IX. New experimental researches on some of the leading doctrines of caloric; particularly on the relation between the elasticity, temperature, and latent heat of different vapours; and on thermometric admeasurement and capacity

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3d. That in syllables prosodially *short*, the present short sounds of all our vowels should, as far as possible, be retained : but where impracticable or ungraceful, as in the first and last syllable of *αειδε*, or the second syllable of *recubans*, that *then* the long sound shortened in its dimensions be introduced. Here too it must be noticed, that all half-articulated or *muttered* sounds are inadmissible—such as that with which the generality of readers distinguish or rather *ex-tinguish* the second syllables of *Titÿre* and *Tegmÿne*, which syllables should necessarily be read as if written *tee* and *mee* ; for otherwise these words, in place of becoming Dactyls, would be converted into a species of Cretic, thus — $\overset{\circ}{\text{u}} \overset{\circ}{\text{u}}$.

4th. That the *iteration* of consonants, as the λ of *Αχιλλεύς*, the l of *Amaryllida*, &c. being foreign to our English usage, and now rendered needless, should never be attempted.

5th. That in order to obviate all *drawling* habits, the comparatively unemphatic long syllables should, when expedient, yield the precedence, in length, to the more emphatic long ones.

[To be continued.]

IX. *New experimental Researches on some of the leading Doctrines of Caloric; particularly on the Relation between the Elasticity, Temperature, and latent Heat of different Vapours; and on thermometric Admeasurement and Capacity.*
By ANDREW URE, M.D.

Glasgow, July 1817.

1. *On the elastic Force of Vapours, with new Formulæ to determine it at any Temperature; and a Review of those given by DALTON and BIOT.*

THE phænomena attending the conversion of liquids into elastic fluids, were first accurately investigated by Dr. Black. He observed in the rising of vapour, and melting of ice, a beautiful system of relations, connecting and modifying the grandest operations of nature, while they were destined to afford new principles for the advancement of the arts. If it be the prerogative and characteristic of genius, to discover in the most familiar, or, as some would say, vulgar phænomena, that mystic chain of causation, which had eluded all other eyes, unquestionably, the doctrines of latent heat entitle their author to rank in the first class of philosophers.

Dr. Black directed his attention principally to the establishment of the general laws, which he placed on an immoveable

* From the Transactions of the Royal Society for 1818, Part II.

basis ; leaving to his pupils, the subordinate task of investigating their individual applications. Hence, the elastic forces of the vapours, arising from different bodies, at different temperatures, seem to have occupied him very little, if at all. This subject was examined, however, with great ability, by two of his most distinguished friends, Professor Robison and Mr. Watt. The investigations of the former were published in the *Encyclopædia Britannica*, article *Steam* ; while we have still to regret our ignorance of those executed by the latter philosopher, with probably a more complete apparatus, and more extensive views. We are indebted to him, indeed, for some curious observations on the latent heat of steam, at different temperatures, which make us lament more, the want of those on the elastic forces themselves.

Mr. Dalton, whose peculiar speculations on caloric and meteorology led him to study the formation and variable elasticity of vapour with great attention, has since then favoured the world with many excellent dissertations, and is now reckoned the first authority on the subject. Mr. Dalton's experiments on the steam of water were carried no higher than its ordinary boiling point ; but from the observed progression of its elastic force he investigated a formula, and calculated from it a table for the higher temperatures*.

In the second number of the *Journal Polytechnique*, M. Betancourt, an eminent Spanish engineer, long resident at Paris, published a set of experiments on the same subject, the results of which differ from those of Mr. Dalton in many particulars, but most remarkably in the higher part of the scale.

Having had my mind often called to this important inquiry in the course of my public lectures on the applications of Science to the Arts, an apparatus of a very simple nature occurred to me, about two years ago, by which I hoped to be able to determine, with great precision, the elastic forces of vapours at any temperature, from zero of Fahrenheit to a much higher degree of heat than even Betancourt seems to have reached. The experiments were made soon after that time, but circumstances have till now prevented me from arranging them for publication.

With Betancourt's apparatus I am not acquainted, having seen only the brief table of results, inserted in our systematical works on chemistry. Professor Robison's consisted of a strong boiler or digester, containing the water, and furnished with three small apertures ; the first receiving the bulb of a thermometer, the second covered with a safety-valve, and the third having a barometer tube attached. At first I used a similar construction ; but finding it hazardous, and somewhat unmanageable in the high

* Manchester Memoirs, vol. v. p. 563.

heats, and difficult to render air-tight in the lower temperatures, I abandoned it, after some unsatisfactory trials. At the low degrees of heat, the vacant part of the barometer tube introduces errors, since it has not the temperature of the boiler; and the bulb of the barometer, used in high heats, occasions a similar fallacy in the determination of the true elasticities.

Still, however, it was ingeniously conceived, and the results furnish good approximations, creditable to the celebrated experimenter*. They agree nearly with those of Betancourt, being obtained probably in a similar way. The method adopted by Mr. Dalton is recommended by an elegant simplicity. It is merely a common barometer, into which a little of the vapour-giving liquid is introduced, so as to moisten, and float above the mercury. The vapour which is generated, depresses more or less the barometric column. Hence, by subjecting the liquid to successive degrees of temperature, the corresponding depressions of the barometer, or elasticities of the vapour, are obtained.

