PHILOSOPHICAL TRANSACTIONS.

I. *On the Quantity and Quality of the Gases disengaged from the Thermal Spring which supplies the King's Bath in the City of Bath.*

By Charles Daubeny, *M.D., F.R.S., Professor of Chemistry in the University of Oxford.*

Received November 2,—Read December 19, 1833.

In some remarks on a paper of Dr. John Davy's, entitled "Notice on the Remains of the recent Volcano in the Mediterranean," which were inserted in the last Part of our Transactions, I expressed my regret, that no accurate statement of the quantity of gas evolved in a given time from any thermal waters had been published, and intimated my intention to make this the subject of special examination, whenever suitable opportunities should occur.

Accordingly, having in my former visits to Bath been struck with the copious evolution of gas from the centre of the principal of the hot springs of that city, I solicited from the gentlemen composing the Committee appointed to manage and regulate them, leave to institute such experiments as appeared to me desirable on the spot; and having obtained from them the requisite facilities for so doing, I determined to collect and measure the gas evolved, repeatedly, during a period sufficiently extended to enable me to fix with tolerable precision its average amount, and to ascertain, whether any greater diurnal variation in its quantity could be detected, than what might be fairly set down to errors of manipulation, or to oscillations in the quantities discharged extending over a wider range of time, than that during which it might be found convenient to protract the period of each observation.

Anticipating, also, that a variation might be discovered, I carried on during the same period a corresponding register of the leading conditions of the atmosphere as to pressure, temperature and humidity, in order to learn, whether any connexion could be traced between these and the quantities of gas evolved.

I likewise examined, on several occasions, the quality of the gas emitted, not only in order to fix with greater exactness its actual composition, but likewise to learn, whether any variation in these respects could be perceived during the course of my observations.

The Bath waters arise from three distinct sources, or springs, contiguous to each other, which supply respectively the King's Bath, the Hot Bath, and the Cross Bath. In addition to the above, which belong to the Corporation, there is likewise said to be another spring of water, which supplies the Kingston Baths, the property of an individual.

Of these by far the most copious is the first-named, which fills the King's Bath and the Queen's Bath annexed; it gives out in a regular and unremitting stream no less than 126 gallons of water per minute, and in nine hours replenishes the whole area of these two baths, when emptied, to the height of forty-six inches.

The evolution of gas takes place chiefly from this spring, the quantity discharged by the Hot and Cross Baths being comparatively insignificant; for I found that the latter of these, which, of the two, is considered to yield the most, disengaged no more than about twelve cubic inches a minute at the time I attempted to estimate it.

I therefore confined my inquiry to the King's Bath, from the centre of which gas rises in great quantities, whilst it is also given off in a slighter degree and in a more irregular manner, from the various holes and crevices, that exist in the stone pavement of the bath throughout the whole extent of the area embraced by it.

To form an exact estimate of the amount of the gas which escapes from these minor lateral spiracles, would have been an irksome and difficult task; but I ascertained, that it bore but a very small proportion to that discharged from the centre, and from a certain distance round it, being in the one case emitted in bursts at uncertain but distant intervals, in the other proceeding in a current as regular and unintermitting as the spring itself.

I therefore attempted to do no more, than collect that portion of the gas which finds its way upwards, from an area round the centre of the bath, about twenty feet in diameter*: and in order to accomplish this, I contrived a funnel-shaped apparatus, which for brevity's sake I shall in the rest of this paper call the Shield, consisting of several sheets of iron riveted together, and rendered airtight by means of white lead interposed between the seams of the joints, so that there might be no means of escape for the gas detained under the lower surface of the shield, except at its centre, where an aperture of two inches in diameter was left, towards which it would be conducted, and thus find a ready vent. The apertures in the pavement of the bath within the area above specified, which the shield was not large enough to cover, were carefully stopped up either with corks or tow, covered over with boards, which by means of weights were made to press closely upon the surface of the pavement.

The apparatus being thus arranged, it was easy, by placing inverted jars of suitable dimensions filled with water over the central orifice, to collect and measure the gas that might escape within a given period.

The iron shield being six feet square, and therefore from its size somewhat unwieldy, it was found convenient to erect a kind of temporary framework of wood, from which the apparatus, when not in use, might be suspended out of the way of bathers.

* See the ground plan of the bath.

