APPLICATION NOTE

SPECTROSCOPY EXPERIMENT: DRY ICE EFFECT ON COLOR ABSORBANCE OF PH INDICATORS

CONDUCTED BY SARA BEARD

INTRO

BACKGROUND OF APPLICATION

In this experiment, we tested the color change of three pH indications from a basic initial state to an acidic final state. The three indicators used were universal indicator, bromocresol green, and phenol red. Dry ice was used to increase the acidity of these solutions. Dry ice is the solid form of carbon dioxide, and when dissolved in water, it produces carbonic acid. Once the carbon acid is formed, the hydrogen atoms dissociate, and the acidity of a system increases. Before adding the dry ice to the solutions, absorbance measurements will be taken to compare the colors of the initial and final solutions.

The smoke that occurs when dry ice is dissolved in water is the carbon dioxide and water vapor that freezes due to the low temperature. The temperature of dry ice is around -77o C. The main use of dry ice in this experiment is to lower the pH of the solutions. A bonus to running this experiment is to see the sublimation of carbon dioxide. Sublimation is the phase transition of a substance from solid to gas and is why, in this case, the final solution outputs fog.

DESCRIPTION OF SPECTROSCOPY SETUP

The AvaSpec-ULS2048XL-EVO (Figure 1) is a SensLine High UV and NIR Sensitivity back-thinned CCD (charged-coupled device) spectrometer. The AvaSpec-ULS2048XL-EVO has exceptional sensitivity over the range from 200-1160 nm and allows for a minimum integration time of 2 microseconds due to an embedded electronic shutter in the detector. Unlike many back-thinned CCD spectrometers, which have two-dimensional arrays, the ULS2048XL-EVO has large monolithic pixels of 14X500 microns with unusually high quantum efficiency in the UV, from 200- 400 nm, and the NIR (Near Infrared Range), from 950- 1160 nm. The ULS2048XL-EVO uses the AS7010 (AKA EVO) electronics board, which offers USB3.0, and Gigabit Ethernet communication options. Connection to a PC is handled either via a USB3.0 connection or Ethernet, delivering a scan every 2.44 milliseconds (data transfer rate).

FIGURE 1 System Setup including Avaspec-ULS2048XL-EVO

The light source used for this experiment was the AvaLight-HAL-S-Mini which is a Tungsten-Halogen light source that is commonly used for spectral measurements in the visible to near-infrared wavelength ranges. It's a compact, stabilized halogen light source, with adjustable focusing of the fiber connection, maximizing output power at the desired wavelength. The light source also has adjustable output power to provide extra power or longer lamp life depending on the application needs. This light source was chosen for the experiment because the AvaLight-HAL is ideal for absorption/transmittance measurements in the visible spectrum. The wavelength range of this light source is 360- 2500 nm. The AvaLight-HAL-S-Mini also features an internal TTL-shutter, controllable from an AvaSpec Spectrometer. This gives the ability to periodically shutter the light source to take a dark during an experiment or process. This shuttering can be done manually or via software control.

The other two components of the system were a cuvette sample holder (CUV-UV/VIS) and two 400-micron UVIR fiber optic cables. The cuvette sample holder was designed for absorption and fluorescence measurements and should be used with a standard 10x10mm cuvette. A quartz cuvette was used inside the sample holder. Two 400-micron UVIR broadband fiber optic cables were used to connect the light source & cuvette and spectrometer & cuvette.

DESCRIPTION OF METHODOLOGY AND TESTING

Three ethrlenmeyer flasks were filled with 500 mL of distilled water to begin the experiment. In each vessel, a different acid-base indicator was used. Ten to fifteen drops of the indicators went into the respective flasks. One to two drops of ammonia were added to each beaker to get the basic solution color of the indicators. The leftmost beaker had universal indicator, which in basic solution (pH ~ 11), has a purple color (Figure 2). The middle beaker had bromocresol green, which in basic solution (pH ~ 5.4), has a bright blue color. The right beaker had phenol red, which in basic solution (pH ~ 7.8), has a magenta color.

FIGURE 2: Initial colors of the pH indicators in basic solution

Once the basic solutions were mixed, 2 mL of each solution were pipetted into a cuvette to test the absorbance of each sample. Absorbance measures the amount of light absorbed by a solution for a specific wavelength. Absorbance will be helpful with identifying the color change from basic to acidic solution once the dry ice is added.

