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12, for h' read h. The subsequent *formula*, in line 14, will then be accurate: but the *cases* mentioned in page xxv require a slight correction, and should be as follow:

Case 1. Arg. = Feb. 10 + (·500 − ·378)		= Feb. 10·122
Case 2. Arg. = Feb. 10 + (·750 − ·378)		= Feb. 10·372
Case 3. Arg. = Feb. 10 + (·250 − ·378)		= Feb. 9·872
Case 4. Arg. = Feb. 10 + (·125 − ·378)	+ ·018	= Feb. 9·765

This error has likewise led to the inaccurate expression $x - l$ in pages xxii line 18, xxiii line 9, xxiv lines 1 and 5, and xxv line 10; in each of which places it ought to be $x + l$.

It is evident that this error will not affect the argument of the Tables, when they are used in *this country*, or at any of the observatories in the neighbouring states. But, as it might probably mislead a computer under a more *distant meridian*, unless previously detected, I have taken the earliest opportunity of making the error known; although it is manifest that the effect will seldom be of much importance.

Jan. 23, 1827. FRANCIS BAILY.

XXI. *Investigation of the Heat extricated from Air when it undergoes a given Condensation.* *By* J. IVORY, *Esq. M.A. F.R.S.**

CONCEIVE a quantity of air confined in a close vessel, and let heat be applied to it, the pressure remaining invariable, till it is expanded to a given volume. Again, taking the same mass of air in its first state, let the dimensions of the vessel be suddenly enlarged till the air has acquired the same volume to which it was before expanded by heat: the air within the vessel will become colder, and after a short moment of time will resume its first temperature. We must therefore infer that air, when its volume is increased, absorbs heat, which occasions the coldness; and that the coldness disappears because the loss of temperature is supplied by the communication of heat from the surrounding bodies. That this is a true account of the matter, and that no heat is lost, it is easy to prove; for if the vessel containing the expanded air be reduced to its original bulk, the heat before absorbed will be extricated as the air contracts, producing a rise of temperature which is soon dissipated. Now let heat be applied to the expanded air, while its volume is kept from changing, till the temperature is raised to the same degree as in the first operation: it it evident that the air will now be in

* Communicated by the Author.

the same condition to which it was before brought by the agency of heat alone. For, in both cases, there is the same volume and the same temperature, and consequently there must be the same density and pressure.

And, since the air is precisely in the same state, it must have acquired the same quantity of heat in both processes. It follows, therefore, that when air, under a constant pressure, expands by the agency of heat, the absolute heat which causes a given rise of temperature, or a given dilatation, is resolvable into two distinct parts; of which one is capable of producing the given rise of temperature, when the volume of the air remains constant; and the other enters into the air, and somehow unites with it while it is expanding. Of this latter part there is no perceptible sign, except the cold, or the heat, which appears at the instant of its entrance, or *exit*. The two heats have no mutual dependence on one another, since either of them may be varied in any manner while the other remains unchanged. It is necessary to distinguish them by appropriate names. The first may be called the *heat of temperature*; and the second might very properly be named the *heat of expansion*; but I shall use the well known term, *latent heat*, understanding by it the heat that accumulates in a mass of air when the volume increases, and is again extricated from it when the volume decreases.

We must next inquire according to what law the latent heat accumulates when air expands. When a mass of air, under a constant pressure, varies by the application of heat, I assume it as an acknowledged principle that equal quantities of absolute heat produce equal increments of volume. It is evident that this principle cannot be deduced by reasoning: it must be established by experiment. It is true, so long as an air-thermometer can be reckoned an exact measure of heat; for, if it were not true, the indications of that instrument would be irregular. But, what proof have we that an air-thermometer measures heat exactly? To this it must be answered, that we arrive at the conclusion indirectly, and that there is no direct proof. If we suppose that a given quantity of absolute heat applied to all bodies caused an increment of volume, always the same in the same body although different in different bodies, it is evident that all bodies would indicate by their dilatations the same progression of temperatures. Two thermometers, made of any materials, which agreed in two points of their scales, would always mark the same degrees of heat. Now if we compare two thermometers, one of air and the other of mercury, which have their scales adjusted to the fixt points at which water freezes and boils, and

and find that their indications agree for a long range of temperature, we must infer that the supposed principle is true in nature for the whole of the interval, and that equal quantities of absolute heat have uniformly caused equal expansions on both scales.

