

**On hydrofluoric acid : on a momentary molecular change in iron wire : and on the development of electric currents by magnetism and heat / by G. Gore.**

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ON

HYDROFLUORIC ACID;

ON

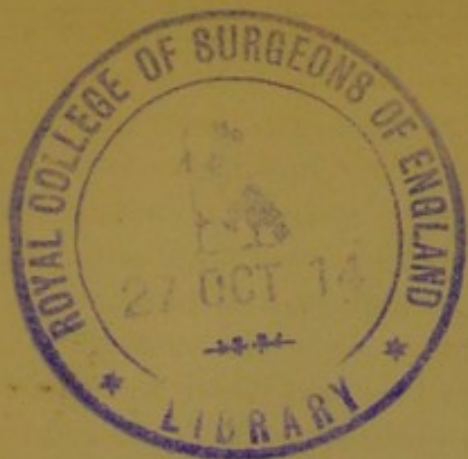
A MOMENTARY MOLECULAR CHANGE IN  
IRON WIRE;

AND ON

THE DEVELOPMENT OF ELECTRIC CURRENTS  
BY MAGNETISM AND HEAT.

BY

G. GORE, F.R.S.



On Hydrofluoric Acid. By G. GORE, F.R.S.

(Abstract.)

*A. Anhydrous Hydrofluoric Acid.*

This paper contains a full description of the leading physical and chemical properties of anhydrous hydrofluoric acid, and also an account of various properties of pure aqueous hydrofluoric acid. The author obtained the anhydrous acid by heating dry double fluoride of hydrogen and potassium to redness in a suitable platinum apparatus (shown by a figure accompanying the paper), and states the conditions under which it may be obtained in a state of purity.

The composition and purity of the anhydrous acid are shown and carefully verified by various methods of analysis, both of the double fluoride from which it was prepared and of the acid itself; and particulars are given of all the circumstances necessary to insure reliable and accurate results. Nearly all the operations of preparing, purifying, analyzing, and examining the properties of the acid were conducted in vessels of platinum, with linings of paraffin, sulphur, and lampblack; articles of transparent and colourless fluor-spar were also employed in certain cases. Nearly all the manipulations with the acid were effected while the vessels containing it were immersed in a strong freezing-mixture of ice and crystallized chloride of calcium.

The pure anhydrous acid is a highly dangerous substance, and requires the most extreme degree of care in its manipulation. It is a perfectly colourless and transparent liquid at 60° Fahr., very thin and mobile, extremely volatile, and densely fuming in the air at ordinary temperatures, and absorbs water very greedily from the atmosphere. It was perfectly retained in platinum bottles, the bottle having a flanged mouth with a platinum plate secured with clamp-screws, and a washer of paraffin.

A number of attempts were made, finally with success, to determine the molecular volume of the pure anhydrous acid in the gaseous state, the acid in these cases being prepared by heating pure anhydrous fluoride of silver with hydrogen in a suitable platinum apparatus over mercury. Particulars are given of the apparatus employed and of the manipulation. The results obtained show that one volume of hydrogen, in uniting with fluorine, produces not simply one volume of gaseous product as it does when uniting with oxygen, but two volumes, as in the case of its union with chlorine. The gaseous acid transferred to glass vessels over mercury did not corrode the glass, or render it dim in the slightest degree during several weeks, provided that moisture was entirely absent.

The author concludes that the anhydrous acid he has obtained is destitute of oxygen, not only from the various analyses and experiments already referred to, but also, 1st, because the double fluoride from which it was prepared, when fused and electrolyzed with platinum electrodes, evolved abundance of inflammable gas at the cathode, but no gas at the anode, although oxides are by electrolysis decomposed before fluorides; 2nd, because the electrolysis of the acid with platinum electrodes yielded no odour of ozone, whereas the aqueous acid of various degrees of strength evolved that odour strongly; and, 3rd, because the properties of the acid obtained from hydrogen and fluoride of silver agree with those of the acid obtained from the double salt. He considers also that the acid obtained from pure fluor-spar and monohydrated sulphuric acid heated together in a platinum retort is free from oxygen and water.

