# PHILOSOPHICAL TRANSACTIONS.

XIV. *New Experiments upon Heat. By Colonel Sir* Benjamin Thompson, *Knt. F. R. S. In a Letter to Sir* Joseph Banks, *Bart. P. R. S.*

Read March 9, 1786.

DEAR SIR,

I HAVE at length begun the courſe of experiments upon heat which I have ſo long had in contemplation; and I have already made a diſcovery, which, if not new to you, is perfectly ſo to me, and which I think may lead to a further knowledge reſpecting the nature of heat.

 Examining

Examining the conducting power of air, and of various other fluid and ſolid bodies, with regard to heat, I was led to examine the conducting power of the *Torricellian vacuum*. From the ſtriking analogy between the electric fluid and heat reſpecting their conductors and non-conductors (having found that bodies, in general, which are conductors of the electric fluid, are likewiſe good conductors of heat, and, on the contrary, that electric bodies, or ſuch as are bad conductors of the electric fluid, are likewiſe bad conductors of heat), I was led to imagine that the Torricellian vacuum, which is known to afford ſo ready a paſſage to the electric fluid, would alſo have afforded a ready paſſage to heat.

The common experiments of heating and cooling bodies under the receiver of an air-pump I concluded inadequate to determining this queſtion; not only on account of the impoſſibility of making a perfect void of air by means of the pump; but alſo on account of the moiſt vapour, which exhaling from the wet leather and the oil uſed in the machine, expands under the receiver, and fills it with a watery fluid, which, though extremely rare, is yet capable of conducting a great deal of heat: I had recourſe therefore to other contrivances.

I took a thermometer, unfilled, the diameter of whoſe bulb (which was globular) was juſt half an inch, Paris meaſure, and fixed it in the center of a hollow glaſs ball of the diameter of 1¾ Paris inch, in ſuch a manner, that the ſhort neck or opening of the ball being ſoldered faſt to the tube of the thermometer 7½ lines above its bulb, the bulb of the thermometer remained fixed in the center of the ball, and conſequently was cut off from all communication with the external air. In the bottom of the glaſs ball was fixed a ſmall hollow tube or point, which projecting outwards was ſoldered

to

to the end of a common barometer tube about 32 inches in length, and by means of this opening the ſpace between the internal ſurface of the glaſs ball and the bulb of the thermometer was filled with hot mercury, which had been previouſly freed of air and moiſture by boiling. The ball, and alſo the barometrical tube attached to it, being filled with mercury, the tube was carefully inverted, and its open end placed in a bowl in which there was a quantity of mercury. The inſtrument now became a barometer, and the mercury deſcending from the ball (which was now uppermoſt) left the ſpace ſurrounding the bulb of the thermometer free of air. The mercury having totally quitted the glaſs ball, and having ſunk in the tube to the height of 28 inches (being the height of the mercury in the common barometer at that time), with a lamp and a blow-pipe I melted the tube together, or ſealed it hermetically, about three-quarters of an inch below the ball, and cutting it at this place with a fine file, I ſeparated the ball from the long barometrical tube. The thermometer being afterwards filled with mercury in the common way, I now poſſeſſed a thermometer whoſe bulb was confined in the center of a *Torricellian vacuum*, and which ſerved at the ſame time as the body to be heated, and as the inſtrument for meaſuring the heat communicated.

## *Experiment* N° 1.

With this inſtrument (ſee fig. 1. Tab. VI.) I made the following experiment. Having plunged it into a veſſel filled with water, warm to the 18th degree of REAUMUR's ſcale, and ſuffered it to remain there till it had acquired the temperature of the water, that is to ſay, till the mercury in the incloſed thermometer ſtood at 18°, I took it out of this veſſel and plunged it ſuddenly into a veſſel of boiling water, and holding it in the water (which was kept conſtantly boiling) by the end of the tube, in ſuch a manner that the glaſs ball, in the center of which was the bulb of the thermometer, was juſt ſubmerged, I obſerved the number of degrees to which the mercury in the thermometer had ariſen at different periods of time, counted from the moment of its immerſion. Thus, after it had remained in the boiling water 1 min. 30 ſec. I found the mercury had riſen from 18° to 27°. After 4 minutes had elapſed, it had riſen to $44^{\circ}\frac{9}{10}$; and at the end of 5 minutes it had riſen to $48^{\circ}\frac{2}{10}$.

## *Experiment* N° 2.

Taking it now out of the boiling water I ſuffered it to cool gradually in the air, and after it had acquired the temperature of the atmoſphere, which was that of 15° R. (the weather being perfectly fine), I broke off a little piece from the point of the ſmall tube which remained at the bottom of the glaſs ball, where it had been hermetically ſealed, and of courſe the atmoſpheric air ruſhed immediately into the ball. The ball ſurrounding the bulb of the thermometer being now filled with air (inſtead of being emptied of air, as it was in the before-mentioned experiment), I re-ſealed the end of the ſmall tube at the bottom of the glaſs ball hermetically, and by that means cut off all communication between the air confined in the ball and the external air; and with the inſtrument ſo prepared I repeated the experiment before-mentioned; that is to ſay, I put it into water warmed to 18°, and when it had acquired the temperature

perature of the water, I plunged it into boiling water, and obſerved the times of the aſcent of the mercury in the thermometer. They were as follows:

| | Time elapſed. | Heat acquired. |
|---|---|---|
| Heat at the moment of being plunged into the boiling water, . . . | | 18° R. |
| | M. S. | ° |
| After having remained in the boiling water | 0 45 | 27 |
| | 1 0 | $34\frac{4}{10}$ |
| | 2 10 | $44\frac{9}{10}$ |
| | 2 40 | $48\frac{2}{10}$ |
| | 4 0 | $56\frac{2}{10}$ |
| | 5 0 | $60\frac{9}{10}$ |

From the reſult of theſe experiments it appears evidently, that the Torricellian vacuum, which affords ſo ready a paſſage to the electric fluid, ſo far from being a good conductor of heat, is a much worſe one than common air, which of itſelf is reckoned among the worſt: for in the laſt experiment, when the bulb of the thermometer was ſurrounded with air, and the inſtrument was plunged into boiling water, the mercury roſe from 18° to 27° in 45 ſeconds; but in the former experiment, when it was ſurrounded by a Torricellian vacuum, it required to remain in the boiling water 1 minute 30 ſeconds = 90 ſeconds, to acquire that degree of heat. In the vacuum it required 5 minutes to riſe to $48°\frac{2}{10}$; but in air it roſe to that height in 2 minutes 40 ſeconds; and the proportion of the times in the other obſervations is nearly the ſame, as will appear by the following table.

