

the effect of a moving charge is the same as that of an electric current conveying the same quantity of electricity in the same time, the author calculated the velocity of light from the results, and arrived at values ranging from  $2.95 \times 10^{10}$  to  $3.00 \times 10^{10}$ . This is a striking confirmation of Maxwell's theory, and a complete refutation of Crémieu's negative contentions.—H. Pender, *Phys. Review*, November, 1902.

**MAGNETOMETERS FREE FROM DISTURBANCE.**—It seems hardly likely at present that it will be found possible to devise undisturbed magnetometers corresponding to the galvanometers which have been protected from the disturbance of outside magnetic fields. But H. du Bois indicates a possible method of eliminating disturbances even of magnetometers, if they obey certain rules, although that elimination is necessarily tedious and associated with a certain loss of sensitiveness. As a rule, the effect to be measured is variable from point to point, and may be calculated for special positions. The disturbing effect is much subjected to variation in time, but when the source of disturbance is at some distance, it may, as a rule, be represented by a uniform horizontal component within a certain space. This indicates the possibility of differentiating the two effects. A rough-and-ready arrangement for thus measuring the magnetic moment of a bar magnet is indicated by the author. Two magnetometers are used, and placed at different distances along the same line drawn from the center of the bar. The difference of their readings is then proportional to the magnetic moment, and this difference is independent of any disturbance, such as that of an electric railway. The author describes various differential suspensions, but admits that the choice of a suspension depends altogether upon the particular disturbance to be combated.—H. du Bois, *Ann. der Physik*, No. 12, 1902.

**FORMATION OF OZONE.**—The electric discharge produces ozonization in a closed volume of oxygen, but the formation of ozone has a limit which varies with the conditions of the experiment. There exists, therefore, besides the ozonizing effect, a contrary effect which counterbalances it after a time. Now, since for the limited duration of the ozonizing process the spontaneous decomposition of the ozone is negligible, it follows that the electric discharge itself must produce the contrary effect. E. Warburg endeavors to obtain a measure of both effects, and starts from the assumption that the ozonizing effect is proportional to the number of molecules of oxygen present, while the decomposition is proportional to the number of molecules of ozone present. He shows that there is a decided difference between the behavior of a positive discharge and that of a negative discharge in this respect. The maximum percentage of ozone is about three times as high for negative as it is for positive discharges. When, after the negative maximum is reached, the mixture is subjected to the positive effluvia, the percentage falls to the positive maximum. The decomposing activity is the same for positive and negative electricity, but the ozonizing action itself is three times higher for negative electricity. The effect of temperature on both discharges is the same.—E. Warburg, *Ann. der Physik*, No. 12, 1902.

**ELECTRIC ORIGIN OF MOLECULAR ATTRACTION.**—W. Sutherland makes a highly interesting attempt to reduce molecular action to the electron theory. He starts with the conception of a neutral gaseous molecule, containing a positive and a negative electron. Such a molecule will have poles like a magnet, and will exert upon a similar molecule an attractive or a repulsive action accordingly as unlike or like poles are nearest. But an attraction tends to increase itself, and a repulsion tends to diminish itself, and so it comes about that on the whole there is more attraction than repulsion. Like magnets, the molecules attract each other with a force varying inversely as the fourth power of the distance. The author shows that a strong contrast is shown to the law of gravitation, and the first condition of the electron theory is satisfied by the fact that molecular mass does not enter into the expression for molecular attraction. It may be considered that the two electrons of a molecule like NaCl, when giving the line spectrum of sodium, revolve round one another in a circle of such size that centrifugal force and electric attraction are in equilibrium. They revolve perhaps entirely within the Na atom. The author calculates a theoretical frequency of revolution amounting to  $28 \times 10^{14}$  per second, which is about 10 times as large as that of the visible part of the spectrum.—W. Sutherland, *Phil. Mag.*, December, 1902.

