OVERHEAD PROJECTOR DEMONSTRATIONS USING HOUSEHOLD MATERIALS

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Introduction

Demonstrations performed on an overhead projector (OHP) can easily be seen by everyone in a large classroom. The ones described here require simple equipment (Table 1) and small amounts of household chemicals (Table 2), making them not only inexpensive, but virtually free of problems with safety and waste disposal. Demonstrations on topics such as the properties of light, behavior of liquids, and the nature of acids and bases were chosen because of their usefulness in discussions of biology or physics as well as chemistry.

Properties of Light

The interaction of light with a substance can provide qualitative and quantitative information about the substance. The amount of light absorbed is used in analytical chemistry to find the concentration of an absorbing species. The pattern of light absorption gives information about the structure of the absorbing species. Scattered light can be used to distinguish solutions from colloidal suspensions. Rotation of polarized light identifies compounds that exhibit optical isomerism, of particular importance in biochemistry where reactions occur for only one member of a pair of optical isomers. The relationship of color to absorption of light is studied by converting the OHP into a spectrometer. All of these phenomena can be investigated with very simple equipment.

Absorption of Light

Absorbance (A), the amount of light absorbed by a species, depends on concentration (c) and path length (b), according to the Beer-Lambert Law, $A = \varepsilon bc$. The extinction coefficient (ε)

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is a constant that depends upon the absorbing species. To observe the effect of path length, identical concentrations of food dyes (1 drop per 4 mL water) are poured into three different beakers using heights of 0.5, 1.0 and 1.5 cm. The colors appear more intense to the eye as the path length increases [1].

To see the effect of concentration, the path length is kept the same while using several different dilutions. The more concentrated the solution, the more intense the color. Since absorbance depends on concentration, it can be used to make quantitative determinations of the amount of absorbing species present in the solution.

Polarized Light

Polarizers absorb all but a single plane of light. Polarizing lenses in sunglasses are set to cut out horizontally polarized light because the glare-producing light reflected from road or water surfaces is polarized in the horizontal direction. Squares of polarizing plastic (Table 1) can be crossed to demonstrate that no light is transmitted, actually very little light since the plastic is not perfect polarizing material.

Chemical compounds that are optically active, like sucrose or table sugar, can be shown to rotate polarized light. When sucrose solution (45g/30 mL) is placed in a 50-mL beaker, light can be seen through crossed polarizers [2-4]. Since different wavelengths rotate to different extents, colors of the rainbow appear as the top piece of polarizing film is rotated.

Light Scattering

A colloidal suspension consists of dispersed particles that are suspended and are too small to settle out. The scattering of light by the particles can be used to distinguish a colloidal suspension, such as milk, from a true solution. This phenomenon, known as the Tyndall Effect, can be viewed on the OHP [5]. The stage is covered using cardboard with a 2-cm hole. Any size beaker containing water to a height between 1 and 2 cm is placed over the hole. The typical yellow color of the overhead bulb is seen. When about five drops of milk is added to the water (stir to mix), the color changes from yellow to red as colloidal particles form and blue light scatters first.

This is the same phenomenon responsible for the color of sunset. Toward evening when sunlight travels a large distance through the atmosphere to reach a point over an observer, much of the blue light is removed by scattering. When the sunlight, with blue removed, is incident on a cloud the light reflected has a yellow or red hue.

Spectroscopy on the OHP

The OHP is turned into a visible spectrometer [6-8] by putting a 7-cm square of diffraction grating over its lens to separate the light from the projector bulb into colors of the visible spectrum. Project Star plastic diffraction grating (Table 2) is chosen because most of the light appears in the first order. The OHP stage is covered with an opaque housing that has two rectangular openings (1.5 x 3 cm) to provide both a reference and sample beam. The grating is turned so that the two visible spectra appear vertically (red at the top and violet at the bottom). Only partial darkening of the room should be needed.

