

V. *Experimental Researches in Electricity.—Sixth Series.* By MICHAEL FARADAY, D.C.L. F.R.S. Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal and Imp. Acadd. of Sciences, Paris, Petersburg, Copenhagen, Berlin, &c. &c.

Received November 30, 1833,—Read January 11, 1834.

§ 12. *On the power of Metals and other Solids to induce the Combination of Gaseous Bodies.*

564. THE conclusion at which I have arrived in this section may seem to render the whole of it unfit to form part of a series of researches in electricity; since, remarkable as the phenomena are, the power which produces them is not considered as of an electric origin, otherwise than as all attraction of particles may have this subtil agent for their common cause. But as the effects investigated arose out of electrical researches, as they are directly connected with others which are of an electric nature, and must of necessity be understood and guarded against in a very extensive series of electro-chemical decompositions (707.), I have felt myself fully justified in detailing them in this place.

565. Believing that I had proved (by experiments hereafter to be described (705.)) the constant and definite chemical action of a certain quantity of electricity, whatever its intensity might be, or however the circumstances of its transmission through either the decomposing body or the more perfect conductors were varied, I endeavoured upon that result to construct a new measuring instrument, which from its use might be called, at least provisionally, a *Volta-electrometer* (739.).

566. During the course of the experiments made to render the instrument efficient, I was occasionally surprised at observing a deficiency of the gases resulting from the decompositions of water, and at last an actual disappearance of portions which had been evolved, collected, and measured. The circumstances of the disappearance were these. A glass tube, about twelve inches in length and $\frac{3}{4}$ ths of an inch in diameter, had two platina poles fixed into its upper, hermetically sealed, extremity: the poles, where they passed through the glass, were of wire; but terminated below in plates, which were soldered to the wires with gold (Plate I. fig. 1.). The tube was filled with dilute sulphuric acid, and inverted in a cup of the same fluid; a voltaic battery was connected with the two wires, and sufficient oxygen and hydrogen evolved to occupy $\frac{4}{5}$ ths of the tube, or by the graduation 116 parts. On separating the tube from the voltaic battery the volume of gas immediately began to diminish, and in about five hours only $13\frac{1}{2}$ parts remained, and these ultimately disappeared.

567. It was found, by various experiments, that this effect was not due to the escape or solution of the gas, nor to recombination of the oxygen or hydrogen in consequence of any peculiar condition *they* might be supposed to possess under the circumstances; but to be occasioned by the action of one or both of the poles within the tube upon the gas around them. On disuniting the poles from the pile after they had acted upon dilute sulphuric acid, and introducing them into separate tubes containing mixed oxygen and hydrogen, it was found that the *positive* pole effected the union of the gases, but the negative pole apparently not (588.). It was ascertained also that no action of a sensible kind took place between the positive pole with oxygen or hydrogen alone.

568. These experiments reduced the phenomena to the consequence of a power possessed by the platina, after it had been the positive pole of a voltaic pile, of causing the combination of oxygen and hydrogen at common, or even at low, temperatures. This effect is, as far as I am aware, altogether new, and was immediately followed out to ascertain whether it was really of an electric nature, and how far it would interfere with the determination of the quantities evolved in the cases of electro-chemical decomposition required in the fourteenth section of these Researches.

569. Several platina plates were prepared (fig. 2.). They were nearly half an inch wide, and two inches and a half long: some were $\frac{1}{200}$ dth of an inch, others not more than $\frac{1}{600}$ dth, and some were as much as $\frac{1}{70}$ th of an inch in thickness. Each had a piece of platina wire, about seven inches long, soldered to it by pure gold. Then a number of glass tubes were prepared: they were about nine or ten inches in length, $\frac{5}{8}$ ths of an inch in internal diameter, were sealed hermetically at one extremity, and were graduated. Into these tubes was put a mixture of two volumes of hydrogen and one of oxygen, at the water pneumatic trough, and when one of the plates described had been connected with the positive or negative pole of the voltaic battery for a given time, or had been otherwise prepared, it was introduced through the water into the gas within the tube; the whole set aside in a test-glass (fig. 3.), and left for a longer or shorter period, that the action might be observed.

570. The following result may be given as an illustration of the phenomenon to be investigated. Diluted sulphuric acid, of the specific gravity 1.336, was put into a glass jar, in which was placed also a large platina plate, connected with the negative end of a voltaic battery of forty pairs of four-inch plates, with double coppers, and moderately charged. One of the plates (569.) was then connected with the positive extremity, and immersed in the same jar of acid for five minutes, after which it was separated from the voltaic battery, washed in distilled water, and introduced through the water of the pneumatic trough into a tube containing the mixture of oxygen and hydrogen (569.). The volume of gases immediately began to lessen, the diminution proceeding more and more rapidly until about $\frac{3}{4}$ ths of the mixture had disappeared. The upper end of the tube became quite warm, the plate itself so hot that the water boiled as it rose over it; and in less than a minute a cubical inch and a half of the

gases were gone, having been combined by the power of the platina, and converted into water.

571. This extraordinary influence acquired by the platina at the positive pole of the pile, is exerted far more readily and effectively on oxygen and hydrogen than on any other mixture of gases that I have tried. One volume of nitrous gas was mixed with a volume of hydrogen, and introduced into a tube with a plate which had been made positive in the dilute sulphuric acid for four minutes (570.). There was no sensible action in an hour: being left for thirty-six hours, there was a diminution of about one eighth of the whole volume. Action had taken place, but it had been very feeble.

572. A mixture of two volumes of nitrous oxide with one volume of hydrogen was put with a plate similarly prepared into a tube (569. 570.). This also showed no action immediately; but in thirty-six hours nearly a fourth of the whole had disappeared, i. e. about half of a cubic inch. By comparison with another tube containing the same mixture without a plate, it appeared that a part of the diminution was due to solution, and another part to the power of the platina; but the action had been very slow and feeble.

573. A mixture of one volume olefiant gas and three volumes oxygen was not affected by such a platina plate, even though left together for several days (640. 641.).

574. A mixture of two volumes carbonic oxide and one volume oxygen was also unaffected by the prepared platina plate in several days (645. &c.).

575. A mixture of equal volumes of chlorine and hydrogen was used in several experiments, with plates prepared in a similar manner (570.). Diminution of bulk soon took place; but when after thirty-six hours the experiments were examined, it was found that nearly all the chlorine had disappeared, having been absorbed, principally by the water, and that the original volume of hydrogen remained unchanged. No combination of the gases, therefore, had here taken place.

576. Reverting to the action of the prepared plates on mixtures of oxygen and hydrogen (570.), I found that the power, though gradually diminishing in all cases, could still be retained for a period varying in its length with circumstances. When tubes containing plates (569.) were supplied with fresh portions of mixed oxygen and hydrogen as the previous portions were condensed, the action was found to continue for above thirty hours, and in some cases slow combination could be observed even after eighty hours; but the continuance of the action greatly depended upon the purity of the gases used (638.).

