some degree of certainty as Tertiary beds *in situ*. The sands at Netley Heath and at Chipstead have a remarkable *Upper* Bagshot facies. Those at Headley do not present such a strong character in this respect, but I have no hesitation in referring them on lithological grounds to the Bagshot series.

Wellington College, Berks, September 27. A. IRVING.

MODERN VIEWS OF ELECTRICITY.[1]

PART I.

I.

IT is often said that we do not know what electricity is, and there is a considerable amount of truth in the statement. It is not so true, however, as it was some twenty years ago. Some things are beginning to be known about it; and though modern views are tentative, and may well require modification, nevertheless some progress has been made. I shall endeavour in this lecture to set forth as best I may the position of thinkers on electrical subjects at the present time.

It will at once strike you that the whole subject of electricity as at present known is too gigantic for anyone to make an attempt to compass it in a single lecture, even though he assume on the part of his audience a perfect acquaintance with all the ordinary phenomena; and you will admit that it is much better to limit one's self definitely at the beginning to some one branch than by attempting too broad and discursive a survey to risk slurring the whole and becoming totally unintelligible.

I begin by saying that the whole subject of electricity is divisible for purposes of classification into four great branches.

(1) Electricity at rest, or static electricity: wherein are studied all the phenomena belonging to stresses and strains in insulating or dielectric media brought about by the neighbourhood of electric charges or electrified bodies at rest immersed therein; together with the modes of exciting such electric charges and the laws of their interactions.

(2) Electricity in locomotion, or current electricity: wherein are discussed all the phenomena set up in metallic conductors, in chemical compounds, and in dielectric media, by the passage of electricity through them; together with the modes of setting electricity in continuous motion and the laws of its flow.

(3) Electricity in rotation, or magnetism: wherein are discussed the phenomena belonging to electricity in whirling or vortex motion, the modes of exciting such whirls, the stresses and strains produced by them, and the laws of their interaction.

(4) Electricity in vibration, or radiation: wherein are discussed the propagation of periodic or undulatory disturbances through various kinds of media, the laws regulating wave velocity, wave-length, reflection, interference, dispersion, polarization, and a multitude of phenomena studied for a long time under the heading "Light." Although this is the most abstruse and difficult portion of electrical science, a certain fraction of it has been known to us longer than any other branch, and has been studied under special advantages, because of our happening to possess a special sense-organ for its appreciation.

Now, with some qualms of regret I have decided to refrain from speaking to you about any one of these great and comprehensive groups except the first. It is hopeless to attempt more; and even the small portion of that on which I shall touch will tax the time at our disposal to the utmost, and I must assume acquaintance with the elementary facts in order to proceed to their elucidation.

The great names in connexion with our progress in knowledge as to the real nature of electricity, irrespective of a mere study and extension of its known facts, are

FRANKLIN, CAVENDISH, FARADAY, MAXWELL.

To these, indeed, you may feel impelled to add the tremendous name of THOMSON; but one has some delicacy in attempting to estimate the work of living philosophers, and as Maxwell has been very explicit in acknowledging his indebtedness to his illustrious contemporary, whose work will in the course of nature have to be criticised and appraised by far abler hands than mine and by the philosophers of generations yet unborn, we may well afford to abstain from minute considerations and accept for the present the name of Maxwell as representative of the great English school of mathematical physicists, under whose influence, Cambridge, in the pride of having reared them, is awaking to new and energetic scientific life, and whose splendid achievements will shine out in the future as the glory of this century.

The views concerning electrification which I shall try to explain are in some sense a development of those originally propounded by that most remarkable man, Benjamin Franklin. The accurate and acute experimenting of Cavendish laid the foundation for the modern theory of electricity; but, as he worked for himself rather than for the race, and as moreover he was in this matter far in advance of his time, Faraday had to go over the same ground again, with extensions and additions peculiar to himself and corresponding to the greater field of information at his disposal three-quarters of a century later. Both these men, and especially Faraday, so lived among phenomena that they yielded up their hidden secrets to them in a way unintelligible to ordinary workers; but while they themselves arrived at truth by processes that savour of intuition, they were unable always to express themselves intelligibly to their contemporaries and to make the inner meaning of their facts and speculations understood. Then comes Maxwell, with his keen penetration and great grasp of thought combined with mathematical subtlety and power of expression; he assimilates the facts, sympathizes with the philosophic but untutored modes of expression invented by Faraday, links the theorems of Green and Stokes and Thomson to the facts of Faraday, and from the union there arises the young modern science of electricity, whose infancy at the present time is so vigorous and so promising that we are all looking forward to the near future in eager hope and expectation of some greater and still more magnificent generalization.

