XXXIV. *On the Cryſtallizations obſerved on Glaſs.* By James Keir, *Eſquire, of* Stourbridge. *Communicated by* G. Fordyce, *M. D. F. R. S.*

R. May 23, 1776.

THE peculiar figure of rock-cryſtal has been long obſerved. Many other ſubſtances, as ſpars, precious ſtones, pyrites, ores, metals (a), ſalts, water (b), and oil (c), are alſo known to affect an uniformity of ſhape, when they are expoſed to certain degrees of heat, cold, fluidity, and other neceſſary circumſtances. From their reſemblance in this reſpect to rock-cryſtal, they are ſaid, when they aſſume their peculiar forms, to cryſtallize; and the regularly-ſhaped bodies, into which theſe ſubſtances concrete, are alſo called cryſtals.

(a) Native gold has been found in a cryſtallized form. M. ROME DE L'ISLE, in his *Eſſai de Cryſtallographie*, p. 390, ſays, that he has ſeen pieces of native gold which were eight-ſided ſolids, like cryſtals of allum, and one piece which was an hexagonal plate. In Dr. HUNTER's muſeum, ſome fine ſpecimens of cryſtallized native gold are to be ſeen. Gold may be cryſtallized by art alſo. Some æther having been poured into a ſolution of this metal in *aqua regia*, I obſerved, a few months afterwards, the gold ſeparated from the *menſtruum*, in the form of diſtinct polygonous priſms.

(b) The various and regular forms of the particles of ſnow, which is nothing elſe than water cryſtallized, are well known.

(c) The cryſtals, formed by cold, in the oil of ſaſſafras, have been obſerved to be very beautiful, regular, hexagonal priſms.

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In many ſubſtances, when broken, the parts appear to have ſome determinate figure. This determination of figure, or grain, as it is called, is obvious in biſmuth, regulus of antimony, zinc, and all other metallic bodies, which may be broken without extenſion of parts; and although the ductility of gold, ſilver, lead, and tin, prevents the appearance of the peculiar grains, when pieces of theſe metals are broken, yet we have reaſon to believe, that, by expoſing them to proper circumſtances, they alſo would ſhew a diſpoſition to this ſpecies of cryſtallization, as it may be called, by a further extenſion of that term; for Mr. HOMBERG has obſerved, that when lead is broken while hot, in which ſtate it is not ductile, a granulated texture appears. Perhaps all homogeneous bodies, in their tranſition from a fluid to a ſolid ſtate, would, if this tranſition were not effected too haſtily, concrete into cryſtals, or bodies ſimularly figured. Inſtances of ſuch cryſtallization have occurred to me in glaſs, which had paſſed very ſlowly from a fluid to a ſolid ſtate; and the form, regularity, and ſize of theſe vitreous cryſtals have varied according to the circumſtances with which their concretion had been accompanied. I ſend along with this paper a few ſpecimens of this cryſtallized glaſs, together with a drawing of ſome of the moſt remarkable cryſtals.

The pieces of glaſs, marked N° 1. were taken from the bottom of a large pot, which had ſtood in a glaſs-houſe furnace at the time the fire was allowed gradually to extinguiſh. In this caſe, the maſs of heated matter was ſo great that, without the addition of fuel, the heat con-

