(fig. 2*b*); but after a few moments these cylinders were seen to congeal again, and change thereby into broader plates, sharpened at their outer edges by two planes of a regular hexagonal prism. The whole crystal became thus again a hexagonal star, but with broader and shorter rays than it hadbefore.

Other crystals, which had at the beginning such flat and broad rays (fig. 2*c*), changed these by melting into feathered ones (fig. 3*c*), because on their liquefaction there remained only the middle of each plate, like an icy needle, in the water, until, the new congelation ensuing, a number of needles ran at each side out of this rib at angles of 60 degrees.

Some of the stars were feathered in the beginning, but only at the outer half of their rays. I did not see any change take place in them, nor did this happen with some other more complicated forms. Thus I observed among others a small and continuous hexagonal plate, with simple rays issuing like diagonals out of its angles; but then each adjoining pair of these rays was still connected by a couple of needles which met at an angle of 60 degrees (fig. 4).

But these complicated forms were comparatively rare; and those transformed under my eyes were so predominant, and presented a spectacle so full of motion, that at last I could hardly help comparing them with living beings. In fact it is only in the case of such that we are accustomed to witness changes so mysterious without inquiring after the forces that produce them. We got, however, a partial explanation of this phenomenon by remarking that the outer parts of the snow-crystal, which were the first to melt, borrowed their warmth of liquefaction from the parts that remained solid, and thereby cooled these below the point of congelation. The newly-formed water could then freeze again by its collecting round this cold ice, and by its offering at the same time a smaller surface[2] to the air whose temperature had melted the crystal. This water then assumed in freezing a more complicated form, because the remainder of the old crystal exerted in it a greater variety of attraction than that which occurs in a wholly liquid drop. Perhaps all complicated forms of snow [crystals] result from the simple one by melting and freezing again in this way, a process which they must then undergo during their fall thru the air; and here this hypothesis seemed somewhat confirmed by the complicated crystals being always of less diameter than the simple ones.

Additional remark (April, 1859).—I have sometimes watched the snow-crystals which fell at Berlin when the temperature of the air was a little higher than the freezing-point, but till now without seeing again the phenomenon just mentioned. We may suppose either that these observations were still too rare to present some one of those neglected and apparently trifling circumstances that are requisite for the phenomenon in question, or that this depended also on the spot where I made my first observation having been at a considerable elevation, and consequently not far from the atmospheric stratum where the snow was first formed. But then, as to the explanation of the observed metamorphosis of snow, I think it might have some connection with the equally obscure property of some chemical precipitates, which, like carbonate of lime, according to M. Ehrenberg, consist, when first consolidated, of regularly arranged solid globules, and which are then changed, "all of a sudden and quite wonderfully," to aggregates of true crystals of microscopic size. (Cf. Ehrenberg in Abhandlungen der Berliner Akademie, 1840.)

THE CRYSTALIZATION OF UNDERCOOLED WATER.

By BORIS WEINBERG. Dated St. Petersburg, July, 1908.

[Reprinted from the Physical Review, 1908, 27:509–510.]

In order to show the undercooling of water and to allow the free development of its crystals I endeavored to introduce into the undercooled water a piece of ice put in a finely drawn out glass tube. The experiment, carried out the first time by Michael Tvanov, gave an unexpected result. When the crystallization attained the end of the tube there began to grow at this point an ice crystal having the shape of an hexagonal star and very similar to the characteristic snow crystals.

The greater the undercooling of the water the more numerous were the ramifications and the greater the velocity of crystallization. With water undercooled to a temperature between —0.3° and —1° C. I obtained small stars with few narrow ramifications, see fig. 1. Undercooling to a temperature between —1° and —3° C. gave rise to stars with such dense ramifications that they resembled hexagonal plates, see fig. 2. The plane of the stars contains the direction of the end of the tube, and therefore when this end is vertical a sufficiently large plate can divide the tube into two parts. An undercooling greater than —3° C., especially when the end of the tube is not narrow enough, produces several plates set in different azimuths, and the whole mass becomes at last a mass of differently sized crystals and water, resembling the so-called "anchor ice."

