November 20, 1879.

THE PRESIDENT in the Chair.

In pursuance of the Statutes, notice of the ensuing Anniversary Meeting was given from the Chair.

Mr. George Matthey was admitted into the Society.

Mr. Bramwell, Mr. Busk, Mr. De La Rue, Mr. Newmarch, and Mr. Perkin, having been nominated by the President, were elected by ballot Auditors of the Treasurer's Accounts on the part of the Society.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "Experimental Researches on the Electric Discharge with the Chloride of Silver Battery." By WARREN DE LA RUE, M.A., D.C.L., F.R.S., and HUGO W. MÜLLER, Ph.D., F.R.S. Received August 7, 1879.

(Abstract.)

PART III.—*Tube-Potential; Potential at a Constant Distance and Various Pressures; Nature and Phenomena of the Electric Arc.*

In the first part of this paper the authors describe a series of experiments to determine the potential necessary to produce a discharge in a tube, exhausted gradually more and more while using a constant number of cells in all the experiments. In consequence of the life of the battery becoming so much exhausted by the method employed, the experiments were confined to one gaseous medium, namely, hydrogen. Since the completion, however, of the measurements described in the paper, the authors have found two other more convenient methods for determining the tube-potential, which do not exhaust the battery injuriously; these are described in an appendix. The tube, 162, employed was 33 inches long and 2 inches in diameter, the distance between the ring and straight wire terminals being 29·75 inches; the battery consisted of 11,000 cells. The discharge took place when the pressure was reduced to 35·5 m.m., 46,710 **M**, and the exhaustion was afterwards continued gradually until it fell to 0·0065 m.m., 8·6 **M**. In commencing each set of experiments the deflection of a tangent-galvanometer was observed when the battery was short-circuited. By

a table previously calculated, the value of the deflection in ohms of resistance per cell could be read off; this multiplied by 11,000 gave the total resistance of the battery; the tube was then connected with the terminals and the galvanometer again observed; this gave a less deflection and indicated a greater resistance, which, multiplied by 11,000, gave the total resistance of the tube and battery: by subtracting the resistance of the battery the resistance of the tube was ascertained. Calling the total resistance R, the tube resistance r, the tube-potential V, $V=\frac{r\times 11,000}{R}$. The tube-potential requisite to produce a discharge, with a pressure of 46,710 M, was found to be 10,250 cells; this gradually fell until a pressure of 0·642 m.m., 1,082 M, was reached, the tube-potential being then only 430 cells, after which it rapidly rose and, at 8·6 M, it required a potential of 8,937 cells to produce a discharge. From the experiments described in Part II (p. 103, foot note), it was found that, in another tube, it required the full potential of 11,000 cells to produce a discharge at 3 M, and that, at 1·8 M, this potential was insufficient. The obstruction to the discharge in tube 162 was as great at 8·6 M, as at 28,553 M pressure, and required 8,950 cells in each case. A few of the more remarkable phases of stratification in tube 162 are shown in one of the plates which illustrate the paper.

The next part of the paper deals with the potential necessary to produce a discharge between disks 1·5 inch in diameter, at a constant distance and at various pressures.

In the first instance, an experiment was made in order to ascertain whether there was either any condensation or dilatation of the gas in contiguity with the terminals before the actual passage of the discharge. In order to do this an apparatus was constructed, as shown in fig. 1.

It consists of a glass cylinder, the depth of which is accurately the same in every part, so as to ensure the parallelism of two glass disks which close its ends.