577. Some plates (569.) were made positive for four minutes in dilute sulphuric acid of specific gravity 1.336: they were rinsed in distilled water, after which two were put into a small bottle and closed up, whilst others were left exposed to the air. The plates preserved in the limited portion of air were found to retain their power after eight days, but those exposed to the atmosphere had lost their force almost entirely in twelve hours, and in some situations, where currents existed, in a much shorter time.

578. Plates were made positive for five minutes in sulphuric acid, specific gra-

vity 1.336. One of these was retained in similar acid for eight minutes after separation from the battery: it then acted on mixed oxygen and hydrogen with apparently undiminished vigour. Others were left in similar acid for forty hours, and some even for eight days, after the electrization, and then acted as well in combining oxygen and hydrogen gas as those which were used immediately after electrization.

579. The effect of a caustic solution of potassa in preserving the platina plates was tried in a similar manner. After being retained in such a solution for forty hours, they acted exceedingly well on oxygen and hydrogen, and one caused such rapid condensation of the gases, that the plate became much heated, and I expected the temperature would have risen to ignition.

580. When similarly prepared plates (569.) had been put into distilled water for forty hours, and then introduced into mixed oxygen and hydrogen, they were found to act but very slowly and feebly as compared with those which had been preserved in acid or alkali. When, however, the quantity of water was but small, the power was very little impaired after three or four days. As the water had been retained in a wooden vessel, portions of it were redistilled in glass, and this was found to preserve prepared plates for a great length of time. Prepared plates were put into tubes with this water and closed up; some of them, taken out at the end of twenty-four days, were found very active on mixed oxygen and hydrogen; others, which were left in the water for fifty-three days, were still found to cause the combination of the gases. The tubes had been closed only by corks.

581. The act of combination always seemed to diminish, or apparently exhaust, the power of the platina plate. It is true that in most, if not all instances, the combination of the gases, at first insensible, gradually increased in rapidity, and sometimes reached to explosion; but when the latter did not happen, the rapidity of combination diminished; and although fresh mixtures of gas were introduced into the tubes, the combination went on more and more slowly, and at last ceased altogether. The first effect of an increase in the rapidity of combination depended in part upon the water flowing off from the platina plate, and allowing a better contact with the gas, and in part upon the heat evolved during the progress of the combination (630.). But notwithstanding the effect of these causes, diminution, and at last cessation of the power, always occurred. It must not, however, be unnoticed, that the purer the gases subjected to the action of the plate, the longer was its combining power retained. With the mixture evolved at the poles of the voltaic pile in pure dilute sulphuric acid, it continued longest; and with oxygen and hydrogen, of perfect purity, it probably would not be diminished at all.

582. Different modes of treatment applied to the platina plate, after it had ceased to be the positive pole of the pile, affected its power very curiously. A plate which had been a positive pole in diluted sulphuric acid of specific gravity 1.336 for four or five minutes, if rinsed in water and put into mixed oxygen and hydrogen, would act very well, and condense perhaps one cubic inch and a half of gas in six or seven

minutes; but if that same plate, instead of being merely rinsed, had been left in distilled water for twelve or fifteen minutes, or more, it would rarely fail, when put into the oxygen and hydrogen, of becoming, in the course of a minute or two, ignited, and would generally explode the gases. Occasionally the time occupied in bringing on the action extended to eight or nine minutes, and sometimes even to forty minutes, and yet ignition and explosion would result. This effect is due to the removal of a portion of acid which otherwise adheres firmly to the plate.

583. Occasionally the platina plates (569.), after being made the positive pole of the battery, were washed, wiped with filtering-paper or a cloth, and washed and wiped again. Being then introduced into mixed oxygen and hydrogen, they acted apparently as if they had been unaffected by the treatment. Sometimes the tubes containing the gas were opened in the air for an instant, and the plates put in dry; but no sensible difference in action was perceived, except that it commenced sooner.

584. The power of heat in altering the action of the prepared platina plates was also tried (595.). Plates which had been rendered positive in dilute sulphuric acid for four minutes were well washed in water, and heated to redness in the flame of a spirit-lamp: after this they acted very well on mixed oxygen and hydrogen. Others, which had been heated more powerfully by the blowpipe, acted afterwards on the gases, though not so powerfully as the former. Hence it appears that heat does not take away the power acquired by the platina at the positive pole of the pile: the occasional diminution of force seemed always referable to other causes than the mere heat. If, for instance, the plate had not been well washed from the acid, or if the flame used was carbonaceous, or was that of an alcohol lamp trimmed with spirit containing a little acid, or having a wick on which salt, or other extraneous matter, had been placed, then the power of the plate was quickly and greatly diminished (634. 636.).

585. This remarkable property was conferred upon platina when it was made the positive pole in sulphuric acid of specific gravity 1.336, or when it was considerably weaker, or when stronger, even up to the strength of oil of vitriol. Strong and dilute nitric acid, dilute acetic acid, solutions of tartaric, citric, and oxalic acids, were used with equal success. When muriatic acid was used, the plates acquired the power of condensing the oxygen and hydrogen, but in a much inferior degree.

586. Plates which were made positive in solution of caustic potassa did not show any sensible action upon the mixed oxygen and hydrogen. Other plates made positive in solutions of carbonates of potassa and soda exhibited the action, but only in a feeble degree.

587. When a neutral solution of sulphate of soda, or of nitre, or of chlorate of potassa, or of phosphate of potassa, or acetate of potassa, or sulphate of copper, was used, the plates, rendered positive in them for four minutes, and then washed in water, acted very readily and powerfully on the mixed oxygen and hydrogen.

588. It became a very important point, in reference to the *cause* of this action of

the platina, to determine whether the *positive* pole *only* could confer it (567.), or whether, notwithstanding the numerous contrary cases, the *negative* pole might not have the power when such circumstances as could interfere with or prevent the action were avoided. Three plates were therefore rendered negative for four minutes in diluted sulphuric acid of specific gravity 1.336, washed in distilled water, and put into mixed oxygen and hydrogen. *All* of them *acted*, though not so strongly as they would have done if they had been rendered positive. Each combined about a cubical inch and a quarter of the gases in twenty-five minutes. On every repetition of the experiment the same result was obtained; and when the plates were retained in distilled water for ten or twelve minutes, before being introduced into the gas (582.), the action was very much quickened.

589. But when there was any metallic or other substance present in the acid, which could be precipitated on the negative plate, then that plate ceased to act upon the mixed oxygen and hydrogen.

