

XXVII. *An Account of a Doubler of Electricity, or a Machine by which the least conceivable Quantity of positive or negative Electricity may be continually doubled, till it becomes perceptible by common Electrometers, or visible in Sparks. By the Rev. Abraham Bennet, M. A.; communicated by the Rev. Richard Kaye, LL.D. F. R. S.*

Read May 10, 1787.

THE great importance of a machine for the purpose of detecting very minute quantities of electricity has occurred to many of the cultivators of this science; as by such an assistant not only many chemical combinations or solutions, but also many yet unexplained atmospheric phenomena, may become intelligible.

The labours of M. VOLTA have been very successful on this subject by the application of his condenser (as he terms it), which, by means of a thin-coated electric, is capable of receiving a greater quantity of the electrical fluid than a common insulated conductor, and rendering it perceptible by separating the positive and negative sides of the charged plate. On this ingenious contrivance Mr. CAVALLO made a very considerable improvement by transferring the received quantity of electricity from a larger to a smaller condenser, as explained in the Phil. Transf. Vol. LXXII.

Notwithstanding the very great sensibility of this apparatus, the electricity of the atmosphere is sometimes too weak to be discoverable by it: for instance, in some showers, when the negative state of the falling rain is nearly equal to the positive state of the air. Add to this the trouble of keeping an insulated and elevated conductor sufficiently dry, and the danger

ger of it in a thunder-storm. I therefore contrived the following doubler for the purpose of more easily making an electrico-meteorological diary, which I undertook at the request of my friend Dr. DARWIN, who hoped, that from thence some lights might be thrown on the causes of the sudden changes of ærial currents, a circumstance of so much importance to the early growth and maturity of vegetation.

I place upon my electrometer, described in a former Part of the Philosophical Transactions, a circular brass plate, three or four inches in diameter, polished and thinly varnished on the upper surface. On this I place another brass plate, of equal diameter, polished and varnished on both sides, with an insulating handle attached to one edge of it. A third plate is also provided, of equal diameter, polished and varnished on the under side, and with a perpendicular insulating handle from the center of the upper side, similar to those mentioned in the Appendix to my last Paper.

The method of collecting electricity from the atmosphere, and continually doubling it as much as required, is as follows. If the weather be dry, I carry into the open air a lighted torch, not liable to be easily blown out, or a small lantern with a lighted candle in it, to the bottom of which is fixed, by means of a socket, an insulating handle of glass covered with sealing-wax; in the other hand is carried a coated phial: then, elevating the flame a little higher than my head, I apply to it the knob of the phial, holding it in this situation about half a minute. Then returning into the house (where the above described doubler is kept dry, by being placed on a table not far from the fire), I apply the knob of the phial to the under side of the first plate, which lies immediately upon the electrometer, and at the same time touching the second plate with a finger of the other hand. Then laying aside the phial, I lift up
the

the second plate by its insulating handle, and if the electricity be not now sensible by the electrometer, I place the third plate, by means of its insulating handle, upon the second plate, thus elevated: then touching the third plate, by stretching a finger over the juncture of its insulating handle, and again withdrawing the finger, I then again separate the third plate from the second. In this situation it will be apparent to electricians that two of the plates are of one kind of electricity, and nearly of equal quantity, and one only of the other. I then apply the third plate to touch the under surface of the first plate which remains on the electrometer, and at the same time covering the first plate with the second, I then touch the second plate by stretching a finger over the juncture of its insulating handle; and first taking away the third plate, and then withdrawing my finger from the second, and lifting it up from the first plate, the electricity becomes doubled. If by this first operation the quantity of electricity does not become sensible by the electrometer, I repeat the process to ten or twenty times, which, by doubling it every time, makes visible the smallest conceivable quantity of electricity, since, at the twentieth operation, it is augmented to above 500,000 times. And though in description the above process of doubling to twenty times may appear tedious, yet when the operator can perform it with sufficient readiness (which is soon acquired) it takes less time than 40 seconds. The collection of electricity from the air, and the touching and position of the plates, are represented in Tab. XI. figures 1. 2. 3. 4. 5. and 6.

