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XXV.—*Decomposition of Gaseous Compounds by Electrical Incandescence.*

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THE experiments described in the following pages were undertaken in the hope, that the slow decomposition of compound gases by the long-continued passage of electric sparks, might be effected by the spark-current of the induction-coil with such rapidity and precision, as to furnish a simple experimental illustration of relations with difficulty attainable by other methods. The relation of the spaces occupied, respectively, by a compound gas and by the sum of its gaseous constituents is but rarely capable of *synthetical* demonstration. In most cases this relation can only be exhibited by *analytical* operations which are not always compatible with the conditions of a lecture experiment. The successful application of the spark-current appeared to promise a considerable simplification of these processes. With this view we have studied the action of the current, produced by a powerful Ruhmkorff coil, on the more frequently occurring compound gases and on the vapours of several liquids of low boiling point.

At the same time we examined the deportment of these gases and vapours, under the influence of iron or platinum coils electric-

ally incandescent, together with the effects produced by the high temperature of the electric arc.

The mode of performing the experiments may be briefly stated.

For the convenient introduction of the spark-current into the gas confined over mercury, a fine platinum wire was fused into the shorter limb of a thin U-shaped glass tube, and filed off so as scarcely to project beyond the glass. At a distance of a few millimetres from the platinum pole thus obtained, the loop of a second platinum wire was thrown over the tube, and the wire wound round the tube, until it nearly reached the bend, as seen

FIG. 1.

in fig. 1. The tube was then filled with mercury, and the shorter limb introduced into the graduated gas-tube, inverted over mercury, in a deep cylinder-trough. The pole-wires of the induction coil being now introduced, the one into the open end of the U-tube filled with mercury, the other into the mercury of the cylinder-trough, the spark-current could be established or interrupted at will, by either depressing the U-tube, until the outer platinum wire reached the mercury surface, or by lifting it, so as to break contact.

It need scarcely be mentioned that, in most cases, an ordinary eudiometer or a syphon-eudiometer may be used, with the same effect. They are not, however, to be recommended for the decomposition of those gases which yield a deposit of carbon, inasmuch as the separation of this element in the form of a filament, between the platinum points, is apt to interrupt the experiment. In such cases, the U-tube may be readily removed, cleaned, and replaced. The syphon-eudiometer has been provided, by Professor Bunsen, with a simple but ingenious little contrivance, which renders it particularly adapted for lecture experiments. It consists of a small glass tube, communicating with the eudiometer near the bend, the outer end of which is closed by an India-rubber tube, provided with a glass valve. By a gentle lateral compression, the metal runs out through the opening between the glass and caoutchouc, until the mercury assumes a level position in both limbs of the instrument, when the true change of volume becomes at once apparent.

The decompositions by incandescent coils of iron and platinum, or by the electric arc, were accomplished by an arrangement

similar to that previously mentioned. For experiments of this description both limbs of the U-tube remain open; the iron or platinum wire is inserted into the shorter limb, and then coiled downwards round the tube. Since the powerful heat emitted from the coil is apt to crack the U-tube, we have found it convenient to surround the latter with a somewhat wider glass tube which separates it from the incandescent coil. (See fig. 2.) The U-tube, as in the previous case, is filled with mercury, and the pole wires of the battery are adjusted in a similar manner. By depressing the U-tube, until the lower end of the coil dips into the mercury, the coil may be readily heated; by raising this end to a proper height above the level of the mercury in the tube, the arc may be conveniently adjusted.

Our experiments were made partly in Giessen, with the Ruhmkorff coil in the University collection; partly in London, with a splendid instrument which Dr. Bence Jones had liberally placed at our disposal.

Fig. 2.

AMMONIA.