**ELECTRIC PROPERTIES OF THIN METAL FILMS.**—J. Patterson has carried out some researches on the conductivity of thin metallic films with a view toward elucidating the problem of conduction in metals. The films were deposited *in vacuo* by the cathode discharge. He found that the resistivity of such films was several times greater than that of the metal from which they were deposited. The specific resistance of platinum films which have been subjected to the same treatment remains constant above a thickness of about  $7 \times 10^{-7}$  cm. Below this thickness the increase of specific resistance with decrease in the thickness is very rapid. Heat diminishes the resistance of both silver and platinum films, and the thinner the film the greater the decrease. In platinum films the greatest decrease is produced by the electric current. The values obtained for  $\lambda$ , the mean free path of the electron in the metal, are of the same order as those obtained from the change of resistance produced by a transverse magnetic field. In his experiments to determine the thickness of the transition layer, Vincent found  $\lambda = 6 \times 10^{-6}$  cm. The value calculated from the change of resistance of pure silver in a transverse magnetic field is  $\lambda = 1.3 \times 10^{-6}$  cm., and the author's present value is  $\lambda = 1.1 \times 10^{-6}$  cm. These figures are all of the same order.—J. Patterson, *Phil. Mag.*, December, 1902.

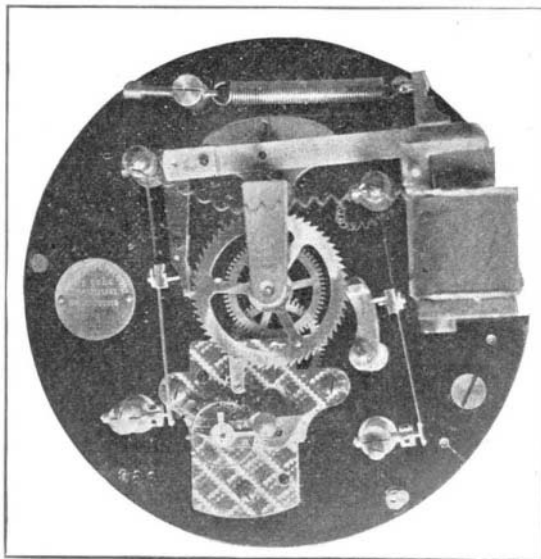
**MAGNETO-OPTIC BEHAVIOR OF LIQUID OXYGEN.**—According to Kundt and du Bois, the strongly magnetic metals Fe, Co, and Ni show also a strong magnetic rotation of the plane of polarization. Oxygen in the state of gas possesses the smallest Verdet constant measured, and the strongly magnetic solutions of

ferric chloride have a negative Verdet constant. This shows that there is no simple connection between magnetic and magneto-optic behavior. F. Harms has, therefore, studied the strongly magnetic liquid oxygen. Its susceptibility is, according to Fleming and Dewar,  $228 \times 10^{-6}$ , or four times that of an aqueous solution of FeCl<sub>3</sub>. He poured the liquid oxygen into a small beaker, on the bottom of which a plane mirror was fastened, and this beaker was placed between two vertical and co-axial electromagnets. Of these the upper one was hollow to transmit a beam of polarized light, which was reflected by the bottom of the beaker upward and analyzed. The double angle of rotation was 2.6 deg., or about one-fifth of the rotation in liquid carbon bisulphide, and about 2,000 times the rotation produced in the gas at the pressure of the atmosphere. The author gives a corrected table of rotations and susceptibilities for a number of solids, gases, and liquids, but fails to discover any regularity.—F. Harms, *Physikal. Zeitschr.*, December 1, 1902.

#### THE DAVID PERRET ELECTRIC CLOCK.\*

By EMILE GUARINI.

A new electric clock has been invented by Col. David Perret, the well-known Swiss electrician. According to Col. Perret, the motive force, as em-



THE PERRET ELECTRIC CLOCK.

ployed in electric clocks, has hitherto been attended with different causes of rapid wear or irregularity in running, among which may be mentioned particularly:

1. The more protracted duration of the closing of the circuit than is necessary; whence useless consumption of electric energy.
2. The oxidation of the pivoting parts of the apparatus when the current passes through the pivots.
3. The variation in the relative position of the different parts in contact by the wear caused by the oxidation of the contacts, when these occur with a sliding movement.
4. Closing and opening of the circuit at one and the same point of contact, by which the oxidation caused by the rupture spark increases the chances of imperfect contacts.

