XXIV. Researches on heat. Third series. § 1. On the unequally polarizable nature of different kinds of heat. § 2. On the depolarization of heat. § 3. On the refrangibility of heat

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whole figure shows the exact relative proportions of the plates, the exact distances and dimensions of the mass of liquid, on a scale reduced from those actually employed.

158. The lines *a, a, a*, represent the copper-plates found by the experiments contained in the first table (No. 8), and those marked *b, b, b*, the plates from the second table (No. 9). It is almost needless to remark, that the plates, though shown separately in the figure for the sake of the comparison, must be considered as having occupied precisely the same position in actual experiment.

[To be continued.]

XXIV. *Researches on Heat. Third Series.* § 1. *On the unequally Polarizable Nature of different Kinds of Heat.* § 2. *On the Depolarization of Heat.* § 3. *On the Refrangibility of Heat.* By JAMES D. FORBES, Esq., F.R.SS. L. & E., Professor of Natural Philosophy in the University of Edinburgh.

[Continued from p. 113 and concluded.]

§ 3. *On the Refrangibility of Heat.*

SINCE the admirable discovery by M. Melloni of the power of rock-salt to transmit and refract heat of every kind, one of the most obvious and important questions (formerly intractable) of which it seemed to offer the means of solution, was the accurate determination of the refrangibility of heat from various sources, luminous or non-luminous. Such a determination is of the first consequence to the formation of a just theory of heat, and a detection of the subtle bond by which it is connected with the comparatively familiar modifications of light.

Such experiments have not been wanting. M. Melloni, in his second memoir on radiant heat, in the *Annales de Chimie* for April 1834, has described the apparatus which he employed, and which is figured in Plate III. of that volume*. It consists of a thermo-electric pile, constructed of a single vertical row of elements, so as to be exposed to a very narrow beam of heat. It was made to move on a sector of a circle, at whose centre was placed a prism, by which the beam of heat was refracted from its primitive direction *ab* into that *cd*, (see next page), and therefore produced a maximum effect on the galvanometer when the pile was at *d*. The other parts maintaining the same positions, it is evident that the pile must be moved into the position *d'*, if the source of

[* A translation of Melloni's second memoir on radiant heat will be found in the Scientific Memoirs, vol. i. p. 39.—EDIT.]

heat be now one yielding rays of greater refrangibility. Although the radius of the circular arc was (if I understand the

Fig. 1.

account rightly) eleven inches, but little deviation of position was required for heat from different sources; and M. Melloni admits that, whilst his experiment *indicates* the difference of refrangibility, it is inadequate to *measure* it.

There are many reasons why such a form of apparatus must be rejected for accurate observations. I will mention only the impossibility of obtaining a beam of heat which shall preserve the same breadth at different distances from its source (of course, supposing the rays rendered as parallel as possible by refraction through a rock-salt lens), arising, 1. from the angular magnitude of the source; 2. from the scattered reflection and refraction at the surfaces of the lens and prism; 3. from the want of homogeneity of the ray. On all these accounts, the beam must have acquired a very sensible breadth at the distance of the pile, and consequently the effect of heat must be perceptible, and even nearly uniform, through a certain space. I may also add from experience, that the difficulty of varying the arrangement of an experiment, so as to get a maximum heating effect at the pile, is so considerable, that no delicate result can be deduced from the merely tentative procedure. Finally, the smallness of the variation of refrangibility seems to require some more critical method of ascertaining its measure. On all these grounds, it seemed to me desirable to discover a method in some degree less open to objection.

The phænomenon of total reflection, successfully employed by Dr. Wollaston in the measurement of refractive indices in the case of light*, presents the advantage of being (theoretically at least) abrupt in its action, the transition from partial to total reflection being (with the necessary exception arising from the want of homogeneity) an instantaneous change, amounting in the case of light to many times the intensity of

* Phil. Trans. 1802.

the smaller effect. It seemed reasonable to expect, that an apparatus constructed on the principle of determining the critical angle of total reflection of heat from different sources within a prism, would afford much more definite information as to the refrangibility of heat than any other method. After much consideration, an apparatus of the following kind was adopted.

