Fluorescence in cola drinks and caramel

The popularization of laser pointers makes accessible to everybody many optical experiences of large didactic value. In this work we report color-changing fluorescence in cola drinks and in water-dissolved caramel. When illuminated by a green laser pointer (532 nm wavelength) in a darkened room, the light path within the liquid becomes reddish or even deep red, in sharp contrast with the green color in air, tube water and container walls (see Fig. 1). In the first instance, when confronted with this phenomenon most people regards the color change as natural because of the very same reddish color of cola drinks and caramel in a white-light environment. Thus, we find extremely formative the physical reasoning that, starting from laser monochromaticity and darkened environment, leads to frequency-changing fluorescence as the most plausible explanation. In this work we provide several simple tests whose results are compatible with this hypothesis.

The basic idea of frequency-changing fluorescence is schematized in Fig. 2. Sample internal energy levels are represented by horizontal lines. The absorption of a green photon drives the internal state from the ground state (the only populated in darkness) to an excited level. Excited levels are unstable so this is followed by a transition to some less energetic state. When this is slightly above the ground state, the emitted photons have lesser energy, this is lesser frequency or larger wavelength according to the Einstein relation according to which photon energy is proportional to frequency or the inverse of wavelength. This allows the change from green to larger wavelengths in the reddish part of the spectrum.

We have observed the effect in most reddish cola drinks having in common just the caramel-based food coloring E150d. Moreover, there was no effect in some other reddish drinks without such ingredient. This led us to try the effect in home-prepared caramel dissolved in water, obtaining a more pronounced effect for large concentrations, displaying stronger green absorption and conversion to deeper red (see Fig. 1).

We have tested the frequency-changing fluorescence hypothesis in several different ways. On the one hand we expect the samples to be more absorbing for green light than for red light. This has been tested by measuring the spectral transmittance by collecting in a pre-calibrated Hamamatsu photodiode the light intensity leaving the sample when illuminated by the frequency-varying output of an Oriel Cornerstone 260 monochromator (1 nm resolution) illuminated by white light. The records are in Fig. 3 confirming that the cola drink and the caramel absorb more in the blue-green part of the spectrum (with vanishing transmittance below 550 nm for cola drink) than in the red parts of the spectrum (with 30% to transmittance around 700 nm for cola drink). Note the strong similarity of the spectra for cola drink and caramel in full agreement with their reddish color under white light. A resonance around 970 nm can be also clearly appreciated.

A more powerful hypothesis contrast is provided by observing and recording the fluorescence spectrum.

The spectrum observation has been carried out with an Edmund Optics spectroscope whose output has been photographed with a Nikon D90 digital camera (see Fig. 4). The spectrum clearly shows the appearance of new spectral components, all them with larger wavelengths than the original one. This is compared in Fig. 4 with the spectrum of common fluorescent lamp where ultraviolet radiation is converted at the phosphor coating inside the tube into smaller wavelengths distributed through the whole visible spectrum.

The spectra have been recorded by forming an image of the pointer-beam path within the liquids in the input of an Ocean Optics USB4000 spectrometer. The spectra are displayed in Fig. 5 being compared with the spectrum when the samples are removed. The red-shifted fluorescence is clearly visible confirming that the color change is not a visual deception. Note the stronger red shift in the most concentrated caramel sample, and the equality of the background noise for all spectra.

Finally, we have observed no polarization in the fluorescence light emitted at right angles with respect to the pointer beam, that excludes Rayleight scattering.

Concerning bibliography, we are aware of the same effect arising in oil [1,2] and in tonic water [3] illuminated by ultraviolet radiation. We don't have found any report of frequency shifts in cola drinks or caramel. Fluorescence in caramel has been used to detect its presence in different drink environments [4].

