ONE HOUR OF CHEMICAL DEMONSTRATIONS

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This article describes a diverse set of chemistry demonstrations especially selected to encourage student interaction and to be easily transported. The demonstrations may be presented at a level that can be tailored to any audience-- from very young children to high school students planning careers in science. An ideal environment is a small classroom with 20-30 students where everyone can take part in the discussion. Once the chemicals are prepared, the collection of demonstrations takes about ten minutes to set-up, and one hour (or less) to perform. Very little is needed at the visiting site, no more than a table and a pitcher of water. A single electrical outlet is useful, but not essential. In Table 2 the demonstrations are listed in the order suggested for their presentation, along with all chemicals and equipment needed. Emphasized below are original procedures developed in this laboratory as well as sources of materials, background chemistry and ideas for discussion.

The Color Chase

In the "color chase" adapted from an experiment in a magician's handbook [1], a pale yellow liquid turns wine-red, deep blue, sparkling yellow, and brilliant pink as it is poured from the first flask into four successive flasks each of which contains a tiny amount of chemical reagent. The size of the flasks or beakers depends upon the room in which the performance is to take place. A 1-L vessel with 500 mL liquid should be visible in a lecture hall. For a smaller room the 500 mL size would suffice. The amounts below are intended for 500 mL flasks, and may be adjusted as needed. To the first flask, which should be very dry, is added 0.06 to 0.07 g of the pale violet ferric ammonium sulfate, $FeNH_4(SO_4)_2 \cdot 12H_2O$ or FAS. This amount, which fills the tip of a spoon spatula, is the only one that must be measured accurately. The FAS can be crushed before weighing, however, prepare only what is needed, since the pulverized FAS begins to degrade within a day. The next two flasks contain spatulatips of sodium salicylate, $2\text{-}(HO)C_6H_4CO_2Na$, and of sodium (or potassium) ferrocyanide, $Na4Fe(CN)_6 \cdot H_2O$. About 4-5 mL sodium silicate solution or "water glass", 37-40% Na_2SiO_3 (aq), are placed in the fourth flask. A few drops of phenolphthalein indicator solution are added to the fifth.

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The demonstration is started by adding distilled water to the solid FAS producing a light yellowish solution as the pale purple hexaaquo ion undergoes hydrolysis to form the yellow hydroxo species [2]:

$$[Fe(H_2O)_6]^{3+} = [Fe(H_2O)_5(OH)]^{2+} + H^+ \quad K = 10^{-3.0}$$
$$[Fe(H_2O)_5(OH)]^{2+} = [Fe(H_2O)_4(OH)_2]^{+} + H^+ \quad K = 10^{-6.3}$$

When the original concentration of FAS is 0.1% or less (0.02 M), the pH is greater than 3 and bridged species form. Within a minute or two a cloudy colloidal gel appears, and eventually ferric oxide, $Fe_2O_3 \cdot nH_2O$, precipitates. At higher concentrations ranging from about 0.2% to 0.4% (0.04 to 0.08 M) the pH falls to 2.6, and it takes hours for the solutions to become cloudy. At concentrations of 0.5% or more (greater than 0.1 M), the pH dips below 2.5 and little or no cloudiness develops. For this demonstration, the tiny quantity of FAS mixed with water (0.06 - 0.07 g in 250 mL) produces the very dilute 0.03% solution, which has a pH much greater than 3. Therefore, the water must not be added to FAS ahead of time or the solution will turn cloudy almost immediately and the iron(III) needed for the ensuing reactions will be depleted.

The fresh FAS solution is then poured into the second flask containing sodium salicylate giving a wine red color. The shade of red is *extremely* sensitive to the amount of iron(III) present, varying from pale orange to nearly opaque dark red within a small range of iron concentrations. If the color in flask 2 is the desired wine-red, the next color, produced by pouring the contents of flask 2 into flask 3, should be just the right shade of blue. The blue color is due to formation of Prussian Blue, ferric ferrocyanide, $Fe_4[Fe(CN)_6]_3$, a water-insoluble dark blue pigment used in printing inks. Too little iron(III) will make this color a pale green--too much-- a color so dark it is difficult to recognize as blue and may hardly be distinguishable from the red that preceded it. As the blue mixture is poured into the aqueous sodium silicate in flask 4, it is transformed into a clear yellow solution as the deep blue ferric ferrocyanide breaks down into an iron complex and ferrocyanide ion. Pouring the alkaline solution into the final container gives the typical phenolphthalein pink.

