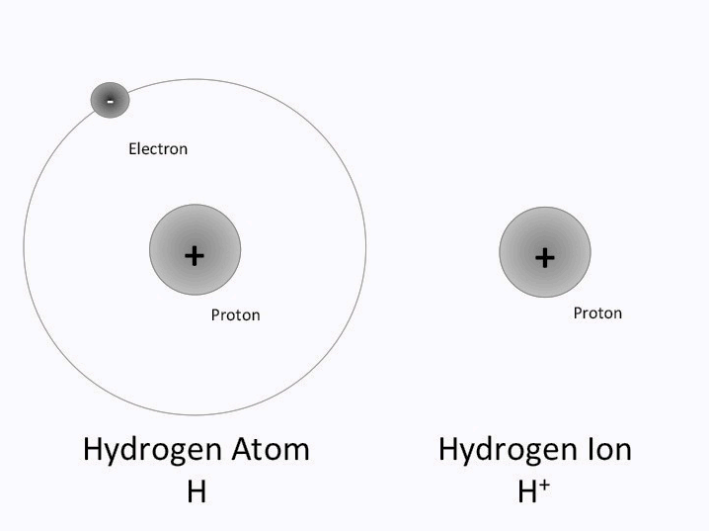
Lab 19. Strong and Weak Acids: Why Do Strong and Weak Acids Behave in Different Manners Even Though They Have the Same Chemical Properties?

Introduction

Johannes Nicolaus Brønsted and Thomas Martin Lowry published nearly identical explanations for the nature of acids and bases in 1923. These two explanations were later combined into a single explanation, which is now known as the Brønsted-Lowry acid-base theory. This theory defines acids and bases in terms of how molecules interact with *hydrogen ions*. A hydrogen ion is just a proton (see Figure L19.1). An *acid*, according to the Brønsted-Lowry definition, is any substance from which a proton can be removed, and a base is any substance that can remove a proton from an acid molecule. In an acid, the hydrogen ion is bonded to the rest of the molecule. It therefore takes energy to break that bond. So an acid molecule does not "give up" or "donate" a proton, it has it taken away. When a base molecule interacts with an acid molecule, it will (if it is strong enough) rip the proton off the acid molecule.

FIGURE L19.1

A hydrogen atom and a hydrogen ion



To illustrate how this works, consider what happens when hydrogen chloride (HCl) is mixed with water. In this situation, the water is able to remove a proton from the hydrogen chloride. The hydrogen chloride is therefore an acid and the water is therefore a base. In Brønsted's original explanation for the nature of an acid-base interaction, he used H^+ to describe how the proton is removed from an acid by a base. This interaction between the molecules of hydrogen chloride and water can therefore be represented as

$$HCl + H_2O \leftarrow \rightarrow H^+ + Cl^- + H_2O$$

A hydrogen ion (H^+), however, does not exist for very long in water because the proton affinity of H_2O is approximately 799 kJ/mol. As a result, a hydrogen ion quickly combines with a water molecule once it is removed from an acid molecule. This can be represented as

$$H_2O + H^+ \rightarrow H_3O^+$$

Lowry therefore used H_3O^+ rather than H^+ to describe the transfer of protons in his explanation of what happens on a submicroscopic level during an acid-base reaction. In his explanation, Lowry explained that when an acid is added to water, a proton from the acid is split off and taken up by water (the base) to produce hydronium ions (H_3O^+). For the hydrogen chloride and water example, this can be represented as

$$HCl + H_2O \leftarrow \rightarrow Cl^- + H_3O^+$$

The Brønsted-Lowry acid-base theory was a groundbreaking idea when it was first introduced because it was able to explain a wide range of macroscopic observations about the behavior of acids and bases by providing a model for how acid and base molecules interact with each other on the submicroscopic level. In this investigation, you will use the Brønsted-Lowry definition for an acid and a base as a starting point to develop a model that can be used to explain the behavior of strong and weak acids.

Your Task

Develop a model that can be used to explain why strong and weak acids behave in a different manner even though they have the same chemical properties. The two chemical properties of acids that you will focus on during this investigation are electrical conductivity and reactivity with metal. To develop your model, you will first need to determine how acid strength affects electrical conductivity and reaction rate. You will then need to determine how to explain your observations on the macroscopic level by describing the nature or behavior of strong and weak acids on the submicroscopic level. The Brønsted-Lowry definition of acids and bases will serve as the theoretical foundation for your model.

The guiding question for this investigation is, **Why do strong and weak acids behave in different manners even though they have the same chemical properties?**

Materials

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

Consumables	**Equipment**
• 1 M solution of acetic acid, CH_3COOH (weak acid) • 1 M solution of hydrochloric acid, HCl (strong acid) • 1 M solution of sulfuric acid, H_2SO_4 (strong acid) • Magnesium ribbon	• Conductivity tester or probe • Pneumatic trough and tubing • Graduated cylinder (250 ml) • Graduated cylinder (10 ml) • Filtering flask (50 ml) and rubber stopper • Stopwatch • Electronic or triple beam balance

Safety Precautions

Follow all normal lab safety rules. All of the acids you will use are corrosive to eyes, skin, and other body tissues. They are also toxic by ingestion. Magnesium metal is a flammable solid and burns with an intense flame. Keep away from flames. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- 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 first determine how the behaviors of strong and weak acids differ in terms of electrical conductivity and reactivity with metals. A conductivity tester or probe can be used to measure the conductivity of the three different acid solutions. You can design and carry out an experiment to determine how acid strength affects reactivity with metal. All of the acids that you will be using react with magnesium to produce hydrogen gas. Your goal is to determine the relationship between acid strength and the rate of this reaction. You will therefore need to determine what type of data to collect, how you will collect the data, and how you will analyze the data to accomplish your goal.

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

FIGURE L19.2

Gas collection using water displacement

- What type of measurements will you need to make during your investigation? You could, for example, measure the amount of H_2 gas that is produced, the time it takes to produce a set amount of gas, or the time it takes for the reaction to go to completion.
- When will you need to take your measurements?

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

- What equipment can you use to capture and measure the volume of a gas? You could, for example, capture and measure the volume of a gas using water displacement (see Figure L19.2).
- What types of test conditions will you need to set up and how will you do it?
- How will you eliminate confounding variables?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How often will you collect data and when will you do it?
- 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:

- How will you determine if there is a difference between the test conditions?
- 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 carried out your experiment, your group will need to develop your conceptual model. The model should be able to explain why strong and weak acids differ in terms of electrical conductivity and reactivity with metal. The model should also include a description of the interactions that take place between molecules and should be based on the Brønsted-Lowry definition of acids and bases.

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

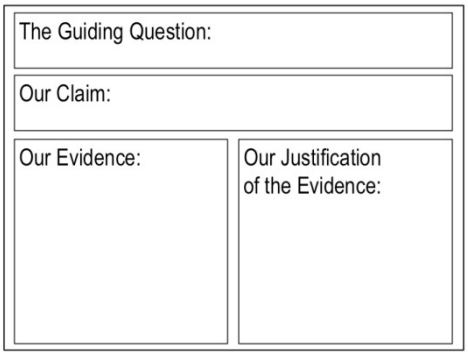
- the importance of developing causal explanations for observations,
- how models are used to help understand natural phenomena,
- the importance of imagination and creativity in science, and
- the nature and role of experiments in science.

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 L19.3.

FIGURE L19.3

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:

- How did your group collect the data? Why did you use that method?
- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- What did your group do to analyze the data, and why did you decide to do it that way? Did you check your calculations?
- 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!