The specific gravity of the anhydrous liquid acid was several times determined, both in a specific-gravity bottle of platinum, and also by means of a platinum float submerged and weighed in the acid. Concordant and reliable results were obtained; the specific gravity found was 0.9879 at 55° Fahr., that of distilled water being = 1.000 at the same temperature.

The anhydrous acid was much more volatile than sulphuric ether. Its boiling-point was carefully determined in a special apparatus of platinum, and was found to be 67° Fahr. Not the slightest sign of freezing occurred on cooling the acid to -30° Fahr. (= -34° 5 C.); and it is highly probable that its solidifying temperature is a very great many degrees below this. Its vapour-tension at 60° Fahr. was also approximately determined, and was found to be = 7.58 lbs. per square inch. On loosening the lid of a bottle of the acid at 60° Fahr., the acid vapour is expelled in a jet like steam from a boiler; this, together with the low boiling-point, the extremely dangerous and corrosive nature of the acid, and its great affinity for water, illustrates the very great difficulty of manipulating with it and retaining it in a pure state. Nevertheless, by the contrivances described, and by placing the bottles in a cool cellar (never above a temperature of 60° Fahr.), the author has succeeded in keeping the liquid acid perfectly, without loss and unaltered, through the whole of the recent hot summer.

The electrical relations of different metals &c. in the acid were found to

oe as follows at 0° Fahr. :—zinc, tin, lead, cadmium, indium, magnesium, cobalt, aluminium, iron, nickel, bismuth, thallium, copper, iridium, silver, gas-carbon, gold, platinum, palladium.

Numerous experiments were made of electrolyzing the anhydrous acid with anodes of gas-carbon, carbon of *lignum-vitæ* and of many other kinds of wood, of palladium, platinum, and gold. The gas-carbon disintegrated rapidly ; all the kinds of charcoal flew to pieces quickly ; and the anodes of palladium, platinum, and gold were corroded without evolution of gas. The acid with a platinum anode conducted electricity much more readily than pure water ; but with one of gold it scarcely conducted at all. These electrolytic experiments presented extreme difficulties, and were conducted in a platinum apparatus (shown by a figure) specially devised for the purpose. The particulars of the conditions and results obtained are described in the paper. Various mixtures of the anhydrous acid with monohydrated nitric acid, with sulphuric anhydride, and with monohydrated sulphuric acid were also electrolyzed by means of platinum anodes, the particulars and results of which are also described.

To obtain an idea of the *general* chemical behaviour of the pure anhydrous acid, numerous substances (generally anhydrous) were immersed in separate portions of the acid in platinum cups, kept at a low temperature (0° to —20° Fahr.). The acid had scarcely any effect upon any of the metalloids or noble metals ; and even the base metals in a state of fine powder did not cause any evolution of hydrogen. Sodium and potassium behaved much the same as with water. Nearly all the salts of the alkali and alkaline-earth metals produced strong chemical action. Various anhydrides (specified) dissolved freely. Strong aqueous hydrochloric acid produced active effervescence. The alkalies and alkaline earths united strongly with the acid. Peroxides gave no effect. Numerous oxides (specified) produced strong chemical action, some of them dissolving. Some nitrates were not chemically affected ; others (those of lead, barium, and potassium) were decomposed. Fluorides generally were unchanged ; but those of the alkali-metals and of thallium produced different degrees of chemical action, those of ammonium, rubidium, and potassium uniting powerfully. Numerous chlorides were also unaffected, whilst those of phosphorus (the *solid* one only), antimony (the perchloride), titanium, and of the alkaline-earth and alkali metals, were decomposed with strong action, and generally with effervescence. The chlorates of potassium and sodium were also decomposed with evolution of chloric acid ; the bromides of the alkaline-earth and alkali metals behaved like their chlorides. Bromate of potassium rapidly set free bromine. Numerous iodides were unaffected ; but those of the alkaline-earth and alkali metals were strongly decomposed, and iodine (in some cases only) set free. The anhydrous acid decomposed all carbonates with effervescence, and those of the alkaline-earth and alkali metals with violent action. Borates of the alkalies also produced very strong action. Silico-fluorides of the alkali metals dissolved with effervescence.

