I. *On the Existence of Two New Fluids in the Cavities of Minerals, which are immiscible, and possess remarkable Physical Properties.* By DAVID BREWSTER, LL.D. F. R. S. Lond. & Sec. R. S. Edin.

(Read March 3. and 17. 1823.)

IN the year 1818, my attention was accidentally directed to the subject of water in crystallised bodies, by the explosion of a crystal of Topaz, which I had exposed to a red heat, for the purpose of expelling its colouring matter. This violent disruption of the specimen, which was shivered into a thousand films, of extreme tenuity, arose from the expansion of the imprisoned fluid, and induced me to institute a series of experiments, for the purpose of determining the nature of the fluid, the form of the cavities which contained it, and the arrangement of these cavities in reference to the crystalline form of the mineral*.

Small portions of fluid had been long ago observed by mineralogists in *Topaz*, *Rock-Crystal*, and *Fluor-Spar*. Mr SIVRIGHT found them also in *Calcareous Spar*, *Sulphate of Barytes*, and *Sulphate of Lime*; and I detected them in the *Emerald*, in *Beryl*,

* An account of these experiments was announced for publication in 1819, in the 1st Number of the *Edinburgh Philosophical Journal*; but the desire of obtaining more general results prevented me from publishing it at that time.

Cymophane, Peridot, Feldspar, and in the following crystals formed by aqueous solution.

Sulphate of Iron.	Sulphate of Ammonia and Magnesia.
Sulphate of Zinc.	Nitrate of Silver.
Sulphate of Copper.	Nitrate of Strontian.
Sulphate of Nickel.	Muriate of Barytes.
Sulphate of Soda.	Acetate of Lead.
Sulphate of Magnesia.	Oxymuriate of Potash.
Sulphate of Ammonia.	Muriate of Barytes.
Sulphate of Magnesia and Iron.	Oxalic Acid.
Sulphate of Soda and Magnesia.	Tartrate of Potash and Soda.
Sulphate of Alumine and Ammonia.	Carbonate of Potash.

Being persuaded, from these results, that water will be found in *every* crystal deposited from a solution, I was next desirous of finding it in crystals formed by heat, or by sublimation ; but in no case have I been able to discover the slightest trace of its existence ; and, in the absence of all other information on the subject, I considered this result as highly favourable to the aqueous origin of those minerals in which water has been discovered.

SIR HUMPHRY DAVY was, we believe, the first philosopher who conceived the idea of opening the cavities of crystals, and of examining chemically the nature of the fluid which they contain, and of the gas by which it is sometimes accompanied ; and the experiments which he undertook for this purpose, were conducted with that sagacity and address which characterise all his labours. Upon opening the cavities in a variety of rock-crystals of different localities, and collecting the fluids in fine capillary tubes, he discovered, that, in every case, except one, the fluid was *Water* nearly pure ;—that, in this single case, it seemed to be *Naphtha* ;—that the gas was in two cases *Azote*, and was about 65 times more *rare* than that of the atmosphere ;—that, in one case, the gas (the nature of which is not mentioned) was *compres-*

sed about 10 times more than atmospheric air ; and that in the naphtha cavity there was almost a perfect *vacuum* *.

Such was the state of the subject, when my attention was again turned to the examination of these cavities.

In resuming this enquiry, I have been fortunate, not only in possessing many excellent specimens of my own, but in having the free use of an interesting collection, belonging to Mr SIVRIGHT of Meggetland ; and though I have employed only the microscope, and the agency of heat and of light, I have been led to results of considerable generality and interest. This physical method of determining the properties of minute quantities of matter, though often very difficult, and sometimes perplexing in its manipulations, carries with it a degree of evidence not inferior to that of chemical analysis ; while it possesses the advantage of examining the substance in its original and unchanged condition, and may be applied, in many cases, where the chemist cannot avail himself of any of the resources of his art.

When the cavities in crystals are very large, which seems to be the case principally when they contain water, the elegant method pursued by the distinguished President of the Royal Society of London will afford precise results, and may be expected to add greatly to our knowledge of this mysterious subject. Leaving, therefore, this branch of the enquiry in the skilful hands of Sir HUMPHRY DAVY, I have pursued the subject under a more general form, and have studied the phenomena in their various relations to the principles and methods of general physics.

* *Philosophical Transactions*, 1822, p. 367.

SECT. I. *On the Existence of a New Fluid in the Cavities of Minerals.*

In examining the cavities of crystallised bodies, I observed the most striking difference in the phenomena presented by the fluids which they enclosed. Impressed with the opinion that the fluid was water, I tried every method of explaining, upon ordinary principles, the phenomena which were thus presented to me, but the results of a more minute examination were incompatible with such a supposition, and rendered it necessary to ascribe them to new fluids, possessing new physical properties. In order to convey to the Society a correct idea of the methods of observation, and the train of reasoning by which I was led to this conclusion, I shall give a detailed account of the phenomena, as exhibited in different minerals.

1. *Topazes from New Holland, Scotland, and Brazil.*

As the cavities in the New Holland topazes are frequently arranged in strata parallel or slightly inclined to its most eminent cleavage, or the one perpendicular to the axis of the prism, they are peculiarly fitted for carrying on this enquiry. The facility with which this mineral may be split, allows us to dispense with the aid of the lapidary, and to study the phenomena through perfectly flat and highly polished surfaces.

In examining these specimens with the microscope, we observe the cavities arranged in strata. These cavities are sometimes beautifully crystallised, and sometimes amorphous, sometimes extremely shallow, and at other times deep. They have often the shape of long canals, with parallel sides and round

terminations, and at other times their form is not far from that of a circle.

The cavities now described, are filled with a colourless and transparent fluid, as shewn at ABCD, Fig. 1. Plate I., and have almost always a vacuity V, of a circular form, which moves by an inclination of the plate to different parts of the cavity. The depth of the cavity may be easily estimated, by the breadth of its bounding line ABCD, which, in the flat cavities, is generally the same as that of the circle V. In very shallow cavities, this boundary is a narrow line, scarcely visible, and in deep ones it is broad, with a penumbral termination inwards, arising from the deviation of the light at the separating surfaces of the fluid and the topaz, and at that of the fluid and the vacuity.

When the hand is applied to the crystal, the heat of it gradually expands the fluid. The vacuity V consequently diminishes, and being in a short time reduced to a physical point, it entirely disappears. When the fluid again cools, by withdrawing the hand, it of course contracts, and quits the sides of the cavity. The vacuity V reappears, increasing till it resumes its former magnitude; and it deserves particular notice, that the evanescence and reappearance of the vacuity takes place simultaneously in many hundred cavities, of the same general form, which may be seen in the field of view.

In order to obtain an accurate measure of the temperature at which the vacuity reappears, which is almost the same as that at which it vanishes, I plunged the topaz in heated water, and by means of an accurate thermometer, I obtained the following results :

<i>Nature of the Cavities.</i>	<i>Temperature at which the Vacuity reappeared.</i>
1. Topaz from New Holland, with shallow cavities,	74 $\frac{1}{3}$ ° Fahr.
2. Blue Topaz from Aberdeenshire, with cavities of different forms, - - -	$\left\{ \begin{array}{l} 74 \\ 77 \\ 78 \frac{1}{2} \\ 82 \end{array} \right.$

<i>Nature of the Cavities.</i>	<i>Temperature at which the Vacuity reappeared.</i>
3. Colourless Topaz from Brazil, with only one cavity $\frac{1}{8}$ th of an inch long, $\frac{1}{16}$ d of an inch broad, and $\frac{1}{8}$ th of an inch wide, -	79 $\frac{1}{2}$
4. Topaz from New Holland, with large and rugged cavities, - - -	79 $\frac{5}{4}$
5. Topaz from New Holland, with a very flat cavity, - - -	81 $\frac{1}{4}$
A very long and very irregular cavity in the same crystal, - - -	82 $\frac{1}{4}$
6. Another colourless Topaz from Brazil, -	83 $\frac{1}{3}$
7. Another colourless Topaz from Brazil with a deep cavity, -	83 $\frac{5}{4}$

The reappearance of the vacuity at different temperatures in different cavities of the same crystal, admits of an easy explanation. In those which are of the same size and form, and equidistant from the cooling surface, the vacuities disappear at the same time; but in those which are deep, and in those which, though shallow, are near the cooling surface, the vacuities reappear at a lower temperature. In very shallow cavities, the adhesion of the fluid to the sides of the cavity prevents the vacuity from reappearing so soon as it would otherwise do; while in cavities that have a rough or irregular bottom, they reappear earlier.

