CHEMISTRY IN ART RESTORATION: INSTRUCTOR GUIDE

Additional Background

This experiment is inspired by a true story. You may want to consider showing or having your students read or watch the following materials either before or after class.

Tate Modern video: *Restoring Rothko* (17:25 min)
https://www.youtube.com/watch?v=AGqAggmwyMU

CEN Online. Restoring Art Done Right – Speaking of Chemistry Ep. 6. (2:12 min)
https://www.youtube.com/watch?v=eGR_AxXdSk0

Telegraph article: *Vandalised Rothko restored by Tate Modern*
http://www.telegraph.co.uk/culture/art/art-news/10826531/Vandalised-Rothko-restored-by-Tate-Modern.html

Guardian article: *Tate Modern unveils painstakingly restored Rothko*
https://www.theguardian.com/artanddesign/2014/may/13/tate-modern-unveils-restored-mark-rothko-black-on-maroon

Additionally, while the following is probably too technical and long for students, instructors might want to peruse Tate Paper No. 23 about the restoration:
http://www.tate.org.uk/research/publications/tate-papers/23/conserving-mark-rothkos-black-on-maroon-1958-the-construction-of-a-representative-sample-and-the-removal-of-graffiti-ink

Materials

- Skim milk (20 mL per group)
- Vinegar (5 mL per group)
- Linseed oil binder (10 mL linseed oil diluted to 100 mL with turpentine, useful for a class of 24 students)
- Gum Arabic [5 mL per group. The pertinent solution can be prepared from one part gum Arabic (available at Hobby Lobby, via Amazon, etc.) dissolved in four parts distilled water.]
- Pigment (a few spatula tips per group; we used Red Iron Oxide B from Earth Pigments LLC; several other colors are available)
- Watercolor cardstock (One or two 5'x7' sheets per group, available from Amazon)
- Molotow ink (a few mL per group, purchased from commercial sources such as Amazon, Staples, Walmart and Blick Art Store)
- Q-tips

A Word about Format of the Student Guide to the Activity
The student guide is organized using the Science Writing Heuristic (SWH).[1,2] The SWH approach encourages students to consider the research questions of the activity, gather data to explore the questions, and generate claims based on the evidence. It also creates an interactive classroom where students discuss their ideas with one another.

Helpful Hints

- Encourage students to consider the amount of solvent they need to complete the activity with an eye toward minimization of use. If not, students will likely use more solvent than they really need to complete the activity, which may drive up both reagent and disposal cost.
- Have students make and apply the paints first, before considering other parts of the activity. This will keep the activity within a three-hour time block. While the paints are drying, they can consider the solubility of the ink.
- A hair dryer can be used to speed the drying of the materials.
- To test the ability of solvents to remove the ink but not damage the underlying painting, a Q-tip dipped into solvent is recommended. This minimizes the use of solvent. Additionally, students should be encouraged to examine both the painting and the Q-tip to determine if ink or paint was removed. If there is both black and red (the color of the pigment used in our activity), this indicates both the ink and paint have been removed. Students can qualitatively rank how effective each solvent is at removing more of the ink relative to the paint.

Expected Results

Procedure, Part 1: Test the solubility of the ink in different solvents (water, octanol , and one other solvent of your choice from the structures shown in Table 1). What do your results suggest about the polarity of the ink?

- The Molotow black ink should dissolve in benzyl alcohol, DMSO, ethyl lactate and octanol but not in water.

Procedure, Part 2: Making the binders and painting
[Procedure taken from: Hill, P.; Simon, D.; Uffelman, E. Chemistry and Art: Chemistry Collaborations, Workshops, and Communities of Scholars (National Science Foundation), 2010.]

- The casein binder should have a thick consistency, such as that of curdled milk (Figure 1a).
- Thick strips of paint should be painted on watercolor paper (Figure 1b). It is important that students label each to indicate which binder was used since they look similar. A small amount of graffiti ink should then be painted over each.

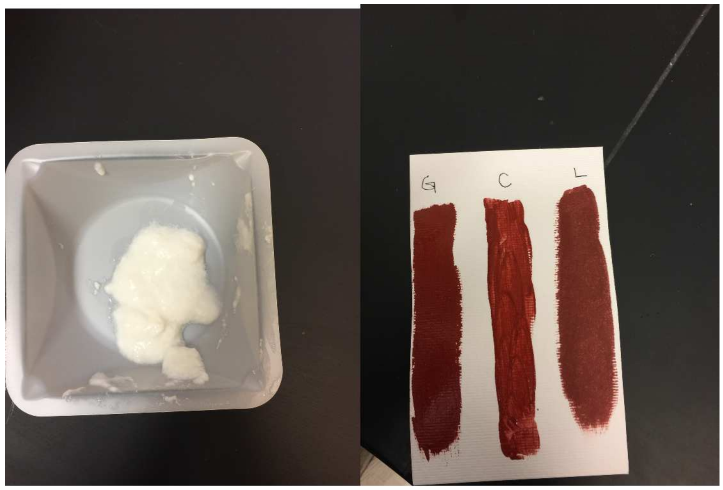

Figure 1. A (left). Picture of casein binder before pigment is added. B (right). Picture of strips of paint made with each binder.