All sulphides, except those of the alkaline-earth and alkali metals, exhibited no change; the latter evolved sulphuretted hydrogen violently. Bisulphite of sodium dissolved with effervescence. Sulphates were variously affected. The acid chromates of the alkali metals dissolved with violent action to blood-red liquids, with evolution of vapour of fluoride of chromium. Cyanide of potassium was violently decomposed, and hydrocyanic acid set free. Numerous organic bodies (specified) were also immersed in the acid; most of the solid ones were quickly disintegrated. The acid mixed with pyroxylic spirit, ether, and alcohol, but not with benzole; with spirit of turpentine it exploded, and produced a blood-red liquid. Gutta percha, india-rubber, and nearly all the gums and resins were rapidly disintegrated and generally dissolved to red liquids. Spermaceti, stearic acid, and myrtle wax were but little affected, and paraffin not at all. Sponge was also but little changed. Gun-cotton, silk, paper, cotton-wool, calico, gelatine, and parchment were instantly converted into glutinous substances, and generally dissolved. The solution of gun-cotton yielded an inflammable film on evaporation to dryness. Pinewood instantly blackened.

From the various physical and chemical properties of the anhydrous acid, the author concludes that it lies between hydrochloric acid and water, but is much more closely allied to the former than to the latter. It is more readily liquefied than hydrochloric acid, but less readily than steam; like hydrochloric acid it decomposes all carbonates; like water it unites powerfully with sulphuric and phosphoric anhydrides, with great evolution of heat. The fluorides of the alkali metals unite violently with hydrofluoric acid, as the oxides of those metals unite with water; the hydrated fluorides of the alkali metals also, like the hydrated fixed alkalies, have a strongly alkaline reaction, and are capable of expelling ammonia from its salts. It may be further remarked that the atomic number of fluorine lies between that of oxygen and chlorine; and the atomic number of oxygen, added to that of fluorine, nearly equals that of chlorine.

#### *B. Aqueous Hydrofluoric Acid.*

Under the head of the aqueous acid the author enumerates the various impurities usually contained in the commercial acid, and describes the modes he employed to detect and estimate them, and to estimate the amount of  $\text{HF}$  in it. The process employed by him for obtaining the aqueous acid in a very high degree of purity from the commercial liquid, is also fully described. It consists essentially in passing an excess of sulphuretted hydrogen through the acid, then neutralizing the sulphuric and hydrofluosilicic acids present by carbonate of potassium, decanting the liquid after subsidence of the precipitate, removing the excess of sulphuretted hydrogen by carbonate of silver, distilling the filtered liquid in a leaden retort with a condensing-tube of platinum, and, finally, rectifying.

The effect of cold upon the aqueous acid was briefly examined, the result being that a comparatively small amount of hydrofluoric acid lowers the freezing-point of water very considerably.

The chemico-electric series of metals &c. in acid of 10 per cent. and in that of 30 per cent. were determined. In the latter case it was as follows:—zinc, magnesium, aluminium, thallium, indium, cadmium, tin, lead, silicon, iron, nickel, cobalt, antimony, bismuth, mercury, silver, copper, arsenic, osmium, ruthenium, gas-carbon, platinum, rhodium, palladium, tellurium, osmi-iridium, gold, iridium. Magnesium was remarkably unacted upon in the aqueous acid. The chemico-electric relation of the aqueous acid to other acids with platinum was also determined.

Various experiments of electrolysis of the aqueous acid of various degrees of strength were made with anodes of platinum. Ozone was evolved, and, with the stronger acid only, the anode was corroded at the same time. Mixtures of the aqueous acid with nitric, hydrochloric, sulphuric, selenious, and phosphoric acids were also electrolyzed with a platinum anode, and the results are described.