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tinued long, and the tranſition of the glaſs from a fluid to a ſolid ſtate was very ſlowly accompliſhed. The upper part of this glaſs was found to be changed into a white, opaque, or rather ſemi-opaque ſubſtance, reſembling in colour and texture ſome of the white ſpars. Under this cruſt, which, in ſome places, was a quarter of an inch thick, and in others more, the glaſs was tranſparent, but conſiderably obſcured, and its colour was changed from a dark green to a dull blue. In this ſemi-pellucid glaſs were diſperſed many white, opaque, regular cryſtals, the form of which was generally that of a ſolid, whoſe ſide-view is repreſented by fig. 1. and whoſe baſis by fig. 2. The ſurface of theſe cryſtals ſeems to be bounded by lines rather elliptical than circular, which are ſo diſpoſed, that a tranſverſe ſection of a cryſtal, that is, a ſection perpendicular to its axis, is an hexagon, as is ſhewn in fig. 3. and 4. the former of which repreſents a view, and the latter a plan, of that ſection. In the middle of each baſis of the cryſtal, a conical cavity appears, as is ſhewn in fig. 1. and 2. The elliptical lines which bound the ſurface of the cryſtals ſeem to be occaſioned by the edges of many thin plates, ſo arranged round the axis of each cryſtal, that their longitudinal diameters are parallel to that axis. Of theſe plates, twelve are larger, more conſpicuous, and better defined, than the reſt. They are placed in pairs, at an equal diſtance from each other, forming the ſix angles of the hexagonal ſection and baſis, as appears in fig. 1. 2. 3. and 4. The intervals between the pairs of plates, that is, the areas of the triangles into which the hexagonal

hexagonal ſection is divided by theſe pairs, are filled up partly by ſmaller plates affixed to the ſides of the principal plates, and of each other, at an angle of 60°, and partly by a ſubſtance ſomewhat leſs-opaque and darker-coloured than that of the plates. The ſize of the contiguous and of the neighbouring cryſtals does not vary much, although that of cryſtals, found at different depths of the ſame pot, were obſerved to differ conſiderably. The greateſt diameter of the cryſtals, from which the figures 1. 2. 3. and 4. were copied, was about $\frac{1}{20}$th part of an inch, ſo that theſe figures repreſent the cryſtals conſiderably magnified. All the cryſtals are not by any means formed with the ſame exactneſs as thoſe deſcribed; ſome having the hexagonal form leſs diſtinctly marked; but the regularity of moſt of them is ſo obvious, that no doubt can remain of the perfection of the cryſtallization.

Another kind of vitreous cryſtallization appears on the piece of glaſs marked N° 2. which was taken from the bottom of a pot, that had been pulled out of the furnace, while the glaſs was red-hot. The cryſtals are of two kinds; thoſe repreſented by fig. 5. are of the columnar form; their altitude is about one-eighth of an inch, and the diameter of their baſes about one-fifth part of their altitude; their ſides ſeem to be irregularly fluted, or cut in grooves. The other kinds of cryſtals, which are repreſented by fig. 6. 7. and 8. have baſes of nearly the ſame diameter as the columnar ones; but their altitude is much leſs, being only about one-ſixth part of their diameter. Their baſes are bounded by lines, ſeemingly

ragged and irregular; but ſeveral of them ſhew a tendency to an hexagonal form, the regularity of which may have been diſturbed by the motion of the melted glaſs acting upon and bending theſe very thin cryſtals, while they were hot and flexible, at the time when the pot was pulled out of the furnace.

The ſpecimens marked N° 3. are pieces of a glaſs-houſe pot, down the outer ſides of which ſome melted glaſs had run, and adhered long enough for the formation of various kinds of cryſtals. The inner ſides alſo of theſe pieces are covered with glaſs variouſly cryſtallized. Some of theſe cryſtals ſeem to be ſemi-columns, of which the flat ſides, or interior ſurfaces, are expoſed to view, and are repreſented by fig. 9. Other cryſtals, repreſented by fig. 10. ſeem to conſiſt of ſeveral ſemi-columnar ones, uniting together in the ſame plane round a common center, like broad, flat ſpokes of a wheel. Many of theſe ſpokes ſeem to become narrower as they approach the center of the wheel, and, therefore, reſemble more the ſegments of *fruſta* of cones cut along their axis, than of cylinders. But, perhaps, this appearance proceeds only from the ſemi-columns being ſo diſpoſed near the center of the wheel, that the edge of one is laid over the edge of the contiguous ſemi-column, like the ſpokes of a fan.