You know well that there have been fluid or material theories of electricity for the past century; you know, moreover, that there has been a reaction against them. There was even a tendency a few years back to deny the material nature of electricity and assert its position as a form of energy. This was doubtless due to an analogical and natural, though unjustifiable, feeling that just as sound and heat and light had shown themselves to be forms of energy so in due time would electricity also. If such were the expectation, it has not been justified by the event. Electricity may possibly be a form of matter—it is not a form of energy. It is quite true that electricity *under pressure* or *in motion* represents energy, but the same thing is true of water or air, and we do not therefore deny them to be forms of matter. Understand the sense in which I use the word electricity. *Electrification* is a result of work done, and is most certainly a form of energy; it can be created and destroyed by an act of work. But electricity—none is ever created or destroyed, it is simply moved and strained like matter. No one ever exhibited a trace of positive electricity without there being somewhere in its immediate neighbourhood an equal quantity of negative.

This is the first great law, expressible in a variety of ways: as, for instance, by saying that total algebraic pro-

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[1] Expansion of a lecture delivered by Dr. Oliver Lodge, partly at the London Institution on January 1, 1885, and partly at the Midland Institute, Birmingham, November 15, 1886, but not hitherto published.

duction of electricity is always zero ; that you cannot produce positive electrification without an equal quantity of negative also ; that what one body gains of electricity some other body must lose.

Now, whenever we perceive that a thing is produced in precisely equal and opposite amounts, so that what one body gains another loses, it is convenient and most simple to consider the thing not as generated in the one body and destroyed in the other, but as simply *transferred. Electricity in this respect behaves just like a substance.* This is what Franklin perceived.

The second great law is that electricity always, under all circumstance, flows in a closed circuit, the same quantity crossing every section of that circuit, so that it is not possible to exhaust it from one region of space and condense it in another.

Another way of expressing this fact is to say that no charge resides in the interior of a hollow conductor.

Another is to say that total induced charge is always equal and opposite to inducing charges.

[This is illustrated by the well-known experiment of insulating and charging a parrot-cage with a sensitive electroscope inside connected to its wires ; also by the ice-pail experiment.]

When we thus find that it is impossible to charge a body absolutely with electricity, that though you can move it from place to place it always and instantly refills the body from which you take it, so that no portion of space can be more or less filled with it than it already is, it is natural to express the phenomenon by saying that electricity behaves itself like a perfectly *incompressible* substance or fluid, of which all space is completely full. That is to say, it behaves like a perfect and all-permeating *liquid.* Understand, I by no means assert that electricity *is* such a fluid or liquid ; I only assert the undoubted fact that it behaves like one, *i.e.* it obeys the same laws.

It may be advisable carefully to guard one's self against becoming too strongly imbued with the notion that because electricity obeys the laws of a liquid therefore it is one. One must always be keenly on the look-out for any discrepancy between the behaviour of the two things, and a single certain discrepancy will be sufficient to overthrow the fancy that they may perhaps be really identical. Till such a discrepancy turns up, however, we are justified in pursuing the analogy—more than justified, we are impelled. And if we resist the help of an analogy like this there are only two courses open to us : either we must become first-rate mathematicians, able to live wholly among symbols and dispensing with pictorial images and such adventitious aid ; or we must remain in hazy ignorance of the stages which have been reached, and of the present knowledge of electricity so far as it goes. I need hardly say that by "modern views" I do not mean *ultimate* views ; nor do I mean that I can give an account of all the speculations and ideas floating in the minds of some two or three of our most advanced thinkers. All I attempt is to give an account of the stage which has certainly been attained, and to ask you to take for granted that the next quarter of a century will see as great advances made upon these views as they are superior to the doctrines inculcated by the ordinary run of text-books.