When the cavities are very small and narrow, only one vacuity reappears; but when they are large, several small circular vacuities make their appearance, and gradually unite into one, though sometimes they remain permanently separate. When the cavities are deep, a very remarkable phenomenon accompanies the reappearance of the vacuity. At the instant that the fluid has acquired the temperature at which it quits the sides of the cavity, a rapid ebullition takes place, and the transparent cavity is for a moment opaque, with an infinite number of minute

vacuities, which instantly unite into one vacuity, that gradually goes on enlarging as the temperature diminishes.

In order to determine the expansion which takes place by a given increment of temperature, I measured the relative size of the vacuity, and the cavity at the temperature of 50° and 80° , the temperature at which the fluid had expanded so as wholly to fill the cavity. In many cases this could be estimated with tolerable accuracy, and it may be stated in general, from the estimates and measures taken by myself, and by others, to whom I shewed the cavities, that the fluid expands fully *one-fourth* of its size, by an increment of 30° of heat.

Hence, since water expands $\frac{1}{22}$ d of its bulk in passing from 41° , its state of maximum density, to 212° , it will expand $\frac{1}{122}$ th of its bulk for 30° , and $\frac{1}{122} \div \frac{1}{4} = 31\frac{1}{4}$; that is, the fluid contained in the cavities is above 30 times more expansible than water, by an increment of 30° of heat at the temperature of 50° .

This extraordinary result proved beyond a doubt, that the substance contained in the cavity was a new fluid, differing from all known fluids in its high expansibility, and resembling in this respect a gaseous more than a fluid body.

In order to confirm this result, I was desirous of examining the other physical properties of this remarkable substance. I could not fail to notice, in the deep cavities especially, the singular volubility of the fluid, and its slight adherence to the sides of the cavity, as indicated by the motion of the vacuity V. In small cavities containing water, the adhesion of the fluid to the stone is so strong, that the air-bubble moves with extreme difficulty, and even when very large, it often changes its place by starts, or remains stationary at the bottom or in the middle of the cavity. In the present case, however, the vacuity moved about with great facility, and in the cavity, $\frac{1}{20}$ th of an inch long, by $\frac{1}{38}$ th and $\frac{1}{62}$ d of an inch wide and deep, the slightest tap of the

finger on the microscope caused the air-bubble to tremble and oscillate in this microscopic level. Hence the new fluid is distinguished by a second physical property, no less remarkable than the first.

Although I now entertained no doubt of the accuracy of the conclusion, that the fluid was a new one, yet I conceived it might be possible to obtain at least an approximate measure of its refractive power, and thus to put its novelty beyond the reach of a doubt. In order to do this, it became necessary to observe the manner in which the total reflexion of the upper surface of the cavity was modified by the contact of the fluid, and, if possible, to measure the angle at which total reflexion was effected, by the separating surface of the fluid and the solid. For this purpose I took a plate of topaz AB , Fig. 2., with a stratum of cavities mn , perfectly parallel to the natural surface of the plate. I then placed upon each surface the rectangular prisms ABC , ABD , and introduced between them a thin film of oil of cassia. Rays of light RS , RS were then allowed to fall upon the stratum of cavities mn , so that the rays reflected from the upper surface of the cavity could be examined by a microscope whose object lens is LL . Upon making this arrangement, the stratum of cavities was seen in the most beautiful manner. The vacuity V , Fig. 3. of a cavity seen in this way, shone with all the brilliancy of total reflexion, the separating surface of the new fluid $ABCD$, and the cavity, exhibited a faint grey tint, while the surrounding portions of the solid topaz were comparatively black. The variations which the vacuity V undergoes by heat are now finely seen, and at a temperature of 80° it vanishes in a brilliant speck, leaving the whole of the cavity $ABCD$ of the same uniform tint as in Fig. 4.

The phenomena now described are not so distinctly seen when the stratum mn is deeply seated beneath the surface of

the topaz, in consequence of the duplication and overlapping of the images formed by double refraction.

This inconvenience, however, may be nearly removed, by making the plate of topaz very thin; or it may be entirely remedied, in plates of any size, by causing the incident rays RS RS, Fig. 2., to pass along one of the resultant axes of the topaz, while the reflected rays SL SL pass along the other resultant axis.

In order to compare the angle at which total reflexion took place at the upper surfaces of the fluid and the cavity, with that which would have taken place had the fluid been water, I placed a drop of water on part of the lower surface of the plate AB, and I found that the light reflected at the same angle of incidence, was much more brilliant from the separating surface of the new fluid and the cavity, than from the separating surface of the topaz and the water, a result which indicated, in the most unequivocal manner, that the new fluid had a refractive power inferior to water, and that it differed in this respect from every other known fluid.

Although, in this estimate, I attended carefully to the circumstance, that, in the one case, the light reflected from the bottom of the cavity was combined with that reflected from its surface, and therefore used deep cavities, where the two reflexions could to a certain degree be separated; yet, in order to remove any doubt that might remain on the subject, I took a plate of topaz that contained water, or, to speak more correctly, a fluid which did not expand by heat, and upon comparing the reflexions from the cavities, the difference was most palpable.

In one specimen I measured the difference between the angles of incidence at which total reflexion took place, at the separating surface of the new fluid and topaz, and at the separating surface of water and topaz, and I estimated that the refractive power of the new fluid was below 1.300, that of water being 1.336.

In one specimen of *Amethyst* I was enabled to determine, that the angle of total reflexion took place at $51^{\circ} 26'$, and, consequently, that the refractive power of the Fluid, or m , was $= m' + \sin 51^{\circ} 26' = 1.21066$, m' being taken equal to 1.5484, the ordinary refractive power of *Amethyst*.

Many other details might have been added under the present head, in support of these conclusions; but they are necessarily reserved for the next section, with which they have a more immediate connection.

2. *Cymophane or Chrysoberyl from Brazil.*

In several specimens of this mineral I have discovered strata of cavities, which contain the new fluid. One of these is remarkable for having two strata parallel to one another; one of which, about $\frac{1}{4}$ th of an inch square, contains no fewer than 30,000 cavities, filled with the new fluid, which expands and fills the cavity with the heat of the hand. The cavities are in general very small; but I succeeded in determining that the vacuities all reappear simultaneously, at a temperature of $83\frac{1}{4}^{\circ}$.

3. *Quartz-Crystals from Quebec.*

In examining the crystals of quartz from Quebec, I have found that almost every specimen of it contains cavities with the new fluid.

In one crystal the vacuity reappeared at 76° . Another vacuity in the same crystal reappeared at 80° ; while another, almost in contact with this, required a temperature of 125° to make the fluid fill the cavity.

In another specimen of the crystals there are cavities where the new fluid expands fully $\frac{1}{3}$ d of its bulk, by an additional temperature of 30° ; and though they are very shallow, the vacuities reappear in the form of several smaller vacuities, and exhibit an appearance as if the fluid were thick and viscid.

