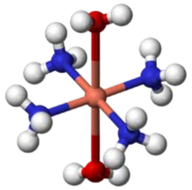


Coordinated copper model
(https://en.wikipedia.org/wiki/Copper)

Combining Chemistry and Art: Visualization, Analysis, and Use of Pigments and Natural Dyes

Josiah Belfield & Pamela Artz, Albright College

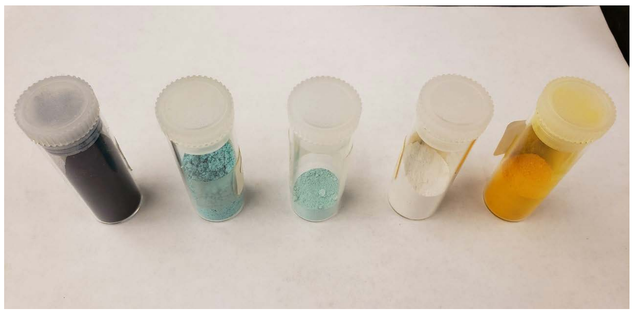
Introduction

The intention is the combination of chemistry and art to create a lab science class. Inorganic pigments were made and tested with binders with varying abilities to suspend the pigments. In exploring the chemistry, students understand the energy transitions that result in different frequencies of electromagnetic radiation making different colors. We will use these and purchased pigments in making frescos with lime plaster on terra cotta. Students will explore fresco technique and understand base resistant pigments.

Natural dyes were extracted from red cabbage and onion skin. Absorbance of these dye solutions was investigated at varying pH affecting color and absorbance. This experiment demonstrates the effect of pH on electronic structure impacting energy transitions, light absorbance, and color. The red cabbage juice transitions from purple to green as the pH increases. The onion dye color intensifies as the pH increases. We observed the fluorescence of red cabbage juice at pH 4.5 and 7.2 finding emission maxima at ~440 nm and ~515 nm for excitation at 300 nm and 410 nm, respectively. Using GC-MS, we found polyphenolic compounds that provide color and are putative anti-inflammatory compounds. The onion skin dye was used to color eggs with patterns using small plants as “resists.”

Methods

Pigments prepared[1, 2, 3] and tested with linseed oil, tempera and gum Arabic binders

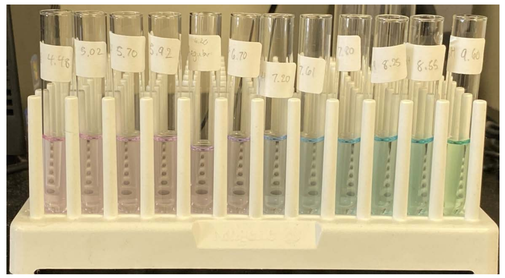


Pigment	Chemical composition	Color
Prussian blue[1]	$Fe_4[Fe(CN)_6]_3.xH_2O$ – Hydrated iron(III) hexacyanoferrate(II)	Deep blue black
Blue verditer[2] Synthetic malachite	$CuCO_3.Cu(OH)_2$) - Basic copper(II) carbonate	Blue green (depends on prep)
Green verditer[2] Synthetic malachite	$CuCO_3.Cu(OH)_2$) - Basic copper(II) carbonate	Green blue (depends on prep)
Egg shell white[3]	$CaCO_3$ – Calcium carbonate	Egg shell white
Chrome yellow[1]	$PbCrO_4$ – Lead(II) chromate(VI)	Bright yellow

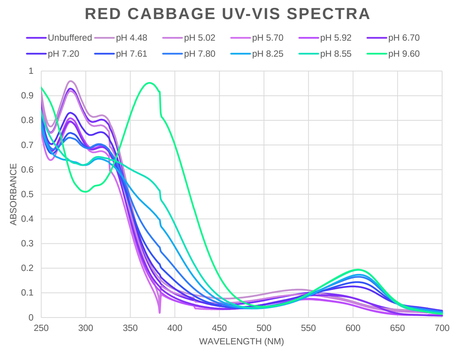
Natural dyes were isolated from red cabbage by grinding and then blending with DI water in a blender jar. The solids were filtered from the cabbage extract. Onion skin dye was made by boiling the papery outer skins of onions in water for several hours and then allowing the mixture to come to room temperature prior to filtering out the skins from the extract.

Results

The following picture is a visual of the cabbage juice at buffered pHs as labeled. The color goes from purple to green due to changes in electronic structure.

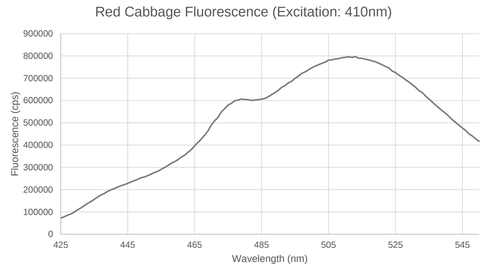


Red cabbage juice, unbuffered and then buffered from pHs 4.48 to 9.6, absorbance was measured from 250 to 700 nm as shown below.

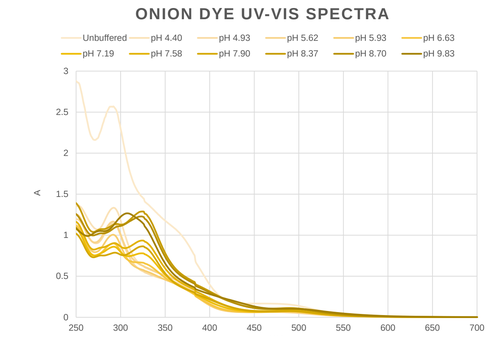


(results cont’d)

The following figure shows the fluorescence of red cabbage juice at pH 7.21 with excitation at 410 nm. The emission maximum = 511 nm



Onion dye, unbuffered and buffered from pH 4.48 to 9.6, UV-vis spectra.



Conclusions

- Art techniques/concepts can be used to demonstrate chemical principles.
- Paint pigments are colored coordination complexes of transition metals that can be combined with different binders.
- Most dyes are organic molecules with delocalized aromatic systems.[1] GC-MS of onion dye and cabbage juice identified polyphenolic compounds.
- The color and absorbance of dyes is affected by pH, which alters the electronic structure. pH affects the color and absorbance of cabbage juice mainly in visible range. pH affects the absorbance of onion dye mainly in the UV range.
- Cabbage juice has been found to fluoresce at 511 nm (green range).
- Pigments synthesized will be used in the fresco technique.
- Onion dye was used to color eggs with small plants as “resists.”
- Other art related experiments will be developed to demonstrate chemical principles.

References

1. Berry, M.; Osborne, C.; Peppin, A.; Johnston, J. *The Chemistry of Art*; Royal Society of Chemistry: London, 1999.
2. Gaquere-Parker, A. C.; Doles, N. A.; Parker, C. D. Chemistry and Art in a Bag: An Easy-To-Implement Outreach Activity Making and Painting with a Copper-Based Pigment. *Journal of Chemical Education* **2015**, *93* (1), 152–153.
3. Hrafnkelsdottir, T. J. To Make Many Pigments for use in Illuminations. https://heraldry.sca.org/kwhss/2017/To_Make_Many_Pigments_Jorhildr.pdf.