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P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
www.flinnsci.com • E-mail: flinn@flinnsci.com

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Match the Mystery Solutions

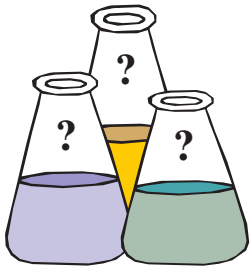
Guided-Inquiry Laboratory Kit

Introduction

Solve the puzzle of the unknown solutions. How can you match three colorless mystery solutions with the same solutions your partner has? There is one catch—once a course of action has been determined, no visual comparisons allowed!

Concepts

- Observation
- Problem solving
- Scientific inquiry
- Scientific method



Background

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.

Experiment Overview

The purpose of this experiment is to design and carry out a test method to identify pairs of matching solutions in two sets of "unknown" or "mystery" solutions. Each group will receive two sets of three solutions—one set of solutions labeled with consecutive letters and a second set labeled with consecutive numbers. Based on observations, each lettered solution will be matched with its respective numbered solution.

Pre-Lab Questions *(Answer on a separate sheet of paper.)*

1. Which of the following is NOT a characteristic of the scientific method: (a) logic, (b) creativity, (c) bias, (d) evidence? Explain your answer.
2. What safety precautions should be taken during this laboratory activity? Explain why.

Materials (for each pair of students)

Unknown solutions in labeled pipets, 6
Acetate sheets, 3 cm × 5 cm, 2
Notebook paper, 2 sheets
Paper towels
Pipet holder

Safety Precautions

One of the solutions used in this activity 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. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines.

Procedure

1. Obtain a pipet holder with six labeled pipets, but do not open the holder yet.
2. With your partner, brainstorm possible ways to determine which lettered solution corresponds to which numbered solution. For example, perhaps 8 is the same as J, 9 is the same as K, and 10 is the same as L. Remember to review the *Safety Precautions*.
3. Record your ideas on a piece of notebook paper. *Note:* No other chemicals or materials may be used for this activity.
4. Discuss your plans as a group with the instructor.
5. Once the instructor has approved your plan, you may open the pipet holder and begin *with the following restrictions*.
   a. Dispense one or two drops of the solutions onto the acetate sheet at a time.
   b. Avoid contaminating the pipets—never place the tip of a pipet into a different solution.
   c. Sit sideways at the lab table so you are back-to-back with your partner or place a visual barrier between your work area and your partner's work area.
   d. The only method of comparing results with your partner is verbal—no visual comparison allowed.
6. Once an observation is made, record your findings on a piece of notebook paper and read your description on the paper or pass it to your partner. Continue in this manner until you have determined which of your unknown solutions corresponds to each of your partner's solutions.
7. Complete the Match the Mystery Solutions Worksheet.

Disposal

Use a paper towel to wipe the acetate sheet dry. Place the pipets and acetate sheets back in the pipet holder.

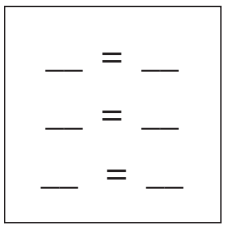
Name: _____

Match the Mystery Solutions Worksheet

In the space below, describe the test method used and summarize your observations.

Post-Lab Questions

1. Write your matches in the box below and describe the reasoning that led to your conclusion.



2. What steps of the scientific method listed in the *Background* section were used in solving the mystery of the unknown solutions?

3. Forming a hypothesis is often considered an essential step of the scientific method. Why was it not appropriate to develop a hypothesis in this experiment?

4. "Don't mix chemicals unless instructed to do so" is a good general safety rule—unpredictable reactions may take place. The following are some common "chemicals" found in most homes.

   A. Vitamin C

   B. Baking soda

   C. Washing soda

   D. Epsom salts

   E. De-icing salt

Continued on back of sheet.

Compounds A–E are all white solids that are soluble in water. When the solids were dissolved in water and then mixed pairwise in a laboratory as shown in the table below, several reactions were observed (NR—no reaction; ppt—precipitate). Note that since mixing A + B has the same effect as mixing B + A, only half the table is filled in.

	A	**B**	**C**	**D**	**E**
A	—	bubbles	NR	NR	NR
B		—	NR	NR	ppt
C			—	ppt	ppt
D				—	NR
E					—

Assume someone removed the labels from the household substances and scrambled them—they are now called 1–5. Identify 1–5 based on the data below.