While I was applying a heat not above 170° to some of these specimens, they frequently leapt from the plate of glass on which they lay, and at other times threw off, with an explosion, considerable fragments. In one of these experiments, I was fortunate enough to observe a phenomenon which will be considered a very remarkable one. When the compound microscope was adjusted to a distinct view of a stratum of globules containing the new fluid, but particularly to a vast number of minute specks, which the microscope had not power to resolve, a heat of about 150° , which happened to be applied to the specimen, produced a sort of crackling noise, which arose from the bursting of the cavities near the surface. Upon looking into the microscope, I was astonished to observe a great number of *darkish brown* globules rising through the solid quartz, like globules of air in water. In examining them more minutely, I observed, as shewn in Fig. 5., that they took their origin from the minute specks or cavities, which gradually enlarged and went off in the form of a globule. This phenomenon lasted fully five minutes, when the specimen burst into two or three pieces. While examining the cavities of one of the fragments, I found that several of the large ones, with flat faces, had been emptied of their contents, through a fissure parallel to their flat faces, and that the faces of the fissure had closed up, so as to transmit a brownish light, while a bright light was freely transmitted through the polished faces of the cavities as shewn in Fig. 6*.

Had only one of the cavities shewn in Fig. 6. existed, the fluids which it contained might have escaped through a narrow fissure, not wider than its own breadth; and this narrow fissure

* In a specimen of Topaz which split in the fire, I found that a quantity of the new fluid had got into a fissure, where it has been permanently detained without reaching the surface. It exhibits the same brown tint as the globules, at particular inclinations.

might, in virtue of the elasticity of the stone, have closed up completely, so as to transmit the light as freely as if it had never existed. This process is by no means a hypothetical one. I have repeatedly formed these fissures in glass, and have sometimes seen them close up in a few minutes, without leaving a trace of their existence behind. When they are wide, a day, a week, and sometimes a month was necessary, to effect the reunion of their sides *.

These circumstances enable us to give a satisfactory explanation of the remarkable phenomenon represented in Fig. 5. When the expansive force of the imprisoned fluid was sufficient to make it penetrate the stone, it would probably escape at the weakest point of the cavity, and pass to the surface through a narrow channel, which the elasticity of the stone would immediately close up. These fissures would probably lie in the direction of the cleavage, and this seemed to be the path which the globules took in their oblique ascent, as represented in Fig. 5.

4. *Amethyst from Siberia.*

The greatest quantity of the new fluid which I have yet seen, exists in a specimen of *Amethyst* belonging to THOMAS ALLAN, Esq. This very interesting specimen is represented in Fig. 7., where *a, b, c, d, e*, represent five cavities parallel to each other. The largest of these is $\frac{1}{8}$ of an inch in length, and $\frac{1}{16}$ th of an inch in breadth; and the vacuity is about one-fourth part of the whole cavity. By the heat of the hand the fluid swells, and fills all the cavities, and when the vacuity has been considerably reduced by heat, it moves from one end of the cavity to the other, with a degree of volubility truly surprising. By a

* A full account of these experiments will be found in the *Philosophical Transactions* for 1816, p. 73.

careful experiment, I found that the vacuity disappeared at a temperature of $83\frac{1}{3}^{\circ}$; and when it was made to reappear by rapid cooling, an ebullition took place, as in the deep cavities of topaz.

As the cavities in this specimen were terminated with crystallised summits at *a, b, c, d*, I was enabled to observe a curious optical phenomenon, which accompanied the expansion of the fluid. Whenever the vacuity was so much reduced by the expansion of the fluid, that it could be made to occupy one of the crystallised summits, and afterwards to vanish, it left behind it, on that summit, a system of beautiful concentric coloured rings, which were constantly varying in tint, in diameter, and in number. These rings had the highest order of colours in their centre, and continued while the fluid preserved its expanded state; but they invariably disappeared when the fluid was allowed to contract by cold, as if the substance which formed them had assumed a gaseous form, and entered into the vacuity.

SECT. II. *On the coexistence of two Immiscible Fluids, of different Physical Properties, in the Cavities of Minerals, and accompanied with a vacuity.*

Although many of the cavities which have been described in the preceding section, contain only the new fluid, yet in a very great number, particularly in Topaz, another phenomenon presents itself, which requires a very minute examination. This phenomenon, as exhibited in Topaz, is represented in Figures 8, 9, and 10, where *V* is the vacuity, *NNN* the new fluid, and *WWW* another fluid, which we shall distinguish by the name of the *Second Fluid*. This second fluid *WW* commonly occupies the angles of triangular cavities, as in Fig. 8., or the terminations of longitudinal ones. It is always separated from the new fluid by a curved surface *m n, m n, &c.* It never expands perceptibly

with heat, and never mixes with the new fluid NN. By a little management, the vacuity V may be made to come in contact with the bounding lines $m n$, $m n$, &c.; but it never affects its curvature, and seldom enters the fluid W. When the vacuity V has been made to vanish by heat, these bounding lines remain exactly the same.

Having at first observed this second fluid only in the angles of cavities, as in Fig. 8., I experienced considerable difficulty in establishing its fluidity. The improbability of two fluids existing in a transparent state, in absolute contact, without mixing in the slightest degree, induced some of my scientific friends to refer it to an optical illusion, and to consider the line which separated it from the new fluid as a septum or partition in the cavity. The beautiful curvature of the bounding line, and its perfect similarity to that of two contiguous fluids, rendered this conjecture untenable. It was next supposed to be a vacuity into which the new fluid could not expand itself; but though this idea explained the curvature of the bounding line, it was inconsistent with other facts, and especially with the important one, that the second fluid acted upon light neither like topaz nor a vacuum, but like water.

These difficulties were gradually overcome by more numerous observations.

Although the cavities were generally like those in Fig. 8., where V is the vacuity, NN the new fluid, and WW the supposed second fluid; yet I found several in which the second fluid filled a great part of the cavity, as in Fig. 9., where NN is the new fluid, and W the second fluid, or as in Fig. 10., where a vacuity V also appeared within the globule N of the new fluid.

This great enlargement in the quantity of the second fluid, removed most of the difficulties which had formerly presented themselves; but something was still wanting to prove its fluidity. This desideratum was fortunately obtained in a specimen of to-

paz belonging to Mr SIVRIGHT. In examining this specimen, I observed a very remarkable cavity, of the form shewn in Fig. 11., where A, B and C are three separate portions of the new fluid, insulated by the interposition of the second fluid DEF. The first portion A of the new fluid had four vacuities V, X, Y, Z, while the other two portions B, C, had no vacuity. Having often succeeded in making the vacuities pass from one branch of a cavity to another branch, I did not doubt that the vacuities of the portions B and C had passed over the second fluid into the portion A. In order to determine this, I took an accurate drawing of all the phenomena at a temperature of 50° , as represented in Fig. 11., and I carefully watched the changes which took place, by raising the temperature to 83° . The new fluid at A gradually expanded itself, till it filled up all the four cavities V, X, Y, Z; but as the portions B, C, had no cavities for this purpose, they could only expand themselves, by pushing back the supposed second fluid DEF. This actually happened. The second fluid quitted entirely the edge of the cavity at F. The two portions of new fluid B, C, were immediately united into one; and the second fluid having retreated to its new limit $m n n' o$, and being itself but slightly expansible, like common fluids, its other limit necessarily advanced to $p q r$. This experiment, which I have often repeated, and shewn to others, involves one of those rare combinations of circumstances, which Nature sometimes presents to us, in order to lay open some of the most mysterious of her operations. Had the portions B, C, of the *new fluid* been accompanied, as is usual, with their vacuities, the interposed *second fluid* would have remained immoveable between the two equal and opposite expansions: but from the accidental circumstance of these vacuities having passed over into the other branch A of the cavity, the *second fluid* is placed in a sort of unstable equilibrium, and, like the arms of a lever, it yields to every variation of the power and of the resistance.