To take the spectral absorbance readings, we first set an integration time of 45 µs with an average of 30 on the AvaSoft software. We then took light and dark references to prepare for the basic solution samples. The light reference was taken with a cuvette filled with clear distilled water. The absorbance of the basic solution of universal indicator (purple), bromocresol green (blue), and phenol red (magenta) can be seen in Figure 3. The colored lines in the spectral readings correspond to the color of the solutions

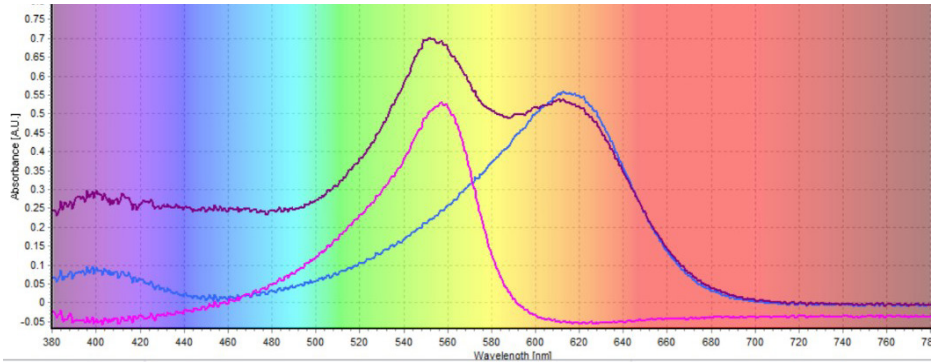

FIGURE 3: Figure 3: Absorbance of the basic solutions of universal indicator (purple line), bromocresol green (blue line), and phenol red (magenta line)

DESCRIPTION OF METHODOLOGY AND TESTING

After the absorbance measurements were taken for the initial-colored solutions, we then set up the beakers for the addition of dry ice pellets. One small pellet of dry ice was added to each beaker sequentially from left to right. In a matter of seconds, the colors of the basic solutions began to change. The Figure below gives a time-lapse of the solutions after the dry ice pellets were added.

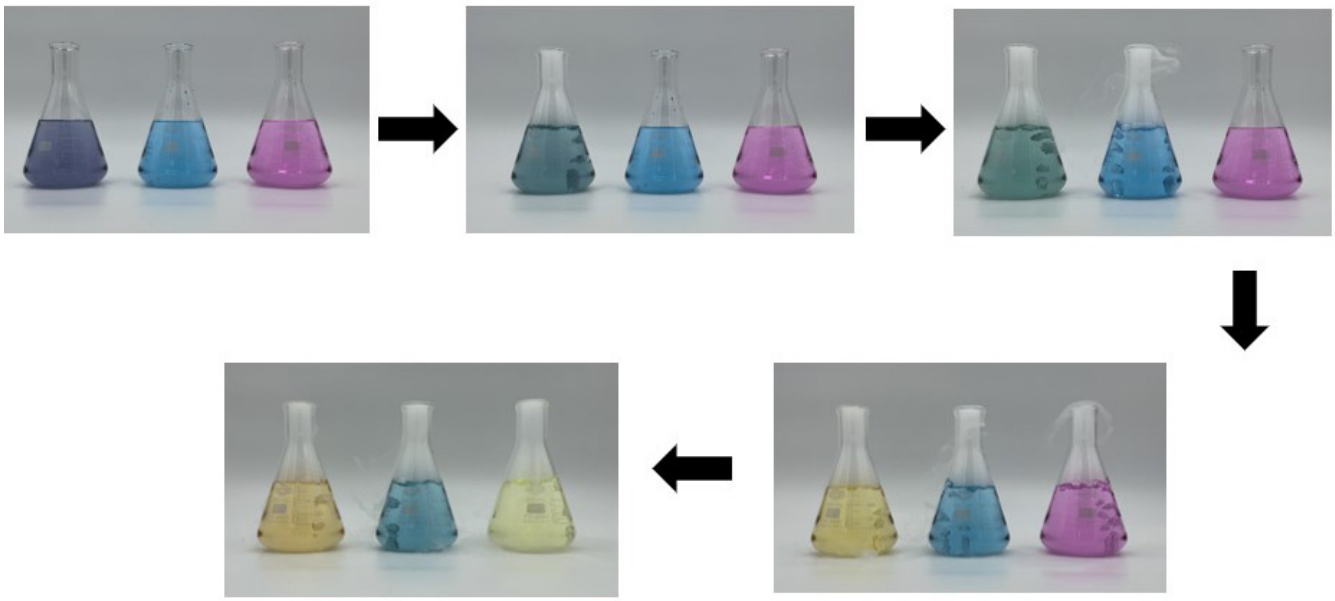

FIGURE 4: Basic solutions of indicators turning acidic over a span of a 45 seconds

Picture 1 in Figure 4 photographed the initial basic solutions of each indicator at time equals zero. Picture 2 occurred when a dry ice pellet was added to the universal indicator beaker (left beaker). Almost immediately, the universal indicator basic solution began to change color. Picture 3 occurred a couple of seconds after adding a pellet to the bromocresol green basic solution (middle beaker).