In the ſpecimen of glaſs, marked N° 4. which had run through a crack in a pot, and had remained adhering to the bars of the grate of a furnace, ſufficiently long for a cryſtallization to take place; ſome of the cryſtals appear oblong

oblong and needle-like, and others globular, or nearly of the globular form. In this piece of glaſs, many of the needle-like cryſtals are ſeen to unite round a common center; and although they have probably been prevented, by the too ſudden cooling of the glaſs, from concreting in a ſufficient number to make complete globular cryſtals, yet they ſufficiently ſhew the manner in which thoſe, which are complete, have been formed. All the cryſtallizations, hitherto deſcribed, were obſerved in a dark, green window-glaſs, made at Stourbridge, and called Broad-glaſs. This glaſs is compoſed of ſand, kelp, calcareous earth, and lixiviated vegetable aſhes.

Cryſtallizations frequently occur alſo in the glaſs of which common bottles are made, the materials uſed in the compoſition of which are nearly the ſame as thoſe above mentioned for broad-glaſs, with the addition ſometimes of the *ſcoria* of iron furnaces. Of this kind is the ſpecimen marked N° 5. in which the cryſtals are not inveloped in a medium of tranſparent uncryſtallized glaſs, for the whole piece is an opaque, cryſtallized ſubſtance; but they are prominent from the ſurface of the maſs. The form of the cryſtals is that of the blade of a two-edged ſword, whoſe point is truncated. In no other glaſs have I ſeen ſuch perfect cryſtals as in thoſe two kinds above mentioned, broad and bottle-glaſs, which being more fluid and leſs tenacious, when melted, than any other, the minute particles of which cryſtals conſiſt, more eaſily concrete, and apply themſelves to each other with leſs reſiſtance from the medium. Perhaps alſo the greater

greater proportion of calcareous and other earthy particles may difpofe thefe glaffes to cryftallize more than others, which contain a larger quantity of faline and metallic fluxes.

Flint-glafs, when long expofed to a dull red-heat, acquires a cloudinefs, which, probably, proceeds from a number of fmall white particles, concreted by means of cryftallization; but thefe cryftals are too minute for obfervation. I fufpect alfo, that the opaque whitenefs, given to glafs by arfenic, is the effect of a cryftallization, to which this fubftance difpofes certain kinds of glafs; for the opacity given to fuch glafs by arfenic, being greater than the opacity of the arfenic itfelf, cannot be communicated to a large proportion of tranfparent glafs, merely by the mechanical interpofition of this opaque, and fometimes only femi-opaque fubftance.

Mr. REAUMUR has obferved, that fome kinds of glafs, by long expofure to certain degrees of heat, acquire a white opaque cruft on their furface; and that this change of colour and texture, by a longer continuance of the heat, penetrates farther, till at length the whole fubftance of the glafs is converted into a white, opaque body, which, from fome fuppofed refemblance to porcelain, has been diftinguifhed by the name of REAUMUR's porcelain, but is really nothing elfe than glafs indiftinctly cryftallized.

Some of the properties of glafs are confiderably changed by cryftallization; its tranfparency is deftroyed, and it acquires an opaque or femi-opaque whitenefs; its denfity is

increaſed, for the denſity of a piece of cryſtallized glaſs was found, by experiment, to be to that of water as 2676 to 1000; whereas the denſity of a piece of uncryſtallized glaſs, which had been contiguous to the former, and conſequently had been compoſed of the ſame materials, and expoſed to the ſame heat and other circumſtances, was to the denſity of water as 2662 to 1000. The brittleneſs of glaſs is diminiſhed by cryſtallization; for cryſtallized glaſs is leſs apt to crack by change of heat and cold.

