Mystery Solutions Lab

Scientific Method Inquiry Lab Activities

FLINN SCIENTIFIC CHEM FAX!

Introduction

On one of the first class periods of the year, students are paired-off and given a lab-based puzzle to solve. One in each pair is given a set of three colorless solutions, designated with numbers, the other is given a matching (but scrambled) set of solutions, designated with letters. Through careful mixing, observing, reporting and reasoning, they work together to pair up the lettered solutions to their matching numbered solutions.

Concepts

- Observation
- Scientific inquiry
- Scientific method

Materials (for class of 30 working in pairs)

Aluminum potassium sulfate (alum) solution, 2%, 200 mL
Sodium bicarbonate (baking soda) solution, 2%, 200 mL
Vinegar, white, 200 mL
Acetate sheets (write-on transparencies for the overhead projector), 3
Cassette boxes, empty, 30
Paper towels, 1 per student
Permanent marker
Pipets, Beral-type, jumbo, 90
Pipets, thin-stem, 90
Plastic cups, wide-mouth, 3
Rubber bands, 15
Scissors

Safety Precautions

The chemicals in this laboratory activity are considered safe. All food-grade items that have been brought into the lab are considered laboratory chemicals and are for lab use only. Do not taste or ingest any material in the lab and do not remove any remaining food items after they have been used in the lab. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Cut the stems off the Jumbo pipets and then cut the bulbs in half. Push three halves, open-side up, side-by-side, into each cassette box. These will act as holding cups for the thin stem pipet bulbs (see Figure 1).
2. Cut off all but 1 cm of the stem off each thin-stem pipet.
3. Label 15 of the thin-stem pipet bulbs "A," 15 of them "B," 15 of them "C," 15 of them "1," 15 of them "2," and 15 of them "3."
4. Place 200 mL of alum solution (2%) in a wide mouth cup labeled "A, 2."
5. Place 200 mL of baking soda solution (2%) in a cup labeled "B, 3." Place 200 mL of white vinegar in a cup labeled "C, 1."
6. Pick up two of the bulbs labeled "A" (one in each hand), squeeze them and then draw up half a bulb-full of the solution from cup "A, 2." Place these bulbs directly into the first holding cups in the first two cassette boxes. Repeat with two more "A" bulbs, placing them in the third and fourth cassette boxes. Continue until all fifteen "A" bulbs are done (see Figure 1).
7. Pick up two of the bulbs labeled "B" (one in each hand), squeeze them and then draw up half a bulb-full of the

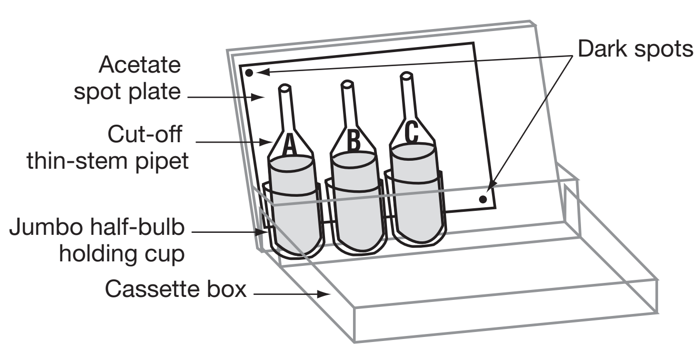

Figure 1.

solution in cup "B, 3." Place them directly into the second holding cups in the first two cassette boxes, just along side the "A" bulbs. Repeat until all fifteen "B" bulbs are done.

8. Repeat this procedure with all the "C" bulbs. Set aside these fifteen completed cassette boxes.
9. Pick up two of the bulbs labeled "1" and then draw up half a bulb-full of the solution from cup "C, 1." Place them directly into the first holding cups in the next two cassette boxes. Repeat until all fifteen "1" bulbs are done.
10. Repeat step 9 with all the "2" bulbs using solution "A, 2."
11. Repeat step 9 with all the "3" bulbs using solution "B, 3."
12. Cut the overhead transparencies into rectangular sheets approximately 3 cm x 5 cm.
13. With a permanent marker, place a dark spot in opposite corners of each sheet, and then slide them into each of the thirty cassette boxes, wedged in behind the holding cups (See Figure 1). *Note:* The dark spots in the corners just make it easy to find the sheets should they fall onto the floor, and it also helps confirm that the students are remembering to turn the sheets back in when the boxes are being returned.
14. Close the boxes and rubber band them together in pairs—a numbered box (1, 2, 3) paired up with a lettered (A, B, C) box.

