Integrating the visual arts and inorganic chemistry

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July 31, 2008

20th Biennial Conference on Chemical Education
Indiana University
Introduction

- APSU is a regional university in Clarksville, TN with 9,200 students.
- Chemistry department has 8 faculty and graduates 10-15 majors per year.
- One semester Inorganic Chemistry class for juniors and seniors.
- Experiments from the Chemistry in Art workshop were adapted for inclusion into Inorganic lecture and lab.
Purpose

• Share experience with integration of art concepts into Inorganic lecture and lab
• Discuss two main modules used in lecture and lab during past 3 classes.
  o Inorganic Pigments
  o Chemistry of Photography
• Highlight connections between inorganic chemistry and these art related topics.
Brief course outline

- Topics covered in 1-semester Inorganic Chemistry class at APSU
  - Atomic Structure
  - *Inorganic Pigments*
  - Simple Bonding Models
  - Symmetry
  - Molecular Orbitals
  - Acid/Base Chemistry
  - *Chemistry of Photography*
  - Coordination Chemistry

- Art topics promote connections to real-world applications
Inorganic Pigments: Lecture

• Colorants: Inorganic Pigments and Indigo
  o Definitions
  o Brief history of colorants
  o Highlight chemical reactions of synthetic pigments
  o What causes color in inorganic pigments?
  o Ideal properties of pigments
    ▪ Lightfast, inert, insoluble, high opacity, uniform particle size
Inorganic Pigments: Lab Experiment #1

- Synthesis of inorganic pigments
  - Barium white (BaSO₄)
    - $\text{BaCl}_2 \text{ (aq)} + \text{Na}_2\text{SO}_4 \text{ (aq)} \rightarrow \text{BaSO}_4 \text{ (s)} + 2 \text{NaCl}$
  - Synthetic malachite (CuCO₃•Cu(OH)₂)
    - $\text{CuSO}_4 \text{ (aq)} + \text{NaHCO}_3 \text{(s)} \rightarrow \text{CuCO}_3 \cdot \text{Cu(OH)}_2 \text{(s)} + 2\text{Na}_2\text{SO}_4 + 3\text{CO}_2 + \text{H}_2\text{O}$
  - Chrome yellow (ZnCrO₄•Zn(OH)₂)
    - $\text{K}_2\text{CrO}_4 \text{ (aq)} + 2\text{ZnCl}_2 + 2\text{NaOH} \rightarrow \text{ZnCrO}_4 \cdot \text{Zn(OH)}_2 \text{(s)} + 2\text{NaCl} + 2\text{KCl}$
  - Chrome Oxide Green (Cr₂O₃)
    - $\text{Na}_2\text{Cr}_2\text{O}_7 \text{(s)} + \text{S}_8 \text{(s)} + \text{O}_2 + \text{heat} \rightarrow \text{Cr}_2\text{O}_3 \text{(s)} + \text{SO}_2 \text{(g)}$
Inorganic Pigments

Barium White

Synthetic Malachite

Chrome Yellow

Chrome Oxide Green
Inorganic Pigments: Lab Experiment #2

- White Pigment Analysis
- Student driven qualitative analysis experiment
  - Microscopic and macroscopic observations to identify an unknown pigment
  - Pigment samples
    - Chalk or whiting (CaCO₃)
    - Lead White (2 PbCO₃ · Pb(OH)₂)
    - Zinc White (ZnO)
    - Gypsum (CaSO₄)
    - Titanium White (TiO₂)
    - Barium White (BaSO₄)
  - Available reagents such as 3M HNO₃ and KI and a polarizing light microscope are used in analysis
Photographic Chemistry

- Brief History
- Salted Paper Prints
  - William Henry Fox Talbot - 1840
  - Connected to acid/base chemistry
  - Sensitizing Paper
    - NH$_4$Cl (aq) + AgNO$_3$ (aq) → AgCl (s) + NH$_4$NO$_3$ (aq)
  - Development
    - 3 AgCl (s) + light → 2 Ag (s) + Cl$_2$ + AgCl (s)
  - Fixing image
    - AgCl (s) + 2 Na$_2$S$_2$O$_3$ (aq) → Na$_3$[Ag(S$_2$O$_3$)$_2$] (aq) + NaCl (aq)
Chemistry of Photography: Lecture

• Photographic Chemistry
  ○ Cyanotypes
    ✷ Sir John Herschel - 1842
    ✷ \( K_3\text{Fe(CN)}_6 + C_6\text{H}_8\text{O}_7\cdot n\text{Fe} \cdot n\text{NH}_3 \rightarrow \text{Fe[Fe(CN)}_6] \)
      ○ Light sensitive \( \text{Fe[Fe(CN)}_6] \) absorbs into the support
    ✷ \( \text{Fe}^{3+} + \text{light} \rightarrow \text{Fe}^{2+} \)
    ✷ \( \text{Fe}^{2+} + [\text{Fe(CN)}_6]^{3-} \rightarrow \text{KFe[Fe(CN)}_6] \cdot 5\text{H}_2\text{O} (s) \)
      ○ \( \text{KFe[Fe(CN)}_6] \cdot 5\text{H}_2\text{O} (s) \) is Prussian Blue
  ○ Alternative processes and toning
  ○ Color and instant photography
Chemistry of Photography: Labs

- **General Supplies**
  - Clip frames and binder clips
  - Support (watercolor paper or cotton)
  - Paint trays and foam brushes
  - Photographic negatives or transparencies
  - Sunlight or Blacklight
Chemistry of Photography: Lab #1

- Silver Salted Prints
  - Students compare different binder, starch or gelatin
Chemistry of Photography: Lab #2

- Cyanotypes
  - Students compare different supports, paper or cloth
Chemistry of Photography: Lab #3

- Design Your Own Photography Experiment
  - Students plan and carry out individual experiments related to the past weeks of photography experiments
  - Topics studied have included
    - What light sources work for cyanotypes?
    - What exposure times are required for silver salted prints?
    - How does wash temperature affect image quality?
    - What stoichiometric ratio of reagents give the best print?
    - Do other silver halides work as well as AgCl?
    - Can silver halide chemistry be used on cloth?
  - The experiment concludes with a formal report
Student Comments

- “I really liked developing my own lab experiment. The photography experiment was definitely my favorite.”
- “This lab was one of my favorites...I really enjoyed the photography experiments and am actually interested in doing some alternative photography on my own time.”
- “The pigment labs were interesting. I learn best by seeing processes step by step.”
- “The labs applied new perspectives of chemistry which were both interesting and informative.”
Conclusions

- Student response has been overwhelming positive, even from those who do not normally enjoy lab or consider themselves creative.
- Enjoyable and interesting topics hold student attention and are useful for elucidating concepts like acid/base chemistry and synthetic methods.
- Design Your Own Experiment requires independent scientific thought
- The integration of experiments learned from the Chemistry in Art Workshop into my inorganic classes has been very successful.
Acknowledgments

- Robin B. Reed, Chair of APSU Department of Chemistry
- Mary C. Clay, undergraduate research student and lab assistant
- Patricia Hill and Michael Henchman, directors of Chemistry in Art Workshop, June 2005
- My inorganic students