Of all the compound gases, ammonia appeared to promise the simplest and most striking result. During the decomposition of this body into nitrogen and hydrogen, the original volume of the gas is, as is well known, doubled. Priestley* had observed that the passage of electric sparks through ammonia expands its volume, giving rise, at the same time, to the separation of an inflammable gas; and the further development of this observation became, in the hands of the elder Berthollet, the key to the composition of ammonia. The spark exerts simply a thermal effect in this decomposition, as is obvious from the fact, likewise observed by Priestley, that the decomposition takes place also when the gas is passed through a red-hot narrow glass tube. More recently some experiments upon the action of electrically incandescent platinum wires upon ammonia were published by Grove,† in an interesting paper to which we shall have frequently to refer.

* Kopp, *Geschichte der Chemie*, Bd. III, 246.

† *Phil. Mag.*, Dec., 1845.

Grove found that a complete decomposition of ammonia may be accomplished by this process.

Our experiments have furnished the following results.

Even in favourable weather, several hours are required in order to decompose 4 c.c. of ammonia by means of the spark-current produced by a powerful frictional electric machine.

The decomposition by electrically incandescent platinum wire is likewise rather slow. 4 c.c. of ammonia, in which a platinum wire of 60^{mm} length and 0.2^{mm} diameter was heated to whiteness by means of 6 Bunsen elements, were by no means completely decomposed even after the lapse of an hour. On the other hand, by employing 20 elements and a platinum wire of 0.4^{mm} diameter, the length of which was regulated by lifting or depressing it in the mercury until the most powerful white heat had been attained, we succeeded in perfectly decomposing 6.25 c.c. of ammonia in from 20 to 25 minutes.

A very remarkable effect is obtained by means of the electric arc produced by 20 elements. By heating the platinum wire opposite the mercury to incipient fusion, 23 c.c. of ammonia were so entirely decomposed in 5 minutes, that water injected into the tube no longer exhibited an alkaline reaction. Rapidly as the decomposition is accomplished in this manner, this mode of experimenting nevertheless is scarcely to be recommended, inasmuch as the mercury, heated to ebullition, coats the tubes with an opaque metallic mirror, not to speak of the risk of breaking the glass tubes by the intensity of the heat.

The decomposition of ammonia may be most rapidly and elegantly accomplished by the spark-current of the induction-coil. From 3 to 4 Bunsen elements are quite sufficient. The spark-current, traversing the ammonia, exhibits a violet light surrounded with a blue edge. At first the mercury falls rapidly, the rate of expansion of course diminishing with the progress of the decomposition; but in 5 minutes the decomposition of a moderate volume of ammonia is accomplished. The original volume is then doubled, and the spark-current exhibits the pure violet light characteristic of hydrogen. 5.5 c.c. of ammonia furnished in 4 minutes 11 c.c. gas; 11.3 c.c. of ammonia 22.7 c.c. of gas. Water, injected into the tube, no longer produced a diminution of volume, although it sometimes still exhibited a faint alkaline reaction. This also entirely disappeared when the spark-current was continued a few minutes longer.

It appeared of some interest to make a few comparative experiments with some of the basic derivatives of ammonia.

METHYLAMINE CH_5N .*

On passing the spark-current through methylamine gas, the tube becomes filled with white fumes which, when the current is interrupted, are condensed into a network of long white needles. Water, injected into the gas, exhibits the hydrogen already eliminated, and the solution contains cyanide of methyl-ammonium. This result is of some interest, as it shows that, in the first stage, the action of the current induces the formation of simpler compounds. On renewing the current, the white crystals entirely disappear, and are replaced by a black resinous substance which is deposited in considerable quantity within the tube: at the same time the volume of the gas is considerably expanded. The decomposition is, however, by no means complete, and we found it impossible to obtain the theoretical volume, even after a long-protracted passage of the current. 5.1 c.c. methylamine gas gave, after 20 minutes, 13.5 c.c., and, after 10 minutes more, 13.7 c.c. of gas: the continued passage of the current produced no further change. Assuming the decomposition of the methylamine to be perfect, the original volume should have trebled (1 vol. of methylamine-gas affording $\frac{1}{2}$ vol. of nitrogen and $2\frac{1}{2}$ vol. of hydrogen), and the above experiment should have therefore furnished $3 \times 5.1 = 15.3$ c.c. of gas.