590. These experiments led to the expectation that the power of causing oxygen and hydrogen to combine, which could be conferred upon any piece of platina by making it the positive pole of a voltaic pile, was not essentially dependent upon the action of the pile, or upon any structure or arrangement of parts it might receive whilst in association with it, but belonged to the platina *at all times*, and was *always effective* when the surface was *perfectly clean*. And though, when made the *positive* pole of the pile in acids, the circumstances might well be considered as those which would cleanse the surface of the platina in the most effectual manner, it did not seem impossible that ordinary operations should produce the same result, although in a less eminent degree.

591. Accordingly, a platina plate (569.) was cleaned by being rubbed with a cork, a little water, and some coal-fire ashes upon a glass plate: being washed, it was put into mixed oxygen and hydrogen, and was found to act at first slowly, and then more rapidly. In an hour, a cubical inch and a half had disappeared.

592. Other plates were cleaned with ordinary sand-paper and water; others with whitening and water; others with emery and water; others, again, with black oxide of manganese and water; and others with a piece of charcoal and water. All of these acted in tubes of oxygen and hydrogen, causing combination of the gases. The action was by no means so powerful as that produced by plates having been in communication with the battery; but from one to two cubical inches of the gases disappeared, in periods extending from twenty-five to eighty or ninety minutes.

593. Upon cleaning the plates with a cork, ground emery, and dilute sulphuric acid, they were found to act still better. In order to simplify the conditions, the cork was dismissed, and a piece of platina foil used instead; still the effect took place. Then the acid was dismissed, and a solution of *potassa* used, but the effect occurred as before.

594. These results are abundantly sufficient to show that the mere mechanical

cleansing of the surface of the platina is sufficient to enable it to exert its combining power over oxygen and hydrogen at common temperatures.

595. I now tried the effect of heat in conferring this property upon platina (584.). Plates which had no action on the mixture of oxygen and hydrogen were heated by the flame of a freshly trimmed spirit-lamp, urged by a mouth blowpipe, and when cold were put into tubes of the mixed gases: they acted slowly at first, but after two or three hours condensed nearly all the gases.

596. A plate of platina, which was about one inch wide and two and three quarters in length, and which had not been used in any of the preceding experiments, was curved a little so as to enter a tube, and left in a mixture of oxygen and hydrogen for thirteen hours: not the slightest action or combination of the gases occurred. It was withdrawn at the pneumatic trough from the gas through the water, heated red hot by the spirit-lamp and blowpipe, and then returned when cold into the *same* portion of gas. In the course of a few minutes diminution of the gases could be observed, and in forty-five minutes about one cubical inch and a quarter had disappeared. In many other experiments platina plates when heated were found to acquire the power of combining oxygen and hydrogen.

597. But it happened not unfrequently that plates, after being heated, showed no power of combining oxygen and hydrogen gases, though left undisturbed in them for two hours. Sometimes also it would happen that a plate which, having been heated to dull redness, acted feebly, upon being heated to whiteness ceased to act; and at other times a plate which, having been slightly heated, did not act, was rendered active by a more powerful ignition.

598. Though thus uncertain in its action, and though often diminishing the power given to the plates at the positive pole of the pile (584.), still it is evident that heat can render platina active, which before was inert (595.). The cause of its occasional failure appears to be due to the surface of the metal becoming soiled, either from something previously adhering to it, which is made to adhere more closely by the action of the heat, or from matter communicated from the flame of the lamp, or from the air itself. It often happens that a polished plate of platina, when heated by the spirit-lamp and a blowpipe, becomes dulled and clouded on its surface by something either formed or deposited there; and this, and much less than this, is sufficient to prevent it from exhibiting the curious power now under consideration (634. 636.). Platina also has been said to combine with carbon; and it is not at all unlikely that in processes of heating, where carbon or its compounds are present, a film of such a compound may be thus formed, and thus prevent the exhibition of the properties belonging to *pure* platina.

599. The action of alkalies and acids in giving platina this property was now experimentally examined. Platina plates (569.) having no action on mixed oxygen and hydrogen, being boiled in a solution of caustic potassa, washed, and then put into the gases, were found occasionally to act pretty well, but at other times to fail. In

the latter case I concluded that the impurity upon the surface of the platina was of a nature not to be removed by the mere solvent action of the alkali, for when the plates were rubbed with a little emery, and the same solution of alkali (592.), they became active.

600. The action of acids was far more constant and satisfactory. A platina plate was boiled in dilute nitric acid: being washed and put into mixed oxygen and hydrogen gases, it acted well. Other plates were boiled in strong nitric acid for periods extending from half a minute to four minutes, and then being washed in distilled water, were found to act very well, condensing one cubic inch and a half of gas in the space of eight or nine minutes, and rendering the tube warm (570.).

601. Strong sulphuric acid was very effectual in rendering the platina active. A plate (569.) was heated in it for a minute, then washed and put into the mixed oxygen and hydrogen, upon which it acted as well as if it had been made the positive pole of a voltaic pile (570.).

602. Plates which, after being heated or electrized in alkali, or after other treatment, were found inert, immediately received power by being dipped for a minute or two, or even only for an instant, into hot oil of vitriol, and then into water.

603. When the plate was dipped into the oil of vitriol, taken out, and then heated so as to drive off the acid, it did not act, in consequence of the impurity left by the acid upon its surface.

604. Vegetable acids, as acetic and tartaric, sometimes rendered inert platina active, at other times not. This, I believe, depended upon the character of the matter previously soiling the plates, and which may easily be supposed to be sometimes of such a nature as to be removed by these acids, and at other times not. Weak sulphuric acid showed the same difference, but strong sulphuric acid (601.) never failed in its action.

605. The most favourable treatment, excepting that of making the plate a positive pole in strong acid, was as follows. The plate was held over a spirit-lamp flame, and when hot, rubbed with a piece of potassa fusa (caustic potash), which melting, covered the metal with a coat of very strong alkali, and this was retained fused upon the surface for a second or two*: it was then put into water for four or five minutes to wash off the alkali, shaken, and immersed for about a minute in hot strong oil of vitriol; from this it was removed into distilled water, where it was allowed to remain ten or fifteen minutes to remove the last traces of acid (582.). Being then put into a mixture of oxygen and hydrogen, combination immediately began, and proceeded rapidly; the tube became warm, the platina became red hot, and the residue of the gases was inflamed. This effect could be repeated at pleasure, and thus the maximum phenomenon could be produced without the aid of the voltaic battery.

606. When a solution of tartaric or acetic acid was substituted, in this mode of preparation, for the sulphuric acid, still the plate was found to acquire the same power,

* The heat need not be raised so much as to make the alkali tarnish the platina, although if that effect does take place it does not prevent the ultimate action.

and would often produce explosion in the mixed gases ; but the strong sulphuric acid was most certain and powerful.

