UNIVERSITY OF PITTSBURGH

DEPARTMENT OF CHEMISTRY

CLASSROOM DEMONSTRATIONS

Stanley Paul       Bruce C. Gray

July, 1984
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ABSOLUTE ZERO DEMONSTRATION

Materials: Sargent-Welch No. 1602 Absolute Zero Demonstrator
Boiling water
Ice water
Dry ice in alcohol, or acetone/CO₂ bath

With this apparatus the zero of absolute pressure, and therefore the absolute zero of temperature, can be interpreted to occur at approximately -273°C. A short length of tubing connects the bulb with a pressure gauge calibrated to read absolute pressure in lbs/in². A nipple with valve makes it possible to change the pressure in the bulb. A handle is provided for convenience and safety when the bulb is held in boiling water. The handle must be threaded into the assembly opposite the valve.
Submerge the bulb successively in liquids at several known temperatures. Observe and record the corresponding gauge reading for each case. Three convenient known temperatures are: boiling water (100°C), ice water (0°C), and crushed dry ice in alcohol (−78.5°C). If dry ice is not available, a third convenient temperature might be room temperature.

Caution: Do not operate the apparatus at temperatures for which the pressure exceeds 30 lbs/in², as indicated by the gauge.

Plot pressure against corresponding temperature. A straight line should (within experimental limits) pass through the three points and, on extrapolation to zero pressure, indicate that zero pressure and the absolute zero of temperature occur at approximately −273°C.

If desired, the pressure in the bulb at room temperature may be increased or decreased a few lbs/in². Follow the procedure to determine the pressure-temperature curve. While having a different slope, it should on extrapolation pass through zero pressure at approximately the same temperature, namely −273°C, thus demonstrating that this point is independent of the starting pressure.

At room temperature the pressure in the bulb is easily increased by means of a hand-operated tire pump or by connection to a standard laboratory air outlet. The pressure may be decreased by removing and replacing the valve core, or by simply depressing the valve stem for several seconds while the bulb is submerged in boiling water.

¹The absolute zero demonstrator was designed for use at temperatures not exceeding that of boiling water (100°C). The hollow ball (air chamber) is soldered at the seam joining the two hemispheres with "soft" solder (low melting point). For this reason, it is recommended that the highest test temperature not exceed 100°C.

**NOTE:**

Acetone/CO₂ bath can also be used.

Temperature = −77°C
ALUMINUM
(Chemistry of Aluminum)

Materials: 6M HCl
6M NaOH
Al foil
balloons
AlCl₃, anhydrous
Bromthymol blue indicator

1. Show that Al reacts with both acid and base by dropping aluminum foil strips into flasks containing 6M HCl and 6M NaOH. If desired the reactions can be done in filter flasks with balloons attached to the side-arms. The Al is dropped in and the flasks are stoppered. The balloons inflate with H₂ gas and can be ignited with matches and a taper.

2. Fill a large beaker with water and make slightly basic with a few drops of 0.1M NH₄OH. Add about 10 drops of bromthymol blue indicator. With care, dump a scoopula of anhydrous AlCl₃ into the beaker. The AlCl₃ reacts violently, and the water turns from blue to yellow, as HCl is produced in the reaction.

See also: Amphoterism
AMMONIA FOUNTAIN

Demonstrate the solubility of gaseous NH₃ in water.

Materials: 1 gal. size bottle (glass)
Ring stand with iron rings and clamps
NH₃ gas cylinder (lecture bottle)
2-3 liter beaker with water
Phenolphthalein indicator

Pinchcock
2-hole rubber stopper fitted as shown below
Syringe bulb

Set up as shown below using ring stand and clamps for support.

Fill the syringe bulb with water and attach to the rubber stopper as shown below but do not insert stopper in the gal. size bottle yet. Make sure the pinch cocks are also attached to the rubber tubing approximately where shown.
AMMONIA FOUNTAIN
(continued)

Charge the gallon size bottle with ammonia gas under a hood, and now without wasting too much time, insert the rubber stopper assembly containing the filled syringe into the bottle with the ammonia. Insert as tight as possible.

Put the rubber tubing in the beaker with the water and add 15-20 drops of phenolphthalein to the water.

To start the demonstration, remove the pinchcock first and squeeze the syringe bulb to force the water in the bottle with the ammonia. A red fountain will begin at once and it will continue until the bottle gets full with water.

HCl gas may also be used. Follow the same procedure except make the water in the beaker slightly basic (by adding 0.1M NaOH dropwise) and add bromothymol blue and water. Water will go from blue to yellow as demonstration proceeds.
AMPHOTERISM

Materials:

$\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$
$50\% \ \text{NaOH}$
Conc. HCl
Distilled water

To 400 ml of water add 2 grams of $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ and dissolve it.

Dropwise add 50% NaOH while stirring until the solution gets cloudy.

Keep adding NaOH until the solution becomes clear again.

Now add conc. HCl dropwise until the solution becomes cloudy.

Add more HCl to get the solution clear once more.

$\text{KAl}(\text{SO}_4)$ can also be used, but the $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ works better.
AMPHOTERISM DEMONSTRATION

Materials:

- 4M Be(NO₃)₂·3H₂O
- 50% NaOH
- Concentrated HNO₃

To 500 milliliters of water and 50 milliliters of 4M Be(NO₃)₂·3H₂O. To this solution add slowly and with stirring:

1. Three milliliters of 50% NaOH. [This is enough to produce a precipitate in suspension.]

2. More 50% NaOH (12 milliliters), drop by drop at the endpoint. [The precipitate dissolves.]

3. Eight milliliters of concentrated HNO₃. [Precipitate forms.]

4. Seven milliliters of concentrated HNO₃. [The precipitate dissolves.]

NOTE

Sn(OH)₂, Al(OH)₃, and Zn(OH)₂ are not good. Too much reagents are needed to cause the necessary pH changes.
ATOMIC ORBITALS
(Models)

A complete set of the s, p, and d orbitals supported on stands, and each on its own 3d axes is available for display.

Molecular Orbitals

Bonding and antibonding molecular orbitals of \( \text{N}_2 \) mounted on a stand are available for display.

Hydrocarbon Models
Molecular Geometry (JSEPR)

Styrofoam ball and stick models of \( \text{AX}_5, \text{AX}_5, \text{AX}_4, \text{AX}_3, \text{and AX}_2 \) geometric shapes are available for display.

Also, balloons may be used. Fill 6 large balloons with air, and tie them all together, so that an octahedron is formed. Next, tie all six balloons together at their knots, forming an octahedral arrangement. Pop one balloon, and the balloons will adopt a trigonal bipyramidal arrangement. Continue popping balloons to get the AX4, AX3, ax AX2 geometric arrangement.
ATOMIC STRUCTURE AND BONDING
(Computer-Generated Electron Dot-Density Diagrams)

These diagrams are transparencies to be used with an overhead projector. Both atomic and molecular diagrams are available, and they include:

1. Hydrogen atom
2. Helium atom
3. Lithium atom
4. Beryllium atom
5. Boron atom
6. Carbon atom
7. Nitrogen atom
8. Arrangement of p electrons in B, C, and N atoms
9. Lithium hydride
10. Hydrogen molecule
11. Water molecule
12. Hybrid orbitals
13. Hydrogen Fluoride
14. Lone and bonding pairs
15. Electronegativity
16. Ethene

* Accompanying detailed notes on these diagrams are available upon request.
**BEATING HEART**

**Materials:** Large watch glass
Mercury
6M H₂SO₄
conc. H₂SO₄
0.1M K₂Cr₂O₇
Long iron nail
Droppers and 50 ml beakers

Place a pool of mercury about 3/4 in. in diameter in the watch glass. Cover the mercury with 6M H₂SO₄. Add 1 ml of 0.1M K₂Cr₂O₇. Place the iron nail in the watch glass so that its tip just touches the mercury and the nail lies along the radius of the glass.

Slowly add 5-2 ml of conc. H₂SO₄ above the pool of mercury. As soon as rhythmic motion occurs in the mercury, stop adding acid. The pool of mercury will "beat".

The demonstration may be performed on an overhead projector for better visibility.
Boiling Water At Reduced Pressure

Materials: Filter flask, 1000 ml
Water
Stopper
Rubber suction tubing
Food Coloring

Pour about 300 ml of cold water into the flask and insert stopper. Connect one end of the tubing to the side-arm of the flask, and the other end to an aspirator. Turn faucet on. Water in flask soon boils. Food coloring may be added to the water for better visibility.

Note: In winter, the top water is very cold, and boiling occurs rapidly. However, in summer, the water in the lines is much warmer, and as a result, the vacuum created by the aspirator is not sufficient for rapid boiling. To compensate, add warm water to the flask.
BOYLE'S LAW

Materials: Boyle's Law apparatus shown below (supported on a ring stand)
Meterstick
Grease pencil

Show that the pressure is inversely related to the volume at constant temperature and moles.

\[ PV = K \]

Show that the PV product is constant by taking at least three different P and V readings by either raising or lowering the leveling bulb.
BROMINATION OF ACETONE

Materials:
- 6 ml beakers (5)
- 8 M acetone
- 2 M HCl
- Distilled water
- 0.02 M Br₂
- Stirrers
- Light Box
- Clock

A. Reference Reaction

In 500 ml beaker:

- 100 ml 8 M acetone
- 100 ml 2 M HCl
- 100 ml water

Now add 50 ml 0.02 M Br₂ and simultaneously start the clock and stir the solution.*

Time = 5 minutes
2.05

B. Concentration Effect

In 500 ml beaker:

- 200 ml 8 M acetone
- 100 ml 2 M HCl

Add 50 ml 0.02 M Br₂, start the clock, and stir the solution.

Time = 245 minutes

C. Acid Effect

In 500 ml beaker:

- 100 ml 8 M acetone
- 200 ml 2 M HCl

Now add 50 ml of 0.02 M Br₂, start the clock, and stir the solution.

Time = 245 minutes

*The solution is stirred until all of the bromine color disappears.
A. **Reference Reaction:**

In a 600 ml beaker, add:
- 100 ml. 8 M Acetone
- 100 ml. 2 M HCl
- 100 ml. WATER

Then add 100 ml of .01 M Br₂

\[ t = \pm 1 \text{ min} \]

B. **Acetone EFFECT:**

In a 600 ml beaker, add:
- 200 ml. 8 M Acetone
- 100 ml. 2 M HCl

Then add 100 ml of .01 M Br₂

\[ t = \pm 30 \text{ sec} \]

C. **Acid EFFECT:**

In a 600 ml beaker, add:
- 100 ml. 8 M Acetone
- 200 ml. 2 M HCl

Then add 100 ml of .01 M Br₂

\[ t = \pm 30 \text{ sec} \]
D. Temperature Effect

In a 600 ml beaker, add: (same as reference reaction)

100 ml 85% Acetone
100 ml 2M HCl
100 ml H₂O

Heat solution to about 40°C. Then add 100 ml of .01 M Br₂. \( t = 30 \text{ sec.} \)

E. Bromine Effect:

In a 600 ml beaker add:

100 ml 85% Acetone
100 ml 2M HCl
150 ml H₂O

Then add 50 ml .01 M Br₂. \( t = \pm 1 \text{ min} \)
BUFFERS

Materials: 0.1M NaOAc
0.1M HOAc
Methyl red or bromothymol blue
Beakers

Prepare solutions according to chart:

\[ \text{pH} = -\log \left(1.8 \times 10^{-5} \frac{[\text{HOAc}]}{[\text{NaOAc}]} \right) \]

<table>
<thead>
<tr>
<th>Volume (milliliters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
</tr>
<tr>
<td>Salt</td>
</tr>
<tr>
<td>pH</td>
</tr>
</tbody>
</table>

In each beaker add 1.5 ml Methyl red and stir.*

This will show the gradual color changes.

*Bromothymol blue may work better because the gradual color changes may be easier to detect.
BUFFERS AND pH

**Materials:**
- 3M HOAc
- 3M NaOAc
- 3M HCl
- 3M NaOH
- 1M HOAc
- solid NaOAc
- 1M NaOH
- pH meters (2) and electrodes
- Sargent-Welch strip chart recorder
- Lighted magnetic stirrers (2)

Connect the pH meter and strip chart recorder as described in the Titration Curve Demonstration on page 43.