If any additional evidence were wanted on this subject, we have only to examine the mode in which the two portions of the new fluid B, C, are united into one by a disunion of the second fluid at $g h$, and again separated by its reunion. Upon the application of heat, the summits g, h , become more acute, and gradually approach to each other, till they suddenly unite, and force back the surface of the second fluid into the line $m n n' o$. A portion of the second fluid, however, is retained by capillary attraction, in the angular meeting of the planes, between c and F, and between d and F, and also a small portion at f , a phenomenon which affords an ocular explanation of the immobility of the second fluid in the terminations and angles of cavities. When the fluids again cool, the surface $n n'$ approaches to $c d$, and when n is near c , the surface $n n'$ of the second fluid and that of the same fluid in $c d$, suddenly start into union, in virtue of their mutual attraction, and the portions B and C are again separated.

By allowing the specimen to rest in particular positions, I have often driven part of the vacuity V towards X, so as to unite all the three vacuities X, Y and Z into one; and in like manner I have caused the vacuities Y, Z and part of X to disappear and unite with the vacuity V.

In order to examine the refractive power of the second fluid, I made the arrangement represented in Fig. 2., and found that the second fluid W always reflected less light than the new fluid, and consequently that its refractive power approached nearer to topaz than the new fluid. By the same means I determined, that the angle at which total reflection took place at the separating surface from the topaz, was very nearly the same as if the second fluid were water.

The fortunate circumstance of the cavities B, C, being without a vacuity, and the consequent mobility of their bounding lines $a b c, d e f$, enabled me to compare the optical properties of the

two fluids, by means of transmitted light. The sides of the cavity being inclined to one another, like those of a prism, it is manifest, that if abc is the boundary of two fluids of equal refractive power, the image of a luminous object will have the *same deviation, by the refraction of both*. As the cavity, however, is too minute to permit an image to be distinctly seen through it, it becomes necessary to look with a microscope at the illumination of the surface of the cavity, and if the two refractive powers are *equal*, the portion above abc will be *dark*, when the portion below it is *dark*, and *vice versa*. I found, however, that the portion of fluid B abc was often *dark*, when the second fluid below abc was *light*, and I therefore concluded that this arose from their unequal refraction. To this conclusion it may be objected, that the inclination of the refracting faces might accidentally be different behind B abc , although it is not likely that the portion possessing this difference of inclination would be bounded by a curve line abc . I therefore applied heat to the specimen, and, by expanding the new fluid at B and C, the bounding lines were made to move from abc, def , to $mnn'o$, and I remarked, that, during this change of position, the boundary of the two fluids was always the boundary of the unequal shades produced by unequal refraction.

As the arrangement of the fluids which enabled me to make these experiments, possesses a peculiar interest, I have carefully looked for similar cavities, but I have not succeeded in finding more than a few examples, one of which is represented in Fig. 12., as it appears at the temperature of 32° . This cavity consists of two wide portions, separated by a narrow channel. The new fluid occupies the portion between cc, dd , and also that between aa and bb , these two portions being separated by the second fluid dd, aa . The whole vacuity exists at V. If we now apply heat, the new fluid at N and N expands, and the boundaries dd, aa and bb , advance towards B. The vacuity V becomes

an elliptical bubble, and finally vanishes. When this takes place, the boundary bb has of course disappeared, and dd and aa have advanced to $d'd'$ and $a'a'$, and cc is invisible, in consequence of the new fluid having spread over it, as it were, in the manner described in the following section.

Another cavity, consisting of three separate portions, AB, CDE, FGHK, is shewn in Fig. 13., and is remarkable, in consequence of each of these masses being connected with the adjacent one, by a portion of the second fluid, which moves between them like a piston through the extremely narrow channels BC, EF. As the portion of new fluid between ab and ef expands without having an air-bubble, it pushes the portion of the second fluid Bab through BC into $C a' b'$. In like manner, the second fluid cd EF $c' d'$ varies its position with the expansion of the fluids on each side of it. When the vacuity V disappears, a portion of the second fluid shews itself in the space Dkh , and it again withdraws itself when the vacuity V touches the sides of the triangular cavity.

In some cavities where there is a large proportion of the second fluid, the vacuities sometimes form *two-thirds* and even *three-fourths* of the space occupied by the expansible fluid when the cavity is full, and yet these vacuities are filled at the usual temperature of 83° . In these cases, the circular vacuity did not contract by heat, but extended itself till it disappeared. This effect admitted of an easy solution, by supposing the surface of the fluid to rise gradually by expansion; but I found, by optical observations, that the vacuity occupied the whole thickness of the cavity, and that it vanished by extension, when it was held in a vertical direction. This remarkable fact will be fully explained in the 5th section.

In some specimens, the faces of the cavities are accidentally inclined to the surfaces, nearly at the angles of total reflection from the surface of the new fluid, so that all the part of the ca-

vity which it occupied appears of a brownish-blue colour, while the part occupied by the second fluid is perfectly transparent. This phenomenon explains, in many cases, the apparent opacity of the cavities, which become perfectly transparent by inclining the specimen. When the stratum of cavities is very much inclined, all of them appear like black specks, and hence they have been generally considered by lapidaries as opaque particles.

Two immiscible fluids, possessing the properties now described, exist also in *Quartz*, *Amethyst*, and *Cymophane*, and I have reason to conclude that the one never occurs without the other, as I have in almost every case discovered the second fluid in cavities, where the difficulties of observation had at first prevented me from detecting it.

SECT. III. *On the Phenomena of Two Immiscible Fluids without a Vacuity in the Cavities of Minerals.*

The preceding results conduct us gradually to the development and explanation of phenomena, which, had they been observed alone, would have occasioned no inconsiderable perplexity.

In the same specimen of topaz, I have noticed the two classes of cavities which form the subject of the two preceding sections; and, along with them, I have likewise found a third class, such as AB, Fig. 13., which differs in no respect from those of the first class, shewn in Fig. 1., when examined by the microscope alone. Their difference, however, becomes very manifest by the agency of heat and light.

When heat is applied to these cavities, the circular space N, Fig. 14., in place of diminishing, as it does in Fig. 1., actually increases, as in Fig. 15., as if the fluid WW had contracted with

heat. This perplexing fact induced me to examine the cavity under the circumstances of total reflexion, and it was then apparent, that N was neither a vacuity nor a space filled with gas, but a portion of the new fluid floating as it were on the second fluid WW.

This phenomenon was analogous to what takes place in the right hand portion of the cavity in Fig. 11.; but, as there were here no vacuities into which the expansion of the new fluid could push the second fluid, the difficulty remained unsolved.

It may be proper to mention, that the cavities which present this phenomenon are most frequently connected by a dark line with other cavities, accompanied with vacuities, as shewn at N, in Fig. 16, and 17. In Fig. 16., by a considerable cold, I have caused a small vacuity to appear at V ; but it sometimes remains, and sometimes disappears.

As there are cavities, however, such as that in Fig. 14., where no connection can be traced with other cavities, and where the fluid N seems to expand, and WW to contract, it is necessary to seek for some explanation of this singular anomaly. That the expansions and contractions are here only apparent, cannot, we think, be doubted. Let AB, therefore, Plate II. Fig. 18. be a section of the cavity in Fig. 14., where the new fluid NN floats as it were on the other. When NN is heated, the effect of the heat will tend to diminish the cohesive force of the fluid WW, and to make the fluid WW spread itself into a thinner film, as shewn in Fig. 19., so that it seems to occupy a greater space, as shewn in Fig. 15.