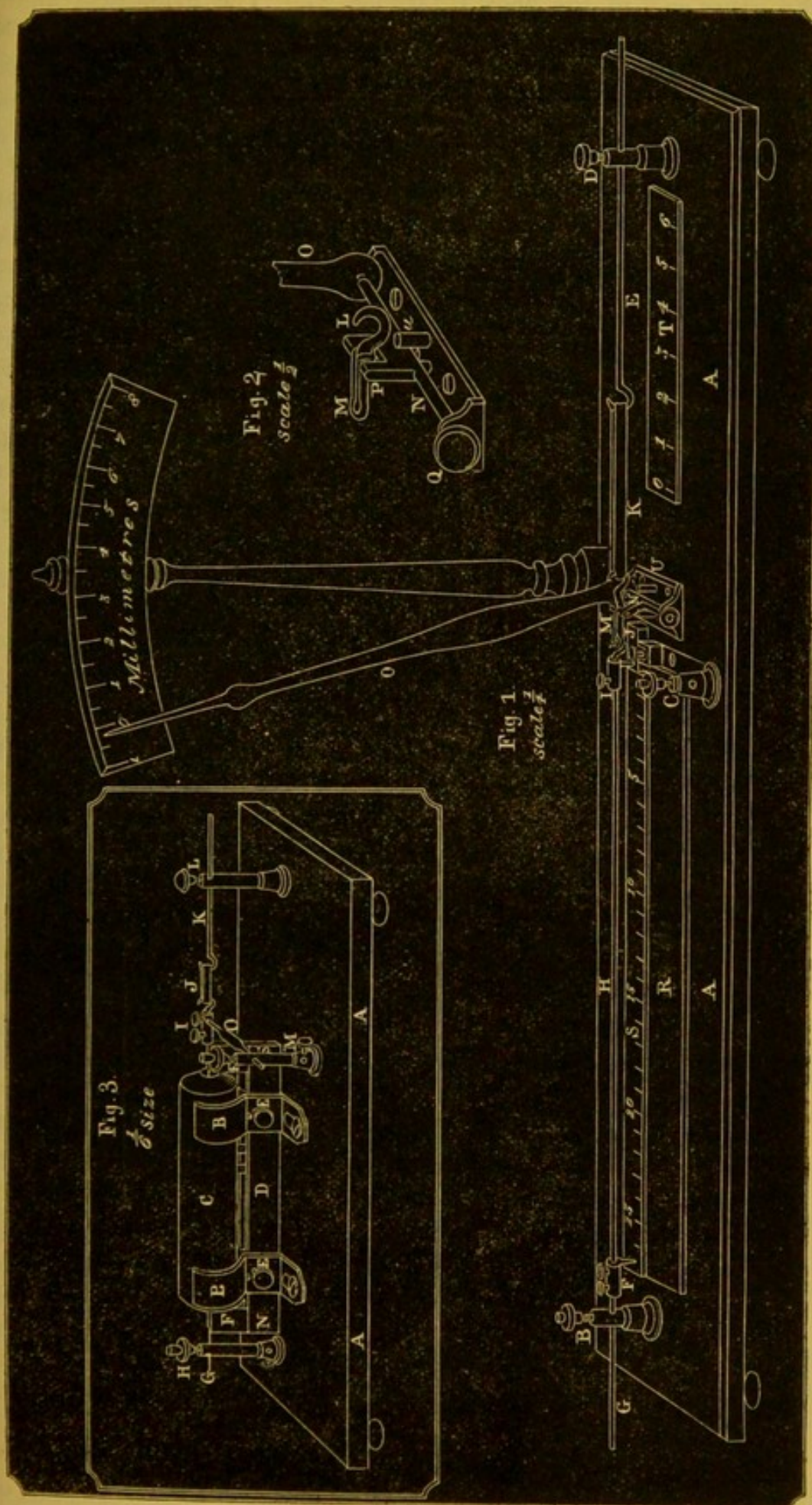
### On a momentary Molecular Change in Iron Wire.