This consisted of four upright posts, fixed by means of cords to opposite angles of the hand-rail which separates the central portion of the King's Bath from its sides; these posts being connected together by planks extending from one to the other, and resting horizontally on the tops of each.

This framework served as a point of attachment to the pulleys by means of which the iron shield was raised and depressed; and it at the same time enabled me to cover over that portion of the bath in which my operations were conducted, with an awning, to serve both as a protection from the weather, and as a screen from observation.

In this manner I was enabled to carry on my experiments for the period of a month, without being any hindrance to others, and with comparative ease to myself and my assistants, choosing a time of day after the hours of bathing were concluded, when the water was comparatively low, which, as the bath is emptied regularly once a day, and afterwards replenished from the spring at the uniform rate of nearly six inches per hour, could always be reckoned upon at a similar time in the afternoon.

On one occasion, however, I caused the water to be kept low during the space of twenty-four hours, in order to satisfy myself that there was no material deviation from the mean quantity of gas evolved each day, at the particular period that had been commonly selected; and for this purpose I collected the gas at intervals of about six hours, namely on Saturday at 1 P.M., again at 6 in the evening, again about midnight, again at 7 o'clock on Sunday morning, and lastly at noon of the same day. Finding, however, a greater variation between the quantity collected at the same hour on the two successive days, than between that obtained at different hours of the same day, I saw no advantage in departing again from the usual routine.

There might be more reason for suspecting, that the periods to which each observation extended were not sufficiently long to secure a fair average; and fearing that this might have been the case in the first trials, I gradually prolonged the duration of them from five to fifteen minutes: so that the time occupied in the experiments amounted altogether to more than four hours.

If it be objected, that this period even might have been too short to insure exact results, I may reply, that the correspondence which is frequently to be traced between the amount obtained on two or even three successive days, affords in itself a presumption, that the numbers given furnish in general a pretty fair expression of the mean quantity of gas emitted every minute from the spring.

Assuming this to be the case, it would appear from the sum total of the observations recorded, that the quantity of gas evolved averages 264 cubic inches, or, rejecting observation 3rd, (which was noted at the time as of doubtful accuracy, on account of some defect in the apparatus subsequently remedied,) 267 cubic inches each minute.

The largest quantity ever obtained in the course of one minute appears to have been 530 cubic inches; the smallest in the same time, 80: but if we take the mean of the observations, we shall find, that the quantity usually varied from 339 to 207, so that on an average the volume of gas evolved differed between one minute and others as 12 to 20, or about one third, whilst the extreme variation was as 3 to 20, or four times as great.

By comparing together periods of five minutes, the difference between one observation and another will be found greatly reduced, the greatest variation being no more than as 14 to 20, the mean only 19 to 20, as I have calculated by referring to my original notes, and taking at hazard eleven observations, each extending to ten minutes, and comparing the amount of gas obtained in the former half with that in the latter half of the time.

I conceive, therefore, we may be warranted in calculating, on the above data, that no less than 223 cubic feet of gas are usually disengaged in the space of twenty-four hours from this source alone; and, large as this amount may appear, we have positive testimony * that it was as constantly taking place almost a century and a half ago; nor is there much reason to doubt that it may have continued in an equally unintermitting flow from the earliest periods at which the springs were known: the analogy, indeed, of other thermal waters leading us to conclude, that the evolution of gas is a phenomenon as intimately connected with the constitution of the waters as the presence of a definite quantity of certain saline ingredients, or the possession of a particular temperature; both which, it is probable, continue unaltered during periods, historically speaking, of long duration.

Dr. CLARKE has shown †, that the hot springs which gush out from the foot of the limestone precipices of Mount Œta at the pass of Thermopylæ, retain at this moment a temperature of 111°, which probably is as high as that belonging to them in the times of ancient Greece; and, what is more to the point, the boiling up of gaseous bubbles, which this traveller ascertained to be owing to the escape of sulphuretted hydrogen from the springs, would seem to be noticed by SOPHOCLES, who, if we adopt Dr. CLARKE's ingenious interpretation of the passage referred to ‡, makes a poetical use of the phenomenon in his Trachiniæ.

