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Substances with a Single Visible Absorption Band Cannot Be Green

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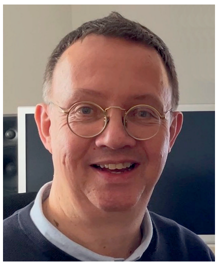
Abstract: Some chemistry textbooks use an inappropriate colour model when discussing the colour of a substance that absorbs light at a specific wavelength. More specifically, these textbooks state that substances that absorb only in the violet end of the visible spectrum are green-yellow and substances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

Keywords: Absorption · Colour · Visible spectrum



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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.[4–6] 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 λ_{abs}, the observed hue of this substance can be inferred using the CIE chromaticity diagram[7] 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 λ_{abs} = 380 nm (the violet end of the visible spectrum) has a hue corresponding to approximately 570 nm (yellow). Another substance with λ_{abs} = 700 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.[9] As for the red end of the visible spectrum, the author unfortunately is not aware of any substance that only absorbs at wavelengths around λ_{abs} = 700 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

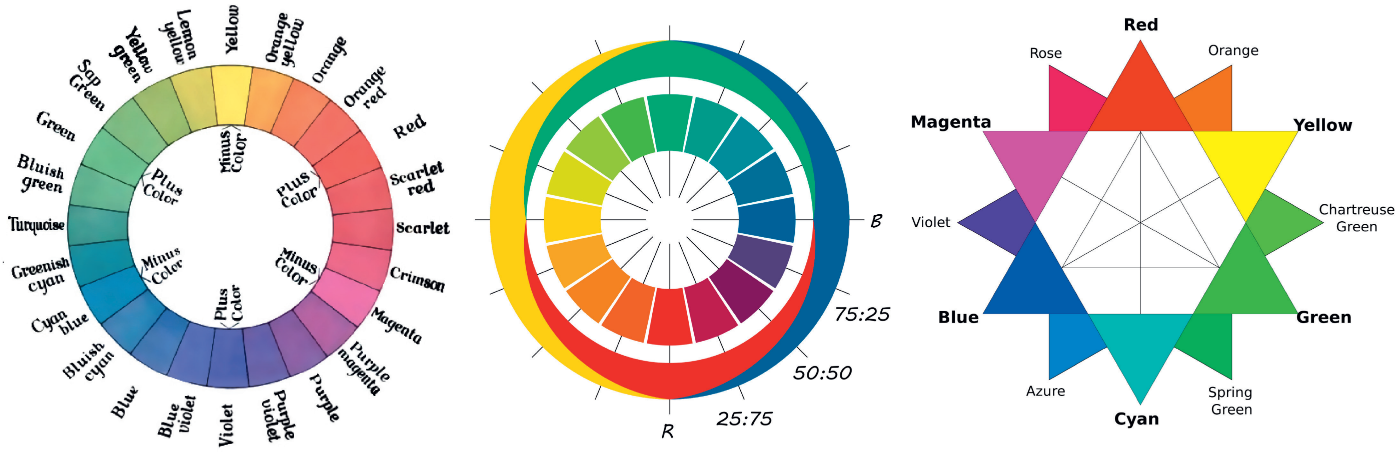

Fig. 1. Three examples of colour wheels: the left one[1] and middle one[2] are taken from historical treatises, the right one[3] refers to the RGB colour model.

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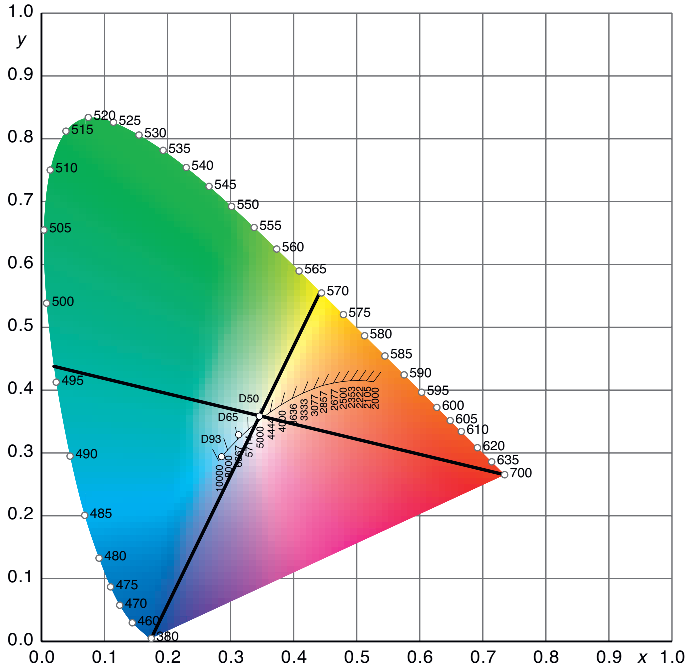

Fig. 2. Using the 1931 CIE chromaticity diagram[8] for inferring the perceived hue from the absorption frequency.

