Demonstration Resources

The following is a non-inclusive list of demonstration resources. I highly recommend building up a file of demonstrations, and periodically editing it. Eventually you will find that you have more 'live' science at your fingertips than you had ever imagined.

Books:

Chemical Demonstrations: A Handbook for Teachers of Chemistry
Shakashiri, Bassam Z. University of Wisconsin Madison Press. Volumes 1-4

Hands-On Physics Activities with Real-Life Applications
Cunningham and Kerr. The Center for Applied Research in Education 1994

Why Toast Lands Jelly-Side Down
Ehrlich. Princeton University Press 1997

Journals:

Journal of Chemical Education
The Physics Teacher

Materials:

American Science Surplus (www.amsciplus.com) A science 'junk store'. They sell surplus materials ranging from wires and glassware to optics and lasers.

Flinn Scientific (www.flinn.com)

Jewel-Osco: You would be amazed at how much science shopping can be done at the grocery store. HEET is straight laboratory Methanol while lock De-Icer is pure Isoproanol.

Dairy Queen: They sell dry ice at about $1.50/pound.

Hair Salons: They sell 12% Hydrogen Peroxide used in the hair bleaching process.

Contact Information:

Mike Davis
Associate Vice Chancellor for STEM
City Colleges of Chicago
Phone: 312-553-2773
Email: mdavis@ccc.edu

A Word About Safety

The purpose of any demonstration as presented in this text is to inspire and motivate students towards a scientific mindset.

As teachers, we know that it is hard enough to create interest in the sciences. We would be shooting ourselves in the foot by creating an atmosphere for any sort of accident. In performing a demonstration, we must be absolutely certain that all safety concerns have been met and are displayed as well.

Make sure that safety glasses are properly adorned, and that a fire extinguisher is easily accessible. It's better to have these things before you need them.

Most accidents are easily avoidable, and with the proper precautions will never have to be dealt with. The safety of your students is of prime importance. Similarly as a teacher and a role model, it is important to train future scientists to respect the same set of procedures.

I recognize that any of the demonstrations in this collection has the potential to be hazardous. These procedures are for people that are experienced scientists, who appreciate and understand the nature of the chemicals involved. I take no responsibility for the use of any chemical or procedure specified in this book. I urge care and precaution in handling any of these chemicals or procedures.

<u>Ethanol Cannon</u>[•]

Materials:

5-Gallon Plastic Jug
Clear Packing Tape
~10 mL Ethanol.

Instructions:

Before you ever do this demonstration, wrap the jug up in packing tape. If there should ever be an accident, this will keep the jug from shattering outwards. (Never use a glass jug in place of a plastic one.)

Pour the ethanol into the jug and cap it. Shake the jug for at least 2 minutes. Place the jug on a tabletop, and remove the cap. Pass a match over the jug. You may have to place it slightly into the jug. I recommend using a long BBQ lighter, to minimize the possibility of a burn. There will be an initial whoosh, followed by a dancing blue flame in the jug. Wait until the flame is gone to handle the jug again, it will be hot. The jug cannot be used for at least forty-five minutes after the demonstration. To prove that CO_2 was made, tip the jug over onto a lit candle, and watch it go out.

Discussion:
Ethanol, is a flammable liquid, and should be treated with care. By pouring only a small amount into a large container and shaking it, you are encouraging the liquid to evaporate. Because of increased surface area, ethanol vapors are more explosive than liquid methanol. This demonstration shows several areas of science.

- Volatility
- Partial Pressures of Gases
- Combustion

Ethanol is a volatile liquid, which means that it has a low vapor pressure at room temperature. Because it evaporates quickly, it is ideal for this reaction. Other alcohols can be used, however, methanol is advised since it is cheap, readily available, and creates the least amount of energy and soot upon being burned. Iso-propanol has been used before, but ethanol remains the most visually stimulating.
Remind the students that before ethanol is put into the jug, it is full of air. By pouring a volatile liquid in and sealing the container, you are, in effect increasing the pressure inside the bottle. There will be an audible “fzzzz” when you remove the cap. This is because the pressure inside has been increased by the addition of methanol vapor.
Three things are needed for combustion: energy, fuel, and oxygen. The bottle has all three as soon as a match is passed over it. After the reaction is over remind the students that they just saw a combustion reaction, which has reactants and products just like any other reaction. Remind them what the products are, and why you cannot do the experiment again, regardless of how much they whine.