I. Solution A: 

1. Add 15 ml of 3M HOAc + 1.5 ml of 3M NaOAc \( \rightarrow \) pH = 3.75 (i.e. \( \text{pK}_a - 1 \))
   
   \[
   \text{pH} = \text{pK}_a + \log \left( \frac{[\text{NaOAc}^-]}{[\text{HOAc}]} \right)
   \]

2. Add 13.5 ml of 3M NaOAc (1:1 buffer now) \( \rightarrow \) pH = 4.75 (i.e. \( \text{pK}_a \))

3. Add 3 ml of 3M HCl \( \rightarrow \) pH = 4.59

4. Add 2 portions of:
   - 3 ml of 3M NaOH \( \rightarrow \) pH = 4.75
   - 3 ml of 3M NaOH \( \rightarrow \) pH = 4.88

   \[
   \text{pH} = \text{pK}_a + \log \left( \frac{[\text{NaOAc}^-]}{[\text{HOAc}]} \right)
   \]

Solution B: 96 ml of dist. H2O (make acidic (pH = 4.75) \( \rightarrow \) HCl or NaCl)

1. Add 3 ml of 3M HCl \( \rightarrow \) pH = 1.01

2. Add 2 portions of:
   - 3 ml of 3M NaOH \( \rightarrow \) pH = 7
   - 3 ml of 3M NaOH \( \rightarrow \) pH = 12.9

   \[
   \text{pH} = -\log \left( 1.8 \times 10^{-5} \cdot \frac{[\text{HOAc}]}{[\text{NaOAc}^-]} \right)
   \]

Addition of strong acid or base causes only a slight change in pH in the buffer solution, but causes a drastic change in pH in the distilled water.

The expected pH values for each addition can be calculated in class using the equations above. These results are then confirmed using the pH meter to obtain actual values.
Solution A:

1. Add 50 ml of 1M HAc + 5 ml of 1M NaOAc \(\rightarrow\) pH = 3.75
   (10:1 buffer)

\[pK_a = 4.75\]

2. Add 45 ml of 1M NaOAc \(\rightarrow\) pH = 4.75
   (1:1 Buffer)

3. Make another beaker of 1:1 buffer by adding 50 ml 1M HAc + 50 ml of 1M NaOAc

4. To one of the buffers, add 3 ml of 3M HCl \(\rightarrow\) pH = 4.78

5. To the other 1:1 buffer, add 3 ml of 3M NaOH \(\rightarrow\) pH = 4.88
   \[pH = pK_a + \log \frac{[\text{base}]}{[\text{acid}]}\]

Solution B:

1. Prepare 2 beakers of 100 ml water
   Adjust pH with 1M HCl or 1M NaOH to give reading of 4.75 (same as for the 1:1 buffer above \(\rightarrow\) pH 4.75

2. To one beaker, add 3 ml of 3M HCl \(\rightarrow\) pH = 1.01

3. To the other beaker, add 3 ml of 3M NaOH \(\rightarrow\) pH = 12.9
   \[pH = -\log \left(\frac{1.8 \times 10^{-5} \cdot [\text{HAc}]}{[\text{OH}^-]}\right)\]
II. Measure the pH of 300 ml of 0.1M HNOAc (pH = 2.9). Without removing the electrode, add 1/1000 g of solid NaNOAc • 3H₂O and stir. This forms a 1:1 buffer whose pH should be around 4.75.

To prove that this is indeed a buffer solution, add 1 ml of 0.1M NaOH and observe that there is no effect on the pH. Now add 1 ml of 0.1M NaOH to a beaker containing 300 ml of distilled water. The pH changes drastically (pH = 10.5).

\[\text{suitably adjust } \text{H}_2\text{O to } \text{pH} = 4.75\] with dilute \text{HCl}.

III. Prepare a KH₂PO₄/K₂HPO₄ Buffer of pH = 7.4.

By adding 50 ml of

Prepare a 3.5:1 K₂HPO₄:KH₂PO₄ buffer.

Dissolve 1.183 g of KH₂PO₄ in 50 ml of water, and dissolve 5.30 g of K₂HPO₄ in 50 ml of water. Add 50 ml of the K₂HPO₄ solution + 50 ml of the KH₂PO₄ solution to give a buffer with pH = 7.4.

Add universal indicator if desired. Drop a clink of pepsin into the buffer, and note that the pH does not fall abruptly.

Do the same for a beaker containing 300 ml of water whose pH has been adjusted to 7.4. Note the sharp decrease in pH as the clink is dropped into the beaker.
CATALYSIS
(Ostwald Reaction)

Used in the preparation of HNO₃.

\[ 3\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_3(\text{aq}) + \text{NO}(\text{g}) \]

Materials: Pt wire loop attached to glass rod as shown below
250-300 ml Erlenmeyer flask
Bunsen burner and matches
conc. NH₃(\text{aq})

Place about 50 ml conc. NH₃(\text{aq}) in flask. Warm the Pt wire loop in flame of burner (be careful not to heat glass) and place inside flask above the solution as shown. Turn lights out to show that the wire glows.

\[ 4\text{NH}_3(\text{g}) + 5 \text{O}_2(\text{g}) \xrightarrow{\text{Pt}} 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g}) \]

\[ 2\text{NO}(\text{g}) + \text{O}_2 \rightarrow 2\text{NO}_2(\text{g}) \]

Note: Copper wire may be used instead of Pt. Make a coil of Cu wire and suspend over the \text{NH}_4\text{OH}. The copper will glow brightly, and soon will melt from the heat produced in the reaction. The hot Cu will react \text{with} \text{NH}_4\text{OH to form blue...}
CATALYSIS DEMONSTRATION

Materials: 0.02 M KMnO₄
          1.0 M Oxalic acid
          6.0 M H₂SO₄
          MnSO₄ + H₂O (powder)

To 400 milliliters of water add 30 milliliters of 0.02 M
KMnO₄, 30 milliliters of 1.0 M oxalic acid and 40 milli-
liters of 6.0 M H₂SO₄. Stir and note that there is no
reaction. Add approximately one gram of the MnSO₄ +
H₂O powder to the solution. Stir again and note that
the color changes this time:

   purple → red → orange-red → yellow → colorless

Reaction:

\[
\begin{align*}
\text{MnO}_4^- + \text{H}_2\text{C}_2\text{O}_4^- + \text{H}^+ & \rightarrow \text{Mn}^{2+} + \text{CO}_2 \text{(gas)} \\
\text{MnSO}_4 & \rightarrow \text{Mn}^{2+} + \text{SO}_4^{2-}
\end{align*}
\]

NOTE:

6.0 M HCl or HNO₃ acids may be substituted for the
H₂SO₄. MnO₄ must be the limiting reagent, other-
wise the reaction does not go to completion
(colorless).

To each beaker, add 400 ml of H₂O and
30 ml of 0.01 M KMnO₄. Place on heated mag. stirrers
and begin stirring at equal speeds. To each beaker
add simultaneously 30 ml of 1.0 M oxalic acid, then add
40 ml of 6.0 M H₂SO₄. Note that there is no reaction
in either beaker. Now add approximately 1 gram of
MnSO₄·H₂O powder to one of the beakers. This
beaker quickly becomes clear. After several
minutes the other beaker will slowly fade to
clear as well.

Color change is...
CHARLE'S LAW
(Crude Gas Thermometer)

Materials: Charle's Law Apparatus containing blue liquid.

Qualitatively, show that the volume is directly proportional to the temperature:

\[ \frac{P}{V} = k \]

Heat up the test tube to increase the temperature of the gas in the test tube. As the temperature of the gas increases, the volume of the gas in the test tube increases and the height of the column of the blue solution decreases.

The test tube can be heated by hand warming, by direct flame (be careful), or by using a hot water bath.
CHEMICAL CANNON
(Evolution of CO₂ gas)

Materials:
Ring stand
Clamps
Large test tube (200 ml)
Cork to fit tube
5-10 g Na₂CO₃, NaHCO₃
10 ml vinegar
1 M HOAc

Set up the test tube on the ring stand with the clamps, and elevate it at 30°. Pour in the Na₂CO₃ first and then the vinegar. Very quickly stopper the test tube, tight. The CO₂ generated will pop the cork with a loud pop.

Na₂CO₃ + 2HOAc → 2NaOAc + CO₂↑ + H₂O

Wrap 5-10 g NaHCO₃ in a small amount of
KIMWIPE TISSUE. Push this to the bottom of the test tube with a glass rod and poke a hole in the center of the bundle to provide an inner channel for the "vinegar" to flow into.

Pour ~20-25 ml of 1 M HOAc into the test tube and very quickly insert the stopper. The CO₂ evolved will pop the cork with a loud "pop".

NaHCO₃ + HOAc → NaOAc + CO₂↑ + H₂O
The reaction is:

\[ \text{bis 2,4-dinitrophenyl oxalate (DNPO)} + \text{H}_2\text{O}_2 \rightarrow \text{dye plus (DEP)} \rightarrow \text{bright blue chemiluminescence} \]

- **H}_2\text{O}_2** (oxidizing agent)
- Dye
- DEP

9,10-diphenylanthracene (DDA)
diehtyl phthalate

Prepare solution A: .002M DPA
.04M DNPO
in diethylphthalate

Prepare solution B: .5M H}_2\text{O}_2 in diethylphthalate

Add some of solution B to solution A and it will glow for about two minutes.

**STRUCTURES**

[Chemical structures of DNPO and DEP with molecular formulas and structures of 9,10-diphenylanthracene]
CHEMILUMINESCENCE

Materials: Small test tube with stopper or, small glass vial with cap. Solid KOH pellets, DMSO, Crown ether, Luminol

Place a few KOH pellets in the glass tube; add DMSO and crown ether. Also add luminol (small amount) and shake well and continuously. Emission of light will start in 10-15 seconds.

Chemiluminescence

Materials: Luminol, Na\textsubscript{2}CH\textsubscript{2}O\textsubscript{2}, K\textsubscript{3}Fe(CN)\textsubscript{6}, H\textsubscript{2}O

Make two solutions:

A) 2.00 mL Na\textsubscript{2}CH\textsubscript{2}O\textsubscript{2} to 500 mL with WATER

B) 1.0 mL 30% H\textsubscript{2}O\textsubscript{2}
5.0 g K\textsubscript{3}Fe(CN)\textsubscript{6}

dilute to 500 mL with H\textsubscript{2}O

Mix equal volumes of A and B. Solution will immediately glow, then will quickly fade after 5 seconds.

Note: Fluorescein or eosin Y indicators may be added if desired to get different colours (an 50/50 mixture)
Chemiluminescence II

Materials:
- anhydrous Na₂CO₃
- luminol
- Na₃HCO₃
- (NH₄)₂CO₃ + H₂O
- CuSO₄·5H₂O
- 30% H₂O₂

Solution A-1:
- 4.0 g Na₂CO₃ (or 4.7 g Na₂CO₃·H₂O)
- 0.2 g luminol
- 2.0 g Na₃HCO₃
- 0.05 g (NH₄)₂CO₃
- 0.10 g CuSO₄·5H₂O
- Dilute to 1 L with water

Solution A-2:
- 5.0 ml of 30% H₂O₂
- Dilute to 1 L

Mix equal volumes of A-1 and A-2. Solution will glow blue for ~30 sec.
COLORFUL PRECIPITATION REACTIONS

Materials: Beakers, 500 ml to 800 ml
Reagents shown below
Stirring rods

Any concentration of each reagent (unless otherwise specified) should work.

1. Pb(NO₃)₂ + K₂CrO₄ → PbCrO₄(s) (bright yellow)
2. Pb(NO₃)₂ + H₂SO₄ → PbSO₄(s) (white)
3. Pb(NO₃)₂ + KI → PbI₂(s) (bright yellow)
4. Ni(NO₃)₂ + NaOH → Ni(OH)₂(s) (blue) Br₂(aq) → Ni(OH)₃(s) (black)
5. AgNO₃ + K₂CrO₄ → Ag₂CrO₄(s) (dark red)
6. HgCl₂ + (NH₄)₂S(aq) → HgS (black)
7. MgSO₄ + NaOH → Mg(OH)₂(s) (white)
8. FeCl₃ + NaOH → Fe(OH)₃ (rust brown)
9. CuSO₄ + KI → CuI(s) + I₂ (dark brown)
10. CuSO₄ + NaOH → Cu(OH)₂(s) (light brown)
11. Co(NO₃)₂ + NaOH → Co(OH)₂(s) (pale blue)
12. Ba(NO₃)₂ + (NH₄)₃PO₄ → Ba₃(PO₄)₂(s) (white)
13. Pb(OAc)₂ + (NH₄)₃PO₄ → Pb₃(PO₄)₂(s) (white)
14. Ba(NO₃)₂ + K₂SO₄ → BaSO₄(s) (white)
15. Pb(OAc)₂ + K₂SO₄ → PbSO₄(s) (white)
16. FeCl₃ + Pb(OAc)₂ → PbCl₂(s) (white)
17. FeCl₃ + Na₂CO₃ → Fe₂(CO₃)₃ + NaCl → CO₂ + H₂O + FeCl₃
COMMON ION EFFECT  
(Silver Acetate)

Materials:  2M AgNO₃, 2M NaOAc  
Glassware  
Filter paper  

1. To 400 ml of water add 50 ml 2M AgNO₃ and 50 ml 2M NaOAc. Filter off the solid AgOAc that forms.  

2. In each of three clean and dry beakers add 20 ml of the filtrate which contains both Ag⁺ and OAc⁻. One of these beakers will serve as a blank for comparison.  