Imagine now that we live immersed in an infinite ocean of incompressible and inexpansible all-permeating perfect liquid, like fish live in the sea, and how can we become cognizant of its existence? Not by its weight, for we can remove it from no portion of space in order to try whether it has weight.

We can weigh air, truly, but that is simply because we can compress it and rarefy it. An exhausting or condensing pump of some kind was needed before even air could be weighed or its pressure estimated.

But if air had been incompressible and inexpansible, if it had been a vacuum-less perfect liquid, pumps would have been useless for the purpose, and we should necessarily be completely ignorant of the weight and pressure of the atmosphere.

How then should we become cognizant of its existence? In four ways :—

(1) By being able to pump it out of one elastic bag into another [not out of one bucket into another: if you lived at the bottom of the sea you would never think about filling or emptying buckets—the idea would be absurd ; but you could fill or empty elastic bags], and by noticing the strain phenomena exhibited by the bags and their tendency to burst when over full. [Water (or air) was here pumped out of one elastic bag into another, and the analogy with an electrical machine charging two conductors oppositely was pointed out.]

(2) By winds or currents ; by watching the effect of moving masses of the fluid as it flows along pipes or through spongy bodies, and by the effects of its inertia and momentum. [A hanging vane in a tube deflected by a stream of water was here likened roughly to a galvanometer ; also the effect of suddenly stopping a stream of water, as in a water ram, was mentioned as analogous to self-induction.]

(3) By making vortices and whirls in the fluid, and by observing the mutual action of these vortices, their attractions and repulsions. [Whirlwinds, sand-storms, waterspouts, cyclones, whirlpools.]

(4) By setting up undulations in the medium : *i.e.* by the phenomena which in ordinary media excite in us through our ears the sensation called "*sound.*"

In all these ways we have become acquainted with electricity, and in no others that I am aware of. They correspond to the four great divisions of the subject which I made above. But there are differences, very important differences, between the behaviour of a material liquid ocean such as we have contemplated and the behaviour of electricity. First it is doubtful whether electricity by itself and disconnected from matter has any inertia. It is by no means certain that it has not : the experiments made by Maxwell with a negative result need only prove either that its speed of flow is very small, or that an electric current consists of equal opposite streams of equal momentum. The laws of electric flow in conductors are such as indicate no inertia, and this fact would be conclusive were it not that a recent brilliant paper by Prof. Poynting explains the reason of it completely otherwise, and leaves the question of inertia quite open ; on the other hand, the facts of magnetism seem definitely to require inertia, or something corresponding to it. Leaving this therefore as an open question, there can be no doubt but that when in connexion with insulating or dielectric matter *the combination* most certainly possesses inertia.

A more serious and certain difference between the behaviour of electricity and that of an incompressible fluid comes out in the fourth category—that concerned with wave-motion. In an incompressible fluid the velocity and length of waves would both be infinite, and none of the phenomena connected with the gradual propagation of waves through it could exist. Such a medium therefore would be incapable of sound vibrations in any ordinary sense. On the other hand, it is quite certain that the disturbances concerned in light radiation take place at right angles to the direction of propagation—they are tranverse disturbances—and such disturbances as these no body with the entire properties of a fluid can possibly transmit. Remember, however, that the medium which transmits light is the ether and not simply electricity. We have nowhere asserted that electricity and the ether are identical. If they are, we are bound to admit that ether, though fluid in the sense of enabling masses to move freely through it, has a certain amount of rigidity for enormously rapid and minute oscillatory disturbances. If they are not identical, we can more vaguely say that ether contains electricity as a jelly contains water, but that the rigidity concerned in the transverse vibrations belongs not to the water in the jelly but to the mode in which it is entangled in its meshes. However all this is a great and difficult question into which we shall be able to enter with more satisfaction twenty years hence.

Provisionally we will accept as a working hypothesis the idea of the ether consisting of electricity in a state of entanglement similar to that of water in jelly; and we are driven to this view by the exigencies of mode 1, the electrostatic or strain method of examining the properties of electricity, because otherwise the properties of insulators are hard to conceive. If it turn out that space is a conductor, which seems to me highly improbable, then we must fall back upon the other view that it is rigid only for infinitesimal vibrations, and fluid for steady forces.