Procedure

1. With students working in pairs, assign each pair a group number (1 through 15).
2. Hand out the cassette box pairs, one set-up to each pair of students. Tell them to look at the boxes but do not open them up yet.
3. Hand out the Mystery Solutions Lab Worksheets, one to each pair.
4. Explain the objective of the lab is to determine which solutions in the numbered box match the corresponding solutions in the lettered box.
5. Allow students a few minutes to brainstorm different ways to solve the problem, writing down their ideas in the space provided on the worksheet.
6. As a class, have the students discuss the ideas they came up with; invariably a student will offer the approach of mixing the solutions together to see what happens. Discuss the merits of this approach, and instruct them all to give it a try. Show them how to use the cut-off pipets to squeeze out drops and mix them on the acetate sheet, and how to avoid contamination—never placing the tip of a pipet into a drop of a different solution.
7. Explain to the students one final restriction—they are not to talk with their partners, nor have any visual contact. Their only means of communicating their findings is by writing, or "faxing."
8. Have the students separate from their partners (across the room) or have them at least sit squarely back to back. If they are across the room, then you and/or a designated helper must serve as the "fax machine" carrying their messages on the lab sheet back and forth between them. If they are back to back, simply have them pass the sheet behind them. You may need to re-emphasize with some groups that the goal is to get the correct match-ups for the solutions. Collect the sheets as they finish.
9. In the end, discuss the method and reasoning process as an entire class.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Solutions on the acetate sheets may be wiped up with a paper towel and thrown away in the regular trash. Leftover solutions may be disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b."

Tips

- This is a great lab for the first day of class. When conducted as written, 100% participation is guaranteed, and good inquiry and communication skills are emphasized.
- To avoid students copying from other groups, number or letter each pair of boxed pipets differently—5, 6, 7 and D, E, F, etc.
- Students may want to taste the solutions for identification. Obviously, tasting chemicals is not allowed in the laboratory.
- Students may be able to identify the vinegar by smell. To avoid this, use a 2% solution of citric or ascorbic acid (Vitamin C). The results will be the same as with vinegar.
- To facilitate efficiency and avoid excess communication, tell students their first five messages are free; each subsequent message will cost one point.

Discussion

The *scientific method* is a way of solving problems using a systematic approach. An organized strategy such as the scientific method is an effective way of approaching a problem. A wide variety of strategies are described in the literature and the following is a list of "typical" steps that scientists may use to solve a problem. Keep in mind, however, that the strategy and the order of steps may vary greatly from problem to problem.

Typical steps in the scientific method

1. Define a *problem* or ask a question — A clear statement of the problem or question is a crucial step in beginning an investigation.
2. Make *observations* about the problem — All possible information on the problem will be helpful in writing a plausible hypothesis and in designing a good experiment.
3. Develop a *hypothesis* — This is a possible answer or tentative explanation to the problem or question. It should be based on the facts and observations and should be capable of being tested.
4. Design and implement an *experiment* — Experimental testing will provide evidence which either supports or contradicts the hypothesis. There are several factors that must be determined before conducting an experiment.

   Variables: The factors that influence the outcome of an experiment.

   Constants: All other factors which remain the same throughout an experiment except the one whose effect is being studied.

   Independent Variable: The variable that is intentionally changed or manipulated by the experimenter. Dependent Variable: The variable being measured or watched, sometimes called the outcome or the responding variable.
5. Record and analyze *data* — Data, such as observations and measurements, are recorded and then analyzed. If the data support the hypothesis, then the conclusion would state that the hypothesis is correct. If the data contradict the hypothesis, then a new hypothesis must be made and tested.
6. Draw a *conclusion* — Scientists base their conclusions on observations made during experimentation.

