Science, Technology, Engineering and Math Objectives:

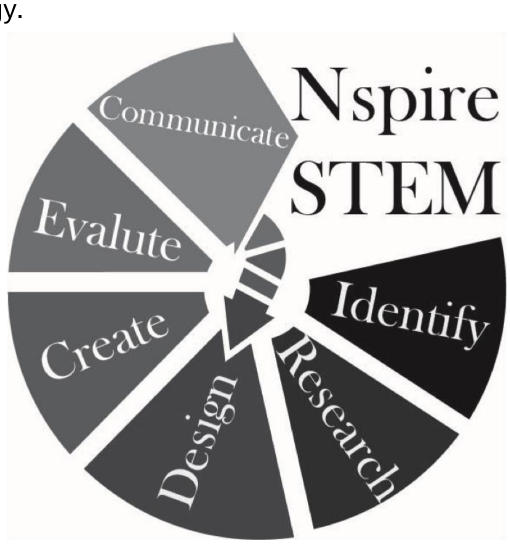
- Students will research science topics including:
  - The nature of acids and bases
  - pH indicators
  - Proper set up and use of laboratory apparatus
- Students will set up and run an experiment on a chemical titration of an acid with a base.
- Students will use appropriate technology to evaluate their design, collaborate with colleagues and present their findings.
- Students will use mathematical processes of:
  - Graphing
  - Non-linear modeling
  - Determination of an equivalence point
  - Data analysis

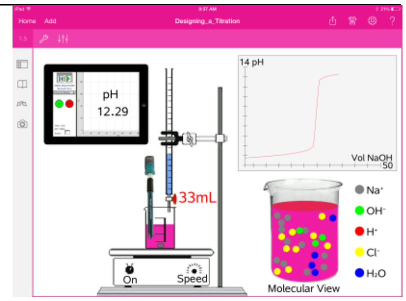
Vocabulary

- Acid and Base
- pH
- Titration
- Equivalence point

About the Lesson

- This is a project based STEM activity that will engage your students in the engineering design process while using TI-Nspire technology.





Tech Tips:

- This activity includes screen captures taken from the TI-Nspire App for iPad. It could also be used with the TI-Nspire family of products including TI-Nspire handheld and software and a traditional wired Vernier temperature sensor. Slight variations to these directions may be required if using other technologies besides the iPad app.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:
Student Activity
- Designing_a_Titration_Student.doc
- Designing_a_Titration_Student.pdf
- Designing_a_Titration.tns

Activity Materials Per Student Group

- Compatible TI Technologies: TI-Nspire™ Apps for iPad®
- Vernier™ Go Wireless® pH Sensor
- .10M HCl solution
- .10M NaOH solution
- Phenolphthalein
- 250 mL beakers
- Burets and Clamps
- Ring stands
- Stir plates and magnetic stir bars, if available
- Safety googles

Safety Tip: Always use safety goggle and always wash hands when working through this activity.

Safety Tip: Although recommended acids and bases are weak concentrations, be sure to know the appropriate procedures for spillage in the lab.

Discussion Points and Possible Answers

The Engineering Problem

Your Company designs and produces medicines. Your project manager has tasked you with designing a new medicine that will relieve acid indigestion for people who suffer acid reflux disease. Your task is to design a new antacid that will neutralize excess stomach acid and to support you product with test data.

What happens at the molecular level during a titration of a strong acid with a strong base?

STEM Career

A chemical engineer is a person who generally deals with the application of chemical principles to convert raw materials into a variety of products and deals with the design and operation of manufacturing plants and equipment. They work in the fields of petroleum, pharmaceuticals, food and beverage and biotechnology. It is a branch of engineering that may involve the design, production and the operation of chemical plants that produce gasoline, medicines and processed food and drink.

1. **Identify:** State your engineering goal here. What are you trying to make? What does it need to accomplish? How will you evaluate how well it works?

   Answers will vary

2. **Research:** Use appropriate internet resources to learn about your engineering goal. Your research may include building processes, constraints, potential problems, sources of error, materials, time limits, and scientific principles that apply to your design.

Answers will vary

> **Teacher Tip:** If your students are familiar with a titration you may skip this step.

A titration is a volumetric analysis used to measure the amount (moles) of an unknown acid or base.

Next, you will set up a data collection experiment using a titration apparatus and a GoWireless pH Sensor

- Follow the instructions on how to set up the GoWireless pH Sensor.
- Put 25 mL of .10 M HCl into a 250 mL beaker.
- Put a few drops of phenolphthalein into the beaker with the HCl.
- Set up the Sensor to collect data in Events with Entry mode. Rather than simply having "Event" as the descriptor, you can change it to "drops" or "mL".
- Collect your first data reading in the beaker of acid and phenolphthalein.
- Add a squirt of .10 M NaOH to the beaker, swirl the contents of the beaker and then collect another data reading once the pH reading has stabilized on your iPad.
- Continue to add squirts and take collect data readings until the pH has leveled off.
- At this point, you can stop the data collection and begin the analysis of your data.

a) Describe the shape of your graph.

Suggested Answer: An "S" curve or logistic curve.

b) What was the initial pH?

Sample Answer: About 3-4

c) What was the final pH?