Return now to the consideration of electrostatics. We are to regard ourselves as living immersed in an infinite all-permeating ocean of perfect incompressible fluid (or liquid), as fish live in the sea; but this is not all, for if that were our actual state we should have no more notion of the existence of the liquid than deep-sea fish have of the medium they swim in. If matter were all perfectly conducting, it would be our state: in a perfectly free ocean there is no insulation—no obstruction to flow of liquid: it is the fact of insulation that renders electrostatics possible. We could obstruct the flow and store up definite quantities of a fluid in which we were totally submerged by the use of closed vessels of course. But how could we pump liquid from one into another so as to charge one positively and another negatively? Only by having the walls elastic: by the use of elastic bags, and elastic partitions across pipes. And so we can represent a continuous insulating medium (like the atmosphere or space) by the analogy of a jelly, through which liquid can only flow by reason of cracks and channels and cavities.

Modify the idea of an infinite ocean of liquid into that of an infinite jelly or elastic substance in which the liquid is entangled, and through which it cannot penetrate without violence and disruption; and you have here a model of the general insulating atmosphere. Our ocean of fluid is not free and mobile like water, it is stiff and entangled like jelly.

Nevertheless bodies can move through it freely. Yes *bodies* can, it is the *liquid* itself only which is entangled. How we are to picture freely and naturally the motion of ordinary matter through the insulating medium of space it is not easy to say. It is a difficulty not fatal but sensible, and due to an imperfection in our analogy.

Insulators being like elastic partitions or impervious but yielding masses, conductors are like cavities, porous or spongy bodies perfectly pervious though with more or less frictional resistance to the flow of liquids through them. Thus, whereas bodies easily penetrable by matter are impervious to electricity, bodies like metals which resist entirely the passage of matter, are quite permeable to electricity. It is this inversion of ordinary ideas of penetrability that constitutes a small difficulty at the beginning of the subject.

However, supposing it overcome, let us think of these insulated spheres and cylinders on the table connected by copper wire as so many cavities and tubes in an otherwise continuous elastic impervious medium which surrounds them and us, and extends throughout space wherever conductors are not. All, however, cavities as well as the rest of the medium, are completely full of the universal fluid. The fluid which is entangled in insulators is free to move in conductors; whence it follows that its pressure or potential is the same in every part of a conductor in which it is not flowing along. For if there were any excess of pressure at any point, a flow would immediately occur until it was equalized. In an insulator this is by no means the case. Differences of pressure are exceedingly common in insulators, and are naturally accompanied by a strain of the medium.

[Here certain electrostatic experiments were shown as evidence of the strain existing at the ends of a long insulated wire connected to a Voss machine.]

There have been, as you know, two ancient fluid theories of electricity—the one-fluid theory of Franklin, and the two-fluid theory of Symmer and others. A great deal is to be said for both of them within a certain range. There are certainly points, many points, on which they are hopelessly wrong and misleading, *but it is their foundation upon ideas of action at a distance that condemns them, it is not the fluidity*. They concentrate attention upon the conductors; whereas Faraday taught us to concentrate attention on the insulating medium surrounding the conductors—the "*dielectric*" as he termed it. This is the seat of all the phenomena: conductors are mere breaks in it—interrupters of its continuity.

To Faraday the space round conductors was full of what he called lines of force; and it is his main achievement in electrostatics to have diverted our attention from the obvious and apparent to the intrinsic and essential phenomena. Let us try and seize his point of view before going further. It is certainly true as far as it goes, and is devoid of hypothesis.

Take the old fundamental electric experiment of rubbing two bodies together, separating them, and exhibiting the attraction and repulsion of a pith ball, say, and how should we now describe it? Something this way.

Take two insulated disks of different material, one metal, say, and one silk, touch them together, the contact effects a transfer of electricity from the metal to the silk; rub slightly to assist the transfer, since silk is a non-conductor, then separate. As you separate the disks the medium between them is thrown into a state of strain, the direction of which is mapped out by drawing a set of lines, called lines of force, from one disk to the other, coincident with the direction of strain at every point. As Faraday remarked, the strain is as if these lines were stretched elastic threads endowed with the property of repelling each other as well as of shortening themselves; in other words, there is a tension along the lines of force and a pressure at right angles to them. When the disks are near, and the lines short, they are mainly straight, Fig. 1, but as the distance increases they become curved, bulging away from the common axis of the two disks, and some even curling round to the back of the disk (Fig. 2), until when the disks are infinitely distant as many lines spring from the back of each as from its face; and we have a charged body to all intents existing in space by itself.

