Week 1: Polymers

Intro

Materials:

- Rubber bands (enough for each student)
- Cooked and raw spaghetti

PTW talks about polymers. Have kids stretch/contract rubber bands and feel temperature changes. Use cooked/uncooked spaghetti as a model for polymers and crosslinking. Brief discussion on heat and entropy.

Water Uptake of Diaper Polymer

Materials:

- 8 oz paper cups
- ~ 1.2 g sodium polyacrylate (SPA)
- Balance
- Spatula

Preparation:

For each group, pass out one empty cup (for the SPA) and one cup full of water.

The Experiment: (separate students into four groups)

- Weigh empty paper cup and record the mass.
- Carefully add SPA into cup and take combined mass. Each group should be assigned 100 mg, 200 mg, 300 mg, or 400 mg. (more than 400 mg won’t fit well into the 5 oz cups)
- Pour water into the polymer until saturated; decant any excess water. (It’s probably best for the grad students to do the decanting, or at least demonstrate carefully how to do it – it’s very easy for the SPA to pour out of the cup too during decanting)
- Weigh final mass
- Determine mass of H$_2$O added by difference.
- Plot each group’s data on the board. The data should, in principle, fall along a straight line.

Cleanup:

The SPA polymer (and everything else) can go in regular trash.
Preparation of PVA Slime

Materials:

- 1 L PVA Solution (4 wt. %, mw 146,000-186,000)
  - Dissolve 40 g PVA in 1 L water by heating water to boiling and adding small portions of polymer while stirring vigorously. This typically takes several hours!
- Ziploc snack bags containing 400 mg Borax for each student
- 5 oz paper cups
- Tongue depressors for stirring
- Food coloring
- Plastic lunch trays (to keep things clean)
- Graduated cylinder

Preparation:

- Pour 50 mL PVA solution into cups for each student
- Pour 10 mL H₂O into cups for each student

The Experiment:

- Distribute PVA cups, H₂O cups, borax bags, and stirrer to each student
- Have students dissolve borax in water. Add food coloring (only a couple of drops) to borax solution
- Add borax solution to PVA solution slowly while stirring constantly
- Have students play with slime. How does the consistency change as borax is added? Is the resulting slime bouncy or not? Is it sticky after all the borax is added?
Cleanup:

Put slime in the small Ziploc bags to send home with the students. Everything else may be thrown in the trash or washed down the drain with plenty of water.

**Preparation of Glue Slime**

**Materials:**

- Glue (2 – 3 oz per student)
- 1 L 4% Borax solution
- 5 oz paper cups
- Tongue depressors for stirring
- Food Coloring
- Plastic lunch trays (to keep things clean)

**Preparation:**

- Pour ~ 2 oz glue into cups for each student
- Pour ~ 3 oz borax solution for each group of students

**The Experiment:**

- Distribute glue, Borax solution, and stirrer to each student
- Add food coloring to glue.
- Add borax solution incrementally to glue while stirring until a good consistency is achieved (this takes approximately 5 mL borax solution per 2 oz glue). As the glue slime thickens, it can be removed from the cup and kneaded to mix.
- Play with slime; compare properties with PVA slime

**Cleanup:**

Put slime in the small Ziploc bags to send home with the students. Everything else may be thrown in the trash or washed down the drain with plenty of water.
Week 2: Colors (Acids/Bases and Chromatography)

Intro:

PTW talks about:

- Colors – what does it mean when you see a given color? The complimentary color is blocked out!
- Acids and Bases – many household cleaners and items are commonly encountered acids and bases. Acids are a bit sour, and bases feel soapy.
- Indicators – these show you whether something is acidic or basic

Demo: Universal Indicator in Basic Solution and Dry Ice

Materials:

- 1 L Graduated cylinder
- Big stick for stirring solution in the graduated cylinder
- Universal Indicator
- Several mL of base
- Dry ice pellets (not crushed!)

The Experiment:

- Fill graduated cylinder with H₂O, leaving the top couple inches of the cylinder empty to prevent spilling.
- Add universal indicator and note the color of neutral pH.
- Add base and note the color of basic solution.
- Explain what dry ice is and how it’s acidic in water.
- Add dry ice pellets to cylinder and note color changes.
- Note: Dry ice pellets must be used because crushed dry ice won't sink to the bottom of the graduated cylinder.
- If desired, more base may be added to the graduated cylinder to go through the color changes again.