Picture 4 was taken after a pellet was added to the phenol red basic solution (right beaker). Picture 5 was 45 seconds after the first pellet was added to the first beaker. Over this period, the universal indicator solution changed from a deep purple to a yellowish orange (pH ~ 2.5), the bromocresol green solution changed from a vibrant blue to more of a muted teal (pH ~ 3.8), and the phenol red solution changed from magenta to light yellow (pH ~ 6.4). These color changes demonstrate the basic solutions turning acidic due to the addition of dry ice.

TESTING AND ANALYSIS

Once the solutions underwent the main acidic color change, 2 mL of the solutions were pipetted into cuvettes to test the absorbance of the samples. The absorbance spectra of the acidic solutions can be seen in Figure 5.

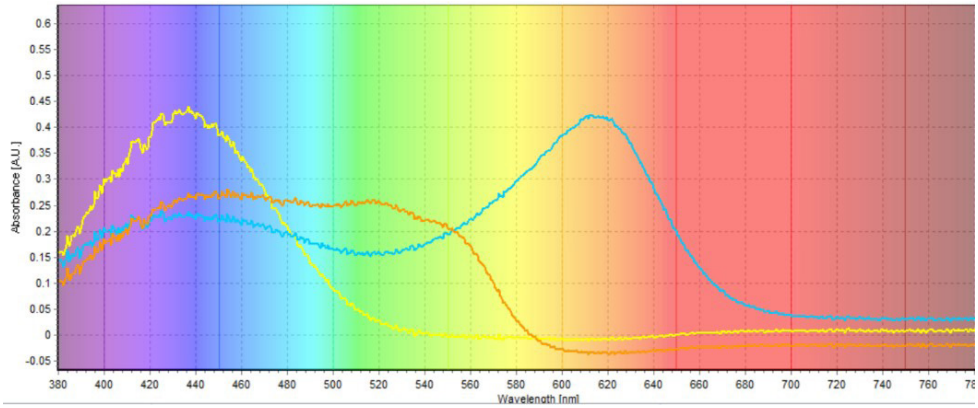

FIGURE 5: Recommended dilution concentration at 10mm and 5mm path length

Analysis:

Figures 6, 7, and 8 show the comparison of the basic and acidic solutions for each pH indicator. The spectra shows what wavelength and what color light is absorbed by the solution. The colored lines in the spectral readings correspond to the color of the solutions. For the universal indicator solution (Figure 6), the basic color was purple and absorbed mostly orange and yellow light (540-640 nm). After the dry ice and the solution turned acidic, it transmitted yellow and absorbed purple and blue light (420-520 nm).

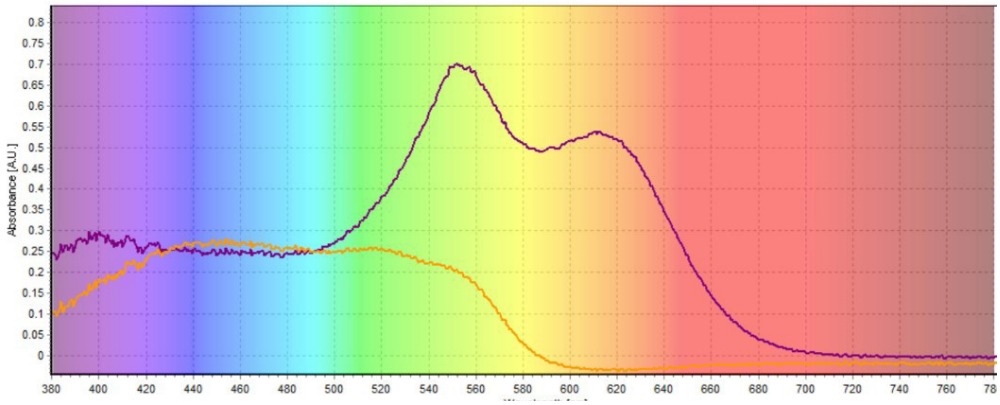

FIGURE 6: Basic and acidic absorbance spectra for the universal indicator solution

TEST DATA AND CONCLUSION

For the bromocresol green solution (Figure 7), the basic color was a light cobalt blue and absorbed mostly orange light (580-640 nm). After the dry ice and the solution turned acidic, the solution now absorbed more purple light (420-460 nm) than before which caused the new blue color to have a yellow/ green hue. The bromocresol green acidic solution color was similar to teal.