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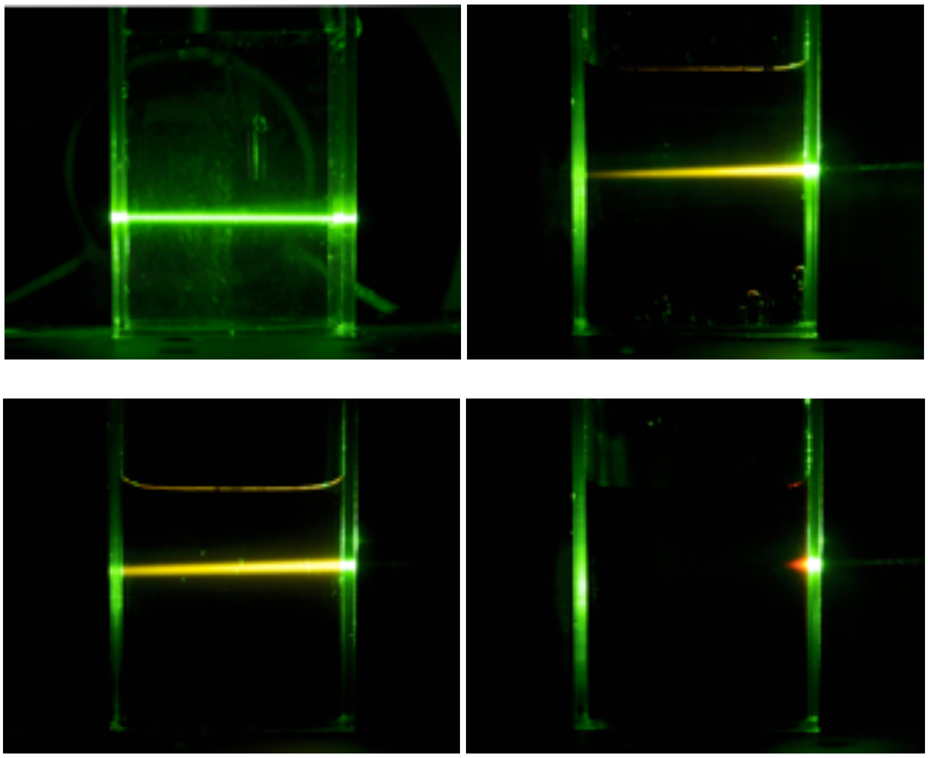

Figure 1.- Green laser pointer in tube water (upper left), cola drink (upper right), less concentrated caramel (lower left), and more concentrated caramel (lower right).

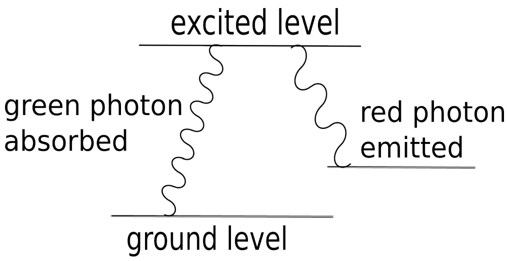

Figure 2.- Energetic relations involved in frequency-changing fluorescence.

