

The Iterative Nature of Science



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ETP Type: *classroom*

Subject/Grade: Chemistry/10th

Abstract (~150 words)

The nature of science is more than students following a recipe of instructions in a laboratory experiment. Students are required to learn how scientists acquire knowledge through the process of scientific discovery. They learn by doing science as scientists behave in the lab. Students will do an exploratory activity with acid base reactions. Then they will design their own acid base indicator using household items and create their own indicator. Through an iterative process students will record their work and any changes they make to improve the reaction process. They will create an indicator or indicators that can be purchased at a grocery store that can detect three different pH levels (acid, base, and intermediate). The goal is to produce three distinct colors. This process will be completed in groups of three to four students. Finally they will present their reaction(s) to the class using slides.

Focal Content & Supporting Practices

NGSS SEP -Obtaining, evaluating, and communicating information. Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

HS-PS1-2

Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns

NGSS Appendix H

- a) Scientific investigations use a variety of methods.
- b) Scientific knowledge is based on empirical evidence.
- c) Scientific knowledge is open to revision in light of new evidence.
- e) Science is a way of knowing.

21st Century Skills and Applications (1 - 2 bullets)

Creativity and Innovation: Student groups will propose a new lab procedure based on new evidence.

Communication and Collaboration: While planning and performing the lab students will collaborate in lab groups. There will be in class discussions while presenting data.

Measurable Objective(s)

1. Lab recording of the discovery process of making acid base indicators.
 - a. Students will record 3 iterations of creating an acid/base indicator.
 - b. Students will take pictures of their process and final product.

2. Presentation with slides.
 - a. Students will explain the characteristics of a chemical reaction.
 - b. Students will explain the characteristics of an acid/base reaction.
 - c. Students will present to the class their iterations for 5-7 minutes.

Formative Assessment(s)

1. Conduct an investigation and record their work.
2. Students will exchange their 2nd iteration and provide feedback to another group.
3. Students will practice with their presentation to another group and provide feedback to each other.

Summative Assessment(s)

[Final presentation](#)

Students will create a presentation with their group on the 3rd iteration of finding an acid/base indicator and present in a slideshow.

[Rubric](#)

Fellowship Description (300-500 words)

Nanoparticles made of palladium and platinum are the main active metals in catalytic converters in cars. The purpose of catalytic converters is to take exhaust waste and turn them into less powerful greenhouse gasses, such as methane to carbon dioxide. Research has shown that at high temperatures catalytic converter substances change and reduce surface area over time by combining to one large unit. This reduces its effectiveness to convert greenhouse gasses and is costly in the production process while using up rare and expensive metals. At high temperature the catalysis reactions in catalytic converters become inactive and inefficient. Also, if a better and more cost effective method is developed, then the potential to reduce greenhouse gasses increases.

My research focuses on finding a better way to create nanoparticles that can bind to good substrates without coalescing into one unit. First we must find the correct ratio of nanoparticles to substrate for optimal reaction. Then we place the nanoparticles into a polymer that binds the nanoparticle in place so it does not move around on the substrate. Then we test the material. There are different types of substrates such as Aluminum based, zirconium and cerium based, or silicon based. We will try different sizes on different substrates to see if any of the combinations is better than the known amounts.

There was a polymer that contained sulfur compounds and it was used to trap the nanoparticles into place. It produced a very nasty terrible smell. Some of the reactions still require this polymer. But another graduate student created a new polymer that does not have sulfur so it does not smell and that is the polymer that I use in my experiments. Within four years the procedures and techniques for making nanoparticles have changed drastically due to new discoveries and invention. Science is constantly adding new knowledge each day.

Fellowship Connection to School/Classroom (300-500 words)

Four years ago I worked on synthesizing large nanoparticles (9 nm). This year I am still making the exact same nanoparticles but in smaller sizes (2-5 nm). The procedures are slightly different and not as predictable as the previous "recipe." The research is still the same, which is to find a better way to make a catalytic converter that requires less expensive metals and works better. Catalytic converters become inactive over time at high temperatures. So manufacturers infuse an excessive amount of palladium and

platinum to make sure catalytic converters have a long lifespan. This is costly and uses up valuable precious metals that are a limited resource.