	1	**2**	**3**	**4**	**5**
1	—	ppt	NR	ppt	NR
2		—	NR	NR	NR
3			—	NR	bubbles
4				—	ppt
5					—

Teacher's Notes

Match the Mystery Solutions

Materials Included in Kit (for 15 groups of students working in pairs)

Aluminum potassium sulfate (alum) solution, $AlK(SO_4)_2 \cdot 12H_2O$, 1%, 100 mL
Citric acid, $C_6H_8O_7 \cdot H_2O$, 2 g
Sodium bicarbonate (baking soda) solution, $NaHCO_3$, 0.5 M, 100 mL
Acetate sheets, 5½″ × 8½″, 2
Pipet holders, 15
Pipets, Beral-type, thin-stem, 90

Additional Materials Needed (for each lab group)

Notebook paper, 1 sheet per student
Paper towel, 1 per student

Additional Material Needed (for *Pre-Lab Preparation*)

Water, distilled or deionized (DI), 100 mL
Graduated cylinder, 100-mL
Marker, permanent
Scissors

Pre-Lab Preparation

Part 1. Solution Preparation

Use 100 mL of DI water to prepare the 2% citric acid solution. Add 100 mL of DI water to the 2 g of citric acid powder in the bottle and mix.

Part 2. Preparing the Pipets

1. Cut off all but 1 cm of the stem from each thin-stem pipet, enough for three shortened pipets for each student (see Figure 1).
2. Using a permanent marker, label 15 of the thin-stem pipet bulbs "A," 15 of them "B," and 15 of them "C." *Note:* To avoid students copying from other groups, you may letter each set of three pipets differently—D, E, F, etc.
3. Using a permanent marker, label 15 of the thin-stem pipet bulbs "1," 15 of them "2," and 15 of them "3." *Note:* To avoid students copying from other groups, you may letter each set of three pipets differently—3, 4, 5, etc.

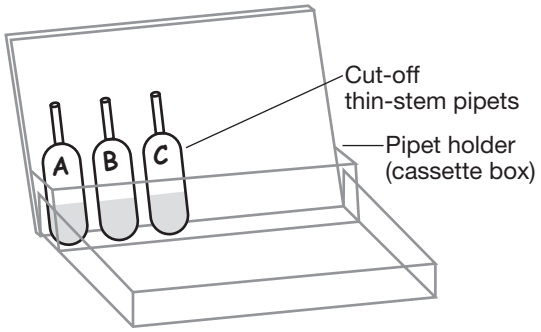


Figure 1.

4. Take one pipet labeled "A" (or its equivalent), draw up half a bulb-full of the alum solution and place the pipet in the pipet holder. Repeat with the other "A" pipets. *Note:* By pouring each solution into a labeled wide-mouth cup, this step may be easily done with two pipets at a time.
5. Repeat step 4 for the pipets labeled "2" or its equivalent. Place these pipets in the pipet holder (see Figure 2).
6. Take one pipet labeled "B" (or its equivalent), draw up half a bulb-full of the baking soda solution and place the pipet in the pipet holder. Repeat with the other "B" pipets.
7. Repeat step 6 for the pipets labeled "3" or its equivalent. Place these pipets in the pipet holder (see Figure 2).
8. Take one pipet labeled "C" (or its equivalent), draw up half a bulb-full of the citric acid solution and place the pipet in the pipet holder. Repeat with the other "C" pipets.

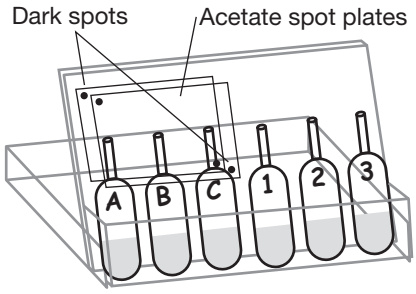


Figure 2.

9. Repeat step 8 for the pipets labeled "1" or its equivalent. Place these pipets in the pipet holder (see Figure 2).

Part 3. Preparing the Acetate "Spot Plates"

10. Cut the acetate sheet into 3 cm × 5 cm pieces.
11. Using a permanent marker, place a dark dot in opposite corners of each small acetate sheet. *Note:* The dark dots make it easy to find the acetate sheets should they fall onto the floor as well as help the instructor confirm the sheets were returned to the pipet holders at the end of the lab.
12. Slide two acetate spot plates into each of the pipet holders, behind the pipets (see Figure 2).
13. Close each pipet holder and store with pipet tips up.