The

| | The bulb of the thermometer placed in the center of the glafs ball, and | | | |
|---|---|---|---|---|
| | furrounded by a Torricellian vacuum. (Exp. N° 1.) | | furrounded by air. (Exp. N° 2.) | |
| | Time elapfed. | Heat acquired. | Time elapfed. | Heat acquired. |
| Upon being plunged into *boiling* water | | 18° | | 18° |
| | M. S. | ° | M. S. | ° |
| After remaining in it | 1 30 | 27 | 0 45 | 27 |
| | —— | —— | 1 0 | $30\frac{4}{10}$ |
| | 4 0 | $44\frac{9}{10}$ | 2 10 | $44\frac{9}{10}$ |
| | 5 0 | $48\frac{2}{10}$ | 2 40 | $48\frac{2}{10}$ |
| | —— | —— | 4 0 | $56\frac{2}{10}$ |
| | —— | —— | 5 0 | $60\frac{9}{10}$ |

Thefe experiments were made at Manheim, upon the firft day of July laft, in the prefence of Profeffor HEMMER, of the Electoral Academy of Sciences of Manheim, and CHARLES ARTARIA, Meteorological Inftrument-maker to the Academy, by whom I was affifted.

Finding the conftruction of the inftrument made ufe of in thefe experiments attended with much trouble and rifque, on account of the difficulty of foldering the glafs ball to the tube of the thermometer without at the fame time either clofing up, or otherwife injuring, the bore of the tube, I had recourfe to another contrivance much more commodious, and much eafier in the execution.

At the end of a glafs tube or cylinder ten or eleven inches in length, and near three-quarters of an inch in diameter internally, I caufed a hollow globe to be blown 1½ inch in diameter,

meter, with an opening in the bottom of it correſponding with the bore of the tube, and equal to it in diameter, leaving to the opening a neck or ſhort tube, about an inch or three-quarters of an inch in length. Having a thermometer prepared, whoſe bulb was juſt half an inch in diameter, and whoſe freezing point fell at about 2¾ inches above its bulb, I graduated its tube according to REAUMUR's ſcale, beginning at 0°, and marking that point, and alſo every tenth degree above it to 80°, with threads of fine ſilk bound round it, which being moiſtened with lac varniſh adhered firmly to the tube. This thermometer I introduced into the glaſs cylinder and globe juſt deſcribed, by the opening in the bottom of the globe, having firſt choaked the cylinder at about 2 inches from its junction with the globe by heating it, and crowding its ſides inwards towards its axis, leaving only an opening ſufficient to admit the tube of the thermometer. The thermometer being introduced into the cylinder in ſuch a manner that the center of its bulb coincided with the center of the globe, I marked a place in the cylinder, about three-quarters of an inch above the 80th degree or boiling point upon the tube of the incloſed thermometer, and taking out the thermometer, I choaked the cylinder again in this place. Introducing now the thermometer for the laſt time, I cloſed the opening at the bottom of the globe at the lamp, taking care, before I brought it to the fire, to turn the cylinder upſide down, and to let the bulb of the thermometer fall into the cylinder till it reſted upon the lower choak in the cylinder. By this means the bulb of the thermometer was removed more than 3 inches from the flame of the lamp. The opening at the bottom of the globe being now cloſed, and the bulb of the thermometer being ſuffered to return into the globe, the end of the cylinder was cut off to

4 within

within about half an inch of the upper choak. This being done, it is plain, that the tube of the thermometer projected beyond the end of the cylinder. Taking hold of the end of the tube, I placed the bulb of the thermometer as nearly as poffible in the center of the globe, and obferving and marking a point in the tube immediately above the upper choak of the cylinder, I turned the cylinder upfide down, and fuffering the bulb of the thermometer to enter the cylinder, and reft upon the firft or lower choak (by which means the end of the tube of the thermometer came further out of the cylinder), the end of the tube was cut off at the mark juft mentioned (having firft taken care to melt the internal cavity or bore of the tube together at that place), and a fmall folid ball of glafs, a little larger than the internal diameter or opening of the choak, was foldered to the end of the tube, forming a little button or knob, which refting upon the upper choak of the cylinder, ferved to fufpend the thermometer in fuch a manner that the center of its bulb coincided with the center of the globe in which it was fhut up. The end of the cylinder above the upper choak being now heated and drawn out to a point, or rather being formed into the figure of the fruftum of a hollow cone, the end of it was foldered to the end of a barometrical tube, by the help of which the cavity of the cylinder and globe containing the thermometer was completely voided of air with mercury; when, the end of the cylinder being hermetically fealed, the barometrical tube was detached from it with a file, and the thermometer was left completely fhut up in a Torricellian vacuum, the center of the bulb of the thermometer being confined in the center of the glafs globe, without touching it in any part, by means of the two choaks in the cylinder, and the button upon the end of the tube.

Of thefe inftruments I provided myfelf with two, as nearly as poffible of the fame dimenfions; the one, which I fhall call N° 1. being voided of air, in the manner above defcribed; the other, N° 2. being filled with air, and hermetically fealed.

With thefe two inftruments (fee fig. 2.) I made the following experiments upon the 11th of July laft, at Manheim, between the hours of ten and twelve, the weather being very fine and clear, the mercury in the barometer ftanding at 27 inches 11 lines, REAUMUR's thermometer at 15°, and the quill hygrometer of the Academy of Manheim at 47°.

## *Experiments* N° 3, 4, 5 and 6.

Putting both the inftruments into melting ice, I let them remain there till the mercury in the inclofed thermometers refted at the point 0°, that is to fay, till they had acquired exactly the temperature of freezing water or melting ice; and then taking them out of the ice I plunged them fuddenly into a large veffel of boiling water, and obferved the time required for the mercury to rife in the thermometers from ten degrees to ten degrees, from 0° to 80°, taking care to keep the water conftantly boiling during the whole of this time, and taking care alfo to keep the inftruments immerfed to the fame depth, that is to fay, juft fo deep that the point 0° of the inclofed thermometer was even with the furface of the water.

Thefe experiments I repeated twice, with the utmoft care; and the following table gives the refult of them.

*Thermometer* N° 1.

Its bulb half an inch in diameter, ſhut up in the center of a hollow glaſs globe, $1\frac{1}{2}$ inch in diameter, *void of air*, and hermetically ſealed.

*Taken out of freezing water, and plunged into boiling water.*

| Time elapſed. Exp. N° 3. M. | S. | Time elapſed. Exp. N° 4. M. | S. | Heat acquired. |
|---|---|---|---|---|
| | | | | 0° |
| 0 | 51 | 0 | 51 | 10 |
| 0 | 59 | 0 | 59 | 20 |
| 1 | 1 | 1 | 2 | 30 |
| 1 | 18 | 1 | 22 | 40 |
| 1 | 24 | 1 | 23 | 50 |
| 2 | 0 | 1 | 51 | 60 |
| 3 | 30 | 3 | 6 | 70 |
| 11 | 41 | 10 | 27 | 80 |
| 22 | 44 | 21 | 1 | = total time of heating from 0° to 80°. |

Total time from 0° to 70°:

| | M. | S. |
|---|---|---|
| In Exp. N° 3. = | 11 | 3 |
| In Exp. N° 4. = | 10 | 34 |
| Medium = | 10 | $48\frac{1}{2}$ |

*Thermometer* N° 2.

Its bulb half an inch in diameter, ſhut up in the center of a hollow glaſs globe, $1\frac{1}{2}$ inch in diameter, *filled with air*, and hermetically ſealed.

