Chemistry Club Demos

CAUTION:
All of the following experiments are potentially hazardous, and may only be performed by trained individuals while wearing proper attire (long pants, closed-toe/heel shoes) and full Personal Protective Equipment (PPE). Minimum PPE is an appropriate lab coat, safety glasses or splash-proof goggles, and nitrile gloves. Additional PPE might be required, depending on the hazards of the demonstration. This additional PPE will be detailed in the demo write-up.

Contents

Bang in a Can

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles**,** **hearing protection**, nitrile gloves
Equipment	**Chemicals**
Steel can with metal lid (shipping/1 gallon paint can)	Methane (CH_4) or hydrogen (H_2), with regulator and tubing installed.
Drill/punch and pliers for preparing can	
BBQ-style butane lighter (≥ 6" long)	
Masking tape	

Procedure:

1.) To prepare the can, first punch or drill a small (1/8-1/4") hole in the center of the bottom of the can; this will act as the gas outlet and pilot light. Then cut/drill two medium (1/2") holes in the side of the can, roughly 1" from the rim of the opening and opposite each other; these act as air-intake vents. Cover all three holes with adhesive tape such that they can be opened quickly. Finally, use pliers to compress the press-fit ring around the circumference of lid, such that it fits very loosely on the can – the lid should fall off when the can is inverted.

2.) To fill the can with a fuel gas, hold the lid slightly offset from the can and insert the hose barb or the end of the tube attached to the regulator on a cylinder or other supply of flammable gas (CH_4 or H_2). Untape the small pilot hole on the bottom of the can, and proceed to fill the can (~30 seconds with a 5 psi regulator). When the can is filled, retape the pilot hole, remove the hose barb or tube, and press the lid loosely onto the can to trap the gas.

3.) Immediately place the can on a table (far away from the gas cylinder) with the bottom of the can and pilot hole facing up. Ensure you are wearing hearing protection and that the audience has been warned to cover their ears before proceeding. Remove the tape from the pilot and vent holes, and use the lighter to ignite the gas escaping from the pilot hole, stepping back once it is lit. There will be a small flame visible from the pilot hole, though it will be very difficult to see if the fuel gas is hydrogen (dimming the lights will be helpful to see the pilot flame). Once the upper explosive limit is reached, the mixture of gases in the can will ignite with a loud bang, sending the can flying upwards (~10-30 feet).

Clean-up: None required.

Hazards: The explosion in the can produces heat, fire, and a loud noise, and the can is launched upwards with considerable force. Hazards include thermal burns from the fire or the can immediately after the explosion, hearing damage from the explosion, or physical injury from being hit with the can.

Principle: The gas in the can is lighter than air, and escapes from the hole in the top of the inverted can, while air is pulled into the can through the holes in the sides to equalize the pressure. Lighting the stream of gas through the top creates a pilot light than remains lit until the mixture inside reaches a particular concentration known as the upper explosive limit. At this point, the flame will flash back through the hole and ignite the entire mixture at once, forming hot gaseous H_2O (and CO_2 if using methane) that forces the can upwards when it separates from the lid. The upper explosive limits in air are roughly 15% for CH_4 and 75% for H_2 by volume.

Notes: It may take up to 1-2 minutes for the mixture to ignite, depending on the fuel gas and the size of the holes. If the ignition does not occur, do not place your hand over the can if you attempt to relight the pilot, as the flame may still be lit and the mixture may ignite at any moment. In the event of a failed ignition, leave the can undisturbed for at least 5 minutes before removing the lid well away from any ignition sources.

Blue Bottle

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
500-mL Florence/Erlenmeyer flask (or larger)	Dextrose (D-glucose, $C_6H_{12}O_6$)
Rubber stopper to fit flask	Potassium hydroxide (KOH)
	Methylene Blue (M.B.), 1% solution

Procedure:

1.) Add 300 mL water, 8 g KOH, and 10 g dextrose to the flask, swirling the solution until everything has dissolved. 2.) Add 5-6 drops of the M.B. indicator solution, swirling again to mix. The solution will initially turn blue, but after a few moments it will become colorless.

3.) To perform the demo, stopper the flask and shake the solution vigorously, making sure to hold the stopper in place with one hand. The solution will turn blue after sufficient shaking. After the solution has turned blue, stop shaking and let the solution rest for ~10 seconds, at which point it will become colorless again.

4.) This reaction can be repeated several times (occasionally up to 8) before the solution decomposes and turns cloudy.

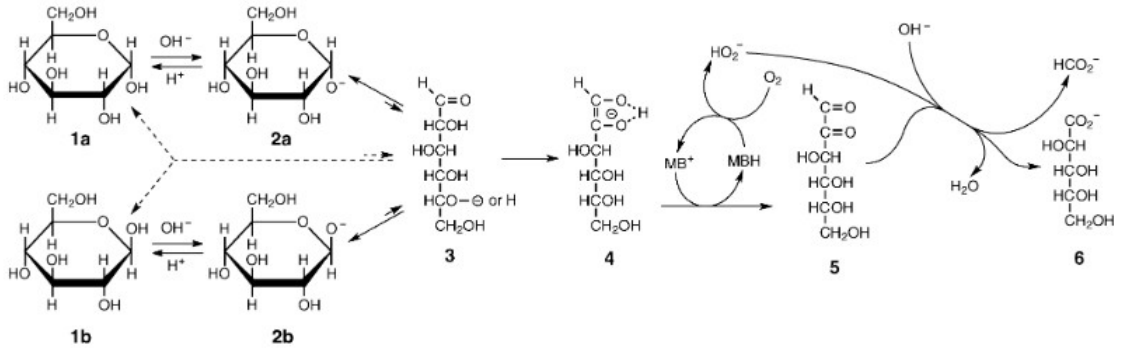
Clean-up: The waste solution may be rinsed down the sink with copious amounts of water.

Hazards: KOH is a strong base and its solutions are highly corrosive, causing immediate chemical burns on contact.

Principle: This demonstration involves a reversible oxidation-reduction reaction between M.B., oxygen (O_2), and a reducing sugar. M.B. is a common redox indicator that is blue in oxidizing environments and colorless in reducing environments. When the flask is shaken, atmospheric O_2 is dissolved in the solution and oxidizes the M.B. to its blue form. Dextrose is a reducing sugar, and in alkaline solution it is converted to an enolate which reduces the M.B. back to its colorless form; the dextrose is ultimately oxidized into arabinonic acid and formate anions (Scheme 1, see reference). Shaking the flask again introduces more oxygen, which repeats the cycle until no dextrose remains.

Notes: The solution will remain blue at the gas-liquid interface, as there is sufficient oxygen to keep the M.B. in its blue form. The transition time from blue to colorless will increase with successive cycles; also, the conversion can be drastically slowed by halving the concentrations of the reagents. Alternately, stirring/swirling the flask instead of shaking it will cause much more rapid color changes, as less oxygen is dissolved and less of the M.B. is oxidized.

Scheme 1. Reactions Occurring in the Blue Bottle Experiment[a]



[a] **1a**, α-D-glucopyranose; **1b**, β-D-glucopyranose; **2a**, α-D-glucopyranosyloxy anion; **2b**, β-D-glucopyranosyloxy anion; **3**, open chain form of glucose; **4**, enediolate anion; **5**, D-*arabino*-hexos-2-ulose (glycosulose, open chain form); **6**, D-arabinonate anion; MB^+, methylene blue; MBH, methylene white; HO_2^-, hydroperoxide anion; HCO_2^-, formate anion.

References: Andersen *et al. J. Chem. Educ.* **2012**, *89*, 1425-1431. DOI: 10.1021/ed200511d.