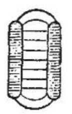

FIG. 1.—Rough diagram of the state of the medium near two oppositely charged disks when close together.

The state of tension existing in the medium between the disks results in a tendency to bring them together again, just as if they were connected by so many elastic threads of no length when unstretched. The ends of the lines are the so-called electrifications or charges, and the lines perpetually try and shorten and shut up, so that their ends may coincide and the strain be relieved. If one of the disks touch another conducting body, some of its lines instantly leave it and go to the body; in other words, the charge is capable of transference, and the new body is urged toward the other disk, just as the disk was from which it received the lines. If this new body *completely surrounds* the disk, it receives the whole of its lines, and the disk can be withdrawn perfectly free and inert. [Faraday's "ice-pail" experiment.]

Now take the two charged disks, facing one another, and let, say, a suspended gilt pith ball hang between them. Being a conductor there is no strain inside it, and so it acts partially as a bridge, and several of the lines pass through it—or, rather, they end at one side of it and begin at the other: thus it has opposite charges on its two faces—it is under induction (Fig. 3). Let it now be moved so as to touch one of the disks, the lines between it and the disk on that side have shut up, and it remains with those only which go to the other disk. In other words, it has received some lines from the touched disk. These will pull it over to the far disk and there shut themselves up. From that disk it receives more, and travels with their ends back to the first disk, and so on (Fig. 4), perpetually receiving lines and shutting them up until they are all gone and the disks are discharged.

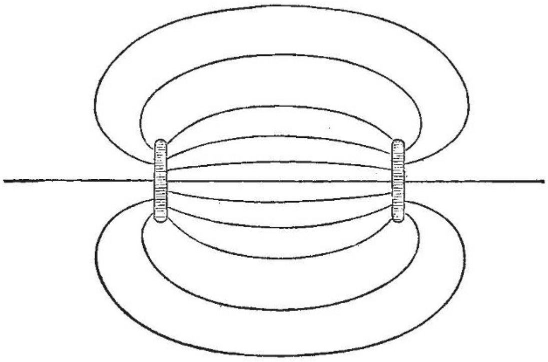

FIG. 2.—Rough diagram of the state of the medium near two oppositely charged disks when separated.

This mode of stating the facts involves no hypothesis whatever—it is the simple truth. But the "lines of force" have no more and no less existence than have "rays of light." Both are convenient modes of expression.

But so long as we adhere to this mode of expression we cannot form a complete mental picture of the actually occurring operations. In optics it is usual to abandon rays at a certain stage and attend to the waves, which we know are of the essence of the phenomenon, though we do not know yet very much about their true nature.

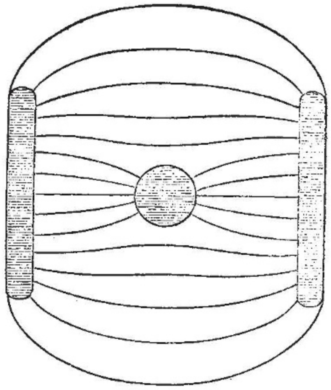

FIG. 3.—Rough diagram of the medium between two disks disturbed by the presence of an uncharged metal sphere. The two halves of the sphere are oppositely charged "by induction."

Similarly in electricity, at a certain point we are led to abandon lines of force and potential theories, and to try to conceive the actual stuff undergoing its strains and motions. It is then we get urged towards ideas similar to those which are useful in treating of the behaviour of an incompressible fluid.

In an utterly modified sense, we have still a fluid theory of electricity, and a portion of the ideas of the old theories belong to it also.

Thus Franklin's view that positive charge was excess and negative charge was a deficit in a certain standard quantity of the fluid which all bodies naturally possessed in their neutral state, remains practically true. His view that the fluid was never manufactured, but was taken from one body to give to another, so that one gained what the other lost—no more and no less—remains practically true. Part also—a less part—of the two-fluid theory likewise remains true, in my present opinion; but this is not a branch of the subject on which I shall enter in the present discourse. It will suffice for the present to fix our attention on one fluid only.