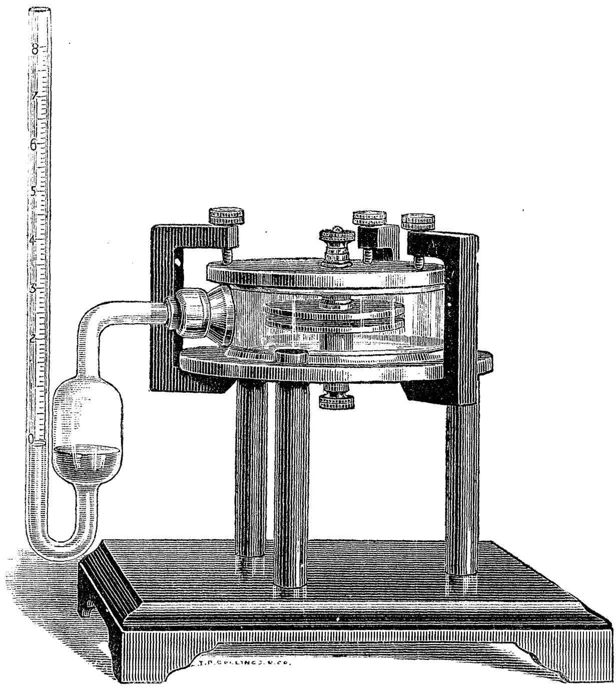
These are held in contact with the ends of the cylinder by means of screw-clamps made of ebonite, and the whole apparatus is supported on a tripod ebonite stand, which is fastened to a square wooden foot. Attached parallel to the top and bottom glass disks, by means of flanged-screw rods, are two brass disks with rounded edges, 4 inches in diameter; these are maintained at a distance of 0·13 inch, 3·3 m.m., at which the discharge of 11,000 cells would only just take place.

The ends which project through the glass disks are furnished with binding-screws for attaching wires from the battery.

On the side of the cylinder is a tubulure in which is fitted a gauge containing strong sulphuric acid, so as to dry the inside of the apparatus, and to indicate whether any condensation or dilatation of the

gas contained in the cylinder occurs on connecting the metallic disks with the battery by means of the contact-key. The edges of the cylinder were rubbed with grease, and care was taken to prove that the apparatus was perfectly tight, by causing the fluid in the limb of the gauge to stand for some time higher than that in the bulb. When contact was made with a battery of 9,800 cells, there was not the

FIG. 1.



slightest indication of any alteration of volume of the contained air, so that there was neither condensation about the disks which would have caused a contraction, nor repulsion from the disks which would have caused an expansion of volume. The fluid in the stem was observed with a lens, but not the slightest motion of it took place. The same result was noticed even when water was substituted for sulphuric acid. So far, then, as this apparatus would indicate it, the result is entirely negative.

Potential necessary to produce a discharge between disks at a constant distance and at various pressures.

The experiments were made by placing the micrometer-discharger, Part I, fig. 1, under a bell-jar, and in the first instance adjusting the

disks to the striking distance at atmospheric pressure for the battery of 11,000 cells. Afterwards a less number of cells was connected with the disks and the bell-jar gradually exhausted until the discharge occurred; the height of the gauge was then read off. Then a less and less number of cells was connected with the disks and the operation was repeated. There was a gauge about 36 inches long attached to the pump-plate in order to indicate the pressure beyond the range of the gauges attached to the pumps.

In air the discharge took place at ordinary atmospheric pressure with 11,000 cells when the disks were 0·13 inch, 3·3 m.m. distant; and with 600 cells at an average pressure of 10 m.m.

In hydrogen it took place at atmospheric pressure with 11,000 cells when the disks were 0·22 inch, 5·59 m.m. distant; and with 600 cells at an average of 14 m.m. pressure.

In carbonic acid, at atmospheric pressure with 11,000 cells, when the disks were 0·122 inch, 3·096 m.m. distant; and with 600 cells at an average pressure of 5·2 m.m.

The numbers obtained for air, hydrogen, and carbonic acid respectively were plotted down on millimetre scale paper, the abscissæ being 1 m.m.=2,500 M, the ordinates 1 m.m.=25 cells, and curves drawn to give a mean of the several observations. These appeared to resemble hyperbolic curves so closely that true hyperbolic curves were found partly by a geometric construction, partly by computation, which would intersect the mean experimental curves in two points. The results of experiment were again laid down on these new curves, and it was found that they did not differ more from them than they did from each other.

The ratio of the transverse axis (pressure) to the conjugate axis (potential) of the hyperbolas set out on the above-mentioned scale, was—

For air	0·9665
,, hydrogen	1·0170
,, carbonic acid	1·0690

The striking distances at atmospheric pressure for spherical surfaces 3 inches radius and 1·5 inch diameter, with various potentials, as given in Part I, page 14, curve VIII, and at page 64, also those for nearly flat surfaces in pages 19 and 64, were reduced to millimetres distance and plotted down in the same way, but not on precisely the same scale as the preceding curves for constant distance and various pressures. Hyperbolic curves were also found which intersected the experimental curves in two points.