3. To the first beaker add 10 ml of 2M NaOAc by dropper and stir simultaneously. Within 30 seconds AgOAc crystals will be visible.  

4. To the second beaker add 10 ml of 2M AgNO₃ in the same manner, and solid AgOAc will precipitate out.  

This demonstration works equally well on an overhead projector. Use large Petri dishes (40 ml capacity) and follow the same instructions in steps 2 through 4 above.  

CAUTION: Make sure that the molarity of the prepared solutions is exact, and make sure the volumes used are measured out carefully. If no overhead projector is used, it may be better to use larger volumes of filtrate and excess ion for quicker reaction and visibility.
CONCENTRATIONS
(Molarity = Molality Difference)

**Materials:** Solid NH₄Cl
2 ea. 1L volumetric flasks
1000 ml graduated cylinder
dropper bottle of water

To each of the 1 liter volumetric flasks add 1 mole (52.5g) of NH₄Cl.

To the one flask add enough water to come to the mark and therefore make 1 molar solution.

To the other flask add 1 kg of water (1000 ml) to make a 1 molal solution.*

*If a balance is available, the 1 kg of water may be weighed to emphasize the mass of the solvent.
CONCENTRATION CELLS

Preparation of salt bridges:

Use 1M KNO₃ solution in the U tubes and rolled up paper tiles for plugs.

A. Using Cu(NO₃)₂

1. A = 0.01M Cu(NO₃)₂
   B = 0.5M Cu(NO₃)₂
   
   \[ E = 0 - \frac{0.0592}{2} \log \left( \frac{0.001}{0.5} \right) \]
   
   \[ E = 0.0799 \text{ volts} \]

2. To A add excess concentrated NH₃. The voltage should increase as Cu²⁺ is removed to form Cu(NH₃)₂⁺.

3. To A after step 2 add concentrated HCl. The voltage should decrease as Cu(NH₃)₂⁺ is neutralized and CuCl₂⁻ is formed (light yellow-green).

The voltmeter used should be an HP digital meter capable of reading millivolts. One can be borrowed from the physical chemistry division.

B. Using Pb(NO₃)₂

1. A = 0.01M Pb(NO₃)₂
   B = 1M Pb(NO₃)₂
   
   \[ E = 0.0 - \frac{0.0592}{2} \log \left( \frac{0.01}{1} \right) \]
   
   \[ E = 0.0592 \text{ volts (Best actual reading = 0.024 volts)} \]

2. Add 1M NaI to beaker A. The voltage increases as PbI₂ precipitates out. The more I⁻ added the higher the voltage.
CONDUCTANCE
(Liquid Ammonia)

Materials: Glass Dewars and stands (2)
Suction tubing
Sodium metal
Ammonia gas cylinder
Liquid N₂ device and separable bath
Test tubes (2), 200 mm
Ring stand and clamps
Large glass funnel
Conductance apparatus with Cu electrodes.

I.

Fill the Dewar with liquid N₂ and assemble the apparatus as shown below. Connect the funnel and suction tubing (used for fume removal) to the aspirator and turn on the faucet. Slowly open the valve on the ammonia gas cylinder and condense ammonia in the cold test tube. Close the valve when a sufficient amount of liquid NH₃ has been collected. Show that liquid NH₃ is non-conductive using the Cu electrodes.

Add a small, freshly cut piece of sodium to the test tube of liq. NH₃. The solution becomes blue due to ammoniated electrons. Show that this solution is conductive with the Cu electrodes. Addition of more Na causes the solution to change to a bronze color.

\[ \text{Na} + \text{NH}_3 \rightarrow \text{Na(NH}_3\text{)}^+ + e^-(\text{NH}_3)^- \]
II.

Prepare another test tube of liquid NH₃ as described above. Add a few crystals of NH₄Cl and dissolve it. Show that there is conductance.

\[
2 \text{NH}_4\text{Cl} + 2 \text{Na} \xrightarrow{\text{NH}_3} 2 \text{Na}^+ + 2 \text{Cl}^- + 2 \text{NH}_3 + \text{H}_2(g)
\]

*A CO₂-isopropanol bath may be substituted for the liquid N₂ and Dewars.*
CONDUCTIVITY DEMONSTRATION

**Materials:** Conductance apparatus with Cu electrodes
(12) Tall beakers, 250 ml.
Reagents listed below

Test the conductance of each of the following solutions with the conductance apparatus:

<table>
<thead>
<tr>
<th>Ethanol</th>
<th>1M NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar (aq)</td>
<td>1M HCl</td>
</tr>
<tr>
<td>Toluene</td>
<td>1M HNO₃</td>
</tr>
<tr>
<td>Ether</td>
<td>1M HNO₃</td>
</tr>
<tr>
<td>Glycerin</td>
<td>1M NaOH</td>
</tr>
<tr>
<td>Distilled water</td>
<td>1M K₂CO₃</td>
</tr>
<tr>
<td>Tap water</td>
<td></td>
</tr>
</tbody>
</table>

Dip the electrodes into each solution (rinse with dist. H₂O). The light bulb lights when there is conductance.
COPPER CHEMISTRY

Materials: Cu metal
conc. HNO₃
conc. NH₄OH
conc. H₂SO₄
conc. HCl
conc. H₃PO₄
0.25M CuSO₄
Zinc metal
Bromthymol Blue indicator.

1. Fill four beakers with one each of the following acids: conc. HCl, conc. H₃PO₄, conc. H₂SO₄ and conc. HNO₃ (about 20 ml). Show that only the nitric acid reacts with copper metal by dropping a small quantity (± 0.5g) of copper in each beaker.

2. Pour about 50 ml conc. HNO₃ into a 500 ml filter flask that is fitted with a rubber hose. Fill a 2000 ml beaker with water and add ~20 drops of bromthymol blue and ~5-10 drops of 0.1M NH₄OH. Place the open end of the hose in the water. Drop ~2 grams of copper into the flask and quickly stopper. NO₂ gas is evolved and turns the water from blue to yellow, demonstrating the acidity of NO₂.

3. Pour ~10 ml conc. HNO₃ into a small beaker or large test tube and add about 0.5g of copper. A green complex is produced. Pour this into a beaker containing 100-200 ml H₂O and the blue complex is formed.

4. Prepare a saturated solution of CuSO₄·5H₂O in conc. HCl. A green chloro complex is produced. Pour 20.0 ml of this into 200 ml of H₂O. The blue aquo complex results. Using a dropper, add while stirring conc. NH₄OH until Cu(OH)₂ precipitates* (about 18 ml of conc. NH₄OH needed for this). Add more conc. NH₄OH to form the tetra-ammine complex Cu(NH₃)₄⁺⁺.

5. Place a strip of zinc metal in a beaker containing 0.25M CuSO₄. A layer of copper is deposited on the zinc strip.

*A fresh beaker of 0.25M CuSO₄ may be substituted for this step.

* anhyd CuSO₄ works a bit better.
CORROSION

Materials: Petri dish
Thin strip of zinc metal (passive)
Thin wire of copper or copper penny
1M HCl

Set up in the Petri dish a solution of 1M HCl. In the solution drop the zinc metal which is first bent into an L shape. Across the zinc metal drop a piece of copper wire. Hydrogen gas will be liberated.

The entire demonstration is performed on an overhead projector. The hydrogen gas bubbles can be observed on the screen.
CROOKES TUBES: ELECTRON GAMES

Materials:

- Crookes tubes (~half dozen available)
- DC rectifier and induction coil
- Flashlight
- Magnet (bar)
- Vacuum pump
- Suction hoses and vacuum grease

The demonstration is more impressive with the room lights turned off.

The long tube can be hooked to the vacuum pump to show conductance while evacuating the tube.
DECOMPOSITION OF HYDROGEN PEROXIDE

Materials:  
30% H$_2$O$_2$  
0.5 M KI  
Food Coloring  
MnO$_2$(s)  
Droppers  
Gloves

Construct 2 of the set-up shown below:

Set-up #1:

1. Measure 200 ml H$_2$O and pour into flask. Add 3 ml 30% H$_2$O$_2$, stopper the flask, and begin stirring. No O$_2$ is collected.

2. Now add a pinch of MnO$_2$, quickly re-stopper, and take timed readings of the volume of O$_2$ collected.

Set-up #2:

1. Add to the flask 200 ml 0.5M KI. Then add 3 ml 30% H$_2$O$_2$, quickly stopper, and stir. Take timed readings of the volume of O$_2$ collected.
DISSOLUTION DEMONSTRATION

Materials:

NH₄Cl solid or NaNO₃, or NH₄NO₃ is (very good!)
Thermometer
Water

Record the temperature of the water in the beaker before adding the NH₄Cl. Add the solid NH₄Cl, stir and take another temperature reading.

1. If 50 grams of NH₄Cl is added to 250 milliliters of water the temperature drops from room temperature to 9°C

2. If 35 grams of NH₄Cl is added to 100 milliliters of water the temperature drops from room temperature to 4°C with condensation forming on the side of the beaker.
DUST EXPLOSION
(kinetics)

Materials: Lycopodium powder
Either one of the two set-ups below
Matches
Air supply

I. Fill the funnel shown above in set-up I about 3/4 full of lycopodium powder, light the candle and throw the powder straight up in the air. An explosion with flames takes place about four to five feet away from your person.

II. The lycopodium powder can be placed in one's hand. A match can be lit and held with the same hand and the powder thrown up in the air as above for the same type of results.

III. Another alternative is to use set-up II. Here the funnel is filled about 3/4 full of lycopodium powder. The hose is connected to a strong air supply. After the candle is lighted and the lid carefully placed on the wooden box, the air supply is quickly turned on at full force. A dust explosion occurs with the lid blown off the box with flames visible to all spectators.
EFFECTS OF BUFFERS

MATERIALS: buffer pH 7
H₂O pH 7
concentrated HCl
concentrated NaOH
pH meter

A. Take a pH reading of beaker A and then add concentrated acid. Take another pH reading to show the big change in pH.

B. Take a pH reading of beaker B and then add concentrated base. Take another pH reading and show the big change in pH.

C. To C add concentrated acid after taking an initial pH reading. Shows very little change in pH.

D. To D add concentrated base after taking an initial pH reading. Now add concentrated base and take another pH reading to show that again there is very little change in pH.

must... didn't work
try... on 2/2/88

Buffer (commercial) not strong enough - get large changes in pH with addition of acid or base
ELECTRICITY BY CHEMICAL REACTION
(Flashbulb Demonstration)

Materials: 3M H₂SO₄
150 ml beaker
Magnesium ribbon
No. 16 copper wire
Flash bulb socket

Connect the copper wire and magnesium ribbon to the
socket terminals as shown below. Lower the Mg ribbon and Cu spiral simultaneously into a beaker containing ~100 ml 3M H₂SO₄. Electricity is generated, setting off the flash bulb.

\[
2 \text{H}_3\text{O}^+ + 2 \text{e}^- \rightarrow \text{H}_2 + 2 \text{H}_2\text{O}
\]

\[
\text{Mg} + \text{H}_2\text{SO}_4 \rightarrow \text{MgSO}_4 + \text{H}_2
\]

\[
\text{Mg} \rightarrow \text{Mg}^{++} + 2 \text{e}^-
\]

![Flashbulb diagram]
ELECTROLYSIS
(Reduction of oxidized ferroin)

Materials:  Conc. Ferroin solution*  
Cl₂ gas cylinder  
NaClO₄(s)  
DC power supply and leads  
Apparatus shown below

Pt. electrodes  
U-tube  
white  
mounting board  
ring stand

Add 2-3 ml of conc. ferroin to about 200 ml of water. Bubble Cl₂ gas through the solution for a minute and stir. The chlorine oxidizes the iron(II) complex to the blue iron(III) complex. Aqueous chlorine works well also. After several minutes (when the solution turns blue), measure 150 ml of the solution and dissolve in it approx. 20g of sodium perchlorate. Pour this into the U-tube and lower the electrodes into the solution. Connect the circuit and turn on the power (run at 20V). The blue iron(III) complex is reduced back to the orange iron(II) complex at the negative electrode, and that side of the U-tube becomes orange.

* Ferroin is 1,10 Phenanthroline Ferrous Sulfate. The concentrated commercial solution is 0.025 Molar.
ELECTROLYSIS OF NaI

Materials:
- 1000 ml beaker
- DC power supply
- Meter (ammeter)
- Copper electrodes, 1" x 8"
- NaI(s)
- Phenolphthalein
- Partition with paper towel
- Wire leads

Connect the circuit as shown below. Use the 0-5 amp terminal on the ammeter.

Fill the beaker 3/4 full with deionized H$_2$O. Using the meter, test for conductance. Now add 0.5 g of NaI and stir to dissolve. Add 5-5 drops of indicator. If the solution is basic, add a few drops of 1M HCl to neutralize. Tape squares of paper towel to both sides of the partition, and place the partition in the beaker. Turn on the DC power supply (set voltmeter to 2.5-3 volts). The solution turns pink at the negative electrode and brown at the positive electrode.