It is fundamentally composed of a jointed frame, resembling a box exactly square, ten inches in the side, without top or bottom, and having hinges at every angle, so that it may be formed into a lozenge of any degree of obliquity. This is seen in Plate IV. fig. 1, and marked A B. By an arrangement presently to be described, the rays of heat are made to pass parallel to the edge ac of one of the sides of the box, and to fall upon the prism P, whence, after undergoing reflection (total or partial) at the posterior surface of the prism, they proceed parallel to the line ad , and fall upon the sentient extremity of the pile at p . Now, in order that this course may be taken by the reflected rays, it is necessary that, supposing the prism to be an isosceles one, the posterior reflecting surface $a'b'$, fig. 2, should form equal angles with the incident and reflected rays ce and fd . It was to effect this that the arrangement of the jointed lozenge was adopted. The prism P (fig. 1.) rests on a column O, moveable round the line of junction of the sides C and D of the lozenge. The column O has connected with it a tail-piece of brass aE passing through the diagonal of the frame, and preserved constantly in that position by a slit parallel to its length, through which passes a clamping screw b , serving at once to maintain this constancy of direction, to secure the form of the moveable lozenge, and by means of an index pointing to a graduated scale of inches reckoned from a , along aE , to determine the length of the diagonal ab at any moment, and consequently the angles of the lozenge.

A little consideration of this mechanical arrangement, will show how it is adapted to the end in view. The rays from a source of heat S, rendered parallel by the lens of rock-salt L, fall upon the prism P, and after undergoing two refractions and one reflection, they fall upon the sentient surface of the pile p . This will always take place so long as the posterior surface of the prism forms equal angles with the lines ac ; ad , which will be secured by making it truly perpendicular to the tail-piece aE , by which it is guided, and which of course always bisects the angle cad . Now, it is evident that, whilst the angle cad remains small, the reflection will continue *partial*, but that as the diagonal ab is shortened, a point will

be reached when *total* reflection abruptly commences, which ought to be indicated by a *saltus* in the movement of the galvanometer connected with the pile. This critical angle will be soonest attained for rays of greatest refrangibility, and the calculation of the refractive index of the prism is reduced to a simply mathematical problem.

The following is the problem to be solved, viz.: *A ray of light G D (fig. 2.) falls upon the surface A C of a prism, which has the angles at A and B equal; it falls upon the surface A B at the critical angle of total reflection; required the index of refraction (μ) of the prism, the angle of incidence (α) being given.*

Fig. 2.

An investigation of little difficulty gives the following result.

$$\mu = \sqrt{1 + \left(\frac{\sin \alpha + \sin \frac{1}{2}I}{\cos \frac{1}{2}I} \right)^2}.$$

I had a rock-salt prism constructed, so that the incidence on the first surface might be nearly vertical at the critical angle of total reflection, so as to avoid as much as possible any error arising from imperfections of the surface, or want of absolute equality of the angles at A and B; and likewise, that within the limits of the experiment, the loss of heat by reflection at the two surfaces might be nearly unaltered, as it is believed to be almost constant at incidences tolerably nearly perpendicular*. This prism, constructed for me by Mr. John Adie, had two angles of 40° and one of 100° ; and so accurately was it made, that (satisfying myself with a careful measurement by the common goniometer, extreme nicety being unimportant) the angles appeared to be true to those quantities within a few minutes of a degree.

By a reference to Plate IV., fig. 1, it will now be understood that the required arrangement is of this kind. The heat diverging from the source S, is converted into an ap-

* See Melloni on the Reflection of Heat, *Annales de Chimie*, Dec. 1835.

proximately parallel beam by the lens L. It then passes through a diaphragm T, placed on one or other side of the prism (it does not much matter which, as the beam which arrives at the pile is always much wider than the second diaphragm *t*, placed there to admit only the central rays arriving parallel to the line *ac*). The use of this diaphragm is, that a narrow enough pencil of rays may be employed, to be independent of the variable breadth under which the surface of the prism is presented to the incident beam. The usual dimension of this diaphragm was one inch in breadth and one and a quarter in height, but in some instances its breadth was reduced to three-eighths of an inch.

The pile *p* has its funnel-shaped orifice closed by a screen with a vertical slit, an inch wide, in the direction of its axis. But there is a peculiarity in the arrangement of the pile very essential to the success of these experiments, where the pile itself is moveable, which I must not omit to mention. Its exposure to currents of air would render the observations, when the pile cannot be entirely inclosed by a box or screen, very capricious in its action. I therefore adapted to the end, bearing the conical reflector, an adjustable wooden tube *r*, containing a rock-salt lens, which still further increased its sensibility, and totally protected it from aerial currents.