The David Perret motor can be applied to every system of spring or of pendulum clocks. It is characterized by a double circuit breaker, designed to avoid all the defects that have been mentioned. The motor and the clock work in the following manner:

A ratchet, *F* (Figs. 1 and 2), receives an advance movement, tooth by tooth, from the spring, *R*, which is energized by an electromagnet, *A*, every time that the ratchet, *F*, has advanced by one tooth, and when the two springs, *D* and *D'*, are both in contact with

When the extremity of the armature, *C*, is lowered under the action of the spring, *R*, the click, *C'*, presses the contact spring, *D'*, which is inserted in the circuit of the electromagnet, *A*, against the contact piece, *I'*, of the stop, *B'* (Fig. 1), in such a manner that the circuit of the electromagnet is closed, when toward the end of this action of the spring, *R* (Fig. 2), the spring, *D*, comes in contact with the contact piece, *I*, of the stop, *B*. The springs, *D* and *D'*, are then at the same time in contact; the first with the contact piece, *I*, the second with the contact piece, *I'*.

The stop, *B*, is connected with one of the poles of one or of two dry or liquid batteries, and the stop, *B'*, with the other. The stops, *B* and *B'*, and the two others to which the springs, *D* and *D'*, are attached, are insulated.

The spring, *D*, is left free to strike against the stop, *B*, or it is removed from it by a second click, *C''*, whose pivot, *e*, is fixed eccentrically on a button, *E*, which can turn in the plate of the movement. The pivot of the click, *C''*, may therefore be placed higher or lower by turning the button, *E*.

The clicks (Fig. 4) do not engage directly with their extremities with the ratchet, *F*; each one is furnished with a lateral pin, whose size is adapted to the function which the click fills.

The pin, *C'*, of the click, *C'*, is cylindrical, so that the friction between the pin and the teeth of the ratchet, *F*, may be reduced to the minimum.

The pin, *C''*, of the click, *C''*, is semi-cylindrical, so that it may be easily raised by the teeth of the ratchet, *F*, without exerting too much pressure on the spring, *D*. Too strong a tension of the spring, *D*, must be avoided; otherwise the ratchet, *F*, would experience too great a resistance in its movement.

The contact springs (Fig. 3), *D*, *D'*, have each several leaves, which, when expanded, are found in different but neighboring planes. The extremities of these leaves are furnished with thin plates of silver or of platinum or other but slightly oxidizable metal, which come in contact with the contact pieces, *I* and *I'*, also of silver or other slightly oxidizable metal, this contact taking place essentially by pressure.

As these different leaves, when expanded, are not in the same plane, one—*d*<sup>2</sup> for instance—will leave the contact last, and consequently will alone receive the rupture spark; it alone will be oxidized, and in spite of this oxidation the contact will take place very well with the other leaves, *d* or *d*<sup>3</sup>, which will prevent the disturbances so frequently occurring in other arrangements.

If, instead of oxidation, dust has settled anywhere, the multiplicity of leaves will afford the same remedy as against oxidation.

Such is the arrangement of the David Perret electric motor as applied to clocks.

If desired, the spring, *R*, may be replaced with a weight or with a storage battery of any force. The two stops, *B* and *B'*, may be replaced with one, but carrying two contacts, situated in two different points of the stop.

The simplicity of the mechanism, it must be acknowledged, could scarcely be surpassed. Col. Perret runs his clock with one or two dry batteries, which, once per minute and during about a three hundredth part of a second, have to furnish a feeble current. Their wear is therefore minimized. The durability of the batteries depends on their dimensions. The usual type adopted is guaranteed to last for three years, but the time will usually in most cases be much longer. Some clocks have been going for a long time, and the batteries which maintain them are far from being exhausted.

The electric system (as may be seen from the illustrations) is combined in such a way that the current does not touch any part of the horological movement. It traverses fixed pieces or springs and does not pass through any pivoting piece. There need therefore be no fear of the pivots becoming oxidized. The contacts, studied with the greatest care, in order to avoid their oxidation, are two in number; one establishing the electric current, the other breaking it. Consequently the clock runs with absolute security. The contacts need never be cleaned. The action of the spring replacing the barrel being renewed every min-

