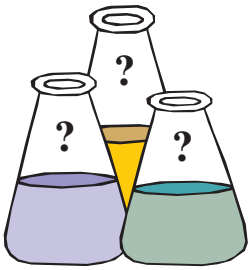
Mystery Solutions Match-up

Introduction

Challenge your students to solve the puzzle of the unknown solutions. How can they match three colorless mystery solutions with the same solutions their lab partners have? There is one catch—once a course of action has been determined, no visual comparisons allowed! A great lab for the first day of class, emphasizing good inquiry and communication skills with 100% participation guaranteed!



Concepts

- Observation
- Problem solving
- Scientific inquiry
- Scientific method

Materials (for each pair of students)

Unknown solutions in labeled pipets, 6 (see *Preparation* section)
Acetate sheets, 3 cm × 5 cm, 2
Notebook paper, 2 sheets
Paper towels
Pipet holder

Safety Precautions

Citric acid is a severe eye irritant. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Do not taste, touch, or smell any solutions or chemicals used in the lab. Remind students to wash their hands thoroughly with soap and water before leaving the laboratory. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Part 1. Solution Preparation

Make a 2% solution of each of the following: aluminum potassium sulfate (alum), $AlK(SO_4)_2 \cdot 12H_2O$, citric acid, $C_6H_8O_7 \cdot H_2O$, and sodium bicarbonate (baking soda), $NaHCO_3$.

1. Weigh 2 g of one of the solids.
2. Add 50 mL of distilled or deionized (DI) water to a small beaker.
3. Add the solid to the beaker. Stir until dissolved.
4. Add an additional 50 mL of DI water to the beaker and stir. Label.
5. Repeat steps 1–4 with each of the remaining solids in separate beakers.

Part 2. Preparation of Pipets

1. Use a permanent marker to label a set of six thin-stem disposable pipets, each with a different letter or number such as A, B, C, and 1, 2, 3. Mark enough sets for each pair of students.
2. Cut off all but 1 cm of the stem from each pipet.
3. Draw a half-bulb of the 2% alum solution in pipets marked as A and pipets marked as 2.
4. Draw a half-bulb of the 2% baking soda solution in pipets marked as B and pipets marked as 3.
5. Draw a half-bulb of the 2% citric acid solution in pipets marked as C and pipets marked as 1.
6. Place a set of six (A, B, C, 1, 2, 3) filled pipets in a pipet holder (empty cassette tape case, see Figure 1).

Part 3. Preparing the Acetate "Spot Plates"

1. Cut an overhead transparency acetate sheet into 3 cm × 5 cm pieces.
2. Using a permanent marker, place a dark dot in opposite corners of each small acetate sheet. *Note:* The dark dots make it easier to find the acetate sheets should they fall onto the floor as well as help the instructor confirm the sheets were

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returned to the pipet holders at the end of the lab.

3. Slide two acetate spot plates into each of the pipet holders, behind the pipets (see Figure 1).
4. Close the boxes and rubber band them.

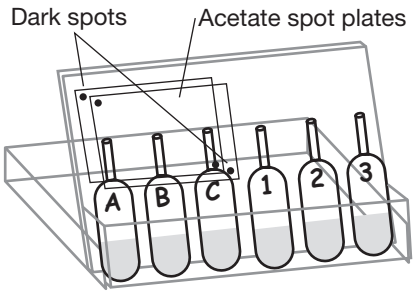

Figure 1.

Procedure

1. With students working in pairs, assign each pair a group number (1 through 15).
2. Hand out the prepared pipet holders, one setup to each pair of students. Tell students to look at the boxes but do not open them up yet.
3. Explain the objective of the lab is to determine which solutions in the numbered pipets match the corresponding solutions in the lettered pipets. One partner may only use the numbered pipets and the other partner only the lettered pipets.
4. Allow students a few minutes to brainstorm different ways to solve the problem, writing down their ideas.
5. 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. Stirring the drops together will not be necessary—the reactions will take place immediately and the results are obvious.
6. Explain to the students there is one final restriction—they are not to visually compare their results. Their only means of communicating their findings is verbally, by describing their results orally and in writing.
7. Have each pair of students place a visual barrier, such as a notebook or folder, between their work spaces and then let them open the pipet holders and begin.
8. 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, and review all federal, state and local regulations that may apply, before proceeding. Solutions on the acetate sheets may be wiped up with a paper towel and thrown away in the regular trash. All leftover solutions may be rinsed down the drain with plenty of excess water according to Flinn Suggested Disposal Method #26b.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions

Disciplinary Core Ideas: High School
HS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions

Science and Engineering Practices
Planning and Carrying Out Investigations
Analyzing and Interpreting Data
Constructing explanations and designing solutions
Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts
Cause and effect
Structure and function

Tips

- Students may want to taste, smell or feel the solutions for identification. Remind students that such practice is not allowed in the laboratory.
- Extra-large bulb pipets (available from Flinn Scientific, Catalog No. AP1445) are great for holding thin-stem pipets in place in the cassette boxes. Cut and discard the stems from the extra-large bulbs and then cut the bulbs in half. Place six of the half-bulb "cups" in the cassette box. Insert one filled pipet into each cup.

- To avoid students copying from other groups, number or letter each pair of boxed pipets differently—4, 5, 6 and D, E, F, etc.
- The purpose of the "no visual comparison" restriction is to prevent one partner from monopolizing the lab. For a greater challenge, add a "no talking allowed" restriction. Students must then describe their results and reasoning in writing and pass their papers back and forth.
- Vinegar may be used in place of the citric acid solutions. However, students may be able to identify the solution by its smell. Ascorbic acid (vitamin C) may also be used. Vitamin C tablets have additional binders that may cloud the solution.
- A video of this lab activity, Mystery Solutions Lab, presented by Bob Becker, is available for viewing as part of the Flinn Scientific Best Practices for Teaching Chemistry Videos. Please visit the Flinn Web site at http://www.flinnsci.com for viewing information. The activity is found with the *Scientific Method* videos.

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 may be implemented and the following is a list of steps that scientists may use to solve a 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 pertaining to the problem will be helpful in writing a plausible explanation 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 carry out an *experiment* — Experimental testing will provide evidence that either supports or contradicts the hypothesis. Several factors must be determined before conducting an experiment.

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

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

   Independent Variable: The variable that is intentionally changed or manipulated by the experimenter.

   Dependent Variable: The variable being measured or watched, also 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 developed and tested.
6. Draw a *conclusion* — Scientists base their conclusions on observations made during experimentation.

Keep in mind, however, that although the above list of steps may be a "typical" approach, the strategy and the order of steps may vary greatly from problem to problem.

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 citric acid and sodium bicarbonate produces sodium citrate and carbonic acid (Equation 1).

$$C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2CO_3(aq) \qquad \textit{Equation 1}$$

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 alum and baking soda solutions are combined, a white precipitate of aluminum hydroxide is formed (Equation 4).

$$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s) \qquad \textit{Equation 4}$$

None of the products of the citric acid and alum reaction are insoluble in water; therefore no change is observed.

Sample Test Method and Observations

Mixtures of solutions were systematically tested pairwise within each set of three solutions. Results of each mixture were recorded and compared.

A + B = cloudy white
A + C = no visible reaction
B + C = bubbles

1 + 2 = no visible reaction
1 + 3 = bubbles
2 + 3 = cloudy white

A = 2
B = 3
C = 1

Solution B was the only solution involved in both the cloudy white and the bubbling reactions. Likewise for solution 3, therefore solution B must be the same as solution 3. C was the other solution involved in making bubbles, as was solution 1. Therefore solution C must be the same as solution 1. By process of elimination, solution A must be the same as solution 2 (both solutions A and 2 were involved in the cloudy white precipitate reaction and the combination that produced no reaction).

Acknowledgment

Special thanks to Bob Becker, Kirkwood High School, Kirkwood, MO, for providing the idea and the instructions for this activity to Flinn Scientific.

Materials for *Mystery Solutions Match-up* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7323	Match the Mystery Solutions—Guided-Inquiry Laboratory Kit
A0265	Aluminum Potassium Sulfate, 100 g
C0231	Citric Acid, Monohydrate, 100 g
S0043	Sodium Bicarbonate, 500 g
AP1519	Pipet Holder Cassette Case
AP1444	Pipet, Beral-type, Thin-Stem, Pkg/500
AP8464	Acetate Sheets, Pkg/100

Consult the Flinn Scientific website for current prices.