Islands, and several others identified these same flames. They are referred to in Prof. Dana's book upon "The Characteristics of Volcanoes" (p. 119) as being pale in color and of a slightly greenish color rather than bluish. This corresponds with my observations. In order to test this matter I took with me upon my recent visit to the volcano (Sept. 14 to 25, 1893) a pocket spectroscope. I did not imagine that I should have such a splendid opportunity, or I should have taken a better instrument; however, the little spectroscope did good service, and the observations may possibly lead to something better later on.

I spent the greater part of three evenings down on the edge of the boiling caldron in Halemaumau, and the observations I made were repeated many times, so that I have every confidence in them. As to the conditions, I may say that they were exceptionally favorable. The surface of the molten lava was so high during the whole of our visit that it could be reached with an ordinary walking stick. The volcano seemed to be in a very active state, as several overflows occurred, and the ebullition from what appeared to be three centers of weakness or disturbance was very remarkable. The lava was thrown into the air a distance of 40 to 50 feet, and as we could approach these fountains quite closely in two instances, we could form very good estimates of their size and the amount of lava involved in such an outbreak. Their surface for a considerable area near one of these centers (for they seemed very constant in position) would sway up and down, at first gently and then more violently, particularly in the neighborhood of the intersection of the fissures, which were constantly forming in the crust of slag, then there would be two or three small explosions accompanied by a bumping sound, as though gas had escaped from the mouth of an uncorked bottle; after this there would be a great rush of lava into the air, to be repeated several times, when the surface would become quiet once more.

At the edge of this caldron, 1,000 feet in diameter, I placed myself after dark, and for a couple of hours in each instance had opportunities nearly every five minutes to observe the flames which almost invariably accompanied these explosions. At times they would make their appearance along the fissures in the crust, when they would be very short lived; and I failed to get much information from them, aside from the fact that they seemed to be the exact counterpart of the hydrogen flame from a Bunsen burner.

It was the study of the flames which accompanied the larger outbreaks which appeared to promise most return. Getting as near as possible to one of the giant fountains (probably 50 yards distant) I watched for the premonitory symptoms of an outbreak and got all ready for it, and seldom failed to catch indications of the presence of gases.

For a good part of the time there was a continuous spectrum while the spectroscope was directed across the lava. The first thing that impressed me was the sudden appearance and disappearance of broad bands of white light, showing conclusively the presence of gas burning under high pressure. The location of these bands became the next problem, and then I longed for a better instrument with a micrometer eyepiece. The first which appeared with constancy was a band in the green, indicating the presence of carbonic oxide in all probability. Then I found on other occasions bands of lighter intensity in the red and blue, and the red and purple portions of the spectrum, thus apparently marking the presence of the hydrocarbons. There were also occasionally noticed upon a full spectrum a large series of dark lines in the yellow and orange, sometimes completely blotting these colors out of the spectrum altogether. These need more careful study before assigning them definitely to any substance or substances.

It is hoped that the above may serve to indicate a point upon which valuable work can be done, and that some one will take advantage of it and follow the subject up.

CRYSTALS IN BOOKS.

By A. F. TAIT.

In a certain "kind play-book" known as "Love's Labor Lost," Sir Nathaniel speaks of the "dainties that are bred in a book," but the dainty bred in books known as the dendritic crystal, which is the subject of this paper, never came within Sir Nathaniel's observation.

It is a curious fact that the dendritic crystal, one of the most interesting and most lovely of crystalline forms, is almost unknown, and has only lately come

DENDRITIC CRYSTALS IN BOOKS.

1 and 3, natural sizes; 2, magnified.

within the ken of workers with the microscope. Still more curious is the fact that most of us possess specimens, and some of us dozens of really fine examples, and we never knew until now that we possessed them. Only the initiated know the home of the dendritic crystal, for, as Mark Twain said of international law, the subject is "not yet hackneyed." Being, then, so new to observers, the crystal in question is not even named in the usual text books. I must, therefore, beg the indulgence of my readers for the fragmentary and imperfect character of this paper, based solely on personal observation. The dendritic crystal (from the

Greek, *dendron*, a tree) may be found where Nature is holding a perpetual exhibition of specimens at once brilliant, beautiful, and practically indestructible. Within the printed pages of our books, for years and years, she has been working unseen in silence and in darkness, drawing for us pictures of tree life of such loveliness as Rembrandt, prince of etchers, would have failed to imitate.

