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LXVIII. On the diurnal change of the aqueous portion of the atmosphere, and their effects on the barometer

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nate functions of the modulus; notwithstanding that they are given by the apparently determinate conditions,

$$\frac{1}{2}\omega = \int_0^{\frac{1}{c}} \frac{dx}{\sqrt{(1-c^2x^2)(1+e^2x^2)}},$$

$$\frac{1}{2}\upsilon = \int_0^{\frac{1}{e}} \frac{dx}{\sqrt{(1+c^2x^2)(1-e^2x^2)}}.$$

In fact definite integrals are in many cases really indeterminate, and acquire different values according as we consider the variable to pass through real values, or through imaginary ones. Where the limits are real, it is tacitly supposed that the variable passes through a succession of real values, and thus ω, υ may be considered as completely determined by these equations, but only in consequence of this tacit supposition. If c and e are imaginary, there is absolutely no system of values to be selected for ω, υ in preference to any other system. The only remaining difficulty is to show from the integral itself, independently of the theory of elliptic functions, that such integrals contain an indeterminateness of two arbitrary integers; and this difficulty is equally great in the simplest cases. Why, *à priori*, do the functions

$$\sin^{-1} x = \int_0 \frac{dx}{\sqrt{1-x^2}}, \qquad \text{or } \log x = \int_0 \frac{dx}{x}$$

contain a single indeterminate integer?

Obs. I am of course aware, that in treating of the properties of such products as $\Pi\left(1+\frac{x}{m\omega+n\upsilon}\right)$, it is absolutely necessary to pay attention to the relations between the infinite limiting values of m and n; and that this introduces certain exponential factors, to which no allusion has been made. But these factors always disappear from the quotient of two such products, and to have made mention of them would only have been embarrassing the demonstration without necessity.

LXVIII. *On the Diurnal Changes of the Aqueous Portion of the Atmosphere, and their Effects on the Barometer.* By THOMAS HOPKINS, *Esq.*[*]

IT is admitted by meteorologists, that the various quantities of aqueous vapour which exist in the atmosphere during the different hours of the day, contribute to the production of

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[*] Communicated by the Author; having been read at the Manchester Literary and Philosophical Society, October 7, 1845.

the variable atmospheric pressure, and the semi-diurnal fluctuations of the barometer. The vapour is, at a certain hour in the morning, at its minimum quantity, from which it increases during the day up to its maximum; after that it declines, and its variable pressure is exerted on the mercury of the barometer, and affects the height of the column. This takes place in a less or greater degree in all latitudes, though to the greatest extent near the equator.

The quantity of vapour existing in the atmosphere in each hour of the day is ascertained from the dew-point, or point of condensation; it having been found that each particular quantity of vapour diffused through the air has its separate dew-point. The dew-point is therefore taken as the measure of the quantity of aqueous matter existing in the atmosphere, and of the vapour pressure, at every period of time. This pressure, thus ascertained, being deducted from the whole atmospheric pressure, furnishes the amount of the gaseous pressure, as given in our Meteorological Registers and Tables.

But, is the dew-point a correct measure of the quantity of aqueous matter that passes into and remains in the atmosphere during the different times of the day? On the answer to this question it depends whether the hourly vapour and gaseous pressures on the barometer are, or are not, correctly given in our registers. If the dew-point be a true measure, then the pressure arising from aqueous matter may be taken to be such as is stated in those registers, and so far all the reasonings respecting the causes of the diurnal fluctuations of the barometer may be correct; but if the dew-point is a fallacious measure of that pressure, then the alleged facts may be unfounded, and the conclusions drawn from them erroneous.

There is reason to believe that in certain parts of the world, and for considerable periods of time, the dew-point may be a correct indicator of the pressure of aqueous matter, but in other parts it may not; and in order that we may trace this difference, in different times and places, we will inquire what are the relative quantities of vapour that hourly pass into the atmosphere, in some of those parts from which we have been furnished with accounts, and endeavour to learn whether those quantities are such as to accord with the dew-points.

Kaemtz, a German meteorologist, in his Course of Meteorology, has furnished tables of the hourly vapour pressure in different places, deduced, in the usual way, from the dew-point, and among them of that which is found to be the mean of the year at Appenrade, in Denmark, from seven in the morning to eleven in the evening. At seven, the pressure, in French measure, is 8 millimetres ·119, from which it increases until one in the afternoon, when it reaches 9·511. From this time it diminishes, and at 11 P.M. is only 7·863.

The same writer has given the vapour pressure on the coasts of the Baltic, at Trapstow near the Rya, for the months of July and August. It appears that in those parts the minimum pressure for July is 10·05 at two o'clock in the morning, and the maximum is 11·41 at two o'clock in the afternoon. For August, the minimum is 11·18 at three o'clock in the morning; and there are two risings, the first until ten o'clock, when it is at 12·05: from this time it falls till two, and then suddenly rises until three o'clock, from which time it falls for the rest of the day. From these statements we find that there is, on the coasts of the Baltic, particularly in August, in the middle of the day, a material departure from a single rise and a single fall in the vapour pressure.

