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Glow sticks: Spectra and color mixing revisited

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A previous *TPT* article discussed using glow sticks to demonstrate color mixing by comparing the spectra of red, green, and blue glow sticks to those of yellow and magenta glow sticks.[1] More recently, a paper in the *Journal of Chemical Education* describes a method to separate glow stick dyes using chromatography with chalk and a solvent of acetone or alcohol.[2] This method, while a valuable experience in a chemistry class, requires the glow stick to be opened. Care must be taken by preparers to remove glass shards, and participants are exposed to possible skin irritants. Here we propose a non-destructive, hazard-free method to "separate" the dyes using the RSpec Explorer spectroscope that can be used as a laboratory experiment or a student project.

Glow sticks are now available in a broad range of colors: red, green, blue, yellow, aqua (cyan), orange, purple, pink (magenta), and white. For example, Lumistick makes six-inch long glow sticks in the above colors. These can be purchased on Amazon.com or glowsource.com. Here we use Lumistick glow sticks in primary colors (red, green, blue) and secondary colors (yellow, cyan, magenta).

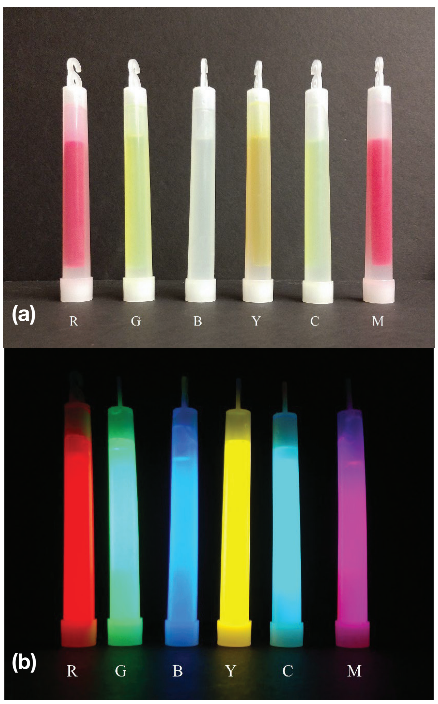

Fig. 1. (a) The six unactivated glow sticks used in this study: from left to right red (R), green (G), blue (B), yellow (Y), cyan (C), magenta (M). (b) The six glow sticks upon activation as viewed in the dark.

Figure 1 shows the glow sticks both prior to and after activation. A visual examination of the unactivated glow sticks might lead one to suspect that the dyes used in red and blue are mixed to produce the magenta glow stick: red fluid mixed with clear fluid would likely yield the slightly less intense shade of red. The same reasoning applies to the other colors. Our hypothesis is that the dyes used in the primary color glow sticks are simply mixed as per the usual color addition formulae: Red + Blue = Magenta, Red + Green= Yellow, and Green + Blue = Cyan.[3]

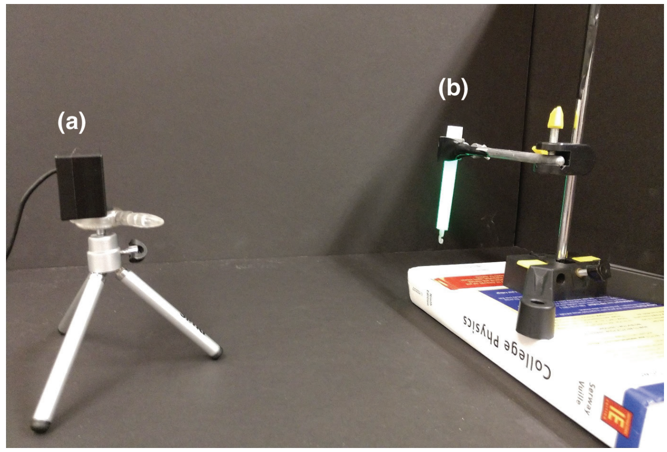

Fig. 2. The experimental setup, which includes the RSpec Explorer spectroscope (a) attached via USB cable to (unseen) laptop and the glow stick (b) held by a clamp and ring stand combination. The glow stick is inserted upside down so that different glow sticks can be swapped in and out with ease. The spectroscope is about 20 inches from the glow stick. The black foam boards provide contrast and reduce stray light and reflections. Data are obtained in a darkened room.

We test this hypothesis by examining the spectra of the glow sticks using an RSpec Explorer spectroscope. If the secondary colors are produced by simple 1:1 mixing of primary color dyes, then we should see common spectral features. The RSpec Explorer is a webcam-based grating spectroscope that comes with its own software. It displays a wavelength-calibrated spectral plot for semi-quantitative spectral analysis: the intensity is uncalibrated and can only provide a sense of relative intensity if source distance is fixed relative to the spectroscope.

The experimental setup is illustrated in Fig. 2. A clamp and ring stand combinationwere used to hold the glow stick. Black foam board was used as a background to increase contrast and block extraneous light. Data are obtained in a darkened room. While collecting data, we did not move the ring stand or the spectroscope; we simply swapped out glow sticks. The glow stick and spectroscope remained at the same distance, about 20 inches apart.

