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Among the other crystals which M. Rudberg will doubtless examine, we trust he will not omit *sulphate of lime* and *glauberite*, on the doubly refracting structure of which, heat produces such extraordinary effects.—D. B.

LXXI. *On the Action of Heat in changing the Number and Nature of the Optical or resultant Axes of Glauberite.* By SIR DAVID BREWSTER, K.H. LL.D. F.R.S. V.P.R.S. Ed.

SEVERAL years ago Prof. Mitscherlich made the beautiful discovery, "that the ordinary *sulphate of lime* or *gypsum* which, at common temperatures, has two optic axes in the plane of its laminae inclined at 60° to each other, undergoes a great change by elevation of temperature; the axes gradually approaching each other, collapsing into one, and (when yet further heated) actually opening out again in a plane at right angles to the laminae."

Sir John Herschel, in whose words we have described this remarkable experiment, goes on to observe, "This singular result we cite from memory, having in vain searched for the original source of our information; but it might have been expected, from the low temperature at which the chemical constitution of this crystal is subverted by the disengagement of its water, that the changes in its optical relations by heat would be much more striking than in more indestructible bodies. We have not, at this moment, an opportunity of fully verifying the fact; but we observe that the tints developed by a plate of sulphate of lime, now before us, exposed as usual to polarized light, rise rapidly in the scale when the plate is moderately warmed by the heat of a candle held at some distance below it, and sink again when the heat is withdrawn, which, so far as it goes, is in conformity with the result above stated. Mica, on the contrary, similarly treated, undergoes no apparent change in the position of its axes or in the size of its rings, though heated nearly to ignition*."

In repeating this important experiment, I made use of one of the specimens described in the Phil. Trans. for 1818, in which I discovered one of the resultant axes of this mineral. It was about $1\frac{1}{2}$ inch thick in the plane of the laminae, and the system of rings which surrounded this axis was exceedingly minute, with the usual black brush at each end of them. The other system of rings could not be seen in this specimen, owing to the manner in which it was cut. Having brought the crystal to a considerable heat, and exposed it to polarized light, it

* Treatise on Light, Encyclop. Metrop. p. 568.

was a singular sight to see the system of rings travelling along towards the line which bisects the optic axes, like a celestial body passing through the field of a telescope, and changing their form and size as they advanced. The specimen did not permit me to see the two systems unite, and still less to see them open out again in a plane at right angles to the laminae; but from the degree of heat which I used, and which drove off the water of crystallization from part of the specimen, I presume that the complete phænomenon cannot be developed without destroying the constitution of the crystal; that is, that after the two systems of rings have opened out in a new plane, they will not return by cooling, through their state of union, into their primitive inclination of 60° in the plane of the laminae.

A property of a similar kind, but perhaps a still more extraordinary one, I discovered some years ago, subsequent to Professor Mitscherlich's discovery; and I have slightly noticed it in a paper on Glauberite, published in the *Edinburgh Transactions**. This interesting mineral has at ordinary temperatures the curious property of *two axes of double refraction for red light*, and only *one axis for violet light*. If we apply heat to it, the two optic axes for red light gradually close, and, at a temperature which the hand can endure, the two systems of rings for red light have united into one system, so that the crystal has now only one axis of double refraction for red light. By continuing to increase the heat the two axes separated, and the single system of rings opened out into two systems lying in a plane at right angles to that in which they were placed at first. The heat was now less than that of boiling water. By increasing it, the inclination of the optic axes gradually increased.

I now applied artificial cold to a crystal of glauberite at the ordinary temperature of the atmosphere. The inclination of the optic axes for red light increased, as might have been predicted; but, what was very unexpected, *a new axis was created for violet light*, the plane of the two violet axes being coincident with the plane of the two red optic axes at and below the ordinary temperature. An increase of cold increased the inclination of the optic axes for all the colours of the spectrum; the inclination of the axes being *least* for the *most refrangible*, and *greatest* for the *least refrangible* rays.