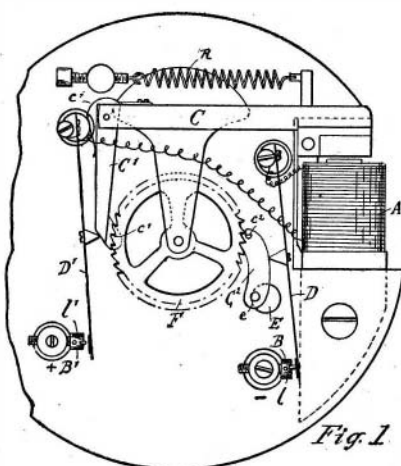


Fig. 1

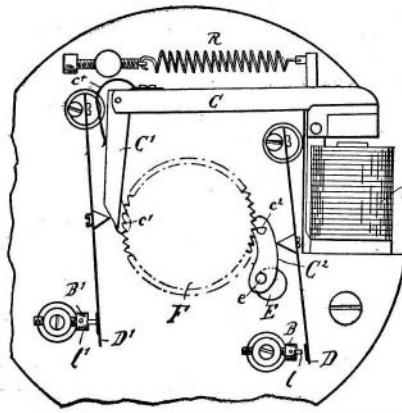


Fig. 2

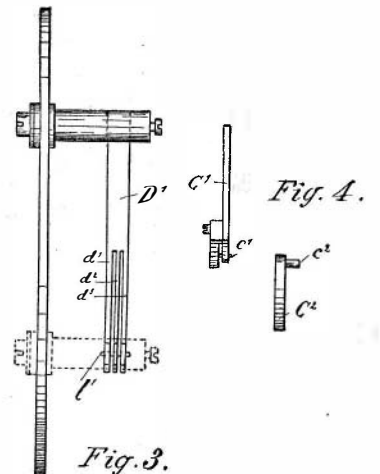


Fig. 3

DETAILS OF THE ELECTRIC CLOCK.

THE TRAIN OF GEARS.

the stops, *B* and *B'*. Fig. 1 shows the position at the moment when the spring, *R*, has been distended by the electromagnet. Fig. 2 shows it at the moment when the spring is on the point of being relaxed.

The extremities of the conductor of the electromagnet, *A*, are connected, one with the contact spring, *D'*, and the other with the contact spring, *D*. The armature, *C*, of the electromagnet carries a click, *C'*, which serves to start the ratchet, *F*. The click, *C'*, is pressed against the ratchet, *F*, by a spring, *C''*, in order to weaken the force of the spring, *D'*, sufficiently, and thus diminish the friction on the click.

ute by a small quantity of motive force, is practically constant. This spring acts directly on the minute arbor; the number of wheels is therefore reduced, and no organ is subjected to as strong a pressure as that endured by the barrel of a clock wound up for a week or a fortnight.

The David Perret electric clock is admirably adapted to the distribution of time, especially for post offices, telegraph stations, hotels, soldiers' barracks, railway stations, factories, theaters, hospitals, schools, and other public establishments. It has been adopted extensively in Switzerland. The David Perret astronomical clock installed at the Observatory of Neuchâtel, where it is utilized for the transmission of time

\* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

signals to the different stations, has, at ordinary temperature and pressure, a daily variation not exceeding three or four hundredths of a second, and goes quite as well as the other clocks of the observatory under constant pressure, according to the present Director of the Observatory, Dr. L. Arndt.

[Continued from SUPPLEMENT No. 1429, page 22899.]

#### ON ELECTRONS.\*

By SIR OLIVER LODGE, F. R. S., Vice-President.

#### PART III.

#### DETERMINATION OF SPEED AND ELECTROCHEMICAL EQUIVALENT OF CATHODE RAYS.

THE curvature of path produced in cathode rays by a transverse magnetic field, or the amount of rotation produced by a longitudinal magnetic field, constitutes an evident mode of attacking the problem of estimating their velocity.

If the velocity is constant and the magnetic field uniform, the curve into which the beam is bent will be a circle, and its course can be readily traced either directly, after Crookes' manner, by letting it graze a phosphorescent substance, or indirectly by inference from the position of a linear target placed so as to catch the deflected rays.

Consequently there will be no difficulty in determining the radius of curvature; and the theory is the simplest possible, nothing more than stating that the magnetic force, acting on the current element, is the necessary deflecting or centripetal force, required to overcome the mechanical inertia of the particles.

In 1897, J. J. Thomson arranged that the magnet should deflect the rays into an insulated hollow vessel, connected with an electrometer and a known capacity, so that the aggregate charge of the cathode ray particles collected in a given time could be measured by the rise of potential observed. He also arranged that inside the hollow vessel they should fall upon a thermal junction of known heat capacity, connected by very thin wires to a galvanometer (acting therefore as a calorimeter), so as to measure their aggregate energy.

