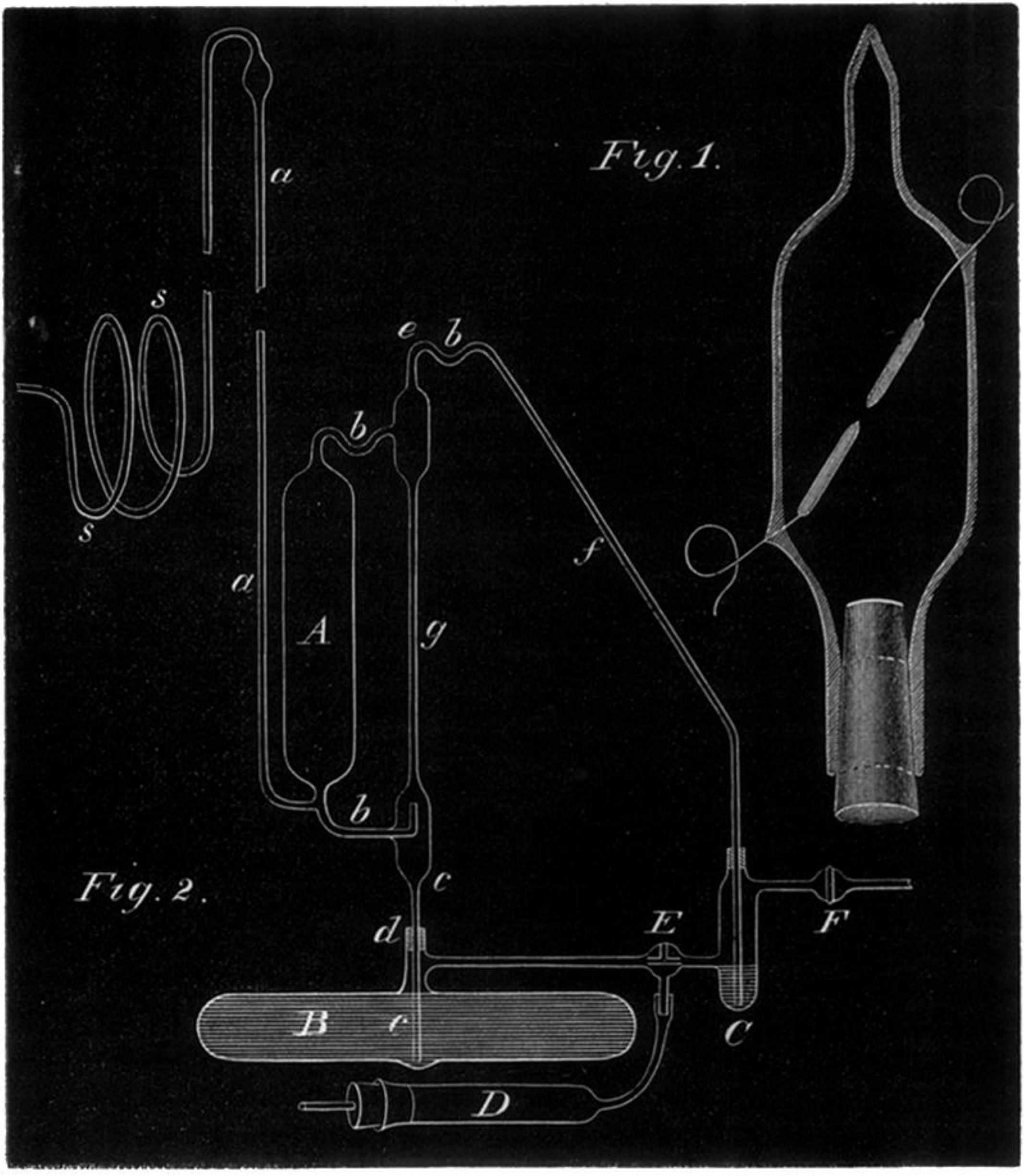



*Fig. 2.*