It was seen in the case of spherical surfaces, the result having been obtained as the average of a great number of experiments, that the hyperbola coincided closely with the observations, while for plane

surfaces, for which only a few experiments were made, the coincidences were not quite so perfect. Nevertheless, it would appear that the law of the hyperbola holds equally well for a constant pressure and varying distance as it does for a constant distance and varying pressure; the obstacle in the way of a discharge being up to a certain point as the number of molecules intervening between the terminals.*

In the two cases of spherical and plane surfaces the ratio between the transverse (distance) and conjugate (potential) axes of the respective hyperbolas was—

For spherical surfaces	1·240
,, disks	1·285

With the data already published in Part I, the authors have laid down a fresh curve for the striking distance between flat disks on a scale of 10 centims. for a millimetre and 5 centims. to 1,000 cells.

From the curve thus laid down the following numbers were deduced:—

EMF in volts.	Striking distance in centimetres.	Difference of potential per centimetre.	Intensity of force.	
			Electromagnetic.	Electrostatic.
		volts.		
1,000	0·0205	48,770	$4·88 \times 10^{12}$	163
2,000	0·0430	46,500	4·65 ,,	155
3,000	0·0660	45,450	4·55 ,,	152
4,000	0·0914	43,770	4·38 ,,	146
5,000	0·1176	42,510	4·25 ,,	142
6,000	0·1473	40,740	4·07 ,,	136
7,000	0·1800	38,890	3·89 ,,	130
8,000	0·2146	37,280	3·73 ,,	124
9,000	0·2495	36,070	3·61 ,,	120
10,000	0·2863	34,920	3·49 ,,	116
11,000	0·3245	33,900	3·39 ,,	113
11,309	0·3378	33,460	3·35 ,,	112

The remainder of the paper is chiefly occupied with the study of the phenomena of the electric arc under various conditions of distance, pressure, and potential; the results obtained support the view that the arc and the stratified discharge are merely modifications of the same phenomenon.

* Dr. Alexander Macfarlane has published in the "Transactions of the Royal Society of Edinburgh," 1878, vol. xxvii, an elaborate and careful research of the "Disruptive Discharge of Electricity" in air and different gases, and between terminals of various forms. An abstract of this paper will be found in "Nature," December 26, 1878, pp. 184, 185. Dr. Macfarlane used a Holtz machine and employed higher potentials than those we used; he found that the results for the discharge between two disks 4 inches in diameter at various distances up to 1·2 centims. and with various pressures were satisfactorily represented by the hyperbola.

The experiments were made in a bell-jar, containing the terminals, which could be gradually exhausted after having been filled with air or other gas. One of the terminals was fixed to the bottom plate, the other could be adjusted to any distance from it by a rod sliding through a stuffing-box in the glass cover. The foot of the stand was insulated by a disk of ebonite, on which it stands. One such bell-jar is $9\frac{1}{4}$ inches (23·4 centims.) high and $5\frac{7}{8}$ inches (14·9 centims.) in diameter; its cubical content, obtained by covering the open ends with glass plates and filling with water from a graduated measure, was found to be 3,787 cub. centims.

A remarkable phenomenon was observed on making connexion between the terminals and the battery by means of the discharging key (already described in Part I, page 4), namely, that within certain limits of pressure in the bell-jar a sudden expansion of the gas took place, and that as soon as the connexion was broken the gas then as suddenly returned nearly, but not quite, to its original volume in consequence of a slight increase of temperature. The effect was exactly like that which would have been produced if an empty bladder had been suspended between the terminals, and suddenly inflated and as suddenly emptied.

The followed experiment in rarefied air, at a pressure of 56 m.m., at a temperature of 17°·5 C., will give an idea of the amount of instantaneous expansion which occurs when the terminals are connected with the poles of the battery of 11,000 cells, current 0·01102 W; the resistance of the bell-jar was reproduced by substituting 600,000 ohms wire resistance.

	m.m.		M.
Distance of the terminals—the top one a point, the lower a disk—6 inches; pressure	56		73,684
On making contact the arc passed and the column of mercury was depressed......	15·8		20,789
Pressure on connexion........	71·8	=	94,473

The increased was to the normal pressure in the ratio of 1·282 to 1; as the gas was kept at a constant volume, and supposing the expansion to be due to an increase of temperature, the pressure would vary as the absolute temperature,* therefore $\frac{T'}{T}=\frac{71\cdot8}{56}=1\cdot282$, whence $T'=1\cdot282\times291\cdot2=373^\circ\cdot3$ C.; $(373\cdot3-273\cdot7)=99^\circ\cdot6$ C., the temperature of the bell-jar, and $(99\cdot6-17\cdot5)=82^\circ\cdot1$, the rise of temperature while the discharge was taking place. But the temperature of the bell-jar as determined by a thermometer enclosed in it with its bulb uppermost only rose 0°·64 C. per second, taking into account the rate

* Absolute zero $=273\cdot7$ C., $273\cdot7+17\cdot5=291\cdot2$.