By G. GORE, F.R.S.

Whilst making some experiments of heating a strained iron wire to redness by means of a current of voltaic electricity, I observed that, on disconnecting the battery and allowing the wire to cool, during the process of cooling the wire *suddenly elongated*, and then gradually shortened until it became quite cold.

On attempting, some little time afterwards, to repeat this experiment, although a careful record of the conditions of the experiment had been kept, it was with some difficulty, and after numerous trials, that I succeeded in obtaining the same result. Having again obtained it, I next examined and determined the successful conditions of the experiment, and devised the following arrangement of apparatus.

A A (fig. 1) is a wooden base 61 centimetres long and 15.5 centimetres wide. B and C are binding-screws; they are provided with small brass mercury-cups fixed in the heads of the screws for attachment of the wires of a voltaic battery. D is a binding-screw for holding fast the sliding wire hook E. F is a cylindrical binding-screw, fixed to the sliding wire G, which is held fast by the binding-screw B. H is the iron or other wire (or ribbon) to be heated: one end of this wire passes through the screw F and is tightly secured by it, whilst the other end is held fast by the cylindrical binding-screw I; the binding-screw I has a small projecting bent piece of copper wire secured to it, which dips into a little shallow dish or cup of mercury, J; and the mercury in this cup is connected by a screw and strip of brass to the binding-screw C. K is a stretched band of vulcanized india-rubber, attached at one end to the hook of the wire E, and



at the other end to the hook L (see fig. 2). The cylindrical binding-screw I has a hook by which it is attached to the loop M (fig. 2). N is an axis suspended delicately upon centres, and carrying a very light index pointer O. The hook L and loop M are separate pieces of metal, and move freely upon an axis, P (fig. 2). The distance from the centre of the axis N to that of P is 12.72 millimetres ( $=0.5$  inch), and to the top of the index pointer 25.45 centimetres ( $=10.0$  inches); every movement horizontally, therefore, of the loop M is attended by a movement, twenty times the amount, of the top of the pointer. Q is a screw for supporting the axis N. I have found it convenient to put the zero-figure of the index towards the left-hand side of the index-plate. R is a separate piece of wood fitting into a rectangular hole in the base board; it carries a graduated rule, S, for measuring the length of the wire to be heated, and is easily removed, so that the wire may, if necessary, be heated by means of a row of Bunsen's burners. The rule T is used when measuring the amount of strain. U is a vertical stud or pin of brass (of which there are two) for limiting the range of movement of the pointer O.

In using this apparatus, a straight wire or ribbon, H, of a suitable length and thickness was inserted, the index pointer brought to 0 by adjustment of the sliding-wire G, and a suitable amount of strain (varying from less than two ounces to upwards of twenty) put upon the wire by adjusting the sliding hooked wire E. One pole of a voltaic battery, generally consisting of six Grove's elements, was connected with the binding-screw C, and the other pole then inserted in the mercury-cup of B. As soon as the needle O attained a maximum or stationary amount of deflection, the battery-wire was suddenly removed from B, and the wire allowed to cool. The movement of the needle O was carefully watched both during its movement to the right hand and also during its return, to see if any irregularity of motion occurred.

Wires of the following metals and alloys were employed:—palladium, platinum, gold, silver, copper, iron, lead, tin, cadmium, zinc, brass, german silver, aluminium, and magnesium; metallic ribbon was also employed in certain cases.