Cryſtallization is always accompanied or preceded by an evaporation of the lighter and more fluid parts of the glaſs; for I found, that, by expoſing a piece of tranſparent glaſs till it was entirely cryſtallized, one fifty-eighth part of its weight was loſt by evaporation: and I am induced to believe, from other trials, that glaſs, which contains too large a proportion of ſaline fluxes, is leſs capable of cryſtallizing than other harder glaſſes, till it has loſt its ſuperfluous quantity of ſuch fluxes by evaporation. A doubt may therefore ariſe, whether the change of properties, induced by cryſtallization, be merely the effects of altering the texture, that is, the arrangement of the minute integrant parts of glaſs; ſince this change is always accompanied with a loſs of the lighter parts of the cryſtallizing ſubſtance. But, although a ſuperfluous quantity of ſaline or other fluxes may impede the cryſtallization, yet, that the change of properties, induced by cryſtallization, is principally or ſolely the effect of an alteration of texture, is evident from this obſervation; that a piece of cryſtallized glaſs, when expoſed to a heat conſiderably

confiderably more intenfe than is fufficient merely for its fufion, and afterwards haftily cooled, lofes all its acquired properties, and is again reduced to the ftate of tranfparent brittle glafs, which, however, by means of the evaporation it has fuftained of its lighter and more volatile parts, is rendered confiderably harder, denfer, and lefs fufible, than it was before the cryftallization.

Many analogous inftances might be adduced to fhew how much the properties of bodies depend merely on the different arrangements of their integrant parts, or on their modes of cryftallization. Thus, for inftance, caft-iron and fteel, when cooled fuddenly, acquire a much finer grain or texture than when annealed, or flowly cooled, and are alfo more hard, elaftic, brittle, and fonorous. From the above defcription of vitreous cryftals we learn, that very different cryftallizations occur in the fame kind of fubftance expofed to different circumftances; and even that fometimes differently-fhaped cryftals are found in the fame piece of glafs; in which cafe, the circumftances muft have been the fame. Perhaps, indeed, the difference, obfervable in the fhape of the cryftals in the fame piece of glafs, may only mark the different periods in the progrefs of cryftallization; for the cryftals reprefented by fig. 6. 7. and 8. which are found in the fame piece of glafs as thofe reprefented by fig. 5. do chiefly differ from thefe in their altitude; and perhaps the latter kind may have been compofed of a number of the former uniting by their bafes. The wheel-like cryftals alfo, fig. 10. feem to confift of feveral

of

of the ſemi-columnar ones, arranging themſelves round a common center like the ſpokes of a wheel. The globular cryſtals in the ſpecimen N° 4. have been already obſerved to conſiſt of many needle-like cryſtals, converging to one central point.

Does not this diſcovery, of a property in glaſs to cryſtallize, reflect a high degree of probability on the opinion, that the great native cryſtals of *baſaltes*, ſuch as thoſe which form the Giant's Cauſeway, or the pillars of Staffa, have been produced by the cryſtallization of a vitreous *lava*, rendered fluid by the fire of volcanos?

This opinion is further confirmed by the following conſiderations. The priſmatic and other regularly-ſhaped *baſaltes* have been almoſt always found to be accompanied with *lava*, pummice-ſtones, and other veſtiges of the fire of the volcanoes, whenever they have been carefully examined by intelligent naturaliſts, as has been ſhewn by M. DESMARETS, in his Memoir on the *Baſaltes* of the province of Auvergne, in France; *Mem. de l'Acad. des Sciences*, 1771. Baſaltic columns have even been diſcovered, according to the ſame author, among the productions of volcanoes now exiſting, as of thoſe of Mount Etna and of the Iſle of Bourbon.

2. The ſubſtance of which theſe baſaltic maſſes conſiſt, is generally of the ſame nature and appearance as the neighbouring and adjoining *lava*. It is generally compact, fuſible, and of various degrees of hardneſs, probably according to the matters of which the vitreous maſs was compounded. M. DESMARETS has further

 obſerved,

observed, that the prismatic *basaltes* of Auvergne is actually a continuation, and generally the termination, of a current of *lava*.