*Taken out of freezing water, and plunged into boiling water.*

| Time elapſed. Exp. N° 5. M. | S. | Time elapſed. Exp. N° 6. M. | S. | Heat acquired. |
|---|---|---|---|---|
| | | | | 0° |
| 0 | 30 | 0 | 30 | 10 |
| 0 | 35 | 0 | 37 | 20 |
| 0 | 41 | 0 | 41 | 30 |
| 0 | 49 | 0 | 53 | 40 |
| 1 | 1 | 0 | 59 | 50 |
| 1 | 24 | 1 | 20 | 60 |
| 2 | 45 | 2 | 25 | 70 |
| 9 | 10 | 9 | 38 | 80 |
| 16 | 55 | 17 | 3 | = total time of heating from 0° to 80°. |

Total time from 0° to 70°:

| | M. | S. |
|---|---|---|
| In Exp. N° 5. = | 7 | 45 |
| In Exp. N° 6. = | 7 | 25 |
| Medium = | 7 | 35 |

It appears from theſe experiments, that the conducting power of air to that of the Torricellian vacuum, under the circumſtances deſcribed, is as $7\frac{35}{60}$ to $10\frac{48\frac{1}{2}}{60}$ inverſely, or as 1000 to 702 nearly; for the quantities of heat communicated being

4 equal,

equal, the intenſity of the communication is as the times inverſely.

In theſe experiments the heat paſſed through the ſurrounding medium *into* the bulb of the thermometer: in order to reverſe the experiment, and make the heat paſs *out of* the thermometer, I put the inſtruments into boiling water, and let them remain therein till they had acquired the temperature of the water, that is to ſay, till the mercury in the incloſed thermometers ſtood at 80°; and then, taking them out of the boiling water, I plunged them ſuddenly into a mixture of water and pounded ice, and moving them about continually in this mixture, I obſerved the times employed in cooling as follows.

| *Thermometer* N° 1. Surrounded by a *Torricellian vacuum.* *Taken out of boiling water, and plunged into freezing water.* | | | *Thermometer* N° 2. Surrounded by *air.* *Taken out of boiling water, and plunged into freezing water.* | | |
|---|---|---|---|---|---|
| Time elapſed. | | Heat loſt. | Time elapſed. | | Heat loſt. |
| Exp. N° 7. | Exp. N° 8. | | Exp. N° 9. | Exp. N° 10. | |
| — | — | 80° | — | — | 80° |
| M. S. | M. S. | ° | M. S. | M. S. | |
| 1 2 | 0 54 | 70 | 0 33 | 0 33 | 70 |
| 0 58 | 1 2 | 60 | 0 39 | 0 34 | 60 |
| 1 17 | 1 18 | 50 | 0 44 | 0 44 | 50 |
| 1 46 | 1 37 | 40 | 0 55 | 0 55 | 40 |
| 2 5 | 2 16 | 30 | 1 17 | 1 18 | 30 |
| 3 14 | 3 10 | 20 | 1 57 | 1 57 | 20 |
| 5 42 | 5 59 | 10 | 3 44 | 3 40 | 10 |
| Not obſerved. | Not obſerved. | 0 | 40 10 | Not obſerved. | 0 |
| Total time of cooling from 80° to 10°. | | | Total time of cooling from 80° to 10°. | | |
| M. S. | | | M. S. | | |
| In Exp. N° 7.=16 4 | | | In Exp. N° 9. =9 49 | | |
| In Exp. N° 8.=16 16 | | | In Exp. N° 10.=9 41 | | |
| Medium=16 10 | | | Medium=9 45 | | |



By

By theſe experiments it appears, that the conducting power of air is to that of the Torricellian vacuum as $9\frac{45}{60}$ to $16\frac{10}{60}$ inverſely, or as 1000 to 603.

To determine whether the ſame law would hold good when the heated thermometers, inſtead of being plunged into freezing water, were ſuffered to cool in the open air, I made the following experiments. The thermometers N° 1. and N° 2. being again heated in boiling water, as in the laſt experiments, I took them out of the water, and ſuſpended them in the middle of a large room, where the air (which appeared to be perfectly at reſt, the windows and doors being all ſhut) was warm to the 16th degree of REAUMUR'S thermometer, and the times of cooling were obſerved as follows.

| (Exp. N° 11.) *Thermometer* N° 1. Surrounded by a Torricellian vacuum. *Heated to* 80°, *and ſuſpended in the open air warm to* 16°. | | (Exp. N° 12.) *Thermometer* N° 2. Surrounded by air. *Heated to* 80°, *and ſuſpended in the open air warm to* 16°. | |
|---|---|---|---|
| Time elapſed. | Heat loſt. | Time elapſed. | Heat loſt. |
| | 80° | | 80° |
| M. S. | ° | M. S. | ° |
| Not obſerved. | 70 | Not obſerved. | 70 |
| 1 24 | 60 | 0 51 | 60 |
| 1 44 | 50 | 1 5 | 50 |
| 2 28 | 40 | 1 34 | 40 |
| 4 16 | 30 | 2 41 | 30 |
| 10 12 = total time employed in cooling from 70° to 30°. | | 6 11 = total time employed in cooling from 70° to 30°. | |

Here the difference in the conducting powers of air and of the Torricellian vacuum appears to be nearly the ſame as in the foregoing experiments, being as $6\frac{11}{60}$ to $10\frac{12}{60}$ inverſely, or as 1000 to 605. I could not obſerve the time of cooling from

80° to 70°, being at that time bufied in fufpending the inftruments.

As it might poffibly be objected to the conclufions drawn from thefe experiments that, notwithftanding all the care that was taken in the conftructing of the two inftruments made ufe of that they fhould be perfectly alike, yet they might in reality be fo far different, either in fhape or fize, as to occafion a very fenfible error in the refult of the experiments; to remove thefe doubts I made the following experiments.

In the morning towards eleven o'clock, the weather being remarkably fine, the mercury in the barometer ftanding at 27 inches 11 lines, REAUMUR's thermometer at 15°, and the hygrometer at 47°, I repeated the experiment N° 3. (of heating the thermometer N° 1. in boiling water, &c.) and immediately afterwards opening the cylinder containing the thermometer at its upper end, where it had been fealed, and letting the air into it, I re-fealed it hermetically, and repeated the experiment again with the fame inftrument, the thermometer being now furrounded with air, like the thermometer N° 2.

The refult of thefe experiments, which may be feen in the following table, fhews evidently, that the error arifing from the difference of the fhapes or dimenfions of the two inftruments in queftion was inconfiderable, if not totally imperceptible.

(Exp.

(Exp. N° 13.)

*Thermometer* N° 1

Its bulb half an inch in diameter shut up in the center of a glass globe 1½ inch in diameter, *voided of air*, and hermetically sealed.

*Taken out of freezing water, and plunged into boiling water.*

| Time elapsed. M. S. | Heat acquired. 0° |
|---|---|
| | ° |
| 0 55 | 10 |
| 0 55 | 20 |
| 1 7 | 30 |
| 1 15 | 40 |
| 1 29 | 50 |
| 2 2 | 60 |
| 3 21 | 70 |
| 13 44 | 80 |

24 48 = total time of heating from 0° to 80°.

Total time from 0° to 70° = 11′ 4″.

(Exp. N° 14.)