Borate Flame

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
1-L Erlenmeyer flask with boiling chips	Boric acid ($B(OH)_3$)
Rubber stopper fitted with an S-shaped glass tube	Methanol (CH_3OH)
Hotplate with clamp for flask	Sulfuric acid (H_2SO_4), 18 M
BBQ-style butane lighter (≥ 6" long)	

Procedure:

1.) Add 2-3 mL of H_2SO_4 to 150 mL of CH_3OH in the 1-L Erlenmeyer flask. 2.)
Add 30 g of $B(OH)_3$ to the mixture and stir until all solids have dissolved.

3.) Add a few boiling chips to the flask and place it in the clamp on the hotplate. Put the rubber stopper with the 'S'-shaped tube in the neck of the flask, and heat the mixture to a vigorous boil. This may take 5-10 minutes, and should be started slightly before the demo is to be performed.

4.) Ignite the vapor at the top of the 'S'-shaped tube with the lighter. If the vapor does not ignite, increase the heat from the hotplate. Ensure the mixture is boiling rapidly enough to maintain a flame ~4-6" in height, but not so rapidly that it boils over.

5.) When finished, turn off the hot plate. You may either blow out the flame or simply wait until the mixture has cooled sufficiently, as the flame will diminish and then self-extinguish as the boiling subsides.

Clean-up: The flask should remain clamped to the hotplate to minimize the chance of spilling methanol around any ignition sources. Once everything has cooled to room temperature, the mixture should be saved for future use by replacing the 'S'-shaped tube with a solid rubber stopper.

Hazards: Sulfuric acid is strongly oxidizing and corrosive, and will cause immediate chemical burns on contact. Methanol is toxic and highly flammable. Keep all solutions away from ignition sources until the demo is performed.

Principle: $B(OH)_3$ will react with CH_3OH in the presence of a dehydrating agent (H_2SO_4) to form trimethylborate ($B(OCH_3)_3$) and H_2O. This borate ester is volatile (b.p. = 68 °C) and burns with the green flame characteristic of all boron compounds. The color is due to broad band emissions in the green region of the spectrum from various molecular species as they relax from excited electronic states back to their ground states.

Notes: A freshly-prepared solution may be added to the flask whenever the volume of the solution becomes too low to perform the demonstration (<50 mL). Do not heat the flask with an open flame, as this may cause the mixture to bump and boil out of the flask, creating a fast-spreading methanol fire. Performing the demonstration without the S-shaped glass tube is not recommended; while this produces a larger flame, it is not self-extinguishing and there is a much greater risk of the solution boiling over if it bumps.

Bottle Rockets

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles, **hearing protection**, nitrile gloves

Equipment	Chemicals
Clean, dry 1- or 2-L soda bottles with caps	Methanol (CH_3OH)
Launch pad (small/medium iron rings on steel lab stand)	Oxygen (O_2), with regulator and tubing installed
BBQ-style butane lighter (≥ 6" long)	

Procedure:

1.) Rinse and dry the soda bottles if necessary.

2.) Fill the bottles with oxygen gas from the cylinder in the dispensary. Hold the bottle over the outlet of the regulator (set to ~5 psi) for ~30 seconds.

3.) Quickly add ~5 mL of methanol to the bottle and screw the cap on tightly. Shake the closed bottle to disperse the methanol. The demo can be performed immediately, but the effect will be greater if the bottle is allowed to sit at room temperature for at least 20 minutes. Do not store prepared bottle rockets for more than 24 hours, and keep them out of direct sunlight and away from heat or ignition sources.

4.) Before the demo, quickly loosen the cap and allow any excess methanol to drain out, and then retighten the cap. Do this away from any ignition sources.

5.) To mount the bottle on the launch pad, simply place the bottle cap side down in one of the iron rings.

6.) Ensure you are wearing hearing protection and that the audience has been warned to cover their ears before proceeding. Unscrew the cap from the bottle and hold the flame from the butane lighter near the opening. Keep your hand to the side of the bottle rocket, and never place anything directly above or below the bottle. The bottle rocket should never be pointed towards other performers or the audience. Once ignited, there will be a loud noise and the bottle rocket will quickly launch ~10-100 feet into the air, largely depending on ambient temperature.

Clean-up: None required, except for retrieving all bottles and caps for recycling.

Hazards: Methanol is toxic and highly flammable; it should be kept away from heat or ignition sources, especially when in an oxygen-rich environment such as a prepared bottle rocket. Methanol burns with an almost invisible blue flame, which is extremely difficult to see in bright light. Launching the rockets produces heat, fire and a loud noise, and the bottle is launched upwards with great force. Hazards include thermal burns from the fire, hearing damage from the explosion, or physical injury from being hit by the launching bottle.

Principle: The combustion of methanol in a pure oxygen environment produces carbon dioxide (CO_2), water vapor, and heat. These hot gases quickly expand and exit the bottle through the neck, creating thrust that propels the rocket upwards.

Notes: Methanol has a flash point of 11 °C (52 °F), and the vapor pressure increases dramatically with increasing temperature. If this demo is to be performed during the winter months, the bottle rockets need to be kept above this temperature in order to ignite, and kept close to 20 °C (68 °F) in order for there to be enough fuel in the mixture to get a decent launch. This can be achieved by placing room-temperature bottles in an insulated bag, only removing them one at a time as they are launched. If it is sunny outside, the bottles may be warmed by placing them in direct sunlight for no longer than 5-10 minutes, or until they are just barely warm to the touch. Under no circumstances should the bottle rockets be heated beyond this point, as this could cause them to burst or ignite in an uncontrolled fashion. 2-L bottles will become slightly warped from the heat of the launch, and should not be reused; smaller 1-L bottles hold up significantly better and can usually be reused 2-3 times.

Elephant Toothpaste

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
1-L glass graduated cylinder	Hydrogen peroxide (H_2O_2), 30% solution
Clear plastic tub	Potassium iodide (KI), solid powder or sat. solution
	Dish soap
	Food coloring (optional)

Procedure:

1.) Place the clear plastic tub on the ground, and then place the graduated cylinder in middle of the tub.
2.) Pour ~50 mL H_2O_2 into the graduated cylinder.
3.) Pour ~3 mL of dish soap into the cylinder and agitate slightly to mix.
4.) (optional) Run a few drops of food coloring down the sides of the cylinder for a striping effect.
5.) There are two methods for performing this demonstration:
   Method 1) Quickly pour ~10 mL of the potassium iodide solution into the cylinder and step back, as a large volume of soap suds will very quickly erupt from the top of the cylinder and land in the plastic tub.
   Method 2) Add 0.5 g of solid KI powder to the cylinder and step back. As the solid must dissolve and diffuse through the solution, this reaction is much slower and produces a stream of foam from the cylinder that may continue for up to a minute.
6.) This reaction produces a significant quantity of heat, and the graduated cylinder will be hot to the touch. Allow it to cool sufficiently before moving the demonstration.

Clean-up: Once everything has cooled to room temperature, all waste can be safely rinsed down the drain.

Hazards: 30% H_2O_2 is corrosive and strongly oxidizing, causing immediate chemical burns on contact with skin. Always wear nitrile gloves when preparing, performing, or cleaning up this demo. Furthermore, the catalytic decomposition of H_2O_2 is strongly exothermic, and the graduated cylinder may become warm enough to cause thermal burns during the demonstration.