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 Material Safety Data Sheets for additional safety, handling, and disposal information.

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.

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

Lab Hints

- Enough materials are provided in this kit for 30 students working in pairs, or for 15 groups of students. Both parts of this laboratory activity can reasonably be completed in one 50-minute class period. The pre-laboratory assignment may be completed before coming to lab, and the questions may be completed the day after the lab.
- Students may want to taste, smell or feel the solutions for identification. Remind students that such practice is not allowed in the laboratory.
- While discussing their ideas for solving the mystery, invariably a student will offer the approach of mixing the solutions. Discuss the merits of this approach, and show the students how to use the cut-off pipets to squeeze out drops of solutions and mix them on the acetate "spot plate," and how to avoid contamination. Stirring the drops together will not be necessary—the reactions take place immediately and the results are obvious.
- Additional pipet holders, Catalog No. AP1519, are available from Flinn Scientific.
- Extra-large bulb pipets (available form Flinn Scientific, Catalog No. AP1445) are great for holding thin-stem pipets in place in the cassette boxes. Cut the extra-large bulbs in half, discarding the part attached to the stem. Place six of the half-bulb "cups" in the cassette box. Insert one filled pipet into each cup.

Teaching Tips

- This is a great lab for the first day of class. The purpose of the "no visual comparison" restriction is to prevent one partner from monopolizing the lab. When conducted as written, 100% participation is guaranteed, and good inquiry and communication skills are emphasized.
- If sitting back-to-back is awkward for the students, a barrier such as a notebook or pocket folder may be placed between their work areas.
- 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.
- A video of this lab activity, *Mystery Solutions,* presented by Bob Becker, is available for viewing as part of the Flinn Scientific "Teaching Chemistry" eLearning Video Series. Please visit the eLearning Web site at http://elearning.flinnsci.com for viewing information. The video is part of the *Scientific Methods Inquiry Labs* video package.

Answers to Pre-Lab Questions *(Student answers will vary.)*

1. Which of the following is NOT a characteristic of the scientific method: (a) logic, (b) creativity, (c) bias, (d) evidence? Explain your answer.

   The correct answer is (c) bias. Bias can enter scientific reasoning in subtle ways. A scientist may ignore an observation or measurement that seems "out of line." Another scientist may propose a "cause and effect" relationship without doing proper control experiments to see if the same effect is observed in the absence of the proposed cause. ***Note:*** *Some students may challenge the importance of creativity in the scientific process. The best science is usually the most creative as well. It takes creativity to propose hypotheses to explain how or why something works and then to design experiments that truly test these explanations.*

2. What safety precautions should be taken during this laboratory activity? Explain why.

   Since all the solutions in this activity are unknown and one of the solutions is a severe eye irritant, it is important to wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. The sense of taste, touch, or smell should not be used to identify any solutions or chemicals in the lab. Hands must be washed thoroughly with soap and water before leaving the laboratory. All laboratory safety guidelines must be followed.

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

Teacher's Notes *continued*

Answers to Post-Lab Questions *(Student answers will vary.)*

1. Write your matches in the box below and describe the reasoning that led to your conclusion.

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).

2. What steps of the scientific method listed in the *Background* section were used in solving the mystery of the unknown solutions?

   Define a problem, make observations, design and implement an experiment, record and analyze data, and draw a conclusion were steps included in this investigation.

3. Forming a hypothesis is often considered an essential step of the scientific method. Why was it not appropriate to develop a hypothesis in this experiment?

   No hypothesis was developed since the solutions were unknown. Any possible answer prior to testing would be simply a guess, not based on facts or observations.

4. "Don't mix chemicals unless instructed to do so" is a good general safety rule—unpredictable reactions may take place. The following are some common "chemicals" found in most homes. Identify 1–5 based on the data below. ***Note to teachers:*** See student worksheet for data tables.

A. Vitamin C	*1 = C, Washing soda*
B. Baking soda	*2 = D, Epsom salts*
C. Washing soda	*3 = A, Vitamin C*
D. Epsom salts	*4 = E, De-icing salt*
E. De-icing salt	*5 = B, Baking soda*

Acknowledgment

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

