Monday, 4th February 1861.

Principal FORBES, V.P., in the Chair.

The following communications were read :—

1. Notes on the Snow Crystals observed during the late Frost.
By Professor Allman.

On the 26th of December last, about half-past 11 A.M., a light snow shower fell in Edinburgh, and lasted about half an hour. The air was at the time still, and the sky overcast with a thin haze, while the thermometer stood at many degrees below the freezing point. The appearance of the snow was very remarkable. It fell in loose open flakes, and lay upon the surrounding objects in little masses like tufts of exquisitely white, soft and light down.

Remembering the descriptions of the crystals of snow in high arctic regions, and during intense frost even in our own latitudes, as given by Scoresby, Glaisher and others, I was desirous of determining how far the structure of the snow now falling corresponded with the accounts of these observers. I accordingly, with the view of rendering their composition more apparent by contrast with a dark surface, collected a few of the falling flakes upon a sheet of blackened pasteboard, when, even to the unassisted eye, a structure of marvellous beauty was at once revealed. The white down-like snow-flake was now seen to be an aggregate of symmetrical and transparent ice stars, many of them more than a quarter of an inch in diameter. When examined under the compound microscope with the aid of a two-inch object-glass, their beauty became still further enhanced, and it was then seen that every star was itself composed of a multitude of transparent crystals, in some cases tabular, in some acicular, and all grouped in obedience to a definite law, so as in their wonderful assemblages to give rise to shapes of exquisite symmetry,—shapes, too, of almost infinite variety ; the kaleidoscope, in its magical transformations, is not more rich in forms,—yet all pervaded by an unbroken unity, for their type had been already fixed ; and even in their most sportive mood, they could be seen to be under the con-

trol of a definite number and a definite quantity—the number 6 and the angle of 60° determining their form and limiting their variations.

Among the various figures which I observed on the occasion referred to, we may perhaps select, as the archetypal combination, a 6-rayed star (fig. 1), having for its centre or nucleus a tabular crystal in the form of a regular hexagon, each of whose angles supports one of the six rays of the star. Each of these rays would seem to be a very much elongated hexagonal prism, and every one of them gives off from each side, and in the common plane of the figure, secondary arms, which spring from it with a pinnate arrangement, and at an angle of 60° . These secondary arms in the figure under consideration are also elongated hexagonal prisms; in the greater number of instances, however (figs. 2–5), the secondary arms are wedge-shaped, and probably the result of more complex conditions than those under which the type form is produced. The axis of symmetry of each of these wedge-shaped arms is inclined to the ray at an angle of 60° , but I cannot say at what angle the sides of the arms are inclined to one another. The central hexagon in the figure, from which the sketch was taken, was marked with elegant concentric striæ.

It is here worth noting, that the figure I have assumed as the type consists exclusively (if we except the termination of the arms) of a combination of the two limiting forms of the Rhombohedron mR ; namely, that in which m becomes practically 0, and that in which it becomes infinite, producing in the former case the tabular crystal OR , which constitutes the centre of the figure, and in the latter case the prismatic crystals αR , which constitute the rays and their branches.

Assuming then the form now described as the type, there would seem to be but little difficulty in deducing from it most of the peculiarities presented by the other figures which I have had an opportunity of observing. In fig. 2, the central hexagon has disappeared, and the rays meet at a point in the centre of the star.

In fig. 3, a tabular hexagonal crystal is developed diagonally in the course of each ray at a uniform distance from the centre, and in the common plane of the star.

Fig. 4 is easily derived from fig. 3; for in order to produce it, we have only to suppose all the six hexagons to be simultaneously prolonged in the direction of the ray, until they meet in the centre of the figure, when, in consequence of mutual and symmetrical

interference, they will terminate in an angle of 60° , or of half the proper angle of the hexagon, thus forming *maccles* whose plane of union is inclined to the principal axis of the ray at an angle of 30° .