You are to think of an electric machine as a pump which, being attached to two bodies respectively, drives some electricity from the one into the other, conferring upon one a positive and upon the other a precisely equal negative charge. One of the two bodies may be the earth, in which case the charge makes little or no difference to it.

But, as has been objected before, if electricity is like an incompressible and inextensible fluid, how is it possible to withdraw any of it from one body and give it to another? With rigid bodies it is not possible, but with elastic bodies it is easy.

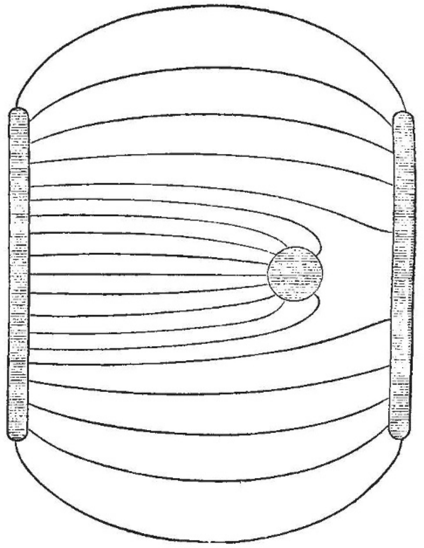

FIG. 4.—Rough diagram of the medium near two oppositely charged disks between which a metal carrier ball is oscillating, having just touched the right-hand disk. (Discharge by "alternate contact.")

The act of charging this sphere is therefore analogous to pumping water into this elastic bag, or rather into a cavity in the midst of an elastic medium, whose thick walls, extending in all directions and needing a great pressure to strain them, better represent the true state of the case than does the thin boundary of a bag like this.

Draw a couple of such cavities and consider fluid pumped from one into the other, and you will see that the charge (*i.e.* the excess or defect of fluid) resides on the outside. You may also show that when both are similarly charged the medium is so strained that they tend to be forced apart; whereas when one is distended and the other contracted they tend to approach.

Further you may consider two cavities side by side, pump fluid into (or out of) one only, and watch the effect on the other. You will thus see the phenomena of induction, the near side of the second cavity becoming oppositely charged (*i.e.* the walls encroaching on the cavity), the far side similarly charged (the cavity encroaching on the walls), and the pressure on the fluid in the cavity being increased or diminished in correspondence with the change of pressure in the charged or inducing cavity. In other words, conductors rise in potential when brought near a positively charged body.

The actual changes in volume necessary to the strain of these cavities are a defect in the analogy. To avoid this objection, one will have to accept a dual view of electricity—a sort of two-fluid theory, which many phenomena urge one to accept, but about which I will say nothing to-night. It is sufficient at first to grasp the one-fluid ideas.

Return Circuit.—Sometimes a difficulty is felt about electricity flowing in a closed circuit—as, for instance, in signalling to America and using the earth as a return circuit: the question arises, How does the electricity find its way back?

The difficulty is no more real than if a tube were laid to America with its two ends connected to the sea and already quite full. If now a little more sea-water were pumped in at one end, an equal quantity would leave the other end, and the disturbed level of the ocean would readjust itself. Not the same identical water would return, but an equal quantity would return. That is all one says in electricity. One cannot label and identify electricity.

To imitate the inductive retardation of cables, the tube should have slightly elastic walls; to imitate the speed of signalling, the water must be supposed quite incompressible, not elastic as it really is, or each pulse would take three-quarters of an hour to go.

Condensers.—Returning to the subject of charging bodies electrically, how is one to consider the fact that bringing an earth-plate near a conductor increases its capacity so greatly, enabling the same pressure to force in a much larger quantity of fluid? how is one to think of a condenser, or Leyden jar?

In the easiest possible way, by observing that the bringing near an earth-connected conductor is really *thinning down the dielectric* on all sides of the body.

The thin-walled elastic medium of course takes less force to distend it a given amount than a thick mass of the same stuff took. A Leyden jar is like a cavity with quite thin walls—in other words, it is like an elastic bag.