There are also tables for Zurich, and other places in its neighbourhood. At Zurich, in the month of June, the minimum pressure is 10·56 at 4 A.M., from which hour it rises until 8 A.M. After this it falls a little, and irregularly fluctuates until 8 P.M., when it reaches 11·34, having fluctuated greatly during twelve hours, namely, from 8 A.M. to 8 P.M., and ranged 0·78.

In September, at the same place, the minimum was at 5 A.M., and there were two risings, with an intervening fall. The first rise was up to twelve o'clock,—four hours later than the first in June; and the advance above the minimum was 1·73, making a greater range than that of June by 0·95. Here, too, the disturbance in the middle of the day is very palpable. These parts of the world are at comparatively low levels,—the first named being near the sea, and the last (at Zurich) an inland situation, which, though considerably above the sea, is not on a mountain.

When these observations were made at Zurich in the month of June, others were made on the adjoining mountain, called the Righi, 1402 metres above the Lake of Zurich. On the Righi, the minimum pressure was at 5 A.M., an hour later than that on the plain, being then 6·27, from which it rose until noon, and reached 7·54, making a range of 1·27. From this hour the pressure declined until five the next morning.

On the Faulhorn, a mountain in the same locality, but higher than the Righi by 870 metres, observations were made in September, at the same time as others were made at Zurich; and on the mountain the minimum pressure was 3·40, and occurred at 6 A.M., an hour later than at Zurich. From this time it rose until three in the afternoon, when it reached 5·07, making the range in the day so much as 1·67. It is thus shown that the range of vapour pressure was greatest, not where the temperature was the most raised, and where evaporation must have been the greatest, but in the latest and coolest month, and on the highest mountain! And in September the pressure increased to the latest period of the day, not near the surface, the source of evaporation, but on the high mountain. These irregularities show that some cause was in operation, which determined the vapour that had been produced by evaporation from the surface of the earth in the warm and comparatively dry month of June to continue increasing at the low level up to eight in the evening, but to accumulate only to a moderate extent, whilst on the mountain it accumulated to a much greater extent, but not later than until noon. In the cooler month of September, however, the vapour accumulated to about an equal extent, and about the same times, on the low level and on the high mountain, presenting a great difference between the action of the vapour in June and in September. The absolute pressure of the vapour, it will be recollected, is greater in the lower than in the higher strata; but the increase of that pressure is greater in the higher part in the dry and warm month of June, while it is only equal in the moist and cool month of September, showing that it was not merely expansion and diffusion of the vapour produced by evaporation that were in operation, but that some other cause was at work, which made the vapour accumulate on the mountain more than on the plain in June, but not in September.

In high latitudes the pressure of the vapour is the least in winter, and the most in summer. In Halle, in Prussian Saxony, for instance, it is 4·509 in January, and in July 11·626, almost three times the amount; and the same kind of difference between winter and summer is found in other northern parts. Generally it may be said to be the least in winter and in cold climates, and the most in summer and in warm climates.

When the dew-point, contiguous to the surface of the earth, is the nearest to the temperature, which is, say, at four or five in the morning, both the temperature and the dew-point are the lowest. From this time the temperature rises more than the dew-point, until the former reaches the highest point for the day. There is consequently in the lower part of the atmosphere an increasing difference occurring between the temperature and the dew-point up to the time of the highest temperature. But this does not take place in the same degree in the higher strata, as in them the dew-point progressively approximates to the temperature, until at some height the two become the same. In the forenoon, therefore, the lower air has its temperature removed progressively further from the dew-point, but when it ascends, it approaches the dew-point of the higher strata, until at last, at some height, condensation takes place and cloud is formed. When this occurs, the vapour that is in the air below the cloud, being partially relieved from incumbent vapour pressure, ascends more freely from the lower to the higher regions, where the cloud is forming. Thus it is the rise of temperature near the surface that increases evaporation and raises the dew-point, and the vapour produced by this evaporation expands and forces its way upwards by its own laws of expansion and diffusion. But in ascending it cools by expansion 1° for, say, every 500 yards, whilst it has to pass through the gaseous atmosphere, a medium which is made colder by its own law of cooling, 5° for every 500 yards of elevation; therefore, as the vapour ascends, it must at some height reach a temperature low enough to condense a part of it and form cloud. On the formation of the cloud taking place, a part of the vapour that is in the atmosphere is converted into globules of liquid (water), and the pressure of this condensed vapour on that immediately below it nearly ceases: for these globules of water, unlike the vapour from which they have been formed, do not rest upon or float in the *vapour* atmosphere alone, but also on the *gaseous* portion of the atmosphere, which, from its superior quantity and density, will sustain the greater part of the weight of this floating water. The lower vapour, relieved from a portion of that which previously pressed on it, expands upwards more rapidly, and ascends sometimes so freely as to prevent such an accumulation as shall further raise the dew-point, although evaporation continues active below. Indeed the pressure from above may be so far removed by cloud formation, and the ascent of the vapour be rendered so free and rapid as to lower the dew-point, as took place both at Zurich and on the coast of the Baltic. The processes which have been here described may be traced by attending at the same time to the dew-point and the heights of the ordinary and the wet-bulb thermometers. These are exhibited in the Plymouth registers and diagrams, presented to the British Association by Mr. S. Harris.