Principle: This demonstration involves the catalytic decomposition of H_2O_2 into water (H_2O) and oxygen gas ($O_2(g)$). The overall reaction is:

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

This reaction is slow, but may be catalyzed by the iodide ion (I^-). One proposed mechanism for this reaction is:

$$H_2O_2(aq) + I^-(aq) \rightarrow OI^-(aq) + H_2O(l)$$

$$H_2O_2(aq) + OI^-(aq) \rightarrow I^-(aq) + H_2O(l) + O_2(g)$$

A significant quantity of heat is also generated ($\Delta_r H° = -196$ kJ/mol), which vaporizes some of the H_2O into steam. The soap catches the evolved steam and oxygen, forming many small bubbles that coalesce into a foam.

Notes: More is going on in solution than just the reactions given in the mechanism listed above. Upon the addition of KI, the solution becomes a red-brown color that slowly clears, evidence for the formation and subsequent consumption of iodine (I_2) and the triiodide (I_3^-) anions that form upon reaction with excess I^-. Research on the reaction mechanisms and kinetics of this system is still ongoing. This demonstration is nearly identical to Genie in a Bottle, which does not use soap to catch the evolved gases.

Ethanol Cannon

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
Ethanol Cannon Assembly – six 250-mL Nalgene bottles with nails inserted halfway into the sides	Ethanol (EtOH), ≥95% solution
Corks to fit bottles	
Tesla coil	

Procedure:

1.) Pour ~2mL of EtOH into each bottle, then cork the bottles and wait ~2 minutes for the EtOH to evaporate.
2.) Ensure that the bottles are not pointed at the audience, other performers, or anything fragile (i.e. light fixtures).
3.) Turn on the Tesla coil and touch the tip to one of the nails. A spark should jump the gap between the nails inside the bottles, causing the ethanol vapor to ignite and the corks to shoot out of the bottles.
4.) The demo can be repeated several times without adding any more EtOH, so long as the bottles are flushed with air before they are re-corked.

Clean-up: Excess EtOH can be rinsed down the drain, or left in the bottles until it evaporates. Be sure to retrieve all of the launched corks.

Hazards: EtOH is highly flammable and should be kept away from ignition sources. The corks can fly 30-40 feet with considerable force, and a direct impact could result in physical injury. The Tesla coil produces a high-voltage, low-amperage electrical discharge, and careless handling can result in a painful electrical shock.

Principle: The Tesla coil causes a spark to jump between the nails in the bottle, and this spark supplies enough energy to initiate the combustion of EtOH, creating CO_2 (g) and H_2O (g). These gases cannot escape the closed vessel, so the pressure increases until the cork is ejected. While essentially all of the oxygen in the bottles is consumes, a significant amount of the EtOH remains, such that refreshing the air in the bottles allows for repetition of the demonstration.

Notes: Make sure there is no rust or corrosion on the nails, and that the tips are spaced just far enough apart that there is a visible spark between them when the Tesla coil is touched to one nail. The explosive limits of EtOH vapor in air are ~3-20% by volume, and the flash point is 12.8 °C (55 °F). The ambient temperature must be above the flash point for the cannon to ignite, and the strength of the combustion increases with temperature.

Exploding Balloons

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles, **hearing protection**, nitrile gloves

Equipment	Chemicals
Latex balloons	Helium (He), with regulator and tubing installed
String	Hydrogen (H_2), with regulator and tubing installed
Weighted objects to anchor balloons	Oxygen (O_2), with regulator and tubing installed
Candle on 1-meter stick/pole	Methane (CH_4) (optional), with regulator and tubing installed

Procedure:

1.) Fill the balloons from the gas cylinders in the dispensary with appropriate mixtures of gases. This includes pure helium, pure hydrogen or methane, and a 2:1 mixture of hydrogen and oxygen. Never make a mixed CH_4/O_2 balloon – the power output is too large (~3 times that of a H_2/O_2 balloon), making it unsafe for performance even when outdoors. Tie the balloons off and attach the strings to both the balloons and the weighted anchors. Label the top of each balloon with a sharpie marker so the performers know which gas/mixture is inside.

2.) Position the balloons and their anchors at least 10 feet from the audience. Alternatively, tie the balloons directly to stationary, non-flammable objects that are a similar distance from the audience.

3.) Ensure you are wearing hearing protection and that the audience has been warned to cover their ears before proceeding. Furthermore, if there is any wind, make sure you are standing upwind of the balloon. Light the candle on the end of the pole, and place it next to the balloon. It will pop (helium), ignite (H_2 or CH_4), or explode (H_2/O_2) after a few seconds.

Clean-up: Make sure to clean up all of the pieces latex and string.

Hazards: The H_2, CH_4, and H_2/O_2 balloons produce heat, fire, and a loud noise when ignited. Hazards include thermal burns from the fire and hearing damage from the explosion. When transporting H_2, CH_4, and H_2/O_2 balloons, take care to keep them away from ignition sources and each other, if moving multiple balloons. They should never be grouped into a bag for transportation, as the build-up of static electricity could cause them to ignite. **Never** bring a H_2/O_2 balloon into a confined space such as an elevator, as an accidental explosion could cause deafness and great personal injury. H_2/O_2 balloons cannot be transported in vehicles for legal reasons, and may only be used for outdoor demonstrations on campus.

Principle: The helium balloon doesn't explode because helium is an inert gaseous element. The flammable gases in the balloons combust into water vapor (and CO_2 with CH_4 fuel) when ignited. The CH_4 balloon releases the most energy, but it has the lowest power because the combustion proceeds slowly. The H_2 balloon releases approximately $1/3^{rd}$ of the energy, but it burns much faster and therefore produces much more power. The H_2/O_2 balloon releases the same energy as the H_2 balloon, but with significantly more power (creating a shock wave); as the gas does not need to diffuse into the air to mix with oxygen, the combustion occurs with much greater speed.

Notes: When making mixed H_2/O_2 balloons, first fill the balloon one third with oxygen, and then fill it the rest of the way with hydrogen, stopping shortly after it becomes positively buoyant. This is still a very oxygen-rich mixture, but it limits the concussive force of the explosion. The mixed balloons should not exceed 6-8" in diameter, and must **never** be ignited indoors. When igniting CH_4 balloons, occasionally they will pop and blow out the candle without igniting. It is helpful to hold the candle to one side of the balloon, and to keep it in place after the balloon has popped to ensure ignition.

Five Colors from One Solution

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
Five 250-mL beakers	Phenolphthalein in ethanol solution
Disposable pipettes	Sodium carbonate (Na_2CO_3), 5% solution
	Iron (III) chloride ($FeCl_3$), 50% solution
	Ammonium thiocyanate (NH_4SCN), 30% solution
	Potassium ferrocyanide ($K_4[Fe(CN)_6]$), 5% solution

Procedure:

1.) To prepare this demonstration, add the following to five separate beakers:
- #1: 100 mL water and 1 mL phenolphthalein solution
- #2: 10 drops of Na_2CO_3 solution
- #3: 7 drops of $FeCl_3$ solution
- #4: 1 mL of NH_4SCN solution
- #5: 1 mL of $K_4[Fe(CN)_6]$ solution

2.) Pour the contents of beaker #1 into #2, then from #2 into #3, then from #3 into #4, and finally from #4 into #5. There will be a distinct color change with each successive step; #1 is colorless, #2 is fuchsia (basic phenolphthalein), #3 is yellow (acidic $Fe^{3+}(aq)$), #4 is red ($Fe(SCN)^{2+}$ species), and #5 is deep blue (Prussian blue).

Clean-up: The contents of beaker #5 can be diluted with water and rinsed down the drain.

Hazards: Ethanol solutions are flammable, and should be kept away from ignition sources. Solutions of $FeCl_3$ are corrosive to metals. Phenolphthalein, $FeCl_3$, and NH_4SCN are toxic if swallowed, and phenolphthalein is a potential carcinogen and reproductive hazard. The Prussian blue present in beaker #5 will stain skin and clothing.