Determination of the pH of Common Household Items

Materials:

- 100 mL 0.1 M HCl (“toilet cleaner”)
- 100 mL 1% acetic acid (“vinegar”)
- 100 mL Lemon Juice
- 100 mL Soda (Something colorless, like Sprite)
- 100 mL Water
• 100 mL Bleach (NaOCl)
• 100 mL Saturated NaHCO₃(aq) (“baking soda”)
• 100 mL Saturated Na₂CO₃(aq) (“baking powder”)
• 100 mL 0.1 M NH₃ (“Windex”)
• 100 mL 0.1 M NaOH (“Draino”)
• 1 L red cabbage solution
  o Bring ~ 1 L H₂O to a boil. Add chopped red cabbage – only about ½ head or so is needed for 1 L solution. Boil for one hour (in a fume hood – the cabbage solution smells terrible) until the solution is a deep purple and the cabbage is white. Filter off cabbage.
• pH paper (Universal pH 1-14 strips)
• Clear plastic cups
• 8 oz cups
• Plastic lunch trays

Preparation:

• For each group, fill clear plastic cups with 10-20 mL each solution and label with common names.
• Fill 8 oz cup with cabbage juice

The Experiment:

• Distribute plastic cups with acid/base solutions, pH paper, and cabbage juice to each group
• Have each student dip a strip of pH paper into each solution and come to a consensus on the pH of that solution
• Repeat for all solutions
  o Note: Bleach (obviously) bleaches the pH strips. In order to get a number, a rough pH reading must be obtained very quickly before the strip turns white.
• Record the pH for each solution for each group and plot on a scale on the board.
• Have students pour ~ 20 mL cabbage juice into each solution and observe color changes
  o Acidic = Red
  o Neutral = Purple
  o Basic = Green
  o Note: Bleach is an outlier; it changes to a sort of yellowish color
• Correlate colors with pH

Cleanup:

All solutions may be thrown down the drain and pH paper can be thrown in regular trash.

Chromatography

Materials:
- Developing Solutions – 250 mL each of methanol, acetone, and water
- Plastic Cups for developing (organic solvents eat through paper cups quickly)
- Filter Paper (Whatman’s Qualitative 110mm Circles #1)
- Pens
  - Blue Pilot Razor pens separate very well in acetone (red Pilot Razor Point also separates well in acetone, but red doesn’t separate into as nice of colors. Black separates, but not well)
  - Black Papermate Flame pens separate well in acetone and methanol
  - Red Papermate Flame pens don’t separate in anything
  - Permanent Markers and Overhead Pens don’t seem to separate
  - Water is terrible for everything and takes forever to dry, but it is the most green solvent.

The Experiment:

- Distribute to each group 3 cups containing the developing solutions and plenty of filter paper
- Demonstrate how to do chromatography:
  - Take the filter paper and tear in half
  - Fold into thirds or fourths so that the paper will stand up in the cups
  - Make pen marks ~ 1 cm from the bottom of the filter paper, carefully ensuring that the solution doesn’t touch the pen marks.
  - Allow to elute!
- Allow students to test out various pens with different developing solutions
  - Note: Developing solutions will almost certainly get contaminated with ink at some point – make sure there’s enough methanol and acetone on hand to replace the solutions
- Creative options: Flute filter paper and mark in either the center or edges and allow to elute, use multiple pens at once to get a mix of patterns, use angled lines of ink, etc.

Cleanup:
All solutions can be flushed down the drain with plenty of water. Dry H₂O-developed filter paper with paper towels and send students home with whatever filter paper they wish to keep. Everything else can be thrown in the trash.
Week 3: Metals and Electrochemistry

Intro:

PTW talks about:

- Atoms: protons, neutrons, and electrons
- e- can move from one atom to another! Get to the point of $2 \text{Ag}^+ + \text{Cu}_0 \rightarrow 2 \text{Ag}_0 + \text{Cu}^{2+}$

Growing Silver Crystals on Copper Wire + Copper on Aluminum Nails/Foil

Materials:

