example, be placed between the tourmalines arranged in this way, the light will again pass, showing that it has been depolarized by the rock crystal.

This has been accepted as an infallible test of the genuineness of quartz lenses. In the hands of an expert it is undoubtedly valuable, but glass lenses may be put under strain by heating them and allowing them to cool rather quickly. They will then, to some degree, act on the polarized beam like the true crystal.

This form of polariscope is useful in the examination of crystals generally, but on account of the natural dark color of the tourmaline, the utility of the instrument is limited.

In Fig. 275 is shown a polariscope designed for the examination of large objects, such as glassware, etc. It consists of a bundle of 16 glass plates, about 20 or 24 inches square, arranged with reference to the Nicol prism employed as an analyzer at an angle of 35° 25′. Behind the series of plates is hinged a board covered with black velvet, which may be raised up parallel with the glass plates when it is desired to polarize the beam by reflection.

The analyzer, a Nicol prism, is mounted in a revoluble tube, supported by the small adjustable standard. Articles to be examined are placed on the small table between the polarizer and analyzer.

The light for the polariscope should be taken through either a white paper or cloth screen or a plate of ground glass. Any strain in the article examined will exhibit itself by its depolarizing effect on the polarized beam.

SIMPLE POLARISCOPE FOR MICROSCOPIC OBJECTS.

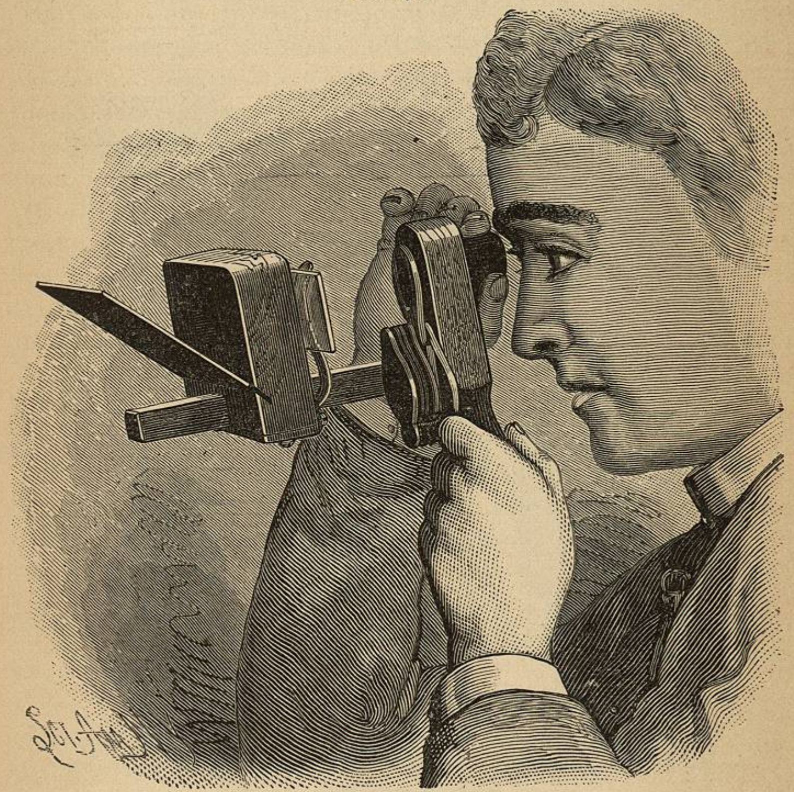
The examination of microscopic crystals by the aid of the polariscope is an exceedingly interesting part of the study of polarized light. The indescribable play of colors, and the variety of exquisite forms of the smaller crystals, render this branch of the subject very fascinating. But to undertake the examination of this class of objects in the usual way requires a microscope with the addition of a polariscope, which calls for an outlay of at least fifty dollars, besides the cost of the objects, and while it is believed that

such an outlay would be indirectly, if not directly, profitable, it is not necessary to expend a fiftieth of that amount to arrive at very satisfactory results.