In support of this explanation, I may adduce the case of other cavities in topaz, such as those shewn in Figs. 20. and 21., where the globule N of the new fluid never expands with heat,—an effect which is probably owing to its occupying the whole thick-

ness of the cavity, and not a portion of that thickness, as in Fig. 18 *.

With the view of confirming this explanation, I took a cavity AB, Fig. 22., in which the new fluid N occupied the whole or one side of the cavity, and the second fluid W the whole of the other side. Having made the vacuity vanish, and increased the heat to about 200°, the effect of this was to expand N, and make the boundary *ab* move very slowly towards A; but in a short time, a portion of the fluid W, which had thus been pressed out along the bottom of the cavity, made its appearance at the end B, and gradually increased in quantity as *ab* moved towards A. The new fluid then occupied the space between the dotted lines *cd* and *ef*, which contained a greater area than the space between *ab* and B. The portion *efB* of the second fluid remained for two hours in the position shewn in the figure; but being connected below N with the other portion *cdA*, it was drawn over to the other side, and occupied its original position, as shewn by A *ab*.

In one of the Quebec crystals of *Quartz*, where the cavities are filled with a slightly yellowish fluid, I observed a very deep cavity, such as that shewn in Fig. 23., where the globule N expanded very considerably to the width of *nn* by a considerable heat. I sought in vain for a vacuity, which, however, might have been concealed in a cavity of such a depth, and of such irregularity of surface; but, upon plunging the crystal in hot water, and applying the microscope, I observed two very minute globules, either of vacuity or something else, floating within N, which gradually diminished and disappeared. During another

* In Figs. 20. and 21. there are small squares, such as S, S, within the cavities, which seem to be filled up with crystallized matter. These squares being sometimes united only by contact with the surface of the cavity, exhibit very brilliantly the colour of thin plates.

experiment with this crystal, one of the cavities burst, with a heat not above 150° , and the fracture round the cavity was covered with specks of an inspissated fluid *.

The formation of cavities with two fluids, and without any vacuity, admits of an easy explanation, when they are connected with other cavities, as in Figs. 15. 16., as there can be no doubt, from the phenomena already described, that part of the fluid W has passed through the narrow channel which connects the cavities. When the cavities, however, are entirely insulated, the explanation is more difficult.

SECT. IV. *On the Changes which these Fluids have undergone in particular Crystals.*

In the absence of all information respecting the nature and constitution of these fluids, it becomes interesting to ascertain, whether time, or accidental causes, have produced any perceptible changes in their physical properties. With this view, I have examined an immense variety of specimens, and have been led to results of considerable interest.

In some specimens of topaz containing the two fluids, I have observed several cavities in which the new fluid N is quite opaque, as at *a*, Fig. 24., and others in which it has the appearance shewn at *b*.

There are some cavities, such as that shewn at *c*, where the fluid seems to have left a crust, lining the interior of it, and there are others where a sort of black farinaceous matter appears, both within and around the cavities, that appear to have been burst by some accidental cause.

* This crystal is the one referred to in page 11.

The most unequivocal proofs, however, of a change in the fluid, are obtained from various topazes, where the induration of the fluid is perfectly obvious to the eye. It resembles a resinous substance, and has a sort of cellular structure, like that shewn at *d*, Fig. 24., where the vacuity retains its circular form. No change whatever is produced upon these appearances by heat. In the figure at *e*, the fluid N, with its vacuity V, still exists, and the latter vanishing with heat; but the induration is distinctly seen at the lower end of the cavity.

In other specimens the same cellular structure appears, but the vacuity has lost, in different degrees, its circular form, as shewn at *f*.

Similar phenomena occur in *cymophane* and *felspar*, in the last of which the induration of the fluid is most distinct.

SECT. V. *On the Vaporisation and Decomposition of the New Fluid at low Temperatures, when enclosed in the Cavities of Minerals.*

Let ABCD, Plate II. Fig. 30. be the summit of a crystallised cavity in topaz, and let the length of the cavity be in a vertical direction, so that SS is the second fluid, NN the new fluid, bounded by a circular line *abcd*, and V the vacuity in the new fluid, bounded by the circle *efgh*. Let the face ABCD be placed under a compound microscope, so that the rays of a luminous body incident upon it, may be reflected at an angle less than that of total reflexion. When the observer now looks through the microscope, the temperature of the room being 50°, he will see the second fluid SS shining with a very feeble reflected light, the new fluid NN with a light perceptibly brighter, and the vacuity VV with a light of considerable brilliancy. The boundaries *abcd*, *efgh*, are marked by a well defined outline, and also by

concentric coloured rings of thin plates, produced by the extreme thinness of each of the fluids at the edges.

If we now raise the temperature of the room gradually to 58° , we shall observe a brown spot appear in the centre of the vacuity V. This spot marks the visible commencement of evaporation from the new fluid below, and arises from the attenuated vapour which attaches itself to the roof of the cavity. As the heat increases, the brown spot enlarges, and becomes very dark. It is then succeeded by white, and one or more rings rise in the centre of the vacuity. The vapour then seems to form a drop, and all the rings disappear, by retiring to the centre, but only to reappear with new lustre. During the application of heat, the circle *efgh* is in a state of constant contraction and dilatation, like the pupil of the eye when exposed to light, being always greatest when the rings disappear, and contracting its dimensions when they are again formed.

When the vaporisation is so feeble as to shew itself only by a single ring of one or two tints of the second order, they may be made to disappear instantly by the slight degree of heat produced by a single breath upon the crystal; and the same effect is produced by the approximation of a heated body. When the heat reaches the fluid, however, it makes it throw off fresh vapour, and the rings again appear.

If we put a drop of ether upon the crystal when the rings are in a state of rapid play, the cold occasioned by its evaporation immediately causes them to disappear, till the temperature again rises.

When the temperature is perfectly uniform, the rings remain stationary, and it is interesting to observe the first ring produced by the vapour swelling out to meet the first ring at the margin of the fluid, and sometimes coming so near it, that the darkest parts of both form a broad black band.

As the heat increases, the vacuity V advances to the summit AB, and disappears at $79\frac{1}{2}^{\circ}$, exhibiting several curious phenomena, which we have not room to describe. One of these, however, is so singular that it deserves to be particularly noticed. After V has disappeared entirely, a brown spot comes from the summit AB, and takes its station in the centre of the ring of the new fluid *a b c d*. This brown tint sometimes rises to higher orders of colours; but disappears by the application of heat. That the coloured rings formed within VV are vapour, and not a film of the fluid itself, may be inferred from its never mixing with the fluid with which it is in immediate contact. It might, however, be a fluid substance, arising either from the decomposition of the fluid itself, or from the condensation of gaseous matter within the vacuity; though this is not very probable, from its constant disappearance when it has accumulated to a certain degree, and its constant reproduction while the temperature remains the same.

These views respecting the vaporisation of the expansible fluid, have been fully confirmed by the discovery of the cavities already noticed, in which the expansible fluid occupies only *one-third* or *one-fourth* of the cavity. Cavities of this kind are represented in Fig. 26., where AB is the cavity, V the vacuity in the expansible fluid *m n o p*, and *A m n*, *B p o* the second fluid. When heat is applied to this cavity, the vacuity V does not contract, as in ordinary cases, but expands, till its circumference coincides with the boundary *m n o p*. This unexpected effect might have arisen from the expansible fluid occupying the lower part of the cavity below V, as in the section, Fig. 27. In this case *c e f d* might have been the vacuity, and the surface of the fluid *e f* might have risen by heat, and gradually filled the vacuity V, while its boundary *c d* retired to *m* and *n* as the surface *e f* ascended. In order to determine if this supposition was true, I placed AB

vertically between two rectangular prisms of glass; and having examined in succession the light reflected from the surfaces mp and no , I found that it had suffered total reflexion, both from the side cd and the side gh of the vacuity, and consequently that the vacuity occupied the whole thickness of the cavity. After the heat was applied, the sides cd and gh continued equally luminous, and when cg and dh had retreated to mn and po , as shewn in Fig. 28., it became quite manifest, that the space mno was not filled with the *expanded fluid*, but with the fluid *in the state of vapour*. The coloured rings at first appeared both on the faces cd and gh , and when the whole was converted into vapour they disappeared, and the light reflected from both the surfaces mp , no , which was now uniform, was not that of total reflexion, nor yet that of the expanded fluid, but of an intermediate intensity, corresponding to that of a dense vapour, with a refractive power much lower than 1.21066.