- 4 dram snap cap vials filled ~3/4 full with 0.1 M AgNO$_3$ (enough for each student to have one, as well as a few extras)
- 4 dram snap cap vials filled ~3/4 full with 0.5 M Cu(SO$_4$)$_2$ (enough for each student to have two, as well as a few extras)
- Vial caps with small holes punctured in the top (punctured with a thumbtack – enough for each student + extras)
- Copper wire, cut into ~6 cm pieces (enough for each student + extras)
- Sandpaper to clean the wire
- Aluminum nails, one for each student
- Aluminum foil (2”x2” square), one piece per student
- Several vials of NaCl, ~2 grams each
- Extra vials and caps, Cu wire, nails, Al foil, 0.1 M AgNO$_3$, 0.5 M CuSO$_4$, and thumbtack
- Permanent Markers
- Gloves
- Goggles
- Plastic lunch trays

The Experiment:

- Distribute vials with solutions (one AgNO$_3$ and two CuSO$_4$ per student), punctured vial caps (one per student), copper wire (one per student), Al nails (one per student), Al foil (one piece per student), sandpaper (one piece per group) and NaCl (one container per group)
- Demonstrate how to grow Ag crystals
  - Write name on vial with permanent marker
  - Clean Cu wire with sandpaper
  - Push wire through hole in vial cap
  - Snap “wired” cap onto vial of AgNO$_3$, making sure the wire is in solution but not touching the bottom of the vial
  - Allow students to each set up their own crystal growth.
  - Place vial in an undisturbed place for the week.
Note: the Ag⁰ that comes out initially is black and powdery, but crystals grow off this powder. The majority of Ag⁰ will already have come out of solution by the end of 1 hr.

- Demonstrate how to grow Cu crystals on Al nails
  - Write name on Cu vial in permanent marker
  - Clean nail off with sandpaper
  - Drop nail into vial
  - Cap vial with a punctured vial (to allow any gas formed to escape)
  - Place in an undisturbed location for the week.

- Demonstrate how to grow Cu crystals on Al foil
  - Write name on vial in permanent marker
  - Fold sheet of aluminum foil into a tube
  - Drop foil into Cu solution
  - Observations! (nothing will happen initially)
  - Add a (small!) pinch of NaCl to vial
  - Observations! (bubbles will start to form on foil surface; foil will start to turn red. In some cases, a white thick precipitate will form (most likely Al(OH)₃).
    - What’s happening: NaCl etches surface of Al foil, allowing redox reaction with Cu to occur. The reaction of Al(s) with H₂O is competitive – that’s where the bubbles and white solid come from.
  - Allow reagents to react for the day (~1 hr), occasionally making observations.
**Cleanup:**

Cap up Al foil vials and bring back to Cornell to dispose (decant off Cu solution and throw in aqueous waste, throw Cu crystals in trash.

**Next Week – Isolation of crystals:**

**Materials:**

- Short Pipettes
- Pipette bulbs
- Water wash bottle
- 4 dram vial caps (without hole)

**The Experiment:**

- Have each student grab their vial of crystals from last week and bring them to a grad student to isolate.
- For Ag crystals:
  - Shake crystals off remaining Cu wire
  - Carefully pipette out Cu$^{2+}$ solution and discard
  - Wash Ag 1-2 time with water and cap vial with a fresh vial cap
  - Instruct students to leave cap off at home to allow H$_2$O to evaporate, then to keep the vial capped after that.
- For Cu crystals (they may look pretty terrible!)
  - Shake crystals off remaining Al nail.
  - Carefully pipette out Cu$^{2+}$ solution and discard. If a large quantity of white precipitate has formed, make a slurry of the precipitate with water and pipette out.
  - Wash Cu 1-2 time with water and cap vial with a fresh vial cap
  - Instruct students to leave cap off at home to allow H$_2$O to evaporate, then to keep the vial capped after that.

**Cleanup:**

Bring all aqueous waste back to Cornell to dispose.

Separate students into 3 groups. Send each group to one of the following 3 stations – each should take ~15 minutes. Students must keep on their gloves and goggles!

**Station 1: Tollens Test**

**Materials:**

- 0.1 M AgNO$_3$ in H$_2$O (800 mL)
- 0.8 M KOH in H$_2$O
Concentrated (14.8 M) NH₄OH – bring in a small dropper bottle to avoid NH₃ fumes as much as possible

Aldehyde solution
  o Dan Lorey’s miracle sugar solution recipe:
    o Mix 80 grams sucrose, 100 mL 95% ethanol, 800 mL distilled water, and 3.5 mL concentrated HNO₃
    o Allow to sit at least one week before use (very important!)
    o Note: dextrose solution also works in this experiment, but not as well as the prepared sugar solution

Fancy vials for each student to coat with Ag (+ extras, just in case). Best size is ~4 dram or 20 mL.