In fig. 5 we have a central hexagon, carrying symmetrically on each of its angles a wedge-shaped five-sided table, which thus takes the place of the acicular ray in fig. 1. Three of the sides of this

table appear to be those of the regular hexagon, while the remaining two sides would, if continued, meet at an angle which I have not been able to measure, somewhere within the central hexagon. From each of the free angles of the wedge-shaped ray, a little hexagonal prism is developed.

The simply pinnate rays of fig. 2 occasionally become doubly pinnate. I have found even trebly pinnate varieties.

I also noticed a form (fig. 6) which is not exactly traceable to the *type*, and which I am inclined to view rather as an abnormal condition induced upon one of the other forms by the coalescence, or imperfect development, of the secondary arms. It consisted of a six-rayed star, in which the rays, instead of being prismatic or wedge-shaped, were lanceolate, the curved boundaries thus bringing this modifica-

tion almost entirely into the type of organic form. The edges of the rays were marked with pinnate serrations or striæ.

In this last form we are strongly reminded of the beautiful stellate figures, like six-petalled flowers, which have been recently described by Professor Tyndal as being developed within a block of ice, when the rays of the sun are concentrated on a point in the interior of it by a burning lens.

Besides the forms now described, the snow which fell on the 26th contained many others, any one of which would well repay the trouble of drawing, though no figure can give an adequate idea of the elegance of the actual object, in which the most beautifully symmetrical flowers, and elaborately divided fern leaves, are repeated with that marvellous fidelity with which inorganic nature occasionally imitates the forms of organisation when the formative forces are directed by an undeviating symmetry.

But the ordinary snow of our latitude is not thus constituted. We may seek in vain in the snow as it usually falls with us for the beautiful stellate crystalline groups now described. Why is this? There are doubtless needed, for the perfect development of the ice crystals in the freezing cloud which is about to descend in the form of snow, several conditions, as yet but partially understood. Of these, it is possible that a temperature considerably below the freezing point may be one, and a stillness in the higher regions of the atmosphere, where the snow is formed, another. It is exceedingly probable, as has been ingeniously suggested by Fr. Vogel,* in explanation of the phenomena of hail, that if the atmosphere be perfectly still, the particles of visible vapour constituting the cloud may be cooled far below the freezing point without freezing; and if in this state a crystal of ice be precipitated into the cloud from some higher elevation, or the stratum of cold vapour be agitated by sudden exposure to some atmospheric current, the balance between the forces of cohesion and adhesion will be destroyed, and the whole cloud will instantly shoot into beautiful ice-crystals, and will fall towards the earth as stellate snow; for the peculiar constitution of the visible vapour is such, that unimpeded action will be permitted to the forces of crystallisation, and no mechanical obstacle will be offered to the perfectly symmetrical development of the crystalline groups.

* See Müller's *Kosmische Physik*, p. 421.

If the temperature of the inferior strata of the atmosphere be sufficiently low, the snow-crystals will reach the earth unaltered ; but if, in their descent, they happen to pass through strata whose temperature is above the freezing point, they will—if they be not actually converted into rain—lose the sharpness and beauty of their outline, while partial thawing, followed, at the surfaces of contact, by the singular phenomenon of regelation, which, as has been shown by Faraday, may take place in an atmosphere considerably above the freezing point, will probably contribute to their irregular conglomeration into an ordinary snow-flake, contrasting as this does so strongly with the light, open, down-like flake produced under circumstances favourable to the perfect development and persistence of the crystals.

On the 27th, the snow which had fallen during the preceding day was still lying on the ground, and, with the view of continuing my observations, I again placed some of it under the microscope. I now, however, found that the crystals had lost all their beauty, and no longer presented the sharpness of outline and symmetry of form which had so forcibly struck me the day before. And yet, during the interval, the thermometer had never risen to the freezing point, nor had the snow been exposed to the direct action of the sun. The change of form thus undergone by the crystals appears to me to admit of but one explanation, and is evidently due to the partial dissipation of the crystal by evaporation, thus affording an interesting example of the evaporability of ice at temperatures considerably below the freezing point.

While on this subject, I may as well mention another fact illustrative of the same phenomenon.

