Substances with a Single Visible Absorption Band Cannot Be Green

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Abstract: Some chemistry textbooks use an inappropriate colour model when discussing the colour of a substance that absorbs light at a specific wavelength. More specifically, these textbooks state that substances that absorb only in the violet end of the visible spectrum are green-yellow and substances that absorb only in the red end are blue-green. This paper presents a more accurate approach.

Keywords: Absorption · Colour · Visible spectrum

In colour theory there is a long-standing tradition of representing the colour spectrum with a wheel; some examples are shown in Fig. 1. One of the main features of these colour wheels is that complementary colours are opposite to each other. However, the complementary colour of a given colour strongly depends on the colour model (RGB, CMYK, etc.) used. In many of these colour wheels (as can be seen in Fig. 1) the complementary colour of violet is a greenish yellow, and the complementary colour of red is a bluish green. Unfortunately, this has become established in some chemistry textbooks and websites when the colour of a substance is discussed as a function of the absorbed wavelength in the visible spectrum. So a substance that absorbs only in the short-wavelength (violet) end of the visible spectrum is wrongly considered to be green-yellow, and a substance that absorbs only in the long-wavelength (red) end is wrongly considered to be blue-green. The purpose of this paper is to provide a more accurate discussion of colour versus absorbed wavelength.

If a substance absorbs only monochromatic light with the wavelength \( \lambda_{\text{abs}} \), the observed hue of this substance can be inferred using the CIE chromaticity diagram by drawing a straight line from the absorbed wavelength through the white point, which depends on the colour temperature of the illuminant (Fig. 2). If we use a colour temperature of 5000 K (point D50 in Fig. 2), which roughly corresponds to sunlight, a substance with \( \lambda_{\text{abs}} = 380 \text{ nm} \) (the violet end of the visible spectrum) has a hue corresponding to approximately 570 nm (yellow). Another substance with \( \lambda_{\text{abs}} = 700 \text{ nm} \) (the red end of the visible spectrum) has a hue corresponding to approximately 495 nm (cyan), which is definitely closer to blue than the colour called ‘blue-green’.

A famous example of a substance that absorbs only at the far violet end of the visible spectrum is retinol with five conjugated double bonds (UV-VIS absorption spectrum in Fig. 3). This substance is definitely yellow and not green-yellow. As for the red end of the visible spectrum, the author unfortunately is not aware of any substance that only absorbs at wavelengths around \( \lambda_{\text{abs}} = 700 \text{ nm} \) without absorbing shorter wavelengths as well.

As for green substances, it is clear from Fig. 2 that drawing a straight line from, say, 520 nm through the white point leads to

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a hue on the so-called purple line that connects the wavelengths 380 nm and 700 nm, and these hues do not correspond to monochromatic light. A famous example for a green substance is chlorophyll, which indeed has two absorption maxima (Fig. 3).

In Fig. 4 the author attempts to make a more accurate rendition of the perceived colour of a substance that absorbs light only in a narrow band. The colour spectrum on the upper part (absorption) has been made using the wavelength-to-colour conversion in Wolfram Alpha[11] and the perceived colour on the lower part using the procedure described above with the white point D50. In conclusion, although the author is perfectly aware that no computer screen – and even less printed paper – is able to reproduce hues of monochromatic light with reasonable accuracy, he recommends using a diagram similar to Fig. 4 when discussing the colour of substances with a single visible absorption band.

**Supplementary Material**

In order to provide a truer reproduction of the colours under discussion, the original graphics files of Figs 1-4 are available as Supplementary Material at https://chimia.ch/chimia/article/view/2023_688.

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Fig. 2. Using the 1931 CIE chromaticity diagram[8] for inferring the perceived hue from the absorption frequency.

Fig. 3. UV-VIS spectrum of all-trans-retinol[9] and chlorophyll.[10]

Fig. 4. Hues of substances with single absorption bands in the visible-light spectrum.


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