Cathode: pink

\[ 2 \text{H}_2\text{O} + \text{e}^- + 2 \text{OH}^- + \text{H}_2(\text{g}) \]

Anode: brown

\[ 2\text{I}^- \rightarrow \text{I}_2 + 2 \text{e}^- \]
\[ \text{I}^- + \text{I}_2 + \text{I}_3^- \]

White powder at anode:

\[ \text{Cu} + \text{I}^- \rightarrow \text{CuI(s)} + \text{e}^- \]

Can also be done on:

Overhead projector using the pencil-battery electrode assembly shown below. Pour NaI solution (0.1M-1M) into a small petri dish and place on OH. Immense the tip of the pencil into the NaI. FIP can be added if desired.
ELECTROLYSIS OF WATER

Materials: DC power supply
           Wire leads
           Apparatus as shown below.

Connect the Pt electrodes to the power supply. Remove the stopper from the water reservoir and open the stopcocks slowly to fill the gas measuring tubes with water. (A dye has been added to the water to enhance visibility.) Close the stopcocks when the tubes are full. Turn on the power supply. Use the 12 V setting and adjust the voltmeter to read 16-20 volts.

$\text{H}_2$ is collected in the tube housing the cathode, and $\text{O}_2$ is collected in the tube housing the anode in the stoichiometric ratio of 2:1.

$$2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2 + \text{O}_2$$
ELECTROLYSIS OF WATER

Materials:  
1M NaNO₃  
Bromthymol blue indicator  
1M HCl  
DC power supply and leads  
Apparatus as shown below

Pt electrodes

white
mounting board

U-tube

ring stand

Add about 10 drops of bromthymol blue to 150 ml of 1M NaNO₃. Adjust the pH of this solution to 7 by adding dropwise 1M HCl until the solution becomes green. Pour this into the U-tube and lower the electrodes into the solution. Connect the leads and turn on the power supply (run at 16-20V). One side of the U-tube will become blue while the other side turns yellow.
EQUILIBRIUM
(Complex ion formation, FeNCS$^{2+}$)

Materials: 4 ea. x 2000 ml glass cylinders each containing
1500 ml H$_2$O
0.02M KSCN
0.002M Fe(NO$_3$)$_3$
NH$_4$Cl(s) or NH$_4$NO$_3$(s)

To each glass cylinder filled with about 1500 ml water add:

1) 25 ml 0.002M KSCN
   25 ml 0.002M Fe(NO$_3$)$_3$

2) 50 ml 0.002M KSCN
   25 ml 0.002M Fe(NO$_3$)$_3$

3) 25 ml 0.002M KSCN
   50 ml 0.002M Fe(NO$_3$)$_3$

4) same as #1 but add 5-15g NH$_4$Cl or NH$_4$NO$_3$
   (Increase acid content and shift equilibrium
   back to reactants)

Fe$^{3+}$ + HSCN $\rightleftharpoons$ FeNCS$^{2+}$ + H$^+$

Use illuminator (box with light in it) to best see the
intensity of the various solutions.

TRY THIS!

1) 10 ml .20 M KSCN
   10 ml .1M Fe(NO$_3$)$_3$

2) 30 ml .1M KSCN
   10 ml .1M Fe(NO$_3$)$_3$

3) 10 ml .1M KSCN
   30 ml .1M Fe(NO$_3$)$_3$

4) same as # above

Triple one reagent rather than just double
as written. Get better color contrast.
EQUILIBRIUM
(Temperature Effect)

Materials:
2 tubes of NO<sub>2</sub> gas
2 large beakers
1 hot plate
Ice
Dry ice/acetone bath
Rock salt
Thermometer
Tongs lined with rubber tubing

Equilibrium: NO<sub>2</sub> ⇌ N<sub>2</sub>O<sub>4</sub>

Upon cooling the NO<sub>2</sub> filled tube in rock salt/ice bath*, the brown NO<sub>2</sub> gas goes to the colorless N<sub>2</sub>O<sub>4</sub>*.

Upon heating the NO<sub>2</sub> filled tube from room temperature to 80-90°C in hot water bath the brown color becomes more intense indicating that more NO<sub>2</sub> is formed.

The second tube in each case can be used for comparison.

*Dry ice/Acetone bath may be substituted if desired.
FERROMAGNETISM

Materials: conc. (50%) NaOH
0.1 M FeSO₄
0.1 M Fe₂(SO₄)₃ — add just enough conc. H₂SO₄ to dissolve
Test tube, 200 mm.
Magnet
Ring stand with test tube clamp

Add 2 ml of 0.1 M FeSO₄, 2 ml of 0.1M Fe₂(SO₄)₃, and 4 ml of 50% NaOH to a 200 mm test tube. Mix thoroughly. Then add 30 ml of water, and mix again. Secure the test tube with the clamp, and allow several minutes for the black precipitate to settle to the bottom of the tube. The black precipitate contains Fe₃O₄. The magnetic properties of Fe₃O₄ can be shown by running a strong magnet up the sides of the test tube. The precipitate will follow the magnet.
FIRE IN H₂O

**Materials:**
- One gram yellow phosphorus
- Oxygen gas
- Large jar
- 300 ml H₂O
- Hot plate
- Thermometer
- Forceps

Set up the apparatus as shown, and heat up the water to 70°C*. Start to bubble the O₂ near the P pieces and flashes of flame will occur.

Be very careful. If the P explodes on ignition it should still be safe due to the small pieces used.

*Phosphorus melts.
FLAME TESTS

Materials: Solid Li$_2$CO$_3$
Solid K$_2$CO$_3$
Solid Na$_2$CO$_3$
Solid BaCO$_3$
Solid CaCO$_3$
Solid SrCO$_3$

Use the solid carbonates in a small Petri dish. To the solid add concentrated hydrochloric acid. Quickly place the barrel of a Fisher Burner with the air inlet open directly over the fumes given off. The fumes will be pulled directly into the lighted burner and the flame color will change accordingly (depending on which carbonate is used.)

TRY:

<table>
<thead>
<tr>
<th>Carbonate</th>
<th>Flame Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li$_2$CO$_3$</td>
<td>Carmine</td>
</tr>
<tr>
<td>K$_2$CO$_3$</td>
<td>Purple red (through Co glass)</td>
</tr>
<tr>
<td>Na$_2$CO$_3$</td>
<td>Yellow</td>
</tr>
<tr>
<td>BaCO$_3$</td>
<td>Yellow-green</td>
</tr>
<tr>
<td>CaCO$_3$</td>
<td>Yellow-red</td>
</tr>
<tr>
<td>SrCO$_3$</td>
<td>Scarlet</td>
</tr>
</tbody>
</table>
FLOTATION
(METALLURGY)

Materials: Mercury (II) oxide
25 x 200 mm test tube with stopper
Oil
Water
Sand

Set up as shown below:

![Diagram of test tube with layers: oil, water, sand and mercuric oxide.]

On shaking the test tube, the mercuric oxide will concentrate in the oil phase.
FUEL CELL DEMONSTRATION

Fuel for the cell:

80 g NaOH
400 ml H₂O
40 ml CH₃OH

Fill the cell about 3/4 full with the fuel. Connect the wires and add 30% H₂O₂. Turn the motor on. If the blades do not rotate right away start the rotation manually.
GALVANIC (VOLTAIC) CELL

Materials: 2, 400ml beakers
U-tube
1M KNO₃; 1M CuSO₄; 1M ZnSO₄
Zn and Cu electrodes
Ammeter/Voltmeter; alligator clips with wires

In first beaker put 250ml 1M CuSO₄ and a copper electrode. In a second beaker put 250ml 1M ZnSO₄ and a Zn electrode. Fill the U-tube (bridge) with 1M KNO₃ and use paper towel plugs on the ends. Set up as shown below and use voltmeter setting of 1-5 volts D.C. The reading will be ~1.05 volts D.C.*

*The large ammeter can be used with a setting to read milliams. This gives a nice deflection for better visibility.
GELATINATION

(SILICA GEL DEMONSTRATION)

Materials: conc. Sodium Silicate soln. (commercial)
           1M HOAc
           (2)-250 ml beakers

1. Prepare 60 ml of a $40\% \frac{V}{V}$ solution of sodium silicate from the concentrate.
   (24 ml of concentrate + 36 ml $H_2O$).
   Pour into beaker #1

2. Add 50 ml of 1M HOAc to beaker #2.

3. Pour contents of beaker #2 (acid) into beaker #1, and then back again into beaker #2, as if mixing a cocktail. Do this 4 to 5 times until the gel is thick enough to cling to the inside of an inverted beaker.

NOTE: These solutions can be prepared well in advance.
GLOWING SPLINT

Materials: 5 g powdered KClO₃
Test Tube
Wooden splint
Bunsen burner

Set up the apparatus as shown below and heat the powder to a temperature high enough to melt the KClO₃. Drop in the unlit wooden splint. It will light and burn rapidly in a hot atmosphere with oxygen.

Be careful. Wear goggles in case of spattering.
GRAHAM'S LAW: GAS DIFFUSER
(Demonstrate the diffusion of gases)

Materials: Apparatus shown below containing blue colored water
Beaker to fit over porous cup
Tank of hydrogen gas
Rubber tubing

Fill beaker with hydrogen, keeping inverted place over porous cup. Blue soln will squirt out about 5-6'
HALOGENS
(Chemistry of the halogens)

Materials:
- Cl₂ - aqueous
- NaBr - aqueous or solid
- NaI - aqueous or solid
- Lecture bottle of Cl₂
- Bromthymol blue indicator
- PBr₃

1. Displacement of Halogens

   Fill a beaker with aqueous Cl₂. Add to this some solid or aqueous NaBr (or any Br⁻ salt). Orange-brown Br₂ is liberated. Now add solid or aqueous NaI (or any I⁻ salt). Brown-black I₂ is liberated. Display stock solutions of aqueous Br₂ and I₂ for comparisons.

2. Acidity of Cl₂-aq.

   Fill a large beaker with water and add bromthymol blue (make slightly basic by adding 5-7 drops 1M NH₄OH). Attach a rubber hose to a Cl₂ gas cylinder and bubble the Cl₂ through the water. Water turns yellow (acidic).

3. Acidity of PBr₃

   Fill a 1000 ml beaker about 3/4 full with water. Add 2-3 drops of 1M NH₃, and add enough bromthymol blue to give the H₂O a strong blue color. Add PBr₃ (about 20 ml). Solution turns yellow (acidic) and PBr₃ begins to bubble.

See also: Photochemical Reaction (H₂ + Cl₂)
Reaction of Sodium and Chlorine.
HARD WATER
(Burning Gel)

Materials: Saturated calcium acetate
95% ethanol
250 ml beakers (two)

Mix 180 ml of ethanol with 20 ml of saturated calcium acetate; it solidifies into a gel. Squeeze out the liquid, dry hands, place gel on asbestos and ignite it.

The burning gel can be picked up with caution.
HYDROGEN EXPLOSION
(Halloon)

**Materials:**
- balloon
- Matches and taper
- dial rod ~ 3-4 ft. long
- H₂ gas
- String

Fill the balloon to approximately 1½ size with hydrogen gas, tie off with string about 4 feet long and allow to float. Ignite the balloon using a waxed taper attached to the dial rod (from about 4-5 feet away). A magnificent explosion will result.
HYDROGEN EXPLOSION
(Bell jar)

Materials: 1 bell jar with hole on top to receive rubber stopper
1 hole rubber stopper fitted with glass tube ~ 6" long with ~ 3-4mm I.D.
4 pieces 2" x 4" wood each ~1 ft. long
H₂(g) supply
Matches

Stack together 2 pieces of 2 x 4's and set each pair approximately 4" apart and rest the ball jar on top to elevate above working area. Insert rubber stopper with tube in the hole of the bell jar (see below), fill jar with hydrogen gas and light the H₂ gas at the glass tube on top of the bell jar.

The hydrogen will burn until the H₂/air mixture in the bell becomes somewhat stoichiometric at which time an explosion will take place and water condensation on the inside of the bell jar walls will be very visible.
HYDROLYSIS

WEAK ACIDS

Materials:

NaOAc (30 grams)
Na₂S (2 grams)
Na₂P₂O₇ (sodium pyrophosphate; 2 grams)*
Phenolphthalein

Take three separate beakers and pour 500 ml of water in each. To each beaker add 20 drops of phenolphthalein. In the first beaker add the 30 grams of NaOAc, stir and observe the slightly pink colored solution. In beaker number two add the 2 grams of Na₂S stir and observe the strong red color (basic solution). To the last beaker add the 2 grams of Na₂P₂O₇ stir and again obverse the strong red color of the solution due to the hydrolysis reaction.