The only difficulty in this mode of operating, is to bring a considerable length of vertical tube to an uniform temperature.

Mr. Dalton, well aware of this source of error, obviated it in a great measure, by taking a series of different tubes, decreasing in their lengths with the increasing expansions of the vapour, and concomitant descent of the mercurial column. In several experiments conducted on this plan, I found it scarcely possible to obtain results rigidly corresponding with each other, when the column of vapour, exposed in the barometer tube to the influence of surrounding heat, exceeded two inches in length.

M. Biot, in his system of physics recently published, while he adopts Mr. Dalton's results as the basis of his reasoning, treats fully of this difficulty, and suggests an ingenious means of avoiding it. "We have had occasion several times to remark," says he, "that the temperature of a mass of liquid which cools in the air, is not entirely the same at the bottom, as it is at the top of the vessel; because the colder particles subside into the lower strata, by the excess of their weight. Thus the temperature of the column of hot water, which surrounds the tube in the preceding experiment, cannot be rigorously uniform throughout its whole height. We may endeavour to render it equal, by agitating and mingling the different strata of which it is composed; but this would be attended with no little difficulty. It would be better to have several thermometers suspended at different heights, in the body of the water, and to take the arithmetical mean of their indications. Or otherwise, which would probably be more exact, we might employ a thermometer having a cylindrical

* See *Encyclopædia Britannica*, vol. xvii. p. 739, 2d edition.

bulb, equal in length to the column of vapour. It would then be necessary that the column of water should rise sufficiently above this vapour to allow the thermometer bulb to be equally immersed, or we must make on its indications the small correction mentioned p. 59, in order to reduce the temperature of the cylinder of mercury to the temperature of the reservoir. The employment of such a thermometer may appear at first sight sufficiently difficult, since it seems that the length of the cylindrical reservoir must be very considerable, if the elastic force of the vapour be great*."

He then proceeds to show how this difficulty may be obviated (as indeed it had previously been by Mr. Dalton), by taking barometer tubes successively shortened, as the force of the steam is augmented by heat. He proposes to use four, between the freezing and boiling points of water, each being two decimeters, or nearly 8 inches long, and the thermometer bulb having also that length. The plan which I imagined, as it completely obviates the source of errors arising from the large and variable space occupied by the vapour, supersedes the necessity of employing M. Biot's singular remedy. It likewise avoids other complications, introduced by the heating and consequent elongation of the mercurial column itself attending all the other methods; and scarcely capable of being exactly appreciated at high temperatures with the apparatus of Professor Robison.

The space over which the vapour extends in my instrument, need never be greater than half an inch of the barometer tube, against the side of which part the oblong bulb of a delicate thermometer rests, so as to indicate the true temperature. And though the liquid and incumbent vapour are thus always restricted to the summit of the barometer tube, we can, notwithstanding, measure its progressive range of elasticity, from zero of Fahrenheit to one hundred, or even two hundred, degrees above the boiling point of water, from an elasticity of 0.07 of an inch, to that capable of sustaining 14 feet, or even 36 of mercury. Fig. 1 (Pl. I. †) represents the construction employed for temperatures under and a little above the boiling point. Fig. 2 and 3 are used for higher temperatures; the last is the more convenient of the two. Each was suspended from a lofty window ceiling, and placed in a truly vertical position by means of a plumb line.

One simple principle pervades the whole train of experiments; which is, that the progressive increase of elastic force developed by heat from the liquid, incumbent on the mercury at $ll' l''$, is measured by the length of column which must be added over L ,

* *Traité de Physique*, tome i. p. 268.

† This Plate will be given with our next Number.

the primitive level below, in order to restore the quicksilver to its primitive level above, at l . These two stations, or points of departure, are nicely defined by a ring of fine platina wire twisted firmly around the tube.

At the commencement of the experiment, after the liquid well freed from air has been let up, the quicksilver is made a tangent to the edge of the upper ring, by cautiously pouring mercury in a slender stream into the open leg of the syphon D. The level ring below is then carefully adjusted.

From the mode of conducting my experiments, there remained always a quantity of liquid in contact with the vapour, a circumstance essential to accuracy in this research.

Suppose the temperature of the water or the oil in A to be 32° F., as denoted by a delicate thermometer, or by the liquefaction of ice; communicate heat to the cylinder A, by means of two Argand flames, playing gently on its shoulder at each side. When the thermometer indicates 42° , modify the flames, or remove them, so as to maintain an uniform temperature for a few minutes. A film or line of light will now be perceived between the mercury and the ring at l , as is seen under the vernier of a mountain barometer when it is raised a few feet off the ground. Were the tube at l and L of equal area, or were the relation of the areas experimentally determined, then the rise of the quicksilver above L would be one half, or a known submultiple of the total depression, equivalent to the additional elasticity of the vapour at 42° above that at 32° . Since the depressions, however, for 30 or 40 degrees in this part of the scale are exceedingly small, one half of the quantity can scarcely be ascertained with suitable precision, even after taking the above precautions. And besides, the other sources of error, or at least embarrassment, from the inequalities of the tube, and from the lengthening space occupied by the vapour, as the temperature ascends, render this method of reduction very ineligible.