The abruptness of the effect of transition from partial to total reflection is far from being so complete as might be wished; and this is easier accounted for than remedied. It arises mainly from the magnitude of the source of heat, the consequent want of parallelism of the refracted rays, the scattering of these rays in consequence of the imperfect polish of the surfaces, the unequal intensity of the rays in different parts of the section of the cylinder, and lastly, owing to the want of homogeneity of the rays of heat from any source, which the method would serve to measure, were the other imperfections removed, just as in the course of the total reflection of light, prismatic colours are successively presented.

My first rude attempts showed all this very clearly. As the diagonal *ab* of the lozenge (fig. 1) shortened, total reflection obviously succeeded to partial, and the change was not only very great, but near one point very rapid. The point where the most rapid increase took place, is obviously that where the greater proportion of the incident rays underwent total reflection, and might therefore be taken as a mean representation of the quality of the heat. Still the change was too gradual to enable one by mere inspection to determine this point with accuracy, and I speedily resolved to take the sure but laborious method of ascertaining at a number of points

intermediate between total and partial reflection the intensities of the reflected heat, and by constructing a curve having measures of the diagonal of the lozenge (a function of the angle of incidence) for abscissæ, and intensities for ordinates, I endeavoured to discover graphically for what value of the former the measure of the latter increased most rapidly, in other words, where the tangent made the greatest angle with the axis, or where was the point of contrary flexure of the curve.

Plate IV. fig. 2, may represent such a curve. I have found that when the diagonal of the lozenge was 14·5 inches, the reflection was in all cases nearly total, or the galvanometer was little affected by any increase of the angle of incidence. This effect, measured by the vertical line A B, was denoted by 100. When the diagonal was increased to 15·0, the effect was reduced, we shall suppose, to 90, expounded by the line C D, at 15·5 by E F, and so forth. An interpolating curve drawn through the points so fixed, would have its greatest inclination to the axis A X, when, for a given variation of the diagonal, the decrement of the intensity was a maximum, in other words, at the determining angle for the predominating part of the heat used. Such a point of contrary flexure would therefore determine the *mean* index of refraction of the given kind of heat by the aid of the formula above investigated, whilst the form of the curve would lead to some conjecture at least, respecting the distribution of heat of the more or less refrangible kinds in the given ray. Heat of low refrangibility being the last to be totally reflected, would cause the curve to droop fastest near the extremity B, the more refrangible rays would be cut off at the other end I of the curve.

I lost no time in verifying the general truth of the principle, and also of the received doctrines respecting heat, by examining the *quality* of the heat which reached the pile at different stages of total reflection. If, as M. Melloni first rendered probable, heat of *low* temperature is *least* refrangible, and *vice versâ*; and further, if it be admitted that such heat passes most difficultly through such substances as glass, it follows, that after total reflection has proceeded a certain way, so that the more refrangible, and therefore more transmissible, rays have suffered total reflection, whilst the remaining rays constituting the primitive beam continue to be refracted, the heat thus reflected will be more copiously transmitted by glass, than when it came direct from the source. This conjecture was precisely verified.

Subsequent experiment still more fully confirmed this result, and by showing that during the whole progress from partial

to total reflection, the specific quality of the heat changes, gave countenance to the view that the gradation is in a great measure owing to the want of homogeneity of the heat, and that the figure of the curve becomes (as we have said) a real test of the composition of a ray.

At the inferior limit of the curve, or when partial reflection takes place, all kinds of heat are equally reflected (in the case of light, the light is white), just as at the superior limit, or after total reflection is complete, the beam has exactly the same relative composition as before. In the intermediate stages the composition is perpetually varying. The first rays totally reflected (and combining with the scattered and partially reflected rays) are the more refrangible, or those more easily transmitted by glass. At a certain point a maximum proportion of these enter into the reflected beam. As the angle of incidence becomes greater, more and more of the less refrangible rays enter into the composition of the reflected heat, which at last possesses the same qualities as at first. This is well illustrated by the following early experiment which I made on the proportion of the reflected rays transmitted by a plate of glass $\cdot 06$ inch thick, at different stages of reflection (7th February 1838).