Pipettes and pipette bulbs

Wash bottle with water

Optional: acetone for drying out vials

Extra coated vials in case the kids mess up

Gloves

Goggles

The Experiment:

Give each student in the group a vial

Pipette in solutions, in this order – don’t let kids dispense their own solutions!:
  o 2 full pipettes of AgNO₃ – resulting solution will be colorless
  o 1 full pipette of KOH – a brown precipitate should form
  o 3 – 4 drops NH₄OH – the precipitate should dissolve
  o 1 full pipette of aldehyde solution – the resulting solution should be clear and colorless

IMMEDIATELY upon addition of the sugar, cap vial and SHAKE WELL. Silver will start coating out after 1 -2 minutes. Don’t stop shaking to observe the Ag coming out, or the coating will be uneven.
  o Rate of Ag coating seems to be temperature-dependent, so try to warm evenly with hand to ensure an even mirror

Continue shaking 5 – 10 minutes, WITHOUT STOPPING

When a good mirror has formed, dump vial contents down the drain

Rinse several times gently with H₂O, and once with acetone (if available)

Tell students to leave vial cap off overnight for the remaining H₂O to evaporate, then to cap and leave capped (to prevent oxidation)

Cleanup:

Take used pipettes back to Cornell to dispose in glass waste. Gloves may be thrown away in regular trash.
Station 2: Coating Pennies with Zinc and Bronze

This experiment must be run near a sink. Prep modified from www.stevespanglerscence.com/experiment/gold-pennies

Materials:

- ~200 mL 6 M NaOH (this is a fairly concentrated solution, so be careful!)
- Zinc dust – several grams are needed
- Large crystallization dish
- Medium crystallization dish
- ~200 mL 10% acetic acid
- ≥ 4 pairs of tweezers
- Spatula
- Functioning hot plate
- Thick glove for touching hot glassware
- Pennies (enough for each kid to have 3)
  - Note: pre-1982 pennies seem to work best, but newer pennies are still pretty good
  - Pennies may turn out better if they’re pre-soaked in acetic acid or 1 M HCl for at least an hour prior to coating (this should be done by grad student before the day of the experiment)
- Gloves and goggles for the kids

Preparation:

- Add NaOH to large crystallization dish (solution should be 0.5 – 1 cm deep). Add several scoops of zinc powder.
- Start heating solution to slightly less than boiling
  - This should be done as soon as possible – this takes up to 15 minutes to heat up properly
  - Zinc powder tends to clump up, but it’s not really a problem
- Add acetic acid to medium crystallization dish

The Experiment:

- Allow kids to choose 3 pennies each and drop them in the acetic acid solution.
- After a minute, allow kids to fish their pennies out of solution carefully with tweezers and rinse off with water to remove acetic acid.
  - This is really the only interactive part of this station; everything else is dangerous enough that it should be handled by a grad student.
- Allow each kid to keep one copper penny (as a standard)
- Carefully place the other two pennies for each student in the almost-boiling NaOH/Zn solution
- Push Zn clumps near pennies to speed up coating
o The length of time this coating takes is highly dependent on temperature and NaOH concentration (i.e. how much water has boiled off throughout the day) It can take anywhere from 10 minutes for the first group down to less than 4 for the last group.
• Flip pennies with tweezers when it looks like the top side is coated properly
• When completely coated, take all pennies out of solution with tweezers and wash off NaOH/Zn in the sink
  o Zn can sometimes stick to the penny surface, so be careful to clean the pennies as well as possible.
• When all pennies are coated, take the crystallizing dish off the hotplate with a thick glove.
• Place one penny for each student directly on the hotplate. Bronze coating typically appears within one minute. Sometimes the penny may need to be flipped to heat evenly, but this typically isn’t necessary.
• Carefully take penny off hotplate with tweezers and run under water to cool.

Cleanup:

Decant NaOH off Zn and wash down drain with plenty of water. Wash Zn several times with water and bring back to Cornell to dispose. Turn off hotplate as soon as possible to cool down for transport.