There is another set of phenomena of exquisite beauty to an optical observer, which seem to arise either from the decomposition of the fluid, or the condensation of gaseous matter in the vacuity.

When heat is applied to the cavity, the new fluid has its surface in a state of constant agitation, resembling in the closest manner a surface into which a fluid is discharging itself by drops. When the vacuity is just filled up, one or more drops quit the point where the vacuity disappeared, and pass along the surface of the cavity, like a drop of oil adhering to it in close contact, and never mixing with the fluid. Each of these drops begins in a short time to spread circularly, and to exhibit within its disc an immense number of close coloured rings. By slow cooling the drops become thinner, and the rings less numerous, and more completely displayed, till they entirely disappear at a particular temperature. When the cooling is effected quickly, the

matter which composes the thin plate that exhibits the rings, discharges itself rapidly in gaseous bubbles.

When the drops quit the point where the vacuity vanishes, and pass over one of the summits of the cavity, they often leave an irregular streak, which also gives the colours of thin plates ; and sometimes the circular expansion of the drops extends within the circular vacuity, and thus displays two intersecting systems of coloured rings, which proves, in the most incontrovertible manner, that the vapour within the vacuity will not mix with the fluid which composes the drops. The drops now described often quit the vacuity before it is filled up by the expansion of the fluid, and one of them will sometimes remain on the margin of the vacuity, which can be easily seen through it.

SECT. VI. *On the Phenomena of the two New Fluids when taken out of the Cavities.*

From the extreme minuteness of the cavities in topaz, my first attempts to extract the fluid were not attended with much success ; but I at last fell upon a method by which I have opened more than a hundred cavities.

When the most expansible of the new fluids first runs from the cavity upon the surface of the topaz, it neither remains still, like the fixed oils, nor disappears, like evaporable fluids. Under the influence, no doubt, of heat and moisture, it is in a state of constant motion, now spreading itself in a thin plate over a large surface, and now contracting itself into a deeper and much less extended drop *. These contractions and extensions are mark-

* A round hemispherical drop often stretches itself into a plane of more than twelve times its original area.

ed by a very beautiful optical phenomenon. When the fluid has extended itself into a thin plate, it ceases to reflect light, like the most attenuated part of the soap-bubble, and when it is again accumulated into a thicker drop, it is covered with all the coloured rings of thin plates. When one of the drops of fluid is very minute and perfectly circular, it resembles, in the most accurate manner, the small drops which pass from the vacuity, and which have been described in the preceding section.

After performing these motions, which sometimes last for ten or twelve minutes, the fluid suddenly disappears, and leaves behind it a residue of minute and separate particles, which are opaque by reflected, but transparent by transmitted light. Upon examining this residue with a single microscope held in the hand, I was surprised to see it again start into a fluid state, and to extend and contract itself as before. This was owing to the moisture of the hand; and I can at any time revive the indurated substance, by the approach of a moist body. A portion of the fluid, which I took out of a cavity twenty days ago, is still capable of being restored to a fluid state by moisture. This portion was shewn to an eminent naturalist, the Reverend Dr FLEMING of Flisk, who remarked, that, had he observed it accidentally, he would have ascribed its apparent vitality to the movements of some of the animals of the genus *Planaria*.

After the cavity has remained open for one or two days, the second fluid comes out of it, and hardens very speedily into a yellowish resinous-looking substance, which is perfectly transparent. This substance absorbs moisture, but with less avidity than the other. It is not volatilized by heat. It is not soluble in water or alcohol; but it is rapidly dissolved with effervescence by the sulphuric acid. The nitric and muriatic acids also dissolve it.

The residue of the first fluid is volatilized by heat ; and it is also dissolved, but without effervescence, by the sulphuric, the nitric, and the muriatic acids. After standing some time, both these substances acquire a brilliant lustre, as if some metallic body entered into their composition *.

SECT. VII. *On the Existence of Moveable Crystals in a Fluid Cavity of Quartz.*

Although particles of opaque solid matter have been observed in the cavities of crystals containing fluid, as will be described in the next section, yet, so far as I can find, no crystallized body, and, indeed, no matter capable of crystallization, has ever been discovered in them. The quantities of saline impregnation, indicated by a scarcely perceptible cloudiness in solutions of silver and muriate of barytes, were so minute in Sir HUMPHRY DAVY's experiments, that he considered the water as nearly pure. I was, therefore, in no small degree surprised, when I discovered, in a cavity of a quartz crystal from Quebec, from the cabinet of Mr ALLAN, not only insulated crystals, but a tolerably large group, which were moveable through the fluid upon turning the specimen †. The crystal was perfectly sound round the cavity,

* In opened specimens, which had stood more than a month exposed to the air, I observed small green spheres resting on the surface. They were soft and semi-transparent, like green wax, and varied from $\frac{1}{80}$ th to $\frac{1}{60}$ th of an inch in diameter. They were not acted upon by any of the above mentioned acids, and were therefore a distinct substance from that of the two new fluids. They occurred in no fewer than 25 out of 40 crystals, *three* being sometimes found in one specimen ; and there can be no doubt that they consisted of fluid matter which had oozed out of the crevices of the mineral.

† There were also numerous opaque particles in the cavity, which descended slowly in the fluid.

which had a sort of triangular form, one of the sides of the triangle being about one-tenth of an inch long. The fluid was quite transparent; and, as the air-bubble was not perceptibly diminished by heat, there is every reason to think that the fluid is water. The crystals were transparent to a considerable degree, and had a white milky tint, when seen by reflected light.

In considering the circumstances of this singular phenomenon, we are led to suppose, that the included crystals had been dissolved in the fluid at the time of its being shut up in the quartz, and had afterwards been deposited from the solution. The ingenious supposition of Sir HUMPHRY DAVY, that a liquid hydrate of silica may exist at high temperatures, and may contain small quantities of atmospheric air, will no doubt explain the phenomena of water in rock-crystals; but it is not easy to comprehend how the formation of a group of crystals could either have accompanied or followed the separation of the water and the siliceous matter.

As the specimen now alluded to is too valuable to be destroyed, for the purpose of analysing the minute crystals, it is probable, that our information respecting them would have been very limited, had not a circumstance of an accidental nature enabled me to throw some farther light on the subject. Several years ago, when I was examining, along with Earl COMPTON, a large collection of quartz crystals from Quebec, for the purpose of obtaining remarkable crystallizations, I was much struck with the appearance of several spherical groups of whitish crystals, within some of the specimens. Upon pointing out to Lord COMPTON this peculiarity, his Lordship agreed with me in thinking that they belonged to the Zeolite Family. Having purchased all the specimens that could be found, I have since repeatedly examined the included crystals, with the view of determining their nature. I found that they did not belong to the zeolites, but consisted principally of carbonate of lime; and, as

every mineralogist who saw them considered them as something new in appearance, I expected that a greater quantity of them might be found for the purposes of analysis. Familiarised, therefore, with the aspect of these groups, I was convinced that the crystals in the fluid cavity were the same substance ; and a more accurate examination has established their perfect identity.

