Rainbow in a Test Tube

Learning Objectives

- Students will be able to plan and carry out an experiment by using collaboration to determine the ordering of various solutions and liquids to create a rainbow.
- Students will be able to collect appropriate data from experimental tests to answer their collective research question.
- Students will be able to generate an argument from evidence to address their research question.
- Students will be able to communicate their findings by creating some form of presentation and obtaining feedback from other teams during discussion.

Safety and Materials

Of the six liquids, three are non-polar and organic. *These organic liquids can dissolve plastic pipets and other plastic labware.* Use glass pipets, beakers, etc. when transferring and containing these liquids. Avoid plastic to minimize damage to your labware. The following reagents will be available:

- 1,2-Dichlorobenzene
- Ethyl acetate
- Calcium chloride ($CaCl_2$) aqueous solutions
- 1,2-Dichlorobenzene /Ethyl acetate mixture
- Deionized water

Relevant Experimental Techniques: Pipetting Liquids

Task: You have two goals for today's experiment:

1) Develop an experiment to test your research question and an argument that addresses the question to present your findings to the class.
2) Determine the layering order of solutions required to prepare a rainbow of layered dyed solutions (from red on the bottom to purple on top). You will be provided with about 7 mL of each of the six solutions; use them sparingly in tests as additional liquid will not be provided. Make sure to save enough of each solution for the final product. To prepare the rainbow successfully, you will want to consider miscibility, polarity, and density. It is up to your team to determine how you will test these properties.

Research Questions: You will select a research question during the pre-lab quiz and this will determine which team you are joining for the experiment. The possible questions to investigate are below:

1. What are the relative densities of each unknown?
2. What property determines the miscibility of the unknowns?
3. What are the chemical compositions of the unknowns?
4. Which unknowns are polar and which are nonpolar?

Possible Liquids

3.2 M $CaCl_2$ (aq)	**dichlorobenzene**	**ethyl acetate/ dichlorobenzene**
5.5 M $CaCl_2$ (aq)	**ethyl acetate**	**water**

Conceptual Background

Figure 1: Testing miscibility of various liquids.

Liquid-liquid solubility or *miscibility* is responsible for many effects in chemistry and everyday life. For example, the fact that oil and water are immiscible causes many foods (such as peanut butter and mayonnaise) to spontaneously separate over time. Figure 1 shows the formation of layers when two liquids are **immiscible** in the 3 test tubes to the left and the mixing of layers in the 3 test tubes to the right which occurs when liquids are **miscible** with one another. Chemists exploit the immiscibility of **polar** and **non-polar solvents** to separate water-soluble salts and polar compounds from non-polar compounds in a method known as *solvent extraction*. Let's take a closer look at this separation method to address some important background for this experiment.

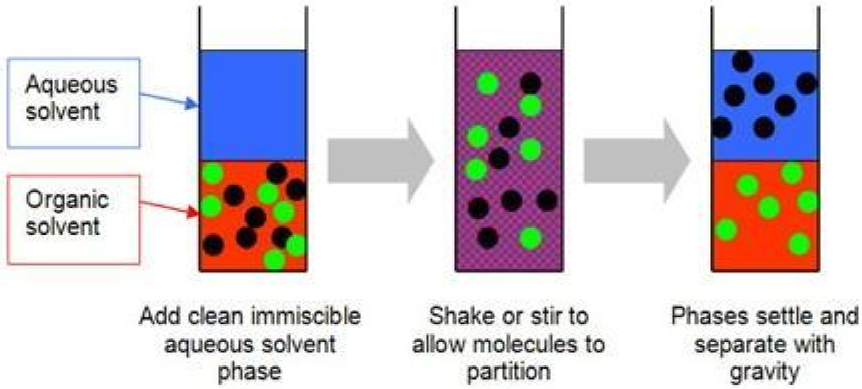

Figure 2: Conceptual representation of solvent extraction technique.

In a typical solvent extraction, water is mixed with a solution containing an organic solvent and both polar and non-polar solutes inside a separatory funnel. When the mixture is shaken, the polar solutes move to the **aqueous phase** while the non-polar solutes remain in the **organic phase**. The mixture is then allowed to sit while the aqueous and organic phases separate spontaneously into two distinct layers. The denser phase *falls to the bottom of the separatory funnel*, where it can be dispensed. A nice example of solvent extraction is shown in Figure 2—note the two layers inside the "funnel".

Note: Some organic solvents have densities less than that of water, others have higher densities compared to water. Also, some organic solvents are miscible with water if they are polar and others are not miscible with water.

In this experiment, we will exploit differences in polarity, miscibility, and density between six solutions (either aqueous or organic) to create a six-layered "rainbow in a test tube." The final product will be a test tube containing the six solutions in layers, but the design process is up to you!