The cost of the compact and efficient little instrument shown in Fig. 276 is as follows:

One pocket magnifier, having two lenses 1½ inches and 2

FIG. 276.

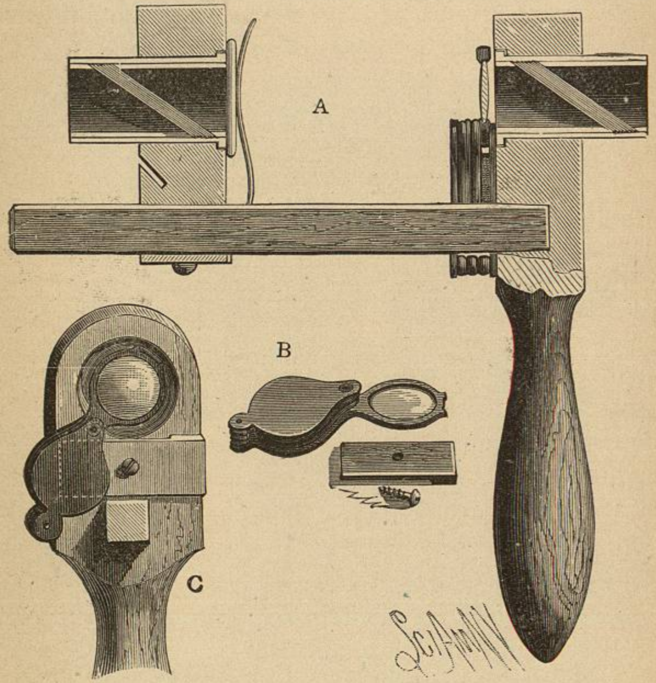


Polariscope for Microscopic Objects.

inches focus respectively, giving when combined a ¾ inch focus, 50 cents; eighteen elliptical microscope cover glasses for analyzer, 38 cents. The cost of wood for the principal parts, the pasteboard tubes, the glass for the polarizer, and the metal strips for the slide-holding springs, can hardly be counted, and the labor must be charged to the account of recreation; so that less than one dollar pays for an instrument that will enable its owner to examine almost the entire range of microscopic polariscope objects with a degree of satisfaction little less than that afforded by the use of the best instruments.

The form, proportions, and material of the body of the instrument are entirely matters of individual taste. In the

Fig. 277.



Longitudinal Section of Polariscope and Details. Half Size.
A, Longitudinal Section. B, Magnifier and Clamp. C, Cross Section showing Clamp and Magnifier.

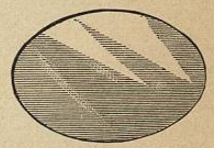
present case, the hand piece and sliding stage are made of ⅞ in. mahogany, the handle being formed on the hand piece by turning. The stage is 2½ in. square, and has in its lower edge a half inch square, transverse groove, which receives the square rod projecting from the hand piece at right angles. The rod is held in the groove by a wooden strip fastened to the lower edge of the stage by two wood

screws, so that it bears with a light friction on the under side of the rod.

The hand piece and stage are both pierced above the rod with holes which are axially in line with each other. The diameter of the holes is governed by the size of the cover glasses. Those in the instrument shown are of the exact size and form of the annexed diagram (Fig. 278).

These cover glasses are procurable from any dealer in supplies for microscopists. Eighteen of them, at least, are required. The paper tube inclosing these glasses is a little more than $\frac{11}{16}$ in. internal diameter; its outside diameter is ⅞ in. and its length is 1¾ in. A narrow paper collar is glued around one end of the tube, and both the hand piece and the stage are counterbored to receive the collar, as shown in the sectional view, A, Fig. 277. To the tube thus described is fitted an internal paper tube, which is about ⅛ in. shorter than the outer tube. The inner tube is divided diagonally at an angle of 35° 25′, which is the complement of the polarizing angle for glass (54° 35′). The oblique surfaces thus formed, when placed in the tube in opposition to each other, support them between the glass plates at the polarizing angle. The simplest way to arrange the angles of the tubes and other parts of the polariscope is by the employment of a triangle of cardboard like that illustrated in Fig. 279. In fact, a copy of the triangle here shown may be used.