If it be required to produce sparks, the plates are to be placed upon an insulating stand, without an electrometer, and the process repeated as above till the sparks appear.

The experiment which proves that the electricity is doubled by each operation is this. If the two slips of pendulous leaf gold

gold of the electrometer be made to diverge to a certain distance by the above process, that distance will be nearly doubled by repeating the operation. Another proof of this duplicate accumulation is, that, when the third plate is applied to the first, the divergency of the leaf gold is apparently undiminished, though in this situation their electricity is diffused over double the quantity of surface.

That flame will collect electricity better than points was mentioned in my former Paper, and is very evident if two phials of equal capacity are exposed to the air, the one furnished with a sharp point, and the other having its knob applied to an insulated flame, and their electricity afterwards examined by the doubler.

If the weather be rainy, an insulated umbrella may be carried in one hand, and the knob of the phial applied to the upper and insulated part of the handle; and if it rains so slowly as not sufficiently to communicate electricity to the umbrella, a torch is carried under the umbrella, and used as described above.

It is obvious that some caution is necessary in managing experiments of so much nicety, since, by the least friction of the hand on the varnished sides of the plates or insulating handles, or if the metallic side of one plate be accidentally rubbed against the varnished side of the other, some degree of electricity is produced, which, becoming sensible by the operation of doubling, may render the experiments equivocal.

To obviate these inconveniencies, I join a conducting handle, by means of an insulating nut, to each of the plates. This handle consists of turned unbaked mahogany, about three inches long, into one end of which is inserted a nut of baked wood, about half an inch long, covered with sealing-wax, upon the other end of which nut the brass socket of the plate is fixed; by this means it is not necessary to touch the sealing-

wax

wax of the insulating nut, but occasionally to stretch a finger over it to touch the plate, whilst the mahogany handle is held in the same hand.

Having found, by repeated experiments, that two clean metallic plates, or two equally varnished plates, rubbed together, produced no electricity, I varnished the second plate on both sides, but more thinly than when one side only was varnished, and in some experiments used thimbles on the ends of the touching fingers. In this way the inconveniencies of accidental friction were in some measure obviated, but much less than I first expected; for, notwithstanding the utmost care, electricity is produced without previous communication: therefore, in experiments requiring the electricity to be often doubled, its communication may yet be ascertained by applying it to the first and second plates alternately; so that positive electricity communicated to the first plate appears positive by the electrometer; but the same electricity, applied to the second plate whilst the first is touched, produces negative in the electrometer.

I beg leave to add, that this method of doubling either positive or negative electricity, as well as M. VOLTA'S condenser, with Mr. CAVALLO'S improvement on it, as also the ingenious experiments of Father BECCARIA with double plates of glass, which he separated after charging, are all of them to be explained from the same principles with the Leyden bottle, of which they may be all said to be only different applications. I shall not therefore trouble the Society with any further theory on this subject, but proceed to lay before them the diary which I have hitherto kept, and during which time I have found no difficulty in collecting electricity from the atmosphere positive or negative, so as to become sufficiently sensible by the above described apparatus, though the hygrometer has sometimes shewn the greatest degree of moisture.