[•] Journal Of Chemical Education Vol. 76, 8 Pg 1092-1094

The Combustion of Peroxyacetone

Materials:

50 mL 30% Hydrogen Peroxide
50 mL Acetone
~2 mL Con. HCl
1 250 mL Beaker

Instructions:

In the beaker, combine equal amounts of peroxide and acetone. Swirl the mixture, and add a few drops of HCl. Swirl again, and allow the beaker to sit overnight. In about 10 minutes, the solution will look a little cloudy, and a white precipitate will begin to rise. Allow it to sit overnight.

Carefully pour any remaining liquid down a drain. The liquid may still contain some 30% peroxide. Dump the precipitate out on a flat dry surface. Allow the powder to dry and collect it in a little plastic bottle.

To perform the demonstration, place about a dime size of the powder down on a surface. Ignite the pile with a long lighter, or a match on a ruler. There will be about a basketball-sized flame. Use caution when lighting, and do not use too much. Also, do not store the material; it has been known to detonate upon being struck with a great deal of force.

Discussion•:

Peroxyacetone is thought to be 2,2-dihydroperoxypropane. This is an example of an unstable compound. It is unstable because it contains 2 if not 3 peroxide bridges (C-O-O-C), which are highly reactive. It only takes a small amount of energy, such as a lit match, to cause this combustion reaction.

It might be helpful for students to see a comparison to the (attempted) combustion of a relatively stable compound (a brick, or a rock). A certain amount of energy is required to make a non-spontaneous reaction proceed. Peroxyacteone does not spontaneously react; it requires the energy from a lit match to combust. A brick also does not spontaneously react. A brick, however, requires considerably more energy to combust, and is therefore more stable. It may also be helpful to draw an energy diagram to elaborate.

• Shakhashiri, Bassam Z. Chemical Demonstrations Volume 1 Pg. 46-49

The Nonburning Towel/Dollar

Materials:

~150 mL Water
~150 mL Isopropyl Alcohol
500 mL Beaker
Tongs

Instructions:

Combine the water and alcohol, and stir. The solution itself will be fine for quite some time. Take a towel and dip it into the solution. Remove it, and wring out the excess liquid. Hold at arms length with the tongs, and light. It may take a few seconds to actually catch fire. Allow the towel to burn visibly, then twirl the towel to put it out. Show the students that the towel itself is unburned. Repeat the demonstration with paper currency. (Caution: It's a good idea to be prepared for the worst, and carry some extra cash.)

Discussion[•]:

In order for this demonstration to work, you really only need water and some miscible flammable solution. It has been my experience that hydrocarbons with fewer than 4 carbons in it will work. If you use something like ethanol, however, you get a dim blue flame, which is difficult to see.

The explanation for this demonstration is pretty simple. Isopropyl alcohol combusts freeing up approximately 1700 kJ. Water absorbs 17 kJ to begin boiling and 113 kJ to begin vaporizing. Most of the energy created by the combustion of isopropyl alcohol is released to the surrounding air. Water absorbed by the towel ensures that there is insufficient energy present to char the towel.

[•] Shakhashiri, Bassam Z. Chemical Demonstrations Vol. 1 pg. 13-15

Chemical Luminescence•

Materials:

4.0g Sodium Carbonate Na_2CO_3
3 Liters Water
0.2g Luminol (3-aminophthalhydrazide)
24.0g Sodium Bicarbonate $NaHCO_3$
0.5g Ammonium Carbonate Monohydrate $(NH_4)_2CO_3 \cdot H_2O$
0.4g Copper (II) Sulfate Pentahydrate $CuSO_4 \cdot 5H_2O$
50 mL 3% Hydrogen Peroxide
(2) 1 L Beakers
(1) 250 mL Beaker

Instructions:

Solution A. In a 1 L flask add 500mL of water. Dissolve the sodium carbonate, luminol, sodium bicarbonate, ammonium carbonate monohydrate, and copper (II) sulfate. Gently heat the solution if everything isn't dissolving. Dilute to a final volume of 1L.

Solution B. In a 1 L flask, dilute the peroxide to a volume of 1L with water.