- Previous studies using the red pigment have shown that for the paint made with linseed oil binder:
  - Water will remove some of the paint, but not the ink.
  - Benzyl alcohol, DMSO, ethyl lactate and octanol all remove both the paint and ink.
- For paint made with the Gum Arabic binder:
  - Water will remove some of the paint, but not the ink.
  - Benzyl alcohol will remove both the ink and paint.
  - DMSO, ethyl lactate, and octanol will remove the ink but not the underlying paint layer.
- For paint made with the casein binder:
  - Water will remove some of the paint, but not the ink.
  - Benzyl alcohol and octanol will remove the ink, and some of the underlying paint layer.
  - DMSO will remove a limited amount of ink and paint.
  - Ethyl lactate will remove the ink without affecting the paint.

Extensions

Instructors may be interested in extending this work to other solvent or pigment systems. For example, a non-polar solvent, such as hexane, could be employed since all the solvents used herein have a measurable dipole moment.

Additionally, instructors may want students to explore a different pigment system. However, we would caution instructors to consider the following three aspects before changing the pigment: (i) differences in results; (ii) safety; and (iii) effect on paint consistency. In addition to Red Iron Oxide B, we also used S.O.F. Blue Oxide from Earth Pigments. However, we observed different results in the ability of various solvents to remove the graffiti ink but not the paint when an alternate pigment was used. We also would encourage instructors to use less toxic pigments and avoid those based on lead, such as chrome yellow. Lastly, although we did not observe any differences in the consistency or homogeneity of the paintings, other studies have shown that the choice of pigment influences the paint consistency.[3,]

References

1. Keys, C. W.; Hand, B.; Prain, V.; Collins, S. Using the Science Writing Heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching*, **1999**, *36*(10), 1065-1084.
2. Greenbowe, T. J.; Hand, B. Introduction to the Science Writing Heuristic. In *Chemists' Guide to Effective Teaching*; Pienta, N.J., Cooper, M.M., Greenbowe, T.J., Eds. Prentice Hall, 2005.
3. Longenberger, T.B.; Ryan, K. M.; Bender; W. Y.; Krumpfer, A.-K.; Krumpfer, J. W., “The Art of Silicones: Bringing Siloxane Chemistry to the Undergraduate Curriculum,” *Journal of Chemical Education*, **2017**, (10.1021/acs.jchemed.6b00769).

Additional Reading

Instructors may also find the following articles of interest if they want to look further into the chemistry of pigments and binders in art conservation.

Cavaleri, T.; Buscaglia, P.; Migliorini, S.; Nervo, M.; Piccablotto, G.; Piccirillo, A.; Pisani, M.; Puglisi, D.; Vaudan, D.; Zucco, M. Pictorial materials database: 1200 combinations of pigments, dyes, binders and varnishes designed as a tool for heritage science and conservation. *Applied Physics A*, **2017**, *123*, 419. (doi**:** 10.1007/s00339-017-1031-1)

Dawson, T.L. Examination, conservation and restoration of painted art. *Coloration Technology*, **2007**, *123*, 281-292. (doi: 10.1111/j.1478-4408.2007. 00096.x)

Saladino, M. L.; Ridolfi, S.; Carocci, I.; Martino, D. C.; Lombardo, R.; Spinella, A.; Traina, G.; Caponetti, E. A multi-analytical non-invasive and micro-invasive approach to canvas oil paintings. General considerations from a specific case. *Microchemical Journal*, **2017**, *133*, 607-613.

Stenger, J.; Khandekar, N.; Raskar, R.; Cuellar, S.; Mohan, A.; Gschwind, R. Conservation of a room: A treatment proposal for Mark Rothko’s Harvard Murals. *Studies in Conservation*, **2016**, *61,* 348-361. (doi**:** 10.1179/2047058415Y.0000000010).

Stenger, J.; Khandekar, N.; Wilker, A.; Kallsen, K.; Kirby, D. P.; Eremin, K. The making of Mark Rothko’s Harvard Murals. *Studies in Conservation*, **2016**, *61*, 331-347. (doi: 10.1179/2047058415Y.0000000009).