By reference to these, it may be seen that at Plymouth the difference between the dry and wet-bulb thermometers is, at five in the morning, say about 1° of Fahrenheit. This difference increases until one in the afternoon, when it is, say, 4°; evaporation must therefore have gone on with increasing activity during this time; and at three o'clock, that is two hours after the time of highest temperature, the difference between the two thermometers is greater than it was at eleven o'clock, two hours before the highest temperature! Evaporation must therefore have been more energetic, and must have continued to throw into the atmosphere more vapour from eleven to three than it had done four hours earlier! Now, if increase of vapour pressure always accompanied increase of vapour, the increase of pressure at Plymouth must have continued up to three o'clock! If however we look at the curve or line of the dew-point, which represents vapour pressure in the diagram, we find that it did not rise after eleven o'clock, but continued stationary from that hour until 4 P.M.! It is therefore apparent, that at Plymouth the quantity of vapour which by evaporation passed into the atmosphere in the middle of the day, to add to the general atmospheric pressure, in some form, was not indicated by the dew-point. And analogy authorises us to infer, that in other parts of the world, the state of the dew-point during the same portion of the day does not express the quantity of vapour that has passed into the atmosphere, and which must have added to its general pressure on the barometer.

In the Toronto registers, reported to the British Association at York in 1844 by Col. Sabine*, the state of the wet-bulb thermometer is not given. But we may assume that if it had been given, it would have shown the same features as those we have in the Plymouth registers and diagrams. In this report it is, however, stated that Mr. Caldecott has transmitted to England five years of hourly observations with the wet and dry-bulb thermometers at Trevandrum, near Cape Comorin, where a large quantity of vapour generally exists in the atmosphere. It appears from these accounts that the minimum and maximum pressures of the atmospheric vapour are there found to occur within three hours of each other,—the minimum coinciding with the coldest hour, 6 A.M., and the maximum occurring so early as at nine in the forenoon! Now, it is very desirable that it should be ascertained whether evaporation did or did not go on freely from the wet-bulb thermometer from six in the morning, not only until nine in the morning, but until two in the afternoon, the time of the highest temperature. Although the dew-point ceased to rise at nine, it is to be presumed, reasoning from analogy, that energetic evaporation continued through the middle of the day, and it probably was (as at Plymouth) more active between nine and two in the day, than it had been in any part of the time between six and nine in the morning. And the vapour which was thus produced at Trevandrum between

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* This report was inserted in the February Number of this Journal for the present year.—Ed.

nine and two, or still later in the day, may have ascended and formed cloud, which cloud must have added to the general weight of the atmosphere. Had we accounts of the state of the wet and dry-bulb thermometers, and of the dew-points at different heights, there is little room to doubt that we might trace the ascent of the vapour at Trevandrum until we found it collected and floating in the atmosphere as a cloud, and in that form adding to the general weight of the atmosphere.

Colonel Sabine says that the maximum of vapour pressure occurring at Trevandrum at 9 A.M. may be a consequence of the sea-breeze blowing at that time. I have however shown that the daily sea-breeze is itself produced by the diurnal cloud formation; the sea-breeze is only another effect arising from the same cause. The sea-breeze blows towards the part, because the atmosphere has there been made lighter than in adjoining parts by the heating power of condensing vapour. The wind too that comes from the sea, particularly in the fine season, when the diurnal disturbance of the barometer is the greatest, comes more fully loaded with vapour after nine o'clock than was the air over the land before that time, and ought to increase the vapour pressure after that hour, instead of stopping the increase. If all the vapour that arose had to come from the same land surface of the locality, it might be supposed that evaporation could not continue to supply an adequate quantity to raise the dew-point after nine; but when the sea-breeze sets in, a current of air comes from an extensive sea surface, and brings with it the vapour which had been evaporated from that surface, not only up to nine o'clock, but until ten, twelve, or two o'clock, or still later: the tendency of the sea-breeze is therefore not to reduce, but to increase the supply of vapour. It may also be remarked, that whilst the maximum of vapour pressure is said to occur at Trevandrum at nine o'clock, the sea-breeze does not set in at Bombay until about eleven or half-past eleven. Supposing both these places affected alike by the sea-breeze, the cause of the stoppage of increase of vapour pressure, whatever that cause may be, must have been in operation two hours before the sea-breeze commenced blowing.