Principle: This demonstration uses an indicator and several different reaction products to produce five different colors from a single solution. The indicator phenolphthalein is colorless in neutral solution (beaker #1), but turns fuchsia in the presence of the basic Na_2CO_3 solution in the second beaker. In the third beaker the H_3O^+ ions produced by the hydrolysis of the iron(III) salt bind the OH^- ions from the Na_2CO_3 solution, leading to decolorization of the phenolphthalein; at the same time the solution turns yellow due to the presence of the hydrolyzed iron(III) species:

$$[Fe(H_2O)_6]^{3+} + H_2O \rightarrow [Fe(H_2O)_5(OH)]^{2+} + H_3O^+$$

$$[Fe(H_2O)_5(OH)]^{2+} + H_2O \rightarrow [Fe(H_2O)_4(OH)_2]^{+} + H_3O^+ \text{ etc}$$

In the fourth beaker iron (III) salts form deep red complexes such as $[Fe(SCN)(H2O)_5]^{2+}$ with the SCN^- ions. The extreme stability of colloidal Prussian blue ($KFe^{III}[Fe^{II}(CN)_6]$) dominates in the fifth beaker, so that the deep blue color brings the series to a close. Deviations from the given concentrations can lead to slight differences in the effects due to the formation of precipitates or mixed colors.

Notes: Ensure the thiocyanate solution is fresh (< 3weeks old), as it slowly decomposes and gives muddy brown precipitates instead of the desired deep red color.

Genie in a Bottle

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
2-L Florence or round-bottom flask and cork ring	Potassium iodide (KI)
	Hydrogen peroxide (H_2O_2), 30% solution

Procedure:

1.) Place the flask on the cork ring on the ground at least 10 feet from the audience.

2.) Pour ~50 mL of H_2O_2 into flask. The liquid should come up to roughly the level of the top of the cork ring.

2.) Add ~0.5 g of solid KI powder into the flask and quickly move back. The reaction begins slowly, but accelerates as more KI dissolves in the solution. A plume of steam will be released from the top of the flask as the contents boil. Allow the flask to cool sufficiently before moving the demonstration.

Clean-up: Once everything has cooled completely, the solution can be rinsed down the drain with water. Make sure to rinse the flask thoroughly with distilled water to prevent premature reactions in future demonstrations.

Hazards: 30% H_2O_2 is corrosive and strongly oxidizing, causing immediate chemical burns on contact with skin. Always wear nitrile gloves when preparing, performing, or cleaning up this demo. Furthermore, the catalytic decomposition of H_2O_2 is strongly exothermic, and the flask may become warm enough to cause thermal burns during the demonstration.

Principle: This demonstration involves the catalytic decomposition of H_2O_2 into water (H_2O) and oxygen gas ($O_2(g)$). The overall reaction is:

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

This reaction is slow, but may be catalyzed by the iodide ion (I^-). One proposed mechanism for this reaction is:

$$H_2O_2(aq) + I^-(aq) \rightarrow OI^-(aq) + H_2O(l)$$

$$H_2O_2(aq) + OI^-(aq) \rightarrow I^-(aq) + H_2O(l) + O_2(g)$$

A significant quantity of heat is also generated ($\Delta_r H° = -196$ kJ/mol), which vaporizes some of the H_2O into steam. The steam produces a nice “smoke” effect.

Notes: More is going on in solution than just the reactions given in the mechanism listed above. Upon the addition of KI, the solution becomes a red-brown color that slowly clears, evidence for the formation and subsequent consumption of iodine (I_2) and the triiodide (I_3^-) anions that form upon reaction with excess I^-. Research on the reaction mechanisms and kinetics of this system is still ongoing. This demonstration is nearly identical to Elephant Toothpaste, which uses soap to catch the evolved gases. Performing with dimmed lights for the audience and brighter light on the flask enhances the effect.

Growling Gummy Bear

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles, nitrile gloves

Equipment	Chemicals
25mm x 200mm silica (quartz) test tube	Potassium chlorate ($KClO_3$)
Lab stand with test tube clamp and inverted glass cone	Gummy bear
Tongs or long forceps	
Propane torch	

Procedure:

1.) Add enough solid $KClO_3$ to the silica tube to fill it to a depth of ~1".
2.) Place the silica tube in the clamp on the lab stand, clamping near the open end of the tube. Position the clamp such that the tube is held vertically, with the opening directly under the inverted glass cone. The rim of the cone should be ~1" above the opening of the tube.
3.) Use the propane torch to evenly heat the bottom of the tube until the $KClO_3$ begins to melt. Bubbles will start to form in the clear liquid as it begins to decompose.
4.) When the $KClO_3$ is almost fully melted, stop heating with the torch and use tongs or forceps to carefully drop one half of a gummy bear into the tube and step back. The vigorous oxidation reaction will release heat, flame, and light as the sugar is oxidized. The liberated heat from the reaction will melt any remaining solid $KClO_3$.
5.) If the initial reaction dies down and there appears to be additional $KClO_3$ in the tube, a second half gummy bear may be added to continue the demonstration. If it is added too soon, it is likely to be ejected from the tube.

Clean-up: Do not attempt to move or clean up the demonstration until everything has cooled significantly. Once cool, the tube can be cleaned with water and all waste products can be disposed of down the drain.

Hazards: Molten $KClO_3$ is a strong oxidizer that will ignite combustible materials on contact, and it may also cause thermal burns. The oxidation of the gummi bear is strongly exothermic and produces heat, flame, and light. The gummy bear and small drops of molten KCl or $KClO_3$ may be ejected from the tube before the reaction is complete, though these should be stopped by the inverted cone. Ensure the tube is over a non-combustible surface as a precaution.

Principle: When heated to a molten state, $KClO_3$ decomposes into potassium chloride (KCl) and potassium perchlorate ($KClO_4$), which upon further heating decomposes into KCl and oxygen (O_2). The O_2 oxidizes the sucrose ($C_{12}H_{22}O_{11}$) in the gummy bear into carbon dioxide (CO_2) and water (H_2O); if the reaction went to completion, it would liberate ~35 kJ of energy per gummy bear. The liberated heat will also caramelize some of the sugar, producing a brown color and giving off a characteristic odor. The lavender color of the flame indicates the presence of potassium ion (as in a flame test).

Notes: It is preferable to use half of a gummy bear instead of a whole one, as it is less likely to be ejected from the tube. To prevent the gummy bear from sticking to the tongs and the side of the tube, it is helpful to coat the cut (sticky) surface with powdered sugar.

Indicator Rainbow

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves

Equipment	Chemicals
Six 400-mL beakers	Phenolphthalein
2-L beaker	Thymolphthalein
Glass stir rod	*p*-nitrophenol
Two 1-L plastic bottles for 0.01 M HCl and NaOH	
30-mL plastic dropper bottle for 12 M HCl	Hydrochloric acid (HCl), 0.01 M, 1 M, and 12 M
30-mL plastic dropper bottle for 3 M NaOH	Sodium hydroxide (NaOH), 0.01 M and 3 M
Six 30-mL plastic dropper bottles labeled Red, Orange, Yellow, Green, Blue, and Violet	Ethanol (EtOH), 95%

Procedure:

1.) Preparation of solutions (each solution is stored in an appropriately labeled 30-mL plastic dropper bottle):
Red: Dissolve 1.5 g *p*-nitrophenol and 0.75 g phenolphthalein in 30 mL EtOH. Acidify with 5 drops of 1 M HCl.
Orange: Dissolve 2 g *p*-nitrophenol and 0.15 g phenolphthalein in 30 mL EtOH.
Yellow: Dissolve 1 g *p*-nitrophenol in 30 mL EtOH. Acidify with 5 drops of 1 M HCl.
Green: Dissolve 0.2 g thymolphthalein and 2 g *p*-nitrophenol in 30 mL EtOH. Acidify with 5 drops of 1 M HCl.
Blue: Dissolve 0.2 g thymolphthalein in 30 mL EtOH.
Violet: Dissolve 0.45 g phenolphthalein and 0.2 g thymolphthalein in 30 mL EtOH.

