On the analogies of light and heat / The Rev. Baden Powell.

Hence the distinction of *at least two species* of heating rays emanating at the same time from the same *luminous* source.

From the neglect of this distinction much confusion has been kept up: and statements involving such confusion have been repeated from one elementary treatise to another.

Again; notwithstanding that the experiments of Leslie and others on the *absorption* of heat from *non-luminous* sources, as well as those of Professor Bache on the *radiation from surfaces*, demonstrate that the effect has *no relation* whatever to *colour*, yet the contrary assertion has been often persisted in.

Again "dark heat" is often spoken of without recollecting that rays of the very same quality and properties exist in the compound radiation from *luminous* sources.

The conclusions drawn from later experiments, (performed with all the advantages derived from the beautiful invention of the thermo-electric instrument of Nobili,) in many instances, are still vague, from want of attention to the distinction of *different species of heat* emanating at the same time from the same source.

Melloni, in a most extensive and valuable series of experiments, taking as the sources of heat successively flame, incandescent metal, boiling mercury, and boiling water, and applying in each instance a long series of substances as screens, estimated the proportion of rays out of 100 stopped, which was very different for each screen and each source: evincing wide differences in "*diathermaneity*," while *rock salt* alone was almost totally "diathermanous" to rays from all sources alike.

But we must still ask, what *species* of rays were those respectively stopped and transmitted? To take the *per centage* simply is ambiguous; the body of rays is not homogeneous; the property of transmissibility should be viewed in combination with other properties of the specific rays, such as those evinced in their relations to the texture or colour of the absorbing surface.

Nor is the ambiguity removed, though the difference of *source* is specially referred to, if the heterogeneity of rays from the *same* source be overlooked. The mere classification of sources into *luminous* and *non-luminous* will not suffice: still less a reference to their *temperatures*: it being perfectly well known that the *temperature of luminosity* is very different for different substances.*

Again Melloni has shewn that the *diathermaneity* is not proportional to *transparency*, by a classified series of transparent screens with the *lamp*.

It must however be recollected that the term* "diathermaneity" is applied indiscriminately to a heterogeneous body of rays: out of which *some species of rays* are entirely stopped, others entirely transmitted; and the great differences in "diathermaneity" for heat

* References in detail to all the different researches here mentioned, will be found in the Author's Two Reports on the state of our knowledge of Radiant Heat in the British Association Reports, 1832 and 1840.

from different sources, which Melloni has also established, are nothing else than *absorption of* PECULIAR *rays* by each medium, not more anomalous than the corresponding absorptions of *luminous* rays by different transparent media so little as yet reduced to law.

While *rock salt* is analogous to colourless media for light, *alum* on the other hand is totally impermeable by heat from dark sources, and partially so by rays from the lamp; that is, wholly impermeable for that portion of the rays which are of the *same kind* as those from non-luminous sources, and permeable to the others.

By other sets of experiments Melloni shewed that rays from the lamp transmitted in different proportions by various screens and then equalized, were afterwards transmitted by *alum* in equally various proportions: or as he expresses it "possess the diathermancy peculiar to the substances through which they had passed."

But this implies no new property communicated to the rays. It shews that as *different specific rays* out of the compound beam were transmitted in each case by the first screen, alum, though impervious to the lower heating rays, is permeable by these higher rays; and in different degrees according to their *nature;* an effect simply dependent on the heterogeneity of the compound rays from a lamp.

Again with differently coloured glasses peculiar differences of diathermaneity were exhibited with rays from a lamp, incandescent metal, and the sun: but not more various or anomalous than the absorption of specific rays of light.

And besides considerations of this kind it must always be borne in mind that a *blackened surface* (like that which was used in all these experiments) itself is *unequally absorptive for the different rays.*

The solar heat being freely transmissible through all colourless transparent media along with the light, there would be no peculiar advantage in experimenting on the solar spectrum formed by a rock-salt prism. Melloni however with such a prism on interposing a thick screen of water, found the most heating rays (*i. e.* those at or beyond the red end) intercepted, as they are known to be by water: and this caused the position of the *relative* maximum to be apparently shifted higher up in the spectrum, even to the position of the green ray.

On the other hand many coloured glasses, he found, absorbed the rays in various proportions, yet they left the point of maximum heat unaltered: *i. e.* though variously absorptive for the higher rays, they were not of a nature to stop the lower, or most heating rays.