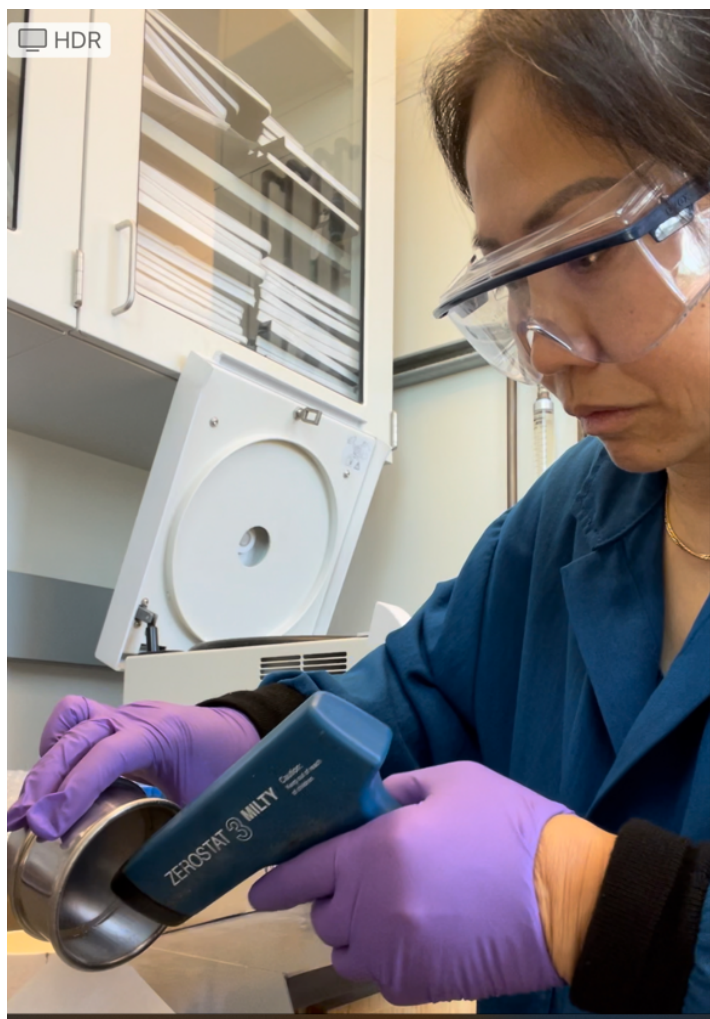
Science is a continuous process of collecting information and revision. It is dynamic and new information is constantly added as people collect more data. Lab work from four years ago that was considered ingenious is now outdated based on new discoveries.

Experiments sometimes do not produce any results. The process and work require constant adjustments and changes as we learn from the previous experimental process. The focus for my classroom is for students to design an experiment using acid base reactions to create visual changes that show a chemical reaction has occurred. It is not expected that they will create something workable the first time. It is expected that they try different methods and reflect on what they learned from the previous experiments that did not produce results. This process will allow them to behave and progress as scientists in the laboratory.

Instructional Plan (This is the bulk of your ETP and may take several pages.)

My experiments this summer did not produce any novel results. When this happens we go back to the experiment and see what the failure means. Then we worked out a new plan to try another avenue. Again, the process did not produce any viable results but it did inform us of the materials that did not work for catalysis. I will explain to students that science often is finding out ways that don't work more than ways that do work, but it always leads to more experimentation. Scientists use their creativity and analytical thinking to continue asking new questions to devise new experiments. Eventually the persistence will yield exciting results.





Part I. Teacher demonstration using Phenolphthalein indicator. Students record observation on [Observation Graphic Organizer](#) while teacher performs demonstration stated in lesson(Do this live if possible)

[Observation Graphic Organizer](#)
[Video of demo](#)

Objectives: The students will make observations and record observations; provide evidence of a chemical reaction

Part I & II (1 class period 45 minutes)

I. Acid Base Demonstration (This is to introduce the topic of chemical reactions)

Materials:

- [Phenolphthalein](#) solution
- [Sodium carbonate](#)
- Vinegar
- 5 glasses and a non-see-through pitcher of water

What You Do:

1. In the first glass put a little less than 1/8 teaspoon of sodium carbonate, in the second put 6 drops of phenolphthalein solution, and in the third put three droppers-full of vinegar.
2. Add a few drops of water to the first glass and stir to dissolve the sodium carbonate.
3. Fill all the glasses with water from the pitcher, then pour all of them back in the pitcher except for the glass with vinegar.
4. Refill the remaining four glasses – the water will be red!
5. Now pour all five glasses back in the pitcher. Refill the glasses one last time—the liquid will be colorless again!