*The same Thermometer* (N° 1.)

The glass globe, containing the bulb of the thermometer, being now *filled with air*, and hermetically sealed.

*Taken out of freezing water, and plunged into boiling water.*

| Time elapsed. M. S. | Heat acquired. 0° |
|---|---|
| | ° |
| 0 32 | 10 |
| 0 32 | 20 |
| 0 43 | 30 |
| 0 50 | 40 |
| 1 1 | 50 |
| 1 24 | 60 |
| 2 38 | 70 |
| 10 25 | 80 |

18 5 = total time of heating from 0° to 80°.

Total time from 0° to 70° = 7′ 40″.

It appears, therefore, from these experiments, that the conducting power of common atmospheric air is to that of the Torricellian vacuum as $7\frac{40}{60}$ to $11\frac{4}{60}$ inversely, or as 1000 to 602; which differs but very little from the result of all the foregoing experiments.

Notwithstanding that it appeared, from the result of these last experiments, that any difference there might possibly have been in the proportions or dimensions of the instruments N° 1. and N° 2. could hardly have produced any sensible error in in the reſult of the experiments in queſtion; I was willing, however, to ſee how far any conſiderable alterations of ſize in the inſtrument would affect the experiment: I therefore provided myſelf with another inſtrument, which I ſhall call *Thermometer* N° 3. different from thoſe already deſcribed in ſize, and a little different in its conſtruction.

The bulb of the thermometer was of the ſame form and ſize as in the inſtruments N° 1. and N° 2. that is to ſay, it was globular, and half an inch in diameter; but the glaſs globe, in the center of which it was confined, was much larger, being 3 inches 7½ lines in diameter; and the bore of the tube of the thermometer was much finer, and conſequently its length, and the diviſions of its ſcale, were greater. The diviſions were marked upon the tube with threads of ſilk of different colours at every tenth degree, from 0° to 80°, as in the before-mentioned inſtruments. The tube or cylinder belonging to the glaſs globe was 8 lines in diameter, a little longer than the tube of the thermometer, and perfectly cylindrical from its upper end to its junction with the globe, being without any choak; the thermometer being confined in the center of the globe by a different contrivance, which was as follows. To the opening of the cylinder was fitted a ſtopple of dry wood, covered with a coat of hard varniſh, through the center or axis of which paſſed the end of the tube of the thermometer: this confined the tube in the axis of the cylinder at its upper end. To confine it at its lower end, there was fitted to it a ſmall ſteel ſpring, a little below the point 0°; which, being confined round the tube of the thermometer, had three elaſtic points projecting outwards, which preſſing againſt the inſide of the cylinder, confined the thermometer in its place. The total length of this inſtrument, from the bottom of the globe

to

to the upper end of the cylinder, was 18 inches, and the freezing point upon the thermometer fell about 3 inches above the bulb; consequently it lay about $1\frac{1}{2}$ inch above the junction of the cylinder with the globe, when the thermometer was confined in its place, the center of its bulb coinciding with the center of the globe. Through the stopple which closed the end of the cylinder passed two small glass tubes, about a line in diameter, which being about a line longer than the stopple were stopped up occasionally with small stopples fitted to their bores. These tubes (which were fitted exactly in the holes bored in the great stopple of the cylinder to receive them, and fixed in their places with cement) served to convey air, or any other fluid, into the glass ball, without being under a necessity of removing the stopple closing the end of the cylinder; which, in order to prevent the position of the thermometer from being easily deranged, was cemented in its place.

I have been the more particular in the description of these instruments, as I conceive it absolutely necessary to have a perfect idea of them in order to judge of the experiments made with them.

With the instrument last described (which I have called *Thermometer* N° 3.) I made the following experiment. It was upon the 18th of July last, in the afternoon, the weather variable, alternate clouds and sun-shine; wind strong at S.E. with now and then a sprinkling of rain; barometer at 27 inches $10\frac{1}{2}$ lines, thermometer at $18°\frac{1}{4}$, and hygrometer variable from 44° to extreme moisture.

In order to compare the result of the experiment made with this thermometer with those made with the thermometer N° 2. I have, in the following table, placed these experiments by the side of each other.

(Exp.

(Exp. N° 15.)
*Thermometer* N° 3.
Its bulb half an inch in diameter, shut up in the center of a glass tube, 3 inches $7\frac{1}{2}$ lines in diameter, and surrounded by *air*.
*Taken out of freezing water, and plunged into boiling water.*

| Time elapsed. | Heat acquired. |
|---|---|
| M. S. | 0° |
| 0 33 | 10 |
| 0 38 | 20 |
| 0 54 | 30 |
| 0 51 | 40 |
| 1 7 | 50 |
| 1 28 | 60 |
| 2 28 | 70 |
| 9 0 | 80 |

16 59 = total time of heating from 0° to 80°.
Time from 0° to 70° = 7′ 59″.

(Exp. N° 4. and N° 5.)
*Thermometer* N° 2.
Its bulb half an inch in diameter, shut up in the center of a glass globe, $1\frac{1}{2}$ inch in diameter, and surrounded by *air*.
*Taken out of freezing water, and plunged into boiling water.*

| Time elapsed. | | | Heat acquired. |
|---|---|---|---|
| Exp. N° 4. | Exp. N° 5. | Medium. | |
| M. S. | M. S. | M. S. | 0° |
| 0 30 | 0 30 | 0 30 | 10 |
| 0 35 | 0 37 | 0 36 | 20 |
| 0 41 | 0 41 | 0 41 | 30 |
| 0 49 | 0 53 | 0 51 | 40 |
| 1 1 | 0 59 | 1 0 | 50 |
| 1 24 | 1 20 | 1 22 | 60 |
| 2 45 | 2 25 | 2 35 | 70 |
| 9 10 | 9 38 | 9 24 | 80 |
| 16 55 | 17 3 | 16 59 | = total |

time of heating from 0° to 80°.
Time from 0° to 70° = 7′ 35″

If the agreement of these experiments with the thermometers N° 2. and N° 3. surprised me, I was not less surprised with their disagreement in the experiment which follows.

## *Experiment* N° 16.

Taking the thermometer N° 3. out of the boiling water, I immediately suspended it in the middle of a large room, where the air, which was quiet, had the temperature of $18^\circ\frac{1}{4}$ R. and observed the times of cooling as follows:

| Time elapsed. | Heat lost. |
|---|---|
| —— | 80° |
| M. S. | ° |
| 1 55 | 70 |
| 0 12 | 60 |
| 0 33 | 50 |
| 2 15 | 40 |
| 4 0 | 30 |
| 9 55 = total time of cooling from 80° to 30°. | |

Time from 70° to 30° = 8′ 0″; but in the experiment N° 12. with the thermometer N° 2. the time employed in cooling from 70° to 30° was only 6′ 11″. In this experiment, with the thermometer N° 3. the time employed in cooling from 60° to 30° was 7′ 48″; but in the above-mentioned experiment, with the thermometer N° 2. it was only 5′ 20″. It is true, the air of the room was ſomewhat cooler when the former experiment was made than when this latter was made with the thermometer N° 3.; but this difference of temperature, which was only 2°¼ (in the former caſe the thermometer in the room ſtanding at 16°, and in the latter at 18°¼) certainly could not have occaſioned the whole of the apparent difference in the reſults of the experiments.