By the other plan we avoid all these evils. For whatever additional elasticity we communicate to the vapour above l , it will be faithfully represented and measured, by the mercurial column which we must add over L, in order to overcome it, and restore the quicksilver under l to its zero or initial level, when the platina ring becomes once more a tangent to the mercury*.

At E a piece of cork is fixed, between the parallel legs of the syphon, to sustain it, and to serve as a point by which the whole is steadily suspended.

For temperatures above the boiling point, the part of the sy-

* Rings of other metals will not suit; for, their expansions being much greater than that of glass, they become loose with the elevation of temperature.

phon under E is evidently superfluous, merely containing in its two legs a useless weight of equipoised mercury. Accordingly for high heats, the apparatus fig. 2, or 3, is employed, and the same method of procedure is adopted. The aperture at O, fig. 3, admits the bulb of the thermometer, which rests as usual on l'' . The recurved part of the tube is filled with mercury, and then a little liquid is passed through it to the sealed end. Heat is now applied by an Argand flame to the bottom of C, which is filled with oil or water, and the temperature is kept steadily at 212° for some minutes. Then a few drops of quicksilver may require to be added to D'' till L'' and l'' be in the same horizontal plane. The further conduct of the experiment differs in no respect from what has been already described. The liquid in C is progressively heated, and at each stage mercury is progressively added over L'' to restore the initial level, or volume at l'' , by equipoising the progressive elasticity. The column above L'' being measured, represents the succession of elastic forces. When this column is wished to extend very high, the vertical tube requires to be placed for support in the groove of a long wooden prism.

The height of the column in some of my experiments being nearly 12 feet, it became necessary to employ a ladder to reach its top. I found it to be convenient in this case, after observing that the column of vapour had attained its primitive magnitude, to note down the temperature with the altitude of the column; then immediately to pour in a measured quantity of mercury nearly equal to three vertical inches, and to wait till the slow progress of the heating again brought the vapour in equilibrium with this new pressure, which at first had pushed the mercury within the platina ring at l'' . When the lower surface of the mercury was again a tangent to this ring, the temperature and altitude were both instantly observed.

This mode of conducting the process will account for the experimental temperatures being very often odd and fractional numbers. I present them to the public as they were recorded on the instant in that particular repetition of the experiment which I consider most entitled to confidence. To trim and fashion the results into an orderly-looking series, would have been an easy task; but in my opinion this is a species of deception very injurious to the cause of science, and a deviation from the rigid truth of observation, which ought never to be made for any hypothesis. We shall afterwards have ample opportunities of exposing the fallacy of such premature geometrical refinements.

The thermometers were constructed by Creighton, with his well-known nicety, and the divisions were read off with a lens,
so

so that $\frac{1}{10}$ of a degree could be distinguished. After bestowing the utmost pains in repeating the experiments during a period of nearly two months, I found that the only way of removing the little discrepancies, which crept in between contiguous measures, was to adopt the astronomical plan of multiplying observations and deducing truth from the mean. It is essential to heat with extreme slowness and circumspection, the vessels, A, B, C. One repetition of the experiment occupies on an average 7 hours.

[To be continued.]

X. *On Specific Heat.* By Mr. JOSEPH LUCKCOCK, of Birmingham.

MUCH ingenuity and patient research have been displayed on the subject of Specific Heat; the thermometer, the meltings of ice, and the times of cooling heated substances, have been the basis of these calculations; and imposing algebraical formulæ have been brought in aid, to give to them the air of demonstrations: the results, however, are unsatisfactory; for in the attempts to fix the natural zero, or point of absolute privation of heat, some have placed it at 900° below the scale of Fahrenheit, whilst others have depressed it to 11000° .

This has principally arisen from a want of precision in our ideas, from the want of a definition of heat. My Essay on the atomical philosophy, published by Longman and Co., has been some time before the public; wherein I have endeavoured to set this matter right. I have identified the matter of heat with the electric fluid, that it is the element of fluidity, and to which I have given the name of Fluidium; because of the meagreness of the terms applied to the subject; such as heat of capacity, or specific heat; heat of transmission, or thermometric heat; creating a confusion of ideas in the mind, of hot heat and cold heat: the term Fluidium may well express latent heat, or heat of capacity, or specific heat; and the term *Heat* will well express its transmission by the means of chemical or electrical agency; and in which sense I shall use the terms, considering Fluidium as a substance, and Heat as a quality.

Sir H. Davy, speaking of the production of light and heat, very happily expresses himself that it is a *general* result of the actions of any substances possessed of strong chemical attractions, or different electrical relations, and that it takes place in all cases in which an intense and violent motion can be conceived to be communicated to the corpuscles of bodies: and he might have added that there can be no chemical attraction, no chemical action whatever, without electrical relations, without the aid
of