Station 3: Density of CO₂

Materials:
• Balloons (enough for everyone in the class + extras)
• Dry ice, crushed
• Scoopula
• Meterstick
• String (~1 meter pieces)
• Balance

The Experiment:
• Give each student in the group a balloon and have them measure and record the mass
• Add crushed dry ice to balloons (aim for less than 1 gram). Tie the balloon closed.
• Allow the dry ice to sublime. This may be sped along by shaking.
• Take final mass. Subtract initial mass to obtain mass of CO₂.
• When all the dry ice has sublimed, form the balloon into a sphere-like shape and measure the circumference with string and meterstick.
• Use the following relationships to solve for volume of gas:
  o Circumference = 2πr
  o Volume of a sphere = 4/3πr³
  o Warning: Students may not actually understand the concept of volume yet....
• Calculate density = mass/volume
• Play with dry ice and balloons if there’s remaining time to kill.
• Actual density of CO$_2$ = 1.977 kg/m$^3$ at 1 atm and 0°C.

**Cleanup:**

None
Week 4: Kinetics and Catalysis

Demo: Oscillating Clock (Briggs-Rauscher Reaction)

Materials:

- 30% H₂O₂
- KIO₃
- Concentrated H₂SO₄
- Malonic Acid
- MnSO₄·H₂O
- Vitex Starch

Preparation:

Solution A: 3.6 M H₂O₂
Solution A must be prepared fresh on the day of the demonstration (it still works if H₂O₂ isn’t fresh, but maybe not as well) Dilute 82 mL 30% H₂O₂ to 200 mL

Solution B: 0.2 M KIO₃ and 0.08 M H₂SO₄
Dissolve 8.6 g KIO₃ and 0.86 mL concentrated H₂SO₄ in 200 mL

Solution C: 0.15 M Malonic acid, 0.02 M MnSO₄·H₂O, and starch
Add 600 mL water-soluble starch to approximately 15 mL distilled water and heat to dissolve. Dissolve 3.2 g Malonic acid and 0.68 g MnSO₄·H₂O in approximately 150 mL water. To this, add the starch solution and dilute to 200 mL.

Presentation:

Add a stirbar to a 1000 mL beaker on a stirplate. Add solutions A and B to the beaker and start stirring. Add solution C. Solution will oscillate between yellow and blue for about 5 minutes.

Cleanup:

Quench with Na₂S₂O₃ (until solution is colorless) and pour down the drain.

Demo: Elephant Toothpaste

Materials:

- 50 mL 30% H₂O₂
- Food coloring
- 10 mL saturated potassium iodide
- Dish soap
• 500 mL graduated cylinder
• Large tray
• Large garbage bag
• Gloves
• Goggles

The Experiment:

• Place large tray on ground on top of plastic garbage bag. Place the graduated cylinder on top of the tray
• Add H₂O₂ to graduated cylinder
• Add some dish soap and stir to mix
• Add 3 – 5 drops food coloring of choice
• Add KI in one portion, being careful to not lean over the cylinder
• Wait for reaction to occur!

Cleanup:

Everything gets washed down the drain

**Kinetics of a Chemical Reaction**

Modified from a Chem 2150 Experiment

**Materials:**

• Solutions (see below) – 4 sets of 10 solutions, + extras if desired
• Clear plastic cups (at least 20)
• Stopwatches or cell phones with a stopwatch function – one per group
• Ice (store 4 “1A” solutions and 4 “B” solutions in this ice)

**Preparation:**

• Solutions that must be prepared (be sure to use volumetric flasks and pipettes, as well as distilled water for all dilutions):
  o 1 L 0.2 M (NH₄)₂S₂O₈ (45.636 g (NH₄)₂S₂O₈ in 1 L H₂O)
    ▪ (NH₄)₂S₂O₈ goes bad slowly over time, so don’t use a bottle that’s decades old.
  o 500 mL 0.2 M KI (16.600 g KI in 500 mL H₂O)
  o 500 mL 0.2 M KNO₃ (10.110 g KNO₃ in 500 mL H₂O)
  o 200 mL 0.01 M Na₂S₂O₃ in starch solution (395 mg Na₂S₂O₃ in 250 mL starch solution)
    ▪ Must be prepared fresh on the day of the experiment
    ▪ To make starch solution, heat 250 mL H₂O to a boil and add 50 – 100 mg starch. Heat until dissolved and cool to room temperature before adding Na₂S₂O₃.
• Students will determine the reaction order of I− for the reaction of $S_2O_8^{2−}$ and I−, as well as note the rate change of reaction upon cooling:

$$S_2O_8^{2−} + 3 I^− \rightarrow 2 SO_4^{2−} + I_3$$

To do this, they will mix two solutions four times at room temperature with varying I− concentrations and one set of two solutions at 0 °C.