TRIMETHYLAMINE $\text{C}_3\text{H}_9\text{N}$.

The decomposition by the spark-current proceeds but slowly, a considerable quantity of a tarry substance separating, and the experiment being frequently interrupted by the formation of a carbon bridge between the platinum points. 3.7 c.c. of trimethylamine-gas furnished, after 50 minutes, a maximum volume of 14.4 c.c. of gas. Perfect decomposition into the elements should have yielded 5 times the original volume ($\frac{1}{2}$ vol. of nitrogen and $4\frac{1}{2}$ vols. of hydrogen), *i.e.* $5 \times 3.7 = 18.5$ c.c. of gas.

* C = 12.

ETHYLAMINE C_2H_7N .

The decomposition which, on account of the fluid condition of this body, was accomplished at a temperature of $36^{\circ}C$., exhibited phenomena perfectly similar to those observed in the previous cases. After 30 minutes, the gas had reached a maximum expansion; 5.2 c.c. ethylamine gas gave 15.1 c.c. of gas which was no longer alkaline, and possessed the odour of cyanide of ethyl in a marked manner; at the same time, a considerable quantity of tarry matter was separated. Theoretically, the original volume should have quadrupled ($\frac{1}{2}$ vol. of nitrogen and $3\frac{1}{2}$ vol. of hydrogen), and the above experiment should have yielded $4 \times 5.2 = 20.8$ c.c. of gas.

CYANOGEN.

According to the observations of Sir Humphry Davy, the continued passage of the electric spark decomposes this gas into carbon, and nitrogen gas of a volume equal to that of the cyanogen employed. The action of heat upon cyanogen has been studied by Gay-Lussac, who states that this gas may be passed through red-hot porcelain tubes, containing gold or platinum, without undergoing any decomposition.

We found that cyanogen may be perfectly decomposed by electrically incandescent iron wires. We employed in the experiment a battery of 20 elements of Bunsen; the same power was used in all other similar experiments in which the number of elements is not especially mentioned. 50 c.c. of cyanogen gas left, after half-an-hour, the same volume of nitrogen, which was no longer affected by potassa. But, in order to produce this effect, it was necessary to introduce not less than six consecutive wires, the first two or three, being transformed into cast-iron and fusing almost immediately.

The decomposition is more rapidly effected by the electric arc, the carbon separating in thick flakes; from 30 to 40 c.c. of gas being used, not a trace of cyanogen was left after 10 or 15 minutes. In some of these experiments we observed an appreciable increase of volume. Thus, in decomposing 36 c.c. of cyanogen we obtained 40 c.c. of gas. In other experiments even a larger expansion was observed. We soon found that this effect was due to the presence of moisture in the gas, the rate of increase

diminishing in proportion as more and more attention was paid to the perfect desiccation of the gas itself and of the mercury; but since the latter is generally heated nearly to ebullition, it is difficult to prevent the rising of a last trace of moisture. When the cyanogen gas was purposely moistened with a drop of water, 39.2 c.c. expanded to 56 c.c. in twenty minutes. Potassa being now injected, it was seen that a considerable quantity of cyanogen had remained undecomposed. The gas left after treatment with potassa, was inflammable, and burned with a blue-edged flame, thus indicating the presence of carbonic oxide. It is obvious that the water, acting upon the cyanogen, gives rise to the formation of carbonic oxide, carbonic acid, and ammonia, the latter then splitting into nitrogen and hydrogen.

