Analysis of Food Dyes in Beverages

Introduction

Assume an investigative role and design a valid procedure using spectroscopy and graphical analysis to determine the concentration of FD&C food dyes in sports drinks. The investigation will develop – and test—your skills in preparing accurate serial dilutions, understanding spectroscopic measurements, and extrapolating from graphical data.

Concepts

Spectroscopy Wavelength Beer’s Law

Absorbance vs. transmittance Consumer science Solution Concentration

Background

The color of a solution is an important tool used by scientists to gain information about the composition of the solution. Color is a physical property that is useful for both qualitative and quantitative analysis. A qualitative method yields information about the nature or type of compound in a sample, whereas a quantitative method provides numerical data for the amount of a compound in a sample.

Spectroscopy is the student of the interaction of light and matter. A spectrophotometer is an instrument that uses electromagnetic radiation from a selected region of the electromagnetic spectrum, such as ultraviolet, visible or infrared length, to analyze the absorption or transmission of radiation by a sample. The basic function of a spectrophotometer is shown in Figure 1. The electromagnetic spectrum (see Figure 2) is the entire range of possible wavelengths or frequencies of electromagnetic radiation. In this investigation a visible spectrophotometer will be used – it scans the visible region of the electromagnetic spectrum from 380 nm to 750 nm. Typical light sources for visible spectrophotometers include xenon and tungsten lamps.



Glass cuvettes or test tubes may be used as sample cells for visible spectrophotometers. More specialized spectrophotometers require quartz cells, which are “invisible” to and do not absorb ultraviolet radiation. In addition to the energy source used in spectrophotometers, a diffraction grating called a monochromator is also incorporated. The monochromator spreads the beam of light into the light’s component wavelengths. The desired wavelength is then focused onto the sample cell to detect any absorption or emission of light by a substance in a sample.

Spectrophotometry is an analytical procedure that uses electromagnetic radiation to measure the concentration of a substance. The success of a spectrophotometric technique requires that the absorption of light by the substance being analyzed must be distinct or different from that of other chemical species in solutions. How do scientists select the desired wavelength?

The absorption of visible light by a substance results from electron transitions, that is, the promotion of a ground state electron to a higher energy atomic or molecular orbital. Both light energy and electron energy levels are quantized, so that the specific wavelength of light absorbed by a substance depends on the energy difference between two electron energy levels. The optimum wavelength for spectrophotometric analysis of a substance is selected by measuring the visible spectrum of the substance, corresponding to a plot of absorbance (A) versus wavelength (λ).

Just seven unique dyes are approved by the Food and Drug Administration for use in foods, drugs and cosmetics. These seven FD&C dyes give rise to the entire palette of artificial food colors. Three FD&C dyes, FD&C Blue 1, FD&C Red 40, and FD&C Yellow 5 are provided in this advanced inquiry lab for the analysis of sports drinks and other beverages. The structure of FD&C Blue 1 is shown in Figure 3. Notice the extensive series of alternating single and double bonds ( also called conjugated double bonds) in the center of the structure. This feature is characteristic of intensely colored organic dyes and pigments. Every double bond added to the system reduces the energy difference between the bonding and nonbonding molecular orbitals so that the resulting energy gap corresponds to visible light.





A solution containing FD&C Blue 1 appears blue under normal white light—this is the color of light transmitted by the solution. The colors or wavelengths of light that are absorbed by this solution are complementary to the transmitted color. A color wheel (figure 4) provides a useful tool for identifying the colors or wavelengths of light absorbed by a substance. The blue solution absorbs yellow, orange,and red light and we would expect the visible spectrum of FD&C

Blue 1 to contain a peak in the 580-650 nm region. The optimum wavelength for spectrophotometric analysis of a

dye solution is generally determined from the wavelength of maximum absorbance ( abbreviated λmax). The value of λmax for FD&C Blue 1 is 630 nm.

The wavelength of light absorbed by a substance is characteristic of its molecular or electronic structure. The

intensity of light absorbed depends on the amount of the substance in solution. Generally, the more concentrated the

solution, the more intense the color will be, and the greater the intensity of light the solution absorbs. A digital spectrophotometer measures both the percent transmittance of light and the absorbance. When light is absorbed, the radiant power (P) of the light beam decreases. Transmittance (T) is the fraction of the incident light (P/Po) that passes through the sample (see Figure 5). The relationships between transmittance and percent transmittance (%T) and between transmittance and absorbance (A) are given in Equations 1 and 2, respectively.

%T = T X 100 = P/Po X 100% Equation 1

A = absorbance = - log T Equation 2

P

Po

B

bBb

b

c

Figure 5

The amount of light absorbed by a solution depends on its concentration c as well as the path length of the sample cell (b) through which the light must ravel. See Equation 3, which is known as Beer’s Law. The constant ε (Epislon) in the equation is a characteristic of a substance and is known as the molar absorptivity coefficient.

A = εbc Equation 3