Fig. 278.



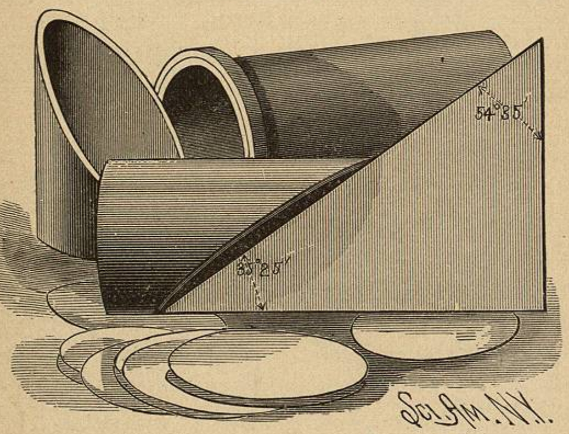
Elliptical Cover Glass

It is sometimes a matter of considerable difficulty to clean the thin cover glasses without the risk of breaking a large percentage of them. An effective device for holding the glasses while they are being cleaned is shown in Fig. 280. It consists of a piece of thin Bristol-board, having an elliptical aperture loosely fitting the edges of the glass to be cleaned, and a plain card glued to the back of the apertured card, and forming the bottom of the shallow recess into which the glasses are dropped for cleaning. The holder may be pressed down upon the table by the fingers of one hand, while the glass is rubbed with a soft linen handkerchief, after being breathed on. Glasses that cannot be easily and thoroughly cleaned in this way are worthless for this purpose.

Before the glass plates are put together, they are dusted with a camel's hair brush to remove any adhering lint and dust. The paper tubes are made dead black inside and outside.

The front of the stage is provided with a pair of thin brass springs, which serve to clamp the object slide with a light pressure to the stage. In the back of the stage, below the central aperture, is formed a groove for receiving the

FIG. 279.



Triangle and Paper Tube. Full Size.

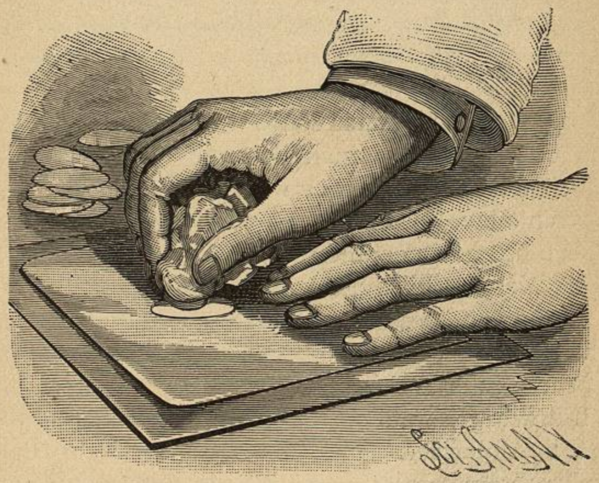
black glass polarizing plate. The groove supports the black glass at an angle of 54° 35′ with the plane of the stage, or at an angle of 35° 25′ with the holes in the stage and hand piece. The polarizing plate may consist of a plate of polished black glass, but it is generally more convenient to employ an ordinary piece of glass blackened on one side. A thin pine wedge cemented to the back of the plate causes it to bind in the groove of the stage.

To the inner face of the hand piece is clamped an ordinary pocket magnifier by means of the wooden clip. At C is shown the arrangement of the magnifier relative to the

analyzer. Any convex lens of suitable focus may be pressed into the service. The face of the stage and other parts of the instrument visible through the analyzer are blackened.

The object to be viewed is placed on the stage and focused, when the instrument is held so that the black glass polarizing plate reflects the light through the object and through the analyzer. The analyzer is then turned, and the object observed. To heighten the color effects, a plate of selenite or mica may be placed immediately behind the

FIG. 280.