The spark-current of the induction coil is very little adapted to the decomposition of cyanogen; the current traverses this gas with a white red-edged light, but is soon interrupted by the separation of carbon filaments between the platinum points. 31 c.c. of cyanogen gas were reduced to 29 c.c. after the current had passed for $1\frac{1}{4}$ hours. Injection of potassa showed that 21 c.c. of cyanogen had remained undecomposed. The slight diminution of volume was probably due to the absorption of cyanogen by the abundantly separated carbon.

NITROUS OXIDE.

The alterations which this gas undergoes when submitted to the action of electricity and of heated metals, have been studied by Gay-Lussac and Thénard, and also by Sir H. Davy. In both cases, free oxygen together with higher oxides of nitrogen was observed.

We found that an incandescent iron coil readily decomposes the nitrous oxide with formation of sesquioxide of iron, a volume of nitrogen equal to that of the gas employed being left behind. From 3 to 4 minutes are sufficient for the decomposition of 30 or 40 c.c. of nitrous oxide.

A similar effect is produced by the electric arc issuing from an iron point.

The incandescent platinum coil does not produce an immediate change, but soon red vapours begin to appear, and the volume of the gas is considerably expanded. After 5 or 6 minutes, a maximum effect is reached, and now the volume diminishes again,

and the red vapours disappear. In the first stage of the reaction, the nitrous oxide seems to split into oxygen and nitrogen; the two gases afterwards partially unite to form hyponitric acid and are fixed by the mercury. The theoretical volume of $1\frac{1}{2}$ volume (1 vol. of nitrogen and $\frac{1}{2}$ vol. of oxygen) is therefore never reached; a result which also follows from Grove's* observations. In an experiment of this kind, 44.8 c.c. nitrous oxide furnished, after 6 minutes, a maximum volume of 59.4 c.c. of gas; assuming the decomposition to be perfect, $1\frac{1}{2} \times 44.8 = 67.2$ c.c. gas should have been obtained.

The spark-current slowly decomposes nitrous oxide into nitrogen and oxygen, which, when the current is continued, partially unite to form red vapours. 9 c.c., after two hours and a half, gave 13 c.c. of gas, which exhibited a slightly reddish tint. In case of perfect decomposition, $1\frac{1}{2} \times 9 = 13\frac{1}{2}$ c.c. should have been obtained. On passing the current for an additional one hour and a half, the volume was reduced to 8 c.c.; hyponitric acid having been formed and fixed by the mercury.

NITRIC OXIDE.

The effects of electricity and of heat upon this gas have been examined, respectively, by Priestley and by Gay-Lussac. In both cases nitrogen is separated, higher oxides of the latter element being formed at the same time. Both Sir H. Davy and Gay-Lussac decomposed nitric oxide by red-hot metals, which were oxidized, a volume of nitrogen equal to half the original volume of gas being left behind.

In our experiments, the decomposition of the nitric oxide succeeded particularly well by the incandescent iron coil. The metal burns with splendid scintillations, continuing for 3 or 4 minutes, according to the volume of the gas; as soon as the scintillation ceases, the experiment is finished. In the first stage of the reaction red vapours are perceptible, which, however, rapidly disappear; as long as they are visible the iron burns with a greenish light. When the experiment is finished, a volume of nitrogen is left behind, equal to half the original volume. The decomposition is so complete that the residuary gas becomes neither red on admission of oxygen, nor black on injection of sulphate of iron.

* Loc. cit. p. 272.

46.9 c.c. nitric oxide, submitted for 5 minutes to the action of the red-hot iron coil, left 23.2 c.c. of pure nitrogen. Such accurate results, however, are obtained only when perfectly pure nitric oxide is employed; in most experiments the residuary gas amounts to more than half the original volume, the ordinary mode of preparing the gas—copper turnings and nitric acid—yielding almost invariably an admixture of nitrogen gas.