To make solutions for individual trials (prepare enough for 4 groups to each do 4 trials):

- Obtain 20 2 oz Nalgene bottles and 20 8 dram vials. Label Nalgene bottles: 8 x “1A”, 4 x “2A”, 4 x “3A”, 4 x “4A”
- To each 8 dram vial, pipette 24 mL ($NH_4)_2S_2O_8$ solution (use a volumetric pipette), cap, and label “B”
- To each “1A” bottle, pipette 25 mL KI. Cap up.
- Obtain 5 125 mL beakers or flasks. Add 25 mL KI to each container.
- Add 25 mL KNO$_3$ to each container and mix well. Take 25 mL of the resulting 50 mL solution and add to bottles labeled “2A”
- Add 25 mL more KNO$_3$ to each container and mix well. Take 25 mL of the resulting 50 mL solution and add to bottles labeled “3A”
- Add 25 mL more KNO$_3$ to each container and mix well. Take 25 mL of the resulting 50 mL solution and add to bottles labeled “4A”. Discard remaining solution.

On the day of the experiment:

- Prepare Na$_2$S$_2$O$_3$ solution and pipette 10 mL into each Nalgene bottle.

**Contents of each container (total volume = 35 mL)**

<table>
<thead>
<tr>
<th>1A:</th>
<th>0.143 M KI</th>
<th>3A:</th>
<th>0.0357 M KI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 M KNO$_3$</td>
<td>0.00286 M Na$_2$S$_2$O$_3$</td>
<td>0.107 M KNO$_3$</td>
<td>0.00286 M Na$_2$S$_2$O$_3$</td>
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<table>
<thead>
<tr>
<th>2A:</th>
<th>0.0714 M KI</th>
<th>4A:</th>
<th>0.0179 M KI</th>
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<tr>
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<td>0.00286 M Na$_2$S$_2$O$_3$</td>
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**Concentrations immediately after mixing (total volume = 60 mL)**

<table>
<thead>
<tr>
<th>1A:</th>
<th>0.0833 M KI</th>
<th>3A:</th>
<th>0.0208 M KI</th>
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<tr>
<td>0 M KNO$_3$</td>
<td>0.00167 M Na$_2$S$_2$O$_3$</td>
<td>0.0625 M KNO$_3$</td>
<td>0.0833 M (NH$_4)_2S_2O_8$</td>
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<table>
<thead>
<tr>
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<th>4A:</th>
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<td>0.0833 M (NH$_4)_2S_2O_8$</td>
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<table>
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<th>4A:</th>
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<tbody>
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<td>0.00167 M Na$_2$S$_2$O$_3$</td>
<td>0.0729 M KNO$_3$</td>
<td>0.0833 M (NH$_4)_2S_2O_8$</td>
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<thead>
<tr>
<th>4A:</th>
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<th>3A:</th>
<th>0.0357 M KI</th>
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<tbody>
<tr>
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<td>0.00167 M Na$_2$S$_2$O$_3$</td>
<td>0.125 M KNO$_3$</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>5A:</th>
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<th>4A:</th>
<th>0.0179 M KI</th>
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</thead>
<tbody>
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<td>0.00167 M Na$_2$S$_2$O$_3$</td>
<td>0.125 M KNO$_3$</td>
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<th>3A:</th>
<th>0.0357 M KI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0179 M KNO$_3$</td>
<td>0.00167 M Na$_2$S$_2$O$_3$</td>
<td>0.125 M KNO$_3$</td>
<td></td>
</tr>
</tbody>
</table>
The Experiment:

- Separate students into 4 groups. Distribute solutions, cups, and stopwatches. Each group should have a “1A”, “2A”, “3A”, and “4A” solution, and 4 “B” solutions.
- Have students pour contents of “1A” into cup then quickly pour contents of “B” into cup. Have another student start swirling immediately upon addition.
- Grad student or a third student in group: start timing immediately upon addition of 2nd solution. Stop timing when solution goes blue and record results. Give times to PTW to tabulate.
- Repeat for trials 2, 3, and 4, switching off who mixes, swirls, and times.
  - Stirring must be maintained through entire reaction or times will be artificially too long.
- Approximate time for each mixture to change color:
  - 1A + B: ~ 21 sec
  - 2A + B: ~ 43 sec
  - 3A + B: ~ 88 sec
  - 4A + B: ~ 160 sec
- Distribute cold “1A” and “B” to each group
- (Quickly) repeat experiment with cold solutions. Warn students to touch only the rim of the cup to avoid warming solution unnecessarily.
  - Note time increase for reaction to occur. (~50 sec) Cold reactions occur more slowly.