607. If borax, or a mixture of the carbonates of potash and soda, be fused on the surface of a platina plate, and that plate be well washed in water, it will be found to have acquired the power of combining oxygen and hydrogen, but only in a moderate degree ; but if, after the fusion and washing, it be dipped in the hot sulphuric acid (601.), it will become very active.

608. Other metals than platina were then experimented with. Gold and palladium exhibited the power either when made the positive pole of the voltaic battery (570.), or when acted on by hot oil of vitriol (601.). When palladium is used, the action of the battery or acid should be moderated, as that metal is soon acted upon. Silver and copper could not be made to show any effect at common temperatures.

609. There can remain no doubt that the property of inducing combination, which can thus be conferred upon masses of platina and other metals by connecting them with the poles of the battery, or by cleansing processes either of a mechanical or chemical nature, is the same as that which was discovered by DOBEREINER*, in 1823, to belong in so eminent a degree to spongy platina, and which was afterwards so well experimented upon and illustrated by MM. DULONG and THENARD†, in 1823. The latter philosophers even quote experiments in which a very fine platina wire, which had been coiled up and digested in nitric, sulphuric, or muriatic acid, became ignited when put into a jet of hydrogen gas‡. This effect I can now produce at pleasure with either wires or plates by the processes described (570. 601. 605.) ; and by using a smaller plate cut so that it shall rest against the glass by a few points, and yet allow the water to flow off (fig. 4.), the loss of heat is less, the metal is assimilated somewhat to the spongy state, and the probability of failure almost entirely removed.

610. M. DOBEREINER refers the effect entirely to an electric action. He considers the platina and hydrogen as forming a voltaic element of the ordinary kind, in which the hydrogen, being very highly positive, represents the zinc of the usual arrangement, and like it, therefore, attracts oxygen and combines with it§.

611. In the two excellent experimental papers by MM. DULONG and THENARD||, those philosophers show that elevation of temperature favours the action, but does not alter its character, Sir HUMPHRY DAVY's incandescent platina wire being the same phenomenon with DOBEREINER's spongy platina. They show that *all* metals have this power in a greater or smaller degree, and that it is even possessed by such bodies as charcoal, pumice, porcelain, glass, rock crystal, &c., when their temperatures are raised ; and that another of DAVY's effects, in which oxygen and hydrogen had combined slowly together at a heat below ignition, was really dependent upon the pro-

* Annales de Chimie, tom. xxiv. p. 93.

† Ibid. tom. xxiii. p. 440.; tom. xxiv. p. 380.

‡ Ibid. tom. xxiv. p. 383.

§ Ibid. tom. xxiv. pp. 94, 95. Also Bibliothèque Universelle, tom. xxiv. p. 54.

|| Annales de Chimie, tom. xxiii. p. 440. ; tom. xxiv. p. 380.

perty of the heated glass, which it has in common with the bodies named above. They state that liquids do not show this effect, at least that mercury, at or below the boiling point, has not the power; that it is not due to porosity; that the same body varies very much in its action, according to its state; and that many other gaseous mixtures besides oxygen and hydrogen are affected, and made to act chemically, when the temperature is raised. They think it probable that spongy platina acquires its power from contact with the acid evolved during its reduction, or from the heat itself to which it is then submitted.

612. MM. DULONG and THENARD express themselves with great caution on the theory of this action; but, referring to the decomposing power of metals on ammonia when heated to temperatures not sufficient alone to affect the alkali. They remark that those metals which in this case are most efficacious, are the least so in causing the combination of oxygen and hydrogen; whilst platina, gold, &c., which have least power of decomposing ammonia, have most power of combining the elements of water; from which they are led to believe, that amongst gases, some tend to unite under the influence of metals, whilst others tend to separate, and that this property varies in opposite directions with the different metals. At the close of their second paper they observe, that the action is of a kind that cannot be connected with any known theory; and though it is very remarkable that the effects are transient, like those of most electrical actions, yet they state that the greater number of the results observed by them are inexplicable, by supposing them to be of a purely electric origin.

613. Dr. FUSINIERI has also written on this subject, and given a theory which he considers as sufficient to account for the phenomena*. He expresses the immediate cause thus: "The platina determines upon its surface a continual renovation of *concrete laminæ* of the combustible substance of the gases or vapours, which flowing over it, are burnt, pass away, and are renewed: this combustion at the surface raises and sustains the temperature of the metal." The combustible substance, thus reduced into imperceptible laminæ, of which the concrete parts are in contact with the oxygen, is presumed to be in a state combinable with the oxygen at a much lower temperature than when it is in the gaseous state, and more in analogy with what is called the nascent condition. That combustible gases should lose their elastic state, and become concrete, assuming the form of exceedingly attenuated but solid strata, is considered as proved by facts, some of which are quoted in the *Giornale di Fisica* for 1824†; and though the theory requires that they should assume this state at high temperatures, and though the *similar* films of aqueous and other matter are dissipated by the action of heat, still the facts are considered as justifying the conclusion against all opposition of reasoning.

614. The power or force which makes combustible gas or vapour abandon its elastic state in contact with a solid, that it may cover the latter with a thin stratum of its own proper substance, is considered as being neither attraction nor affinity. It

* *Giornale di Fisica*, &c., 1825, tom. viii. p. 259.

† pp. 138, 371.

is able also to extend liquids and solids in concrete laminæ over the surface of the acting solid body, and consists in a *repulsion*, which is developed from the parts of the solid body by the simple fact of attenuation, and is highest when the attenuation is most complete. The force has a progressive development, and acts most powerfully, or at first, in the direction in which the dimensions of the attenuated mass decrease, and then in the direction of the angles or corners which from any cause may exist on the surface. This force not only causes spontaneous diffusion of gases and other substances over the surface, but is considered as very elementary in its nature, and competent to account for all the phenomena of capillarity, chemical affinity, attraction of aggregation, rarefaction, ebullition, volatilization, explosion, and other thermometric effects, as well as inflammation, detonation, &c. &c. It is considered as a form of heat, to which the term *native caloric* is given, and is still further viewed as the principle of the two electricities and the two magnetisms.

615. I have been the more anxious to give a correct abstract of Dr. FUSINIERI's view, both because I cannot form a distinct idea of the power to which he refers the phenomena, and because of my imperfect knowledge of the language in which the memoir is written. I would therefore beg to refer those who pursue the subject to the memoir itself.

616. Not feeling, however, that the problem has yet been solved, I venture to give the view which seems to me sufficient, upon known principles, to account for the effect.