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

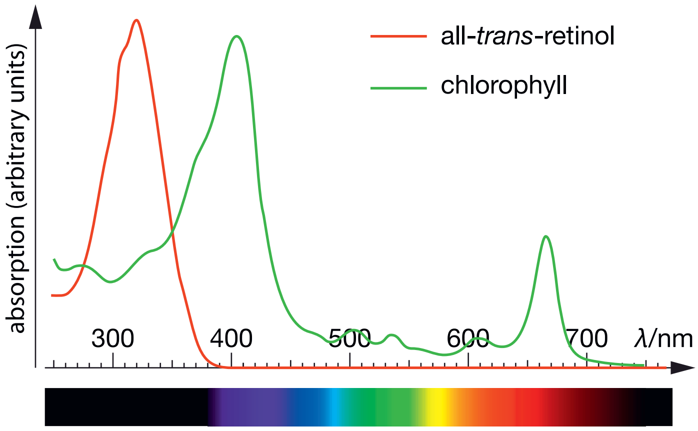

Fig. 3. UV-VIS spectrum of all-*trans* retinol[9] and chlorophyll.[10]

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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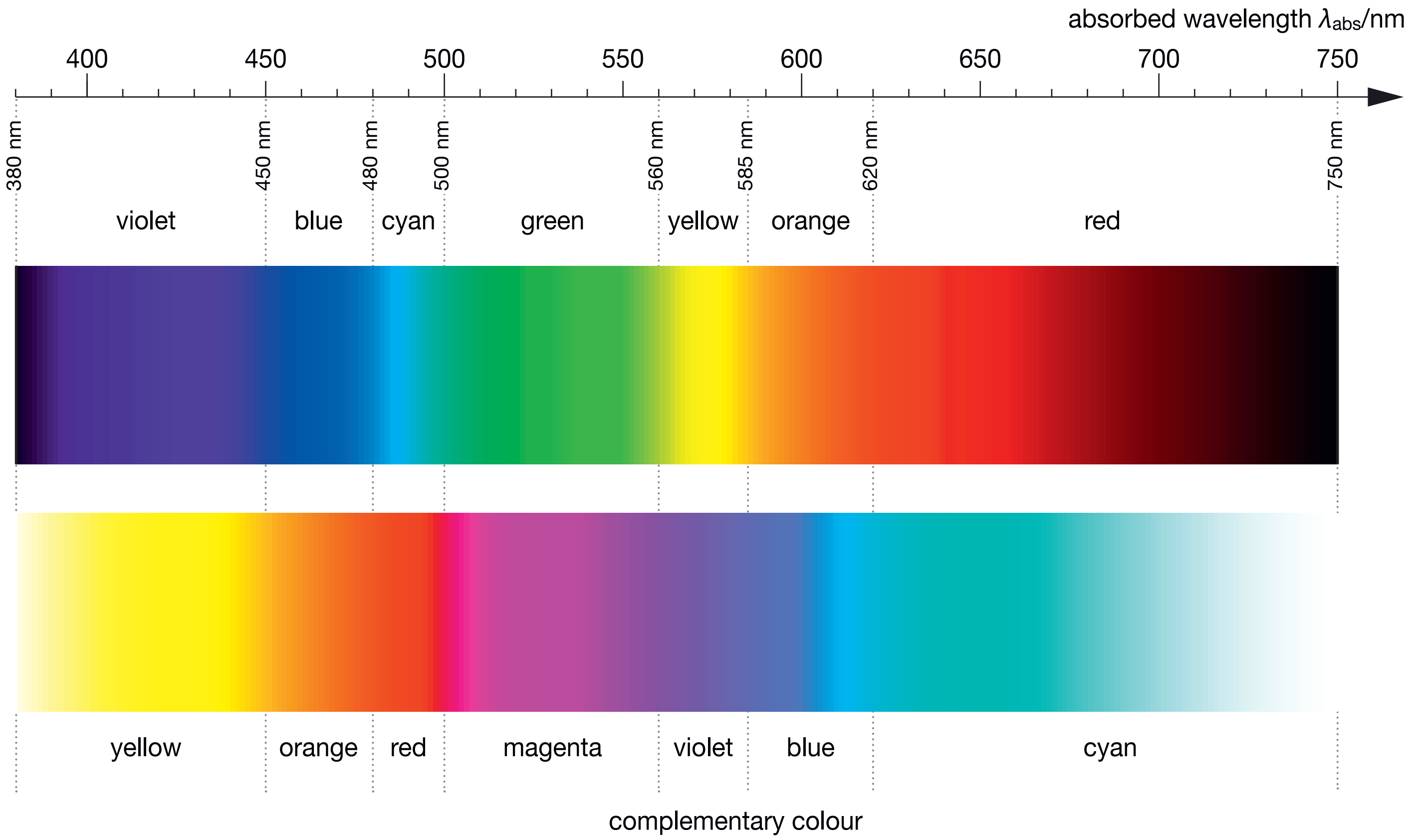

Fig. 4. Hues of substances with single absorption bands in the visible-light spectrum.

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