3. Although the variety of the forms of the crystals, in the same kinds of glass, and even in the same piece of glass, which has been already remarked, sufficiently shews the uncertainty of any inference drawn from a similarity of shape; yet it may not be improper to mark the analogy, in this respect, between the basaltic and vitreous crystals. The columnar or prismatic form is known to appear most generally in the crystallized *basaltes*. Of this form also are evidently the crystals represented by fig. 5. The semi-columnar, vitreous crystals, fig. 9. seem to be analogous to the no less singular basaltic semi-columns observed in the Giant's Causeway by Bp. POCOCK (Phil. Transf. vol. XLVIII.); which, he says, were exactly like hexagonal columns cut in two. M. DESMARETS has observed, in the province of Auvergne, great quantities of spherical and ellipsoid basaltics concretions, which were formed of polygonal columns, rather pyramidal than prismatic, converging from the circumference to the center. These seem to be perfectly analogous to the vitreous globular concretions which have been above observed to be composed of oblong crystals, arranged in a similar manner. The same author also observed, in the same province, regularly-shaped tables or plates of basaltes; of which, he says, assemblages were accumulated in all directions. We have shewn, that the crystals represented by fig. 1. 2. 3. and 4. are

are really aſſemblages of plates or tables, diſpoſed in every direction round a common axis.

Laſtly, The ſtone on which the columns of *baſaltes* generally reſts, and which ſometimes alſo is ſupported by theſe columns, being of the ſame nature and texture as the columns themſelves, ſeems to be a maſs irregularly cryſtallized, analogous to the irregularly-ſhaped maſſes in the ſpecimens of glaſs N° 1. and 2. which evidently conſiſt of a ſimilar ſubſtance as the neighbouring cryſtals, and ſeem to have been compoſed of a number of theſe cryſtals indiſtinctly united; for the peculiar figures of cryſtals are diſtinct only when they are inſulated, or when they are ſeparated from each other by a pellucid or differently-coloured medium. A medium of this kind appears between the vitreous cryſtals, and is nothing elſe than the more fluid parts of the glaſs, which longer reſiſt the concretion, but which, by a further continuance of the heat, would have become, with the parts already cryſtallized, one uniform, white, opaque ſubſtance, without any interpoſition of tranſparent glaſs, or diſtinction of cryſtal, except on the ſurface, as in ſpecimen N° 5, in which the cryſtals ſtand prominent from the indiſtinct maſs, and unenveloped in any medium, in the ſame manner as the baſaltic cryſtallizations appear ſtanding above the maſs of ſtone or *lava* which ſupports them.

Further obſervations on the baſaltic and vitreous cryſtals may probably ſuggeſt more inſtances of analogy

 between

between theſe two ſubſtances. No juſt objection can be drawn againſt this analogy from the magnitude of the former compared with the minuteneſs of the latter: for the difference of ſize between the ſmall vitreous cryſtals and the ſtupendous baſaltic columns, which ſupport mountains, iſlands, and provinces, is no more than is proportionate to the difference uſually obſerved between the little works of art and the magnificent operations of nature.

Fig. 2.

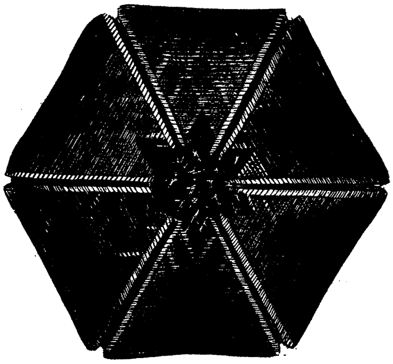
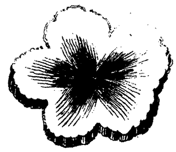
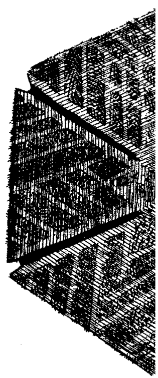


Fig. 6.





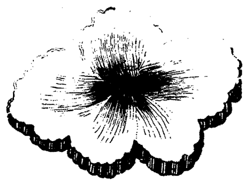


Fig. 9.