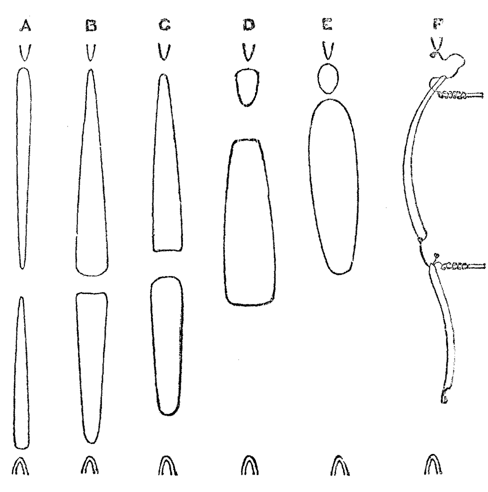
of cooling. It is evident, therefore, that the increase of pressure cannot be ascribed to the instantaneous heating of the bell-jar 82° C.

Taking the dimensions of the arc from a photograph, it was calculated that it must have attained the enormous temperature of 16,114° C., if the increase of pressure was really due to heat. It was found that platinum wires 0·001 inch in diameter supported in various parts of the arc were immediately fused; the temperature of the arc was therefore as high as the fusion-point of platinum, and possibly considerably higher.

If the whole of the heat evolved by a current of 0·01102 W, through a resistance of 600,000 ohms had been communicated to the air in the jar, weighing 0·339 grm. it would raise it 215°·6 C. in one second. It is known from direct experiment that this enormous evolution of heat was not communicated to any extent to the air in the bell-jar, because its temperature only increased about 0°·64 C. per second; the heat must consequently have escaped almost instantaneously by radiation. It is difficult consequently to realise the conjecture that the enormous dilatation which occurred instantaneously could have been caused by increase of temperature. And it points to its being produced by a projection of the molecules by electrification causing them to press outwards against the walls of the containing vessel, this pressure being distinct from the motion caused by heat.

The authors proceed to describe the appearance of the arc with terminals of various forms at different distances and with various pressures. It was found that the light emitted by different parts of the arc was not of the same intensity throughout, and that from the first there was a tendency to break up into distinct entities, as shown in the

Fig. 2.



diagram, fig. 2, which only indicates the central bright portion of the arc, this never quite reached the negative terminal, near which there was always the well-known dark discharge.

As the pressure was diminished the arc widened out until at last the entire surface of the negative disk was covered with a luminous halo, and the discharge took up a stratified appearance.

The appearances presented by the arc in air, hydrogen, and carbonic acid are copiously illustrated by copies, in mezzotint, of photographs and drawings as in Part II in the case of stratified discharges in tubes. During the course of these observations the increased pressure caused by the current was recorded, and an arrangement was made to ascertain whether the increase of pressure was greater near one or the other terminal. For this purpose a divided bell-jar was constructed, both ends of the two halves being accurately ground, and a glass disk divided the chamber into two parts; in this there is a hole half an inch in diameter made with a raised rim, in order that plates of mica with holes of different diameters might be cemented with Canada balsam centrally to the diaphragm. The capacity of the upper half was found to be 1,530 cub. centims., that of the lower half 1,755, total 3,285.

That portion of the chamber which was in communication with the gauge was connected alternately with the positive or negative terminal of the battery, and the depression noted. When this chamber was either − or + the ratio of increase to the normal pressure was—

−	+
1·44	1·39
1·34	1·41
1·13	1·20
1·22	1·34
1·38	1·40
1·16	1·11
1·19	1·16
1·266	1·287

It would appear therefore that the dilatation of the gas is the same both in the positive and negative chambers.

In order to prosecute their experiments in a vessel of still greater capacity, the authors had constructed a larger jar with a neck at each end, or more properly speaking perhaps, a tube supported horizontally on ebonite crutches. It is 37 inches long and $5\frac{13}{16}$ inches in diameter, its cubical content was found to be 14,435 cub. centims., or 3·8 times that of the bell-jar employed in the experiments on the electric arc.