Combine equal portions of Solution A and Solution B.

Discussion:

The chemical luminescence of luminol is a classic. The reaction is an oxidation, where luminol is being oxidized by peroxide in water. The luminescent product of the reaction is the aminophthalate ion. While your students will not understand this, they will understand that energy is being given off.

$$\text{Reactants} \rightarrow \text{Excited Product} \rightarrow \text{Product} + \text{Energy (light)}$$

The reaction of luminol and an oxidant create an excited species, with a lot of energy. Since an excited species is unstable, it must release its energy with an emission at 425 nm. (Your students can calculate the energy released in the reaction.) The light energy is not contained by anything, so light travels from the solution outward.

NOTE:

For more potential luminescent reactions, see
Chemical Demonstrations Vol. 1 Bassam Z. Shakashiri

• Shakhashiri, Bassam Z. Chemical Demonstrations Volume 1 pg 125-204

Alternate Chemiluminescence

Materials:

(2) 100 mL Beakers
~ 50mL of Solution A from other Chemiluminescence Experiment
~ 50mL of Solution B from other Chemiluminescence Experiment
1L Pyrex Erlenmeyer Flask
10mL water
Hot Plate
2 holed rubber stopper
(2) glass tubes fit to the holes in the rubber stopper
(2) equal lengths of clear tygon tubing
Hot Gloves
Ring Stand with round clamp.

Instructions:

Assemble the stopper: VERY CAREFULLY shove the glass tubes through the two holed stopper. Use glycerin or soap to make it easier, and never shove towards your hand. Make sure that the tubes are sticking about 2 or 3 inches into flask. On the outside portion of the stopper, fit the tygon tubing securely over the glass tubes. Holding it up, it should look like big floppy rabbit ears.

Pour solutions A and B into separate 100mL beakers. Place them in front of the ring stand. Pour the water into the Erlenmeyer flask and place it on the hotplate. Stopper it tightly with the stopper assembly. Wait until the steam is pouring out of the tubes. Wearing gloves, take the flask off of the hotplate, invert it, and insert it through the ring-stand. Have someone place a tube in each beaker. In about 20 seconds there will be a glowing fountain in the Erlenmeyer flask.

Discussion:

For the chemiluminescent explanation, please see the previous experiment.

The fountain is a result of the Crush the Can demonstration. Water vapors in the flask quickly condense into the two solutions. To equalize the pressure, a vacuum pulls in air from the outside and the solutions come with it. They solutions combine in a brilliant fountain.

NOTE: I have broken more than one Erlenmeyer flask doing this demonstration. Cool liquid hitting a hot flask is the recipe for a broken bottle. Use extreme caution and make sure the flask is made of Pyrex glass.

Alternate Chemiluminescence(II)

Materials:

256 g Clorox Powder
0.8 g Luminol (3-aminophthalhydrazide)
16 g Potassium Ferricyanide $K_3Fe(CN)_6$
~20 mL Water
3L or larger Round Bottom Flask

Instructions:

Combine the three powders in a large 'mixing bowl' or something equivalent. Stir for a few minutes to ensure a homogeneous mixture. Pour some or all of the mixture into the large round bottom flask. Add water and quickly dim the lights. The mixture will immediately begin to glow. Swirling it around will make a paste that seems to coat the inside of the flask.

Discussion:

This experiment works much like the other luminescent demonstrations. There is a sensitizing molecule, Luminol, getting oxidized by the Clorox Powder. Bright blue light is produced for a minute or so and it begins to fade.

Dissolving an Egg and Observing Osmosis

Materials:

Two eggs
An acid solution (vinegar or 3M HCl will work)
Two containers
Corn syrup

Procedure:

Place both eggs into separate containers with the acid. The shell will begin to dissolve. For vinegar, this should take one night, so let the eggs sit. Rub the remains of the shells until they come off, but be gentle.

Place each egg in a separate container, one filled with water, the other filled with corn syrup.

One egg will change size dramatically compared to the other.

Discussion:

This demonstration is an exercise in observation. First and foremost, when an egg is placed in an acidic solution, bubbles will begin to form. This is result of an acid base reaction between the egg shell (calcium carbonate) and the acid in vinegar (acetic acid). The bubbles are from the formation of carbon dioxide.