Diagonal <i>a b</i> , Fig. 1 in Inches.	Deviations of Galvanometer.		Ratio.	REMARKS.
	Glass.	No Glass.		
14.5	8.3	13.75	60 : 100	Total reflection complete.
15.0	7.85	12.65	62 : 100	
15.25	7.1	10.9	65 : 100	
15.5	5.5	7.85	70 : 100	
15.75	3.4	5.1	67 : 100	
16.0	2.3	3.75	61 : 100	Partial reflection.
16.5	1.45	2.3	63 : 100	

In the following experiments on the law of the transition from partial to total reflection, the arrangement was that shown in Plate IV. fig. 1, and described (with the adjustments) in pages 182—184; the centre of the pile *p* was 13 inches from the prism *P*, and the distance of the source of heat *S* from *P* was 12 inches; that a diaphragm *T*, whose aperture was 1 inch by $1\frac{1}{2}$, was placed in the path of the ray usually between *P* and *L* near *P*; the aperture of the pile was contracted to a breadth of one inch, whose centre was exactly in the line *ad*; and only that part of the prism was employed which was free from flaws capable of producing total reflection.

The diagonal of the lozenge frame was varied from 14.5 inches up to 16.5 or 17.0, about eight observations of the in-

tensity of reflected light being made at intervals. The series was then frequently *reversed*, and the mean results of the going and returning series taken to allow for any change which might have occurred in the intensity of the source. In all cases an observation of verification was made and such change allowed for. The dynamical effect on the galvanometer was observed and noted.

In reducing the observations the following plan was adopted. The intensity corresponding to the diagonal 14·5 inches being assumed = 100, the other intensities were reduced relatively to it, and projected, as explained in art. 60. By this means different series of observations became at once comparable with each other, and the beauty and regularity of the curves thus formed, and the almost perfect identity of those obtained on different days, and with different adjustments, give a degree of confidence in the results which is extremely satisfactory. When from the nature of the heat the effect was very small (as in the case of alum being interposed, or the source being of low temperature), I have endeavoured to supply the deficiency by multiplying observations, and the uniformity of the curves thus obtained has been the test of my success. Where this test has failed (as in the attempt to work with heat of 212°), I have suppressed the results.

Example.—Dark Hot Brass. March 31, 1838.

Measure of Diagonal <i>ab</i> , Plate xiii. Fig. 1. in Inches.	Galvanometer-Needle.		Excess.	Ratio to Result with Diagonal = 14·5.
	Stands at	Swings to		
14·5	A 0°1	A 11°0	10°9	100 : 100
15·0	0°0	9°3	9°3	85 : 100
15·25	0°15	8°0	7°85	72 : 100
15·5	0°15	6°2	6°05	55 : 100
—	0°3	6°3	6°0	
15·75	0°25	4°6	4°35	40 : 100
16·0	0°15	3°15	3°0	28 : 100
16·25	0°2	2°25	2°05	19 : 100
16·5	0°15	1°9	1°75	16 : 100
14·5	0°05	10°8	10°75	

After the observations made as now described have been projected in the form shown, Plate IV. fig. 2, the diagonal corresponding to the maximum rate of decrease of the intensity was determined, for the purpose of deducing the index of refraction. The following enumerations of the kinds of heat employed, and the results derived from the several pro-

jections, will give a just idea of the confidence due to the results.

Sources of Heat.—(1.) The direct rays of the Locatelli lamp. A slightly concave reflector was employed. (2.) The same lamp, with a reflector having the form of a portion of a sphere concentric with the wick; the heat transmitted through *alum*. (3.) Heat from the same source transmitted by *window glass* .06 inch thick. (4.) Heat from the same transmitted by opaque *black glass* (through which the disk of the unclouded sun is just visible). (5.) Heat from the same transmitted through *dark coloured mica*, by which direct sunlight is absolutely stopped. This singular substance I long sought for in vain, it is unknown to many practical mineralogists; it transmits green light at small thicknesses, when thicker its colour is hair-brown. By reflected light its colour is between green and black. (6.) Heat from incandescent platinum. (7.) The same sifted by *window-glass* as above. (8.) The same sifted by *opaque mica*. (9.) Heat from dark brass about 700°. This is obtained from a nearly cylindrical cover of smoked brass placed over the flame of a spirit-lamp, so as entirely to conceal it, and which gives remarkably good results, without increasing considerably the angular breadth of the source (which is greatly to be avoided when a lens is used). It is in fact not much greater in size than the helical coil of platinum wire used in (6). (10.) The same, sifted by clear *mica* .0044 inch thick. (11.) Heat from a crucible of mercury about 450°. The crucible was about 2 inches in the side, smoked externally, and heated by a spirit-lamp. The temperature of the mercury which it contained (covered with sand) was noted at each observation by means of an inserted thermometer.