In these experiments the thickness and length of the conducting-wire or ribbon had to be carefully proportioned to the quantity and electromotive power of the current, so as to produce in the first experiments with each metal only a very moderate amount of heat; thinner (and sometimes also shorter) wires were then successively used, so as ultimately to develop sufficient heat to make the metal closely approach its softening or fusion point. The battery employed consisted in each case of six Grove's cells, each cell containing two zinc plates  $3\frac{3}{4}$  inches wide, and a platinum plate 3 inches wide, each immersed about 5 inches in their respective liquids. The amount of tension imparted by the elastic band required to be carefully adjusted to the cohesive power of each metal; if the stretching power was too weak, the phenomenon sought for was not clearly developed.

loped; and if too great, the wire was overstretched or broken when it approached the softening-point. The amount of strain imparted was approximately measured by temporarily substituting the body of a small spring balance for the hooked wire F. The heated wire must be protected from currents of cold air.

With wires of iron 0.65 millimetre thick (size "No. 23") and 21.5 centimetres long, strained to the extent of 10 ounces or more, and heated to full redness, the phenomenon was clearly developed. As an example, the needle of the instrument went with regularity to 18.5 of index-plate; the current was then stopped; the needle instantly retreated to 17.75, then as quickly advanced to 19.75, and then went slowly and regularly back, but not to zero. If the temperature of the wire was not sufficiently high, or the strain upon the wire not enough, the needle went directly back without exhibiting the momentary forward movement. The temperature and strain required to be sufficient to actually stretch the wire somewhat at the higher temperature. A higher temperature with a less degree of strain, or a greater degree of strain with a somewhat lower temperature, did not develop the phenomenon. The wire was found to be permanently elongated on cooling. The amount of elongation of the wire during the momentary molecular change was usually about  $\frac{1}{240}$  part of the length of the heated part of the wire; but it varied in different experiments; it was greatest in amount when the maximum degrees of strain were applied. The molecular change evidently includes a diminution of cohesion at a particular temperature during the process of cooling; and it is interesting to notice that at the same temperature during the *heating*-process no such loss of cohesion (nor any increase of cohesion) takes place; a certain temperature and strain are therefore not alone sufficient to produce it; the condition of *cooling* must also be included. The phenomena which occur during cooling are not the exact converse of those which take place during heating.

The phenomenon of elongation of iron wire during the process of cooling evidently lies within very narrow limits; it could only be obtained (with the particular battery employed) with wires about 21.5 centimetres ( $=8\frac{1}{8}$  inch) long, and about 0.65 millimetre ( $=$ Nos. 22 & 23 of ordinary wire-gauge) thick, having a strain upon them of 10 ounces or upwards; with a weaker battery the phenomenon could only be obtained by employing a shorter and thinner wire.

The experiment may easily be verified in a simpler manner by stretching an iron wire about 1.0 millimetre diameter between two fixed supports, keeping it in a sufficient and proper degree of tension by means of an elastic band, then heating it to full redness by means of a row of Bunsen's burners, and, as soon as it has stretched somewhat, suddenly cutting off the source of heat. In some experiments of this kind, with a row (42 centimetres long) of 21 burners and a row (76 centimetres long) of 43 burners, and the wire attached to a needle with index-plate, as in the figure, conspicuous effects were obtained; but the momentary elongation was relatively

much less (in one instance  $\frac{1}{800}$  of the length of the heated part) than when a battery was employed, apparently in consequence of the wire being less intensely heated.