Nitric oxide is but slowly decomposed by the spark-current of the induction coil. In the commencement of the experiment, red vapours are generated, which gradually disappear, the mercury becoming considerably tarnished. $12\frac{1}{4}$ c.c. of nitric oxide, submitted to the current for $1\frac{1}{2}$ hour, were reduced to $6\frac{1}{4}$ c.c., which the further passage of the current brought down to 6 c.c. of nitrogen, the oxygen, together with a small quantity of nitrogen, being absorbed by the mercury.

Incidentally we have made a few observations on the passage of the spark-current through atmospheric air. The facility with which the celebrated Cavendish* experiment may be performed by this means has been already pointed out, by Bequerel† and by Böttger.‡ After a few minutes, the passage of the spark-current generates distinctly visible red vapours in a flask filled with dry atmospheric air; moist blue litmus paper becomes red in a few seconds. The presence of water considerably facilitates the combination of nitrogen and oxygen. 12.5 c.c. of *moist* air, when submitted to the current for 2 hours, were reduced to a minimum volume of 9.25 c.c. of gas, which, though not entirely freed from oxygen, no longer supported combustion. To reduce 12.55 c.c. of *dry* air to 9.25 c.c. it was necessary to pass the current for not less than 8 hours.

CARBONIC OXIDE.

The gas, when perfectly dry, resists the action of incandescent platinum and iron, even when the heat is so powerfully urged as to fuse the latter into large globules.

* Phil. Trans., 1784.

† Th. du Moncel's description of Ruhmkorff's coil.

‡ Kopp and Will's Jahresbe-richt, 1853, p. 102.

The electric arc, when issuing from iron, is likewise without effect. Carbonic oxide, confined over water, when submitted to an incandescent platinum coil, is transformed into carbonic acid, as was already observed by Grove,* the converted carbonic oxide being replaced by an equal volume of hydrogen, so that the injection of potassa restores the original volume. The spark-current passes through dry carbonic oxide with a blue light; it is without effect.

CARBONIC ACID.

It is well known that, in the presence of red-hot iron, carbonic acid is reduced to carbonic oxide. This reduction, however, is extremely slow and difficult. In order to transform 30 c.c. of carbonic acid into carbonic oxide, the action of the most powerful electric arc is required for three-quarters of an hour. The volume of the residuary carbonic oxide is equal to that of the carbonic acid employed; injection of potassa no longer affects the volume of the gas. In several experiments, in which the action was not continued longer than a quarter of an hour, not more than about one-half of the carbonic acid was found to be converted into carbonic oxide, the original volume remaining likewise unchanged. In some cases, however, a very appreciable increase of volume was observed, the cause of which was soon found to be the accidental use of *steel springs*, the carbon of steel affording an additional supply of carbonic oxide. With soft iron this increase of volume never occurred.

The imperfect decomposition of carbonic acid by the spark into carbonic oxide and oxygen, was observed many years ago, by Henry and by Dalton. It may be readily exhibited by the spark-current of the induction-coil. The spark traverses the gas with a violet light. In the commencement of the experiment the expansion is very appreciable; $7\frac{1}{2}$ c.c. of carbonic acid, after a few minutes, became $8\frac{3}{4}$ c.c.; but the further decomposition proceeded with extreme slowness, until, after the lapse of half an hour, the accumulated carbonic oxide exploded with the liberated oxygen, when the original volume of the carbonic acid was restored, again to undergo a similar set of changes. Unfortunately the decomposition of carbonic acid by the spark-current is not suffi-

* Loc. cit. p. 272.

ciently rapid to admit of being exhibited as an instructive lecture-experiment.

BISULPHIDE OF CARBON.

From 30 to 40 c.c. of bisulphide of carbon vapour, at a temperature exceeding 60° or 70° , were perfectly decomposed in a few minutes, by an incandescent coil of iron, the iron being converted into sulphide and the carbon liberated. The platinum coil likewise produced the decomposition, but much more slowly. In the latter case, the carbon floating on the surface of the mercury, contained a considerable proportion of free sulphur.