Once the shell is totally rubbed off only the chorion membrane is left over. This membrane does not react with acid, and is semi permeable. One will notice that the egg has changed size considerably already since having its shell dissolved. Once the eggs are placed in corn syrup and water another such change will occur. The chorion membrane, being semi permeable will allow the passage of certain dissolved species like sugar in corn syrup. As a result, the high concentration sugar in the corn syrup will establish an osmotic gradient with the egg, and osmosis will occur. The egg will get larger.

The Magic Jug

Materials

Stock solution (2.5g NaOH, 0.5g KIO3, and 0.5g KI in 50 mL of water)
Dropper bottles

- 1% Phenolphthalein
- 1% Thymolphtalein
- 25% Sulfuric Acid
- 25% Sulfuric Acid and Starch Indicator
- 20% Sodium Thiosulfate Solution

5 Beakers
One Large Container

Instructions:

Add 5mL of stock solution for every 600mL of water you would like to have, and keep this in the large container.

Line the beakers up in a row. Add several drops of phenolphthalein to the first one, thymolphalein to the second and so forth.

Pour the liquid from the large container into each of the 5 beakers. The liquid should become a different color in each of the beakers. Once liquid has been poured into the fifth beaker, there should be no more liquid in the large container. In reverse order, pour the beakers back into the large container. The result liquid should be completely clear, though it might turn brownish over time.

Discussion:

The following reactions are taking place.

Beaker 1: Phenolphthalein detecting NaOH.
Beaker 2. Thymolphathalein detecting NaOH
Beaker 3. $6H^+ + I^- + IO_3^- \rightarrow I_2 + 3H_2O$ where I_2 is yellow.
Beaker 4. $6H^+ + I^- + IO_3^- \rightarrow I_2 + 3H_2O$ where starch reacts with I_2 to make blue.
Beaker 5. No reaction

The reaction that gets rid of all the colors is due to the presence of thiosulfate,

$$H_2O + SO_3^{2-} + I_2 \rightarrow 2I^- + SO_4^{2-} + 2H^+$$

Photochemical Redox Reactions of Thionin

Materials:

Aluminum Foil
10mL 3M Sulfuric Acid
2.0g $FeSO_4 \cdot 7H_2O$
0.0023g Thionin
Distilled Water
1L beaker
Overhead projector

Instructions:

Dissolve 0.0023g of Thionin in 100mL of water.

In a 1L beaker, mix together 500mL of water, 10mL of the thionin solution, 10mL of 3M sulfuric acid, and 2.0g of the ferrous sulfate. Stir to dissolve.

Place the beaker on an overhead projector and turn it on. Within seconds, the solution should change from a dark purple to clear. Turning the overhead the project off will make the solution change back to being purple.

Placing the solution half on and half off a piece of aluminum foil will divide it into distinct halves, one purple, one clear.

Discussion:

This is an example of a reversible photochemical redox reaction. In it thionin gets reduced to a colorless molecule in the presence of light by the Fe^{2+} ion.

$$\text{Thio}^{+} + 2Fe^{2+} + 2H^{+} \rightarrow \text{ThioH}_2 + 2Fe^{3+}$$

This demonstration is good for showing a reversible chemical reaction, and photon initiated oxidation-reduction reaction.

In the past, however, I have used this demonstration to illustrate the scientific method of thought. Using this solution I ask students to determine conclusively, what it is about the overhead projector that initiates a color change, light or heat. In order for them to determine which is responsible for the change, they do a series of tests. One of the most convincing is blocking off half of the light with something like aluminum foil. The foil is conducting enough to transmit heat, but not transparent enough to transmit light.

As it was mentioned, this demonstration can illustrate a number of points.

<u>Highlighter Fluorescence*</u>

Thanks to Tom Higgins at Harold Washington College

Materials:

Overhead Projector
High quality diffraction grating
Manila folder
Cardboard (black if possible)
Highlighter
Piece of paper

Instructions:

The manila folder is simply for holding the diffraction grating in place on the overhead. You will need to cut a whole in it and tape the grating to the folder. Next cut two slits towards the middle of the blackened cardboard. Place them a couple of inches apart. The slits will play a part in the quality of color separation, however, the diffraction grating is the most important piece. Smaller slits will lead to a broader color band. Place the folder with the diffraction grating over the projection piece. Place the cardboard with the slits on the glass. Turn on the projector, and color band will appear on the board. Write a word on the piece of paper with the highlighter. Hold it up at the red end of the spectrum. Slowly move it over to the blue, and it whatever you wrote will light up like a candle.