Time of observation.	Weather.	Winds.	Baro- meter.	Thermo- meter.	Hygro- meter.	F
1787.			ln.	°	In.	
Jan. 23. 11 o'clock morning	Cloudy	W. moderate	29.3	44	0 $\frac{5}{8}$ M	F
24. $\frac{1}{2}$ past 10 morning	Thin clouds	N. moderate	29.44	42	0 $\frac{7}{8}$ M	P
25. 11 morning	Thin clouds	E. gentle	29.51	37	0 $\frac{3}{8}$ D	P
25. 12 at night	Hard frost and aurora borealis	E. gentle	29.56	38	0 $\frac{0}{8}$ D	P
26. 11 morning	Clear frost	N. gentle	29.5	38	0 $\frac{3}{8}$ D	P
26. $\frac{1}{2}$ past 8 at night	Beginning to snow	N.E. brisk	29.5	37	0 $\frac{3}{8}$ D	P
27. 11 morning	Cloudy and likely to snow	N.E. gentle	29.2	35	0 $\frac{2}{8}$ D	P
28. 10 morning	Snowing	S.E. strong	28.8	28	0 $\frac{2}{8}$ D	N
28. 40 min. past 12 noon	Snowing very little	S.E. brisk	28.5	28	0 $\frac{1}{8}$ D	P
28. 11 at night.	Fair, but over-cast	S. gentle	29.06	37	0	P
29. 10 morning	Small rain and mist on the hills	S. brisk	29.06	38	3 $\frac{2}{8}$ M	N
29. $\frac{1}{2}$ past 10 morning	Rain ceased	D°	29.06	38	3 $\frac{0}{8}$ M	P
29. 3 afternoon.	Few drops of rain	S. strong	29.06	41	5 $\frac{3}{8}$ M	P
30. 45 min. past 10 morning	Fair, but over-cast	S. strong	29.45	44	6 $\frac{3}{8}$ M	P
30. 11 morning	D°	D°	29.44	46	7 $\frac{1}{8}$ M	P
31. 10 morning	Fair and clear.	S.W. gentle	29.55	44	3 $\frac{2}{8}$ M	P
Feb. 1. 9 morning	Thick mist with fine drops of rain	Calm	29.53	46	2 $\frac{0}{8}$ M	P
1. 11 morning	Thick mist	S.W. gentle	D°	D°	D°	P
2. 11 morning	Thick mist	S.W. gentle	29.4	44	1 $\frac{3}{8}$ M	P
3. 10 morning	Heavy clouds	S.W. brisk	29.2	46	3 $\frac{0}{8}$ M	P
3. $\frac{1}{2}$ past 11 morning	Small rain	S.W. strong	D°	D°	D°	N
4. 8 morning	Clear and frosty	Calm	29.3	42	0 $\frac{1}{8}$ D	P
5. $\frac{1}{2}$ past 10 morning	Thick mist on the hills	S.E. gentle	29.26	38	0 $\frac{3}{8}$ M	P
6. 10 morning	Thick mist and few drops of rain	S. gentle	29.12	40	1 M	P
7. $\frac{1}{2}$ past 10 morning	Cloudy	S.W. brisk	28.7	46	5 $\frac{5}{8}$ M	P
7. $\frac{3}{2}$ past 2 afternoon	Small rain	S.W. brisk	28.69	47	4 $\frac{7}{8}$ M	N
8. $\frac{1}{2}$ past nine morning	Clear and frosty	Calm	29.28	40	0 $\frac{0}{8}$ M	P
9. 12 noon	Cloudy after rain	S. strong	28.75	46	4 M	P
9. $\frac{1}{2}$ past 1 afternoon	Rain	S. strong	28.68	46	4 $\frac{5}{8}$ M	N
10. 9 morning	Rain	S. gentle	28.64	44	1 $\frac{5}{8}$ M	N
11. 12 noon	Beginning to rain	S. brisk	28.34	42	2 M	N
12. 12 noon	Fair, with heavy clouds	S. strong	27.8	44	2 $\frac{2}{8}$ M	P
13. $\frac{1}{2}$ past 9 morning	Very small rain, thin clouds	N.W. brisk	28.1	44	1 $\frac{2}{8}$ M	N
14. and 15. absent.						
16. 10 morn.	Small rain	S.W. gentle	28.83	47	3 $\frac{1}{8}$ M	N
17. 10 morning.	Very few thin clouds	W. gentle	29.42	44	0	P
18. 1 afternoon	Few white clouds	W. brisk	29.42	48	1 M	P
19. 11 morning	Few distant clouds	N.W. gentle	29.53	47	1 $\frac{3}{8}$ M	P
20. 11 morning	Over-cast	N. gentle	29.47	46	1 $\frac{1}{8}$ M	P
21. 3 afternoon	Heavy clouds	N. gentle	29.42	47	1 $\frac{1}{8}$ M	P
22. 11 morning	Few white clouds	N.E. gentle	29.4	40	0 $\frac{0}{8}$ D	P
23. $\frac{1}{2}$ past 10 morning	Over-cast	E. brisk	29.38	40	1 $\frac{4}{8}$ D	P
24. 10 morning	Clear and frosty	S.E. gentle	29.32	42	0 $\frac{7}{8}$ D	P
25. $\frac{1}{2}$ past 12 noon	Few clouds	N.W. strong	29.23	46	1 M	P
26. $\frac{1}{2}$ past 10 morning	Clear	S. gentle	29.3	45	0 $\frac{2}{8}$ D	P
27. mentioned afterwards						
28. $\frac{1}{2}$ past 12 afternoon	Few white clouds	W. strong	29.07	48	0	P
Mar. 1. 2 afternoon	Few drops of rain	S.W. strong	28.68	50	3 $\frac{4}{8}$ M	N
2. 10 morning	Small rain.	S.W. very strong	28.35	47	4 $\frac{5}{8}$ M	N