The sulphide of carbon corresponding to carbonic oxide, the formation of which, from the deportment of carbonic acid under similar circumstances, might have been expected, was not produced in our experiments. When the tubes had become cold, no gaseous product remained.

MARSH GAS.

According to Dalton, the passage of electric sparks transforms marsh gas into the double volume of pure hydrogen, the carbon being separated; and, from Sir H. Davy's experiments, it appears that electrically incandescent platinum wire produces the same effect. By passing the spark for 30 hours, however, through a small volume, Bischoff succeeded in decomposing only about $\frac{1}{3}$ of the gas, empyreumatic products being invariably produced at the same time. The decomposition was not more perfect when the gas was passed through red-hot porcelain tubes, and very recently Magnus* has shown that the most intense white heat is required to split marsh-gas into its elementary constituents.

The marsh-gas used in our experiments had been prepared by carefully heating acetate of sodium with lime and hydrate of potassa. In none of our experiments did we succeed in perfectly decomposing this gas. The incandescent iron coil acts but slowly. In half an hour 16 c.c. were expanded to 26 c.c.; the iron wire remained bright, but, by absorption of carbon, it had become very brittle. The experiment afforded a good opportunity for observing how difficult it is to maintain the incandescence of the wire, when the hydrogen begins to preponderate in the tube.

* Pogg Ann XC, 1

A somewhat better effect is obtained by allowing the electric arc, issuing from iron, to pass through the gas. 29 c.c. of marsh gas thus became 53 c.c. in a quarter of an hour.

The most perfect result is furnished by the spark-current of the induction coil. The spark traverses the gas with a pale blue light, rapidly changing to violet. 10 c.c. of gas, in half an hour, became 18.3 c.c., which did not increase on the further passage of the current. No carbon was separated on the sides of the tube, but between the platinum points, a thin carbon filament was deposited, which had to be removed once during the experiment. The residuary hydrogen had a peculiar odour and burned with a slightly luminous flame.

OLEFIANT GAS.

According to the experiments of Dalton and W. Henry, the continued passage of electric sparks transforms olefiant gas into a double volume of hydrogen, the carbon being separated. Marchand observed that, at a red heat, olefiant gas is decomposed into carbon and marsh gas, and that, at a white heat, carbon and nearly pure hydrogen are obtained. More recent experiments of Magnus* have proved that, on passing olefiant gas through a red-hot tube, about 90 per cent. of the gas are obtained in the form of marsh gas, containing a little undecomposed olefiant gas and a small portion of hydrogen; the rest of the gas, together with the excess of the carbon, is converted into a tarry substance, consisting chiefly of liquid and even of solid hydro-carbons. At a white heat, according to Magnus, olefiant gas furnishes the double volume of almost pure hydrogen gas.

Quite recently the decomposition of olefiant gas by the spark-current of the Ruhmkorff coil has been effected by Quet.†

On heating, by the battery, a platinum coil in olefiant gas, we observed at once a considerable separation of carbon, which was deposited on the sides of the glass tube. The volume of the gas being scarcely changed, it was obvious that the principal effect consisted in the transformation of olefiant gas into marsh gas. With the electric arc, the decomposition went further. Together with a separation of carbon, an expansion, chiefly in the commencement of the experiment, was observed, which, in the course

* Pogg. Ann. XC, 1.

† Compt. Rend. XLVI, 1213

of 10 minutes, had reached a maximum; the decomposition, however, was not complete: 23 c.c. furnished 40 c.c. gas, which did not expand any further.