In an air-thermometer, or, which is the same thing, in a mass of air under a constant pressure, the rise of temperature is proportional to the increment of volume. Wherefore, since both the absolute heat and the heat of temperature keep pace with the increase of volume, it follows that their difference, that is, the latent heat, must follow the same law of variation.

And, because it is proved that equal increments of latent heat correspond to equal rises of temperature and to equal increments of volume, we may employ the dilatation of a mass of air to measure the accumulation of latent heat, just as we employ it to measure the increase of temperature. Let v' denote the volume of the fluid, at some fixt temperature, suppose zero of the thermometrical scale; and, the pressure being constant, put v for the volume when the temperature has been raised to τ, and the latent heat i has combined with the air: then, α and β being two constants, it is evident that we shall have,

$$\left.\begin{aligned} v &= v'(1 + \alpha\tau) \\ v &= v'(1 + \beta i) \end{aligned}\right\} \quad (A)$$

When v' and v are the same in the two formulæ, the two factors $1 + \alpha\tau$ and $1 + \beta i$ are equal: consequently,

$$\beta i = \alpha\tau, \text{ and } \frac{\alpha}{\beta} = \frac{i}{\tau}.$$

The fraction $\frac{\alpha}{\beta}$ is therefore the proportion of the latent heat to the rise of temperature for the same dilatation of the fluid; a proportion which, as has been shown, is constant so long as the air-thermometer continues to be an exact measurer of heat.

The first of the two formulæ necessarily supposes that the air has varied under a constant pressure; but the second is true in whatever manner the volume has changed from v' to v.

Let ϱ' and ϱ denote the respective densities when the volumes are v' and v: then $\frac{\varrho}{\varrho'} = \frac{v'}{v}$, and hence we derive these other expressions, viz.

$$\left.\begin{aligned} \varrho &= \frac{\varrho'}{1+\alpha\tau} \\ \varrho &= \frac{\varrho'}{1+\beta i} \end{aligned}\right\} \quad (B)$$

Of

Of the two constants α and β, the first is the well-known expansion of elastic fluids for one degree of the thermometer. The fraction $\frac{\alpha}{\beta}$, and consequently β, may be found by ascertaining the heat disengaged from a given mass of air by a given condensation; for the proportion of this heat to the heat of temperature required to produce the same condensation, the pressure remaining constant, would be the fraction sought. I know not that any such experiment has been made with sufficient precision. It appears difficult to perform it with great accuracy, on account of the small quantity of matter in air when compared with the vessels that contain it and with the thermometer, bulk for bulk. But we may employ for the same purpose a very curious and ingenious experiment first made by MM. Clement and Desormes, and afterwards repeated by MM. Gay-Lussac and Welter, which ascertains by the variation of the barometer the heat absorbed or extricated in the changes of volume.

Let p, ϱ, τ denote the barometric pressure, density, and temperature of a mass of air: then

$$p = c\,\varrho\,(1 + \alpha\,\tau),$$

c being a given number. Put $\varrho' = \varrho\,(1 + \alpha\,\tau)$; then ϱ' will be the density of the same mass of air cooled down to zero of the thermometer, the pressure being constant; and we shall have,

$$p = c\,\varrho'. \qquad (1)$$

In this formula we consider ϱ' as a fixed density, and estimate all the changes in the condition of the mass of air by means of the variations of the latent heat and the heat of temperature. The air being contained in a close vessel, let a small additional portion of air be forced into the vessel: the consequent condensation will cause an increase of pressure, an evolution of latent heat, and an equal rise of temperature, all which circumstances are easily expressed by proper changes in equation (1), viz.

$$p + \delta p = c\,\varrho' \times \frac{1 + \alpha\,\delta i}{1 - \beta\,\delta i}.$$

After the condensation, the density being fixed, there will be no change in the latent heat; but the heat of temperature will be dissipated in a short moment of time, and the pressure will decrease a little: let p' be the pressure when the condensed air has resumed the general temperature, then,

$$p' = c\,\varrho' \times \frac{1}{1 - \beta\,\delta i}. \qquad (2)$$

A communication must now be opened between the confined air

air and the atmosphere: the condensed air will rush out and expand within the vessel, attended with a decrease of pressure, an absorption of heat and an equal depression of temperature; and the last equation will now assume this form, viz.