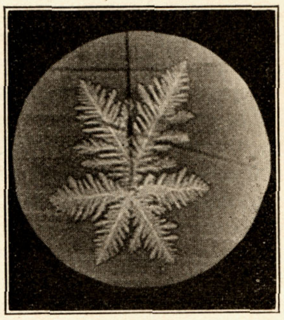

FIG. 1.

The crystals are often a conglomeration of several stars which have their planes, their principal rays, and even the ramifications of higher order parallel as in fig. 3.

If a star is broken, the pieces of it rise horizontally in the water with slight oscillations and attain the surface. This circumstance can explain the verticality of the optic axis by river and lake ice.

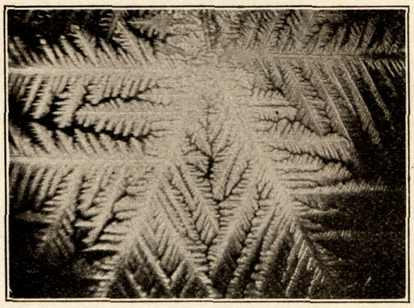

FIG. 2.

The evolution of these artificial snow crystals can be easily projected on a screen, if the vessel (a tumbler, an alembic, an evaporating dish) with undercooled water is put into another vessel with plane-parallel sides containing water at a temperature somewhat higher than the thaw temperature [dew-point?] of the surrounding air. For undercooling any water can serve, but the refrigerating mixture (finely chopped ice upon which is poured a strong solution of NaCl) must not be too cold (from —4° to —6° C.) and its level must be lower than the level of the water which is to be undercooled.

The projection is especially beautiful when the vessel is placed between crost nicols, as in figs. 1–3. A star on a

[2] Viz, the *curved* surface of a single, or of six connected drops.

dark ground grows which gradually becomes more and more bright and at last, when thick enough (the thickness is generally of the order of a tenth of a millimeter), shows the colors of chromatic polarization. One can prove that these crystals are optically uniaxial; if the tube is turned so that the plane of a star is at right angles to the rays of polarized light the image of the star disappears.

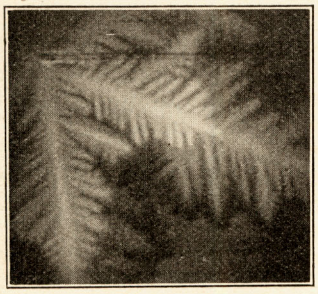

Fig. 3.

Precise measurements of these crystals will be made in winter when it will be possible to prolong their fugitive existence.

The size of the stars depends—at a sufficient undercooling, e. g., —2° C.—principally on the dimensions of the vessel with undercooled water. I often obtained single stars 8 to 12 centimeters broad.

RECENT EXTENSIONS OF THE CANADIAN METEOROLOGICAL SERVICE.

Director R. F. Stupart of the Canadian Meteorological Service in his letter of March 3, 1909, states that during the past summer he supplied barometers and a full equipment to the following stations in extreme northern Canada:

Fort McMurray,	latitude 56.40° N.,	longitude 111.25° W.
Fort Chipewyan,	latitude 58.41° N.,	longitude 111.10° W.
Hay River,	latitude 60.51° N.,	longitude 115.20° W.
Fort Simpson,	latitude 61.52° N.,	longitude 120.43° W.
Fort Norman,	latitude 64.57° N.,	longitude 125.00° W.
Fort Macpherson,	latitude 67.27° N.,	longitude 134.57° W.

where the observers will be paid for satisfactory service. This service has also just started two new stations in Newfoundland at Point au Basques and Burin. In the spring a station at Fogo and another on the Labrador coast will be put in operation, and the service then contemplates issuing storm warnings and forecasts for Newfoundland.—*C. A., jr.*

THEORIES OF THE COLOR OF THE SKY.

By Edward L. Nichols.[1]

Presidential address delivered at the New York meeting of the Physical Society, February 29, 1908.

[abstract.]

The author summarizes the various theories explanatory of the color of the sky, as follows:

1. The turbidity of the atmosphere would of itself give us a blue sky, but the ideal medium of Rayleigh would afford a distribution of intensities to which the actual sky rarely if ever corresponds.

