down the body, so that the objective on the nose-piece nearly touches the crystal; then focus with the draw-tube exclusively. The sub-stage condenser should be racked up close to the under side of the crystal.

The use of monochromatic light is frequently desirable in microscopic work, especially blue light, although of less moment than in pre-achromatic days. The usual method of obtaining coloured light is to pass sunlight through coloured glass, or through a coloured solution, such as the ammonio-sulphate of copper; but this is a most imperfect and unsatisfactory method, and does not give *mono*chromatic light. This most valuable mode of illumination has been made possible by the use of what is now known as the Gifford screen, from the name of its inventor, Mr. J. W. Gifford; and when artificial light is used one of these screens should be interposed between the lamp and the sub-stage condenser. It is shown in fig. 266, and consists of a glass trough, about 3 inches long by 2 inches broad and $\frac{2}{10}$ths deep, filled with a solution of methyl green and glycerin mixed warm. Now this solution passes a little band of infra red, which must be cut out. To do this a piece of signal green glass just fitting the trough is placed in it.

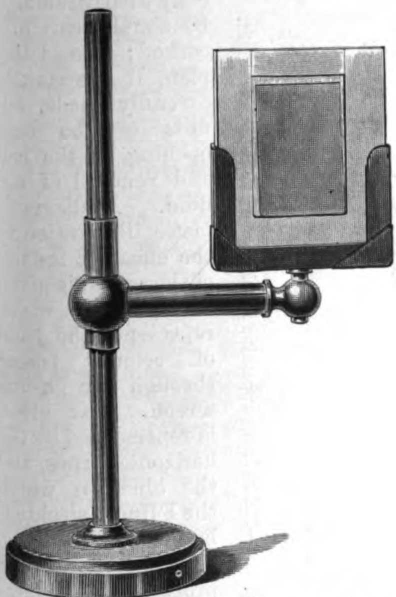

FIG. 266.—Gifford screen with an adjustable stand.

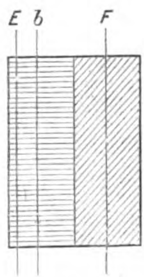

FIG. 267.—Gifford's F-line monochromatic light screen.

A piece of ordinary commercial signal green would cut out too much light, and render the screen too opaque; therefore it is requisite to have this signal green glass worked down to about half its thickness, so that only the infra red passed by the methyl green is cut out, and nothing more. This screen is called an F-line screen, because the F line is in the centre of the band passed by it. The band for general microscopical purposes may usefully extend from E to G. The importance of this screen cannot be held too high by the modern microscopist. It makes semi-apochromatic objectives equal to real apochromatics, and it sharpens the images yielded even by the latter, whilst it increases resolving power in all lenses, and ameliorates the strain often felt by workers who have not before used it.

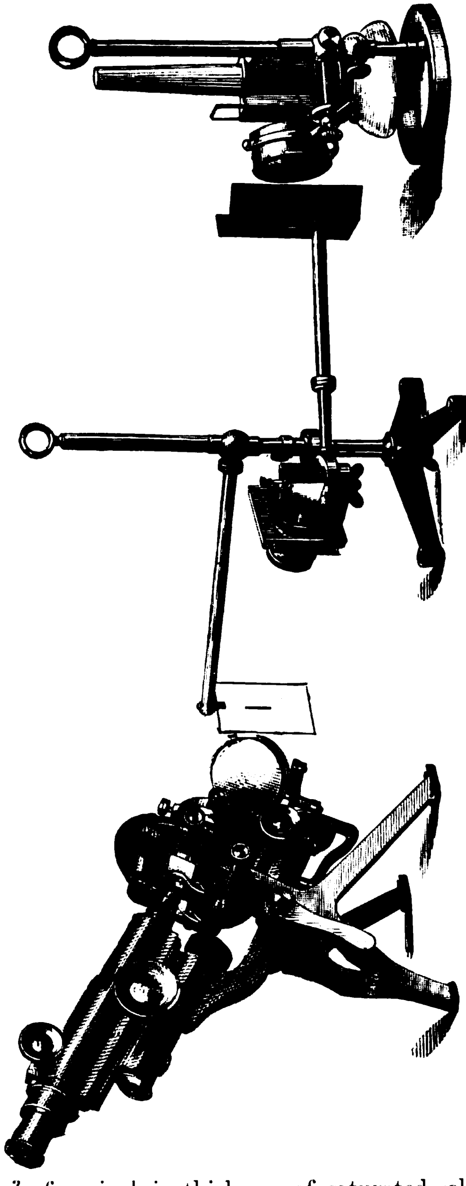

Fig. 268.—Mr. Nelson's apparatus for obtaining monochromatic light.

The cell containing the solution and worked glass may either have its upper end sealed hermetically with paraffin, or be simply carefully corked; the latter plan, if the cork is carefully made, admits of the easy opening of the cell and renewal of the fluid. A diagrammatic illustration of the effect of the use of the screen is given in fig. 267, which represents the band of colour passed through the F-line screen. The green is represented by the horizontal lines, and the blue, in which the F line is situated, by the diagonal lines.

The cell itself is prepared by the Leybolds process, and is fused at the joints and never leaks; a still simpler and less expensive means of making such a filter has been devised by Dr. A. Meithe, professor of spectral analysis at Berlin. The filter consists of a trough containing $\frac{3}{4}$ of an inch in thickness of saturated solution of acetate of copper filtered; a variation in the thickness of the troughs or tanks is desirable, but the results are excellent.