What Happened: Teacher explanation

Phenolphthalein is a pH indicator, but it only turns colors in reaction to bases. When you poured the four glasses back into the pitcher, the phenolphthalein reacted to the sodium carbonate, a base, and turned the solution to bright pink “kool-aid.” To change it back to “water,” all you had to do was add the acidic vinegar, which turned the phenolphthalein colorless again.

Part II. Rainbow Reaction Tube:

[Student Graphic organizer](#)

[Universal Indicator video](#)

Objectives: The students will read and follow a set of procedures. Students will make observations and explain how colors can be separated in one liquid using density.

II. Rainbow Reaction Tube

What You Need:

- [10ml graduated cylinder](#)
- [Universal indicator](#)
- [Sodium carbonate](#)
- [Beaker](#)
- Distilled white vinegar

What You Do:



1. Put 15 drops of universal indicator in the graduated cylinder and add filtered water up to the 10 ml mark.

The solution should be yellow-green.

2. Add 3 drops of vinegar to the solution in the graduated cylinder, and it should turn red.

3. In a beaker, put two scoops of sodium carbonate and then add about 30 ml of water. Mix together with the stirring rod until the sodium carbonate dissolves. The solution should be clear.

4. To start the reaction, fill one dropper full with sodium carbonate solution. Squeeze the dropper into the graduated cylinder quickly, rather than drop by drop. The clear solution should instantly turn dark purple, and slowly sink to the bottom, swirling around to make the rainbow.

5. Let the contents of the cylinder settle, until you can see each color from bluish-purple to red. To make the rainbow disappear, pour it into an empty beaker, and it should turn yellow or yellowish green.

What Happened: Teacher explanation

Universal indicator changes colors to show the pH level of a substance. In this case, when you mixed an acidic solution (vinegar) with a basic one (sodium carbonate), the indicator made a colorful spectrum — from dark blue to red.

Interestingly, if you had added the solutions in the opposite order, you would not have seen a rainbow. To get the rainbow effect, another scientific principle is at work—**density**. The sodium carbonate solution you made is denser than the indicator solution, so it sinks to the bottom. As the sodium carbonate solution makes its way to the bottom, some of its molecules mix with vinegar molecules, making a new solution, which shows up as a color of the pH scale.

If you don't turn the graduated cylinder upside down, the rainbow will last several days. Over time the colors will mix together through the process of diffusion. The molecules of each solution will mix throughout the graduated cylinder, rather than staying concentrated at the top or bottom. Once you mix the acid and base solutions together, the solution will be pH neutral, and look yellow or slightly green.

Part III. Designing home-made acid/base indicator

Student Graphic Organizer

Template for Final product: Student presentation

Objectives: The students will design and conduct an investigation to find an appropriate "home-made" acid/base indicator.

III. Design your own reaction with indicator (2 class periods 90 minutes total)

Create a colorful display of at least 3 different colors that are not lighter versions of one color. One color must indicate a base and another color must indicate an acid. You must use household ingredients with an indicator you made yourself (hint: the grocery store has fruits and vegetables that may help you make indicator solutions.)

Additional Supports

Tools to meet the needs of all learners (SEL, ELL, SPED)

Graphic organizers are provided for students so they have scaffolding to help them complete the work.

Materials

Include links to all files within this ETP

-Phenolphthalein

- universal indicator
- graduated cylinder
- baking soda
- distilled white vinegar
- distilled water
- various foods to create home-made indicators
- beaker
- laptop/chromebook for student use
- clear cups/glass/beakers

Part 1 - Phenolphthalein Intro Demo and Observations

[Teacher Phenolphthalein demo video](#)

[Student Observation Sheet](#)

Part 2 - Rainbow Universal Indicator Reaction Scaffolded Lab activity

[Universal Indicator demo video](#)

[Student Graphic organizer](#)

Part 3 - Designing an acid/base indicator open ended lab activity

[Student Graphic Organizer](#)

[Template for Final product: Student presentation](#)

References

Ossevoort, Miriam, et al. "Exploring Scientific Research Articles in the Classroom – Science in School." *Science in School*, 5 Jan. 2023, www.scienceinschool.org/article/2012/research/.

HST. "Acids and Bases: Fun Experiments to Try at Home." *Home Science Tools Resource Center*, 29 July 2021, learning-center.homesciencetools.com/article/acid-base-reactions-ph-experiments/.

Keywords (2-4)

Nature of science
Experimental process
Acid base reactions
Chemical reactions