2.) Add 3 drops of the Red, Orange, Blue, and Violet indicators, and 4 drops of the Yellow and Green indicators to the 400-mL beakers. Arrange the beakers in a line running from Red to Violet, as in a rainbow. Add 10 drops of 12 M HCl to the 2-L beaker and set it aside until the end of the demonstration.

3.) Fill each 400-mL beaker with ~50 mL of 0.01 M HCl. All solutions should remain clear and colorless.

4.) Add ~75 mL of 0.01 M NaOH to each beaker, causing a rainbow of colors to develop in the beakers.

5.) The solutions can be turned colorless by further addition of HCl, and re-colored with NaOH. To finish the demonstration, add enough NaOH to make the solutions colored, and then pour all of them into the 2-L beaker. The 12 M HCl will cause the solutions to become colorless again.

Clean-up: Neutralize the solution by titration with NaOH until it just becomes yellow – the transition for *p*-nitrophenol is complete at pH 7.5. The neutralized solution may be rinsed down the sink with water.

Hazards: HCl, and NaOH are highly corrosive, and will cause chemical burns on contact. Ethanol solutions are flammable, and should be kept away from ignition sources. Phenolphthalein and p-nitrophenol are toxic by ingestion, and phenolphthalein is a potential carcinogen and reproductive hazard.

Principle: This demonstration requires only three indicators to produce six colors of the rainbow. Each indicator has an acidic proton in a hydroxide functional group. In acidic solutions, all three indicators are fully protonated and appear colorless; however, in basic solutions they become deprotonated, giving rise to colored anions -- phenolphthalein appears red (fucshia), *p*-nitroaniline appears yellow, and thymolphthalein appears blue. These three colors can be combined in appropriate ratios to give any color of the rainbow, similar to how LCD monitors use red, green, and blue pixels to recreate vibrant images. Alternating between acidic and basic conditions will reversibly decolorize and re-colorize the solutions as the indicators switch between protonated and deprotonated forms.

Notes: This demonstration can also be performed on a smaller scale by adding 1-2 drops of each indicator solution to 6 test tubes that are half filled with water. The colors can be produced or removed by adding drops of HCl or NaOH, and all of the tubes can be poured into a single 100-mL beaker containing 1 drop of 12 M HCl to finish the demonstration.

Instant Coca-Cola

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
Empty 581-mL (20-oz) Coca-Cola bottle	Soluble starch
Three graduated 20-mL beakers or vials, labelled Solution 1, Solution 2, and Solution 3.	Potassium iodate (KIO_3)
	Sodium sulfite (Na_2SO_3)
	Sulfuric acid (H_2SO_4), 18M

Procedure:

1.) Preparation of solutions:
Solution 1: add 0.4 g soluble starch to 200 mL boiling water. Let cool to room temperature before use.
Solution 2: add 4 mL H_2SO_4 to 200 mL water, then add 10 g KIO_3 and stir until dissolved.
Solution 3: add 4.2 g Na_2SO_3 to 200 mL water and stir until dissolved.
2.) Place ~500 mL of water inside a clean, empty Coca-Cola bottle. This comes to just above the top of the label.
3.) Add 10 mL of Solution 1 (starch), then recap the bottle and shake well for several seconds.
4.) Add 15 mL of Solution 2 (KIO_3/H_2SO_4), then recap the bottle and shake well again.
5.) Add 15 mL of Solution 3 (Na_2SO_3), then *quickly* recap the bottle and shake very well for ~3-5 seconds to thoroughly mix the contents. As soon as Solution 3 is added, have the audience start counting up, as it will only take 10-15 seconds before the solution abruptly (almost instantaneously) turns a dark blue/black color.

Clean-up: Wash the bottle out with water. All waste can be rinsed down the drain.

Hazards: KIO_3 is an oxidizer and should be kept away from flammable materials and reducing agents. H_2SO_4 is strongly oxidizing and corrosive, and will cause immediate chemical burns on contact.

Principle: Bisulfite anions (HSO_3^-) from Na_2SO_3 reduce KIO_3 to form iodide anions (I^-), which further react with KIO_3 to form iodine (I_2). In solution I_2 reacts with I^- to form triiodide anions (I_3^-). I_3^- is immediately reduced back to I^- by any remaining HSO_3^-. Once the supply of HSO_3^- is exhausted, I_3^- persists in solution and reacts with starch molecules to form a dark blue starch-iodine complex. Excess I_3^- is a brown color in solution, and together this produces the dark blue/black/brown color of coca-cola. As the concentration of I_3^- rises extremely quickly, the color change is almost instantaneous. The volume of Solution 3 (Na_2SO_3) added to the reaction will change the time required for the color change – larger volumes will increase the delay, and smaller volumes will decrease it.

Notes: It has not yet been conclusively determined if starch-I_3^- or starch-I_5^- is responsible for the blue-black color. Several different problems can be encountered with this demo, each relating to a different starting solution:

1. The solution gradually transitions to a medium brown color, rather than an abrupt change, indicating a problem with the starch solution. Make sure the mixture is brought to a boil in order to dissolve a sufficient amount of starch. Over time bacteria will eat the starch and decompose the solution; if this occurs, remake Solution 1.
2. The solution takes a very long time (> 25-30 seconds) before the abrupt color change occurs, indicating a problem with the KIO_3 solution. Over a long period of time the KIO_3 can crystallize out of the solution; if this occurs, remake Solution 2.
3. The solution changes to a dark blue/black color much too quickly (< 5 seconds), indicating a problem with the Na_2SO_3 solution. Na_2SO_3 is slowly oxidized by air to Na_2SO_4, losing its reducing ability; if this occurs, remake Solution 3.

Instant Fire

Required Training	Required PPE
UC Lab Safety Fundamentals	**Flame-resistant lab coat**, safety glasses/goggles, nitrile gloves

Equipment	Chemicals
Wide-mouth screw-top glass jars for mixing/storage	Potassium chlorate ($KClO_3$)
Plastic dropper bottle for sulfuric acid	Powdered sugar ($C_{12}H_{22}O_{11}$)
	Sodium nitrate ($NaNO_3$), potassium nitrate (KNO_3)
Ceramic crucibles	Strontium nitrate ($Sr(NO_3)_2$), barium nitrate ($Ba(NO_3)_2$)
Flame-proof surface (or concrete)	Sulfuric acid (H_2SO_4), 18 M

Procedure:

1.) To prepare the instant fire mixtures, weigh out 20 g each of $NaNO_3$ (yellow), KNO_3 (lilac), $Sr(NO_3)_2$ (red), or $Ba(NO_3)_2$ (green) into the glass jar labeled for each color mixture. Add 10 g of $KClO_3$ and 10 g of powdered sugar to each jar and replace the screw tops. Gently shake the closed jars to thoroughly mix the powders – **DO NOT** grind them together in a mortar, as the friction could cause the mixture to ignite.

2.) Pour 10-20 g of the instant fire mixture into a ceramic crucible, one for each color.

3.) Set the crucibles on a fire-proof surface, such as concrete. Make sure the crucibles are at least 2 feet from each other, to prevent accidental ignition by flying sparks.