These white crystals sometimes occur in minute insulated spiculæ within the solid mass, but most frequently in spherical groups of extreme beauty, surrounded with the most transparent quartz. Many of the open hollows and crevices of the quartz crystals are filled with them, and numerous aggregated groups adhere to their external surface. These crystals, though very minute, I have found to have a powerful double refraction ; and as they are wholly dissolved with effervescence, excepting a little adhering silex, in diluted nitric acid, there can be no doubt that the external crystals and consequently those in the fluid cavity, are *carbonate of lime* *.

SECT. VIII. *On the Phenomena of a single Fluid in the Cavities of Minerals and Artificial Crystals.*

The phenomena which I propose now to describe, are essentially different from those which form the subject of the preceding sections. The fluid which occupies this class of cavities exhibits no properties different from water or mineral oil, which have long ago been detected by mineralogists, and the vacuity which often accompanies these fluids, is either a perfect vacuum, or filled with a gaseous body.

* Since these observations were made, Mr NORDENSKJOLD has confirmed this result by experiments made with the blowpipe.

This class of cavities might, with propriety, have been divided into three subdivisions : 1. Those where the cavities are entirely filled with fluid ; 2. Those which have a perfect vacuum along with the fluid ; and, 3. Those where the fluid is accompanied with a gaseous body ; but, as several crystals seem to possess cavities with all these characters, I shall describe the different crystals in their order.

1. AMETHYST from CEYLON.—This fine specimen, in the cabinet of Mr THOMSON of Forth Street, originally belonged to the King of Candy. It is about 3 inches long and $1\frac{3}{4}$ broad, and has a large cavity, of the size and form shewn in Fig. 29. The bubble V, which I have ascertained to be gaseous, by the reflexion of light, moves by starts from one end of the cavity to the other. It is not sensibly altered by heat. Another cavity C, near the large one, has a small air-bubble in the middle, which refuses to move from its place. There are several pieces of opaque solid mater, which, with a little management, may be seen within the cavity AB, and which may be made to fall from one side of it to the other. This is the largest cavity that I have ever seen in a solid crystal.

2. ROCK CRYSTAL.—This mineral abounds with cavities, containing water and mineral oil, which is sometimes black, sometimes of a faint yellow, and sometimes of a rich orange red colour.

The largest cavities are generally amorphous ; but there are many crystals with thousands of cavities all regularly crystallized, and of the exact form of the secondary crystal.

The quartz crystals from Quebec contain great quantities of mineral oil, which does not perceptibly expand by the application of heat. There are frequently within the cavities dark little fragments, which are carried about by the motion of the

fluid. In a crystal of quartz belonging to Mr ALLAN, and containing a large cavity, with water and an air-bubble, he observed a little black globule which adhered to the air-bubble. Upon looking at it afterwards, he remarked that the black globule had separated into a great number of minute black particles. This opaque matter is likely to have had the same origin as that which is described in page 23.

One of the most remarkable specimens of quartz which I have ever met with, was shewn to me by Mr SIVRIGHT. The cavities are of the most singular shape, and are almost all nearly filled with a fluid, accompanied with a small air-bubble, which does not perceptibly expand with heat. Some of the cavities contain a yellow fluid, with various air-bubbles, which seem to be naphtha apparently in a very viscid state. This specimen is shewn, though very imperfectly, in Fig. 30.

3. TOPAZ.—There are many topazes from Brazil, New Holland, and Scotland, which contain a single fluid, with an air-bubble. In these the fluid does not perceptibly expand with heat; and I have ascertained that it is aqueous, and that the vacuity is filled with a gas.

In several topazes, both from Aberdeenshire and Brazil, the form of the cavities is extremely curious, resembling the writing in Eastern MSS. These grotesque forms generally contain the new fluid; but many of them have no vacuity at all, while some of them contain a fluid of a decided yellow colour, which I have never found accompanied with a vacuity. These cavities are shewn in Fig. 31. The cavities in topaz containing the two new fluids are shewn in Fig. 40.

In a particular specimen of topaz, I observed a regular rhomboidal space apparently filled with particles of dust suspended in it. This rhomboidal space appeared *green* by reflected, and *red* by transmitted, light.

4. CYMOPHANE.—In several specimens of cymophane, there are strata of cavities apparently containing one fluid, but without any perceptible vacuity. In the crystal containing the stratum with the new fluids, there is another stratum parallel to it, of a very remarkable kind, where the cavities have the form shewn in Fig. 32. The nature of the fluid, however, I have not been able to determine.

5. PERIDOT.—The largest and finest crystals of this mineral are often intersected, in various directions, with strata of fluid cavities having globules of air. In a set of unusually large crystals a kind of resinous indurated matter seems to have been diffused, sometimes in strata and sometimes throughout the mass of the crystal. These peridots, which are very magnificent, belong to the COUNTESS of WEMYSS; but in consequence of their being cut and set in gold, it was impossible to subject them to an accurate examination.

6. FELSPAR.—The cavities in this mineral are very flat, and irregularly formed. They contain a single fluid and an air-bubble, which neither vanishes nor diminishes with heat.

7. EMERALD and BERYL.—The great degree of foulness which is so common in these gems, arises generally from strata of cavities containing a single fluid, and an air-bubble, which do not perceptibly decrease with a temperature of 150°.

8 FLUOR-SPAR.—The crystals of green fluor-spar from Alston Moor frequently contain cavities with water. I have seen several about half an inch long, and of the form of a triangular pyramid. The air-bubble moves sluggishly even in these large ones, and with great difficulty in the small ones. The apparent air-bubble is gaseous, and the fluid does not perceptibly expand

with heat. These crystals frequently burst with a heat not above 150° . In several cavities I have observed solid fragments falling through the fluid, by the inversion of the crystal.

9. SULPHATE OF LIME.—In this mineral the cavities have often a very singular form ; and in all the specimens which I have examined, the fluid is aqueous, and is accompanied with a gas or a perfect vacuum.

In Fig. 33. I have represented one of the most singular arrangements of cavities that I have met with. In order to determine the thickness of the cavity, I reduced the specimen, so as to give the polarized colours of the second order of Newton's Scale, and, by carefully observing the difference of tint in the cavities, and in the solid parts, I obtained a measure of the thickness of crystalline matter abstracted in these parts. The difference of tint was very obvious, and proved that the thickness of the cavity did not exceed the $\frac{1}{5000}$ th part of an inch.

In many specimens, these very shallow cavities occur in long canals. In others they resemble some foreign crystalline matter, shooting out into the most singular forms, as at *a, b*, Fig. 34. and sometimes the cavities appear to the eye like tufts of white silk compressed between the laminae, though they are, in reality, strata of rhomboidal cavities, occurring in thousands, and arranged in the direction of their longest diagonals, while the strata themselves are highly inclined to the surfaces of the laminae. In other specimens, the cavities have the most singular forms, as represented in Fig. 34. One of the canals in sulphate of lime is shewn at AB, in Fig. 35., where *abcd, efgh* are two air-bubbles or vacuities. By applying heat to the side B, these air-bubbles shift their places. All the lines *ab, cd, ef, gh*, advance to B, but *cd* and *ef* approach to one another, and the moment they come in contact, the two vacuities are converted into one, which has the position *a' b' g' h'*.

10. SULPHATE OF BARYTES.—The cavities in sulphate of barytes were first pointed out to me by Mr SIVRIGHT. I have since found them in various specimens. They are generally of a very irregular shape, though sometimes they have regular crystalline forms.

Many of these cavities are entirely filled with fluid, but in several a very small apparent air-bubble may be seen. This vacuity does not vanish by the heat of the hand, but it disappears entirely at a temperature of about 150° , and again returns when the specimen has cooled. It is therefore a vacuum.