Holder for Glass.

object, or between the stage and black glass plate. Mica plates of suitable thickness are selected by trial in the instrument, and preserved for future use.

It is sometimes desirable to rotate the polarizer. When the black glass plate is used, this is impracticable, but on removing this plate, and inserting in the stage a polarizer consisting of a tube containing plates like the analyzer, the effects of rotating the polarizer may be observed. To render the rotation of the paper tubes smooth and uniform, their bearings in the hand piece and stage are rubbed over with the point of a soft lead pencil, imparting to them a thin coating of plumbago, which diminishes friction and prevents sticking. The objects which may be examined by the aid of this instrument are very numerous. Many of them are easily prepared, and some need no preparation at all. The chemical salts mentioned below may be prepared for observation by allowing their solutions to evaporate on a slip of glass: Alum, bichromate of potash, bichloride of mercury, boracic acid, carbonate of potash, carbonate of soda, citric acid, chlorate of potash, hyposulphite of soda, iodide of potassium, nitrate of ammonia, nitrate of copper, nitrate of soda, oxalic acid, prussiate of potash (red), prussiate of potash (yellow), sugar, sulphate of copper, sulphate of iron, sulphate of nickel, sulphate of potash, sulphate of soda, sulphate of zinc, tartaric acid.

Slips of glass, 1×3 inches, are convenient for this purpose. A circle about ¾ inch diameter is formed on each slip with a piece of paraffin or wax, and while the slips are supported in a level position, a few drops of a rather strong solution are placed in each circle, and the slips are allowed to remain quietly until the crystals form.

For methods of covering and preserving these crystals, as well as for hints on the preparation of the more difficult crystals, the reader is referred to the chapter on microscopy.

The following vegetable and animal substances may be examined by polarized light:

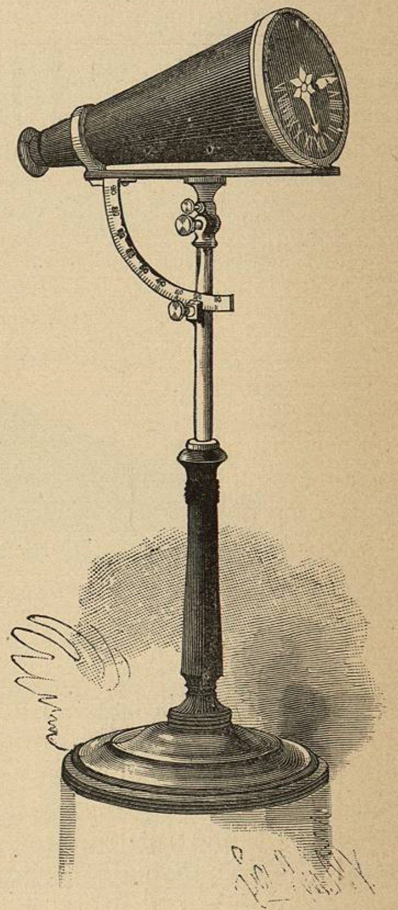
Cuticles, hairs, scales from leaves, fibers of cotton and flax, starch grains, thin longitudinal sections of wood, oiled; spicules of sponges and gorgonia, cuttlefish bone, hairs, quills, horn, finger nail, and skin. These objects should be thin and translucent or transparent. It is necessary in some cases to increase their transparency by soaking them in oil or some other suitable liquid. Many rock sections and sections of minerals may be studied advantageously by the aid of polarized light, but since the object sare quite difficult to prepare, no list of them is given.

PRACTICAL APPLICATIONS OF THE POLARISCOPE.