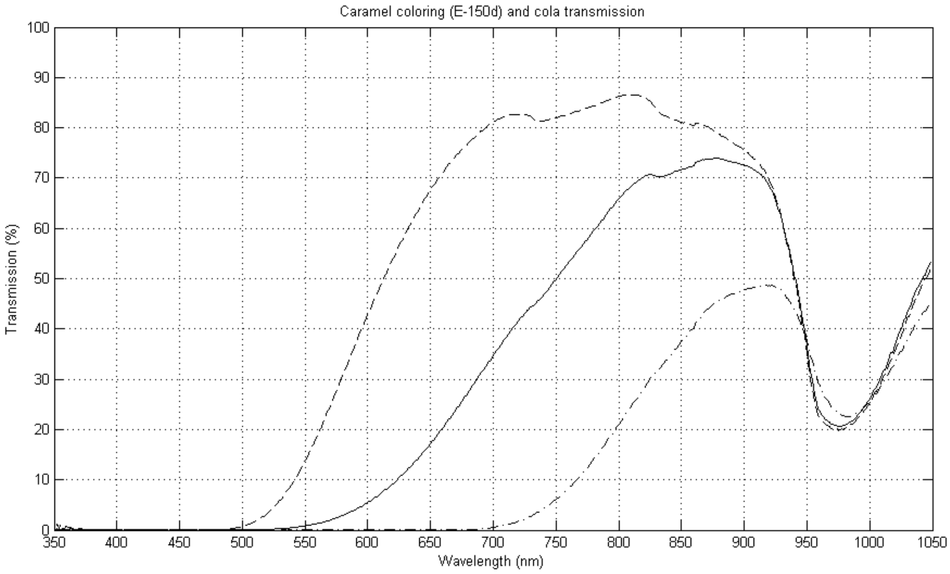

Figure 3.- Transmittance spectra of cola drink (solid line), less concentrated caramel (dashed), and more concentrated caramel (dot dashed).

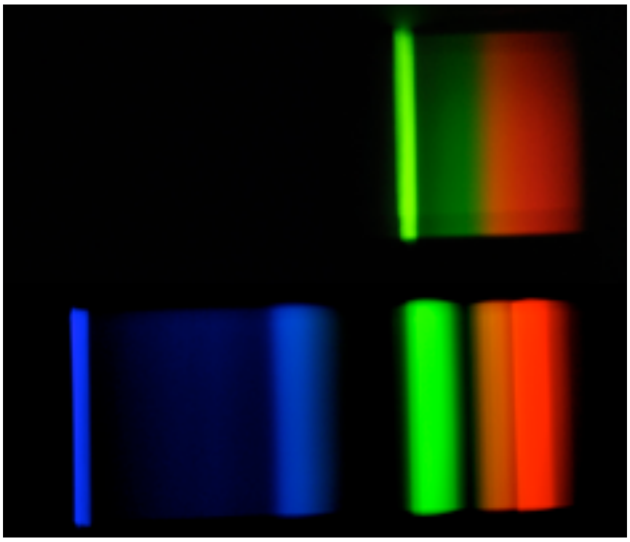

Figure 4.- Spectroscope output of the laser-pointer beam within cola drink (upper) and of a common fluorescent lamp for the sake of comparison (lower).

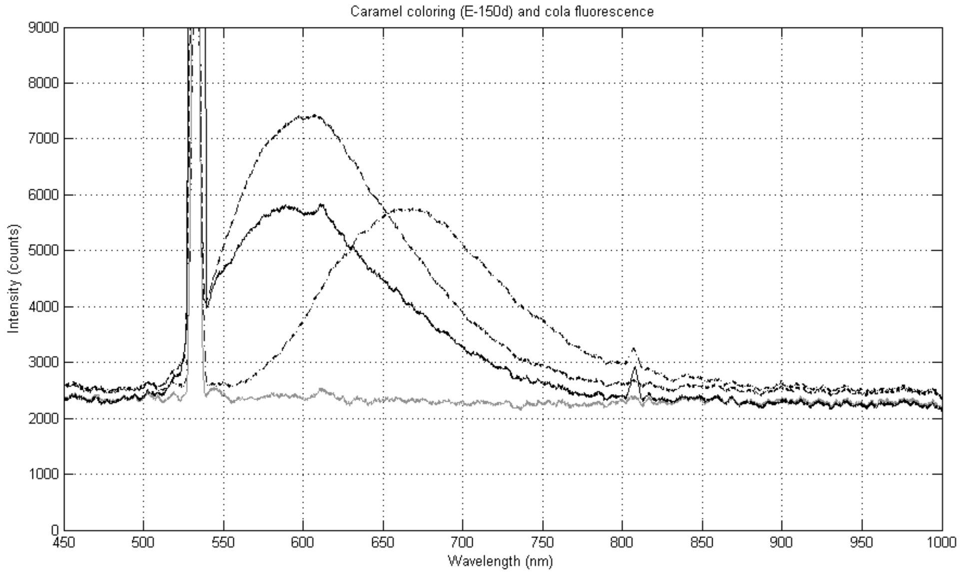

Figure 5.- Recorded spectra of the pointer light within cola drink (solid line) less concentrated caramel (dashed line higher), more concentrated caramel (dashed line reddish), and in air (grey line).