Formation of cloud is a cause sufficiently powerful in its operation to prevent the dew-point rising at Trevandrum after 9 A.M., as the vapour produced after that hour may be equal only to that which is consumed in cloud formation; and we are authorised to conclude that it is to that formation we are to attribute the stoppage of the dew-point at Plymouth at eleven, and at Trevandrum at nine o'clock, instead of having it rising with the temperature during the hottest portion of the day in both places. And in the more northern or drier climates, if we do not always trace the same stoppage, it is to be attributed to the absence of daily cloud formation. In a very dry and cold climate there is not in the course of the day sufficient water evaporated to produce a daily thick cloud, and therefore small vapour pressure goes on increasing with the temperature up to the hottest period. Under these circumstances, the vapour pressure, when exhibited in a diagram, forms a regular curve, having one rise and one fall in the twenty-four hours; but where much vapour exists, and much more is produced daily, the dew-point does not at all times indicate the pressure which results from evaporation, because the rise of the dew-point is stopped at certain periods, not by a cessation of the production of vapour, but through its ascent in the atmosphere and conversion into a floating cloud. Boiling water in the open air does not rise above 212°, yet heat continues to pass into it from the fire that is under the water. The reason that the temperature of the water does not rise higher is, that as much heat passes from the water into the air as from the fire into the water. In like manner, evaporation of water may continue to throw vapour into the air without the quantity in the air increasing, because condensation may convert vapour into water as fast as evaporation furnishes it. But neither the fire nor the vapour is annihilated,—the fire passes into the atmosphere and the vapour becomes cloud, and we may trace both of them in their new state of existence, and mark the effects they produce.

Taking the period of a year, in all places the average daily march of the temperature shows a single rise from about six in the morning till one or two in the day; and evaporation, as shown by the wet-bulb thermometer, increases with the rise of temperature. If the whole weight of the vapour thus produced were to be registered and exhibited in the form of a curve, that curve would be the same in form as the curve of temperature, having one rise and one fall. But in the actual curve or line of the dew-point there is frequently found to be a fall where there should be a rise. At Zurich and near the Baltic the departure from the regular curve is considerable; in Plymouth the line is level from eleven to four; and in Trevandrum, if a curve were formed, the line would cease to rise at nine o'clock, five hours before the hottest period! At Trevandrum the minimum and maximum of the dew-point occurred within three hours, whilst on the Faulhorn they were nine hours asunder; at Zurich, in June, they were sixteen hours asunder; and in other parts similar anomalies occur. These irregularities may be accounted for on the supposition that condensation of vapour produces them, because that process is very irregular in its action; but if this supposition is admitted to be true, it will follow that the dew-point is not a correct measure of the daily addition that is made to the weight of the atmosphere in the middle of the day by the vapour that has been thrown into it, and therefore it does not present the means of ascertaining the separate gaseous pressure. For the same operation that keeps down the dew-point in the middle of the day, creates cloud that floats in and rests upon the whole mass of the atmosphere; and the gaseous portion of that atmosphere must then press on the surface of the earth, not only with its own weight, but with the additional weight of nearly the whole of the cloud that is then floating in it. And if the curve of gaseous pressure, as commonly given, does not show a rise resulting from this additional pressure, it is because the whole atmosphere is at the same time made lighter by the heat which has been liberated by condensation of vapour.

LXIX. *Account of a remarkable difference between the Rays of Incandescent Lime and those emitted by an Electric Spark.* *By* John W. Draper, *M.D., Professor of Chemistry in the University of New York*[*].

SOME years ago M. Becquerel discovered that the rays of an electric spark, if they were transmitted through a screen of glass, could not excite the phosphorescence of sulphuret of lime.

To make this experiment, wash a metallic plate over with gum-water. Dust upon it, from a fine sieve, a quantity of Canton's phosphorus (oyster-shells calcined with sulphur), and allow the plate to dry. An uniform surface is thus obtained, suitable for these purposes. Place before that surface a piece of glass and a piece of polished quartz, and discharge a Leyden phial a few inches off, so that the rays of its spark may fall on the plate. It will be found that under the quartz the phosphorus will shine as much as on the spaces that have not been covered; but under the glass it will remain almost entirely dark.

Last winter I observed the curious fact, that when this experiment is made with a piece of lime incandescing on a stream of oxygen, directed through the flame of a spirit-lamp, the glass, so far from being unable to transmit the rays, appears to be as transparent to them as quartz or atmospheric air.

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[*] Communicated by the Author.