The practical applications of the polariscope are few but important. In chemistry, its most prominent use is in the

determination of sugars. In medicine, it finds an application in the examination of diabetic urine. In geology and mineralogy, it is of utility in determining the origin and nature of rocks and minerals. In photometry, it forms the basis of several photometers. In photography, the polariscope, or at least a part of it—the Nicol prism—has been employed for reducing the glare of highly illuminated objects. In a similar way, the Nicol prism has been used for extending the field of vision in a fog. It forms an important part of the water telescope. It has also been used to some advantage in viewing paintings unfavorably situated in galleries. In the trades the polariscope has proved useful in detecting strains in glass. By opticians, it has for years been recognized as a test for the genuineness of Brazilian pebble lenses for spectacles. It has also proved of great utility to the microscopist in the examination of minute structures.

Fig. 281.

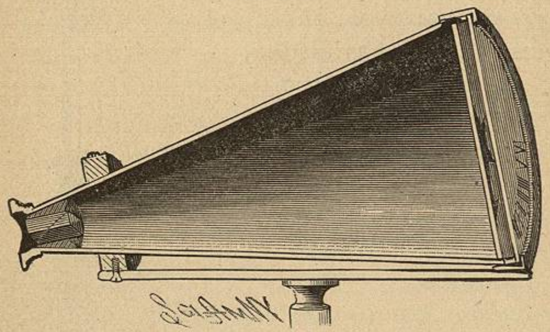


Wheatstone's Polar Clock.

The polariscope has recently been applied in France to determining the temperature of incandescent iron and other metals. The color of a glowing mass of metal varies according to its temperature, and a ray of the light when polarized is rotated by a plate of quartz to a degree dependent upon the color. The degree of rotation is measured by the polariscope, and an empirical scale of temperature is thus obtained, which has been found very useful and reliable in metallurgical operations.

One of the most curious uses of polarized light is the indication of the time of day. Sir Charles Wheatstone devised a polar clock in which a Nicol prism in connection with atmospheric polarization is made to indicate the time of day. Several forms of this instrument have been made; one of them is shown in Figs. 281 and 282.* Atmospheric polarization, according to Professor Tyndall, is due to the reflection of light from the fine particles of matter floating in the air. By examining the sky on a clear day by means of a Nicol prism and a plate of selenite or

FIG. 282.



Longitudinal Section of Polar Clock.

other crystal, polarization will be detected without difficulty. The brightest effects are noticed at a point 90° from the sun. By directing a Nicol prism to the north pole of the heavens —a position always at right angles to the sun, or approximately so—and turning it round, the colors of the crystal plate, viewed through the prism, will change in a definite order, or, if the position of the Nicol be fixed, the movement of the sun will produce similar changes of color. The polar clock is based upon this principle.

The inventor describes this instrument as follows: "At the extremity of a vertical pillar is fixed, within a brass ring, a glass disk, so inclined that its plane is perpendicular to the

* Other forms are described in Spottiswoode's "Polarization of Light."

polar axis of the earth. On the lower half of this disk is a graduated semicircle, divided into twelve parts (each of which is again subdivided into five or ten parts), and against the divisions the hours of the day are marked, commencing and terminating with VI. Within the fixed brass ring containing the glass dial plate, the broad end of the conical tube is so fitted that it freely moves round its own axis; this broad end is closed by another glass disk, in the center of which is a small star or other figure, formed of thin films of selenite, exhibiting, when examined with polarized light, strongly contrasted colors; and a hand is painted in such a position as to be a prolongation of one of the principal sections of the crystalline films. At the smaller end of the conical tube a Nicol prism is fixed so that either of its diagonals shall be 45° from the principal section of the selenite films.

The instrument being so fixed that the axis of the conical tube shall coincide with the polar axis of the earth, and the eye of the observer being placed to the Niçol prism, it will be remarked that the selenite star will in general be richly colored; but as the tube is turned on its axis the colors will vary in intensity, and in two positions will entirely disappear. In one of these positions, a smaller circular disk in the center of the star will be a certain color (red for instance), while in the other position it will exhibit the complementary color.