Thus, too, Dr. HOLLAND detected, at a spot on the coast of Albania, the escape of carburetted hydrogen, probably on the precise spot where the ancient writers describe a Nympheum, or a place where, owing to this cause, a perpetual flame was observed to rise §: and the baths of Bithynia, described by a poet of the time of

* GUIDOT, who wrote on the Bath waters in 1696, speaking of the ochreous sediment thrown up by the spring, says: "ochra hic cum scaturigine regiâ erumpens jugiter, *perenni ebullitionis motu*, ita elaboratur, ut tabulis affixa pictoriam æmuletur."

† Travels, vol. iv. p. 248.

‡ He causes DEIANIRA to relate, that some of the wool stained with the blood of the Centaur NESSUS, falling upon the Trachinian plain, in a place where the sun's rays were the most fierce, there boiled up from the earth *frothy bubbles*.

.... ἐκ δὲ γῆς, ὅθεν
προὔκειτ', ἀναζέουσι θρομβώδεις ἀφροί.—SOPHOCLIS Trachiniæ, vers. 701. (Ed. BRUNCK.)

§ See HOLLAND's Travels in Greece and Albania.

JUSTINIAN* as discharging a hot bubbling fluid†, which (as may be gathered from another passage of the same poem‡,) appeared to boil up, owing to the escape of bubbles of sulphuretted hydrogen, are still found to be impregnated with this same gaseous ingredient§.

To return to the case of the Bath waters, there is no evidence, that it has at any time been the practice to cool them down artificially, before they were employed for bathing; and hence it seems fair to conclude, that they never, since the earliest period at which they have been known, were hotter than they are now, their present temperature probably approaching the highest point which the human body can sustain without inconvenience. From the permanency of the temperature, therefore, we may be led to presume that of the other properties which at present characterize the spring.

It may also be alleged, that geology supplies us with examples of hot springs, of many distinct epochs; some, like that of Castellamare near Naples, connected with the volcano there existing; others, like that of Mount Dor in Auvergne, with volcanos long extinct, but which yet are not more remote than the tertiary period at farthest; whilst a third class, like those of Bath and Buxton, probably are of a much greater antiquity. Yet in all these cases the same evolution of nitrogen is observed; so that we are not at liberty to consider this, as a phenomenon resulting from any one particular period in the existence of a mineral spring, but as one continuing in it from first to last, or at least during a space of time of very extended duration.

Perhaps we shall best explain this regular and long-continued evolution of elastic fluid from the bowels of the earth, by supposing a large amount of these gases to be pent up in some cavern existing in a rock, which is seated at a great depth below the surface, and which had been heated at some former period by volcanic action.

If such a mass of rock were of considerable dimensions, and consisted of materials which slowly transmitted heat, we might suppose its external portions to cool far more rapidly than the internal ones; in which case, the former contracting upon the

* PAULUS SILENTIARIUS (viz. Silence-keeper in the imperial palace at Constantinople). See BRUNCK's Analecta, vol. iii. p. 94, a poem entitled *εις τα εν Πυθιοις θερμα.*

† *ουτω προηλθε πᾶσι*
το θερμοβλυστον ῥεῖθρον,
'Ιπποκρατης ἀψυχος,
τεχνης ἀνευ Γαληνος.

" 'T was thus the hot bubbling fluid issued for the benefit of mankind, an inanimate HIPPOCRATES, a GALEN untaught by art."

‡ Thus he supports his theory as to the cause of this and other thermal waters, by alleging the mephitic offensive stench which accompanies them:

ὀδμη γαρ εστιν, οἶδας,
μυδῶσα, δυσπνοουσα,
τραυον τε μαρτυροῦσα.

§ See, in WALPOLE's Memoirs on Greece and Turkey, a notice of these springs by the traveller BROWNE.

latter, and thus creating a pressure upon the contents of its included cavity, would prove the means of propelling a stream of air, proportionate to the degree of diminution that had taken place in its own temperature, through fissures towards the surface.

In some such way, perhaps, we may imagine the evolution of gaseous matter to go on for centuries, in a manner nearly as uniform, as the shrinking in the dimensions of the cavity, caused by the yielding of its walls to the pressure from without, may be supposed to proceed*.

Be that as it may, the above estimate of the quantity discharged will afford a standard, by which a comparison may be made at present between this and other thermal springs in the above respect, and which may be appealed to hereafter, should it be wished to ascertain, from time to time, whether any change has taken place in the nature of this particular spring, or in the causes from which its heat proceeds.