The discussion accompanying this demonstration can be adjusted to the level of the audience. For very young children, it can simply be said that colors are changing due to chemical reactions. For older students a description of the simplest reaction, the acid-base behavior of phenolphthalein, can be included, and later used in an inexpensive laboratory activity. Phenolphthalein turns pink in solutions of sodium carbonate (washing soda) or ammonia (cleaning products). A more detailed description of the chemistry may be appropriate for some high school students. The color chase can even be used as a demonstration for experienced chemists, by offering a contest in which the audience must identify the five reagents by noticing the colors that form, a non trivial task.

Invisible Writing

Revealing a message written in invisible inks, based upon the chemistry of iron [3], is a good way to welcome the audience. The message appears when sprayed with 10% (0.2M) ferric ammonium sulfate (FAS), the same source of iron(III) used above in the color chase. In this case the FAS solution remains clear since the concentration is high and the pH is well below 2.5. Best results are obtained when the iron solution is applied as a very fine mist using a spraying tool available in hardware stores.

***Caution**: The fine mist can cause coughing, so be sure not to spray near anyone.*

The "painting" inks are dilute aqueous solutions that combine with iron(III) to produce deep blue, reds, and shades of black. Cotton swabs work better than paintbrushes.

Blue Ink

For blue, a 4% solution of sodium or potassium ferrocyanide is used. The color that results from spraying with Fe(III) is the deep blue Prussian Blue, the same compound formed in flask 3 of the color chase described above.

Red Inks

There are two different "inks" that combine with Fe^{3+} to give reds. The reaction of sodium salicylate (10%) with iron(III) gives the same purplish wine red iron salicylate complex produced in the second flask of the "color chase." A more orange hue is derived from using 1% thiocyanate, NH_4SCN or KSCN, to give intense red thiocyanate complexes of iron. However, the color of this complex begins to fade moments after it forms. The demonstrator can take advantage of this instability by creating a message that changes in some interesting way when the thiocyanate red is gone.

Black/Gray Ink

For blacks and grays the ink solution is aqueous tannic acid, which occurs in the bark and fruits of many plants, acorns, for example. The formula of commercial tannic acid, a yellowish water-soluble powder, is given as $C_{76}H_{52}O_{46}$. Depending upon the concentration of the tannic acid, the color of iron tannate can range from gray to black (0.2 - 2%).

Flash Paper

Flash paper is nitrated paper that burns dramatically with an instant bright flash and leaves little or no residue. A commercial version is available in magic and novelty shops.[2] A very fast method for making flash paper similar in size and burning properties to the commercial type has been described [4]. The nitrating mixture is 5 parts of very fresh concentrated HNO_3 mixed with 4 parts concentrated H_2SO_4 in a clean and dry 1 L beaker (the paper may not nitrate properly if the nitrating mixture is in a wide container such as a crystallizing dish, presumably because of the large surface area).

Caution: The concentrated acids should be handled in a hood with great care. Dispose of acids by first neutralizing with sodium bicarbonate, then pouring down the sink with running water.

Once the acid mixture is cooled to about 40°C, a piece of very thin paper, such as the cheapest single-ply toilet tissue, is pushed gently beneath the liquid surface so that it is covered with acid, then soaked in the nitrating solution for 12 to 15 minutes. Very long pieces can be made by carefully folding the paper over on itself making sure that all surfaces are in contact with the nitrating solution. In this way a large supply of flash paper can be made in less than an hour. The nitrated papers are rinsed thoroughly with water, then stored in an ethanol bath until needed. To produce colored flames, the nitrated papers are dried, then coated with powdered salts to make colored-flame flash paper (green $BaSO_4$, orange $CaSO_4$, red-orange $SrCO_3$, blue CuBr, yellow NaCl, and violet KCl or KNO_3). For lighting the paper a candle in holder is more convenient than matches. Smaller pieces of flash paper can simply be lit and tossed in the air. A dramatic effect is achieved by wrapping a fresh (but not wet) flower in a larger piece of flash paper, then while holding on to the stem, burning the flash paper away. The flower seems to appear from nowhere out of the flame.