REATIONS

\[ \text{OAc}^- + \text{H}_2\text{O} \rightleftharpoons \text{HOAc} + \text{OH}^- \]
\[ \text{S}^2^- + \text{H}_2\text{O} \rightleftharpoons \text{HS}^- + \text{OH}^- \quad K_1 \]
\[ \text{HS}^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{S} + \text{OH}^- \quad K_2, \quad K_1 \gg K_2 \]
\[ \text{P}_2\text{O}_7^{4-} + 4 \text{H}_2\text{O} \rightleftharpoons \text{H}_4\text{P}_2\text{O}_7 + 4 \text{OH}^- \]

*  
  
<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaO</td>
<td>P - O - P - ONa</td>
</tr>
<tr>
<td></td>
<td>ONa ONa</td>
</tr>
</tbody>
</table>

WEAK BASES

Materials

1M NH₃
NH₄Cl (2 grams)
(NH₄)₂SO₄ (2 grams)
Bromthymol blue
HYDROLYSIS
(continued)

To each of two beakers add 500 ml of water and 10 drops of the indicator. To each beaker add 1 drop of 1M NH₃ and stir to take the indicator to the basic side (blue color). To one beaker add the 2 grams of NH₄Cl and to the other the 2 grams of (NH₄)²SO₄. Stir to dissolve and both of the solutions will turn yellow showing the acidic properties of the hydrolysis reactions.

REACTION

\[ \text{NH}_4^+ + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{H}_3\text{O}^+ \]
INDICATORS
(color vs. pH range)

Materials: Tall, 1500 ml jars (6)
NH₄OH solution of pH = 10
Dry ice
Indicators: phenolphthalein
          methyl orange
          bromthymol blue

Fill each jar 3/4 full with the pH = 10 ammonia solution. Jars B, D, and F are used as reference jars. In jars A and B place equal numbers of drops of phenolphthalein and stir. In jars C and D add bromthymol blue, and in jars E and F add methyl orange. Into jars A, C, and E drop chunks of dry ice to show how the pH is affected and how some indicators (ones in the correct pH range) will change color with a change in pH.

\[ \text{Phenolphthalein} \quad \text{bromthymol blue} \quad \text{Methyl orange} \]
INDICATORS
(Indicators vs. pH)

Materials:
- pH 5 Buffer
- pH 7 Buffer
- pH 7.5 Buffer

Indicators: bromthymol blue
- methyl orange
- phenolphthalein

15-150 ml beakers
- 1 mL HCl
- 1 M NaOH

1. Add to 3 separate beakers some pH 5 buffer solution. Do the same for the pH 7 and 7.5 buffers, and for the 1 M NaOH and 1 M HCl. Arrange these 15 beakers according to the diagram below.

2. Add the 3 indicators to the beakers as prescribed below. For each indicator, add the same number of drops in each beaker.

3. Compare the colors of the different indicators at various pH values.

<table>
<thead>
<tr>
<th>1 M HCl</th>
<th>pH 5</th>
<th>pH 7</th>
<th>pH 7.5</th>
<th>1 M NaOH</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Methyl orange (3.1 - 4.4)</th>
<th>Bromthymol blue (6.0 - 7.6)</th>
<th>phenolphthalein (8.2 - 10.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH range</td>
<td>pH range</td>
<td>pH range</td>
</tr>
</tbody>
</table>
INDICATORS
Overlay Demonstration

MATERIALS:

Indicator: bromthymol blue (pH range 6.0 - 7.6)
Standard buffers
  .1M NaOH
  .1M HCl
15 Petri dishes (60 x 15)
Overhead projector

1. Using commercial buffers and with the aid of acid (HCl) or base (NaOH) prepare buffers of pH 6, 6.5, 7, 7.5, and 8.

2. To each of 5 dishes containing 5 milliliters of the various buffers (pH 6, 6.5, 7, 7.5, 8) add 10 drops of indicator.

3. To each of 5 more dishes add 5 milliliters of .1M HCl, and to 5 additional dishes add 5 milliliters of .1M NaOH each. For these last five dishes use the covers of the Petri dishes which are larger in diameter.

4. Arrange the dishes on an overhead projector according to the table below and to each of the acid and base solutions add the number of drops of indicator solution which appears in the table.

<table>
<thead>
<tr>
<th>Buffers</th>
<th>pH 6</th>
<th>pH 6.5</th>
<th>pH 7</th>
<th>pH 7.5</th>
<th>pH 8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1M HCl solns</td>
<td>9*</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>.1M NaOH solns</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

5. After all the indicator is dispensed correctly and the solutions stirred, overlay the acid and base dishes. The resulting colors should match the colors of the various buffer solutions.

*Number of drops of indicator
**INVISIBLE INK DEMONSTRATION**

Transition Metal Complexes (Hygroscopy)

Materials:

- 5M CoCl₂·2H₂O
- White paper
- Writing brush
- Hot plate set on #2

Dip the writing brush in the CoCl₂ solution and write something on the white paper making sure to make wide lines for better visibility. Now dry the paper slowly on the hot plate. As the paper dries the writing will become visible with a bright blue color.

**REACTION**

\[
\text{Co(H₂O)²⁺ + 4 Cl⁻} \underset{\Delta(-\text{H₂O})}{\overset{+\text{H₂O}}{\rightleftharpoons}} \text{CoCl}_4^{2⁻} + 6\text{H₂O}\]

pale pink \quad \text{blue (atmosph.)}

The CoCl₂⁻ (tetrahedral geometry) is hygroscopic.
KINETIC ENERGY OF GAS MOLECULES OR ATOMS

Suspension of Glass particles by atomic and molecular mercury.

Materials: Evacuated tube containing glass and mercury shown below:
Bunsen burner
Matches
Ring stand with clamp
Safety glasses
Shield

Carefully, with the Bunsen burner heat the tube containing the red particles of glass and mercury. Glass will rise in the tube as a clump.

NOTE: May be somewhat dangerous. Wear safety glasses and/or use shield if available.

The glass tube may be secured on a ring stand with clamp.
KINETICS

Materials:  .1M Ce(SO₄)₂  
            .1M KI  
            Iodine solution  
            H₃AsO₃ solution*

1. Ceric Ion Oxidizes Iodide Ion:

   Add about 5ml of .1M Ce(SO₄)₂ to approximately 100ml of .1M KI.

   Ce⁴⁺ + I⁻ → Ce³⁺ + 1/2 I₂
   orange             colorless          colorless          brown

2. Arsenous Reduces Iodine:

   Add enough iodine solution to approximately 100 ml of H₂O to give a deep brown color. Add H₃AsO₃ solution until completely decolorized.

   H₃AsO₃ + H₂O + I₂ + 2H⁺ + 2I⁻ + H₃AsO₄

3. Oxidizing Ability of the Intermediate:

   Add approximately 50 ml of .1M Ce(SO₄)₂ to an excess of H₃AsO₃. Nothing happens for a while. Add a drop or two of .1M KI solution. The orange Ce⁴⁺ fades away.

*The H₃AsO₃ solution is prepared by adding the solid H₃AsO₃ to concentrated NH₃ and boiling it. When totally dissolved and cooled to room temperature neutralize the solution with conc. H₂SO₄ to the litmus paper endpoint. Be very careful adding the H₂SO₄.
KINETICS

Materials: 0.02M KMnO₄
1M H₂SO₄
FeSO₄ solution
0.1M oxalic acid
0.1M NaOH
bromothymol blue indicator
isopropyl alcohol
t-butyl chloride
timer

Part I. Nature of the Reactants

Make two identical solutions A and B by adding 6ml of 0.02M KMnO₄ to 400 ml of H₂O and 20ml of 1M H₂SO₄.

To solution A add 20ml of the FeSO₄ solution and time it.

It takes about 3 seconds for the reaction to go to completion. (The solution decolorizes.)

To solution B add 80ml of 0.1M oxalic acid. The solution in this case also decolorizes but it takes much longer. (Approximately 30 minutes)

Part II. Solvent Effect

A. Prepare a solution of 90 ml H₂O plus 10 ml of 0.1M NaOH and a few drops of indicator. Prepare another solution of 100ml isopropyl alcohol plus 1ml of t-butyl chloride. Mix the 2 solutions quickly and start the timer. Stir the mixture well and then let it sit. The time for the blue color to disappear is about 15 minutes.

B. Prepare a solution of 140ml H₂O plus 10ml of 0.1M NaOH and a few drops of indicator. Prepare another solution of 50 ml isopropyl alcohol plus 1 ml t-butyl chloride. Mix the two solutions, stir and time it. Time for decoloration is about 24 seconds.
KINETIC REACTION (OLD NASCO REACTION)

**Materials:**
- 4 ea. 2000 ml glass cylinders
- Magnetic stirrer (use setting of 7)
- Electric timer
- 4 magnetic stirring bars (2)
- Thermometer

**Solutions:**
- 0.5 M HIO₃, starch soln.
- 2 M H₂SO₄

**Procedure:**
1. Set up the 4 beakers, each containing:
   - 1000 ml water
   - 50 ml 0.5 M HI₃
   - 20 ml starch soln.
2. To each beaker 1, 2, and 3, add 50 ml fresh 0.5 M H₂SO₄ and to beaker 3 add 25 ml of 2 M H₂SO₄.
3. Start the timer immediately.
4. Set each cylinder on the stirrer at setting 7. Upon mixing solutions, reaction is complete within 2-2 minutes, with the end point being the blue-to-black immediate color change.

**Reagents:**
- 22% H₂SO₃
- 2 M Na₂SO₃
- 2 M H₂SO₄

**Aliya’s Equations for this reaction are:**

Time: 2 H₂SO₃ + 2 H₂O + 12 → 4 H₂SO₄ + 3 H₂O + 12

The reaction is complete within 2-2 minutes, with the end point being the blue-to-black immediate color change.
KINETICS

(IODINE CLOCK REACTION)

Materials: (4) 600 ml beakers with STIR BARS
Lighted mag. stirrer
Elastic timer
Thermometer

Solutions: 0.1 M KIO₃; STARCH solution;
0.05 M NaHSO₃* (5.20 g/L)

Set up the beakers as follows:

1) 350 ml H₂O
50 ml STARCH
50 ml 0.1 M KIO₃

Room TEMP

→ Add 50 ml 0.05 M NaHSO₃

→ t = 1:05 min:sec

2) 300 ml H₂O
50 ml STARCH
100 ml 0.1 M KIO₃

Room TEMP

→ Add 50 ml 0.05 M NaHSO₃

→ t = 0:32 min:sec

3) 300 ml H₂O
50 ml STARCH
50 ml 0.1 M KIO₃

Room TEMP

→ Add 100 ml 0.05 M NaHSO₃

→ t = 0:35 min:sec

4) SAME AS #1, but
heat to ± 40°C

Upon addition of the NaHSO₃ to the beakers,
the reaction is an immediate color change from clear to blue-black.

* The 0.05 M NaHSO₃ should be freshly prepared. Na₂S₂O₅ is actually a mixture of NaHSO₃ and Na₂S₂O₅; use 5.20 g of
this per liter.)
KINETICS (RATE LAW)

Materials: 3% H₂O₂
KI
Distilled water
6N HCl
Starch solution
Solutions A, B, and C
Timer clock

Reaction: 2H₂O₂ + 2I⁻ → I₂ + 2H₂O

I. Prepare solutions A, B and C as follows:

Solution A 100 ml 3% H₂O₂ (approx. 0.75% H₂O₂)
500 ml H₂

Solution B 1 gram KI
94 ml H₂O
6 ml 6N HCl

Solution C 1 gram starch (Heat to dissolve
100 ml H₂O and then cool)

II. In 250ml beakers mix together the reagents shown in the table below for the three different runs.

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 ml soln. C</td>
<td>3 ml soln. C</td>
<td>3 ml soln. C</td>
</tr>
<tr>
<td>109 ml H₂O</td>
<td>107 ml H₂O</td>
<td>105 ml H₂O</td>
</tr>
<tr>
<td>2 ml soln. A</td>
<td>4 ml soln. A</td>
<td>6 ml soln. A</td>
</tr>
</tbody>
</table>

III. Make a standard 124ml solution of starch in H₂O and I₂ to give a light blue color to use as an endpoint when timing each of the three runs above. Consequently, what one does is to measure the amount of time that it takes to produce the same amount of I₂ in each of the three runs.
IV. To one beaker at a time in step II add 10ml solution B and start the clock simultaneously. Stir. Stop the clock when the blue color of the reaction matches the blue color of the standard prepared in step III.

V. The approximate times for each run are as follows:

Run 1  25 seconds  
Run 2  12.5 seconds  
Run 3  8 seconds

VI. Determine the order of the reaction in $H_2O_2$
LIQUID NITROGEN DEMONSTRATION

I. Show a Silvered Dewar

II. Mercury Hammer

Materials:

- 400 ml beaker
- Mercury
- Hammer handle; 1/2" dia., 8" long with 1/4-20 bolt set in it with 2 1/2" sticking out
- Pink rubber bulb
- Block of wood
- Couple of nails

Make a mercury hammer by freezing the liquid mercury in the rubber bulb and drive a nail into a block of wood.