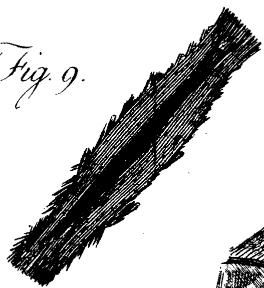
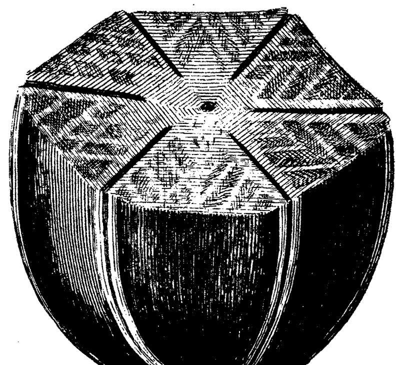


Fig. 7.



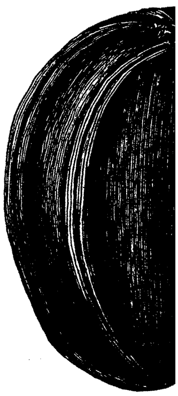
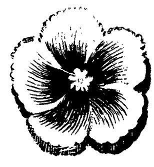


Fig. 8.



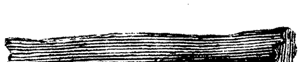


Fig. 3.

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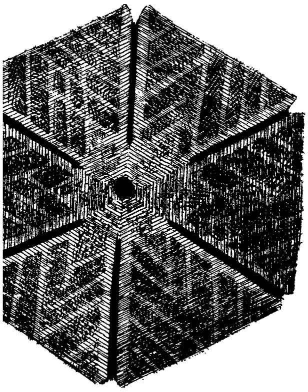
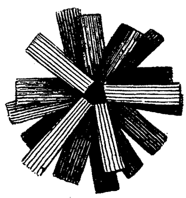


Fig. 10.



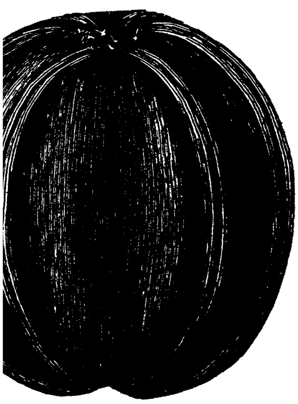


Fig. 1.

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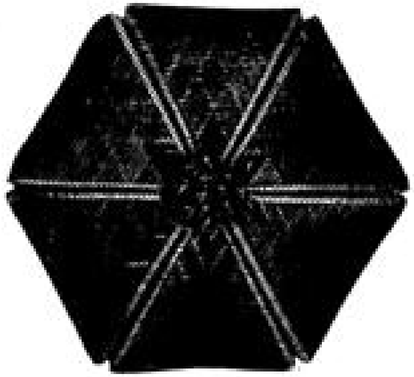

Fig. 2.

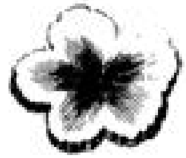

Fig. 6.

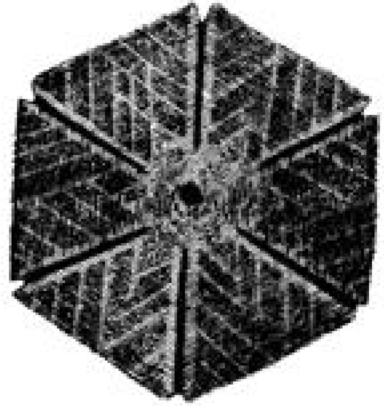

Fig. 4.

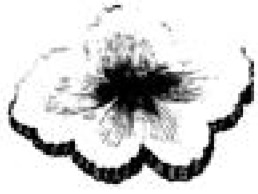

Fig. 7.

Fig. 9.

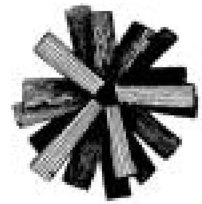

Fig. 10.

Fig. 3.

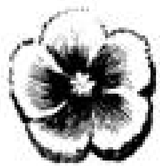

Fig. 8.

Fig. 1.

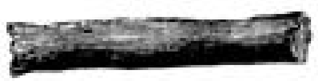

Fig. 5.

Basire sc.