The color of a transparent film or a solution is compared with its absorption spectrum, which appears as dark bands that remove segments of the visible light. For instance, magenta viewed through the sample slit absorbs green and transmits red and violet. A set of 100 different colored plastic filters, made by sealing dye between two microscopically thin layers of clear film, can be purchased (Table 2). Each filter is accompanied by its absorption spectrum. Commercial colored plastic wrap (3-5 layers) may be substituted.

Solution spectra can also be projected on the OHP spectrometer. For best results, the bottom of the glass container must be as optically clear as possible Beakers will do, but petri dishes are flatter and better. Absorption bands of food colorings show up most clearly for solutions made by fourfold dilution of dye with water. A volume of 20 mL provides a path length of 0.5 cm in a 10-cm petri dish. Observing the spectrum of a chlorophyll solution can be used to demonstrate how plants capture energy from the sun. The green pigment is extracted by mixing about fifteen medium sized leaves of spinach with 200 mL alcohol. The strong absorption in the blue region (Soret) can be seen at a path length from 0.5 to 1 cm. The peak in the red is too weak to see clearly.

Properties of Liquids

Properties such as adhesion to glass, rate of evaporation, and solubility in water are easily seen on the OHP.

Adhesive and Cohesive Forces

The behavior of water in contact with glass is compared to that of ethanol (Table 2) by placing a few drops of each of the liquids directly onto the OHP glass. The water drop is tight and stable [9] since the attractive forces among water molecules are greater than those between the water and glass. The ethanol drop spreads out because its intermolecular forces are weaker than those between the alcohol and glass.

Boiling Point and Molecular Size

Boiling points can be estimated by observing how fast liquids evaporate from the warm OHP stage. Compounds with similar structures, such as alcohols, can be used to demonstrate how intermolecular interactions increase with mass, thus leading to higher vapor pressures and higher boiling points. A drop or two of each liquid is put directly on the OHP glass and evaporation rates compared [10,11]. For the difference in evaporation rate on the overhead stage to be obvious, the boiling temperatures must be at least ten degrees apart. For example, methanol (bp 65°C and molar mass of 32) can be seen to evaporate before ethanol (bp 78°C and molar mass of 44).

Solubility in Water

The idea that "like dissolves like" is examined by testing the solubility of polar and nonpolar liquids in water [12-14]. A compound containing an oxygen in its formula is polar and thus soluble in water provided the carbon chain is not too long. For instance, all the alcohols in Table 2 have less than four carbons and are infinitely soluble. Hydrocarbons, such as alkanes, are nonpolar and hence insoluble, appearing as globules when projected.

Whether or not a substance is soluble can have enormous environmental consequences. For example, the formula of the anti-knock agent in gasoline, methyl-*tert*-butylether or MTBE, $CH_3OC(CH_3)_3$ has five carbon atoms, but is still somewhat water-soluble (about 4 g per 100 g water). Dissolving of MTBE in ground water has created serious environmental problems that will require costly remediation.

Nature of Acids and Bases

Many chemical reactions and metabolic processes are extremely sensitive to the acidity of the fluid in which they occur. Acid rain can produce devastating environmental effects. Properties of acids and bases can be demonstrated on the OHP using household materials. Acids release hydrogen gas upon reaction with common metals. The pH of acids and bases can be measured by using anthocyanin in red cabbage to give vivid colors. Weak acids (or bases) are compared to strong ones, and buffered solutions to non-buffered solutions [15-17].

Acids with Metals

Bubbles of hydrogen gas (H_2) appear when certain metals react with 6M hydrochloric acid (20% muriatic acid). In addition to demonstrating typical behavior of some acids, this reaction can be used to compare metal reactivity and thus to create an activity series. Similar amounts of Al, Zn, Fe and Cu (Table 2) are placed in acid, then arranged according to their reactivity. Al reacts most vigorously, then Zn followed by Fe. Cu does not react.