4.) Drop 1-2 drops of H_2SO_4 onto one of the instant fire mixtures and step away. The mixture will ignite after a few seconds and burn intensely for 10-15 seconds, depending on the volume of the mixture in the crucible. If the mixture fails to ignite with the first drops of H_2SO_4, wait 10-20 seconds before adding another 1-2 drops. **Caution** – the combustion may send sparks and small amounts of burning salt mixture flying up to 1-2 feet away, and the extreme heat may cause the ceramic crucible to shatter. Keep the audience and other performers at least 10 feet from the demo.

Clean-up: Allow the crucibles to cool completely before attempting to move them. Once cool, the remaining solids in the crucible that contained $Ba(NO_3)_2$ should be collected and disposed of as hazardous waste, while the solids from the other mixtures may be rinsed down the drain with water.

Hazards: H_2SO_4 is strongly oxidizing and corrosive, and will cause immediate chemical burns on contact. It must be stored in a sealed secondary container to prevent accidental ignition of the bulk instant fire mixtures. The ceramic crucibles will become extremely hot during the demonstration, and could cause thermal burns. If a crucible shatters, wait until the pieces have completely cooled before sweeping them up. $Ba(NO_3)_2$ and its decomposition products are toxic, and should not be released into the environment.

Principle: $KClO_3$ reacts with H_2SO_4 to produce chloric acid ($HClO_3$), which is extremely reactive and will cause spontaneous ignition on contact with any organic materials, such as sugar. The metal nitrates also acts as oxidizers to support combustion, and the heat of the reaction causes electronic excitations in the metal cations, which then emit light at characteristic wavelengths as they relax back to the ground state: sodium emits yellow; potassium emits lilac or violet; strontium emits red; and barium emits green.

Notes: The sodium and strontium mixtures produce the brightest colors, and the audience should be warned not to look directly at these mixtures while they are burning. The green color of the barium mixture is slightly harder to see, and the potassium mixture appears almost white in direct sunlight. For a more efficient burn, the reagents should be fine powders before mixing; each component may be ground in a mortar separately for 1-2 minutes, provided the mortar is cleaned between components to prevent cross-contamination that could lead to spontaneous ignition.

Liquid Nitrogen

Required Training	Required PPE
UC Lab Safety Fundamentals Online Cryogen Safety at UC Davis	Lab coat, safety glasses/goggles, **hearing protection**, **cryo-gloves (blue fabric)**
Equipment	**Chemicals**
Insulated cryogen transfer dewar (1-, 4-, or 10-L)	Liquid nitrogen (LN_2)
Styrofoam cooler	
Tongs	
Items to freeze (flower, balloons, rubber tubing, etc.)	
Electric kettle filled with water	

Procedure:

1.) Carefully pour LN_2 into a Styrofoam cooler from the transfer dewar.
2.) Dip items into the LN_2 until frozen. Use tongs and cryogen gloves to hold items to be frozen. Do not immerse cryogen gloves in liquid nitrogen. When freezing items, immerse them slowly to minimize splashing from boil-off.
3.) Once frozen, items can be broken by hand or by hitting them on the ground.
4.) An audience member may be allowed to freeze a flower, provided they are wearing proper attire and don full PPE. Be sure that the flower has any thorns removed beforehand.

Clean-up: Any remaining LN_2 in the Styrofoam cooler may be emptied on the ground, producing a fog effect for the audience. Never pour LN_2 into a drain or other confined space. LN_2 left in the transfer dewar will boil off completely. Be sure to clean up any pieces of shattered items.

Hazards: LN_2 boils at -196 °C (77 K), and will cause frostbite on contact. Do not allow LN_2 to become trapped against skin – ensure that pants are uncuffed and cover any permeable openings on the tops of shoes. Do not store or transport LN_2 in enclosed spaces (i.e. elevators, cars with windows rolled up), as the vaporized nitrogen will displace oxygen and can create an asphyxiation hazard. Furthermore, never keep LN_2 in sealed containers, as the pressure build-up will eventually cause the vessel to rupture, potentially causing great physical harm to anyone nearby.

Notes: Never pour liquid nitrogen on any part of a person, as it may become trapped by clothing and cause frostbite. Never throw liquid nitrogen up into the air – any liquid that does not boil off will fall, and poses a hazard to anyone standing nearby. Additionally, do not eat frozen food items (graham crackers, pretzels, marshmallows) or offer them to the audience. This has been done in previous years, but there is a small risk of frostbite if a significant amount of liquid nitrogen is absorbed into the food. It also sends the wrong message to the audience – there should not be any consumption of food or drink during a chemistry performance.

Principle: Freezing items in LN_2 is a physical process in which the low temperature of the LN_2 liquefies or solidifies whatever object it comes in contact with, thus increasing the viscosity of the object. If the object is hydrated, such as a flower, then the LN_2 will freeze the water and make the flower shatter like glass. Liquid nitrogen is constantly boiling, as it is exposed to conditions much warmer than its boiling point. As liquid nitrogen is exposed to the air, it condenses any water vapor into a white mist that can be seen at the top of the container.

Examples of items to freeze:

- flowers or other plants can be frozen and then broken by hand, or on a surface.
- elastomers (rubber bands, Tygon tubing) can be shattered when frozen, but become flexible again when warmed. **Caution** – when freezing Tygon tubing, placing an open end of the tube into the liquid nitrogen will create a fountain from the other end of the tube. Ensure that the open end is not pointed at anyone. Also take care when breaking Tygon tubing to prevent shattered pieces from flying towards the audience; it is better to crush it with a hammer than to smash the tubing on the ground.
- balloons can be immersed in liquid nitrogen and shrunk down as the air inside liquefies. The balloon will re-inflate when warmed, provided the latex was not cracked when frozen. Helium balloons will not fully collapse, as helium condenses at 4.2 K, much lower than the boiling point of LN_2.
- bananas, if frozen for > 2 minutes, can be used to hammer nails into wood or other objects. **Caution** – never position your hand directly over the nail, as the banana may shatter on impact and your hand could continue downward onto the nail, causing significant injury.
- boiling water may be dumped into a container of liquid nitrogen, <u>provided the audience is greater than 15 feet away and the performer is wearing hearing protection.</u> This will cause an impressively large plume of water vapor to erupt from the container, and the expansion can be quite loud. There is a technique to maximize the size of the plume of water vapor – the container of boiling water is held at chest level, with the performer standing at arm's length from the Styrofoam cooler; the performer quickly inverts the container of water and forcefully directs the contents into the center of the cooler in a single downward motion, such that all of the water hits the LN_2 once. This frequently produces enough force to break away one of the walls of the cooler, so it should performed after all other demonstrations involving LN_2. Larger, shallower coolers work best, while smaller coolers are more likely to be destroyed.

Luminol

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
"Chemistry Club" neon-style glass tubing on cardboard	3-aminophthalhydrazide (luminol)
Amber 1-L bottle for Luminol A solution	Sodium Carbonate (Na_2CO_3) and bicarbonate ($NaHCO_3$)
1-L bottle for Luminol B solution	Ammonium carbonate monohydrate ($(NH_4)_2CO_3 \cdot H_2O$)
Bottle to catch spent luminol solution	Copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$)
	Hydrogen peroxide (H_2O_2), 30% solution

Procedure:

1.) Preparation of solutions (for 1L of each):
   To make the Luminol A solution (light-sensitive, store in amber bottle), dissolve the following in 1 L deionized H_2O:
      4 g Na_2CO_3
      0.2 g luminol
      24 g $NaHCO_3$
      0.5 g $(NH_4)_2CO_3 \cdot H_2O$
      0.4 g $CuSO4 \cdot 5H_2O$
   To make the Luminol B solution, dissolve 5 mL H_2O_2 in 1 L deionized H_2O.
2.) Prop the "Chemistry Club" glass tubing up against a wall or have two performers hold it upright. Make sure that the outlet tube is open and is held above the level of the funnel attached to the top of the glass tubing.
3.) With the lights off, simultaneously pour equal volumes of Luminol A and Luminol B into the funnel attached to the top of the glass tubing. Pour slowly to avoid vapor-locking the funnel, and make sure that the solution is flowing through the rest of the tubing.
4.) After the demonstration is complete, place the outlet tube into a bottle and drain the solution from the glass tubing.