When examining the resulting spectra in Figs. 3-5, note that small variations in wavelength may result from slight shifts in the ring stand when exchanging glow sticks. Similar to chalk chromatography experiments, the best results were obtained for the magenta or "pink" glow stick (Fig. 3). The blue glow stick has a broad spectral feature centered at about 460 nm and the red a feature near 625 nm; the magenta glow stick spectrum contains the same two features. Students can easily argue that the blue and red glow stick dyes are simply mixed to produce the magenta glow stick.

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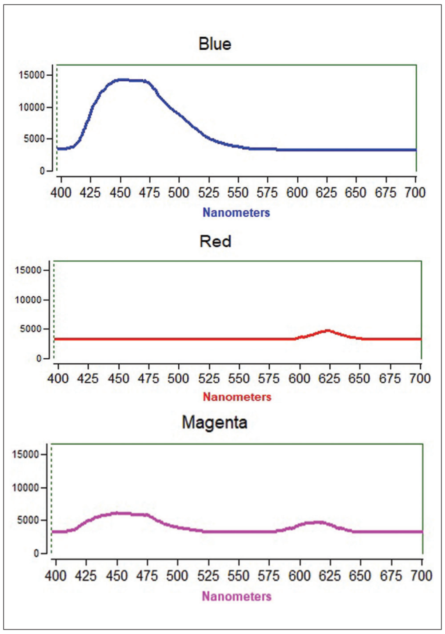

Fig. 3. Blue + Red = Magenta: In this figure and those that follow the *x*-axis is the wavelength in nanometers while the *y*-axis is intensity. However, the intensity values are not calibrated; we have removed them as we are simply interested in the wavelength features in each glow stick. Here we see the same features in the blue and red dyes appearing in the magenta glow stick.

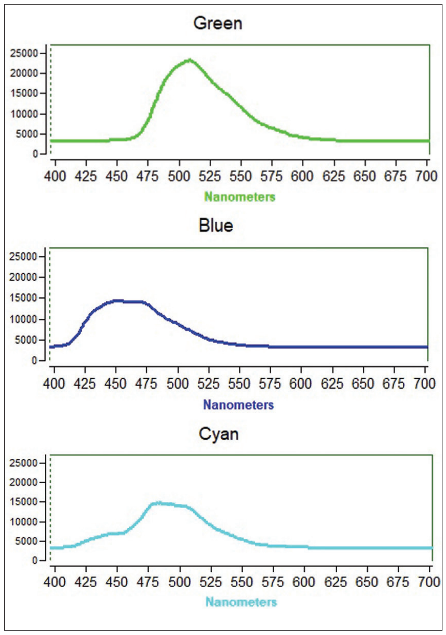

Fig. 4. Green + Blue = Cyan: While not quite as obvious as the previous example, the blue and green dye contributions can be discriminated in the magenta glow stick.

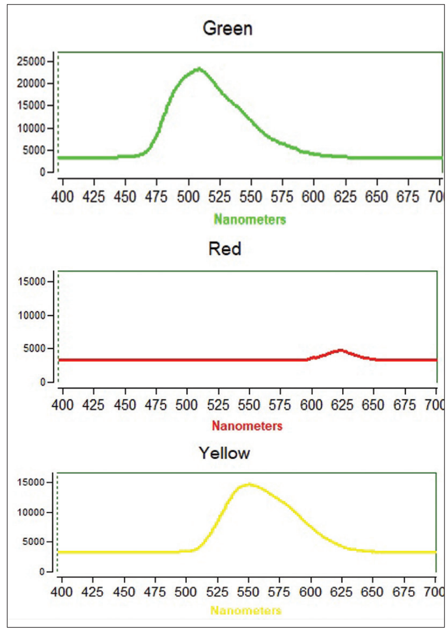

Fig. 5. Green + Red = Yelllow: It might be far more difficult to convince a student that the yellow glow stick is created by mixing the same dyes found in the green and red glow sticks. Either the yellow glow stick contains a different dye or the red dye is absorbing light from 450 to 550 nm.

The spectrum of a cyan glow stick appears to be a blend of the green and blue glow sticks. Note the "peaks" at about 437 nm and 475 nm seen in the blue glow stick and the one at roughly 520 nm seen in the green: these are also discernible in the cyan spectrum. Despite spectral blending, students should still be convinced that the dyes from the green and blue glow sticks are mixed to create a cyan glow stick.

The yellow glow stick spectrum is more problematic. The green spectral component seen in the green dye stick appears to have undergone significant absorption on the short wavelength end and the red spectral feature is difficult to identify. Either the red dye is absorbing some light in the 450 to 550 nm range or there is a chemically unique dye that creates the yellow color, not a mixture of red and green dyes.[4-5] For example, the red dye, rhodamine 6g, which is sometimes used in red glow sticks, has strong absorption in the 450 to 525 nm wavelength range.[6] This might also explain the decreased intensity observed in the blue spectral feature of the magenta spectrum. Without access to a spectral database of fluorophore dyes, we cannot refute either possibility.

These results support color addition of primary fluorescent dyes to create secondary colors in some glow sticks. A high school or college student with access to a digital spectroscope can pursue small research projects with glow sticks, perhaps examining different glow stick brands or examining spectra of orange, purple, and white glow sticks. This technique is simple and nondestructive so glow sticks can be used for other experiments or simply enjoyed afterwards. Students can gain experience with color-mixing concepts, spectroscopic analysis, and the connection between physics and chemistry.

References

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