N. B. The thermometer and hygrometer were placed where they were not likely to be affected up three years and upwards, during which time its index has moved

ANNET's *Description of a Doubler of Electricity.*

Diary of atmospherical Electricity.

Hygrometer.	Electricity.	Instruments to collect.	Number of times doubled, and other observations.
n.			
1/2 M	Positive	Torch and bottle	Plate once lifted up.
1/2 M	Positive	D°	Ditto.
1/2 D	Positive	D°	Ditto.
1/2 D	Positive	D°	Ditto, no stronger than before.
1/2 D	Positive	D°	Ditto; a strong bottle was this day tried, which appeared to collect as well as any.
1/2 D	Positive	Umbrella	Doubled.
1/2 D	Positive	Torch and bottle	Plate once lifted up.
1/2 D	Negative	Umbrella and torch	Ditto.
1/2 D	Positive	Torch and bottle	Doubled.
1/2 O	Positive	D°	Plate once lifted up; divergency of the leaf gold very great.
1/2 M	Negative	D°	Ditto, but weaker.
1/2 M	Positive	D°	Four times doubled.
1/2 M	Positive	D°	Plate once lifted up.
1/2 M	Positive	D°	Ditto.
1/2 M	Positive	D°	Ditto; the hygrometer was higher than known during above three years.
1/2 M	Positive	D°	Ditto.
1/2 M	Positive	Umbrella and torch	Three times doubled.
1/2 D°	Positive	Kite	Strong sparks were produced from a string 260 yards long, with brass wire in it.
1/2 M	Positive	Torch and bottle	Plate once lifted up, very strong.
1/2 M	Positive	D°	Ditto, also very strong.
1/2 D°	Negative	Umbrella	Twice doubled; a few minutes after the torch was tried, when the rain had ceased, a
1/2 D	Positive	Torch and bottle	Plate once lifted up.
1/2 M	Positive	D°	Ditto, strong.
1/2 M	Positive	D°	So strong as twice to strike the sides of the electrometer, and sensible without the pla
1/2 M	Positive	D°	Plate once lifted up.
1/2 M	Negative	Umbrella	Ditto.
1/2 M	Positive	Torch and bottle	Ditto.
1/2 M	Positive	D°	Ditto.
1/2 M	Negative	Umbrella	Ditto.
1/2 M	Negative	Umbrella	Ditto.
1/2 M	Negative	Torch and bottle	Ditto.
1/2 M	Positive	D°	Ditto.
1/2 M	Negative	D°	Ditto; 10 minutes after the rain ceased the electrometer was weakly negative, and 5
1/2 M	Negative	D°	Ditto.
1/2 O	Positive	D°	Ditto.
1/2 M	Positive	D°	Ditto.
1/2 M	Positive	D°	Ditto.
1/2 M	Positive	D°	Ditto.
1/2 M	Positive	D°	Ditto.
1/2 D	Positive	D°	Ditto.
1/2 D	Positive	D°	Ditto.
1/2 D	Positive	D°	Ditto.
1/2 M	Positive	Lantern	Just sensible to the electrometer, without the doubler.
1/2 D	Positive	Lantern	More sensible, the lantern being elevated fifteen feet high.
1/2 O	Positive	Lantern and bottle	Four times doubled.
1/2 M	Negative	Umbrella	Often doubled; a few minutes after rain ceased, and the electrometer became positiv
1/2 M	Negative	Umbrella and torch	Plate once lifted up.