617. It may be observed of this action, that, with regard to platina, it cannot be due to any peculiar, temporary condition, either of an electric or of any other nature: the activity of plates rendered either positive or negative by the pole, or cleaned with such different substances as acids, alkalies, or water; charcoal, emery, ashes, or glass; or merely heated, is sufficient to negative such an opinion. Neither does it depend upon the spongy and porous, or upon the compact and burnished, or upon the massive or the attenuated state of the metal, for in any of these states it may be rendered effective, or its action may be taken away. The only essential condition appears to be a *perfectly clean* and *metallic surface*, for whenever that is provided the platina acts, whatever its form and condition in other respects may be; and though variations in the latter points will very much affect the rapidity, and therefore the visible appearances and secondary effects, of the action, i. e. the ignition of the metal and the inflammation of the gases, they, even in their most favourable state, cannot produce any effect unless the condition of a clean, pure, metallic surface be also fulfilled.

618. The effect is evidently produced by most, if not all, solid bodies, weakly perhaps by many of them, but rising to a high degree in platina. DULONG and THENARD have very philosophically extended our knowledge of the property to its possession by all the metals, and by earths, glass, stones, &c. (611.); and every idea of its being a known and recognised electric action is in this way removed.

619. All the phenomena connected with this subject press upon my mind the conviction that the effects in question are entirely incidental and of a secondary nature;

that they are dependent upon the *natural conditions* of gaseous elasticity combined with the exertion of that attractive force, possessed by many bodies in an eminent degree, and probably belonging to all, by which they are drawn into association more or less close, without at the same time undergoing chemical combination, though often assuming the condition of adhesion; and which occasionally leads, under very favourable circumstances, as in the present instance, to the combination of bodies simultaneously subjected to this attraction. I am prepared myself to admit (and probably many others are of the same opinion), both with respect to the attraction of aggregation and of chemical affinity, that the sphere of action of particles extends beyond those other particles with which they are immediately and evidently in union, and in many cases produces effects rising into considerable importance: and I think that this kind of attraction is a determining cause of DOBEREINER's effect, and of the many others of a similar nature.

620. Bodies which become wetted by fluids with which they do not combine chemically, or in which they do not dissolve, are simple and well known instances of this kind of attraction.

621. All those cases of bodies which being insoluble in water and not combining with it are hygrometric, and condense its vapour around or upon their surface, are stronger instances of the same power, and approach a little nearer to the cases under investigation. If pulverised clay, protoxide or peroxide of iron, oxide of manganese, charcoal, or even metals, as spongy platina or precipitated silver, be put into an atmosphere containing vapour of water, they soon become moist by virtue of an attraction which is able to condense the vapour upon, although not to combine it with, the substances; and if, as is well known, these bodies so damped be put into a dry atmosphere, as, for instance, one confined over sulphuric acid, or if they be heated, then they yield up this water again almost entirely, it not being in direct or permanent combination*.

622. Still better instances of the power I refer to, because they are more analogous to the cases to be explained, are furnished by the attraction existing between glass and air, so well known to barometer and thermometer makers, for here the adhesion or attraction is exerted between a solid and gases, bodies having very different physical conditions, having no power of combination with each other, and each retaining, during the time of action, its physical state unchanged†. When mercury is poured into a barometer tube, a film of air will remain between the metal and glass for months, or, as far as is known, for years, for it has never been displaced except by the

* I met at Edinburgh with a remarkable case as to its extent of hygrometric action, assisted a little perhaps by very slight solvent power. Some turf had been well dried by long exposure in a covered place to the atmosphere, but being then submitted to the action of a hydrostatic press, it yielded, *by the mere influence of the pressure*, 54 per cent. of water.

† FUSINIERI and BELLANI consider the air as forming solid concrete films in these cases.—*Giornale di Fisica*, tom. viii. p. 262. 1825.

action of means especially fitted for the purpose. These consist in boiling the mercury, or, in other words, of forming an abundance of vapour, which coming in contact with every part of the glass and every portion of surface of the mercury, gradually mingles with, dilutes, and carries off the air attracted by, and adhering to, those surfaces, replacing it by other vapour, subject to an equal or perhaps greater attraction, but which when cooled condenses into the same liquid as that with which the tube is filled.

623. Extraneous bodies, which, acting as nuclei in crystallizing or depositing solutions, cause deposition of substances on them, when it does not occur elsewhere in the liquid, seem to produce their effects by a power of the same kind, i. e. a power of attraction extending to neighbouring particles, and causing them to become attached to the nuclei, although it is not strong enough to make them combine chemically with their substance.

624. It would appear from many cases of nuclei in solutions, and from the effects of bodies put into atmospheres containing the vapours of water, or camphor, or iodine, &c., as if this attraction were in part elective, partaking in its characters both of the attraction of aggregation and chemical affinity: nor is this inconsistent with, but agreeable to, the idea entertained, that it is the power of particles acting, not upon others with which they can immediately and intimately combine, but upon such as are either more distantly situated with respect to them, or which, from previous condition, physical constitution, or feeble relation, are unable to enter into decided union with them.

625. Then, of all bodies, the gases are those which might be expected to show some *mutual* action whilst *jointly* under the attractive influence of the platina or other solid acting substance. Liquids, such as water, alcohol, &c., are in so dense and comparatively incompressible a state, as to favour no expectation that their particles should approach much closer to each other by the attraction of the body to which they adhere, and yet that attraction must (according to its effects) place their particles as near to those of the solid wetted body as they are to each other, and in many cases it is evident that the former attraction is the stronger. But gases and vapours are bodies competent to suffer very great changes in the relative distances of their particles by external agencies; and where they are in immediate contact with the platina, the approximation of the particles to those of the metal may be very great. In the case of the hygrometric bodies referred to (621.), it is sufficient to reduce the vapour to the fluid state, frequently from atmospheres so rare that without this influence it would be needful to compress them by mechanical force into a bulk not more than $\frac{1}{10}$ th or even $\frac{1}{20}$ th of their original volume before the vapours would become liquids.

626. Another most important consideration in relation to this action of bodies, and which, as far as I am aware, has not hitherto been noticed, is the condition of elasticity under which the gases are placed against the acting surface. We have but very imperfect notions of the real and intimate conditions of the particles of a body exist-

ing in the solid, the liquid, and the gaseous state ; but when we speak of the gaseous state as being due to the mutual repulsions of the particles or of their atmospheres, although we may err in imagining each particle to be a little nucleus to an atmosphere of heat, or electricity, or any other agent, we are still not likely to be in error in considering the elasticity as dependent on *mutuality* of action. Now this mutual relation fails altogether on the side of the gaseous particles next to the platina, and we might be led to expect *à priori* a deficiency of elastic force there to at least one half ; for if, as DALTON has shown, the elastic force of the particles of one gas cannot act against the elastic force of the particles of another, the two being as vacua to each other, so is it far less likely that the particles of the platina can exert any influence on those of the gas against it, such as would be exerted by gaseous particles of its own kind.

