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XI. On the laws of crystalline reflexion

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42 Mr. MacCullagh on the Laws of Crystalline Reflexion.

cannot on this occasion pass by without notice Mr. Professor Don, of King's College, London, whom we regard as occupying a very elevated station among the botanists of this country, and second only to Dr. Brown in the number of valuable contributions with which he has enriched the Transactions of the Linnæan Society, all tending to advance and to illustrate the system of Jussieu.

[To be continued.]

XI. *On the Laws of Crystalline Reflexion.* By JAMES MACCULLAGH, Fellow of Trinity College, Dublin.*

IN a Number of Poggendorff's *Annalen* (No. 6, for 1836,) which reached Dublin late in November, there are some remarks by M. Seebeck on a paper of mine which appeared in the last February Number of this Journal, (vol. viii. p. 103). That paper contains a general theory of reflexion at the surfaces of crystallized media; and M. Seebeck, in comparing the results with his own experiments, has fully confirmed some of my formulæ, while he has shown that others are defective. I have therefore been obliged to revise my theory, and I have ascertained that it was vitiated by the introduction of a certain relation among the quantities denominated pressures, which, following the example of M. Cauchy, I had supposed to be concerned in the problem. This relation I had observed to hold in the case of singly refracting media, and I concluded, without any other reason, that it would hold good generally. But though it led to the correct formula for the polarizing angles in different azimuths, it was nevertheless arbitrary and unfounded; and therefore it is now banished entirely from the investigation, the place which it occupied being supplied by the natural and simple law of the preservation of *vis viva*, while everything else remains as before. I hope the imperfection of my first essay will be excused, when it is considered that the erroneous proposition bears but a small proportion to the whole theory, and moreover, that the general problem, which I undertook to resolve, is one that has not been attempted by any other person, although the want of a solution has long been felt. The difficulties which we have to deal with, in entering upon this problem, are not mere mathematical difficulties, but difficulties arising from the want of first principles; and, in physical questions of this kind, where we must, at the outset, have recourse to conjecture, in order to supply the very principles of our reasoning, it can hardly be expected that the whole truth should be divined at once. I think, however,

* Communicated by the Author.

that I have now obtained a true mechanical theory; and if so, it will help to decide, not only the question immediately before us, but also the other much-disputed, though more elementary, questions concerning the density of the æther in different media, and the direction of the vibrations in polarized light. In fact, a particular supposition respecting each of the latter questions is included in my theory, the several principles of which, making the single alteration that has been mentioned, I shall here enumerate:

1. The density of the æther is the same in all media.
2. The vibrations of plane-polarized light are parallel to the plane of polarization.
3. The *vis viva* is preserved.
4. The vibrations are equivalent at the common surface of two media.

To these may be added the definition of the polarizing angle of a crystal; namely, the angle of incidence at which the plane of polarization of the reflected ray becomes independent of the plane of polarization of the incident ray. At the polarizing angle, the former plane does not, in general, coincide with the plane of reflexion, but makes with it a small angle which may be called the *deviation*.

It is curious that, about a year and a half ago, I employed these four principles, precisely as I have now enumerated them, in deducing Fresnel's well-known laws of reflexion for ordinary media; but I did not then apply the law of *vis viva* to crystals, because my mind was preoccupied by the notion that there existed some relation among the pressures. This notion I had taken up from reading a little paper, by M. Cauchy, in the *Bulletin des Sciences Mathématiques* for July 1830; and by combining such a relation with the three conditions afforded by my own law of *equivalent vibrations*, I had actually obtained, for the polarizing angles in different azimuths, a formula (that marked (5.) in my former paper,) which I found to agree very well with Sir David Brewster's experiments, and which M. Seebeck has found to agree still better with his own.

The formula for the polarizing angle is obtained by equating two values of the deviation; and it is remarkable that the very same formula comes out in my present theory, although the values of the deviation are entirely different. Referring, for brevity, to the notation* of my former paper, I find, for the case of a uniaxial crystal,

$$\tan \beta = \cos (i + \phi) \tan \theta, \dots\dots\dots (a.)$$

* Erratum in former paper, vol. viii. p. 106, line 2 from bottom, for $\frac{\pi}{2} + \delta$ read $\frac{\pi}{2} - \delta$.

$$-\tan \beta' = \cos(i + \phi') \cotan \theta' + (a^2 - b^2) \frac{\sin \psi' \cos \psi' \sin^2 i}{\sin \theta' \sin(i - \phi')} \quad (b.)$$

These equations (a.) and (b.) are to be substituted for equations (2.) and (3.), which are the equations that M. Seebeck found to be at variance with his experiments.