be altered by accidental heat. The hygrometer consisted of fifteen feet of whipcord, suspen
 moved within the space of 14 inches, which is therefore divided into inches and eighths, mo

tions.

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ceased, and a much stronger positive was produced.

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ne positive.

suspended horizontally: it has been
as, moist and dry.

The atmospherical electricity was sometimes so strong as to need no doubling, and mostly required only one application of the second plate, yet I frequently found it necessary to repeat the process from two or three to twenty times. Perhaps the exact comparative quantity of electricity residing in the atmosphere might be measured by the number of operations required to render it perceptible by the electrometer, all other circumstances being cautiously attended to.

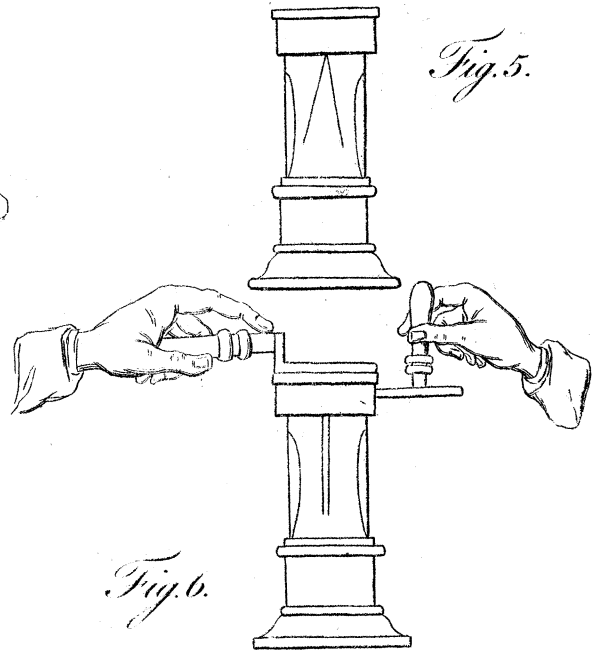