627. But the diminution of power to one half on the side of the gaseous body towards the metal is only a slight result of what seems to me to flow as a necessary consequence of the known constitution of gases. An atmosphere of one gas or vapour, however dense or compressed, is in effect as a vacuum to another : thus, if a little water were put into a vessel containing a dry gas, as air, of the pressure of one hundred atmospheres, as much vapour of the water would *rise* as if it were in a perfect vacuum. Here the particles of watery vapour appear to have no difficulty in approaching within any distance of the particles of air, being influenced solely by relation to particles of their own kind ; and if it be so with respect to a body having the same elastic powers as itself, how much more surely must it be so with particles, like those of the platina, or other limiting body, which, at the same time that they have not these elastic powers, are also unlike it in nature. Hence it would seem to result that the particles of hydrogen or any other gas or vapour which are next to the platina, &c., must be in such contact with it as if they were in the liquid state, and therefore almost infinitely closer to it than they are to each other, even though the metal be supposed to exert no attractive influence over them.

628. A third and very important consideration in favour of the mutual action of gases under these circumstances is their perfect miscibility. If fluid bodies capable of combining together are also capable of mixture, *they do combine* when they are mingled, not waiting for any other determining circumstance ; but if two such gases as oxygen and hydrogen are put together, though they are elements having such powerful affinity as to unite naturally under a thousand different circumstances, they do not combine by mere mixture. Still it is evident that, from their perfect association, the particles are in the most favourable state possible for combination, upon the supervention of any determining cause, such either as the negative action of the platina in suppressing or annihilating, as it were, their elasticity on its side ; or the positive action of the metal in condensing them against its surface by an attractive force ; or the influence of both together.

629. Although there are not many distinct cases of combination under the influence of forces external to the combining particles, yet there are sufficient to remove

any difficulty which might arise on that ground. Sir JAMES HALL found carbonic acid and lime to remain combined under pressure at temperatures at which they would not have remained combined if the pressure had been removed ; and I have had occasion to observe a case of direct combination in chlorine*, which being compressed at common temperatures will combine with water, and form a definite crystalline hydrate, incapable either of being formed or of existing if that pressure be removed.

630. The course of events when platina acts upon, and combines oxygen and hydrogen, may be stated, according to these principles, as follows. From the influence of the circumstances mentioned (619. &c.), i. e. the deficiency of elastic power and the attraction of the metal for the gases, the latter, when they are in association with the former, are so far condensed as to be brought within the action of their mutual affinities at the existing temperature ; the deficiency of elastic power, not merely subjecting them more closely to the attractive influence of the metal, but also bringing them into a more favourable state for union, by abstracting a part of that power (upon which depends their elasticity,) which elsewhere in the mass of gases is opposing their combination. The consequence of their combination is the production of the vapour of water and an elevation of temperature. But as the attraction of the platina for the water formed is not greater than for the gases, if so great, (for the metal is scarcely hygrometric,) the vapour is quickly diffused through the remaining gases ; fresh portions of the latter, therefore, come into juxtaposition with the metal, combine, and the vapour formed is also diffused, allowing new portions of gas to be acted upon. In this way the process advances, but is accelerated by the evolution of heat, which is known by experiment to facilitate the combination in proportion to its intensity, and the temperature is thus gradually exalted until ignition results.

631. The dissipation of the vapour produced at the surface of the platina, and the contact of fresh oxygen and hydrogen with the metal, form no difficulty in this explanation. The platina is not considered as causing the combination of any particles with itself, but only associating them closely around it ; and the compressed particles are as free to move from the platina, being replaced by other particles, as a portion of dense air upon the surface of the globe, or at the bottom of a deep mine, is free to move by the slightest impulse into the upper and rarer parts of the atmosphere.

632. It can hardly be necessary to give any reasons why platina does not show this effect under ordinary circumstances. It is then not sufficiently clean (617.), and the gases are prevented from touching it, and suffering that degree of effect which is needful to commence their combination at common temperatures, and which they can only experience at its surface. In fact, the very power which causes the combination of oxygen and hydrogen is competent, under the usual casual exposure of platina, to condense extraneous matters upon its surface, which soiling it, take away for the time its power of combining oxygen and hydrogen by preventing their contact with it.

* Philosophical Transactions, 1823, p. 161.

633. Clean platina, by which I mean such as has been made the positive pole of a pile (570.), or has been treated with acid (605.), and has then been put into distilled water for twelve or fifteen minutes, has a peculiar friction when one piece is rubbed against another. It wets freely with pure water, even after it has been shaken and dried by the heat of a spirit-lamp; and if made the pole of a voltaic pile in a dilute acid, it evolves minute bubbles from every part of its surface. But platina in its common state wants that peculiar friction: it will not wet freely with water as the clean platina does; and when made the positive pole of a pile, it for a time gives off large bubbles, which seem to cling or adhere to the metal, and are evolved at distinct and separate points of the surface. These appearances and effects, as well as its want of power on oxygen and hydrogen, are the consequences, and the indications, of a soiled surface.

634. I found also that platina plates which had been cleaned perfectly soon became soiled by mere exposure to the air; for after twenty-four hours they no longer moistened freely with water, but the fluid ran up into portions, leaving part of the surface bare, whilst other plates which had been retained in water for the same time, when they were dried (580.) did moisten, and gave the other indications of a clean surface.

635. Nor was this the case with platina or metals only, but also with earthy bodies. Rock crystal and obsidian would not wet freely upon the surface, but being moistened with strong oil of vitriol, then washed, and left in distilled water to remove all the acid, they did freely become moistened, whether they were previously dry or whether they were left wet; but being dried and left exposed to the air for twenty-four hours, their surface became so soiled that water would not then adhere freely to it, but ran up into partial portions. Wiping with a cloth (even the cleanest) was still worse than exposure to air; the surface either of the minerals or metals immediately became as if it were slightly greasy. The floating of small particles of metals under ordinary circumstances is due to the effect of this kind of soiled surface. The extreme difficulty of cleaning the surface of mercury when it has once been soiled or greased, is due to the same cause.

636. The same reasons explain why the power of the platina plates in some circumstances soon disappear, and especially upon use, and MM. DULONG and THENARD have observed the same effect with the spongy metal*, as indeed have all those who have used DOBEREINER'S instantaneous light machines. If left in the air, if put into ordinary distilled water, if made to act upon ordinary oxygen and hydrogen, they can still find in all these cases *that* minute portion of impurity which, when once in contact with its surface, is retained there, and is sufficient to prevent its full action upon oxygen and hydrogen at common temperatures: a slight elevation of temperature is again sufficient to compensate for their effect, and cause combination.