Sample Answer: About 10 - 12

d) Describe what was happening, in terms of the molecularly, during the steepest part of the graph.

Sample Answer: The number of H^+ ions are equal to the number of OH^- ions and have reacted to form H_2O (water).

e) In which section of your graph was the [H+] greater than the [OH-]?

Sample Answer: Between the start and the vertical section, where the pH is less than 7 and the graph rises slowly.

f) In which section of your graph was the [H+] less than the [OH-]?

Sample Answer: In the section after the steep vertical and the end, where the pH is greater than 7 and the graph rises slowly.

g) In which section of your graph was the [H+] pretty equal to the [OH-]?

Sample Answer: The steep region where the graph is most vertical.

h) What was the approximate pH of the solution in the beaker before starting the titration?
Answer: pH of about 1

i) Was the original solution in the beaker an acid or a base? How do you know?

Answer: Acid. pH was 1.

j) What chemical was in the buret?

Answer: NaOH

k) Approximately how many mL of NaOH needed to be added to the beaker before a dramatic change in pH was noticed?

Answer: About 25 mL

l) Besides the dramatic jump in pH, what else did you notice at that point?

Sample Answer: The graph shot up; the contents of the beaker turned pink.

m) Besides a color change, how did the contents of the beaker differ at the end of the titration compared to the beginning?

Sample Answer: At the beginning, there were only H+ ions and Cl- ions in the beaker; at the end, there were Na+ and OH- ions.

3. **Design/Prototype:** Once you have researched the engineering goal, create a plan for making your design. Your design may include drawings, labels, materials lists, cost lists, etc. The prototype may be a first-time attempt at making the final product to learn how to put it together. Share your design and prototype with others, listen to their suggestions and decide for yourself the very best design.

Answers will vary

4. **Create/Build:** Use your design and prototype experience to make your product to your specifications.

Answers will vary

> **Teacher Tip:** Students may choose a combinations of $CaCO_3$, $Mg(OH)_2$, $NaHCO_3$ or Na_2CO_3 solids to create their antacids. Total mass of mixtures should be less than .5 grams. Their design should be placed in a beaker with about 50mL of water in order to test with titration.

5. **Evaluate/Test:** Use the titration setup and the Vernier Go Wireless™ pH probe to justify which one is the best. Be sure the instructor approves each setup and mixture before proceeding at this step

Answers will vary

6. **Analyze:** Analyze the performance of each antacid. An appropriate analysis might be the number of mL of .10M HCl that is neutralized per gram of antacid.

Answers will vary

a) Write a balanced chemical equation for the neutralization of each of the potential antacid bases.

Sample Answer:

i. $CaCO_3 + 2\ HCl \rightarrow H_2CO3 + CaCl_2$ Next, $H_2CO_3 \rightarrow CO_2 + H_2O$

ii. $Mg(OH)_2 + 2\ HCl \rightarrow 2\ H_2O + MgCl_2$

iii. $NaHCO_3 + HCl \rightarrow H_2CO_3 + NaCl$ Next, $H_2CO_3 \rightarrow CO_2 + H_2O$

iv. $Na_2CO_3 + 2\ HCl \rightarrow H_2CO_3 + 2\ NaCl$ Next, $H_2CO_3 \rightarrow CO_2 + H_2O$

b) Consider the amount (number of moles) of HCl in 50mL of .1M HCl solution, along with the mole ratios from the above balanced equations. Calculate the amount of each antacid that should be used in your test titrations.

Answer:

i. 50ml x (1L/1000mL) x (.10HCl/1L) x ($CaCO_3$/2HCl) x (100.g/$CaCO_3$) = .25 g

ii. 50ml x (1L/1000mL) x (.10HCl/1L) x ($Mg(OH)_2$ /2HCl) x (58.3g/$Mg(OH)_2$) = .15g

iii. 50ml x (1L/1000mL) x (.10HCl/1L) x ($NaHCO_3$/HCl) x (84.0g/$NaHCO_3$) = .42g

iv. 50ml x (1L/1000mL) x (.10HCl/1L) x (Na_2CO_3/2HCl) x (106g/Na_2CO_3) = .27g

c) How will you know when the acid is neutralized?

Sample Answer: The curve will quickly rise and become an inflection point on the S curve. This point is where the moles of acid and antacid are equal.

d) List all of the factors that you think would make a good antacid.

Answers will vary

e) Based on the result of your test, what would you change about your antacid?

Answers will vary

7. **Refine:** After you have made your design and tested it, think about what you like and do not like about the design. Show your product to your friends and family and listen carefully to their comments. Include the best suggestions from your customer feedback into your design and rebuild your deign to make it better.

   Answers will vary

8. **Present:** Prepare a brief presentation of your creation in a cloud-based collaborative environment such as Google Drive. Share your presentation with your teacher, family and friends.

   Answers will vary

Wrap Up

When students are finished with the activity, have them email the .tns file to you or upload it to a cloud based collaboration system.

Assessment

- Formative assessment could consist of questions posted to students during the process to determine if they are gathering the necessary information to understand the key vocabulary.
- Summative assessment will consist of the overall quality of the design and student explanation of their model and findings.