By means of formula (5.), equation (a.) becomes

$$\beta = \frac{K}{2} \sin 2q \sin(p - \phi), \quad \dots\dots\dots (c.)$$

from which the deviation in any azimuth may be readily calculated. The azimuth (as M. Seebeck reckons it) begins when $\theta = 0$, and p is then positive. This formula (c.) perfectly represents the experiments of M. Seebeck on Iceland spar. The corresponding expressions for biaxal crystals may be easily deduced, and will be given in a paper which I am preparing to lay before the Royal Irish Academy.

At the time of my last communication I was not aware that the case in which the plane of incidence is a principal section of the crystal (or the azimuth = 0,) had been solved by M. Seebeck, and that formula (7.), which I regarded as my own, had been obtained by him long before.

It remains to say a word respecting the new principle of equivalent vibrations, the most important, perhaps, of all, as it is certainly the simplest that can be imagined. If we conceive an æthereal molecule situated at the common surface of two media, it would seem that its motion ought to be the same, whether we regard the molecule as belonging to the first medium or to the second. Now the incident and reflected vibrations are superposed in the first medium, and the refracted vibrations in the second; and therefore we may infer (when the phase is not changed by reflexion or refraction), that *if the incident and reflected vibrations be compounded, like forces acting at a point, their resultant will be the same, both in length and direction, as the resultant of the refracted vibrations similarly compounded.* This is the law of equivalent vibrations, and it gives, at once, three equations. A fourth equation is afforded by Fresnel's law of the *vis viva*; and thus we have the four conditions necessary for a general solution of the problem. From the principle of equivalent vibrations, as we have stated it, it follows that the vibrations resolved parallel to the separating surface are equivalent in the two media; and in fact, this part of the general principle was assumed by Fresnel; but the other part, namely, that the vibrations perpendicular to the separating surface are equivalent, was not assumed by him, nor is it by any means true in his theory. It appears then that three conditions only are afforded by the

hypotheses which Fresnel successfully employed in solving the problem of reflexion from ordinary media. These hypotheses, therefore, are not sufficient when applied to crystals; except, indeed, in the case before alluded to, where the azimuth = 0, which has been solved by M. Seebeck. It should be observed, that though the reasons which I have assigned for the principle of equivalent vibrations are extremely simple, yet it was not by such simple reasoning that I was led to it originally.

Trinity College, Dublin, Dec. 13, 1836.

XII. *Researches in Organic Chemistry.—First Series. Contributions to the History of Pyroxylic Spirit and of its derived Combinations.* By ROBERT J. KANE, M.D., M.R.I.A.*

MY residence in Giessen during the summer of the present year [1836] allowed me to continue under the guidance of Professor Liebig the examination of pyroxylic spirit, and the compounds obtained from it, which I had commenced prior to my becoming acquainted with the results of Dumas and Peligot, and of which a portion was presented to the British Association assembled in Dublin during August 1835†.

As sent into commerce pyroxylic spirit is contaminated by the presence of a volatile oily material, from which it is extremely difficult to obtain it free. Dumas states that the impurities are completely separated by distillation with fresh-burned lime, a process which in my hands at least has never perfectly succeeded. The pyroxylic spirit thus obtained is always rendered milky by admixture with water, and consequently unfit for accurate examination. Caustic potash and sulphuric acid were found equally unsuccessful in removing this impurity, from which, however, the pyroxylic spirit is obtained free by the following simple process.

Chloride of calcium being dissolved in pyroxylic spirit in considerable quantity, so much heat is evolved that the liquid if in considerable mass rises to its boiling point, and on cooling there is deposited a compound of pyroxylic spirit with chloride of calcium in large brilliant six-sided tables, like those of acetate of zinc. This compound requires for its decomposition a temperature much higher than that of boiling water. If therefore, the rough pyroxylic spirit be saturated with chloride of calcium and distilled, the excess of spirit and the oil come over, and are collected as long as by temperature of a water-bath the distillation continues. When this has

* Communicated by the Author.

† [An abstract of Dr. Kane's paper presented to the British Association, will be found in Lond. & Edinb. Phil. Mag., vol. vii. p. 397, and a notice of the results obtained by MM. Dumas and Peligot at p. 427 of the same volume, of which see also p. 395.—EDIT.]