637. No state of things can be conceived more favourable for the production of this effect than that which is possessed by platina obtained from the ammonio-muriate by

* Annales de Chimie, tom. xxiv. p. 386.

heat: its surface is most extensive and pure, yet very accessible to the gases brought in contact with it. If placed in impurity, the interior, as THENARD and DULONG have observed, is preserved clean by the exterior; and as regards heat, it is so bad a conductor, because of its divided condition, that almost all which is evolved by the combination of the first portions of gas is retained within the mass, exalting the tendency of the succeeding portions to combine.

638. I have now to notice some very extraordinary interferences with this phenomenon, dependent, not upon the nature or condition of the metal, or other acting solid, but upon the presence of certain substances mingled with the gases acted upon; and as I shall have occasion to speak frequently of a mixture of oxygen and hydrogen, I wish it always to be understood that I mean a mixture composed of one volume oxygen to two volumes of hydrogen, being the proportions that form water. Unless otherwise expressed, the hydrogen was always that obtained by the action of dilute sulphuric acid on pure zinc, and the oxygen that obtained by the action of heat from the chlorate of potassa.

639. Mixtures of oxygen and hydrogen with *air*, containing one fourth, one half, and even two thirds of the latter, being introduced with prepared platina plates (570. 605.) into tubes, were acted upon almost as well as if no air were present: the retardation was far less than might have been expected from the mere dilution and consequent obstruction to the access of gas. In two hours and a half nearly all the oxygen and hydrogen introduced as mixture was gone.

640. But when similar experiments were made with *olefiant gas* (the platina plates having been made the positive poles of a voltaic pile (570.) in acid), very different results occurred. A mixture was made of 29.2 volumes hydrogen and 14.6 volumes oxygen, being the proportions for water; and to this was added another mixture of 3 volumes oxygen and 1 volume olefiant gas, so that the olefiant gas formed but $\frac{1}{4\frac{1}{2}}$ th part of the whole; yet in this mixture the platina plate would not act in forty-five hours. The failure was not for want of any power in the plate, for when after that time it was taken out of this mixture and put into one of oxygen and hydrogen, it immediately acted, and in seven minutes caused explosion of the gas. This result was obtained several times, and when larger proportions of olefiant gas were used the action seemed still more hopeless.

641. A mixture of forty-nine volumes oxygen and hydrogen (638.) with one volume of olefiant gas had a well-prepared platina plate introduced. The diminution of gas was scarcely sensible at the end of two hours, during which it was watched; but on examination twenty-four hours afterwards, the tube was found blown to pieces. The action, therefore, though it had been very much retarded, had occurred at last, and risen to a maximum.

642. With a mixture of ninety-nine volumes of oxygen and hydrogen (638.) with one of olefiant gas, a feeble action was evident at the end of fifty minutes; it went on accelerating (630.) until the eighty-fifth minute, and then became so intense that the

gas exploded. Here also the retarding effect of the olefiant gas was very beautifully illustrated.

643. Plates prepared by alkali and acid (605.) produced corresponding effects.

644. It is perfectly clear from these experiments, that *olefiant gas*, even in small quantities, has a very remarkable influence in preventing the combination of oxygen and hydrogen under these circumstances, and yet without at all injuring or affecting the power of the platina.

645. Another striking illustration of similar interference may be shown in *carbonic oxide*, especially if contrasted with *carbonic acid*. A mixture of one volume oxygen and hydrogen (638.) with four volumes of carbonic acid was affected at once by a platina plate prepared with acid, &c. (605.), and in one hour and a quarter nearly all the oxygen and hydrogen was gone. Mixtures containing less carbonic acid were still more readily affected.

646. But when carbonic oxide was substituted for the carbonic acid, not the slightest effect of combination was produced; and when the carbonic oxide was only one eighth of the whole volume, no action occurred in forty and fifty hours. Yet the plates had not lost their power; for being taken out and put into pure oxygen and hydrogen, they acted well and at once.

647. Two volumes of carbonic oxide and one of oxygen were mingled with nine volumes of oxygen and hydrogen (638.). This mixture was not affected by a plate which had been made positive in acid, though it remained in it fifteen hours. But when to the same volumes of carbonic oxide and oxygen were added thirty-three volumes of oxygen and hydrogen, the carbonic oxide being then only $\frac{1}{18}$ th part of the whole, the plate acted, slowly at first, and at the end of forty-two minutes the gases exploded.

648. These experiments were extended to various gases and vapours, the general results of which may be given as follow. Oxygen, hydrogen, nitrogen, and nitrous oxide, when used to dilute the mixture of oxygen and hydrogen, did not prevent the action of the plates even when they made up four fifths of the whole volume of gas acted upon. Nor was the retardation so great in any case as might have been expected from the mere dilution of the oxygen and hydrogen, and the consequent mechanical obstruction to its contact with the platina. The order in which carbonic acid and these substances seemed to stand was as follows, the first interfering least with the action; *nitrous oxide, hydrogen, carbonic acid, nitrogen, oxygen*: but it is possible the plates were not equally well prepared in all, and that other circumstances also were unequal; consequently more numerous experiments would be required to establish the order accurately.

649. As to cases of *retardation*, the powers of olefiant gas and carbonic oxide have been already described. Mixtures of oxygen and hydrogen, containing from $\frac{1}{16}$ th to $\frac{1}{80}$ th of sulphuretted hydrogen or phosphuretted hydrogen, seemed to show a little action at first, but were not further affected by the prepared plates, though in contact

with them for seventy hours. When the plates were removed they had lost all power over pure oxygen and hydrogen, and the interference of these gases was therefore of a different nature from that of the two former, having permanently affected the plate.

650. A small piece of cork was dipped in sulphuret of carbon and passed up through water into a tube containing oxygen and hydrogen (638.), so as to diffuse a portion of its vapour through the gases. A plate being introduced appeared at first to act a little, but after sixty-one hours the diminution was very small. Upon putting the same plate into a pure mixture of oxygen and hydrogen it acted at once and powerfully, having apparently suffered no diminution of its force.

651. A little vapour of ether being mixed with the oxygen and hydrogen retarded the action of the plate, but did not prevent it altogether. A little of the vapour of the condensed oil-gas liquor* retarded the action still more, but not nearly so much as an equal volume of olefiant gas would have done. In both these cases it was the original oxygen and hydrogen which combined together, the ether and the oil-gas vapour remaining unaffected, and in both cases the plates retained the power of acting on fresh oxygen and hydrogen.

