sources are employed, the apertures may be exceedingly fine, and the monochromatism is of very high order.

To diffuse the issuing light, a tube of 2 ins. diameter and equal length, carrying within it either of two diffusing screens of ground glass, of fine and extremely fine texture respectively, is attached to the tapped annulus of the frame of the exit slit by a suitable carrier, which enables the tube to be approached as near to the slit as desired by sliding along a bar. The instrument to be illuminated, the polariscope of the axial angle goniometer for instance, is brought close up, so that the end of the polarising tube enters the diffusing tube and almost touches the ground glass screen, which is best distant about $1\frac{1}{2}$ ins. from the slit; the axes of the optical tubes of the two instruments should of course be made continuous. The illumination of the field of the polariscope, when carrying an adjusted crystal section-plate between its convergent lens systems, is so bright that measurements of the optic axial angle can be carried out with light as far as G, and is greatly superior to that obtained by the use of coloured flames. The interference figures are wonderfully sharp upon a homogeneously coloured and illuminated background.

Cases of crossed axial plane dispersion can be completely traced from the extreme separation of the axes for red in one plane to their extension for blue in the plane at right angles, and the exact wavelength for the crossing point when the biaxial crystal simulates an uniaxial one at once determined.

The instrument is equally adapted for use in the determination of refractive indices by the methods of refraction or total reflection; the refracted images of the slit of the spectrometer are immensely brighter than when coloured flames or a hydrogen Geissler tube are employed. A great saving of time is effected in all these measurements, and this is especially advantageous in observations for different temperatures. Full details of the mode of employing the instrument for these various observations, and for its use in stauroscopical determinations of extinction angles, are given in the memoir.

V. "On Hollow Pyramidal Ice Crystals." By KARL GROSSMANN, M.D., F.R.C.S.E., and JOSEPH LOMAS, A.R.C.Sc. Communicated by Professor JUDD, F.R.S. Received January 4, 1894.

(Abstract.)

I. *The Lava Cavern, Surtshellir.*—At a visit to the lava cavern, Surtshellir (Iceland), in June, 1892, the farthest recess, which contains ice stalactites and an ice pond, was found to be covered on walls and ceiling with ice crystals in the form of hollow hexagonal

pyramids, analogous in shape to the well-known cubic crystals of rock salt. The hollow ice pyramids were, roughly speaking, built in the proportion of base 1 to height 2, and ranged up to about 1 in. diameter of base. They were attached to the wall by their apices, turning their hollow bases towards the interior of the cave. They were only found on those parts where stalactites did not occur. The temperature was +0·5° C. (+33° F.), and, as the cave forms a *cul-de-sac*, the air is perfectly calm. The crystals, having thus evidently been formed from the moisture of the atmosphere, had to be considered as a kind of hoar frost.

II. *Hoar Frost.*—During Christmas week, 1892, similar forms of ice crystals, though on a smaller scale, were found in an unusually fine hoar frost. These forms comprised simple and compound hollow hexagonal pyramids, which were sketched at the time.

III. *Artificial Hoar Frost.*—Experiments had been planned already before Christmas, 1892, for the artificial production of hoar frost. Before so doing, however, it was thought advisable to search for any possible traces of artificial hoar frost in the refrigerating chambers used for the frozen-meat trade in Liverpool. This visit rendered experiments unnecessary, as it yielded a rich harvest of simple and compound forms of similar hollow pyramidal ice crystals. The chambers having been cooled down to −13° C. (+9° F.), it was possible to examine the forms minutely without danger of melting, and photographs and microphotographs were taken by magnesium light.

Similar forms of artificial hoar frost were found in the refrigerating ss. "Hellopes," in Liverpool, and also in the cooling cellars of breweries in Berlin.

[IV. During a severe frost in January, 1894, we found in various parts of Cheshire the same hollow pyramidal ice crystals occurring on the under surfaces of ice crusts covering hollow ruts in clayey soil, and small pools where an air space divided the ice from the water. No ice crystals were found on the sides and bottom of the ruts. There was no trace of hoar frost on adjacent objects. Microphotographs were obtained.—January 31.]

V. *Comparison with other Skeleton Crystals* (*e.g.*, Rock Salt).—Like the "hopper-crystals" of rock salt, the hollow, hexagonal pyramids of ice have to be considered as skeleton crystals. A study of the conditions under which these are formed leads us to distinguish three different types of skeleton crystals:

a. Those due to overgrowth, *e.g.*, KCl.
b. Those due to growth at the upper edge in swimming crystals, *e.g.*, NaCl.
c. Those due to starvation growth, *e.g.*, hoar frost.

VI. *Literature.*—1. In 1697 Camerarius described, amongst hexagonal plates of hoar frost, some slightly depressed in the middle.

2. In 1874 Krenner described and illustrated hollow hexagonal ice crystals found in the ice cave of Dobschau. His remarks on their formation and attachment are, however, quite at variance with our observations.

3. In 1889 Assmann described and illustrated the forms of hoar frost; but his illustrations only show flat fronds growing in one dimension.

VII. *Conclusions.*—1. Water, when changing direct from the gaseous into the solid state, is highly crystalline.

2. The tendency to crystallisation is so strong that in those cases where the area of supply is limited by a wall or other heterogeneous surface, skeleton crystals—hexagonal "hoppers"—are formed, growing away from that wall, even under circumstances of excessively slow growth.

3. Calmness of air seems to be an essential condition for their formation.

4. The natural example of crystallisation of water limited to certain directions is given in hoar frost, showing a very marked tendency to form hexagonal hoppers.

5. From our observations, there can be no doubt as to the identity of the ice crystals of Surtshellir, of the refrigerating chambers and ships in Liverpool, and of the cooling cellars of the Berlin breweries, with natural hoar frost.

Presents, February 1, 1894.

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