When these brilliant measurements were actually made in the laboratory the atomic nature of cathode rays was, if not actually disproved, at all events rendered highly improbable; for their speed was found to be of the order ten thousand miles per second, or even as high as 1-10 that of light in a favorable case, being always of the order  $10^9$  c. g. s., while the electrochemical equivalent was of the order  $10^{-7}$  c. g. s., or about 1-1000 that of hydrogen.

Changing the kind or residual gas in the tube, and changing the electrodes, made no difference to this last value. The cathode rays were evidently independent of the nature of the matter present: an exceedingly momentous fact. If they were matter at all, they appeared to be matter of some fundamental kind independent of the distinctions of ordinary chemistry. Their velocity, however, depended on the potential difference between the electrodes, in a way that suggested that they were really projectiles urged by the potential gradient acting along a given length of path. They were propelled by the cathode through an aperture in the anode, and the measurement of their speed was made in the tube beyond the anode, where they are traveling by their own momentum. The distance apart of anode and cathode did not, and on the projectile hypothesis ought not to, affect this speed; for though the potential gradient is steeper when anode and cathode are put close together, the length of path during which the particles are subject to it is diminished by a compensating amount, so that the velocity is theoretically independent of the distance between the electrodes, as long as the total difference of potential is maintained; it is the absolute difference of potential that determines the speed. But manifestly if the electrodes are too close together it may be difficult to secure a high difference of potential between anode and cathode, since they may spark into each other outside the tube; and if there is much residual gas in the tube it will likewise be difficult to maintain a high potential difference, because that residual gas, under the influence of the cathode rays, will conduct. Consequently the best speeds are obtained at high vacuum; and if the density of the residual gas inside the tube is constant, the speeds will be constant. The nature of the electrodes makes no difference, unless they give off gas or otherwise make it difficult to maintain the required potential difference.

Although the speed of the particles in cathode rays was thus found excessively great, their energy was only moderate, and their aggregate mass therefore excessively minute; their aggregate electric charge, however, was considerable. They were able to raise an electrical capacity of 1.5 microfarads several volts, sometimes as much as 20 volts, in the course of a second; and in the same way they might be able to raise a calorimeter, whose heat capacity was about 4 milligrammes of water, by 2 deg. C. Nevertheless their mass was so small that it would have taken one hundred years to collect a weighable amount, and then only about one-thirtieth of a milligramme. They traveled with a velocity a hundred thousand times greater than the speed of rifle bullets, and represented the greatest velocity up to that time observed or even now known in matter, if matter they were; and the electrochemical equivalent, instead of coming out in accordance with that observed in liquids, came out some thousand times smaller; that is to say, the charge associated with each particle of the cathode rays seemed a thousand times greater in proportion to the mass than the charge associated with an electrolytic ion, even of hydrogen.

If the flying particles were really atoms, there was no escape from the certainty that they were extraordinarily highly charged atoms; but if, as seemed more likely to the instinct of most of those who worked at the subject, the charge on the flying particles was the same as the charge possessed by an

atom in electrolysis, then, assuming that the experiments were correct and correctly interpreted, there would be no escape from the conclusion that the mass associated with the ionic charge in cathode rays must be a thousand times smaller than the mass of a hydrogen atom; in which case the cathode projectiles might conceivably be the detached and hitherto hypothetical individual electrons or atoms of electricity themselves. It would be extremely rash, however, to jump to such a far-reaching conclusion on such comparatively scant evidence. The evidence must be confirmed by other departments of Physics or by other determinations based on a different method; and they must be further scrutinized in the light of the magnetized-radiation phenomenon observed by Prof. Zeeman, of Amsterdam. We will first describe a determination made by another method, and then some striking measurements applied to phenomena which belong apparently to other departments of Physics.

#### FURTHER MEASUREMENTS OF CATHODE RAY VELOCITY AND RATIO OF MASS TO CHARGE BY AID OF ELECTROSTATIC DEFLECTION.

Another and perhaps simpler method of determining the velocity and ratio of mass to charge was also employed by J. J. Thomson, viz., by deflecting the same rays both electrostatically and magnetically; by introducing a pair of supplementary electrodes, one above and one below the course of the rays inside the vacuum tube, and connecting them to the poles of a low potential battery, a few storage cells for instance, thus obtaining a vertical electrostatic field at right angles to the cathode rays. At the same time a magnetic field, produced by lateral magnet poles or by the lines of force due to an electric current in a circular ring, could be arranged at right angles to both the other directions; and thus the electrostatic deflection could be compared with, or used to neutralize, the magnetic deflection.