Whilst engaged in thus determining the aggregate amount of all the gas evolved by the spring, saving the small quantity that finds its way from apertures near the sides of the bath, by means of the apparatus above described, which enabled me to collect whatever was disengaged within an area of twenty feet, I conceived that it might be worth while at the same time to estimate, what proportion of the whole rises up immediately through the stone cylinder, eighteen inches in diameter, which exists in the centre of the bath.

This was readily ascertained by means of a smaller shield, or funnel-shaped apparatus, which exactly fitted that opening, and the results obtained in the space of each minute are accordingly registered in separate columns by the side of the former.

The mean quantity obtained, taking the average of nineteen observations, was 34·75 cubic inches; the maximum ever obtained, 80; the minimum, 5; the average variation

* The dimensions of such a cavern, or series of caverns, need not be supposed so much more considerable than those of many which have fallen under our observation, as to give rise to any serious difficulty. That at Speedwell Mine, in Derbyshire, contains a pool of water 320 feet in depth, and rises to a height of more than 450 feet above the surface of the water. It is therefore nearly 800 feet in perpendicular height. That at Adelsburg, in Carinthia, one only of a series existing in that limestone formation, is in many places more than 100 feet in height, and extends, it is said, to a distance of nine or ten miles. One lately noticed by a traveller in the Caucasus (Colonel MONTEITH) is 600 feet high, 1200 feet in span, and 800 feet in depth. It probably communicates with others by means of fissures. See Geographical Journal, vol. iii., lately published. Now, if we suppose 250 cubic feet of gas to have been expelled daily from a cavern underneath Bath, for a period of about 5000 years, the whole quantity given off would amount to 456,250,000 cubic feet. A cavity, therefore, equal to 2000 cubic feet in its entire dimensions, if in the course of that period it had contracted to $\frac{1}{17}$th of its original size in consequence of the cooling of its walls, would have expelled a quantity of gas corresponding with that which the Bath waters have disengaged within that period. But a contraction of $\frac{1}{17}$th may without difficulty be imagined to have resulted from the cooling down of a mass of rock from 13,000° FAHR. to 400°; for glass contracts about $\frac{1}{1200}$dth part between 212° and 32°, or by cooling 180°; consequently a rock which contracted in an equal ratio with glass would diminish in bulk $\frac{1}{17}$th by an abstraction of heat equal to 12,600°, assuming even that the expansion at elevated temperatures is not more considerable than it is at low ones.

between the quantity at one minute and another appearing to be as 53·5 to 21·5 cubic inches, or as 5 to 2. So that the quantity evolved from the central orifice seems to be about one seventh of that from the area from which the gas was before collected.

Upon reviewing the aggregate of the observations above detailed, I cannot bring myself to believe, that the gas at present disengaged in a given time from the King's Bath is to be regarded as invariable in quantity; for the differences between the results obtained on one day and another are too considerable to be referred to errors of manipulation, or to the escape of the gas in a greater or less degree from other avenues. Besides, there will be seen, by referring to the annexed Table, a kind of flux and reflux in the quantities obtained; that of September 17th exceeding the mean by no less than seventeen cubic inches, those of the 18th, 19th, 20th, 21st, 23rd falling short of it by variable quantities; that of the 24th exceeding it again; on the 25th and 26th approaching it very nearly; on the 27th, and again the next time of observing, namely on October 2nd, exceeding the mean; from thence till the middle of the 5th falling short of it a little, then till the 9th exceeding the mean, on the 17th falling short of it again, but on the 18th again rising somewhat beyond the average.

If, then, a variation in the quantity of gas emitted seems to be fairly substantiated by the observations I have recorded, it becomes a subject for inquiry, to what cause this irregularity may be ascribed.

I at first imagined, that its emission might be in some degree controlled by atmospheric pressure; but the general tenor of the observations seems to dispell this notion, or at least to show, that there are other causes by which its flow is in a greater degree affected. Neither do the other conditions of the atmosphere noticed in the Table appear to exert any appreciable influence upon the current of gas, though, as the weather during the time I spent at Bath was in general fine, and during a large portion of the time remarkably steady for the season, it were to be wished that some gentleman resident on the spot would avail himself of the opportunities that might present themselves for examining the spring under a greater variety of circumstances; especially, as it has been vaguely stated with regard to some other hot springs, on the authority of casual observers, that the evolution of gas is greatest during storms and gales of wind*.