Perfectly similar results were obtained by the spark-current. The spark traverses the gas with a pale reddish light, gradually changing to violet. A considerable amount of carbon separates in filaments, and the current is soon interrupted by a bridge of carbon being thrown from point to point. The volume of the gas, in the commencement of the experiment, rapidly expands, but gradually the rate of expansion becomes very slow; after 20 or 25 minutes a maximum is reached. 7 c.c. of dry olefiant gas furnished, in 25 minutes, 12.25 c.c. of gas. By perfect decomposition, the double volume should have been obtained. The residuary hydrogen had a peculiar disagreeable odour, and burned with a slightly coloured flame. These experiments show that the spark-current decomposes the gas at once into carbon and hydrogen. Marsh gas being so much more stable than olefiant gas, we should not have been surprised to observe, in the first stage of the experiment, the elimination of marsh gas. In this case, however, a considerable quantity of carbon should have been deposited before the volume of the gas commenced to increase. This effect was not observed.

SULPHUROUS ACID.

Sulphurous acid gas is decomposed by the incandescent iron coil with the greatest facility. The reaction would be too powerful, unless the number of elements were reduced to 10; even then, the iron burns with a dazzling bluish-white light and splendid scintillation, a mixture of sulphide and sesquioxide of iron being produced. 48 c.c. of sulphurous acid gas were reduced in an instant to 10 c.c. The experiment had to be interrupted, in order to preserve the tube; the residue was pure sulphurous acid.

The spark-current traverses dry sulphurous acid gas with a bluish light. The action is very slow: 11 c.c. of gas, after one hour and a half, had become 10 c.c.; after 8 hours, the volume was reduced to 4 c.c. During this time, a yellowish-brown substance had been deposited on the sides of the glass tube in the proximity of the poles, collecting in little drops as long as the glass was gently warmed by the passage of the current, and solidifying in the cold to an amorphous mass of a somewhat lighter colour. The residuary gas consisted of pure sulphurous acid; the brown

substance was found to be a compound of anhydrous sulphuric acid and sulphur. On addition of water, sulphur was separated in flakes, and the solution contained free sulphuric acid. Sulphate of mercury could not be traced.

The change had obviously been—

the reaction being the converse of that which is observed when sulphur is allowed to act for some time upon anhydrous sulphuric acid in sealed tubes, at the common temperature. The brown substance resembled the similarly coloured but imperfectly examined product which Vogel obtained many years ago, by the action of anhydrous sulphuric acid upon sulphur. When the spark-current is passed through a dry mixture of sulphurous acid and oxygen, the volume of the gas is slowly diminished, and the sides of the tube become coated with a crystalline deposit of anhydrous sulphuric acid.

SULPHURETTED HYDROGEN.

According to the experiments of Sir H. Davy, this gas is decomposed into its constituents by electrically incandescent platinum wire; more slowly by the electric spark.

When the iron coil was heated in dry sulphuretted hydrogen, we found that a quarter of an hour was by no means sufficient to decompose from 30 to 40 c.c. of the gas. The original volume had not changed, but the gas still contained appreciable quantities of sulphuretted hydrogen.

The decomposition was more readily effected by the electric arc passing over from iron. This metal burned with evolution of a white light, being converted into the sulphide; the unchanged volume of the residuary gas consisted of pure hydrogen. In a quarter of an hour, the decomposition of 30 or 40 c.c. was complete.

Far less satisfactory results were obtained by the incandescent platinum coil. After it had been glowing for a quarter of an hour in 40 c.c. of sulphuretted hydrogen, not less than 32 c.c. of the gas remained undecomposed.

The spark-current decomposed the sulphuretted hydrogen perfectly and with facility. The tube became instantaneously coated

with a film of sulphur, and, after a quarter of an hour, not a trace of sulphuretted hydrogen was left. The volume of the gas was not changed. The spark traversed the gas with a pale blue light, gradually turning violet. The change of colour in a measure indicated the completion of the experiment.

PHOSPHORETTED HYDROGEN.

According to theory, 1 vol. of this gas when decomposed should yield, together with phosphorus, $1\frac{1}{2}$ volumes of hydrogen gas. By the passage of the electric spark, Dalton obtained $1\frac{1}{2}$ volume of hydrogen; but the experiments of Gay-Lussac and Thénard, of Dumas, and of Buff have proved that the action of incandescent metals (antimony, copper, zinc, iron, potassium) both upon the spontaneously inflammable and upon the other variety, gives rise to the evolution of $1\frac{1}{2}$ volume.

