Lab 4. Molarity: What Is the Mathematical Relationship Between the Moles of a Solute, the Volume of the Solvent, and the Molarity of an Aqueous Solution?

Introduction

Most of the matter around us is a mixture of pure substances. The main characteristic of a mixture is its variable composition. For example, a sports drink is a mixture of many substances, such as sugar and salt, with the proportions of substances varying depending on the type of sports drink. Mixtures can be classified as either homogeneous or heterogeneous. Homogeneous mixtures have parts that are not visually distinguishable, whereas heterogeneous mixtures have parts that can be distinguished visually. A homogeneous mixture is often called a solution. A sports drink therefore is a solution.

Much of the chemistry that affects us occurs among substances dissolved in water. It is therefore important to understand the nature of solutions in which water is the dissolving medium or the solvent. This type of solution is called an aqueous solution. An aqueous solution contains one or more chemicals (or *solutes*) dissolved in water (the *solvent*). The most common way to describe the concentration of a solute in an aqueous solution is to use a unit of measurement called *molarity*. In this lab investigation, you will explore the relationship between moles of solute, volume of solvent, and molarity.

Your Task

Use a computer simulation to determine the mathematical relationship between moles of solute, volume of solvent, and molarity. Once you have determined this relationship, you should be able to set up various functions that will allow you to accurately predict

- the molarity of a solution given the moles of solute and solvent volume,
- the moles of solute given the molarity of the solution and the volume of the solvent, and
- the volume of the solvent given the molarity of the solution and the moles of the solute.

The guiding question of this investigation is, **What is the mathematical relationship between the moles of a solute, the volume of the solvent, and the molarity of an aqueous solution?**

Materials

You will use an online simulation called *Molarity* to conduct your investigation. You can access the simulation by going to the following website: *http://phet.colorado.edu/en/simulation/molarity*.

Safety Precautions

Follow all normal lab safety rules.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in developing your mathematical function is to determine how moles of solute and volume of the solvent are related to the molarity of a solution. The *Molarity* simulation (see screenshot in Figure L4.1) allows you to mix different moles of solute in different volumes of water (the solvent). It then provides a measure of the molarity of the resulting aqueous solution.

Before you start using the simulation, you must determine what type of data you will need to collect, how you will collect the data, and how you will analyze the data to answer the guiding question.

To determine *what type of data you need to collect*, think about the following questions:

- What type of observations will you need to record during your investigation?
- When will you need to make these observations?

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

- What types of comparisons will you need to make?
- How will you keep track of the data you collect and how will you organize it?

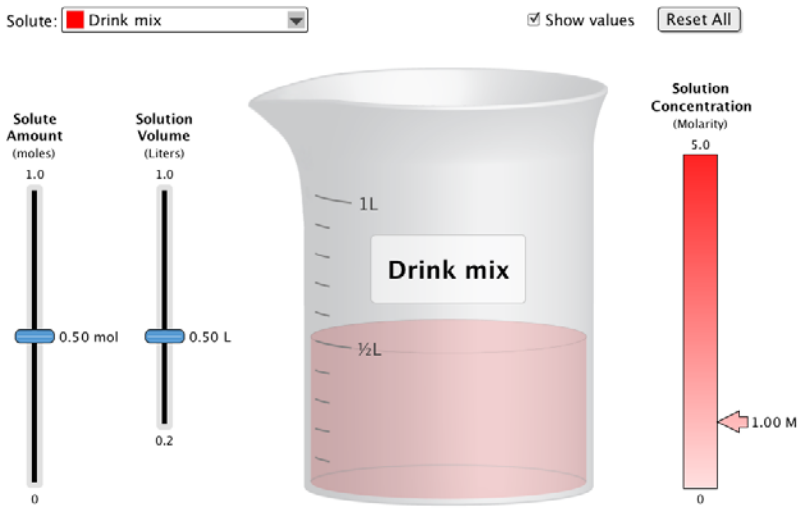
To determine *how you will analyze the data*, think about the following questions:

- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data?

Once you have collected and analyzed your data, your group will need to develop a function that can be used to predict (1) the molarity of a solution given the moles of solute and solvent volume, (2) the moles of solute given the molarity of the solution and the volume of the solvent, and (3) the volume of the solvent given the molarity of the solution and the moles of the solute. You will then need to test your function using the simulation. If you are able to use your function to make accurate predictions, then you will be able to generate the evidence you need to convince others that the function you developed is valid.

FIGURE L4.1

A screenshot from the *Molarity* simulation



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

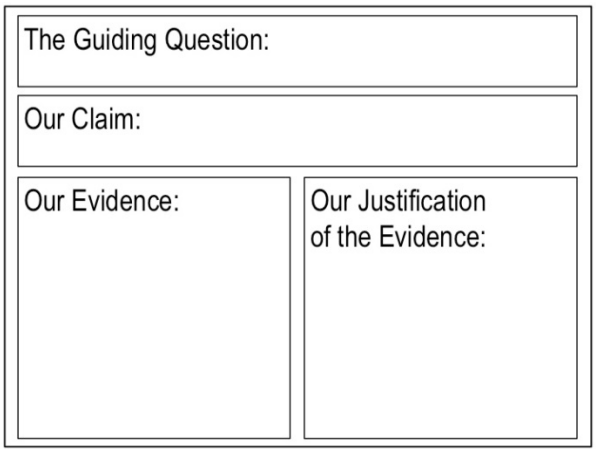
- the importance of looking for proportional relationships between different quantities,
- why it is important to track what happens to matter within a system,
- the difference between data and evidence in science, and
- the wide range of methods that can be used during a scientific investigation.

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 L4.2.

FIGURE L4.2

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!