Does air receive heat more readily than it parts with it? This is a queſtion highly deſerving of further inveſtigation, and I ſhall not fail to give it a full examination in the courſe of my projected inquiries; but leaving it for the preſent, I ſhall proceed to give an account of the experiments which I have already made *.

It

* Conceiving it to be a ſtep of conſiderable importance towards coming at a further

It having been my intention from the beginning to examine the conducting powers of the artificial airs or gasses, the thermometer

further knowledge of the nature of heat, to ascertain, by indisputable evidence, its passage through the Torricellian vacuum, and to determine, with as much precision as possible, the law of its motions in that medium; and being apprehensive that doubts might arise with respect to the experiments before described, on account of the contact of the tubes of the inclosed thermometers in the instruments made use of with the containing glass globes, or rather with their cylinders; by which means it might be suspected, that a certain quantity, if not all the heat acquired, might possibly be communicated: to put this matter beyond all doubt, I made the following experiment.

In the middle of a glass body, of a pear-like form, about 8 inches long, and 2½ inches in its greatest diameter, I suspended a small mercurial thermometer, 5½ inches long, by a fine thread of silk, in such a manner that neither the bulb of the thermometer, nor its tube, touched the containing glass body in any part. The tube of the thermometer was graduated, and marked with fine threads of silk of different colours bound round it, as in the thermometers belonging to the other instruments already described; and the thermometer was suspended in its place by means of a small steel spring, to which the end of the thread of silk which held the thermometer being attached, it (the spring) was forced into a small globular protuberance or cavity, blown in the upper extremity of the glass body, about half an inch in diameter, where the spring remaining, the thermometer necessarily remained suspended in the axis of the glass body. There was an opening at the bottom of the glass body, through which the thermometer was introduced; and a barometrical tube being soldered to this opening, the inside of the glass body was voided of air by means of mercury; and this opening being afterwards sealed hermetically, and the barometrical tube being taken away, the thermometer was left suspended in a Torricellian vacuum.

In this instrument, as the inclosed thermometer did not touch the containing glass body in any part, on the contrary, being distant from its internal surface an inch or more in every part, it is clear, that whatever heat passed *into* or *out of* the thermometer must have passed *through* the surrounding Torricellian vacuum: for it cannot be supposed, that the fine thread of silk, by which the thermometer was suspended, was capable of conducting any heat at all, or at least any sensible quantity. I therefore flattered myself with hopes of being able, with the thermometer N° 3. was constructed with a view to those experiments; and having now provided myself with a stock of those different kinds of airs, I began with *fixed air*, with which, by

assistance of this instrument, to determine positively with regard to the passage of heat in the Torricellian vacuum: and this, I think, I have done, notwithstanding that an unfortunate accident put it out of my power to pursue the experiments so far as I intended.

This instrument being fitted to a small stand or foot of wood, in such a manner that the glass body remained in a perpendicular situation, I placed it in my room, by the side of another inclosed thermometer (N° 2.), which was surrounded by air, and observed the effect of the variation of heat in the atmosphere. I soon discovered, by the motion of the mercury in the inclosed thermometer, that the heat passed through the Torricellian vacuum; but it appeared plainly from the sluggishness or great insensibility of the thermometer, that the heat passed with much greater difficulty in this medium than in common air. I now plunged both the thermometers into a bucket of cold water; and I observed that the mercury in the thermometer surrounded by air descended much faster than that in the thermometer surrounded by the Torricellian vacuum. I took them out of the cold water, and plunged them into a vessel of hot water (having no conveniencies at hand to repeat the experiment in form with the freezing and with the boiling water); and the thermometer surrounded by the Torricellian vacuum appeared still to be much more insensible or sluggish than that surrounded by air.

These trials were quite sufficient to convince me of the passage of heat in the Torricellian vacuum, and also of the greater difficulty of its passage in that medium than in common air; but, not satisfied to rest my inquiries here, I took the first opportunity that offered, and set myself to repeat the experiments which I had before made with the instruments N° 1. and N° 2. I plunged this instrument into freezing water, where I let it remain till the mercury in the inclosed thermometer had descended to 0°; when, taking it out of the freezing water, I plunged it suddenly into a vessel of boiling water, and prepared myself to observe the ascent of the mercury in the inclosed thermometer as in the foregoing experiments; but unfortunately the moment the end of the glass body touched the boiling water, it cracked with the heat at the point where it had been hermetically sealed, and the water rushing into the body, spoiled the experiment: and I have not since had an opportunity of providing myself with another instrument to repeat it.

means

means of water, I filled the globe and cylinder containing the thermometer; and ſtopping up the two holes in the great ſtopple cloſing the end of the cylinder, I expoſed the inſtrument in freezing water till the mercury in the incloſed thermometer had deſcended to 0°; when, taking it out of the freezing water, I plunged it into a large veſſel of boiling water, and prepared myſelf to obſerve the times of heating, as in the former caſes; but an accident happened, which ſuddenly put a ſtop to the experiment. Immediately upon plunging the inſtrument into the boiling water, the mercury began to riſe in the thermometer with ſuch uncommon celerity, that it had paſſed the firſt diviſion upon the tube (which marked the 10th degree, according to REAUMUR's ſcale) before I was aware of its being yet in motion; and having thus miſſed the opportunity of obſerving the time elapſed when the mercury arrived at that point, I was preparing to obſerve its paſſage of the next, when all of a ſudden the ſtopple cloſing the end of the cylinder was blown up the chimney with a great exploſion, and the thermometer, which, being cemented to it by its tube, was taken along with it, and was broken to pieces, and deſtroyed in its fall.

This unfortunate experiment, though it put a ſtop for the time to the inquiries propoſed, opened the way to other reſearches not leſs intereſting. Suſpecting that the exploſion was occaſioned by the rarefaction of the water which remained attached to the inſide of the globe and cylinder after the operation of filling them with fixed air; and thinking it more than probable, that the uncommon celerity, with which the mercury roſe in the thermometer, was principally owing to the ſame cauſe; I was led to examine the conducting power of *moiſt air*, or air ſaturated with water.

For

For this experiment I provided myſelf with a new thermometer N° 4. the bulb of which, being of the ſame form as thoſe already deſcribed (*viz.* globular) was alſo of the ſame ſize, or half an inch in diameter. To receive this thermometer a glaſs cylinder was provided, 8 lines in diameter, and about 14 inches long, and terminated at one end by a globe 1½ inch in diameter. In the center of this globe the bulb of the thermometer was confined, by means of the ſtopple which cloſed the end of the cylinder; which ſtopple, being near 2 inches long, received the end of the tube of the thermometer into a hole bored through its center or axis, and confined the thermometer in its place, without the aſſiſtance of any other apparatus. Through this ſtopple two other ſmall holes were bored, and lined with thin glaſs tubes, as in the thermometer N° 3. opening a paſſage into the cylinder, which holes were occaſionally ſtopped up with ſome ſtopples of cork; but to prevent accidents, ſuch as I had before experienced from an exploſion, great care was taken not to preſs theſe ſtopples into their places with any conſiderable force, that they might the more eaſily be blown out by any conſiderable effort of the confined air.