Let the cathode rays be received upon a needle-point covered with phosphorescent material and movable up and down in a measured manner; then the deflection of the rays can be observed by reading how much the needle has to be moved in order to catch a narrow beam which has traveled through a unit length of either an electric field of strength  $E$ , or a magnetic field of strength  $H$ .

This method appears to give fairly accurate results; and the outcome of the measurements is that when H or CO<sub>2</sub> or air is in the tube—

Velocity  $u = 2$  or  $3 \times 10^9$  centimeters per second,

$\frac{m}{e} =$  from 1.1 to  $1.5 \times 10^{-7}$  c. g. s. units.

The chief difficulty about this mode of experimenting

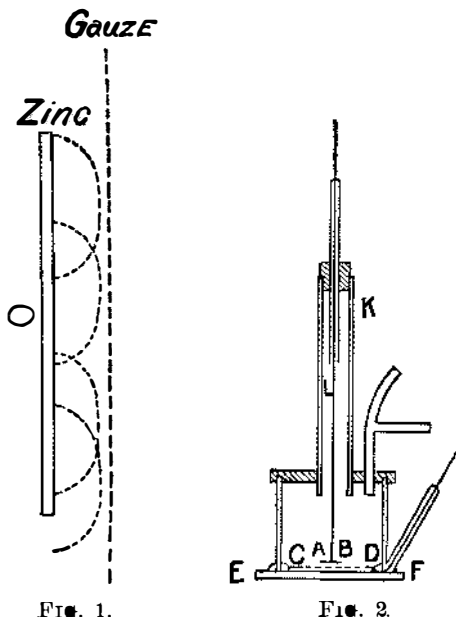


FIG. 1. A B is the insulated zinc plate, C D is the gauze, E F is quartz; the source of ultra violet light is at some distance below, and the vessel can be filled with any gas and exhausted.

is caused by the fact that the ionization of residual air in the tube causes it to become a temporary conductor, and so to screen the flying particles from most of the electrical influence. There is no guarantee that they feel the full effect of the electric field which is ostensibly being applied; indeed it is not easy to let them feel any of the effect. It used to be thought that they were not susceptible to electrostatic action at all, and this was often adduced as an obvious argument against their being electrically charged particles; but fortunately Thomson soon surmised the cause of this masking of the simple effect to be expected, and succeeded in showing that with high enough vacua and other precautions the screening ionized atmosphere could be removed; and the electrostatic deflection metrically observed.

#### DETERMINATION OF ELECTROCHEMICAL EQUIVALENT IN THE CASE OF ELECTRIC LEAKAGE IN ULTRA-VIOLET LIGHT.

The same ratio of  $m:e$ , or a ratio of quite comparable magnitude, is obtained from phenomena which at first sight appear to be distinct.

One of these phenomena is the effect of ultra-violet light in discharging negative electricity from a clean metal or other surface; a phenomenon the investigation of which was begun by Hertz, and continued especially by Righi and by Elster and Geitel. If ultra-violet light, whether from a spark or from a flame, fall upon a negatively electrified surface, then in general there will be a leak of electricity from that surface, which electricity can be received by any body placed opposite the illuminated one, and can be used to charge an electrometer of known capacity, and so be measured. The writer has made very many experiments in this subject, which, however, have not yet been published. Now Elster and Geitel made the notable discovery that the introduction of a magnet

affected the rate of leak, according to the direction of its lines of force. This phenomenon suggested a magnetic deflection of the lines of leak, which were shown by Righi to be singularly definite trajectories, and indicated that the leakage was due to the bodily propulsion of negatively electrified particles analogous to the cathode rays. A vacuum is not necessary to observe the effect, but in a vacuum the effect is more prominent and more accurately measurable. The difference between this case and an ordinary vacuum tube case is that there is no great E.M.F. or gradient of potential applied, there is accordingly nothing of the nature of a disruptive discharge; and in fact there is no leak at all until by the stimulus of the presumably synchronous vibrations of ultra-violet light the molecules are thrown into a state of agitation, and the attachment of the negative charge, or of some negatively charged corpuscles, thereby loosened.