Discussion:

There are a few things worth talking about here. First of all, this is an example of fluorescence, as opposed to phosphorescence. In fluorescence, an emitting species needs to be illuminated prior to emitting. In phosphorescence (such as the chemiluminescence experiments) emission comes from a chemical interaction.

Highlighters are used in conjunction with reading, to ‘mark’ important material. Everyone reads in the light. White light (which is made up of all wavelengths) is our light source for reading. It is the blue end of the spectrum that is responsible for our seeing the bright yellow emission. By using a diffraction grating in a dark room, we can separate light into its components, which is the visible spectrum. By sliding the paper in the red, we can see that it does not absorb. By moving to the blue, we can see that it does absorb. This is a simple experiment that showcases the visible spectrum dramatically to a large audience.

Fluorescent dyes like those used in highlighters are made with fluoroscein, which absorbs below 450nm and emits above 560nm.

Balloon in the Bottle

Materials:

One balloon
Heat Source
~ 5 mL Water
Florence Flask or soda bottle
Tongs / Hot glove

Instructions:

Pour the water into the bottle or flask, and place it on the heat source. Wait until a visible steam cloud is looming above the can. Depending on the heat source it can take 3-5 minutes. Remove the bottle with tongs or the hot glove. Carefully but quickly stretch the opening of the balloon over the lip of the bottle or flask. In time, the balloon will be pushed into the bottle.

Discussion:

This demonstration is exactly like the "Crush the Can" demo that was previously presented. In it, water is heated to create steam, which fills the entire container. As the container cools, and the steam recondenses and takes up less space.

Without the balloon present, there is nothing to really see here. Air would normally fill the recently created vacancy. With the balloon there, the air is blocked from re-entering the container. Since the balloon is squishy and pliable, air pressure is sufficient to 'push' into the bottle, and inflate it at the same time. Air from the outside of the balloon is trying to get into the bottle, but the balloon is in the way.

Some might say that the balloon is getting sucked in, which is not true. Science doesn't 'suck'. The outside air is pushing it in.

The balloon will stay that way for several weeks, or until the balloon degrades.

The Supersaturated Solution

Materials:

175g Sodium Acetate Trihydrate NaC2H3O2.3H2O
50 mL water
2 L Beaker
500 mL Erlenmeyer flask
100 mL Beaker
A few crystals of Sodium Acetate Trihydrate
Hot plate

Instructions:

Fill the 500 mL beaker roughly two thirds full with water. Set it on the hot plate and turn the heat up. In the Erlenmeyer flask combine the sodium acetate and 50 mL of water. Place the flask in the hot water bath. Put the 100mL beaker over the mouth of the flask. In about one hour the solid will have dissolved. If it is not near being dissolved, add a drop or two of water. Once the solution is clear, turn off the heat, but leave the flask in the water bath. In at least an hour, carefully remove the flask and set it on a paper towel. Allow it too cool by itself for a while.

To perform the demonstration, place a few crystals of sodium acetate onto a surface like a watch glass or a tabletop. Slowly pour the solution onto the crystals. The solution will start to solidify as soon as it hits the crystals. Alternately, you could add a couple of crystals to the flask and watch it solidify. To reuse the solid, simply put it back into the flask, and heat with a hot water bath. Do not add water! It may be necessary to add a drop or two of water after repeated uses. This works best when the solution is at room temperature, as opposed to being hot.

Discussion[•]:

It takes two things to dissolve sodium acetate; water and sodium acetate. By dissolving 175g of sodium acetate in 50mL of water, the solution is supersaturated. The saturation point for any liquid is dependent upon its temperature, which is why the solution must be heated, and slowly cooled. By adding a crystal or two to the solution, there is no more water available to dissolve the additional crystals. It serves as a nucleation point for crystallization of the whole solution. The heat of solution of sodium acetate trihydrate is about 20 kJ/mole, and therefore the crystallization is exothermic. Making bonds releases energy, breaking bonds takes energy. The solid or the flask will feel slightly warm.