III. Fill Balloon with N₂ Gas

Materials:

- 500 ml flask with stopper
- Balloon

Fill up a balloon with N₂ gas as it passes into the gaseous phase from the liquid.

IV. Temperature and Pressure Relations

Materials:

- Steel ball (Gay Lusac Bulb)
- Dewars
- Ice Bath
- Bath at 100°C
- Thermometer
LIQUID NITROGEN DEMONSTRATION  
(continued)

Take different temperature and pressure readings with the steel ball and make a plot.

V. Liquid Nitrogen Fountain

Materials:

1000 ml Florence flask
One-hole rubber stopper to fit the flask
Glass tube

Prepare the set-up below for the fountain.

Liquid N₂

---

VI. Liquify Natural Gas and Burn it as it evaporates

Materials:

Rubber tubing
Matches
Natural gas
Dewar with liquid nitrogen
Large test tube fitted with stopper and glass tubing

Liquid natural gas

Liquid N₂

---

VII. Effect of Temperature on Electric Current

Materials:

Dry cell with coil and flashlight bulb hooked up
Dewar
Liquid nitrogen
Show the difference in the lamp's glow before and after immersing the coil in the liquid nitrogen. There is a brighter glow at lower temperature as conductance increases.

VIII. Effect of Low Temperature on Rubber

Materials:

Various pieces of rubber tubing (about 10-12 inches long)
Dewar with liquid nitrogen
Good strong arm

Immerse a part of the tubing in the liquid nitrogen and when it becomes brittle smash it on the table top. Be careful!!!

IX. Low Temperature Effect on a Spring of Solder

Materials:

Weights
Ring stand with clamp
10-12 inch rod
Two fat solder coils (1.5" dia., 3" long with hooks on each end)
Pair of tongs
Dewar with liquid nitrogen

1. Take one of the solder coils and support it by one of its hooks on the 12" rod clamped on the ring stand. To the bottom hook attach the weights and show that the solder has no spring properties.
LIQUID NITROGEN DEMONSTRATION
(continued)

2. Take the second coil and immerse it in liquid nitrogen for about one minute and with the tongs hang this on the ring stand and attach the weights and show that the solder coil is now like a regular spring, springing back and forth.

X. Hardness Produced at Low Temperature

Materials:

Regular hammer
Rubber tubing cut in shape of nail spikes about 1.5" long
Block of wood
Banana
Nails
Dewar of liquid nitrogen
Tongs

1. Freeze a banana and use it as a hammer to drive nails into the wood.

2. Freeze the rubber spikes and while holding with tongs drive the spikes into the wood with the regular hammer.

XI. Smashing the Rose Trick

Materials:

Three long stem roses
Liquid nitrogen

The title of the demonstration is self-revealing.

XII. Frozen Soap Bubbles.
MERCURY VAPOR DEMONSTRATION

Materials: Mercury
- Rectangular dish
- Plexiglass screen, 40 cm x 40 cm.
- TLC plates with fluorescent indicator
- Ultra violet lamp

Tape four 20 cm x 20 cm TLC plates to the plexiglass screen so that the plastic side of the TLC plate is against the plexiglass. Fill the rectangular dish with mercury, and place it behind the fluorescent screen. Place the UV lamp 1 to 2 feet behind the screen and turn it on. The Hg vapor rising from the dish absorbs UV radiation from the lamp, producing dark, wavy shadows on the fluorescent screen.
MIGRATION DEMONSTRATION
(Copper permanganate migration)

Materials: Copper permanganate solution*
1 M HNO₃
DC power supply and leads
Apparatus shown below.

Making sure the stopcock is closed, add 25-30 ml of 1 M HNO₃
to the U-tube. Fill the reservoir with copper permanganate
soln. Very slowly open the stopcock and allow the copper
permanganate soln. to creep up into the U-tube. If done
correctly the 1 M HNO₃ layer and copper permanganate layer
will be unmixed and well defined. Connect the leads and turn
on the power (run at 20V). After several minutes one side of
the U-tube will become pale blue (due to copper ion
migration) and the other side will turn pink-purple (due to
permanganate ion migration).

*The copper permanganate soln is 1 M in NaNO₃ and 1.0 M in
CuSO₄ and saturated with KMnO₄.
MOLE QUANTITIES

Display of gram-atom and moles of various elements and compounds.

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>55.85g/g-atom</td>
</tr>
<tr>
<td>Aluminum</td>
<td>26.98g/g-atom</td>
</tr>
<tr>
<td>Mercury</td>
<td>200.59g/g-atom</td>
</tr>
<tr>
<td>Sulfur</td>
<td>32.06g/g-atom</td>
</tr>
<tr>
<td>Zinc</td>
<td>65.37g/g-atom</td>
</tr>
<tr>
<td>Magnesium</td>
<td>24.31g/g-atom</td>
</tr>
<tr>
<td>Ferrous Sulfide</td>
<td>87.91g/mole</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>58.91g/mole</td>
</tr>
<tr>
<td>Ferrous Sulfate</td>
<td>278.03g/mole</td>
</tr>
<tr>
<td>Water</td>
<td>18.02g/mole</td>
</tr>
<tr>
<td>etc.</td>
<td></td>
</tr>
</tbody>
</table>

Display of 22.4 liter box: indicate 1 mole of any gas occupies 22.4 liters at STP. The one liter box can also be displayed for comparison.
Two complete sets of ball and stick models are available for constructing any molecule. The following aspects can easily be accomplished with these two sets: electron distribution; lone pair electron position; single, double, and triple bonding; construction of \( \pi \) bonds, isomerism (including optical); various configurations; bond angles (including hybrids).

There is also an \( \alpha \)-helix model available that stresses hydrogen bonding.
Models of the molecular orbitals of N(2 (σ₂s, σ₂s*, σ₂p, Π₂p, π₂p*, and σ₂p*) are available for display.
NYLON ROPE TRICK

(Polymerization Demonstration)

Materials:  Adipyl Chloride
            Cyclohexane*
            1,6 Hexanediamine, 70% in H₂O
            6M NaOH
            Ethanol
            **RUBBER GLOVES**

1. Prepare a 5% (w/v) solution of adipyl chloride by weighing 5.0 grams of adipyl chloride in a 100 ml graduate cylinder and diluting to 100 ml with cyclohexane. This solution must be freshly prepared.

2. Prepare a 5% (w/v) solution of 1,6 Hexanediamine by weighing 7.14 grams of 70% Hexanediamine in a 100 ml grad. cylinder and diluting to 100 ml with H₂O. To this add 6-7 drops of 6M NaOH.

3. Pour about 70 ml of the more dense Hexanediamine solution into a 150 ml beaker. Slowly add about 70 ml of the less dense adipyl chloride solution down the side of the beaker. Two distinct liquid layers separated by a nylon interface will be observed. Using forceps, pinch the interface and slowly pull away a continuous "rope" of nylon. Rinse the nylon in an evaporating dish containing ethanol and place on paper towels to dry.

*Tetrachloroethylene may be substituted.

\[ \text{H}_2\text{N} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{NH}_2 \]

\( \text{(or 5.0 of 100% 1,6-Hexane-diamine)} \)
**Materials:** Test tubes, 150 mm
Test tube rack
Droppers
Reagents listed below

**Tests for Alcohols:**

1. Conc. $\text{H}_2\text{SO}_4 + \text{EtOH}$ \[\text{methyl orange} \rightarrow\] (turns from yellow to red)
2. Lucas Reagent + t-amylalcohol \[\rightarrow\] (white ppt.)
3. Schiff Reagent + EtOH \[\rightarrow\] (no reaction)
4. Na(s) + EtOH \[\rightarrow\] (slow reaction)

**Tests for Alkanes:**

5. conc. $\text{H}_2\text{SO}_4 + \text{octane} \rightarrow$ (no reaction)
6. Na + octane \[\rightarrow\] (no reaction)
7. Br$_2$(aq) + cyclohexane \[\rightarrow\] (no reaction)
8. .02M KMnO$_4$ + cyclohexane \[\rightarrow\] (no reaction)

**Tests for Alkenes:**

9. Br$_2$(aq) + cyclohexene \[\rightarrow\] (turns colorless)
10. .02M KMnO$_4$ + cyclohexene \[\rightarrow\] (brown ppt)

**Tests for Aldehydes:**

11. Schiff reagent + formaldehyde \[\rightarrow\] (turns purple)
12. Schiff reagent + o-chlorobenzaldehyde \[\rightarrow\] (turns purple)

**Test for Ketones:**

13. Schiff reagent + acetone \[\rightarrow\] (no reaction)

**Tests for Ethers:**

14. Na + ether \[\rightarrow\] (no reaction)
15. conc. $\text{H}_2\text{SO}_4 + \text{ether}$ \[\text{methyl orange} \rightarrow\] (turns from orange to red)
"OSCILLATING REACTION

(Malonie Acid Oscillator)

Red - Blue Oscillator

Materials:
- NaBrO₃(s)
- NaBr(s)
- Malonic acid (s)
- conc. H₂SO₄
- Ferroin (Phenanthroline Ferrous Sulfate)
- 1000 ml beaker
- Lighted magnetic stirrer
- Stirring bars
- 1000 ml volumetric or Erlenmeyer flask

1. Prepare Solutions A, B, C, and D as follows:

   Solution A: 43.5 grams NaBrO₃
    583 ml H₂O
   17.4 ml conc. H₂SO₄

   Solution B: 5.0 grams NaBr
    50.0 ml H₂O

   Solution C: 10.0 g Malonic acid
    100.0 ml H₂O

   Solution D: 0.2 gram Ferroin
    100 ml H₂O
    + 150 ml H₂O

2. Pour 600 ml of solution A, 50 ml of solution B, and
   100 ml of solution C into a 1000 ml Volumetric or
   Erlenmeyer flask, add stirring bar and stopper.
   Vigorously stir until the orange-brown bromine color
   completely disappears.

   (Add B+C TO A, stir, then
    add Ferroin)

3. Transfer the clear solution to a 1000 ml beaker con-
   taining a stirring bar and add the Ferroin (solution
   D). Stir at setting #4 or #5. Solution will
   oscillate from red to blue color.
   - Change from red to blue occurs in 15 - 20 sec.
   - Change from blue to red occurs in 1-3 sec.
   - Stirring speed has little affect.

   If stirring is stopped, red and blue streaks will be
   observed as localized reactions occur.
NOTES

1. KBrO₃ and KBr can be used as well, giving equally good results.

2. Although stirring speed has little affect on the period of oscillation, if a 500 ml graduated cylinder is filled with the reaction mixture and is stirred, one will observe the color change to occur first at the bottom of the cylinder (where stirring is most vigorous) and travel upwards.

*If 0.025M Ferroin is available, use 25 mL and dilute to 100 mL with H₂O.
Oscillating Reaction
(Briggs-Rauscher)
Colorless - Yellow - Blue Oscillator

Materials:

Solution A-1: 410 ml of 30% H₂O₂
diluted to 1 liter with water

Solution A-2: 43.00 g KIₐ₃
+ 4.30 ml conc. H₂SO₄
dilute to 1 liter with H₂O

Solution A-3: 16.0 g Malonic Acid
3.40 g MnSO₄·H₂O
0.3 g STARCH (dissolve in boiling water first)
dilute to 1 liter with H₂O

Mix equal volumes of A-1, A-2, and A-3 in a 2 liter beaker
with or without stirring. Solution will oscillate
from colorless to yellow to blue for approximately 5 min.

Also, try pouring equal volumes of A-1, A-2, and A-3 down the
sides of a 500 ml graduated cylinder carefully so that mixing does not
occur. Blue, yellow, and clear bands will appear to travel
down the length of the cylinder.

Note: The reaction has at times stopped
oscillating when illuminated by a lighted ring stand.
Why this happens, I am not sure (perhaps due to... effects?)
but oscillations will resume when the light is removed.
PERCENT OXYGEN IN AIR

Materials: Long 1.5" I.D. tube
Deflagrating spoon on rubber stopper that fits tube
Yellow phosphorus
Trough of water (colored red)
Bunsen burner
Matches
Ring stand with clamps
Meter stick

Set up the apparatus as shown and ignite the yellow phosphorus with burner. Insert the ignited phosphorus in the tube making sure that the spoon does not touch the sides of the tube. Insert it tight so that no gas escapes from the top. Measure the rise of the water after the flame goes out. You may turn out the light to determine this point.

Best result obtained was 21.7% O₂ in air in 5 trials.
PHOTOCHEMICAL REACTION  
(Hydrogen and Chlorine)

**Materials:** Round white balloon, 3" uninflated dia.  
Lecture bottles of Cl₂ and H₂  
Flood lamp (1000 watts)  
Ruler  
Apparatus as shown below:

1. Assemble the apparatus above. Tightly secure the balloon to the glass tubing with string or tape.

2. Attach the Cl₂ gas cylinder and remove the pinchcock. Fill the balloon partially with Cl₂ and then disconnect the cylinder, allowing the balloon to deflate (Do in Hood). Squeeze the balloon to remove excess Cl₂ and put the pinchcock back on. This removes any air which was initially in the system.