Scientific Process Background

Table 1 presents the list of tasks or practices that scientists regularly do. These are also intended to be tasks that you will engage in this semester as you conduct your own experiments with your team. It is also important to note that science is a community effort. For this reason you will use collaboration throughout your investigations. During this experiment, there is the possibility of using all eight of these practices. At the end of the lab, your team should reflect on the ways you engaged in science today!

Table 1: General tasks that practicing scientists engage in regularly.

Asking questions	Planning and carrying out investigations

Using mathematical and computational thinking	Developing and using models
Analyzing and interpreting data	Constructing explanations
Engaging in argument from evidence	Obtaining, evaluating, and communicating information

One of these practices will take some practice this semester: argumentation. To aid with this process, we will use an argumentation model known as C.E.R. or Claim – Evidence – Reasoning. This model is described below in Table 2.

Table 2: The Claim-Evidence-Reasoning model for argumentation.

Basic Elements of an Argument	Description
Claim	A statement of your conclusion regarding the question or problem.
Evidence	Analyzed and interpreted data or observations that support the conclusion presented in your claim.
Reasoning	An explicit explanation of the connections you made in order to reach your conclusion (claim) after examining your results (evidence).

To begin crafting an argument, you must be able to identify and/or create a claim. The goal of a claim is to answer your research question based on your results. It is simply a statement presenting your position based on the evidence you collected. <u>Example claim</u>: *It will rain on campus today*.

The next component of your argument is presenting the evidence associated with your claim. If you collected data, you should directly cite this data in your argument. Note: data on it's own does not constitute evidence. It should be analyzed and interpreted in order to classify as "evidence". <u>Example evidence:</u> *The forecast predicted a 55% chance of rain for the Atlanta area, which makes rain more likely than no rain. Additionally, a high concentration of clouds were observed directly over the campus.*

The final component of the argument is the most challenging to construct. This portion provides an explanation of why the evidence is sufficient to state your claim. Others may call this a "justification" or a "warrant". You are using reasoning to be explicit about your thinking here, even if it seems obvious to you. Other times, it may require pulling on theoretical or conceptual background information to explain your thinking. <u>Example reasoning</u>: *Weather forecasts are based on atmospheric data and weather models* *that have a high likelihood of being accurate. This means that the 55% chance prediction is fairly accurate and the likelihood of rain is above 50%. Also, full cloud coverage is a common indication that rainfall is probable and imminent.*

Process

Prelab - online	**Read** (this document) learning objectives, conceptual background, safety and chemical info, scientific investigations background. **Take the prelab quiz** over all content associated with learning objectives (from this document). Select a research question option from within the prelab quiz/this document and **write down the question in your lab notebook**.
Planning investigation (15 min)	Your TA will briefly provide instructions. Groups of ~4 will form **based on the selected research question**. Groups will **discuss ways to test the unknowns** to solve the problem (determine the order to layer all liquids) and **determine a plan** for answering their research question in the process. This plan must be written in the lab notebook along with any data tables needed for the investigation. What tests will be useful? Who will do what? How will you collect and organize data in your notebooks?
Carrying out research question investigation (30 min)	The groups will **follow their plan** to address the research question, , collect key data, and determine an order or categories of the liquids.. Fill in your data tables and add annotations to note any unexpected results, obstacles, or changes.
Investigation analysis (15 min)	Groups will **return to their original research question** then discuss and analyze their data with that in mind. Groups will decide how to present their results **visually**. Groups will **create an argument from evidence** to answer their research question following argumentation guidelines. They will debate amongst themselves **alternative explanations** as applicable.
Results and conclusions (30 min)	Groups will **create some form of presentation** to share. This can be on a white board, poster board, or digitally (PowerPoint, Google slides, etc). They must include their research question, results in some sort of figure, graph, or table, as well as their written argument.

Class discussion of findings (30 min)	Each group will take turns **sharing their presentations with the class**. Other groups can **ask questions, critique, suggest future investigation ideas, or give positive feedback**. (TA's can also contribute positively to the discussion, allowing students to primarily speak)
Problem-solving investigation (45 min)	Use the class data to **determine the order** of the liquids that will allow them to layer appropriately. Once groups have decided on the order of the liquids (bottom to top) they will **add 3-4 drops of their colors** to the solutions in that order (ROYGBIV). You will carefully create your rainbow and take a photo.
Post-lab - online	You will individually **submit your notebook pages** as well as a **written summary** of the methods, results, and conclusions including any relevant data and figures. You must make references to your data and background information to support your conclusion. Use the abbreviated report template to complete the report, making sure to include the photograph of your final rainbow.