With regard to the quality of the gases given off, I have but little to add to what had been before determined. In the air I collected, oxygen certainly was present, as indeed Sir G. Gibbes had already ascertained to be the case, by the test of nitrous gas. Phosphorus heated in a bent tube with a measured portion of the air causes a diminution in its volume, which in almost all my trials amounted so nearly to 1·25 per cent., that I set down the proportion of those two gases one to the other as probably constant; and if we grant that nitrogen obtains an increase of bulk amounting to 2·5 per cent. by phosphorus vapour, I cannot be far wrong in reckoning

* The same thing has been noticed with regard to volcanos. See Scrope's Considerations on Volcanos, p. 7.

the oxygen at rather less than four parts, and the nitrogen as rather more than 96, in the 100. This, however, is to be understood as only applying to the gas remaining after having been agitated with a solution of potash; for there is always present a certain portion of carbonic acid, which on some occasions appeared to amount nearly to what Mr. R. PHILLIPS in his analysis has stated it at, namely at 4·5 per cent. of the whole quantity.

I have at other times, however, found it to reach 8 or 9, and once even 13 per cent.; so that I am forced to conclude this element in its composition to be of variable amount.

As, however, the quantity that escapes is only the excess over and above that which the water itself holds in solution, the cause of its variation may perhaps be explained, without imagining it an indication of any change in the nature or intensity of the processes to which the heat of the springs is owing.

The quantity of water which is discharged per minute has been calculated at about 146 gallons, of which 126 gallons are received at the King's and Queen's Bath, 10 at the Cross Bath, and about 10 at what is called the Hot Bath.

Now it is stated by Mr. PHILLIPS, that every pint of the water contains 1·2 cubic inch of carbonic acid; so that about 1400 cubic inches of carbonic acid are dissolved in the water, whilst the quantity that escapes may vary from about 12·3 to 36·0 cubic inches*.

It is evident, therefore, that an increase in the supply of water from 146 to 150 gallons would occasion the whole of the gas to be absorbed, and that a difference of only two gallons and a half in the amount of the water discharged would account for the utmost variation in the quantity of carbonic acid, which I have ever detected between one day and the next.

Now, though the supply of water is remarkably uniform, I conceive, that so slight a variation as that hinted at, might easily take place without its being observed†.

It might be worth while to ascertain, whether the quantity of gas evolved bears any relation, either to the temperature or the copiousness of the spring from which it rises; and, so far as the thermal waters of this country are concerned, it would appear,

* Mr. WALCKER's analysis (Journal of Science for June 1829,) differs from the above, as he calculates only 0·95 of a cubic inch of carbonic acid in every pint of the water, or 7·6 cubic inches to the gallon. Even then, however, 957·6 cubic inches of gas would be given off every minute by the spring, even if we do not count any portion of that which exists in combination with the iron, lime, or alkalies, as derived from the interior of the earth. The latter Mr. WALCKER has stated at 1·62 cubic inch in every pint.

† This, however, assumes, what perhaps will not be granted, namely, that the carbonic acid present in the water is derived from the gas emitted from below, and not from the atmosphere. A cold spring from the lower part of the city close to the Cross Bath, yielded me in the pint,

Carbonic acid	0·90
Nitrogen	0·64
Oxygen	0·13
Total	1·67 cubic inch.

that such a conjecture is somewhat contenanced by what is observed at Bath, where the hottest and most abundant emits the largest quantity of elastic products.

Thus the King's Bath, which possesses, as I have ascertained by almost daily observations for a month by a thermometer with a scale divided to half-degrees of FAHRENHEIT, an uniform temperature of 115°, and which evolves 126 gallons of water per minute, disengages on the average about 240 cubic inches of nitrogen, whilst the Cross Bath, which affords only about eight gallons, and is at 96°, gives out only 12 cubic inches of gas. What the quantity may be from the Hot Bath, which, besides being hotter, is also somewhat more copious than the Cross, I have not had the means of correctly ascertaining, as, at the spot where it issues from the earth, it is covered over; but I have reason to believe that the emission of gas from it must be small.

The only other warm spring, which I have as yet examined with reference to this point, is that called Taafe's Well, already noticed as occurring near Cardiff, in which the thermometer rises only to 70, and this, which discharges much less water than the others mentioned, gives out only 22·5 * cubic inches per minute †.