Clean-up: Collect the spent luminol solution for disposal as hazardous waste. Thoroughly rinse the glass tubing with water and allow it to dry.

Hazards: 30% H_2O_2 is corrosive and strongly oxidizing, causing immediate chemical burns on contact with skin. Always wear nitrile gloves when preparing, performing, or cleaning up this demo. $CuSO_4$ is toxic if ingested, and is harmful to the environment.

Principle: The Cu^{2+} catalyzes the decomposition of H_2O_2, producing oxygen (O_2). In the presence of hydroxide ions (OH^-), the di-anionic form of luminol is oxidized by O_2, forming an unstable organic peroxide. This decomposes to an excited-state molecule, which then relaxes to a lower energy state and emits the excess energy as a photon of blue light. The iron in hemoglobin can also act as a catalyst, allowing forensic chemists to use luminol to detect trace amounts of blood at crime scenes.

Notes: The current "Chemistry Club" sign is extremely difficult to use for this demonstration, as many of the bends are sharp enough to prevent continuous flow, and instead cause the funnel to vapor lock. It may be more impressive to mix the two solutions in a large spiral tube or even a large flask, as the luminescence only lasts for a few moments.

Source for Luminol:
-Aldrich, Cat# 12,307-2: 3-Aminophthalhydrazide

Magnesium/Dry Ice

Required Training	Required PPE
UC Lab Safety Fundamentals Online Cryogen Safety at UC Davis	**Flame-resistant lab coat**, safety glasses/goggles, **cryo-gloves (blue fabric)**

Equipment	Chemicals
Drill with 2” hole saw bit	Magnesium (Mg) ribbon
Styrofoam cooler for transporting dry ice	Solid CO_2 (dry ice), 2 slabs
Propane torch	

Procedure:

1.) Drill a hole (2” diameter) in the middle of a slab of dry ice, approximately 1/3 of the way through it. Then, with the drill turned off, use the edge of the hole saw bit to chip out the disc in the middle, leaving a circular depression. The back of a claw hammer can also be used to pry out the disc. Take care not to crack the slab when doing this.
2.) Place the slab with the hole on the ground, with the hole facing up, at least 10 feet from the audience and away from flammable materials.
3.) Wrap a 0.5-meter length of Mg ribbon around a pencil or similarly sized object to form a tight coil. Then, wrap this coil into a spiral, such that it will fit in the circular hole in the slab of dry ice.
4.) With a second performer holding the solid slab of dry ice at the ready, place the coil of Mg in the circular hole and use the torch to ignite it. As soon as the Mg starts to burn, the second performer must quickly place the solid slab of dry ice on top of the other, taking care not to crack either slab.
5.) Stand back from the demo, as sparks of burning Mg will escape between the slabs and fly up to 1 foot away.

Clean-up: Once the magnesium has completely combusted, the dry ice may be returned to its cooler. After the show, the ashes of the Mg ribbon may be discarded in the trash, and the dry ice placed in the fume hood of room 272 until it completely sublimes.

Hazards: Dry ice sublimes at -78.5 °C (194.5 K), and prolonged contact with skin will cause frostbite. Never place dry ice in a closed container, as the build-up of pressure may cause it to burst, which could injure anyone nearby. Mg is a flammable solid and burns at extremely high temperatures (>3000 °C), simultaneously producing very bright white and UV light. Hazards include thermal burns and vision damage if the combustion is viewed directly.

Principle: Initially the Mg burns in a conventional manner, using oxygen from the air. After a few seconds the light will dim, and at this point the atmospheric oxygen is being completely consumed in the burning chamber (the space between the slabs). However, Mg has such a powerful affinity for oxygen that it begins to steal oxygen from the dry ice, producing magnesium oxide (MgO) and carbon soot. The reaction then proceeds much faster and the light gets brighter, and the Mg will continue to burn until all of it has been consumed.

Notes: This demonstration is most impressive with the lights dimmed. The Mg ribbon should not be placed in the dry ice significantly before the demonstration, as this seems to diminish the intensity of the reaction. Using larger quantities of Mg ribbon also appears less important to the intensity of the reaction than properly optimizing the available surface area; a smaller piece that has been carefully coiled and wound burns just as brightly as a much larger piece crumpled into a ball.

Silver Mirror in a Flask

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves

Equipment	Chemicals
1-L Florence flask with stopper	Silver nitrate ($AgNO_3$)
Three 500-mL bottles (one amber glass, labelled Solution A, two plastic, labelled Solutions B and C, respectively)	Potassium hydroxide (KOH)
One plastic dropper bottle for NH_4OH solution	Sucrose ($C_{12}H_{22}O_{11}$)
One 1-L plastic bottle for waste neutralization, labelled "Neutralization Solution "	Nitric acid (HNO_3), 16 M
10- and 50-mL graduated cylinders	Ethanol (EtOH), ≥95% solution
3-mL plastic pipette	Ammonium hydroxide (NH_4OH), 6 M
Wash bottle filled with deionized water	Hydrochloric acid (HCl), 1 M
Filtration apparatus (for recycling silver)	Ascorbic acid ($C_6H_8O_6$)

Procedure:

1.) Preparation of solutions:
   Solution A: Dissolve 10 g $AgNO_3$ in 400 mL deionized H_2O (0.15 M $Ag(NO_3)$. Store in a 500-mL amber glass bottle.
   Solution B: Dissolve 18 g KOH in 400 mL deionized H_2O (0.8 M KOH). Store in a 500-mL plastic bottle.
   Solution C: Dissolve 40 g sucrose, 1.75 mL HNO_3, and 50 mL EtOH in 400 mL deionized water. Boil this solution in a beaker on a hot plate for 30 minutes before use, or allow it to age for one month at room temperature. Store in a 500-mL plastic bottle.
   Waste neutralization solution: Add 200 mL HCl to a 1-L plastic bottle.
2.) Make sure that the flask to be silvered is absolutely clean, otherwise the mirror will not deposit properly.
3.) Add 40 mL of Solution A ($AgNO_3$) to the flask, and then titrate the solution with 6 M NH_4OH while swirling the flask constantly. This will initially form a brown precipitate, but upon further addition the precipitate will clear. Stop adding NH_4OH as soon as the precipitate clears.
4.) Add 20 mL of Solution B (KOH) to the flask; this will produce a cream-colored precipitate. Titrate again with NH_4OH, but this time stop the addition just before the precipitate clears (see Notes).
5.) Add 5 mL of Solution C (sucrose) and quickly stopper the flask and begin swirling the solution vigorously, constantly coating all of the interior surfaces. Make sure to hold the stopper in place with one hand while shaking the flask. The flask will start to become darker, and then appear black, but continued swirling will result in the deposition of a shiny silver mirror on the interior surface of the flask.
6.) After 1-2 minutes of shaking, the silver is completely deposited. Remove the stopper and pour the solution into the 1-L bottle with the waste neutralization solution, which will result in a cloudy white precipitate of silver chloride (AgCl) mixed with some gray metallic silver (Ag) that did not deposit on the walls. Use the wash bottle to rinse the inside of the flask thoroughly (4-5 times), with all rinseates being collected in the waste neutralization bottle.