Though in this inſtrument the thermometer was not altogether ſo ſteady in its place as in the thermometers N° 1. N° 2. and N° 3. the elaſticity of the tube, and the weight of the mercury in the bulb of the thermometer, occaſioning a ſmall vibration or trembling of the thermometer upon any ſudden motion or jar; yet I preferred this method to the others, on account of the lower part of this thermometer being intirely free, or ſuſpended in ſuch a manner as not to touch, or have any communication with, the lower part of the cylinder or the globe: for though the quantity of heat received by the tube of the thermometer at its contact with the cylinder at its choaks,

choaks, in the inſtruments N° 1. and N° 2. or with the branches of the ſteel ſpring in N° 3. and from thence communicated to the bulb, muſt have been exceedingly ſmall; yet I was deſirous to prevent even that, and every other poſſible error or inaccuracy, however ſmall, that might ariſe.

Does humidity augment the conducting power of air?

To determine this queſtion I made the following experiments, the weather being clear and fine, the mercury in the barometer ſtanding at 27 inches 8 lines, the thermometer at 19°, and the hygrometer at 44°.

| (Exp. N° 17.) *Thermometer* N° 4. Surrounded by air *dry* to the 44th degree of the quill hygrometer of the Manheim Academy. *Taken out of freezing water, and plunged into boiling water.* | | (Exp. N° 18.) *The ſame thermometer* (N° 4.) Surrounded by air rendered as *moiſt* as poſſible by wetting the inſide of the cylinder and globe with water. *Taken out of freezing water, and plunged into boiling water.* | |
|---|---|---|---|
| Time elapſed. | Heat acquired. | Time elapſed. | Heat acquired. |
| | 80° | | 0° |
| M. S. | ° | M. S. | ° |
| 0 34 | 10 | 0 6 | 10 |
| 0 39 | 20 | 0 4 | 20 |
| 0 44 | 30 | 0 5 | 30 |
| 0 51 | 40 | 0 9 | 40 |
| 1 6 | 50 | 0 18 | 50 |
| 1 35 | 60 | 0 26 | 60 |
| 2 40 | 70 | 0 43 | 70 |
| not obſerved. | 80 | 7 45 | 80 |
| 8 9 = total time of heating from 0° to 70°. | | 1 51 = total time of heating from 0° to 70° | |

From

From theſe experiments it appears, that the conducting power of air is very much increaſed by humidity. To ſee if the ſame reſult would obtain when the experiment was reverſed, I now took the thermometer with the *moiſt air* out of the boiling water, and plunged it into freezing water; and moving it about continually from place to place in the freezing water, I obſerved the times of cooling, as ſet down in the following table. N. B. To compare the reſult of this experiment with thoſe made with *dry air*, I have placed on one ſide in the following table the experiment in queſtion, and on the other ſide the experiment N° 19. made with the thermometer N° 2.

| (Exp. N° 19.) *Thermometer* N° 4. Surrounded by *moiſt air*. *Taken out of boiling water, and plunged into freezing water.* | | | (Exp. N° 10.) *Thermometer* N° 2. Surrounded by *dry air*. *Taken out of boiling water, and plunged into freezing water.* | | |
|---|---|---|---|---|---|
| Time elapſed. | | Heat loſt. | Time elapſed. | | Heat loſt. |
| | | 80° | | | 80° |
| M. | S. | ° | M. | S. | ° |
| 0 | 4 | 70 | 0 | 33 | 70 |
| 0 | 14 | 60 | 0 | 34 | 60 |
| 0 | 31 | 50 | 0 | 44 | 50 |
| 0 | 52 | 40 | 0 | 55 | 40 |
| 1 | 22 | 30 | 1 | 18 | 30 |
| 2 | 3 | 20 | 1 | 57 | 20 |
| 4 | 2 | 10 | 3 | 40 | 10 |
| 9 | 8 | = total time of cooling from 80° to 10°. | 9 | 12 | = total time of cooling from 80° to 10°. |

Though the difference of the whole times of cooling from 80° to 10° in theſe two experiments appears to have been very ſmall, yet the difference of the times taken up by the firſt twenty or thirty degrees from the boiling point is very remarkable, and ſhows with how much greater facility heat paſſes in moiſt air than in dry air. Even the ſlowneſs with which the mercury in the thermometer N° 4. deſcended in this experiment from the 30th to the 20th, and from the 20th to the 10th degree, I attribute in ſome meaſure to the great conducting power of the moiſt air with which it was ſurrounded; for the cylinder containing the thermometer and the moiſt air, being not wholly ſubmerged in the freezing water, that part of it which remained out of the water was neceſſarily ſurrounded by the air of the atmoſphere; which being much warmer than the water, communicated of its heat to the glaſs; which, paſſing from thence into the contained moiſt air as ſoon as that air became colder than the external air, was, through that medium, communicated to the bulb of the incloſed thermometer, which prevented its cooling ſo faſt as it would otherwiſe have done. But when the weather becomes cold, I propoſe to repeat this experiment with variations, in ſuch a manner as to put the matter beyond all doubt. In the mean time I cannot help obſerving, with what infinite wiſdom and goodneſs Divine Providence appears to have guarded us againſt the evil effects of exceſſive heat and cold in the atmoſphere; for if it were poſſible for the air to be equally damp during the ſevere cold of the winter months as it ſometimes is in ſummer, its conducting power, and conſequently its apparent coldneſs, when applied to our bodies, would be ſo much increaſed, by ſuch an additional degree of moiſture, that it would become quite intolerable; but, happily for us, its power to hold water in ſolution is diminiſhed, and with it its power to rob us of our animal heat, in proportion as its

 coldneſs

coldneſs is increaſed. Every body knows how very diſagreeable a very moderate degree of cold is when the air is very damp; and from hence it appears, why the thermometer is not always a juſt meaſure of the apparent or ſenſible heat of the atmoſphere. If colds or catarrhs are occaſioned by our bodies being robbed of our animal heat, the reaſon is plain why thoſe diſorders prevail moſt during the cold autumnal rains, and upon the breaking up of the froſt in the ſpring. It is likewiſe plain from whence it is that ſleeping in damp beds, and inhabiting damp houſes, is ſo very dangerous; and why the evening air is ſo pernicious in ſummer and in autumn, and why it is not ſo during the hard froſts of winter. It has puzzled many very able philoſophers and phyſicians to account for the manner in which the extraordinary degree or rather *quantity* of heat is generated which an animal body is ſuppoſed to loſe, when expoſed to the cold of winter, above what it communicates to the ſurrounding atmoſphere in warm ſummer weather; but is it not more than probable, that the difference of the quantities of heat, actually loſt or communicated, is infinitely leſs than what they have imagined? Theſe inquiries are certainly very intereſting; and they are undoubtedly within the reach of well contrived and well conducted experiments. But taking my leave for the preſent of this curious ſubject of inveſtigation, I haſten to the ſequel of my experiments.