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[2]Distributed by D. Robbins & Company, Inc. Brooklyn, NY 11201.

Giant Bubbles

Large diameter soap bubbles have been prepared by using solutions containing 5% glycerol mixed with 10-12% dish detergent [5] or 2% dioctyl ester of sodium sulfosuccinate [6].The glycerol appears to function primarily as a non-drying agent. It has been found that the use of more concentrated detergent solutions (15-18%) appreciably increases bubble lifetime (See Table 1), making them not only longer-lasting, but much easier to prepare. No "aging" of the bubble solution nor any special coordination is required to create bubbles with diameters as large as 50-60 cm. The brands that were most effective included Ultra Joy and Dawn.[3] The bubble mixture is mixed in a container large enough to accommodate a wand with a diameter of about 20 cm, made by twisting a plastic-coated coat hanger. Studying bubble solutions can be adapted as a laboratory activity in which students compare the lifetimes of bubbles upon variation of detergent brand, concentration of detergent, and concentration of additives such as glycerol. Lifetime measurements should be made in a draft-free room by creating a bubble, catching it, then holding it in place on the wand until it deflates.

Table 1 Lifetime of Bubbles

Detergent Brand	Volume Detergent	Volume Water	Volume Glycerol	Conc % Detergent	Life of Bubble 30cm diameter (min)
Joy	100	700	40	12	0.75 - 1
Joy	150	650	40	18	2 - 3
Joy	200	600	40	23	2 - 3
Joy	150	690	0	18	2 - 3

The Elements

The display of a collection of elements generates immediate interest in chemistry and invites audience participation. Each element can be placed in its own transparent 20-mL screw-cap glass scintillation vial. The original packaging tray with compartments for 100 vials serves as an ideal portable storage case with unused spaces available to house small tools

[3]All concentrations refer to the Ultra type detergents which "require 1/3 less".

and reagents such as a magnet or phenolphthalein solution. A guide available for the assembly of an extensive set of elements includes prices, sources, and handling tips for each element (excluding gases or radioactive elements), as well as specific suggestions about how to use the elements in classroom situations [7-9]. Since the assembly of a complete collection is expensive and time-consuming, the element vials can be labeled and arranged, then filled as the occupying elements become available. The demonstrator can show students the explosive reaction that occurs when a pea-sized piece of potassium or sodium is dropped into water.

Caution: *Be sure to use only small amounts of sodium or potassium.*

Students can help to assemble an initial starting set of elements from household materials such as carbon from pencil lead, aluminum foil, copper wire, iron nails, and tungsten in light bulbs.

Other Demonstrations

Sources of material and references for the rest of the demonstrations are included below.

Radioactivity

This flows naturally from the element discussion. For students who have studied a little chemistry, the idea can be introduced that an element with atomic number greater than 83 decays spontaneously. An inexpensive source of radioactive substances consisting of uranium and thorium ores, may be purchased from Central Scientific Company.[4] Placing a piece of paper, a student's notebook,and finally a piece of lead between the radiative source and the window of a portable Geiger counter demonstrates penetrative power. Students can be reminded that the lead apron they wear at the dentist protects them from similar radiation.

Memory Metal

A wire made of Ni-Ti alloy, twisted out of shape at room temperature, is returned to its original shape upon heating with a blow dryer or candle flame [10]. An inexpensive source for 3-inch samples of memory wire with a critical temperature of 50°C is Educational Innovations, Inc.[5]

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[4]Radioactive Mineral Collection 52630K; CENCO Central Scientific Company, Franklin Park, IL 60130.

[5]Educational Innovations, Inc., 151 River Road, Cos Cob, CT 06807 USA; Telephone (203)629-6049; *http://www.teachersource.com*

Rubber Ball

The latex[6] needed to make a rubber ball is first mixed with an equal volume of water, a few drops of food color, then an equal volume of vinegar. The shapeless rubbery mass is removed with a gloved hand, then submerged in a container of water in order to squeeze out the excess water.