The experiments with this tube will necessarily occupy a considerable period, partly on account of the long time it takes to exhaust

it after each set, partly on account of the variety of experiments it is intended to make with it; consequently they describe only a few of the first results hitherto obtained.

For Example in Air.

Pressure 3 m.m., 3,947 M, 6,300 cells. Two luminosities were formed, the ring negative being surrounded with a nebulosity which completely filled the end of the tube. The tube glowed brilliantly with a blue fluorescent light, which proved to have great actinic power. A dry-plate photograph obtained in 5 seconds records a very curious phenomenon, namely, that the outer boundary of the luminosity appears *darker* than the tube. It is to be remarked that while the discharge was reddish (nitrogen), the fluorescence of the tube was blue; the effect appears to be due to the absorption of a portion of the fluorescent light emanating from the back of the tube in passing through the red luminosity. The effect was quite unexpected, and it was thought at first that it might have arisen from some peculiarity in the development of the dry plate; it was not therefore until the result had been confirmed by other photographs that they ventured on the explanation above given.

The paper closes with the following conclusions:—

1. *For all gases there is a minimum pressure which offers the least resistance to the passage of an electric discharge. After the minimum has been reached, the resistance to a discharge rapidly increases as the pressure of the medium decreases.* With hydrogen the minimum is 0·64 m.m., 842 M; at 0·002 m.m., 3 M, it is as great as at 35 m.m., 46,000 M.

2. *There is neither condensation nor dilatation of a gaseous medium in contiguity with charged terminals.*

3. *When the discharge takes place there is a sudden dilatation of the medium in addition to and distinct from that caused by heat. This dilatation ceases instantaneously when the discharge ceases.*

4. *The potential necessary to produce a discharge between parallel flat surfaces at a constant distance and various pressures, or at a constant pressure and various distances, may be represented by hyperbolic curves. The resistance of the discharge between parallel flat surfaces being as the number of molecules intervening between them.*

5. *This law does not hold with regard to points. In Part I it has been shown that the potential necessary to produce a discharge at the atmospheric pressure and various distances is as the square root of the distances, while with a constant potential and various distances, the pressure has to be diminished in a greater ratio than that of the increase of distance in order to permit a discharge to take place.*

6. *The electric arc and the stratified discharge in vacuum tubes are modifications of the same phenomenon.*

Lastly, the authors say:—

"We have again pleasure in thanking Professor Stokes for his much-valued advice during the course of our investigations. To our assistant, Mr. Fram, we are indebted for his able co-operation, and we have to thank Mr. H. Reynolds for his aid and skill in taking photographs."

II. "Researches on the Action of Organic Substances on the Ultra-Violet Rays of the Spectrum. Part III. On Examination of Essential Oils." By W. N. HARTLEY, F.R.S.E., &c., Professor of Chemistry in the Royal College of Science for Ireland, Dublin, and A. K. HUNTINGTON, F.I.C., F.C.S., Associate of the Royal School of Mines. Received July 22, 1879.

(Abstract.)

Much chemical and physical research by various investigators has been devoted to the class of bodies known as Essential Oils, as, for instance, the work of Dr. J. H. Gladstone ("Journal of the Chemical Society," vol. xviii, p. 1; vol. xxiii, p. 147; vol. xxv, p. 1); of Dr. C. R. A. Wright ("Journal of the Chemical Society," vol. xxvi, pp. 549 and 686; vol. xxvii, pp. 1, 317, and 619, Isomeric terpenes and their derivatives); and of Dr. W. A. Tilden (*loc. cit.*, vol. xxviii, pp. 514 and 1258), as well as of many others.

The new method of research employed by us and described in a paper about to be published in the "Philosophical Transactions," has been applied to the examination of these substances. We have to acknowledge the kindness with which several gentlemen have supplied us with samples of essential oils, namely, Dr. Gladstone, Mr. Farries, of the firm of Burgoyne, Burbidges, Cyriax, and Farries, Dr. Septimus Piesse, and Dr. W. A. Tilden.

As in our previous experiments (Abstracts of Parts I and II, "Proc. Roy. Soc.," No. 192, 1879), photographs were taken of the spectrum transmitted by the undiluted liquid, and then of that transmitted by the liquid in various states of dilution, the dilutions ranging in some cases from 1 in 50 to 1 in 500,000 volumes of alcohol.