One result indeed is recorded which seems at variance with all other experiments on the solar rays: a peculiar green glass (tinged by oxide of copper) was found to absorb so entirely all the most heating rays that the remaining portion produced no heat, though when concentrated by a lens they gave a brilliant focus. Speaking generally however, these experiments only confirm what is on all hands admitted, *viz.* that the *illuminating* and *heating* powers follow very different laws, with relation to the different rays.

The grand discovery by Melloni of the true REFRACTION OF HEAT even of that kind which constitutes the whole radiation from dark sources, by means of the *rock salt* lens and prism, and its extension by Professor Forbes to the determination of the *index of refraction* (μ) for the most heating rays from all sources both luminous and non-luminous, gave the first actual proof of the real analogy, of the propagation of heat by waves in an etherial medium: which was further carried out when it was shewn from Cauchy's theory that for different wave lengths (λ) there must be in every medium a certain *limit of all refrangibility:* that is, as we suppose (λ) to increase, large changes in (λ) will give continually smaller changes in (μ), and when (λ) is very great compared with (Δx) the intervals of the molecules, then the index (μ) assumes its limiting value which is not greatly below that for the extreme red ray, and with this, the index for the lowest heat coincides.

This is seen directly from the formula *

$\frac{1}{\mu^2} = P - Q\left(\frac{\Delta x}{\lambda}\right)^2 + R\left(\frac{\Delta x}{\lambda}\right)^4 -$ &c., which when we suppose $\left(\frac{\Delta x}{\lambda}\right) = 0$ will have for its limiting value $\left(\frac{1}{\mu}\right) = \sqrt{P}$

The results from observation for Rock salt compared with this theory are as follows:

Rock Salt.

rays	μ	
	obs.	theory
mean light	1.558	. .
red ray	1.540	. .
$\lambda = .000079$	. .	1.529
dark hot metal	1.528	. .
Limit	. .	1.527

But it is to the capital fact established by Professor Forbes, of the *polarization* of heat from *dark* sources (for with *luminous* sources little doubt could exist), with all its remarkable train of consequences, that the complete analogy with light is seen in the most uninterrupted point of view; — the transverse vibrations, the dipolarization, the consequent interferences, the production of circular and elliptic vibrations under the proper conditions, — to those familiar with the

* See the Author's Treatise "On the Undulatory Theory applied to the Dispersion of Light," &c. London, J. W. Parker, 1841, pp. 71-122.

wave-theory present an irresistible accumulation of proof of the identity of the rays of heat with a succession of waves in an etherial medium: exhibiting different properties in *some* dependence on their wave-lengths.

Among the most recent researches on the subject are those of Mr. Knoblauch (of which a translation is given in Taylor's Foreign Scientific Memoirs, Part xviii. and xix.) and they are not to be surpassed for extent and accuracy of detail.

One series is devoted to the examination of the alleged differences in radiation of heat *proportioned to the temperature* of the source. This as before observed is an untenable hypothesis, but Mr. Knoblauch distinctly refutes it by a series of experiments on alcohol flame, red hot metal, hydrogen flame and an argand lamp, whose *temperatures* are in the order of enumeration beginning with the highest: but the power of their heat to penetrate screens is found to follow exactly the reverse order. And even with lower stages of heat, the effects bear no proportion to the *temperatures* as such. Hence the effect is evidently not due to a mere extrication of the heat of temperature, but is of a peculiar kind. In a word, agreeably to the preceding remarks, the different species of rays, more or less compounded together in the several cases, exhibit their diversities of character in developing heat by their absorption. One very peculiar result is, that Platinum, at a stage intermediate between red and white heat, transmits through all the screens employed rather less heat than when at a red heat. That is, these intermediate rays are of such a wave-length as to be subject to a peculiar absorption by these screens: while at the same time possibly less of the former may be emitted.

In another section Mr. Knoblauch adverts to the effects of surfaces on the absorption of rays, and particularly remarks (p. 205); "The experiments of B. Powell and Melloni have shewn that one "and the same body is not uniformly heated by rays from different "sources, which exert the same direct action on a blackened thermo-"scope;" a statement which does not very intelligibly express any conclusion of the author's. Mr. Knoblauch however supports it by elaborate experiments shewing, as might be anticipated, that an argand lamp affects a surface of carmine less, and one of black paper more, while a cylinder heated to 212° affects the carmine more and the black paper less.

Another extensive series, on the effect of surfaces on radiation, is directed to shew that the effect is independent of the source whence the heat so radiated, was originally obtained.