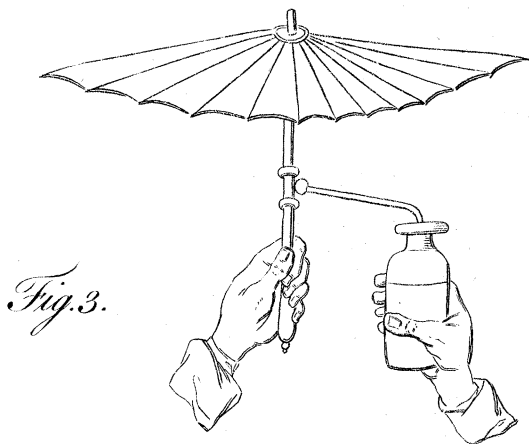
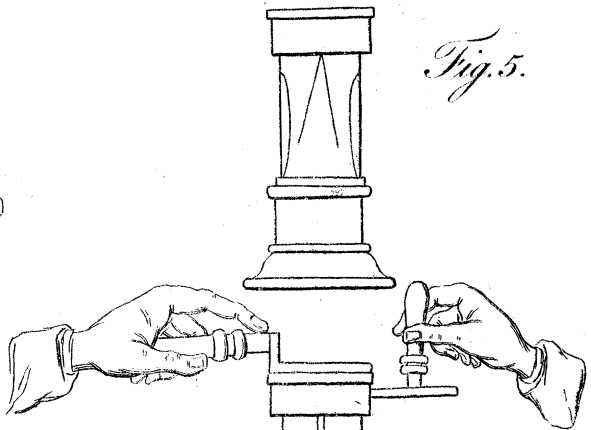
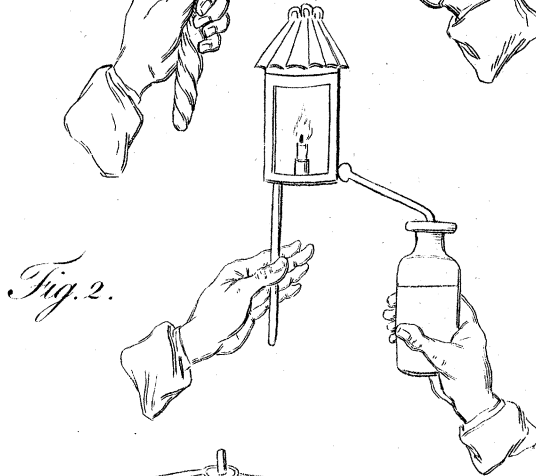
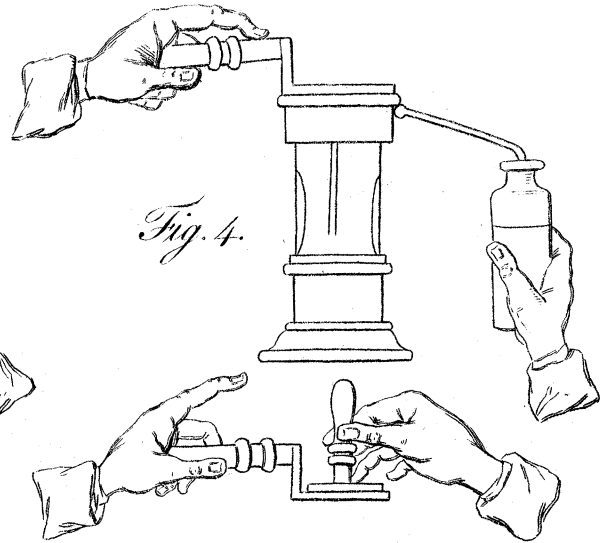
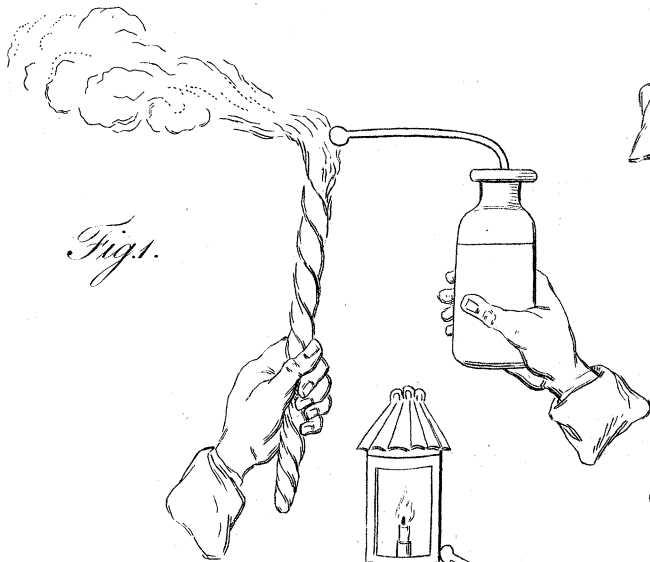
If the electricity of the atmosphere should happen to be much weaker than I have yet found it, there remains not only the resource of doubling oftener, but the capacity of the instruments may be much increased; as, first, by using a larger flame; secondly, by elevating it higher; thirdly, by collecting the electricity with a very thin glass ball, silvered within, and coated on the outside in the common way, or gilt; fourthly, by grinding and polishing the plates of the doubler very exactly; fifthly, by making the experiments in an advantageous situation. In all these particulars my apparatus was defective, yet amply sufficient for the discovery of the atmospherical electricity.