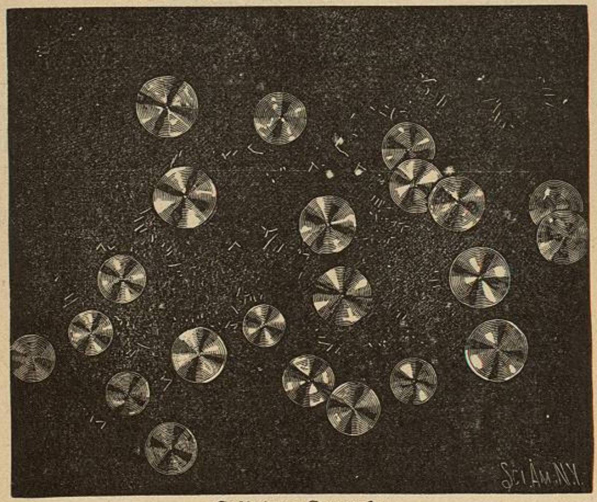
This effect is obtained by placing the principal section of the small central disk $22\frac{1}{2}^\circ$ from that of the other films of selenite which form the star. The rule to ascertain the time by this instrument is as follows: The tube must be turned round by the hand of the observer until the colored star entirely disappears, while the disk in the center remains red; the hand will then point accurately to the hour.

"The accuracy with which the solar time may be indicated by this means will depend on the exactness with which the plane of polarization can be determined. One degree of change in the plane corresponds with four minutes of solar time."

SUGGESTIONS IN DECORATIVE ART.

Occasionally, evidences of the use of the microscope in decorative art are seen, and every microscopist knows that

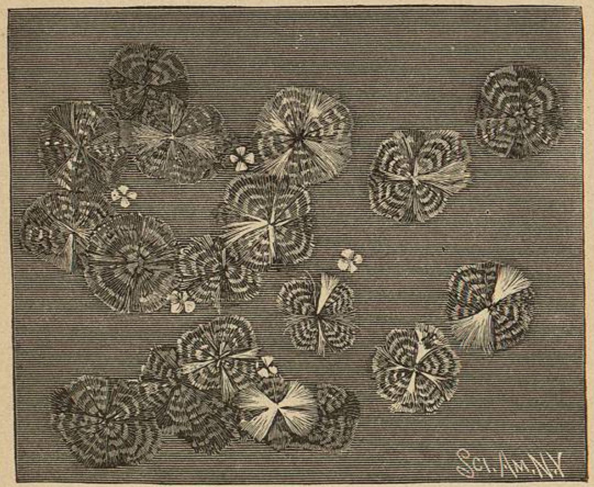
FIG. 283.



Salicine Crystals.

there are thousands of beautiful forms lost to unaided human vision which are revealed only to the user of the

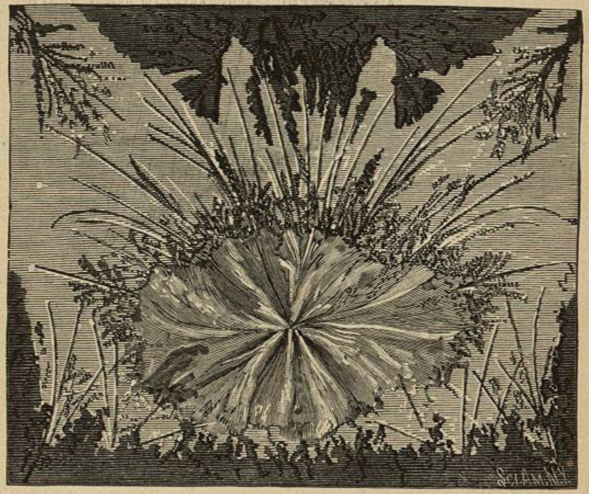
FIG. 284.



Sulphate of Cadmium.

microscope.* These minute forms are always exquisite in their construction and finish, often symmetrical and graceful

FIG. 285.



Santonine.

in form, and quite as often finely colored. All this is true of microscopic objects in general, but it is especially true of

FIG. 286.

Lithic Acid.

* See also chapter on microscopy.