Among the very multifarious results referring to screens and surfaces obtained by Mr. Knoblauch, it can here only be remarked that none of those varied facts appear to present anything *at variance* with the principles here advocated, while in the general conclusions which he indicates at the close of his memoir, the author though professedly avoiding all hypothesis, yet distinctly intimates his conviction of the heterogeneity of the heating rays increasing as the condition of the source rises in the scale from a low heat up to lumi-

nosity or combustion: and that the diversities of heating effect on different media, are due to a selective absorption of particular species of rays, from peculiarities in the nature of those substances, and analogous to the absorption of particular rays of light by coloured media.

It must not however be omitted to notice, however briefly, another recent set of researches of high interest, those of M. Silberman; in which (among others) the very remarkable fact is established, that on transmitting a narrow ray of heat from a heated wire, through *rock crystal*, there is a singular difference according as the ray passes *parallel* or *perpendicular* to the axis of the crystal: the effect being indicated by having the further side of the crystal coated with a fine composition of wax, the portion of which in the direction of the ray is melted in a *circular* form in the first instance and in an *elliptical* in the second.

The general fact of the heterogeneity of heating rays, especially from luminous sources, is fully recognized by Melloni as in some sense the conclusion from all his experiments.

The hypothesis that this heterogeneity consists simply in differences of wave-length would seem a probable one; though it is still possible, as Professor Forbes suggests, that some other element may also enter into the conditions.

This view has been extended by M. Ampère so as to refer both luminous and heating effects to the *same* rays: — a view controverted by Melloni, chiefly on the ground, evinced by several classes of experiments, that *the intensity of the heating effect* (especially in the solar rays) *follows no proportion to that of illumination;* an argument which really amounts to little unless the theory obliged us to infer that the amount of illumination must follow the *same law* as that of heat; which it manifestly does not; since the nature of the effect in the one case is wholly dependent on the unknown constitution of the optic nerve; according to which some precise proportion of the impinging vibrations, with a particular wave-length, is that which gives the greatest perfection of *vision:* while for *heat* the effect has no reference to such peculiar conditions, but is dependent in some way on longer wave-lengths, and probably more simply connected with the intensity or amplitude of the vibrations.

On this theory our view of the case would be thus: —

A body heated below luminosity begins to give out rays of large wave-length only. As it increases in luminosity it continues to send out these, and at the same time others of diminishing wave-lengths, till at the highest stage of luminosity it gives out rays of all wave-lengths from those of the limit greater than the red end of the spectrum, to those of the violet end, or possibly less.

Rays of all these species are transmissible and refrangible by Rock salt; and many of them with numerous specific distinctions by other media.

They are all *more* or *less* capable of exciting *heat* when absorbed or *stopped:* though in some the effect is perhaps insensible. Both this property and that of their transmissibility seems to depend in some way *on the wave-length*, though in no simple ratio to it.

The absorptive effect due to *texture* of surfaces has some *direct* relation to the magnitude of the wave-length, especially near the limit. While that due to *darkness of colour* is connected with shorter wave-lengths such as belong to rays within the limits of the *light spectrum:* and in any case when a ray impinges on any absorbing substance, its vibrations, being stopped, communicate to the molecules of the body vibratory movements of such a kind as constitute heat of temperature.

The peculiar molecular constitution of bodies which determines their permeability or impermeability to rays of any species, gives rise to all the diversities of effect, whether luminous or calorific. We thus escape all such crude ideas, at once difficult and unphilosophical, as those either of two distinct material emanations producing respectively heat and light, or of a conversion of one into the other; and obtain a view far more simple and consistent with all analogy.

[B. P.]

In the Library were exhibited: —

Dr. W. B. Herapath's Iodine of Disulphate of Quinine (a crystalline substance which has the power of Polarizing a ray of Light like a tourmaline. [Exhibited by Col. P. J. Yorke, M.R.I.]

Specimen of Decorative Drawing (by a Lady). [Exhibited by C. B. Mansfield, Esq., M.R.I.]

Specimens of Carving in Wood, by Mr. W. G. Rogers.

Wire Models illustrating Geometry, Crystallography, &c. [Exhibited by Mr. Tennant.]

Plan of Battle at Borodino — Nelson's hat — Antique Military Accoutrements, &c. [From The United Service Institution.]

Ancient sword of State formerly carried before the Bishop of Treves. [Exhibited by Messrs. Hunt and Roskell.]