The results were the following:

Source of Heat.	<i>a b</i> , or diagonal corresponding to the point of contrary flexure.	μ , or Index of Refraction for mean rays computed by the Formula, page 183.
Locatelli, direct	15.49	1.571
———— with alum ...	15.76	1.598
———— window-glass	15.65	1.587
———— opaque glass	15.71	1.593
———— mica	15.61	1.583
Incandescent platinum	15.50	1.572
Ditto with glass.....	15.66	1.588
———— opaque mica	15.62	1.584
Brass at 700°.....	15.45	1.568
Ditto with clear mica	15.55	1.577
Mercury at 450°	15.50	1.572
Mean luminous rays...	15.8	1.602

The preceding results give values of μ all too high; that for light is known by other methods to be only 1·53 or 1·54. This arises from the increasing intensity of the partially reflected light with the obliquity of the incident ray which makes the apparent transition from partial to total reflection too rapid, and consequently gives the index too great. The true indices may be approximately found by diminishing these numbers by ·07; but the *relative* results are the most important.

The results which we have obtained apply, it must be recollected, only to the *predominant* kind of heat in any source, and that we have as yet got no information respecting the *composition* of a ray and the amount of dispersion.

It is very easy to see that were the mathematical conditions of the experiment (p. 183) fulfilled, we should be led to an exact analysis of heat, more perfect far than we have any prospect of obtaining in the case of light, considering the difficulty of applying the photometer to coloured light. Were the curve in Plate IV. fig. 2, solely representative of the progress of reflection due to the heterogeneity of the rays, the increment of intensity between any diagonal E and another C, or D, would denote the proportion of the entire heat incident, which lies between the limits of refrangibility assigned by the diagonal. Thus an entire ray would be decomposed into parcels of known proportions, between given intervals of refrangibility. The case is considerably different. Though the points of contrary flexure agree remarkably well, as we have seen, the curves are in some cases much more flattened than in others, where the source of heat is the same; owing probably to the greater parallelism of the rays at one time than at another, depending on the distance of the source of heat from the lens.

We can, therefore, in this way form but an imperfect idea of the comparative homogeneity of the different kinds of heat. Such comparisons can only be made advantageously by comparing the results obtained in immediate succession from one and the same source with interposed screens of different qualities, as in the comparison which we instituted between heat direct from Locatelli's lamp, and that transmitted by glass, (p. 186).

The facts respecting refrangibility, which may now be considered as ascertained, serve to render our ideas much more precise in several respects. For instance, (1.) the range of *mean* refractive indices for heat is small, all the modifications which we have considered lying within a range of ·04, or between 1·51 and 1·55 nearly, which is little more than

the commonly assigned dispersion of light, which for rock-salt, is between the limits 1.54 and 1.57 nearly. This, however, is for *extreme* rays of light, which can hardly be said of heat; the extremes of dispersion are certainly much wider apart. (2.) The *mean* refractive index of *direct* rays from different sources varies surprisingly little. In fact the differences for *direct* rays of heat from the Locatelli-lamp, incandescent platinum, and from a crucible heated to 450°, seem almost insensible, or within the limits of error of experiment. It is to be recollected, however, that this is compatible with the utmost variety in the *composition* of each. (3.) The effect of interposed screens in modifying the transmitted heat is very remarkable. These, so far as I have tried them, invariably *raise* the index of refraction, (alum, glass, opake glass, and opake mica for the Locatelli-lamp; glass and opake mica for incandescent platinum, and clear mica for dark heat). This is the case even with those substances which suppress light altogether, and which therefore cannot be considered to do more than detach the heat of considerable refrangibility from the light which usually accompanies it, not as stopping the most refrangible rays and admitting the passage of those of lower temperature. Probably no substance acts in this way, though some (as black glass and mica, as the experiments of Melloni indicate) may probably absorb the heat spectrum at *both* extremities. It is probably to this source that we must attribute the very small fraction of heat transmitted by the black glass I used, being only that constituting the rays of the higher degrees of refrangibility, all those of *low* and *mean*, and also of the *highest*, degrees of refrangibility being probably absorbed. (4.) With respect to the homogeneity of different kinds of heat, we can deduce nothing *certain* from the forms of the curves. They confirm, however, a view which I have long entertained, that heat from non-luminous sources is more homogeneous than any other. I argued this partly on the ground stated in p. 111 of this volume, and still more from the uniformity of results which I have in all classes of experiments obtained from dark heat, which often more than made up for the narrower range of the thermal effect, and which showed that the discrepancies observed in other cases were due not so much to errors of observation, as to unavoidable changes in the character of the heat, (p. 100). This result is the more probable from the size of the source of heat necessarily used in the crucible experiments (p. 188), which tends to render the passage from partial to total reflection more gradual, and thus to flatten the curve. To the same cause may also probably be attributed the somewhat greater

index of mean refraction obtained for heat from this source than that of dark heat of higher temperature.