Caution: *Gloves must be used to handle the acidic mass.*

The finished lumpy ball bounces as soon as it is removed from the water, higher as it dries.

Nylon 6,10

The nylon rope forms most effectively with 6% hexamethylene diamine, $NH_2(CH_2)_6NH_2$, in 0.5 M NaOH and 4% sebacoyl chloride, $ClOC(CH_2)_8COCl$, in hexane or cyclohexane. Ready made solutions can also be purchased from Flinn Scientific.[7] The more dense aqueous hexamethylene diamine is poured first into a small beaker, then the other layer. Tweezers remove the nylon rope from the interface between the two layers. The solutions have a long shelf life, but small amounts should be tested before each use to be sure the rope forms.

Polyurethane Foam

Polyurethane foam is made by the combination of viscous solutions that contain a diisocyanate and a polyol. In this case it is much more convenient to purchase the components.[8] The Polyurethane Foam System consists of two parts. Part A contains the polyol and Part B the diisocyanate. The lids can become sealed shut. Be sure to check that they can be removed, particularly for Part B which has a much shorter shelf life than Part A.

Liquid Nitrogen

The properties of liquid nitrogen are particularly intriguing to students. Demonstrations can be as simple as the freezing of flowers or bananas. A more advanced activity suitable even for young children is the Meissner effect. A strong rare earth magnet is elevated above a superconducting pellet cooled to liquid nitrogen temperature. A superconductivity kit

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[6]Flinn Scientific Inc. P.O. Box 219. 131 Flinn St. Batavia, IL 60510.

[7]Flinn Scientific Inc. P.O. Box 219. 131 Flinn St. Batavia, IL 60510.

[8]Flinn Scientific Inc. P.O. Box 219. 131 Flinn St. Batavia, IL 60510.

containing a rare earth cobalt magnet and a ceramic superconducting disc composed of yttrium, barium, and copper oxides is available commercially.[9] Be sure to dry the pellet after each use.

Caution: *When transporting the liquid nitrogen in a car be sure the Dewar flask cannot topple over to avoid asphyxiation.*

During this demonstration the temperature of liquid nitrogen can be expressed using Kelvin, Celsius and Fahrenheit scales and then compared to familiar substances such as ice.

Conclusion

Early exposure of many students to chemistry is from the media where chemicals are often portrayed in a negative light, their toxicity emphasized rather than their usefulness. Hopefully, while engaging and entertaining students, the set of demonstrations described here will also help to counteract the negative impressions students may have absorbed about chemistry and chemicals.

Acknowledgement

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[9] Edmund Scientific Co. Barrington, NJ 08007-1380 Telephone 609-573-6250.

Table 2 Materials Needed for Demonstrations

Demonstration	Chemicals	Equipment/Supplies
Invisible Writing	ferric ammonium sulfate sodium salicylate potassium (or sodium) ferrocyanide tannic acid potassium or ammonium thiocyanate	spray-tool large sheets of paper Q-tips
Collecting the Elements	chemical elements	20-mL scintillation vials packing container
Radioactivity	uranium or thorium ore lead brick or sheet	Geiger counter
Memory Metal	Ni-Ti wire	hair dryer
Color Chase	ferric ammonium sulfate sodium salicylate potassium (or sodium) ferrocyanide sodium silicate (aq) phenolphthalein (aq)	5 flasks (500 or 1000 mL)
Polymers		
Nylon 6,10	sebacoyl chloride 1,6-diaminohexane sodium hydroxide hexane	beaker stirring rod tweezers
Polyurethane	Polyurethane Foam Kit	foam cup stirrer
Rubber	latex vinegar	250-mL beaker stirrer gloves large container (for water)
Flash Paper	sulfuric acid and nitric acid salts ethanol or commercial flash paper	matches flower hair dryer
Giant Bubbles	detergent (Joy or Dawn Ultra) glycerol	container wand
Liquid Nitrogen	liquid nitrogen	Dewar flask superconductor kit flowers bananas

References

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