But if you thin it too far, or strain it too much, the elastic membrane may burst: exactly, and this is the disruptive discharge of a jar, and is accompanied by a spark. Sometimes it is the solid dielectric which breaks down permanently. Ordinarily it is merely the air; and, since a fluid insulator constitutes a self-mending partition, it is instantaneously as good as new again.

There are many things of interest and importance to study about a Leyden jar. There is the fact that if insulated, it will not charge: the potential of both inner and outer coatings rises equally; that, in order to charge it, for every positive spark you give to the interior an equal positive spark must be taken from the exterior. There is the charging and the discharging of it by alternate contacts, as by an oscillating ball; and there are the phenomena of the spark-discharge itself.

But, as you know, *all* charging is really a case of a Leyden jar. The outer coat must always be somewhere—the walls of the room, or the earth, or something—you always have a layer of dielectric between two charges—the so-called induced and the inducing charge. You cannot charge one body alone.

To illustrate the phenomena of charge, I will now call your attention to these diagrams—which less completely but more simply than hydraulic illustrations, serve to make the nature of the phenomena manifest.

(*To be continued.*)

ON THE TEACHING OF CHEMISTRY.[1]

THE question is being often asked, Why does chemistry progress so slowly in this country? Different answers, all more or less true, may be given; one answer that has not, I think, been sufficiently insisted on is: Because chemistry is so little taught.

Classes, nominally in chemistry, are conducted in many schools, and in almost all the colleges, of the country; but I assert that very little of what is taught is really chemistry. For what is it that is taught? On the one hand, catalogues of so-called facts detached from reasoning and from generalizations; on the other hand, definitions and generalizations and speculations detached from the facts on which they rest. But neither detached facts, however accurately stated, nor definitions, in however sharply-cut words they are contained, nor speculations, however interesting they may be, are science; and chemistry really is a branch of natural science.

It is admitted by all that hydrogen is a colourless, odourless gas, 14·435 times lighter than air, produced by the interaction of dilute sulphuric acid and zinc, combustible, condensable to a liquid at very low temperatures. These statements are facts; but when the student of chemistry is required to read, and if possible to remember, such facts as these about each of the elements and its compounds, the statements cease to be facts to him, and become false, inasmuch as they cover up and hide the really important facts regarding the interactions of elements and compounds, and regarding the connexions between changes of composition and changes of properties, which form the subject-matter of chemistry.

I have known students have at their finger-ends the properties of all the elements—as these properties are detailed in the ordinary text-books—and yet be almost wholly ignorant of chemistry.

And I have also known students ready at a moment's notice to repeat the orthodox definitions of atomic and molecular weights, or to draw structural formulæ of complex minerals, or to speak fluently about double bonds and unsaturated units of affinity, and yet be quite innocent of any knowledge of chemistry.

A fatal distinction is too often drawn by chemical teachers between the facts on which chemical science rests, and reasoning and generalizing on these facts: the former, that is statements of detached facts, is called chemistry; the latter, that is reasoning on facts and generalizing to principles, is called chemical philosophy. I believe strongly that there are not two chemistries, but one chemistry. If chemical teachers were quite decided as to what they ought to teach, we might hope for marked advances in our science.

My own experience in teaching chemistry convinces me that it is a very difficult subject both to teach and to learn. Of course there is no great difficulty in restating to a class what is printed in the text-book, and occasionally enlivening the routine by a few experiments; nor does it require high mental capacities and training to tell the laboratory student that bottle A contains a double salt, to be analyzed by the help of the tables on page so-and-so of the book. But do not let us call this kind of thing teaching chemistry. To teach chemistry well requires experience and an educated mind. It is not easy to hit the golden mean. If the teacher despises facts his reasoning becomes absurd, because it is based on nothing; his principles become only speculations; and his laws merely phrases. If he disregards principles, generalizations, and theories, his facts become false, and when facts are false (as they often are) they are deadly, and kill those that trust in them.

Chemistry is a branch of natural science; it deals with one class of natural occurrences, it observes and experi-

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[1] A Paper read before Section B of the British Association at Manchester, by M. M. Pattison Muir, M.A., Fellow of Gonville and Caius College, Cambridge.