The following method might perhaps be used with success for obtaining more exact data respecting the refrangibility, and especially the *dispersion*, of heat, than that just described pretends to give. It must insure a beam of parallel rays of heat of sufficient intensity and uniform in every part of its section. A small point of heat placed behind a lens (or two or three lenses to diminish aberration) is the most obvious plan. But the intensity would be inadequate. I would, therefore, propose a platinum wire, heated by one of Mr. Daniell's constant voltaic batteries, placed behind a refracting semicylinder of rock-salt*. The central rays should be alone employed, and the prism for total reflection should be high and narrow as well as the aperture of the pile. It is possible that in this case the transition from partial to total reflection would be so rapid as to make the error arising from the varying intensity of partial reflection inconsiderable. By changing the force of the battery, heat of all temperatures might be employed in succession. The numerical analysis of the heat spectrum would then take place as described in p. 189.

Conclusion.—My object in these, as in former researches, has not been to group experiments of mere curiosity indiscriminately selected, but to present a basis for a proper theory of heat. Without some such end in view I should have thought the time and labour spent on these experiments in some degree misapplied. Mere numerical results, though ultimately of the highest consequence to science, should never form the exclusive object of the philosopher. I trust to have shown that though many of the conclusions in this paper are based upon quantitative results, these have not been the ultimate aim of the inquiry.

The mutual bearing of the three sections of this paper, and of all upon what (from analogy to physical optics) we may call *physical thermotics*, is now evident. (1.) In the first section we have minutely discussed a point apparently perhaps of minor importance, namely, the unequally polarizable nature of the rays of heat. The importance of the doctrine lies in this: that the common theory of undulation recognises no such variation, nor *perhaps* does it exist in the case of light (I know, however, of no decisive experiments on this point), with the exception of the small effect due to the difference of refrangibility. Now, having proved in the third section that this difference of mean refrangibility is from most sources

* Such a one I have had executed.

very small, which yet differ widely in their polarizability, we infer that that explanation is probably inadequate, and that we must look for a mechanical theory of heat differing in some particulars from that of light.

(2.) This latter conclusion is further confirmed by the results of the second section, in which is deduced, from the singularly accordant results of wholly distinct series of experiments with heat from those distinct sources, that the phenomena of depolarization differ surprisingly, *numerically speaking*, from those of light, whilst in their general character they are entirely similar. The results at which we have arrived oblige us to admit, *either* that the length of a wave of heat is several times greater than that of a wave of light, *or* that the velocities of the ordinary and extraordinary ray in doubly refracting crystals are totally different from those of light; *or else* a combination of these hypotheses. Now, of the two first alternatives, we are bound at present, I think, to prefer the latter, since we know nothing of the phenomena of double refraction but from this experiment; whilst the subsequent experiments on the refractive index, would, according to the prevalent theory of dispersion, seem to show that the mean length of a wave of heat cannot differ very materially from one of light. This amounts to admitting that the doubly refractive energy is more feeble for heat than for light; in other words, that a greater thickness of a crystal is required to produce a given effect. The second and third sections also confirm one another in this respect, that the uniformity of the results of depolarization with heat from different sources, and also of the refrangibility, would both be highly improbable did the length of a wave materially differ in those instances.

(3.) Of the results of the third section, I have already spoken at sufficient length (p. 189). The mean index of refraction for all kinds of heat tried is *less* than for light;—it ranges within narrow limits;—when the heat from different sources is unmodified by transmission through diathermant bodies, these limits are very narrow indeed;—the measure of dispersion is considerable but unascertained, and opens a fair field for experiment;—dispersion is probably least for sources of low temperature.

Such are the chief data for speculation afforded by the experimental results contained in this paper:—too imperfect perhaps in themselves to form the basis of a mechanical theory of heat, yet such I hope as may be considered to be fit contributions towards its construction at a future period.

Edinburgh, April 16, 1838.