THE COLOR OF OBJECTS.

BY ARTHUR W. GRAY,

Berlin, Germany.

In nearly all of our elementary text books of physics the interesting subject of the color of objects is so inadequately treated that it does not seem out of place to describe here a few simple lecture experiments designed to bring out the principal phenomena involved in such a way as to be readily appreciated by the young mind. A clear experimental treatment is especially useful to correct some absolutely false impressions conveyed by several of our texts that enjoy a wide sale, and thereby to convince the pupil that not everything that appears in print is true:

The first step is, of course, to show that the color that an objects appears is determined largely by the color of the light that illuminates it. This may be well brought out by the stock experiment of holding various colored objects in the light of a large sodium flame, and in different parts of a bright spectrum thrown upon a white wall or screen. After it has been thoroughly appreciated that the simple colors that compose the color of the object must be present in the illuminating light, the pupils are liable to draw the erroneous conclusion that is so commonly stated or implied in the current texts, namely: that the body reflects these colors and not the others.

This impression may be corrected by showing that, when a bright beam of light is reflected from the surface of such bodies as colored glass, smooth paper, or copper sulphate solution so as to fall upon a white screen, the bright patch formed on the latter is not colored, but white. When, however, the white light is made to pass through a piece of red glass, the patch on the screen is red; and even if the transmitted beam be reflected from a piece of glass of another color, the patch will still be red. The other objects mentioned behave in a similar manner, showing that they *reflect* whatever colors fall upon them, but *transmit* only their own colors.*

*Those bodies whose surfaces are not polished must have the beam incident at a considerable angle if the reflected light is to form a readily visible patch on the screen. Highly colored glazed tissue paper tightly stretched by wetting and shrinking on a small wooden frame shows both reflection and transmission fairly well.

The next question to be settled is: How do these objects color the light that passes through them? Does a piece of red glass, for instance, add redness to the white beam? or does it subtract the other colors, leaving red as a residue? Holding the glass in the path of a beam which is decomposed by a prism into a spectrum will show that the latter is the case. With this evidence it is easy to build up the idea that in such cases as those shown the color is due to *selective absorption*, or, looked at from the opposite point of view, *selective transmission*. The light must pass through some of the object either on the way to or on the way from the surface that reflects it to the eye, even though the distance passed through be very minute, as is the case with powerful pigments. This notion may be emphasized with the aid of a piece of red glass whose rear surface has been silvered so as to reflect well the light that gets through to it. The reflected light will now form two overlapping patches on the wall, a white one due to the light reflected from the front surface, and a red one due to that which has passed through the glass and has been reflected out again from the silver.

But are we now justified in concluding that the color of an object is *always* due to selective absorption? Try reflecting white light from a piece of polished copper held so as to give a considerable angle of incidence, and preferably bent slightly concave so that the reflected light may be concentrated into a caustic curve. In this case the patch formed on a white screen is not white, but has a decidedly reddish tinge. The reflection from brass or from gold has a slightly yellow tinge. Is the color in the case of these metals due to *selective reflection*? Or does the light that is reflected from the very smooth portions of the surface manage to pass on its way through some minute projections, and thus still have its final color determined by *selective absorption*? We might, perhaps, be able to decide this question if we could obtain the metals thin enough to be transparent, so that we could compare the colors of the transmitted and the reflected light. This may be readily done by smoothly covering one-half of a microscope slide, or other piece of plate glass, with gold leaf, which will adhere if the surface of the former be very slightly oiled. Holding this in the

path of the white light, it is seen that the patch on the screen is bluish green when the light is passed through the gold, but pale yellow when reflected from its surface. The contrast between the part of the patch due to reflection from the gold and the part due to reflection from the neighboring uncovered portion of the glass brings out very clearly the yellow tinge of the former. With this evidence it is easy to develop the conception that, in some cases, notably in that of metals, the color that an object appears is determined largely by *selective reflection*, the object reflecting all colors to a certain extent, but some much better than others.

Another class of cases that may profitably be exhibited merely to show that sweeping generalizations must not be based on meager evidence, is that of fluorescent substances. But here care should be taken to avoid any attempt at giving an explanation of the phenomenon, since its adequate treatment would lead pupils of high school grade into matters that are entirely too deep for them. It is sufficient merely to show that when a beam of light is sent through one of these substances, a color appears in the interior that is different from that of the transmitted light. Very suitable substances are such common ones as kerosene, a freshly prepared alcoholic or ethereal infusion of green leaves, a solution of sulphate of quinine in water containing a little sulphuric acid, very dilute red ink, and many others. Red ink of ordinary strength shows a very strong dark green surface color, which does not seem to penetrate into the interior; with increasing dilution the color extends farther and farther inward; and when the dilution is sufficient, a beautiful bright green fluorescence marks the course of the beam within. As glass strongly absorbs that part of the radiation which causes the fluorescence, the walls of the containing vessel should be thin if the light is admitted from the side; but the better practice is to reflect it vertically downward directly into the liquid. Concentrating by means of a lens so that the focus falls within the body renders the phenomenon still more visible to a large audience.

Irridescence and other color effects due to interference or diffraction, are, of course, entirely outside the province of secondary school instruction.