But we ought not to build on so scanty an induction of particulars, and must pause for the present, in the hope, that in other countries those who may be favourably circumstanced for such inquiries will repeat, with reference to the thermal springs of the Continent, the same observations which I have undertaken at Bath.

Having now, as I hope, faithfully recorded the limits, within which the quantities of elastic fluid evolved by the principal Hot Spring at Bath appeared to fluctuate, during the period of my observations, and submitted to the consideration of the members of this Society a mode of accounting for its regular and nearly equable disengagement, I shall forbear to speculate on the causes of its peculiar chemical constitution, or to dwell upon the inferences that might be deduced from its presence, with regard to thermal springs in general.

I will only remark, that the largeness of the volume of nitrogen gas which is disengaged, and the entire absence of carburetted, sulphuretted and phosphuretted hydrogen, seem to afford an additional presumption against the idea, advanced by a distinguished chemist in a paper recently published in our Transactions, that the nitrogen gas which escapes from volcanos and from thermal springs may be derived from the atmospheric air, held in chemical solution by water generally, but deprived in these instances of the greater part of its oxygen by animal and vegetable putrefaction. It seems obvious, that no amount of water, which can be supposed to obtain access to the depths at which the heat originates, could be sufficient to supply so

* This must be considered only a rude approximation, as I had no apparatus large enough to cover over the whole of the bath, and consequently to collect all the gas that rises at once.

† This gas contained no carbonic acid, but consisted of

Oxygen	3·5	(allowing an expansion of 2·5 for phosphorus vapour, as in the other cases,)
Nitrogen	96·5	

In the 100 parts.

large a quantity of nitrogen, and likewise that no such quantity of vegetable and animal matter could there exist, as would be requisite in order to absorb a corresponding proportion of oxygen.

Neither in such a case could the nitrogen that escaped arrive at the surface, without being contaminated with some of the inflammable products, that commonly arise from the decomposition of organic matter.

I look, therefore, to some process of combustion, during which the atmospheric air that finds admittance is in great measure deprived of its oxygen, as a likelier mode of accounting for the peculiar constitution of the gas emitted; and conceiving that the carbonic acid that accompanies it, is more probably derived from the calcination of earthy carbonates, than from the combustion of beds of coal or bitumen, I am led to conclude from the frequent absence of other gaseous products, that the oxygen becomes united to some base, which forms with it a compound not easily volatilized by heat.

How far these conclusions, if considered to be substantiated, tend to support that theory of volcanos and the connected phenomena, which naturally emanated from the discoveries of our former illustrious President, who also, at one period at least of his life, himself advocated it, must be left for the Society to decide, as it would ill become me to do more, than to lay before its members a statement of such facts, as appear to bear upon a question, respecting which the highest authorities in science have been divided.

In conclusion, therefore, it only remains, that I should express my obligations to the gentlemen who constitute the Committee of the Bath Waters, to whom I applied for leave to institute the above observations, for their ready acquiescence in my wishes, and for the facilities afforded me in the prosecution of these researches.

I must, likewise, acknowledge the kind assistance I received from several of the residents of Bath, particularly from Mr. G. Spry, who has long taken an active concern in the conduct and management of these springs; and from Mr. Thomas Stephens Davies, Fellow of the Royal and the Astronomical Societies, a gentleman well known for several valuable mathematical papers, to whom I am indebted, not only for much occasional information relative to the springs, but also for having, at a considerable sacrifice of time and convenience, attended at the bath whenever the observations were made, and taken upon himself the task of minuting their duration, and of noting down with the utmost regularity the quantities of gas each time obtained.

REGISTER of the quantity and quality of the gases evolved by the hot spring which supplies the King's Bath in the city of Bath, at the times and under the circumstances stated below.