Two things are necessary to get the particles away from the plate; they must be loosened by the impact of ultra-violet light—the direction of polarization of this light having a very decided influence—and the surface to which they cling must likewise be negatively charged, so as to repel them. Neither light alone nor electrification alone will produce the effect; co-operation is necessary.

J. J. Thomson devised a most ingenious method of carrying out this experiment in a metrical manner, and of deducing from it the electrochemical equivalent of the charged particles, that is to say the amount of matter which each contained compared with the electric charge which each carried. To this end he employed the usual arrangement of a small negatively charged zinc plate on which ultra-violet light from a distant arc-lamp could shine, through quartz, and also through a parallel piece of wire gauze connected with an electrometer. The distance between the zinc plate and the metallic gauze was variable, and the experiment consisted in observing how much electricity reached the gauze from the negatively charged plate, under the influence of light, first without, and then with, a magnetic field of measured strength applied crossways to the region between them.

A little calculation of extreme beauty showed him that the paths of the flying particles under magnetic influence would be cycloids, whose generating circles contained the ratio  $m/e$  as well as the ratio of electric to the magnetic field,  $E/H$ ; that is to say their trajectory, if it could be observed, would involve the electrochemical equivalent required and likewise the ratio of the electric to the magnetic field applied, as well as the absolute strength of the magnetic field.

The apparatus employed in determining this critical distance is shown in Fig. 2. The sharpness of actual experimental observation of the critical distance was not found quite so great as this simple theory would indicate, because of disturbing causes, one of which was the presence of some residual air, interfering with the perfectly free path of the moving bodies; nevertheless it was sharp enough for fair determination, and the result was again, in this case also, that the ratio  $e/m$  came out  $10^7$  c. g. s., or more exactly  $7 \times 10^6$ ; corresponding closely with the values found by J. J. Thomson, confirmed subsequently both by Lenard and Kaufmann, for the cathode ray particles.

Another phenomenon on which measurements were made was the discharge of electricity from an incandescent carbon filament in an atmosphere of hydrogen. This also is subject to disturbance by a magnetic field, as was shown by Elster and Geitel; and a series of measurements, on lines similar to the preceding, resulted in a value—

$$\frac{e}{m} = 8.7 \times 10^6 \text{ c. g. s.,}$$

a value of the same order of magnitude as before, one thousand times greater than the electrochemical or electrolytic value for hydrogen, and many thousand times greater than for other substances, but always constant and independent of the nature of the substance present.

The only things which give the ordinary electrolytic value for this ratio are the positive carriers. These are not so easy to observe, but Wien has examined these by detecting and measuring the slight magnetic deflection exhibited by certain rays behind the cathode in a vacuum tube, which Goldstein discovered and called *Kanal-strahlen*, and which Ewers proved were carriers of positive electricity. Wien has shown that they move slowly, and that in hydrogen their ratio  $e/m$  is of the order  $10^4$ , that is to say the proper value for a hydrogen atom or ion; and with other substances the ratio has been found to vary with the substance and approximately to equal the electrolytic value, for these positively charged particles. J. J. Thomson has likewise made measurements on the positive carriers by means of the discharge from incandescent filaments and other positively charged hot bodies, and has confirmed Wien's results.

Thus it is forcibly suggested that whereas the positive carriers of electricity are ions, consisting of a unit + charge associated with an atom, the negative carriers appear to be dissociated from the main bulk of the atom, as if they were only fractions or fragments or constituents or appendages of an atom, which, detached and flying loose, are able to attain to prodigious speed; since any acceleration to which they are subjected is a thousand-fold greater than it is even for an atom of hydrogen, weighed down and burdened as that is with a mass of inert material and subject only to the very same propulsive force.

Think of the mobility of a set of particles which experienced the usual gravitation intensity  $g$  and only 1-1000 of the mass to carry. There is no known way of thus intensifying gravity—there are plenty of ways of diluting it, e.g. Atwood's machine, an inclined plane, etc., etc. But such a mobile particle as that we are now considering would drop under the influence of gravity not 16 feet in the first second, as everything we know does near the surface of the earth, but 16,000 feet, or about three miles; and would in one second acquire under gravity a velocity of six miles per second, enough almost to carry it out of the range of the earth's attraction altogether, and more than enough to carry it round the world.

\* Excerpt from a paper read before the Institution of Electrical Engineers and published in the Journal of Proceedings of the Institution.