A large number of experiments were made with wires of palladium, platinum, gold, silver, copper, lead, tin, cadmium, zinc, brass, german-silver, aluminium, and magnesium (wire and ribbon), diminishing the length and thickness of the wire in each case, and adjusting the tension until suitable temperature and strain were obtained; but in no instance could a similar molecular change to that observed in iron be detected. Palladium and platinum wires of different lengths, thickness, and degrees of strain were examined at various temperatures, up to that of a white heat; but no irregularity of cohesion, except that of gradual softening at the higher temperatures, was observed; they instantly contracted with regular action on stopping the current. Several gold wires were similarly examined at different temperatures up to that of a full red heat; no irregularity occurred either during heating or cooling; but little tension (about 4 ounces) was applied, on account of the weak cohesion of this metal. Wires of silver similarly examined would only bear a strain of about 2 ounces, and a temperature of feeble red heat visible in daylight; no irregularity of elongation or contraction occurred during heating and cooling. By employing exactly the proper temperature and strain, a very interesting phenomenon was observed; the wire melted distinctly *on its surface* without fusing in its interior, although the surface was most exposed to the cooling influence of the air; this occurred without the wire breaking, as it would have done if its interior portion had melted; the phenomenon indicates the passage of the electricity by the *surface* of the wire in preference to passing by its interior. Wires of copper expanded regularly until they became red-hot; they then contracted slightly (notwithstanding the strain applied to them), probably in consequence of a cooling effect of increased radiation produced by the oxidized surface, as a similar effect occurred with brass and german-silver\*. On stopping the current the wire contracted without manifest irregularity. Wires of lead and tin were difficult to examine by this method, on account of their extremely feeble cohesion and the low temperature at which they softened: wires about 1.63 millimetre diameter, 25.5 centimetres long (with a strain upon them of about one ounce), were employed; no irregularity was detected. Wires of cadmium from 1.255 millimetre to 1.525 millimetre thick, and 24.2 centimetres long (with a strain of two ounces), exhibited a slight irregularity of expansion at the lower temperatures; they elongated, and also cooled, with extreme slowness, more slowly than those of any other metal. Wires of zinc exhibited a slight irregularity of expansion, like those of cadmium; the most suitable ones were about 25 centimetres long and 1.2 millimetre in diameter, with a strain of 10 ounces. Wires of brass and german-silver, when heated to redness,

\* This supposition does not agree with the results obtained with iron wire, which also oxidizes freely.

behaved like those of copper in expanding regularly until a maximum was attained, and then contracting slightly to a definite point whilst the battery remained connected; on stopping the current they contracted without irregularity. When examined at lower temperatures, with a greater degree of strain, no irregularity was observed. Various wires of aluminium were examined; the most suitable was one 0.88 millimetre thick, 20.4 centimetres long, with a strain of 12 ounces; no irregularity was observed at any temperature below redness; aluminium expanded and cooled very slowly, but less so than cadmium. Various wires and ribbon of magnesium were also examined below a red heat, but no irregularity of cohesion, except that due to gradual softening by heat, was detected.

All the metals examined exhibited gradual loss of cohesion at the higher temperatures if a suitable strain was applied to develop it. It is probable that if the fractions of time occupied by the needle in passing over each division of the index were noted, and the wire perfectly protected from currents of air, small irregularities of molecular or cohesive change might be detected by this method; cadmium and zinc offer a prospect of this kind.

This molecular change would probably be found to exist in large masses of wrought iron as well as in the small specimens of wire which I have examined, and would come into operation in various cases where those masses are subjected to the conjoint influence of heat and strain, as in various engineering operations, the destruction of buildings by fire, and other cases.

#### IV. "On the Development of Electric Currents by Magnetism and Heat." By G. GORE, F.R.S. Received November 14, 1868.

I have devised the following apparatus for demonstrating a relation of current electricity to magnetism and heat.

A A, fig. 3, is a wooden base, upon which is supported, by four brass clamps, two, B, B, on each side, a coil of wire, C; the coil is 6 inches long,  $1\frac{1}{2}$  inch external diameter, and  $\frac{3}{8}$  of an inch internal diameter, lined with a thin glass tube; it consists of 18 layers, or about 3000 turns of insulated copper wire of 0.415 millim. diameter (or size No. 26 of ordinary wire-gauge); D is a permanent bar-magnet held in its place by the screws E, E, and having upon its poles two flat armatures of soft iron, F, F, placed edgewise. Within the axis of the coil is a straight wire of soft iron, G, one end of which is held fast by the pillar-screw H, and the other by the cylindrical binding-screw I; the latter screw has a hook, to which is attached a vulcanized india-rubber band, J, which is stretched and held secure by the hooked brass rod K and the pillar-screw L. The screw H is surmounted by a small mercury cup for making connexions with one pole of a voltaic battery, the other pole of the battery being secured to the pillar-screw M,