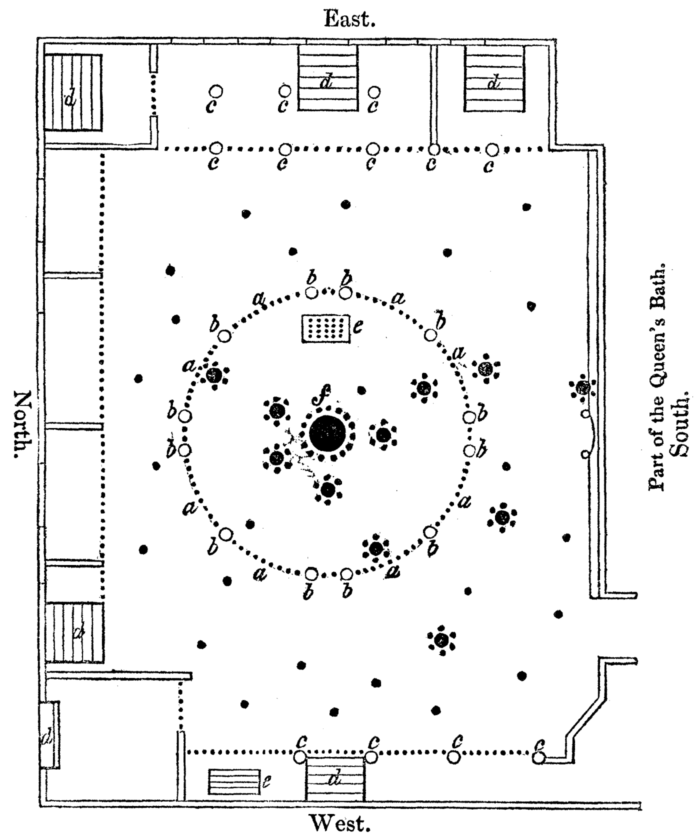
Obs.	Date.	Hour.	Weather.	Barometer.	Thermometer, FAHR.	Dew point.	Gas collected per minute from the central orifice.			Gas collected per minute from an area of twenty feet in the centre of the bath.			Amount of carbonic acid per cent. each day.	Duration of each observation.
							Max.	Min.	Mean.	Max.	Min.	Mean.		
	1833.													Minutes.
1.	Sept. 17.	4 P.M.	Sunshine and rain alternately	29·525	60	....	....	....	28	....	....	280	8·00	5
2.	18.	2 P.M.	Sunshine and rain alternately	29·7	64	50	....	....	28	....	....	253	9·25	5
3.	19.	1 P.M.	Sunshine, followed by storms of rain	29·9	66	52	80	15	39	....	....	194	....	6
4. ☽	20.	1 P.M.	Dull morning, followed by bright sunshine	30·1	60	49	65	20	39	....	....	230	....	7
5.	21.	1 P.M.	Much as the 20th	30·0	66	52	55	20	30	....	....	253	13·50	6
6.	23.	1 P.M.	Fine bright sun during most of the day	29·7	66	49	50	30	40	280	80	247	....	10
7.	24.	1 P.M.	Stormy morning; cloudy afternoon	29·2	62	58	45	35	40	310	220	276	....	10
8.	25.	1 P.M.	Storms of rain, and sunshine, alternately	29·555	61	48	40	30	35	300	220	266	....	10
9.	26.	1 P.M.	Bright sunshine, and cloudless sky	29·65	61	48	40	30	35	300	220	266	....	9
10.	27.	1 P.M.	Bright sunshine as on the 26th	29·72 *	59	49	50	10	30	345	220	276·5	....	12
○	28.													
11.	Oct. 2.	between 1 & 2 P.M.	Bright sunshine, and cloudless sky	30·05 †	63	47	60	15	35	330	240	274·5	....	10
12.	3.	between 1 & 2 P.M.	As on the 2nd	30·00	58	51	50	20	30	310	215	266	4·60	10
13.	4.	1 P.M.	As on the 3rd	29·975	59	49	60	10	36·5	330	200	266·5	4·66	10
14.	5.	1 P.M.	Occasionally overcast, with gleams of sunshine alternately	30·0	58	47	50	23	40·5	310	220	262	9·00	10
15.	....	6 P.M.	Calm, but cloudy evening	30·0	54	....	....	....	....	350	200	265	....	11
16.	....	12 midnight	Calm, but cloudy evening	....	....	....	....	....	....	340	250	280·5	....	10
17. ☾	6.	between 7 & 8 A.M.	Fine bright morning	....	....	....	....	....	....	530	220	300·5	4·60	13
18.	....	1 P.M.	Fine sultry day, somewhat less clear than the preceding ones	29·9	59	49	40	15	30	370	200	295	....	12
19.	7.	1 P.M.	Dull morning; fine afternoon	30·0	57	47	65	5	30	325	235	272	4·50	15
20.	8.	1 P.M.	Dull morning; fine afternoon	29·95	55	43	40	30	33	320	180	271·5	9·00	15
21.	9.	between 1 & 2 P.M.	Very bright morning; duller afternoon, with fleecy clouds, but sunshine.—Wind changed to the west	30·05	58	45	80	35	48	300	215	256·6	9·00	15
●	13.													
22.	17.	1 P.M.	Bright morning; afternoon overcast.—Wind north	29·625	56	....	....	....	....	355	180	244	....	10
23.	18.	Both obs. betwixt 1 and 2 P.M. at intervals of 10 min.	Dull and damp morning	29·5	54	47	40	25	33·3	400	200	266	....	10
24.	....		Rain in the afternoon	....	....	....	....	....	....	350	230	270	5·66	10
Mean of all the Observations				29·814	59·8	48·85	53·5	21·5	34·75	339	207	263·92 ‡	7·43	10·025
Maximum of all the Observations				30·1	66	52	80	35	48	530	250	300·5	13·5	15
Minimum of all the Observations				29·2	54	43	40	5	28	280	80	194 §	4·5	5
Difference between the Maximum and Minimum				0·9	12	9	40	30	20	250	170	106·5 ‖	9·0	10