Equally perfect monochromatic illumination can be obtained by prismatic dispersion.

A method of approximating to monochromatic illumination has been devised by Mr. Nelson which answers admirably with an ordinary ½-inch wick paraffin lamp. Briefly, the rays proceeding from the radiant are passed through a slit, as in fig. 268, and dispersed by a prism of glass, and by means of a second slit any portion we wish may be selected from the spectrum to be used for the purpose required.

First an image of the edge of the flame is focussed upon the slit by means of a bull's-eye consisting of three lenses; next the slit is placed in the principal focus of a lens known as a Wray 5 × 4 R R, working at $\frac{f}{5 \cdot 6}$ (this lens is not shown in the cut). In the parallel beam from this lens and close to it is placed an equilateral prism of dense flint set at minimum deviation. Close to the prism is placed another Wray 5 × 4 R R, working at $\frac{f}{5 \cdot 6}$. If a cardboard screen be held at the principal focus of this lens, there will be seen a spectrum brilliantly illuminated. A slit $\frac{1}{10}$th inch in diameter is cut in the cardboard screen, through which the required colour is allowed to pass to the mirror of the microscope, thence to the sub-stage condenser. For visual work blue green is the best, but for photographic work blue would be chosen unless orthochromatic work required a colour lower down the spectrum.

Sorby-Browning Micro-spectroscope.[1]—When the solar ray is decomposed into a coloured spectrum by a prism of sufficient dispersive power, to which the light is admitted by a narrow slit, a multitude of dark lines make their appearance. The existence of these was originally noticed by Wollaston; but as Fraunhofer first subjected them to a thorough investigation and mapped them out, they are known as *Fraunhofer lines*. The greater the dispersion given by the multiplication of prisms in the spectroscope, the more of these lines are seen; and they bear considerable magnification. They result from the interruption or absorption of certain rays in the solar atmosphere, according to the law, first stated by Ångström, that 'rays which a substance absorbs are precisely those which it emits when made self-luminous.' Kirchhoff showed that while the incandescent vapours of sodium, potassium, lithium, &c. give a spectrum with characteristic *bright* lines, the same vapours intercept portions of the spectrum so as to give *dark* lines at the points where the bright ones appeared, absorbing their own special colour, but allowing rays of other colours to pass through. Again, when ordinary light is made to pass through coloured bodies (solid, liquid, or gaseous), or is reflected from their surfaces so as to affect the eye with the sensation of colour, its spectrum is commonly found to exhibit absorption *bands*, which differ from the Fraunhofer lines not only in their greater breadth, but in being more or less *nebulous* or

[1] For general information on the spectroscope and its uses the student is referred to Professor Roscoe's *Lectures on Spectrum Analysis*, or the translation of Dr. Schellen's *Spectrum Analysis*, and *How to use the Spectroscope*, by Mr. John Browning.

cloudy, so that they cannot be resolved into distinct lines by magnification, while too much dispersion thins them out to indistinctness. Now, it is by the character of these bands, and by their position in the spectrum, that the colours of different substances can be most accurately and scientifically compared, many colours whose impressions on the eye are so similar that they cannot be distinguished being readily discriminated by their spectra. The purpose of the micro-spectroscope[1] is to apply the spectroscopic test to very minute quantities of coloured substances; and it fundamentally consists of an ordinary eye-piece (which can be fitted into any microscope) with certain special modifications. As originally devised by Dr. Sorby and worked out by Mr. Browning, the micro-spectroscope is constructed as follows (fig. 269): Above its eye-glass, which is achromatic, and made capable of focal adjustment by the milled head, B, there is placed a tube, A, containing a series of five prisms, two of flint glass (fig. 270, F F) interposed between three of crown (C C C) in such a manner that the emergent rays, *r r*, which have been separated by dispersion, leave the prisms in much the same direction as the immergent ray entered it. Below the eye-glass, in the place of the ordinary stop, is a diaphragm with a narrow slit which limits the admission of light (fig. 269); this can be adjusted in vertical position by the milled head, H, whilst the breadth of the slit is

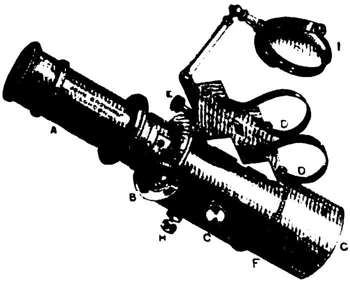

Fig. 269.—Micro-spectroscope.

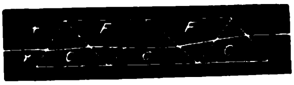

Fig. 270.

regulated by C. The foregoing, with an objective of suitable power, would be all that is needed for the examination of the spectra of objects placed on the stage of the microscope, whether opaque or transparent, solid or liquid, provided that they transmit a sufficient amount of light. But as it is of great importance to make exact comparisons of such artificial spectra, alike with the ordinary or natural spectrum and with each other, provision is made for the formation of a second spectrum by the insertion of a right-angled prism that covers one half of this slit, and reflects upwards the light transmitted through an aperture seen on the right side of the eye-piece. For the production of the ordinary spectrum, it is only requisite to reflect light into this aperture from the small mirror, I, carried at the side; whilst for the production of the spectrum of any substance through which the light reflected from this mirror can be transmitted, it is only necessary to place the slide carrying the section or crystalline film, or the tube containing the solution, in

[1] We do not make the change, lest complications should arise; but we think it would be more harmonious with analogy to call this instrument the *spectro-microscope*.