which is also surmounted by a small mercury cup, and is connected with the cylindrical binding-screw I by a copper wire with a middle flattened portion O to impart to it flexibility. The two ends of the fine wire coil are soldered to two small binding-screws at the back; those screws are but partly shown in the sketch, and are for the purpose of connexion with a suitable galvanometer. The armatures F, F are grooved on their upper edges, and the iron wire lies in these grooves in contact with them; and to prevent the electric current passing through the magnet, a small piece of paper or other thin non-conductor is inserted between the magnet and one of the armatures. The battery employed consisted of six Grove's elements (arranged in one series), with the immersed portion of platinum plates about 5 inches by 3 inches; it was sufficiently strong to heat an iron wire 1.03 millim. diameter and 20.5 centims. long to a low red heat.

By making the contacts of the battery in unison with the movements of the galvanometer-needles, a swing of about 12 degrees of the needles each way was obtained. The galvanometer was not a very sensitive one; it contained 192 turns of wire. Similar results were obtained with a coil 8 inches long and  $1\frac{1}{4}$  inch diameter containing 16 layers, or about 3776 turns of wire of 0.415 millim. diameter (or No. 26 of ordinary wire-gauge), and a permanent magnet 10 inches long. Less effects were obtained with a 6-inch coil consisting of 40 layers, or about 10,000 turns of wire 0.10 millim. diameter, also with several other coils. The maximum effect of 12 degrees each way with six Grove's cells in one series was obtained when the wire became visibly red-hot, and this occurred with an iron wire 1.03 millim. diameter (or No. 19 of ordinary wire-gauge); but when employing ten such cells as a double series of five, the maximum effect was then obtained with an iron wire (size Nos. 17 and 18) 1.28 to 1.58 millim. diameter, the deflection being 16 degrees each way. By employing a still thicker wire and a battery of greater heating-power still greater effects were obtained.

The galvanometer was placed about 8 (and in some instances 12) feet distant from the coil. A reversal of the direction of the battery current did not reverse or perceptibly affect the current induced in the coil; but by reversing the poles of the magnet, the direction of the induced current was reversed. On disconnecting the battery, and thereby cooling the iron wire, a reversed direction of induced current was produced. By substituting a wire of pure nickel 24.5 centims. long and 2.1 millims. diameter, induced currents were obtained as with the iron, but they were more feeble. No induced current occurred by heating the iron wire if the magnet was absent; nor was any induced current obtained if the magnet was present and wires of palladium, platinum, gold, silver, copper, brass, or german-silver were heated to redness instead of iron wire; nor with a rod of bismuth 3.63 millims. diameter enclosed in a glass tube and heated nearly to fusion; it is evident, therefore, that the axial wire must be composed of a *magnetic* metal.

No continuous current (or only a very feeble one) was produced in the

coil by *continuously* heating the iron wire. In several experiments, by employing twelve similar Grove's elements as a double series of six intensity, an iron wire 1.56 millim. diameter was made *bright* red-hot ; and by keeping the current continuous until the galvanometer-needles settled nearly at zero, and then suddenly disconnecting the battery, the needles remained nearly stationary during several seconds, and then went rapidly to about 10 : this slow decline of the current during the first few seconds of cooling was probably connected with the "momentary molecular change of iron wire" during cooling which I have described in the preceding paper. The irregularity of movement of the needles did not occur unless the wire was *bright* red-hot, a condition which was also necessary for obtaining the molecular change.

The direction of the current induced by *heating* the iron wire was found by experiment to be the same as that which was produced by removing the magnet *from* the coil ; therefore the heat acted simply by *diminishing* the magnetism, and the results were in accordance with, and afford a further confirmation of, the general law, that wherever there is increasing or decreasing magnetism, there is a tendency to an electric current in a conductor at right angles to it.

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DICTIONARY

SOME TIGHT  
GUTTERS