The accompanying drawing illustrates specimens of dendritic crystals, Figs. 1 and 3 being natural size. Fig. 2 is an enlargement, drawn from a micro-photograph of Fig. 1, kindly taken by Captain Barnes. The black mark shown in the magnified example appears to be the origin of this beautiful pattern.

The dendritic crystal is formed by chemical action set up by the accidental deposition of a minute fragment of copper upon the surface of paper during the processes of manufacture or of printing: the presence of the minute fragments of copper deposited being prob-

FIG. 1.—SPECTROSCOPIC APPARATUS OF THE MEUDON OBSERVATORY OF PHYSICAL ASTRONOMY.

ably due to the wear and tear of the paper-making or the printing machinery, so far as the mechanism is built up of copper. The agency of manganese and the action of heat or of moisture in building up the dendritic crystal, tracing its arborescent characters black upon white on the surface, as well as in the very substance of the paper, must be left for a future article.

Unlike crystals from saline and other solutions, which may be rapidly formed upon the stage of the microscope "while you wait," as the signboard hath it, the dendritic crystal requires, as far as I have observed, rather more than twenty years before reaching its fullest development.

However, just as there is a firm in Chelsea who have been wresting from Nature one of the most hidden of her geological secrets, by transmuting a block of chalk into a block of marble in a few hours, it is among the possibilities of the near future that dendritic crystals may quickly be produced in the laboratory, rivaling, perhaps excelling, the specimens hitherto known.

I have never as yet seen a specimen in a book older than 1835, or younger than 1882. In the latter case, all the examples of the crystals were small in size, and their arborescent character was not nearly so well

particles, or of pulp manipulation that would be so perfect as to wholly banish the tiny granule of copper, if any of that metal were in the make of the machine.

These crystals vary in size; the smallest are barely visible to the naked eye as, apparently, a minute black dot. A giant specimen would cover a threepenny piece. A good Coddington lens or a two-inch objective is indispensable for examination of the smaller specimens, but much of the beauty of the larger examples is manifest to the unaided eye. With a small lens one may go on a voyage of discovery among one's books in quest of crystalline beauty without any help from the microscope. Non-crystalline marks are hard in outline and of rigidly defined harshness and blackness at their edges, while the dendritic crystal that looks "blottesque" at half a yard's distance is found when closely examined to be fashioned with the utmost delicacy of filigree structure, as if indeed it had been designed in fairyland, and the master craftsman had made

FIG. 2.—EXPERIMENTS WITH THE VERTICAL TUBE AND INCANDESCENT SPIRAL.

the pattern a blending of the beauty of tree life with the fantasy of the marine algae.—*Science-Gossip*.

THE SPECTRA OF OXYGEN AT HIGH TEMPERATURES.

I SPOKE to the Academy at one of its former sessions about a method founded upon the use of electricity and adapted for raising gases under pressure to a very high temperature without perceptibly heating the receptacles containing them.

Before giving an account of the experiments made upon oxygen by means of this method, I shall first speak of those that preceded the latter and in which temperatures not exceeding about 300° were obtained by means of a row of gas lights acting directly upon the tube containing the oxygen gas.

The arrangement was as follows: A steel tube, 10 meters in length and lined internally with copper and closed at its extremities with glass (according to my usual method), was placed in an iron plate trough capable of receiving a sand bath. This trough was directly heated by 100 gas burners in a row.

The temperature of the tube was taken by means of thermometers connected metallicly with the tube.

FIG. 3.—APPARATUS FOR HIGH PRESSURE EXPERIMENTS.

defined and luxuriant as in the volume aged threescore years.

It would be interesting to learn the experience of brother microscopists, and I would be glad to see reports in *Science-Gossip* from those whose experience differs from mine on the point.

A somewhat remarkable fact touching this subject is that, although I have examined scores of volumes of foreign origin, I have never yet been rewarded by the discovery of a single specimen. Never having seen an American or continental paper-making or printing machine, I know not whether the absence of crystals is due to there being no copper in their mechanism. I can hardly imagine any scheme of winnowing away foreign

After introducing the oxygen at the desired pressure, and before the heating of the tube, there was obtained a good spectrum of the luminous source, whose pencil traversed the tube in such a way as to make it possible to estimate the modifications that the elevation of the temperature might bring about in the constitution of the absorption spectrum given by the gas.

The row of burners was lighted and the spectrum was observed in measure as the temperature rose along with the pressure.

When the experiment is properly conducted, the pressure of the gas at the finish (that is to say, when, the lights having been put out, the temperature has