Finding ſo great a difference in the conducting powers of common air and of the Torricellian vacuum, I was led to examine the conducting powers of common air of different degrees of denſity. For this experiment I prepared the thermometer N° 4. by ſtopping up one of the ſmall glaſs tubes paſſing through the ſtopple, and opening a paſſage into the cylinder, and by fitting a valve to the external overture of the other,

other. The inſtrument, thus prepared, being put under the receiver of an air-pump, the air paſſed freely out of the globe and cylinder upon working the machine, but the valve above deſcribed prevented its return upon letting air into the receiver. The gage of the air-pump ſhowed the degree of rarity of the air under the receiver, and conſequently of that filling the globe and cylinder, and immediately ſurrounding the thermometer.

With this inſtrument, the weather being clear and fine, the mercury in the barometer ſtanding at 27 inches 9 lines, the thermometer at 15°, and the hygrometer at 47°, I made the following experiments.

| (Exp. N° 20.) *Thermometer* N° 4. Surrounded by common air, barometer ſtanding at 27 inches 9 lines. *Taken out of freezing water, and plunged into boiling water.* | | (Exp. N° 21.) *Thermometer* N° 4. Surrounded by air rarefied by pumping till the barometer-gage ſtood at 6 inches 11½ lines. *Taken out of freezing water, and plunged into boiling water.* | | (Exp. N° 22.) *Thermometer* N° 4. Surrounded by air rarefied by pumping till the barometer-gage ſtood at 1 inch 2 lines. *Taken out of freezing water, and plunged into boiling water.* | |
|---|---|---|---|---|---|
| Time elapſed. | Heat acquired. | Time elapſed. | Heat acquired. | Time elapſed. | Heat acquired. |
| | 0° | | 0° | | 0° |
| M. S. | ° | M. S. | ° | M. S. | ° |
| 0 31 | 10 | 0 31 | 10 | 0 29 | 10 |
| 0 40 | 20 | 0 38 | 20 | 0 36 | 20 |
| 0 41 | 30 | 0 44 | 30 | 0 49 | 30 |
| 0 47 | 40 | 0 51 | 40 | 1 1 | 40 |
| 1 4 | 50 | 1 7 | 50 | 1 1 | 50 |
| 1 25 | 60 | 1 19 | 60 | 1 24 | 60 |
| 2 28 | 70 | 2 27 | 70 | 2 31 | 70 |
| 10 17 | 80 | 10 21 | 80 | not obſerved. | 80 |
| 7 36 = total time of heating from 0° to 70°. | | 7 37 = total time of heating from 0° to 70°. | | 7 51 = total time of heating from 0° to 70°. | |

 The

The reſult of theſe experiments, I confeſs, ſurpriſed me not a little; but the diſcovery of truth being the ſole object of my inquiries (having no favourite theory to defend) it brings no diſappointment along with it, under whatever unexpected ſhape it may appear. I hope that further experiments may lead to the diſcovery of the cauſe why there is ſo little difference in the conducting powers of air of ſuch very different degrees of rarity, while there is ſo great a difference in the conducting powers of air, and of the Torricellian vacuum. At preſent, I ſhall not venture any conjectures upon the ſubject; but in the mean time I dare to aſſert, that the experiments I have made may be depended on.

The time of my ſtay at Manheim being expired (having had the honour to attend thither his moſt Serene Highneſs the Elector Palatine Duke of Bavaria, my moſt Gracious Maſter, in his late journey), I was prevented from purſuing theſe inquiries further at that time; but I ſhall not fail to recommence them the firſt leiſure time I can find, which I fancy will be about the beginning of the month of November. In the mean time, to enable myſelf to purſue them with effect, I am ſparing neither labour nor expence to provide a complete apparatus neceſſary for my purpoſe; and his Electoral Highneſs has been graciouſly pleaſed to order M. ARTARIA (who is in his ſervice) to come to Munich to aſſiſt me. With ſuch a Patron as his moſt Serene Highneſs, and with ſuch an aſſiſtant as ARTARIA, I ſhall go on in my purſuits with chearfulneſs. Would to God that my labours might be as uſeful to others as they will be pleaſant to me!

I ſhall conclude this letter with a ~~ſhort account~~ of ſome experiments I have made to determine the conducting powers of water and of mercury; and with a table, ſhowing at one view the conducting powers of all the different mediums which I have examined.

Having filled the glaſs globe incloſing the bulb of the thermometer N° 4. firſt with water, and then with mercury, I made the following experiments, to aſcertain the conducting powers of thoſe two fluids.

| (Exp. N° 23.) *Thermometer* N° 4. Surrounded by *water.* *Taken out of freezing water, and plunged into boiling water.* | | (Exp. N° 24, 25, and 26.) *Thermometer* N° 4. Surrounded by *mercury.* *Taken out of freezing water, and plunged into boiling water.* | | | |
|---|---|---|---|---|---|
| Time elapſed. | Heat acquired. | Time elapſed. Exp. N° 24. | Time elapſed. Exp. N° 25. | Time elapſed. Exp. N° 26. | Heat acquired. |
| | 0° | | | | 0° |
| M. S. | ° | M. S. | M. S. | M. S. | |
| 0 19 | 10 | 0 5 | 0 5 | 0 5 | 10 |
| 0 8 | 20 | 0 4 | 0 2 | 0 5 | 20 |
| 0 9 | 30 | 0 2 | 0 2 | 0 4 | 30 |
| 0 11 | 40 | 0 4 | 0 5 | 0 5 | 40 |
| 0 15 | 50 | 0 4 | 0 4 | 0 7 | 50 |
| 0 21 | 60 | 0 7 | 0 4 | 0 8 | 60 |
| 0 34 | 70 | 0 15 | 0 9 | 0 14 | 70 |
| 2 13 | 80 | Not obſerved. | 0 58 | Not obſerved. | 80 |
| 1 57 = total time of heating from 0° to 70°. | | 0 41 | 0 31 | 0 48 = total times of heating from 0° to 70°. | |

The total times of heating from 0° to 70° in the three experiments with mercury being 41 ſeconds, 31 ſeconds, and 48 ſeconds, the mean of theſe times is $36\frac{2}{3}$ ſeconds; and as in the experiment with water the time employed in acquiring the ſame degree of heat was 1′ 57″ = 117 ſeconds, it appears from

from theſe experiments, that the conducting power of mercury to that of water, under the circumſtances deſcribed, is as $36\frac{2}{3}$ to 117 inverſely, or as 1000 to 313. And hence it is plain, why mercury *appears* ſo much hotter, and ſo much colder, to the touch than water, when in fact it is of the ſame temperature: for the force or violence of the ſenſation of *hot* or *cold* depends not intirely upon the temperature of the body exciting in us thoſe ſenſations, or upon the degree of heat it actually poſſeſſes, but upon the *quantity* of heat it is capable of communicating to us, or receiving from us, in any given ſhort period of time, or as the intenſity of the communication; and this depends in a great meaſure upon the conducting powers of the bodies in queſtion.

The ſenſation of *hot* is the entrance of heat into our bodies; that of *cold* is its exit; and whatever contributes to facilitate or accelerate this communication adds to the violence of the ſenſation. And this is another proof that the thermometer cannot be a juſt meaſure of the *ſenſible* heat, or cold, exiſting in bodies; or rather, that the touch does not afford us a juſt indication of their *real* temperatures.