These results appear very complicated when we begin with the effects at an ordinary temperature, and view them in the manner in which they were observed; but if we commence the experiments at a low temperature, such as the freezing

* *Edinb. Phil. Trans.* vol. xi. Part ii. p. 273.

point, the order and connexion of the phænomena will be more easily understood.

At 32° glauberite has two axes of double refraction for rays of all colours, the inclination of the axes for the violet rays being least, and that for the red the greatest. As the temperature rises, the optic axes for all colours gradually approach, and the axes for violet first unite into one. At this time the crystal has two axes for all the other colours; but as the heat increases, all the other pairs of axes unite in succession, and form a single system of rings. But before this has taken place, the axes for violet rays have opened up again in a plane at right angles to that in which they originally lay, and they are followed by all the other pairs of axes; so that at a temperature much below that of boiling water, each pair of axes appears with different inclinations arranged in a new direction.

During all the changes which have been described above, the crystal has preserved its constitution, and by abstracting the heat, the phænomena are all repeated in an inverse order.

If the crystal should happen to be observed at that temperature, which very often occurs, when the greenish-yellow or most luminous rays have the optic axes corresponding to them united, or form a single system of rings, then the blue rays will have two systems of rings lying in one plane, and the red rays also two systems of rings in a plane at right angles to this. In two rectangular positions, namely, when the planes of the double axes coincide with, or are at right angles to, the plane of primitive polarization, the black cross will be very distinct, but in intermediate positions it will be much less so, and the uniaxal system of rings which predominates, from the greater intensity of their light, will have that indistinctness of character which, whenever it occurs, indicates a peculiar action of the doubly refracting force on the differently-coloured rays. When the black cross is perfect and equally distinct in all positions, while the colours of the rings deviate from those of Newton's scale, then the axes for all colours are obviously coincident, and the peculiarity in the colour of the rings is owing to an irrationality in the action of the doubly-refracting forces on the differently-coloured rays. This deviation from the tints of Newton's scale, I have found in many crystals which have only one axis of double refraction. It is extremely common in crystals with two axes.

I have elsewhere described the construction of a *chromatic thermometer*, in which the temperature is indicated by the polarized tints transiently developed by heat in a number of plates of glass;—but it is obvious that a plate of glauberite

may be made a thermometer which will indicate by its change of tint very slight changes of temperature. The temperature at which a ray of definite refrangibility has the optic axes corresponding to it united, so as to form a single system of rings, is a point as well fixed as that of boiling water, and every different inclination of the optic axes of definite rays indicates two different temperatures in the scale of heat, equidistant from those other points at which the same rays have their axes united.

The accurate measurement of these angles would no doubt be difficult, but an instrument might be made to show them by inspection. The temperatures, however, might be more simply indicated by the great variety of tints successively developed by heat; and as each tint has a numerical value in the scale of colours, its accuracy would not be much less than that of the other method.

Allerly, Nov. 3rd, 1832.

LXXII. *An Account of Experiments with an Invariable Pendulum, during a Russian Scientific Voyage. By Captain LUETKE*.*

THE observations of the invariable pendulum occupied the first place amongst the scientific researches to which our attention was directed during the circumnavigation of the *Séniavine*. All these observations are already calculated: but, as I have not yet been able to give them the form in which they will ultimately appear before the public, and as a new appointment confines me at present to other duties, I trust that a summary account of these observations and their results will be acceptable to the Imperial Academy of Sciences, as well as to the scientific world in general.

The apparatus, which we made use of in these experiments, is the same as that which had been previously adopted by Capt. Basil Hall, at the several stations in South America. It is, in fact, the same in construction as that which was employed by Capt. Sabine in his voyage to Spitzbergen. Before quitting England, a series of experiments was made at the Observatory at Greenwich: and again on our return. The second series gave a result, which differed from the first, about $\frac{6}{10}$ ths of a vibration, in excess; which I attribute to a slight wearing of the knife edge. This difference ought perhaps to be distributed over the whole interval, in arithmetical pro-

* Translated from the *Bulletin Scientifique*, page xi., attached to the Memoirs of the Imp. Acad. of Sciences at St. Petersburg. Series vi. vol. i. (1830).