$$p' - \delta p' = c\,\varrho' \times \frac{1 - \alpha\,\Delta i}{1 - \beta\,\delta i + \beta\,\Delta i}.$$

We must here conceive that $\delta p'$ and Δi vary together, and in a very short space of time the pressure will have decreased to its original quantity p: at the instant this is observed to take place, the communication with the external air must be shut, and then we shall have,

$$p = c\,\varrho' \times \frac{1 - \alpha\,\Delta i}{1 - \beta\,\delta i + \beta\,\Delta i}. \qquad (3)$$

But this state of the air will be momentary only; for the loss of temperature will be supplied, and the pressure will increase a little: let p'' be the pressure when it is observed to be stationary, then finally,

$$p'' = c\,\rho' \times \frac{1}{1 - \beta\,\delta i + \beta\,\Delta i}. \qquad (4)$$

Now by comparing (4) with (3) and (2), we get,

$$\frac{p}{p''} = 1 - \alpha\,\Delta\,i,$$

$$\frac{p''}{p'} = 1 + \beta\,\Delta\,i;$$

and hence,

$$\frac{\alpha}{\beta} = \frac{p'' - p}{p' - p''} \cdot \frac{p'}{p''}.$$

Taking the two experiments, one by MM. Clement and Desormes, and the other by MM. Gay-Lussac and Welter, of which the particulars are given in the *Mécanique Céleste* *, we find $\frac{\alpha}{\beta} = 0{\cdot}354$ from the first, and $\frac{\alpha}{\beta} = 0{\cdot}3724$ from the second. By the two latter philosophers the experiment was repeated in a great variety of circumstances, the pressure being varied from 144^{mm} to 1460^{mm}, and the temperature from $-20°$ to $40°$ of the centigrade thermometer; and the results were found nearly the same in every case, and upon the whole equal to about 0·3748, or $0{\cdot}375 = \frac{3}{8}$. This experiment was contrived expressly for solving the problem concerning the velocity of sound; for $\sqrt{1 + \frac{\alpha}{\beta}}$ is the factor by which, according to the suggestion of Laplace, the velocity determined by Newton's Theory must be multiplied, in order to get the true velocity. When a method for finding the numerical

* Liv. xii. chap. 3.

value

value of the quantity sought was known, it became a point of great importance to ascertain, by varying the circumstances of the experiment, whether that quantity always retained the same value independently of the different states of the atmosphere; and all the trials that have been made favour the conclusion that it is nearly constant. But the constancy of the factor is now proved *à priori* by the theory here laid down, and is no longer merely an induction from experiments. Taking $\frac{\alpha}{\beta} = \frac{3}{8}$, we are entitled to enunciate the following proposition, which solves the proposed problem:

The heat extricated from air when it undergoes a given condensation, is equal to $\frac{3}{8}$ of the diminution of temperature required to produce the same condensation, the pressure being constant.

Air, under a constant pressure, diminishes $\frac{1}{480}$th of its volume for every degree of depression on Fahrenheit's scale; and therefore one degree of heat will be extricated from air when it undergoes a condensation equal to $\frac{1}{480} \times \frac{3}{8} = \frac{1}{180}$. If a mass of air were suddenly reduced to half its bulk, the heat evolved would be $\frac{1}{2} \div \frac{1}{180} = 90°$.

Having now solved the proposed problem, I shall reserve what further is important on this subject to a future occasion.

Jan. 8, 1827. J. Ivory.

XXII. *The Bakerian Lecture. On the Relations of Electrical and Chemical Changes. By Sir* Humphry Davy, *Bart. Pres. R.S.*

[Continued from p. 38.]

IV. *On the electrical and chemical effects exhibited by combinations containing single metals and one fluid.*

I KNOW of no class of phænomena more calculated to give just views of the nature of electro-chemical action than those presented by single metals and fluids; and as their results are, with one or two exceptions, entirely new, I shall describe them with some degree of minuteness.—When two pieces of the same polished copper, connected with the platinum wires of the multiplier, were introduced at the same time into the same solution of hydro-sulphuret of potassa, there was no action; but if they were introduced in succession, there was a distinct and often, if the interval of time was considerable, a violent electrical effect—the piece of metal first plunged in being negative, and the other positive.

This result depends upon the circumstance of the production