*Fig. 1.*

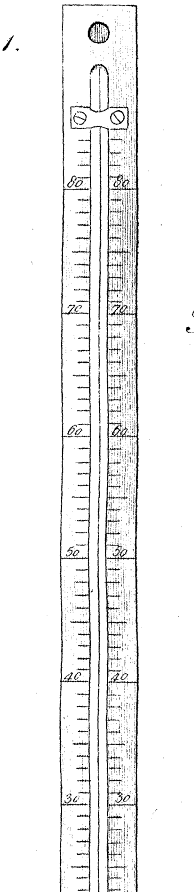



*Fig. 2.*

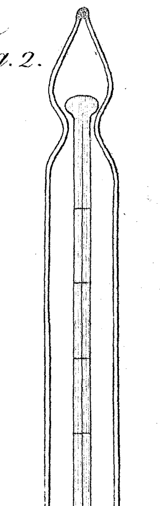


*Fig. 3.*

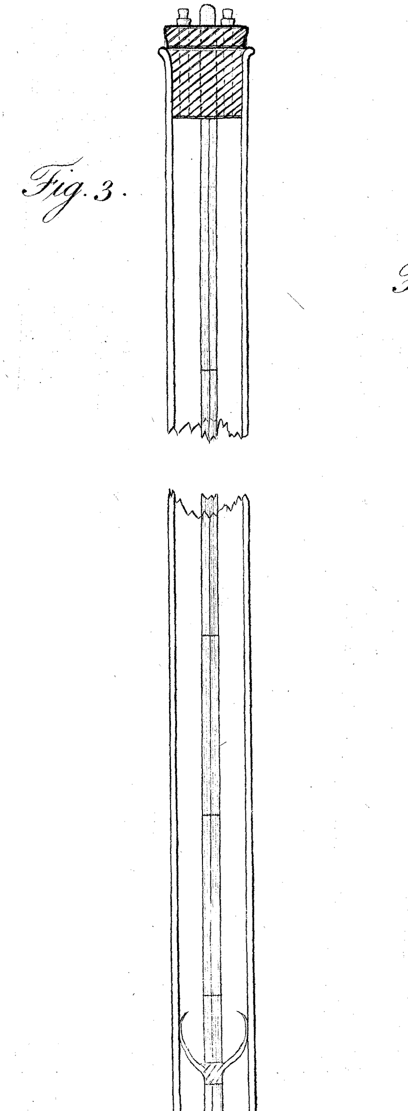
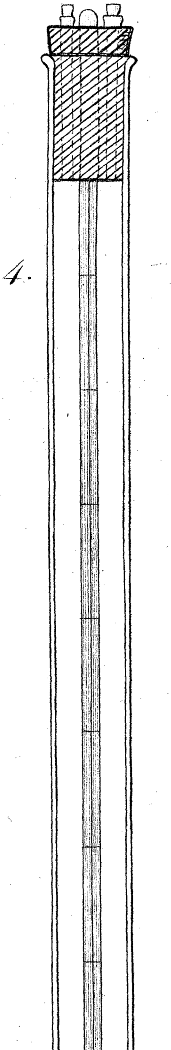


*Fig. 4.*



**Scale** ½ *an Inch to the Inch.*

*Basire sc.*

*A Table* of the *conducting Powers* of the under-mentioned *Mediums*, as determined by the foregoing experiments.

| Thermom. N° 1. | Thermometer N° 4. | | | | | | |
|---|---|---|---|---|---|---|---|
| *Taken out of freezing water, and plunged into boiling water.* | | | | | | | |
| Time elapsed. | | | | | | | |
| Torricellian Vacuum (Exp. N° 3. 4. and 13.) | Common air, density = 1, (Exp. N° 20.) | Rarefied air, density = $\frac{1}{4}$ (Exp. N° 21.) | Rarefied air, density = $\frac{1}{24}$ (Exp. N° 22.) | Moist air (Exp. N° 18.) | Water (Exp. N° 23.) | Mercury (Exp. N° 24, 25, and 26.) | Heat acquired. |
| — | — | — | — | — | — | — | 0° |
| M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | M. S. | ° |
| 0 52 | 0 31 | 0 31 | 0 29 | 0 6 | 0 19 | 0 5 | 10 |
| 0 58 | 0 40 | 0 38 | 0 36 | 0 4 | 0 8 | 0 $3\frac{2}{3}$ | 20 |
| 1 3 | 0 41 | 0 44 | 0 49 | 0 5 | 0 9 | 0 $2\frac{2}{3}$ | 30 |
| 1 18 | 0 47 | 0 51 | 1 1 | 0 9 | 0 11 | 0 $4\frac{2}{3}$ | 40 |
| 1 25 | 1 4 | 1 7 | 1 1 | 0 18 | 0 15 | 0 5 | 50 |
| 1 58 | 1 25 | 1 19 | 1 24 | 0 26 | 0 21 | 0 $6\frac{1}{3}$ | 60 |
| 3 19 | 2 28 | 2 27 | 2 31 | 0 43 | 0 34 | 0 $12\frac{2}{3}$ | 70 |
| 11 57 | 10 17 | 10 21 | —— | 7 45 | 2 13 | 0 58 | 80 |
| 10 53 | 7 36 | 7 37 | 7 51 | 1 51 | 1 57 | 0 $36\frac{2}{3}$ = total times of heating from 0° to 70°. | |

In determining the relative conducting powers of these mediums, I have compared the times of the heating of the thermometers from 0° to 70° instead of taking the whole times from 0° to 80°, on account of the small variation in the heat of the boiling water arising from the variation of the weight of the atmosphere, and also on account of the very slow motion of the mercury between the 70th and the 80th degrees, and the difficulty of determining the precise moment when the mercury arrives at the 80th degree.

Taking

Taking now the conducting power of mercury = 1000, the conducting powers of the other mediums, as determined by these experiments, will be as follows, *viz.*

| | |
|---|---|
| Mercury . . | 1000 |
| Moist air . . | 330 |
| Water, . . | 313 |
| Common air, density = 1 | $80\frac{41}{100}$ |
| Rarefied air, density = $\frac{1}{4}$ . | $80\frac{23}{100}$ |
| Rarefied air, density = $\frac{1}{24}$ | 78 |
| The Torricellian vacuum | 55 |

And in these proportions are the quantities of heat which these different mediums are capable of transmitting in any given time; and consequently these numbers express the relative *sensible* temperatures of the mediums, as well as their conducting powers. How far these decisions will hold good under a variation of circumstances experiment only can determine. This is certainly a subject of investigation not less curious in itself than it is interesting to mankind; and I wish that what I have done may induce others to turn their attention to this long neglected field of experimental inquiry. For my own part, I am determined not to quit it.

In the future prosecution of these inquiries, I do not mean to confine myself solely to the determining of the conducting powers of fluids; on the contrary, solids, and particularly such bodies as are made use of for cloathing, will be principal subjects of my future experiments. I have indeed already begun these researches, and have made some progress in them; but I forbear to anticipate a matter which I propose for the subject of a future communication.