It will be remembered that on more than one occasion during the severe frost a dense fog settled over the city, and was afterwards condensed and frozen on the surrounding objects, covering everything on which it lay, but especially the naked branches of the trees, with the most exquisite frostwork. This beautiful phenomenon, however, was but of short duration ; for in less than twenty-four hours, though the temperature continued all the while below the freezing point, and the air free from wind, which might have shaken the frozen particles from the trees, yet not a trace of the frostwork remained.

To form, then, a true conception of the constitution of a snow-flake produced under the conditions which prevailed during the late

intense frost, we have only to imagine thousands of stellate groups, such as those just described, entangled together by their complex arms into little loose flocculent masses. The peculiar light down-like character of the snow which fell on the 26th of December is thus easily understood.

On the 7th of January, between 4 and 5 p.m., the sky overcast, and the thermometer standing considerably below the freezing point, Edinburgh was visited by another snow shower. On this occasion the shower was of a very peculiar kind, for the stellate groups of crystals, instead of being aggregated into flakes, as in the shower of the 26th December, were for the most part isolated and distinct, so that the whole atmosphere was filled with separate ice-stars in inconceivable multitudes, whirling through the air, and drifting past one another in mazy paths which no eye could follow, so endless were their intersections, and inextricable their labyrinths; the wonderful ice-drift heaping itself up like white sand on the surrounding objects, but when projected against dark surfaces, revealing itself in all the unrivalled symmetry and beauty of its starry atoms. The chief difference between the present snow shower and that which fell on the 26th December, consisted in the segregation of its crystalline particles. There was a brisk breeze stirring at the time, in the lower regions of the atmosphere, and this was doubtless the invisible analyst that broke up the snow-flakes into their component elements, and flung them in stars and flowers to the earth.

The following Note from Mr Stephens to Dr Balfour was also read :—

REDBRAE COTTAGE, 14th *January* 1861.

MY DEAR SIR,—In December 1859, I was visiting Sir Robert Peel at Drayton Manor, in Staffordshire; and while there, a very heavy hoar-frost occurred for nearly two days,—every tree and shrub and the grass was fringed with most beautiful silver filagree. When walking along the shrubbery in the forenoon, I was led, from the remarkable exuberance of the hoar-frost, to examine it more minutely than by a casual glance; and to my surprise and delight, I perceived that the crystals presented quite a different arrangement on different

bushes of evergreens. This there was no doubt of, as I could easily discern the difference in the arrangement of the crystals by the help of a large magnifying glass which I always carry with me when I go from home. I regret I did not take a sketch of the different arrangement of the crystals ; but not being prepared for such a proceeding, and being no hand at sketching, I contented myself with looking from one bush to another. And while thus engaged for some time, I thought I made an interesting discovery—namely, that while different bushes presented a different form of crystallisation, the same sort of bush presented the same form of crystals. This discovery interested me very much—for discovery I deemed it, not having observed any mention of such a thing in any book on meteorology I have seen. Thus, Portugal laurels, laurel bays, laurustinas, different sorts of *Arbor-vitæ*, the yew, some of the new pines, presented different forms of crystals, but the same kind of plant had the same form of crystal. This I made sure of by repeated observation in different parts of the shrubbery ; and more than that, the size of the crystals was about in proportion to the size of the leaves of the evergreens. Thus, the crystals in the Portugal laurel, laurel bays, and larger leaved kinds of evergreens, were larger than on the leaves of the laurustina, and these latter larger than in those of the yew and *Arbor-vitæ*. The crystals, moreover, were not spread over the surface of the leaves, but only along their margins ; and the leaves above, that were exposed fully to the air, had the crystals—those within the bush, or under shelter of the leaves above them, were free of all hoar-frost. I may mention that the sun was obscured the first day by a frost-fog ; the second day was clear, but the crystals retained their form where the sun did not strike ; and on the following morning, the whole fairy scene had disappeared. Tall grasses and sedges by the side of a lake presented different crystals, but the same kind of plant similar forms. The naked branches of trees presented similar results.

I am, &c.,

HENRY STEPHENS.