Clean-up: After the show, the mirror can be removed from the flask by dissolving it with HNO_3. This must only be done inside a chemical fume hood, as it generates highly toxic NO_2 gas. Once the silver is dissolved out, allow the nitric acid solution to evaporate, leaving crystals of $AgNO_3$ that may be reused in future demonstrations.

Hazards: HCl, HNO_3, KOH, and NH_4OH are highly corrosive, and will cause chemical burns on contact. NH_4OH also gives off noxious NH_3 fumes, and should be handled with care. $AgNO_3$ solutions will stain skin/clothing/anything dark brown or black. If allowed to evaporate, basic solutions containing NH_4OH and $AgNO_3$ can produce black crystals of Ag_3N, a highly-unstable, shock-sensitive explosive compound. Always pour the spent silvering solution and flask rinsings into the waste neutralization container, as this prevents the formation of Ag_3N.

Principle: This demonstration uses the chemistry of Tollens' test for aldehydes to produce a silver mirror on the inside of a glass flask. $AgNO_3$ reacts with NH_4OH in basic solutions to form diamminesilver cations ($[Ag(NH_3)_2]^+$), which can be reduced by aldehydes or α-hydroxyketones to form metallic silver (Ag). The sucrose is slowly hydrolyzed in acidic solution (or quickly at elevated temperature) to produce glucose and fructose, which have aldehyde and α-hydroxyketone functional groups, respectively, in their fleeting open-chain conformations. These sugars reduce the diamminesilver into metallic silver, some of which gets deposited on the surface as a silver mirror. The remaining silvering solution is added to a bottle containing HCl, which will react with any Ag^+ ions in solution to form the notoriously insoluble compound AgCl. By doing this, the possibility of forming explosive compounds is completely eliminated, and all of the silver is reclaimed as a solid that can be recycled for future use.

Notes: The second titration step requires a bit of practice to know when it is complete. As the titration proceeds the precipitate will begin to dissolve slowly, and the color change will not be apparent until the last few drops of the titration. Over-titrating is not the end of the demonstration, but it will cause less of the silver to precipitate out in the mirror. The titration can be reversed by adding more of Solution A. Once all of Solution A is used up, a large portion of the silver can be reclaimed from the waste neutralization solution; the solid Ag and AgCl are collected by filtration and washed with water to remove any excess Cl^-, and then redissolved in NH_4OH. Add to this solution an excess of ascorbic acid ($C_6H_8O_6$), which will cause all of the silver to immediately precipitate out as a gray flocculent powder without depositing on the walls of the vessel. The solid Ag is then collected by filtration and washed with water again, and can be converted back to $AgNO_3$ using the method described in the Clean-up section, taking appropriate precautions. If the silver mirror is intended to be kept in the flask for any length of time, it is best to cover the silver with an impermeable barrier (varnish, nail polish, paint, etc.) to prevent tarnishing and protect the mirror from scratches.

Traffic Light Reaction

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
500-mL Florence/Erlenmeyer flask (or larger)	Dextrose (D-glucose, $C_6H_{12}O_6$)
Rubber stopper to fit flask	Potassium hydroxide (KOH)
	Indigo carmine (I.C.), 1% solution

Procedure:

1.) Add 300 mL water, 8 g KOH, and 10 g dextrose to the flask, swirling the solution until everything has dissolved.
2.) Add 5-10 drops of the I.C. indicator solution, swirling again to mix. The solution will initially turn green, but after a few moments it will become yellow.
3.) To perform the demo, stopper the flask and shake the solution vigorously, making sure to hold the stopper in place with one hand. The solution will turn red, and then green after sufficient shaking. After the solution has turned green, stop shaking and let the solution rest for; it will transition back through red and become yellow again.
4.) This reaction can be repeated several times (occasionally up to 8) before the solution decomposes and turns cloudy.

Clean-up: The waste solution may be rinsed down the sink with copious amounts of water.

Hazards: KOH is a strong base and its solutions are highly corrosive, causing immediate chemical burns on contact.

Principle: This demonstration involves a reversible oxidation-reduction reaction between I.C., oxygen (O_2), and a reducing sugar. I.C. is a both a pH and a redox indicator; the oxidized form is blue below pH 11.4, yellow above pH 13, and green in the intermediate range, while the reduced form is yellow at all pH levels. When the flask is shaken, atmospheric O_2 is dissolved in the solution and oxidizes the I.C. to its green form. Dextrose is a reducing sugar, and in alkaline solution it is converted to an enolate which reduces the I.C. first to a red semiquinone intermediate and finally to the yellow reduced form; the dextrose is ultimately oxidized into arabinonic acid and formate anions. Shaking the flask again introduces more oxygen, which repeats the cycle until no dextrose remains.

Notes: This is essentially the same as the Blue Bottle demonstration, only a different indicator is used. In this case, the colors changes are strongly dependent on the pH of the system; above pH 13, the oscillation is between yellow, red, and yellow, whereas below pH 11.4 the color shifts through blue, purple, red, orange, and yellow. This makes for a somewhat more interesting demonstration, but would be rather odd for a traffic light. The structures of the reduced forms of the I.C. indicator are not fully determined, and it is thought that the green color comes from a mixing of the blue and yellow forms.

Vinegar Cannon

Required Training	Required PPE
UC Lab Safety Fundamentals	Lab coat, safety glasses/goggles, nitrile gloves
Equipment	**Chemicals**
Small plastic bottle (with narrow neck)	Sodium bicarbonate ($NaHCO_3$) (baking soda)
Cork to fit bottle	Acetic acid (CH_3COOH), 5% solution (vinegar)
Tissue paper/kim wipe (alternate procedure)	
Small marble (alternate procedure)	

Procedure:

1.) Place ~1-2 grams of baking soda in the bottle.
2.) Pour about 20mL of vinegar into the bottle.
3.) Quickly insert the cork in the neck of the bottle, and then swirl the bottle to mix. Make sure the neck of the bottle is not pointed at people or at fragile materials, and hold the bottle firmly.
4.) When the pressure from the evolved CO_2 becomes great enough, the cork will fly out of the bottle. Depending on how tightly the bottle is corked, it can fly upwards of 10-20 feet.

Alternate procedure:

1.) Pour ~20 mL of vinegar into the bottle, making sure to keep the neck of the bottle dry.
2.) Place a piece of tissue paper/kim wipe over the neck of the bottle and push a portion of it into the bottle using your finger. This creates a small pouch suspended from the top of the bottle.
3.) While holding the edges of the tissue paper to keep it from falling into the bottle, add ~1-2 grams of baking soda and a small marble to the pouch.
4.) Push the cork into the neck of the bottle, wedging the tissue paper in place. The excess tissue paper can then be cut or torn away from the neck of the bottle, taking care not to dislodge the cork. Keep the bottle upright to prevent premature mixing of the baking soda and vinegar.
5.) To activate the demo, sharply lower the bottle onto a table, such that the marble breaks through the tissue paper and allows the baking soda to fall into the vinegar. Alternatively, you can invert the bottle and stand it on the cork, such that the bottle launches upwards (in this case the marble may be omitted).

Clean-up: All waste may be rinsed down the drain with water.

Hazards: The corks can pop out of the bottle with significant force, and could theoretically break something fragile or cause an injury if pointed at someone.

Principle: The reaction between $NaHCO_3$ and CH_3COOH produces carbon dioxide (CO_2) that can't escape the closed bottle; this causes the pressure to build until the cork out.

Notes: Audience members may come up to perform these demos provided they are wearing proper attire and don full PPE. If performing the demo using the first method, the bottle must be corked very quickly, otherwise it turns into a very simple baking soda/vinegar volcano in your hand.