Be careful once the solution is made. Almost anything can serve as a starting point for crystallization. Try to keep it covered with a rubber stopper or some parafilm.

[•] Shakhashiri, Bassam Z. Chemical Demonstrations Vol 1 Pg 27-31

The Potato Gun

Materials:

1 length of PVC tubing
1 length of dowel rod
1 Fresh Potato

Instructions:

Cut two slices of potato a little less than one inch thick. Shove one end of the PVC tube into one potato slice, and the other end into the other potato slice. Using the dowel rod start to push one of the potatoes inward. Push quickly and the other potato will shoot out about 10 to 20 feet with an audible "ploop". It is important to use thick slices of fresh potatoes. Older potatoes are not as firm and can bend or break in the tube, causing a failure.

Discussion:

This is a simple example of Boyle's law. The tube, when stopped with potato is filled with air at atmospheric pressure. By pushing on one of the potatoes the volume occupied by the air is decreasing. Eventually the pressure becomes so great that the other potato has to give.

Boyle's Law is expressed as

$$P\,V = C$$

Where P is pressure, V is volume and C is a constant. An increase in P leads to a decrease in V and vice versa. There are several ways to show this demonstration. One became clear to me on a trip to Ireland. I brought a bag of Doritos with me to give to a friend. Midway through the trip, I got a little peckish and thought I would dig in. So I looked for the bag and was surprised to see it puffed up like a giant pillow. Then I realized that air pressure on an airplane is less than that on the ground. This decrease in pressure led to an increase in the volume occupied by the gas in the bag. Needless to say, I was too in awe of Boyle's law to dig into the Doritos.

Another popular demonstration involves pulling a vacuum on a marshmallow in a clear vacuum chamber. Since a marshmallow if mostly air, decreasing the pressure will increase its volume, and the marshmallow will more than double in size.

Crush The Can

Materials:

One soda can (empty)
Heat Source
~ 5 mL Water
1L Beaker filled with water
Tongs

Instructions:

Pour the water into the soda can, and place it on the heat source. Wait until a visible steam cloud is looming above the can. Depending on the heat source it can take 3-5 minutes. Grab the can with a pair of tongs, invert the can and dip just the top of it into the water.

Discussion:

This is a classic demonstration of Charles Law, and the power of Atmospheric Pressure. By heating the water inside the can, it is effectively being filled with water vapor. The can is full of vapor when steam is clearly visible. By inverting the vapor filled can over the water, the steam quickly cools, and condenses into water.

The water vapor formerly filling the can is gone, leaving nothing in the can. The pressure inside the can is very small compared to the outside air pressure. Since a soda can was not designed to withstand any sort of vacuum, it is crushed.

Charles Law is expressed as

$$V = TC$$

Where V is the Volume of a gas, T is the temperature, and C is a constant. Therefore is temperature increases, volume increases, and vice versa.

Charles law is also responsible for the phenomena of shrinking balloons on a cold day. Anyone that has purchased balloons in a store only to see them deflate upon being taken outside has been a victim of Charles Law.

Balloon in the Bottle

Materials:

One balloon
Heat Source
~ 5 mL Water
Florence Flask or soda bottle
Tongs / Hot glove

Instructions:

Pour the water into the bottle or flask, and place it on the heat source. Wait until a visible steam cloud is looming above the can. Depending on the heat source it can take 3-5 minutes. Remove the bottle with tongs or the hot glove. Carefully but quickly stretch the opening of the balloon over the lip of the bottle or flask. In time, the balloon will be pushed into the bottle.

Discussion:

This demonstration is exactly like the "Crush the Can" demo that was previously presented. In it, water is heated to create steam, which fills the entire container. As the container cools, and the steam recondenses and takes up less space.

Without the balloon present, there is nothing to really see here. Air would normally fill the recently created vacancy. With the balloon there, the air is blocked from re-entering the container. Since the balloon is squishy and pliable, air pressure is sufficient to 'push' into the bottle, and inflate it at the same time. Air from the outside of the balloon is trying to get into the bottle, but the balloon is in the way.

Some might say that the balloon is getting sucked in, which is not true. Science doesn't 'suck'. The outside air is pushing it in.

The balloon will stay that way for several weeks, or until the balloon degrades.