Cleanup:

Everything gets washed down the drain with plenty of water.

**Ferrofluid (time permitting)**

Prepared fresh according to recipe from: http://mrsec.wisc.edu/Edetc/nanolab/ffexp/

Materials:

- Vials of ferrofluid (see below)
- Nd magnets (or other strong magnets, but make sure to test them beforehand)

Preparation:

- Prepare 50 mL 2 M HCl (8.3 mL concentrated HCl in 50 mL H₂O)
- Prepare 20 mL 1 M FeCl₃ in 2 M HCl
  - Weigh out 3.244 g FeCl₃ (the anhydrous is kind of blackish and the hydrate is yellow; this mass is for the anhydrous)
  - Add 20 mL 2 M HCl
- Add solution to 600 mL beaker with large stirbar
- Prepare 5 mL 2 M FeCl₂ in 2 M HCl
  - Weigh out 1.988 g FeCl₂·4H₂O (blue-green solid)
  - Add 5 mL 2 M HCl – takes a bit of stirring to dissolve completely
• Add solution to the 600 mL beaker. Resulting solution is orange-brown.
• Charge a large dropping funnel with 250 mL 1 M NH₃(aq). Position above beaker
• Add ammonia to FeCl₃/FeCl₂ solution over about 5 min while stirring well. Solution gets very hot and turns blackish.
• Remove stirbar. Use magnet to pull magnetite to bottom of flask and decant supernatant.
• Transfer magnetite to a large weighboat. Wash several times with water.
• Add 5 mL 25%(Me₄N)OH –OR– 5 mL 25% (Bu₄N)OH and stir into magnetite at least 1 min.
• Pour off extra liquid until magnetite spikes properly
• Separate product into five 4 dram vials. Purge with Ar and cap tightly.

The Experiment:

• Pass out vials of ferrofluid and magnets to each group. Do a brief demo on how cool ferrofluid is. Let the kids play and encourage groups to trade magnets for increased experimentation.

Cleanup:

None

Humidity Detectors with CoCl₂

Materials:

• At least 200 mL CoCl₂ in acetone (exact concentration doesn’t matter; add 10 – 20 g solid to ~200 mL acetone )
• Large crystallization dish
• Parchment paper
• Scissors in case there aren’t any in the classroom
• Tweezers

The Experiment:

• Distribute paper to each student. Have them cut out a shape (alternative: pre-stencil shapes for them to cut out)
• Pour CoCl₂ solution into crystallization dish, about 0.5 cm deep
• Dip paper into solution, pull out, and lay on paper towels to dry

Cleanup:

Keep excess CoCl₂ solution to recover CoCl₂ solid for reuse

Demo: Beating Heart (time permitting)

Materials:

• Potassium Permanganate Solution
• Hg(l)
• 10 % H₂SO₄ solution
• Large Watchglass
• Iron nail (not galvanized)
• Secondary containment of some sort
• Waste bottle

The Experiment:

• Place some Hg in watch glass. Cover with a layer of H₂SO₄.
• Add a small amount of permanganate solution
• Approach the drop of mercury slowly with the tip of the iron nail. The “heart” will start to beat when the nail is close to the Hg but not quite touching it.

Cleanup:

Everything should go in the waste bottle to take care of at Cornell

Liquid Nitrogen Ice Cream

Materials:

• Heavy whipping cream (1 quart)
• White sugar (3 cups)
• Vanilla extract (2 teaspoons)
• Something to stir with (tongue depressors or sturdy plastic spoons)
• Styrofoam cups (4 oz capacity)
• Big bowl for mixing
• Spatula
• Measuring cup, teaspoon measuring spoon
• Liquid N₂ (full 4 L dewar)

Preparation:

• Mix cream, sugar, and vanilla in large bowl
• Pour evenly into cups, one for each student. Leave some extra just in case someone drops theirs

The Experiment:

• Distribute cups and stirring devices to students. Make sure they’re at a table!
• Pour a couple mL N₂ into cups and have kids stir. Add more N₂ as necessary.
  o Note: Warn kids that their cups will get cold, or they may drop them.

Cleanup: Sponge off anything that spills