

Lab 18. Characteristics of Acids and Bases: How Can the Chemical Properties of an Aqueous Solution Be Used to Identify It as an Acid or a Base?

Introduction

Acids and bases represent two important classes of chemical compounds. These compounds play a significant role in many atmospheric and geological processes. In addition, acid-base reactions affect many of the physiological processes that take place within the human body. Acids and bases are important in atmospheric, geological, and physiological processes because they have unique chemical properties. Acids and bases have unique chemical properties because of the atomic composition of these compounds and how these compounds interact with other atoms and molecules.

Some of the unique chemical properties of acids and bases include how they interact with metals, carbonates, and a class of compounds called acid-base indicators. A *metal* is a solid material that is hard, shiny, malleable, and ductile. Metals are also good electrical and thermal conductors. *Carbonates* are compounds that contain a carbonate ion (CO_3^{2-}), such as calcium carbonate (CaCO_3), potassium carbonate (K_2CO_3), and sodium bicarbonate (NaHCO_3). An acid-base indicator is a dye or a pigment that changes color when it is mixed with an acid or a base. People have used indicators to identify acids and bases for hundreds of years. For example, in the 17th century Sir Robert Boyle described how different indicators could be used to identify acids and bases (Boyle 1664).

In this investigation you will explore some of the unique chemical properties of acids and bases. You will then develop a method that can be used to identify acidic or basic aqueous solutions. This is important because, like all chemists, you will need to be able to determine if an aqueous solution is acidic or basic as part of your future investigations. This is an important aspect of doing acid-base chemistry.

Your Task

Devise, test, and then, if needed, refine a method that can be used to determine if an aqueous solution is acidic or a basic. For this method to be useful, it should provide consistent and accurate results but should also be simple and quick to perform inside the lab.

The guiding question for this investigation is, **How can the chemical properties of an aqueous solution be used to identify it as an acid or a base?**

Materials

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

Consumables	Indicators	Equipment	Aqueous solutions for developing a method	Aqueous solutions for testing a method
<ul style="list-style-type: none">• Zinc• 1 M solution of NaHCO_3• 1 M solution of hydrochloric acid, HCl	<ul style="list-style-type: none">• Thymol blue• Bromphenol blue• Bromthymol blue• Methyl red• Phenol red	<ul style="list-style-type: none">• Conductivity tester or probe• Reaction plate• Small beakers	<ul style="list-style-type: none">• Acid solution 1• Acid solution 2• Acid solution 3• Acid solution 4• Base solution 1• Base solution 2• Base solution 3• Base solution 4	<ul style="list-style-type: none">• Acid test solution A• Acid test solution B• Base test solution A• Base test solution B

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 when ingested. 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 first need to learn more about the unique chemical properties of acids and bases. You will therefore need to explore how aqueous solutions that are classified as acids or as bases react with metal, a solution of sodium bicarbonate, and a solution of hydrochloric acid. You will then determine if these same solutions are able to conduct electricity. Finally, and perhaps most important, you will examine how different acidic and basic solutions interact with different indicators. Your goal is to learn more about the chemical properties of aqueous solutions that are classified as being acids or bases so you can use these unique properties to classify other aqueous solutions. To accomplish this task, you will need to design and conduct a series of systematic observations.

Be sure to think about *how you will collect your data and how you will analyze the data you collect* before you begin your investigation. One way to collect data is to add a small amount (about 5 to 10 drops) of each acid or base solution to the wells in a reaction plate. You can then add a small piece of metal or other solution to each well and observe what happens. You can also create a reaction matrix to help stay organized. A reaction matrix is a chart that allows you to record your observations (see Table L18.1 for an example). Only use the solutions found under the heading “Aqueous Solutions for Developing a Method” in the “Materials” section during this stage of your investigation.

TABLE L18.1

Example of a reaction matrix

Compound	Test				
	Zinc	Conductivity	HCl	Bromthymol blue	Methyl red
Acid solution 1	Observation 1	Observation 2	Observation 3	Observation 4	Observation 5
Acid solution 2	Observation 6	Observation 7	Observation 8	Observation 9	Observation 10
Base solution 1	Observation 11	Observation 12	Observation 13	Observation 14	Observation 15

Notice that the compounds being tested are included in the first column and each test is labeled as a header in the remaining columns. Observations made during each test can be recorded in the boxes.

Once you have made your observations about the chemical properties of acids and bases, you will need to use what you have learned to devise a method for classifying an unknown as either an acid or a base. You can then test your method using the solutions found under the heading “Aqueous Solutions for Testing a Method” in the “Materials” section. If you are able to use your method to accurately classify all four of these solutions, then you will be able to provide evidence that the method you devised will provide accurate results. If you cannot accurately classify all four of the test solutions, you will need to refine your method and test it again. Keep in mind that your method needs to be a simple and quick way to classify an unknown aqueous solution based on its chemical properties.

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, using, and explaining patterns in science;
- the relationship between structure and function in nature;
- the difference between observations and inferences in science; and
- the different methods used in scientific investigations.

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 L18.1.

FIGURE L18.1

Argument presentation on a whiteboard

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

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 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?
- 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!

Reference

Boyle, R. 1664. *Experiments and considerations touching colours first occasionally written, among some other essays to a friend, and now suffer'd to come abroad as the beginning of an experimental history of colours*. London: Henry Herringman.