2. Even were the atmosphere free from particles of dust, condensed water vapor or other extraneous matter it would not, according to Rayleigh's latest paper, be optically empty, to use the term employed by Tyndall, but would be blue by virtue of reflections from the molecules of the air itself.

3. If there were no other source of blueness, the color of the air according to Spring, would give us a blue sky by virtue of the selective absorption-color of various of its constituents. The objections to the adoption of this as a factor are obvious and are regarded by many writers as insuperable, but their arguments are not, in my opinion, conclusive.

4. Reflections from surfaces in a troubled atmosphere as pointed out by Hagenbach, would give us light from the sky increasing in intensity relatively to sunlight in proportion to the square of the wave-length. This is quite sufficient to account for the average blueness of the sky, but not for the intenser blueness frequently observed. It cannot therefore be regarded as the sole or most important factor.

5. Fluorescence as a factor of blueness of the sky cannot be definitely considered at the present time for lack of experimental data concerning it.

6. As regards the subjective or physiological factor it may be said that were there no other cause the sky would undoubtedly appear blue; for we still see it blue where measurements with the spectrophometer indicate a composition relatively much weaker in the shorter wave-lengths of the spectrum than the *average* composition of sunlight. In the present paper I shall, however, consider only the objective factors.

The problem of the color of the sky is stated as resolving itself into a determination of the relative importance of these various factors, the existence of all of which, with the possible exception of fluorescence, may be regarded as experimentally established. The phenomena of aerial polarization are believed to indicate beyond any doubt that the turbidity of the air is one source of the blueness of the sky. But while Rayleigh's masterly theoretical work—which calls for relative intensities of the reflected ray as compared to the incident ray varying inversely as the fourth power of the wave-lengths—has found complete verification in the studies of artificial media, spectrophotometric measurements of the sky itself have led to widely varying results. Thus, Zettwuch, who made many measurements at Rome, calls especial attention to the variability of the ratios. Crova, at Montpellier, whose measurements extend only between wave-lengths 0.635μ and 0.510μ, found the exponent to vary from 1.61 to 6.44. The author therefore seeks other sources than turbidity for the blue color of the sky.

Numerous measurements of the spectrum of the sky made by the author with a portable spectrophotometer show, in general, far greater relative intensities of the longer wave-lengths than one would expect from the theory of Rayleigh, which is based upon the assumption of an ideal turbid medium in which the diameters of all the particles in the medium are small as compared with the wave-length of light. The following are given as obvious causes of the discrepancies between theoretical and observed ratios of intensities:

(*a*) The presence of larger reflecting particles in the atmosphere, sometimes invisible and sometimes forming masses of mist or cloud.

(*b*) Absorption by transmission through the turbid medium itself.

(*c*) Illumination of the atmosphere by light reflected from the surface of the earth.

Curves of ratios based on observations taken at dawn and in the twilight after sunset, show but little variation from day to day in fair weather, and approximate closely to the ratio curves called for by Rayleigh's equations. During the day, while the sky-light taken as a whole increases greatly in intensity as the sun approaches the zenith, the actual intensities of the blue and the violet are much less affected than are the longer wave-lengths. When the moisture of the atmosphere condenses into cloud forms [cumulus] in the middle of the day, there is a marked diminution in the relative intensity of the sky-light at the violet end of the spectrum.

Evidence is found of the modification to a measurable extent of the character of the light of the sky by reflection from foliage, from clouds, and from the ground.

Reference is made to Pernter's study of the polarization of light emitted at right angles to the incident beam by emulsions of different colors. In general, the whiter the emulsion the less the polarization, which is also true of the sky. For a blue emulsion the green ray showed the greatest polarization, the blue next, and then the red. For a white emulsion the red ray showed the more polarization, there being a diminution toward the violet. Pernter found this also to be true of blue and white skies. The author found that the polarization of sky-light was sometimes greatest in the red, sometimes in the violet, sometimes in an intermediate color, and sometimes uniform for all wave-lengths, probably depending upon the size of the particles present in the atmosphere.

[1] Physical Review, Vol. XXVI, p. 497.