3. Re-attach the Cl₂ cylinder, remove the pinchcock, and fill the balloon to a diameter of about 7 inches. Disconnect the Cl₂ cylinder (replace pinchcock!) and attach the H₂ cylinder. Flush air out of hose first and fill the balloon with H₂ to a diameter of about 10 inches. Remove lecture bottle.

4. Place the flood lamp about 6-in. away from the balloon and turn on. The balloon quickly explodes, releasing HCl and any excess gases.

**Note:** Only white balloons allow enough illumination to pass through the balloon walls. Colored balloons filter out too much of the light, although light yellow balloons sometimes work.
PROPERTIES OF METAL AND NONMETAL OXIDES

A. METAL OXIDES

Materials

BaO (solid)
Na metal
Ca metal

1. Take small pieces of Na and drop them in a tall 2 liter jar containing about 150 ml of water with 3-4 drops of phenolphthalein. Violent reaction: BE CAREFUL. The result is the red (basic) color.

\[ \text{Na} + \text{H}_2\text{O} \rightarrow \text{Na}^+ + \text{OH}^- + 1/2 \text{H}_2(\text{g}) \]

2. Same as above, but with Ca metal.

\[ \text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + 2\text{OH}^- + \text{H}_2(\text{g}) \]

3. Take 1 to 2 grams of BaO and dissolve in 700 ml of H_2 with 3-4 drops of phenolphthalein. Color turns red very quickly.

\[ \text{BaO} + \text{H}_2\text{O} \rightarrow \text{Ba}^{2+} + 2\text{OH}^- \]

B. NONMETAL OXIDES

Materials

CO_2 solid
P_4 red solid
Yellow phosphorus
Sublimed sulfur

1. Acidity of CO_2 in H_2O

\[ \text{solid CO}_2 \quad 700 \text{ ml H}_2\text{O} \quad + \quad 30 \text{ ml .1M NH}_3 \quad + \quad \text{bromthymol blue} \]
The color changes from the base color (blue) to the acid color (yellow) in approximately 30 seconds.

\[
\text{CO}_2 + H_2O \rightarrow \text{H}_2\text{CO}_3 \rightarrow H^+ + \text{HCO}_3^- \rightarrow H^+ + \text{CO}_3^{2-} 
\]

2. Burning of \( P_4 \) and \( S_8 \)

Using the tall two liter jars ignite the phosphorus or the sulfur in a deflagrating spoon with a bunsen burner and lower into the jar and cover it until the jar is saturated with the oxides. Remove the spoon quickly and pour in 200 milliliters of water made just basic to the bromthymol blue endpoint. Cover the jar and shake well. The base color (blue) turns to the acid color (yellow).

\[
\text{S}_8(s) + O_2 \rightarrow \text{SO}_2(g) \\
\text{SO}_2(g) + H_2O \rightarrow \text{H}_2\text{SO}_3(aq) \rightarrow H^+ + \text{HSO}_3^- \rightarrow H^+ + \text{SO}_3^{2-} \\
\text{P}_4(s) + 5O_2 \rightarrow \text{P}_4\text{O}_{10}(s) \\
\text{P}_4\text{O}_{10} + 6H_2O + 4H_3\text{PO}_4(aq) 
\]

3. Combustion of white phosphorus

\[
\text{P}_4 + 4O_2 \rightarrow 4\text{PO}_2 
\]

A solution of white phosphorus dissolved in \( \text{CS}_2 \) is prepared. A two liter tall jar is used covered with filter paper which is folded to form a cross in the center:

Pour about two milliliters of the solution onto the filter paper and stand back. As the \( \text{CS}_2 \) evaporates and exposes the phosphorus to the air the phosphorus ignites which sets off the combustion of \( \text{CS}_2 \) vapors in the jar. This is followed by flames and a loud pop with sulfur deposits on the jar walls.
RADIOACTIVITY DEMONSTRATION

Materials: Model 181A Decade Scaler Counter (with timer)
Nuclear radiation detector (Geiger tube)
Geiger tube receptacle mounted to wooden trough.

Test samples: Co-60
Lantern mantle
Wood blocks
Lead plates
Uranium
Cu and Al plates
Pencil lead on paper
Plastic sheet

Insert the radiation detector into the receptacle mounted on the wooden trough and connect the cable to the input terminal at the rear of the counter.*

Recommended control settings are as follows:

High Voltage: ON
Volt meter: adjust to 800V
Test: OFF
Operation: TIME
Scale: 100

Turn counter on and allow it to warm up. Place a sample in the trough and set the timer to a desired counting time. Depress the "count" switch to begin counting the nuclear decays being detected. Counting will stop automatically when time is up, or can be stopped manually by raising the "count" switch. The register can be cleared by depressing the reset key.

Test several samples at various distances from the radiation detector. Lead's ability to absorb radiation is shown by placing varying numbers of lead plates between the Geiger tube and the sample and noting the decreased rate of detection of nuclear decays.

*Do not remove the plastic cap at the end of the Geiger tube.
Materials: Na metal, freshly cut
4 asbestos pads
Pyrex cylinder
Cl₂ lecture bottle
Bunsen burner and tubing

1. Fill the tall Pyrex cylinder with Cl₂ gas and cover with an asbestos pad or parafilm.

2. Place a piece of Na on a double (or triple) layer of asbestos pads on the lecture table. Gently heat the sodium with the Bunsen burner until it melts and a shiny metallic surface is displayed*. Quickly invert the cylinder of Cl₂ and place over the molten sodium. A strongly exothermic reaction occurs. Students may be asked to wet a finger and taste the white dust formed, which is NaCl.

*It may be necessary to agitate the molten Na with a metal deflagrating spoon to break the oxide film and expose a clean Na surface.

Note: Heat the Na GENTLY, as it may easily ignite in air. If this occurs, cover with the glass cylinder of Cl₂.

Need new (safe!) procedure for this demo
11. $\text{MnO}_4^- + H_2O_2 \rightarrow \text{Mn}^2+ + \text{O}_2 + H_2O$

12. $\text{Br}_2(aq) + H_2O_2 \rightarrow$

13. $\text{KI} + H_2O_2 \rightarrow \text{I}_2 + ?$

Try these

*Must start slightly basic (white sometimes very acidic from tap!)*
REDOX REACTIONS

Materials:
- Sat. K₂Cr₂O₇
- Sat. SnCl₂ in HCl
- 0.2M KMnO₄
- 6M H₂SO₄
- 1M FeSO₄ in 1M H₂SO₄
- Cl₂ aqueous
- 1M KI
- 1M CuSO₄
- 1M FeCl₃
- NaHSO₃(s)
- 1M KIO₃
- 1M Oxalic acid
- 25M MnSO₄

1. K₂Cr₂O₇ + 3 SnCl₂ + 14 HCl + 2 CrCl₃ + 7 H₂O + 3 SnCl₄ + 2 KCl
   Color change: yellow-orange to green. Use 6 ml. of saturated K₂Cr₂O₇ and dilute with water to 150 ml. Add 60 ml. of freshly made sat. SnCl₂ in conc. HCl.

2. 2 KMnO₄ + 8 H₂SO₄ + 10 FeSO₄ + K₂SO₄ + 2 MnSO₄ + 5 Fe₂(SO₄)₃ + 8 H₂O
   Color change: Purple to colorless. Use 10 ml. of 0.2 M KMnO₄ and dilute to 300 ml. To this add 10 ml. of 6M H₂SO₄. Then add 30 ml of 1M FeSO₄ in 1M H₂SO₄.

3. Cl₂ + 2 KI → I₂ + 2 KCl
   Color change: yellow-green to dark brown. Use 150 ml of aqueous Cl₂ and add 1M KI to form I₂.

4. 4 KI + 2 CuSO₄ → 2 CuI(s) + I₂ + 2 K₂SO₄
   Color change: colorless to brown. To 150 ml. of 1M KI add enough 1M CuSO₄ to effect color change.

5. 2 FeCl₃ + SnCl₂ → 2 FeCl₄ + SnCl₄
   Color change: yellow to colorless. To 150 ml. of 1M FeCl₃ add aqueous or solid SnCl₂ until color disappears.

6. 2 KMnO₄ + 6 NaHSO₃ → 2 MnSO₄ + 2 Na₂SO₄ + Na₂SO₃ + K₂SO₄ + 3 H₂O
   Color change: purple to colorless. Dilute 5 ml. of 0.2M KMnO₄ to 200 ml. with water. Add 40 ml. of NaHSO₃ solution (30g NaHSO₃/150 ml. sol.).

7. KIO₃ + 5 KI + 3 H₂SO₄ → 3 I₂ + 3 K₂SO₄ + 3 H₂O
   Color change: colorless to dark brown. Add 200 ml. of water to a 400-ml beaker. Make slightly basic by adding ~3 ml. of 1M NaOH. Add first 25 ml of 1M KIO₃, and then 25 ml of 1M KI. No reaction occurs. Now add 10 ml. 6M H₂SO₄. Dark brown I₂ is formed.

8. 2 KMnO₄ + 3 H₂SO₄ + 5 H₂C₂O₄ → 2 MnSO₄ + K₂SO₄ + 10 CO₂ + 8 H₂O
   Color change: purple to colorless in about 2 min. with stirring. Use 25 ml of 0.2M KMnO₄ and dilute to 150 ml. Add 15-20 ml. of 6M H₂SO₄. To this add 40 ml of 0.25M MnSO₄ and 30 ml of 1M oxalic acid.

9. KMnO₄ + SnCl₂ → brown precip (Mn⁺)

10. K₂C₇O₄ + FeSO₄ → Cl₂ and Mn
SHRINKAGE DEMONSTRATION

Materials:

100 ml graduated cylinder with stopper
500 ml volumetric flask with stopper
Solid anhydrous CaCl₂
Ethanol (colored)

A. Using the graduate cylinder

Fifty milliliters of water are added to the cylinder. Slowly, 50 milliliters of colored EtOH are added carefully above the water. The stopper is put in place and the cylinder is shaken vigorously. The volume of the solution shrinks about 2 milliliters.

B. Using the volumetric flask

Approximately 200 grams of the anhydrous CaCl₂ is placed in the flask. The flask is filled to the mark very rapidly with water. The flask is stoppered and shaken vigorously. The volume shrinks considerably with a lot of heat given off.

approx 100g CaCl₂ anhy is placed in a empty 250 ml vol. flask. In another 250 ml vol. fill to mark with water. Add water from this flask to the flask containing the CaCl₂ and shake to dissolve. After all CaCl₂ is dissolved, add more water to the mark. There will still be water remaining in the flask.
SPECTRA DEMONSTRATION

Materials: $K_2Cr_2O_7$ solution (saturated)
Cu(NH$_3$)$_4^{2+}$ solution
Tape
Slide projector (35 mm)
Bausch & Lomb Educational Absorption Spectra Kit

Fill the two cuvettes with the two solutions, seal the openings with tape, and put the cuvettes in the carousel projector making sure that the side with the aluminum heat shield faces the projector lamp.

In a dark room turn on the projector and place the diffraction grating in front of the lens so that the projector's light beam passes through the center of the grating and it is as close to the projector lens as possible. Now focus the image so that a sharp, brilliant spectrum is obtained.

Closely examine the spectra on the screen. If they seem weak and faded, use the other side of the grating. If the spectra seem wide and somewhat diffuse, you have probably located the second order spectrum, which is at a 40° angle to the optical axis of the grating. It is about twice as wide and not as intense. Refocusing the image may be necessary again.

![Diagram of cuvette setup]

The spectra on the screen are reversed. The top will be the reference, and the solution spectrum will be on the bottom. The spectrum of air is (1st order: red, green, blue, violet). For $K_2Cr_2O_7$ red, green. The blue and the violet are the colors absorbed.
SPONTANEOUS REDOX REACTIONS

Materials: Thermometer
Strip of Zn
Strip of Cu
Two large Test tubes
Cu(NO₃)₂ or CuSO₄ solution
2M AgNO₃

I. \[ Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu \]

Fill half of the first test tube with Cu(NO₃)₂ or CuSO₄ solution and drop in the strip of Zn metal. Zn goes into the solution and copper is deposited on the Zn metal. As the Cu²⁺ ion is taken out of solution the Cu²⁺ solution decolorizes and heat is given off in the process. \[ E^\circ = 0.426 \text{ volts} \]

II. \[ Cu + 2Ag^+ \rightarrow 2Ag + Cu^{2+} \]

Fill half of the second test tube with 2M AgNO₃ and drop in the strip of Cu which should be cleaned beforehand. As the Ag plates out and the copper goes into solution the colorless AgNO₃ solution turns blue (the color of the copper solution). Heat is given off and the temperature rises to approximately 45°C. \[ E^\circ = 0.462 \text{ volts} \]

*For best results each of the reactions should be run for approximately ten minutes. The longer each reaction is run the more metal plates out and the better the visibility. A thermometer may be inserted to show the temperature rise.
SUPERSATURATION
(Sodium Acetate)

Materials: 500 ml Florence flask
Solid NaOAc
Thermometer
Spatula

In the Florence flask melt enough NaOAc using a water bath to fill the flask about half way. Some water may be used if necessary to wash the crystals into the melt. Stopper the flask with cotton plug and cool gradually to room temperature. The result will be a supercooled sodium acetate solution.

