Lab 16. Development of a Reaction Matrix: What Are the Identities of the Unknown Chemicals?

Introduction

In chemistry it is often necessary to identify unknown substances. There are many procedures and pieces of equipment that can help a chemist to identify unknown substances, such as mass spectrometry or gas chromatography. While some of these methods and equipment are very complex and others are simpler, a common feature of each of these approaches is the comparison of properties of known substances with those of the unknown substances. Chemists can observe and compare *physical properties* of known and unknown substances, such as boiling point or density; likewise, it is possible to compare *chemical properties* such as how an unknown substance reacts with a known substance. One problem with testing and comparing physical properties of a substance involves solutions. It is possible that two different solutions will have the same density or even the same boiling point; in such a case those properties would not be helpful for differentiating between the two substances. In this situation, it may be more helpful to use observations of chemical reactions involving the unknown substance to determine what is in the solution.

An *aqueous solution* is created when a substance, the *solute*, is dissolved into water, the *solvent*. When different aqueous solutions are mixed together, it is possible that the substances dissolved into the water will undergo a chemical reaction, which may produce a *precipitate*. A precipitate is an insoluble ionic compound. Adding a few drops of an unknown solution to a powder may also cause a reaction, which might result in the formation of a gas. Other observable outcomes of a chemical reaction might be a change in color or a change in temperature. Since the chemical properties of a given substance are consistent when chemicals react with each other, the resulting products are also consistent and predictable; therefore, combining solutions together can be used as a way to identify them. This systematic process can be used to develop a table of reactions and their results, or a *reaction matrix*. If you know how specific known chemicals react with each other, it is possible to identify unknown chemicals by comparison.

Your Task

You will be given six labeled bottles to test and record data in order to generate a reaction matrix. Once your observations are complete and your reaction matrix has been developed, you will turn in your original set of chemicals. Then you will be given a second set of the same chemicals that are missing the correct labels. These unknowns will only be labeled as A–F. Your task will be to match the known solutions to the unknown solutions by comparing reactions with your written observations and the results in your reaction matrix.

The guiding question of this investigation is, **What are the identities of the unknown chemicals?**

Materials

You may use any of the following materials during your investigation:

Consumables	**Equipment**
• 6 known solutions • 6 unknown solutions (labeled A–F)	• Well plates or test tubes • Toothpicks • Dropper bottles or disposable pipettes

Safety Precautions

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. Some of these chemicals may stain your skin and clothing. Take the following safety precautions in addition to any precautions specified by your teacher:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Handle all glassware with care.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to generate a reaction matrix. A reaction matrix is a specific style of data table that allows you to systematically document what happens when you react a series of chemicals with each other (see Table L16.1, p. 262). The reaction matrix accounts for all of the different possible reactions within the set of substances you have available.

TABLE L16.1

Example of a reaction matrix

Solution	Solution				
	A	B	C	D	E
A	Observation 1	Observation 2	Observation 3	Observation 4	Observation 5
B	Observation 6	Observation 7	Observation 8	Observation 9	Observation 10
C	Observation 11	Observation 12	Observation 13	Observation 14	Observation 15

The solutions being tested are listed as entries in the first column and as headers in the remaining columns. Observations made during each test can be recorded in the boxes.

To generate a reaction matrix, you must also determine what type of data you will need to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about what types of observations or measurements will be most useful to include in your reaction matrix.

To determine *how you will collect the data*, think about the following questions:

- How much of each chemical will you need to mix together?
- How often will you collect data and when will you do it?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data*, think about how you will determine if a known substance and an unknown substance match.

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

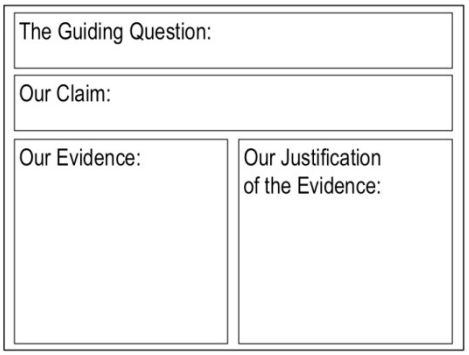
- the importance of identifying patterns in science,
- the difference between observations and inferences in science, and
- the nature and role of experiments in science.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L16.1.

FIGURE L16.1

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

- What did your group do to analyze the data, and why did you decide to do it that way?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!