The following is a list of substances examined, classified according to the optical properties they were found to possess.

Oils and hydrocarbons transmitting continuous spectra.

Australene, from oil of turpentine.	Calamus.
Birch bark.	Citron.
Cajputene dihydrate.	Citronella.
Carraway hydrocarbon (No. 2).	Cedar wood.

FIG. 1.

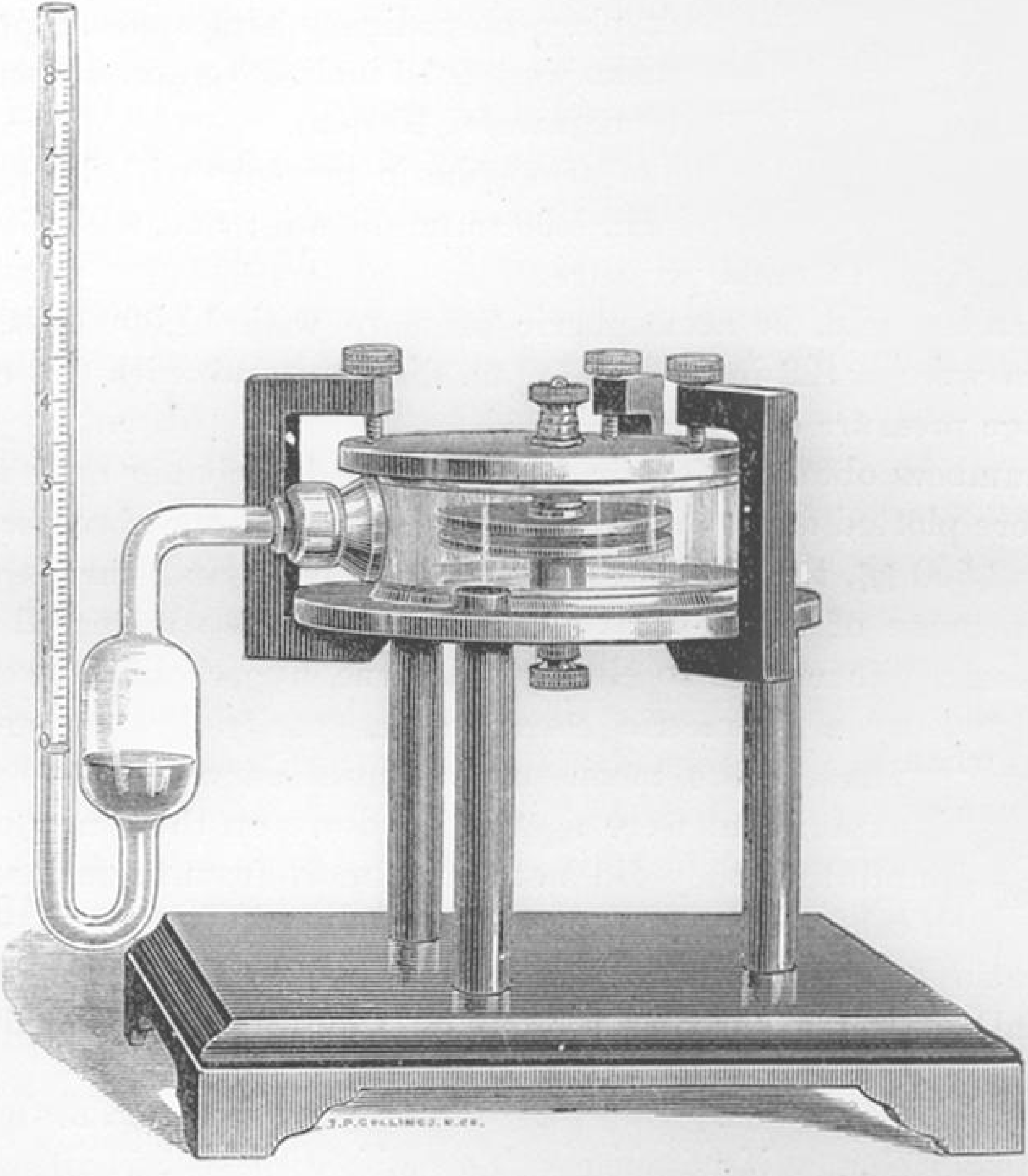


FIG. 2.