Measuring pH

Concentrated red cabbage extract gives vivid colors for the pH ranges: 1-3 (red), 4-6 (pink), 7 (violet), 8 (blue), 9 (blue-green), 10-12 (green) and > 12 yellow. Anthocyanin, the universal indicator in red cabbage, is extracted by mixing 500 g finely chopped cabbage with 1L rubbing alcohol. After boiling for an hour, the mixture is filtered, then reduced leaving 50-100 mL of deep purplish-black extract which keeps for a few weeks upon refrigeration.

The volume of indicator needed to produce sufficiently bright colors is about one drop per one mL of test solution. Among the common household products to test (Table 2) are vinegar (pH 2-3), baking soda (pH 8), washing soda (pH 9) , ammonia (pH 11-12), and lye (pH >12).

Strong vs. Weak Acids (or Bases)

The pH values for the same concentrations of hydrochloric (strong) and acetic acid (weak) are compared. Muriatic acid (20% HCl) is diluted 500 to 1, and vinegar 100 to 1 to prepare 0.01M solutions of both acids. The strong acid, HCl, has a pH of 2 (red) compared to the weak acetic acid with pH between 3 and 4 (pink). Likewise 0.01 M solutions are prepared for the strong NaOH (100 fold dilution of a 1M or 4% solution) and the weak NH_3 (100 fold dilution of the cleaning product). The NaOH has a pH of 12 (yellow) compared to 11 (green) for the same concentration of the weak base, NH_3 .

Buffer Action

Buffers that resist pH changes are essential in living systems. Adding about 4 g NaOH to 200 mL vinegar is an easy way to prepare 1M acetic acid/sodium acetate buffer solution which has a pH of 4.8. When compared to plain water, the behavior of this solution upon addition of strong acid or base (0.1M made by diluting 20% muriatic acid 50 to 1) is dramatic.

To perform the demonstration, three beakers are placed on the OHP, one blank containing water and two with buffer. Indicator is added. A few drops of 0.1M HCl are placed in the water sample and in the buffer. The pH of the water plummets several units, changing the color from violet to red. The pH decrease of the buffer is so small that it appears unchanged from the original pinkish color. With the addition of a base such as 0.1 M NaOH, the pH of the plain water increases several units turning the indicator from neutral violet to greenish blue. Once again, the pinkish color of the buffer changes imperceptibly when the NaOH is added.

Conclusion

A few of the many topics that can be brought to life using OHP demonstrations have been described here. Most demonstrations like these can be accompanied by the writing of definitions, formulas, or equations on transparencies. ■

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Table 1 Materials

Material /Device	Source
Diffraction grating	Project Star Learning Technologies Inc, 59 Walden St., Cambridge, MA 02140 Catalog No: PS-08A (9 in by 5 in) or PS-08B (6 ft x 5 in) 750 lines/mm.
Plastic wrap (teal and rose)	Reynolds® plastic wrap
Filter Color Book of 100	Stock Number NT39-417, Edmund Scientific http://www.edsci.com/ 101 East Gloucester Pike, Barrington, NJ/A 08007-1380
Polarizer Film 8.5" x 15" Polarizer Film 8.5" x 5"	Stock Number , Edmund Scientific NT45-668 $28.80 Stock Number , Edmund Scientific NT45-669 $14.70

Table 2 Chemicals and Sources

Substance	Source
Aluminum	foil
Iron	steel wool (soapless), nails, staples
Zinc	dry cell battery can, pennies (after 1982)
Copper	electrical wire, scrub pad, pennies (before 1982)
Ammonia(aq)	ammonia cleaning solution products
Ethanol	denatured ethanol
Isopropyl alcohol	rubbing alcohol
Methanol	Sterno® (4%)
Alkanes (9 to 12 C's)	Goo Gone® spot remover
Anthocyanin	red cabbage
Hydrochloric acid	muriatic acid (20%)
Food Dyes	McCormack®
Sodium bicarbonate	baking soda
Sodium carbonate	washing soda†
Sodium chloride	table salt
Sodium hydroxide	lye; drain cleaner
Chlorophyll	spinach
Sucrose	table sugar

† Generic brands contain much less sodium carbonate than the Arm & Hammer® brand.