* Falling since the morning. † Falling. ‡ Or, omitting obs. 3, as inexact, 266·96. § Or, omitting obs. 3., 230. ‖ Or, 70·5.

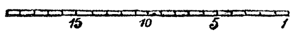
Largest quantity obtained being (300·5 × 1440 = 432,720) at the rate of 432,720 cubic inches, or, 250 cubic feet 72 cubic inches, in the 24 hours.

Smallest quantity, (194 × 1440 = 279,360) at the rate of 279,360 cubic inches, or 161 cubic feet 1152 cubic inches, in the 24 hours. Or, omitting obs. 3, (230 × 1440 = 331,200) at the rate of 331,200 cubic inches, or, 191 cubic feet 1152 cubic inches, in the 24 hours.

Mean quantity, (263,92 × 1440 = 380,044) at the rate of 380,044 cubic inches, or, 219 cubic feet 1612 cubic inches, in the 24 hours. Or, omitting obs. 3, (266·96 × 1440 = 384,422) at the rate of 384,442 cubic inches, or, 222 cubic feet 806 cubic inches, in the 24 hours.



Ground Plan of the King's Bath.



Scale of Feet.

Description.

a. Area, inclosed by the hand-rail, twenty feet in diameter.
b. Upright bars supporting the hand-rail.
c. Pillars supporting the roof of the covered portion of the bath.
d. Steps leading down into the bath.
• :●: Apertures in the bath through which the water and gas rise.

.... Portions of the sides of the bath which are under cover.

e. Drains through which the water is allowed to discharge itself.

f. Stone cylinder eighteen inches in diameter occupying the centre of the bath, through which the spring principally rises.

APPENDIX.

Received January 22,—Read January 23, 1834.

SUBSEQUENTLY to the reading of the above Paper, I have had an opportunity of examining two tepid springs, which, since the setting in of the wet weather, have broken out at the foot of St. Vincent's Rocks, Clifton, immediately below the cliff from which the Suspension Bridge over the Avon was designed to spring, and on the summit of which the Observatory is erected.

The temperature of the one is 72°, that of the other 66° of FAHRENHEIT; and both are continually emitting bubbles of gas, which I found to consist of

Carbonic acid	3
Oxygen	8
Nitrogen	92
	103

The circumstance may be worth noticing on two accounts. First, as evincing that the cause, whatever it may be, of the heat, is not limited to a single spot, but is diffused over a considerable space in the direction along which the chasm extends; thus confirming an observation made to me by that intelligent naturalist, the late Mr. MILLER of Bristol, that when, in consequence of rain, a new spring appears at the foot of these cliffs, its temperature is generally higher than that of the ordinary springs of the district: and secondly, as adding one additional instance to the catalogue of those thermal waters, which are accompanied by an evolution of nitrogen gas.

This is the more important, because, owing to the circumstance of the principal tepid spring at Bristol, which is preserved for medicinal purposes, being covered over at its source, it was impossible to ascertain from this one, whether the thermal waters of this place agreed in that particular with those of other localities, or whether they constituted an exception to the generality of this rule.

January 22nd, 1834.