Phosphoretted hydrogen is most readily and completely decomposed by an incandescent coil of iron or platinum, and likewise by the spark-current of the induction coil. Unfortunately the ratio which the volume of the gas bears to the hydrogen evolved can only be exhibited with difficulty, since all the methods of preparing phosphoretted hydrogen furnish it mixed with free hydrogen; even the gas obtained from phosphide of calcium or from crystallized phosphorous acid, is far from being pure. Accordingly, phosphoretted hydrogen when decomposed invariably expands, but the theoretical volume is scarcely ever reached. In order to obtain definite results, it is necessary to determine the amount of free hydrogen, before effecting the decomposition of the phosphoretted hydrogen. This may be done by shaking the gas over mercury with sulphate of copper, or, better, with chloride of lime; the residue consists of pure hydrogen.

The complete decomposition of 30 or 40 c.c. of phosphoretted hydrogen, either by the incandescent iron coil or by the electric arc passing over from iron, is effected in about 5 minutes. The greater portion of the phosphorus is deposited, in the form of a brown powder on the sides of the tube; the residuary gas is no longer affected by sulphate of copper, and burns without evolution of phosphoric acid vapours.

Similar phenomena are observed when the decomposition is effected by the incandescent platinum coil. In this experiment,

however, not a trace of phosphorus is separated, a silver-white, easily fusible, and very brittle compound of platinum and phosphorus being formed. In consequence of this formation, the platinum wire, unless it has been taken of very considerable thickness, readily fuses, and the experiment has then to be completed by the electric arc.

The decomposition of 4 or 5 c.c. of phosphoretted hydrogen is effected by the spark-current in about a quarter of an hour. The spark traverses the gas with a reddish light which gradually becomes violet. The volume rapidly increases, and the phosphorus separates in the amorphous condition. For an experiment of this kind, the phosphoretted hydrogen was generated from pure crystallized phosphorous acid. 39.5 c.c. of this gas, when treated with a solution of chloride of lime, left 2.5 c.c. of hydrogen. Accordingly, the crude gas contained 93.7 vol. per cent. of pure phosphoretted hydrogen. 5.4 c.c. of the impure gas, containing 5.06 c.c. of pure gas, furnished, after 15 minutes, 7.9 c.c. of hydrogen, which was not further expanded by the continuation of the spark-current. According to theory, $(1.5 \times 5.06) + 0.34 = 7.95$ c.c. should have been obtained.

HYDROCHLORIC ACID.

The incandescent iron coil or the electric arc, issuing from iron, decomposes this gas pretty quickly; the tube becomes filled with white fumes of protochloride of iron, and, after 5 minutes, the original volume is reduced to nearly one-half; but it is difficult, even by long-continued action, to decompose the last traces of hydrochloric acid; and the residuary volume, although apparently one-half of the original volume, invariably undergoes a slight contraction upon injection of water.

The decomposition is sufficiently complete for a lecture experiment, but it can scarcely be recommended for this purpose, since the composition of hydrochloric acid may be exhibited much more rapidly and conveniently, by allowing a sodium pellet to rise through the mercury, and by shaking the gas with the amalgam formed upon the surface.

The spark-current of the induction-coil may be passed through hydrochloric acid gas for a long time, without producing any apparent effect. Ultimately, a slight diminution of the volume is

observed, the surface of the mercury in the tube becoming coated with a thin film of the protochloride.

FLUORIDE OF SILICIUM.

The incandescent coil of iron or platinum, as well as the electric arc, is without any perceptible effect upon this gas. The spark-current traverses the gas with a pale blue light. No change of volume was observed after the lapse of an hour.