After considering the successful effect of flame, in collecting atmospherical electricity, I placed an insulated lantern upon a pole about fifteen feet high, and suspending a gold thread from the lantern connected it with the electrometer, and was agreeably amused with seeing the pendulous gold leaf open and shut with every passing cloud.

On the 27th of February, 1787, when there was a considerable mist whilst the lantern was thus elevated, the leaf gold frequently struck the sides of the electrometer; and, in

about an hour, some drops of rain beginning to fall, the appearance of electricity with this apparatus entirely ceased, though I elevated the lantern several times in the course of the day.





Diary of atmospherical Electricity.

Time of observation.	Weather.	Winds.	Baro- meter.	Thermo- meter.	Hygro- meter.	Electri- city.	Instruments to collect.	Number of times doubled, and other observations.
1787.			in.	°	In.			
Jan. 23. 11 o'clock morning	Cloudy	W. moderate	29.3	44	0½ M	Positive	Torch and bottle	Plate once lifted up.
24. ½ past 10 morning	Thin clouds	N. moderate	29.44	42	0½ M	Positive	D°	Ditto.
25. 11 morning	Thin clouds	E. gentle	29.51	37	0½ D	Positive	D°	Ditto.
25. 12 at night	Hard frost and aurora borealis	E. gentle	29.50	38	0½ D	Positive	D°	Ditto, no stronger than before.
26. 11 morning	Clear frost	N. gentle	29.5	38	0½ D	Positive	D°	Ditto; a strong bottle was this day tried, which appeared to collect as well as any.
26. ½ past 8 at night	Beginning to snow	N.E. brisk	29.5	37	0½ D	Positive	Umbrella	Doubled.
27. 11 morning	Cloudy and likely to snow	N.E. gentle	29.2	35	0½ D	Positive	Torch and bottle	Plate once lifted up.
28. 10 morning	Snowing	S.E. strong	28.8	28	0½ D	Negative	Umbrella and torch	Ditto.
28. 40 min. past 12 noon	Snowing very little	S.E. brisk	28.5	28	0½ D	Positive	Torch and bottle	Doubled.
28. 11 at night.	Fair, but over-cast	S. gentle	29.06	37	0	Positive	D°	Plate once lifted up; divergency of the leaf gold very great.
29. 10 morning	Small rain and mist on the hills	S. brisk	29.06	38	3½ M	Negative	D°	Ditto, but weaker.
29. ½ past 10 morning	Rain ceased	D°	29.06	38	3½ M	Positive	D°	Four times doubled.
29. 3 afternoon.	Few drops of rain	S. strong	29.06	41	5½ M	Positive	D°	Plate once lifted up.
30. 45 min. past 10 morning	Fair, but over-cast	S. strong	29.45	44	6½ M	Positive	D°	Ditto.
30. 11 morning	D°	D°	29.44	46	7½ M	Positive	D°	Ditto; the hygrometer was higher than known during above three years.
31. 10 morning	Fair and clear.	S.W. gentle	29.55	44	3½ M	Positive	D°	Ditto.
Feb. 1. 9 morning	Thick mist with fine drops of rain	Calm	29.53	46	2½ M	Positive	Umbrella and torch	Three times doubled.
1. 11 morning	Thick mist	S.W. gentle	D°	D°	D°	Positive	Kite	Strong sparks were produced from a string 260 yards long, with brass wire in it.
2. 11 morning	Thick mist	S.W. gentle	29.4	44	1½ M	Positive	Torch and bottle	Plate once lifted up, very strong.
3. 10 morning	Heavy clouds	S.W. brisk	29.2	46	3½ M	Positive	D°	Ditto, also very strong.