652. Spongy platina was then used in place of the plates, and jets of hydrogen mingled with the different gases thrown against it in air. The results were exactly of the same kind, although presented occasionally in a more imposing form. Thus, mixtures of one volume of olefiant gas or carbonic oxide with three of hydrogen could not heat the spongy platina when the experiments were commenced at common temperatures; but a mixture of equal volumes of nitrogen and hydrogen acted very well, causing ignition. With carbonic acid the results were still stronger. A mixture of three volumes of that gas with one of hydrogen caused ignition of the platina, yet that mixture would not continue to burn from the jet when attempts were made to light it by a taper. A mixture even of *seven* volumes of carbonic acid and *one* of hydrogen will thus cause the ignition of cold spongy platina, and yet, as if to supply a contrast, than which none can be greater, it cannot burn at a taper, but causes the extinction of the latter. On the other hand, the mixtures of carbonic oxide or olefiant gas, which can do nothing with the platina, are inflamed by the taper, burning well.

653. Hydrogen mingled with the vapour of ether or oil-gas liquor causes the ignition of the spongy platina. The mixture with oil-gas burns with a flame far brighter than that of the mixture of hydrogen and olefiant gas already referred to, so that it would appear that the retarding action of the hydro-carbons is not at all in proportion merely to the quantity of carbon present.

654. In connexion with these interferences, I must state that hydrogen itself, prepared from steam passed over ignited iron, was found when mingled with oxygen to resist the action of platina. It had stood over water seven days, and had lost all fetid smell; but a jet of it would not cause the ignition of spongy platina, commencing at common temperatures; nor would it combine with oxygen in a tube either under

* Philosophical Transactions, 1825, p. 440.

the influence of a prepared plate or of spongy platina. A mixture of one volume of this gas with three of pure hydrogen, and the due proportion of oxygen, was not affected by plates after fifty hours. I am inclined to refer the effect to carbonic oxide present in the gas, but have not had time to verify the suspicion. The power of the plates was not destroyed (640. 646.).

655. Such are the general facts of these remarkable interferences. Whether the effect produced by such small quantities of certain gases depends upon any direct action which they may exert upon the particles of oxygen and hydrogen, by which the latter are rendered less inclined to combine, or whether it depends upon their modifying the action of the plate temporarily (for they produce no real change on it), by investing it through the agency of a stronger attraction than that of the hydrogen, or otherwise, remains to be decided by more extended experiments.

656. The theory of action which I have given for the original phenomena appears to me quite sufficient to account for all the effects by reference to known properties, and dispenses with the assumption of any new power of matter. I have pursued this subject at some length, as one of great consequence, because I am convinced that the superficial actions of matter, whether between two bodies, or of one piece of the same body, and the actions of particles not directly or strongly in combination, are becoming daily more and more important to our theories of chemical as well as mechanical philosophy*. In all ordinary cases of combustion it is evident that an action of the kind, considered either upon the surface of the carbon in the fire, or that in the bright part of a flame, must have great influence over the combinations there taking place.

657. The condition of elasticity upon the exterior of the gaseous or vaporous mass already referred to (626. 627.), must be connected directly with the action of solid bodies as nuclei on vapours, causing condensation upon them in preference to any condensation in the vapours themselves; and in the well-known effect of nuclei on solutions a similar condition may have existence (623.), for an analogy in condition exists between the parts of a body in solution, and those of a body in the vaporous or gaseous state. This thought leads us to the consideration of what are the respective conditions at the surfaces of contact of two portions of the same substance at the same temperature, one in the solid or liquid, and the other in the vaporous state; as, for instance, steam and water. It would seem that the particles of vapour next to the particles of liquid are in a different relation to the latter to what they would be with respect to

* As a curious illustration of the influence of mechanical forces over chemical affinity, I will quote the refusal of certain substances to effloresce when their surfaces are perfect, which yield immediately upon the surface being broken. If crystals of carbonate of soda, or phosphate of soda, or sulphate of soda, having no part of their surfaces broken, be preserved from external violence, they will not effloresce. I have thus retained crystals of carbonate of soda perfectly transparent and unchanged from September 1827 to January 1833; and crystals of sulphate of soda from May 1832 to the present time, November 1833. If any part of the surface were scratched or broken, then efflorescence began at that part, and covered the whole. The crystals were merely placed in evaporating basins and covered with paper.

any other liquid or solid substance ; as, for instance, mercury or platina, if they were made to replace the water, i. e. if the view of independent action which I have taken (626. 627.) as a consequence of DALTON's principles be correct. It would also seem that the mutual relation of similar particles, and the indifference of dissimilar particles which DALTON has established as a matter of fact amongst gases and vapours, extends to a certain degree amongst solids and fluids, that is, when they are in relation by contact with vapours, either of their own substance or of other bodies. But though I view these points as of great importance with respect to the relations existing between different substances and their physical constitution in the solid, liquid, or gaseous state, I have not sufficiently considered them to venture any strong opinions or statements here.

658. There are numerous well-known cases in which substances, such as oxygen and hydrogen, act readily in their *nascent* state, and produce chemical changes which they are not able to effect if once they have assumed the gaseous condition. Such instances are very common at the poles of the voltaic pile, and are, I think, easily accounted for, if it be considered that at the moment of separation of any such particle it is entirely surrounded by other particles of a *different* kind with which it is in close contact, and has not yet assumed those relations and conditions which it has in its fully developed state, and which it can only assume by association with other particles of its own kind. For, at the moment, its elasticity is absent, and it is in the same relation to particles with which it is in contact, and for which it has an affinity, as the particles of oxygen and hydrogen are to each other on the surface of clean platina (626. 627.).

659. The singular effects of retardation produced by very small quantities of some gases, and not by large quantities of others (640. 645. 652.), if dependent upon any relation of the added gas to the surface of the solid, will then probably be found immediately connected with the curious phenomena which are presented by different gases when passing through narrow tubes at low pressures, which I observed many years ago*; and this action of surfaces must, I think, influence the highly interesting phenomena of the diffusion of gases, at least in the form in which it has been experimented upon by Mr. GRAHAM in 1829 and 1831†, and also by Dr. MITCHELL of Philadelphia‡ in 1830. It seems very probable that if such a substance as spongy platina were used, another law for the diffusion of gases under the circumstances would come out than that obtained by the use of plaster of Paris.

660. I intended to have followed this section by one on the secondary piles of RITTER, and the peculiar properties of the poles of the pile, or of metals through which electricity has passed, which have been observed by RITTER, VAN MARUM, YELIN, DE LA RIVE, MARIANINI, BERZELIUS, and others. It appears to me that all these

* Quarterly Journal of Science, 1819, vol. vii. p. 106.

† Quarterly Journal of Science, vol. xxviii. p. 74., and Edinburgh Transactions, 1831.

‡ Journal of the Royal Institution for 1831, p. 101.

phenomena bear a satisfactory explanation on known principles, connected with the investigation just terminated, and do not require the assumption of any new state or new property. But as the experiments advanced, especially those of MARIANINI, require very careful repetition and examination, the necessity of pursuing the subject of electro-chemical decomposition obliges me for a time to defer the researches to which I have just referred.

Royal Institution,
November 30, 1833.