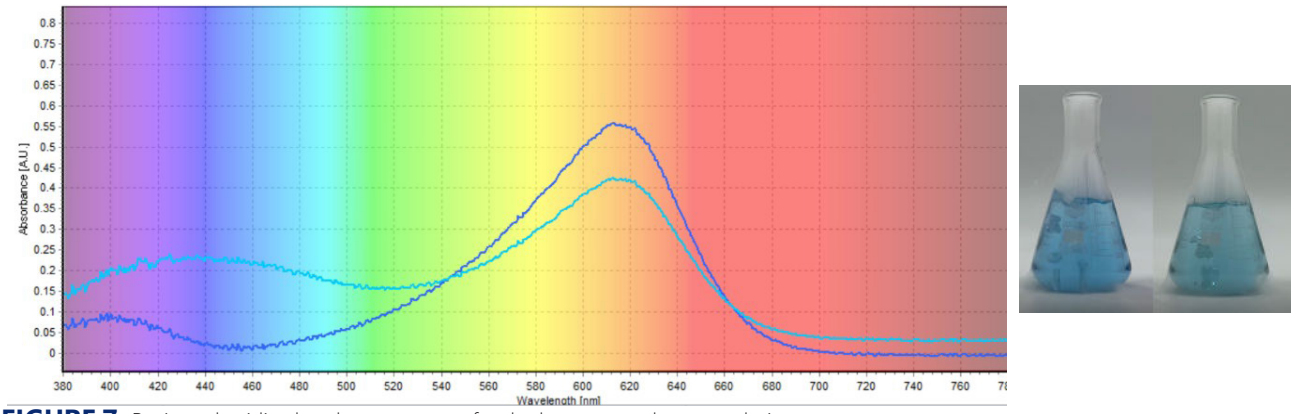

FIGURE 7: Basic and acidic absorbance spectra for the bromocresol green solution

For the phenol red solution (Figure 8), the basic color was magenta, which absorbed mostly greenish-yellow light (520-580 nm). After the addition of dry ice to turn the solution acidic, it transmitted yellow and absorbed mostly purple (400-460 nm). This indicator had the most drastic color change compared to the other indicators. This can be seen visually and by the difference between the initial and final spectra in the absorbance graph.

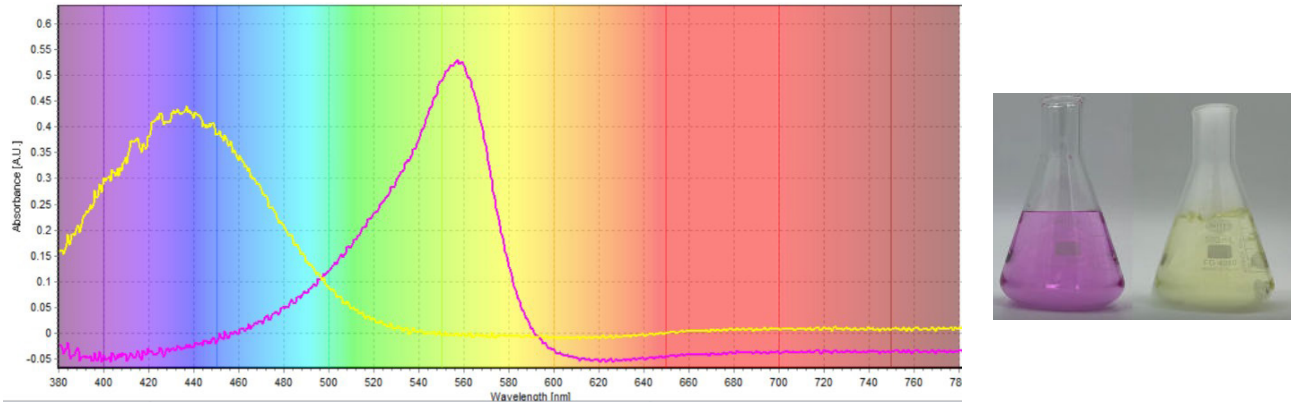

FIGURE 8: Basic and acidic absorbance spectra for the phenol red solution

CONCLUSION

When carbon dioxide (dry ice) dissolves in water, the acidity of the solution will increase due to the dissociation of hydrogen atoms after the carbonic acid is formed. This chemical reaction causes a color change with pH indicators since the basic solutions become acidic solutions. Universal indicator, bromocresol green, and phenol red distilled water solutions were paired with dry ice pellets to cause this pH color change. Absorbance measurements were taken before and after the dry ice pellets so that the colors of the basic and acidic solutions could be compared. Overall, this experiment focused on the acidic properties of dry ice and color comparison of basic and acidic states of indicators.

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