3. ½ past 11 morning	Small rain	S.W. strong	D°	D°	D°	Negative	Umbrella	Twice-doubled; a few minutes after the torch was tried, when the rain had ceased, and a much stronger positive was produced.
4. 8 morning	Clear and frosty	Calm	29.3	42	0½ D	Positive	Torch and bottle	Plate once lifted up.
5. ½ past 10 morning	Thick mist on the hills	S.E. gentle	29.26	38	0½ M	Positive	D°	Ditto, strong.
6. 10 morning	Thick mist and few drops of rain	S. gentle	29.12	40	1 M	Positive	D°	So strong as twice to strike the sides of the electrometer, and sensible without the plates.
7. ½ past 10 morning	Cloudy	S.W. brisk	28.7	46	5½ M	Positive	D°	Plate once lifted up.
7. ½ past 2 afternoon	Small rain	S.W. brisk	28.69	47	4½ M	Negative	Umbrella	Ditto.
8. ½ past nine morning	Clear and frosty	Calm	29.28	40	0½ M	Positive	Torch and bottle	Ditto.
9. 12 noon	Cloudy after rain	S. strong	28.75	46	4 M	Positive	D°	Ditto.
9. ½ past 1 afternoon	Rain	S. strong	28.68	46	4½ M	Negative	Umbrella	Ditto.
10. 9 morning	Rain	S. gentle	28.64	44	1½ M	Negative	Umbrella	Ditto.
11. 12 noon	Beginning to rain.	S. brisk	28.34	42	2 M	Negative	Torch and bottle	Ditto.
12. 12 noon	Fair, with heavy clouds	S. strong	27.8	44	2½ M	Positive	D°	Ditto.
13. ½ past 9 morning	Very small rain, thin clouds	N.W. brisk	28.1	44	1½ M	Negative	D°	Ditto; 10 minutes after the rain ceased the electrometer was weakly negative, and 5 minutes after that strongly positive.
14. and 15. absent.								
16. 10 morn.	Small rain	S.W. gentle	28.83	47	3½ M	Negative	D°	Ditto.
17. 10 morning.	Very few thin clouds	W. gentle	29.42	44	0	Positive	D°	Ditto.
18. 1 afternoon	Few white clouds	W. brisk	29.42	48	1 M	Positive	D°	Ditto.
19. 11 morning	Few distant clouds	N.W. gentle	29.53	47	1½ M	Positive	D°	Ditto.
20. 11 morning	Over-cast	N. gentle	29.47	46	1½ M	Positive	D°	Ditto.
21. 3 afternoon	Heavy clouds	N. gentle	29.42	47	1½ M	Positive	D°	Ditto.
22. 11 morning	Few white clouds	N.E. gentle	29.4	40	0½ D	Positive	D°	Ditto.
23. ½ past 10 morning	Over-cast	E. brisk	29.38	40	1½ D	Positive	D°	Ditto.
24. 10 morning	Clear and frosty	S.E. gentle	29.32	42	0½ D	Positive	D°	Ditto.
25. ½ past 12 noon	Few clouds	N.W. strong	29.23	46	1 M	Positive	Lantern	Just sensible to the electrometer, without the doubler.
26. ½ past 10 morning	Clear	S. gentle	29.3	45	0½ D	Positive	Lantern	More sensible, the lantern being elevated fifteen feet high.
27. mentioned afterwards								
28. ½ past 12 afternoon	Few white clouds	W. strong	29.07	48	0	Positive	Lantern and bottle	Four times doubled.
Mar. 1. 2 afternoon	Few drops of rain	S.W. strong	28.68	50	3½ M	Negative	Umbrella	Often doubled; a few minutes after rain ceased, and the electrometer became positive.
2. 10 morning	Small rain.	S.W. very strong	28.35	47	4½ M	Negative	Umbrella and torch	Plate once lifted up.

N. B. The thermometer and hygrometer were placed where they were not likely to be altered by accidental heat. The hygrometer consisted of fifteen feet of whipcord, suspended horizontally: it has been fixed up three years and upwards, during which time its index has moved within the space of 14 inches, which is therefore divided into inches and eighths, moist and dry.