Guided-inquiry activities simulate the scientific method—students look at data, search for patterns or relationships, and try to identify guiding principles that will explain the data. Guided-inquiry activities are most successful if students understand that the activity replaces the lecture. Students are more likely to take responsibility for learning when they are actively engaged in the process of "constructing knowledge."

Even though understanding the chemistry involved is not the focus of this activity, students may be curious as to what took place. The reaction of vinegar (acetic acid) and baking soda (sodium bicarbonate) produces sodium acetate and carbonic acid (Equation 1).

$$CH_3CO_2H(aq) + NaHCO_3(aq) \rightarrow NaC_2H_3O2(aq) + H_2CO_3(aq) \qquad \textit{Equation 1}$$

The carbonic acid then decomposes into water and carbon dioxide (Equation 2). The carbon dioxide forms the bubbles that students observe.

$$H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g) \qquad \textit{Equation 2}$$

Sodium bicarbonate is the salt of the weak acid, carbonic acid, H_2CO_3. When dissolved in water, sodium bicarbonate, $NaHCO_3$, forms a slightly basic solution (Equation 3).

$$HCO_3^-(aq) + H_2O(l) \rightleftarrows H_2CO_3(aq) + OH^-(aq) \qquad \textit{Equation 3}$$

Alum [$AlK(SO_4)_2$], when dissolved in water, forms the cations $Al^{3+}(aq)$ and $K^+(aq)$ in solution, along with the sulfate anion, $SO_4^{2-}(aq)$. When the two solutions are combined, a white precipitate of aluminum hydroxide, $Al(OH)_3(s)$ is formed. None of the products of the vinegar and alum reaction are soluble in water, therefore no change is observed.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard G: History and Nature of Science, nature of science
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions
Content Standard G: History and Nature of Science, nature of scientific knowledge

Answers to Worksheet Questions

Typical observations and results are shown below:

A + B = cloudy white	1 + 2 = no visible reaction
A + C = no visible reaction	1 + 3 = bubbles
B + C = bubbles	2 + 3 = cloudy white

A = *2*
B = *3*
C = *1*

Reasoning: B was the only one involved in both the cloudy white and the bubbling reaction. Likewise for 3, therefore B must equal 3. C was the other solution involved in making bubbles. Likewise for 1, therefore C must equal 1. By process of elimination, A must equal 2 .

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Mystery Solutions Lab* activity, presented by Bob Becker, is available in *Scientific Method Inquiry Lab Activities* and in *Inquiry Lab Activities*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Mystery Solutions Lab* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0265	Aluminum Potassium Sulfate, 100 g
S0043	Sodium Bicarbonate, 500 g
V0005	Vinegar, White, 3.78 L
AP1519	Pipet Holder Cassette Case
AP1444	Pipet, Beral-type, Thin-Stem, Pkg/500
AP8842	Pipet, Beral-type, Super Jumbo, Pkg/250
AP8464	Acetate Sheets, Pkg/100

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Mystery Solutions Lab Worksheet

You and your partner have a puzzle to solve. One of you will be given a set of three different solutions labeled with consecutive numbers (5, 6, 7 for example). The other will be given a set of matching solutions labeled with consecutive letters (such as E, F, G)—but not necessarily in the same order. Your task is to determine which lettered solution corresponds to which numbered solution. (For instance: perhaps 5 = F, 6 = E and 7 = G.) In the space below, brainstorm as many ideas as you can regarding how you might approach this puzzle.

IDEAS:

Note: Since the solutions each cost about a gazillion dollars per mL, use as little as possible, and do your best not to contaminate them. Now, one more catch—the two of you are working at separate research labs 500 miles apart, and you can communicate with one another only by faxing messages back and forth. Try to limit your messages—the first five are free, but every additional fax will cost you!

Use a separate sheet of paper for your fax messages. When you have your puzzle solved, write the answer in the box below. Describe the reasoning behind your conclusion.

__ = __
__ = __
__ = __