11. CALCAREOUS SPAR.—Cavities filled with water are frequently found in calcareous spar. The apparent air-bubbles, which are very small, occur only in some of the cavities. To some of the cavities I applied a heat of about 150° . The apparent air-bubbles entirely vanished, and, what is very remarkable, they have never again reappeared. This singular fact may be ascribed to the strong cohesion between the fluid and the sides of the cavity, which can only be overcome by a greater degree of cold producing a greater degree of contraction than that of the cabinet in which the specimen has been kept.

12. ROCK-SALT FROM CHESHIRE.—In this mineral the cavities assume the most beautiful forms. In one specimen, shewn in Fig. 36., they have the form of regular cubes of various sizes, and with numerous truncations on their sides and angles. In other specimens the cavities have the form of octohedrons; while in others they have numerous varieties of forms. The cubical hollows above mentioned are in general perfectly filled with fluid; but some of them have small apparent air-bubbles, which contract to fully one-third of their size by a heat of 120° .

13. **SULPHATE OF IRON.**—The cavities in this salt are sometimes finely crystallized in the form of prisms, with double pyramids, and the sharpest truncations. In the same specimen they are frequently oval, or imperfectly spherical. They sometimes contain apparent air-bubbles, and are often quite filled with fluid. By the application of heat, these vacuities disappear entirely, and reappear by cooling.

14. **SULPHATE OF NICKEL.**—In this salt the cavities are sometimes amorphous, and sometimes beautifully crystallized. These vacuities frequently disappear by heat, and reappear by the application of cold.

15. **SULPHATE OF COPPER.**—The air-bubbles move about in this salt by the application of heat, but never vanish. By increasing the heat, they diminish a little in size.

16. **ALUM.**—The air-bubbles in alum do not perceptibly change their magnitude by heat. I have opened several cavities in this salt, but have never found the air to be either in a state of dilatation or compression. The fluid seems to be pure water.

17. **TARTRATE OF POTASH AND SODA.**—The cavities in this salt are both crystallized and amorphous. A considerable vacuity in a large cavity vanished completely with heat ; and in others, where the vacuity was very large, it became extremely small when heated. Two separate cavities, with separate vacuities, became one, and united their vacuities. These phenomena, no doubt, arose from the fluid having its dissolving power increased by heat ; and it is probable that the disappearance of the large vacuity arose from the dissolved salt occupying more space in its fluid than in its solid state.

It is unnecessary to extend these details to all the artificial crystals enumerated at the beginning of this paper, as I have not observed in them any phenomena different from those which have already been described.

There is another class of cavities which require to be studied with some attention, namely, those which are entirely full of fluid, or entirely empty. Mr SIVRIGHT first observed cavities in the diamond *, and in garnet ; but, though I have examined them in various specimens, I have not been able to determine whether they are entirely filled with fluid, or are entirely empty. I have found cavities of a similar kind in *cinnamon-stone*, where they are beautifully crystallized, in *sulphate of Strontian*, in *sulphur*, in *analcime*, and in *chabasie* ; but I observed no appearance of air-bubbles, and have no certain evidence that they contain a fluid †.

It would be improper to conclude this paper, without noticing the relations which are supposed to subsist between this class of phenomena and the two contending Geological Theories. The existence of highly rarified gas in the cavities of crystals, has been regarded by the distinguished President of the Royal Society of London, as “ seeming to afford a decisive argument in favour of the igneous origin of crystalline rocks ;” and the “ fact of almost a perfect vacuum existing in a cavity containing an expansible but difficultly volatile substance,” (as naphtha), he likewise considers as highly favourable to the same theory. The discovery of compressed gas in similar cavities might have been regarded as neutralizing, in some degree, the first of these argu-

* See the *Edinburgh Philosophical Journal*, vol. iii. p. 98., for an account of the polarising structure which sometimes exists round the cavities in diamond.

† This point may be easily determined by grinding the specimens, and examining the light reflected at the surfaces of the cavities.

ments : but Sir HUMPHRY DAVY remarks, that it may be explained by supposing the crystal to have been formed under a compression much more than adequate to compensate for the expansive effects of heat *.

Without presuming to combat these deductions, or to suggest any of the numerous explanations by which the Neptunist might reconcile with his own system the compressed and dilated condition of the included air, I shall content myself with stating, that the facts described in the preceding paper appear to me decidedly hostile to the igneous origin of crystals, and, in some points of view, favourable to their aqueous formation. The existence of a fluid which entirely fills the cavities of crystals, at a temperature varying from 74° to 84°, may, upon the principles assumed in the opposite argument, be held as a proof that these crystals were formed at the ordinary temperature of the atmosphere, while the fact of a perfect vacuity existing in *sulphate of barytes*, and capable of being filled up by the expansion of the aqueous fluid, at a temperature not exceeding 150°, authorises the analogous conclusion, that the crystal could not have been formed at a higher temperature. On the other hand, the filling up of the vacuities in *sulphate of iron*, and *sulphate of nickel*, at a temperature much above that at which they were formed, may lead geologists to renounce a species of argument which appeals only to our ignorance, and to withdraw from the defence even of their outworks, those faithless auxiliaries, which are so ready to enlist themselves in the service of either power.

There is one geological relation, however, of the preceding facts, which may deserve some attention. Hitherto the contend-

* As the effects of heat and compression might exactly balance each other, the gas would in this case be atmospheric air, in a common state of density ; so that the volcanists are here sheltered against experimental hostilities, amid the generalities of their hypothesis.

ing theorists have limited their idolatry to two of the elements ; but the existence of two new substances in minerals, one of which combines a great degree of fluidity with the high expansive power of the gases, renders it probable, either that these substances existed at the formation of the globe, or that they are the result of laws of crystallographic combination which have escaped the notice of the philosophical geologist. Were such fluids the product of the ordinary processes of crystallization, they would occur in artificial as well as in natural crystals : and, consequently, while they remain undiscovered in the cavities of the first of these classes of bodies, we are entitled to attach a new difficulty to the aqueous hypothesis.

Had the two new fluids occurred only in one mineral, or in minerals of a particular composition, they might have been supposed to have some relation to the elementary principles of the body, and to have arisen either from some accidental irregularity, which prevented them from crystallizing, or from the decomposition of the matter subsequently to its crystallization. The perfect identity, however, of the two fluids, as found in pure Quartz, in Amethyst, in Topaz, and in Cymophane,—minerals brought from the most opposite parts of the globe,—from Scotland, Siberia, New Holland, Canada, and Brasil,—establishes the universality of their existence, and adds to the probability of the supposition, that they have performed some important function in the organization of the mineral world.

While the preceding facts thus obviously connect themselves with our geological theories, they promise also to be of some use in the practical branches of Physics. A fluid possessing such a high expansive power would be invaluable in the construction of delicate Thermometers, and various other philosophical instruments ; while its extreme fluidity would enable us to construct levels of singular delicacy. If the resources of the chemist shall

not enable him to form such a substance, a plate of topaz, with particular longitudinal cavities, might be used, as a delicate thermometer, for certain ranges of temperature ; and where slight variations require to be observed, several such plates might be of essential service in many researches, both of a chemical and a physical nature.

Fig. 1.

Fig. 3.

Fig. 4.

Fig. 2.

Fig. 6.

Fig. 5.

Fig. 14.

Fig. 16.

Fig. 13.

Fig. 8.

Fig. 9.

Fig. 7.

Fig. 10.

Fig. 17.

Fig. 13.

Fig. 12.

Fig. 11.

Fig. 18.

Fig. 20.

Fig. 19.

Fig. 22.

Fig. 21.

Fig. 23.

Fig. 26.

Fig. 29.

Fig. 25.

Fig. 30.

Fig. 32.

Fig. 31.

Fig. 36.

Fig. 40.

Cavities containing both Fluids

Fig. 34.

Fig. 24.

Fig. 27.

Fig. 28.

Fig. 33.

Fig. 35.