To the supercooled solution add 1 crystal of solid NaOAc to crystallize the entire solution to a solid mass. Heat is generated, so a thermometer may be inserted, or the flask can be passed around for the students to feel the heat.

*The solution may be regenerated by heating in water bath again.*
THERMITE REACTION

Materials:
- Filter paper
- Tripod with iron ring
- Mg ribbon
- Fe$_2$O$_3$
- Al powder
- Pan with sand
- Hammer
- Magnet
- Bunsen burner
- Tongs
- Wash bottle
- Metal shield
- Fire extinguisher

1. Fold two pieces of filter paper (as for filtering). Fit one cone inside the other, but first punch a small hole in the apex of the outer cone. Place the tripod in the pan of sand and fit the cones of filter paper in the ring. Form a slight depression in the sand under the cones. Place this assembly on the metal bench shield. See figure below.

2. Mix thoroughly 10g of Fe$_2$O$_3$ and 4.0g of aluminum powder. Transfer the mixture to the inner paper cone.

3. Insert three strips of magnesium ribbon (two 5" and one 2" long) into the powder to act as a fuse. The strips should all be in contact with each other.

4. Dampen the outer cone with water from the wash bottle. Ignite the fuse with a bunsen burner and stand back. Reaction occurs violently.

5. Using tongs, drop the product into a beaker of water to cool. Break the Al$_2$O$_3$ shell away from the iron with the hammer. Iron particles can be separated from the sintered Al$_2$O$_3$ using the magnet.

\[
\text{Fe}_2\text{O}_3 + 2 \text{Al} \rightarrow \text{Al}_2\text{O}_3 + 2 \text{Fe}
\]

![Diagram of the thermite reaction setup](image-url)
THERMODYNAMICS

Endothermic Reaction (Entropy driven)

Materials:

- Ba(OH)$_2$·8H$_2$O
- NH$_4$SCN

Thermometer
300 ml flask
Small board
Squirt bottle of water
funnel (wide mouth)

Wet the board first. Place the flask on the board and squirt water underneath and around it. In the flask mix together finely ground 2 moles Ba(OH)$_2$·8H$_2$O (63 g), and 4 moles NH$_4$SCN (30 g). Use the thermometer to stir the 2 solids. The temperature will drop to approximately -25°C and the flask will freeze onto the board.

REACTION

Ba(OH)$_2$·8H$_2$O + 2NH$_4$SCN → Ba(SCN)$_2$(s) + 2NH$_3$(g) + 10H$_2$O(ℓ)

\[ \Delta H_f^0 = -799.5 + -20.0 - 47.9 - 11.04 - 68.32 \]

for Ba(CN)$_2$

with above values
\[ \Delta H = +84.22 \text{ cal} \]

*Ground both solids with mortar and pestle.
TITRATION CURVE DEMONSTRATION

Materials: 1 M HCl  
1 M HNOAc  
1 M H₃PO₄  
1 M NaOH  
pH meter  
Magnetic stirrer with light  
Sargent-Welch strip chart recorder model SRG

Titrates 20 milliliters of each of the above acid solutions using the pH meter and the strip chart recorder. Dilute each acid solution to about 600 ml with water. This will keep the electrode further away from the stirrer. The settings for the recorder are as follows:

Chart speed: Fast

Adjust the zero to have the low pH on the left side of the chart paper. (Use pH = 7 buffer and set detector to about the 50% line on the paper.)

Variable span: Off

Millivolt span: 20

Input: White (guard) on recorder to + HI on pH meter recorder output.  
Red (+) on recorder to ground on pH meter recorder output.

![Diagram of equipment setup]
The titration curves of the three acids.

1M HCl

Volume of base

pH +

1M HOAc

Volume of base

pH +

1M H₃PO₄

Volume of base

pH +
1. Nickel Complexes

   a. Dissolve several grams of NiCl₂(s) in excess conc. HCl. Yellow-green NiCl₂⁶⁺ is observed.
   b. Pour the above solution into about 500 ml H₂O, 4/6 M. Blue-green Ni(H₂O)⁶²⁺ is produced. Divide into two beakers.
   c. To one beaker add a solution of 2M NaOAc and solid EDTA. A blue complex is formed.
   d. To the other beaker add conc. NH₄OH. The blue Ni(NH₃)⁶²⁺ complex is observed. Divide into two beakers.
   e. To one beaker, add dilute ethylene diamine. Lavender Ni(EN)(NH₃)⁶²⁺ is produced.
   f. To the second beaker add a solution of dimethyl glyoxime in ethanol. Red Ni(DMGO)⁶²⁺ is observed.

\[ \text{NiCl}_2 + \text{conc. HCl} \rightarrow \text{NiCl}_6^{(\text{yellow green})} \]
\[ +\text{H}_2\text{O} \]
\[ \text{conc.} + \text{NH}_4\text{OH} \]
\[ \text{Ni(H}_2\text{O)}_6^{+2} \text{(blue-green)} \]
\[ +\text{NaOAc-EDTA} \]
\[ \text{Ni(NH}_3)_6^{+2} \text{(Blue)} \]

Blue Complex

\[ \text{Ni(EN)(NH}_3)_6^{+2} \text{(Lavender)} \]
\[ +\text{EN} \]
\[ \text{Ni(DMGO)}_6^{+2} \text{(Red ppt)} \]
\[ +\text{DMGO} \]
2. Cobalt Complexes
   a. Dissolve several grams of CoCl₂ in conc. HCl. Deep blue Co(Cl)₄⁻² is formed. Pour this into H₂O - the pink Co(H₂O)₆⁺² complex is observed.
   b. Add dilute En to a beaker of aqueous CoCl₂. A brown complex results.
   c. Add KMnO₄ solution to a beaker of aqueous CoCl₂. An orange-brown complex is formed.
   d. Add conc. NH₄OH to a beaker of aqueous CoCl₂ or Co(NO₃)₂. The blue Co(NH₃)₆⁺² complex results.

   See also: Invisible Ink Demonstration

3. Iron Complexes
   a. To a beaker of aqueous Fe(NO₃)₃ add aqueous KSCN. The blood-red FeSCN⁺² complex is observed.

4. Chromium Complexes
   a. To a beaker of Cr(NO₃)₃ add conc HCl and en. A lavender complex results.
   b. To a beaker of Cr(NO₃)₃ add conc. NH₄OH to form the green precipitate Cr(NH₃)₆⁺³. Then conc. HCl.
   c. Add conc. HCl to a beaker of K₂CrO₄. The solution turns orange-brown. Add this to H₂O - the solution turns yellow again.
   d. Add conc. NH₄OH to a beaker of K₂Cr₂O₇. The solution turns yellow.

5. Copper Complexes
   a. Prepare a saturated solution of CuSO₄·5H₂O in conc. HCl. A green chloro-complex is observed. Pour 20 ml of this into 200 ml of H₂O. The blue aquo-complex is formed. Using a dropper, add while stirring conc. NH₄OH until Cu(OH)₂ precipitates* (about 18 ml conc. NH₄OH needed for this). Continue to add conc. NH₄OH to form the deep purple tetra-amine complex Cu(NH₃)₄⁺².

6. Silver Complexes
   a. Add dilute NH₄OH to a beaker of aqueous AgNO₃. Brown Ag(NH₃)₂⁺ precipitates out.

   *A fresh beaker of aqueous CuSO₄ may be substituted for this.
TYNDALL EFFECT

Materials: \( \text{Na}_2\text{S}_2\text{O}_3 \)
\( \text{HCl} \)
2000 ml rectangular shaped jar
Light source

Solid sulfur is generated by the following reaction:

\[
\text{Na}_2\text{S}_2\text{O}_3 + \text{HCl} \rightarrow \text{S}_8
\]

Use very small stoichiometric quantities and pour the mixture in the jar. Keep passing the light beam through the jar and keep diluting the mixture if necessary to give the correct effect.
UP-DOWN REACTION
(with Silver)

Materials: 2000 ml beaker filled with 1000 ml of water
Solutions (.1M) of: NaCl, NaBr, Na₂S₂O₃, NaI,
NaCN, Na₂S or (NH₄)₂S, AgNO₃
Conc. NH₃
Stirrer

To the beaker with the water add 25 ml .1M AgNO₃ and then:
1) Add NaCl soln to AgNO₃ soln and ppt. AgCl
2) dissolve AgCl in NH₃ soln
3) precipitate AgBr by adding NaBr soln
4) dissolve AgBr in Na₂S₂O₃ soln
5) add NaI soln to precipitate AgI
6) dissolve AgI in NaCN soln
7) add Na₂S or (NH₄)₂S to precipitate Ag₂S

Reactions:
Ag⁺ + Cl⁻ → AgCl (conc. NH₃) → Ag(NH₃)⁺ Br⁻ → AgBr

S₂O₃⁻ → Ag(S₂O₃)₂⁻ I⁻ → AgI
CN⁻ → Ag(CN)⁻ S²⁻ → Ag₂S
UP-DOWN REACTION
(Silver Chromate)

Materials: 2000 ml beaker containing 1000 ml water
- 1M AgNO₃, 1M K₂CrO₄, 6M HNO₃,
- 1M NH₃, 1M NaOH, 6M NaOH, 50% NaOH(aq.)
Droppers

To the beaker with the water add 25 ml 1M AgNO₃.
To this solution add quickly with stirring, 5 ml of
1M K₂CrO₄* and:

1. Add 6M HNO₃ by dropper (less than 1 ml) to redissolve.

2. Add 1M NH₃ (~10 ml) slowly to precipitate and another 20-30 ml to redissolve.

3. Add 6M HNO₃ again by dropper (~1 ml) to reprecipitate and another 1 ml to redissolve.

4. Add 2-3 ml 1M NaOH to reprecipitate; an additional 8-10 ml to redissolve; and finally add 6M NaOH or 50% NaOH to form Ag₂O(s).

*Whenever a precipitate forms do not delay too long to redissolve it.

Reactions

\[ 2 \text{Ag}^+ + \text{CrO}_4^{2-} \rightleftharpoons \text{Ag}_2\text{CrO}_4(s) \]
\[ \text{CrO}_4^{2-} + \text{H}^+ \rightleftharpoons \text{HCrO}_4^- \]
\[ 2 \text{HCrO}_4^- \rightleftharpoons \text{H}_2\text{O} + \text{Cr}_2\text{O}_7^{2-} \quad \text{(Not seen)} \]
\[ \text{NH}_3 + \text{H}^+ \rightleftharpoons \text{NH}_4^+ \]
\[ 2\text{NH}_3 + \text{Ag}^+ \rightleftharpoons \text{Ag(NH}_3)_2^+ \]
\[ \text{OH}^- + \text{NH}_4 \rightleftharpoons \text{H}_2\text{O} + \text{NH}_3 \]
\[ \text{Ag}^+ + \text{OH}^- \rightleftharpoons \text{Ag(OH)}(s) \rightleftharpoons \text{Ag}_2\text{O} \]
VAPOUR PRESSURE DEMONSTRATION

Materials: Mercury
Evaporating dish
Ring stand
Vapor pressure tubes (3)
Vapor pressure tube clamp
Acetone
Water
Ethanol
Syringes (3)
Meter stick

Fill one half of the evaporating dish with mercury. Clean and dry the vapor pressure tubes and fill completely with mercury so that no air bubbles are trapped. Holding your finger over the mercury in the tube, carefully invert the tube in the mercury pool in the dish and support the tube on the ring stand as shown below.* Repeat this for the other tubes. To each of the tubes add about one milliliter of each of the liquids using the syringes with the U shaped needles. This is done by trial and error since the tube end is immersed in the mercury. Care must be taken to drive all the air out of the syringe and needle before injecting into the vapor pressure tube.

Note that before adding the liquids to the tubes if the setup has been done correctly, the mercury level in all three tubes should be equal and expressing the atmospheric pressure. If the three levels are not equal look for trapped air or water vapor in the tubes.

A meter stick is used to measure the relative vapor pressures of the liquids.

*You have just prepared a barometer!
VISCOSITY

Materials: Four burettes

Alcohol (ethyl) \( \text{Vis.} = 1.2^* \)
Ethylene glycol \( \text{Vis.} = 19.9 \)
Acetone \( \text{Vis.} = 0.33 \)
Isopropyl alcohol \( \text{Vis.} = 2.83 \)

Show the relative rates of flow by first filling the burettes to the same point with the various liquids and start their flow simultaneously. For better visibility the liquids could be colored if possible or a small colored cork ball can be floated on top of each of the liquid columns.

*The viscosity values cited are at 20°C.