This segment is useful in connecting antacid and acid reflux to the chemistry of acids and bases, relating the strength of acids and bases to their percent dissociation in water and developing a particulate diagram that explains the concepts of the Arrhenius and Bronsted-Lowry model of the acids and bases as well as the concepts of pH and neutralization. This is part 1 of 2 instructional segments for solutions.	
Student Science Performance	
Grade or course: 9-12 Chemistry	**Title:**
Topic: Solutions, Acids & Bases	Exploring Acids and Bases

Performance Expectation for GSE:

SC6. Obtain, evaluate, and communicate information about the properties that describe solutions and the nature of acids and bases.

a. Develop and use a model to illustrate the process of dissolving in terms of solvation versus dissociation.

f. Use mathematics and computational thinking to compare, contrast, and evaluate the nature of acids and bases in terms of percent dissociation, hydronium ion concentration, and pH.
(*Clarification statement*: Understanding of the mathematical relationship between negative logarithm of the hydrogen concentration and pH is not expected in this element. Only a conceptual understanding of pH as related to acid/basic conditions is needed.)

g. Ask questions to evaluate merits and limitations of the Arrhenius and Bronsted-Lowry models of acids and bases.

h. Plan and carry out an investigation to explore acid-base neutralization.

Performance Expectations for Instruction:

1. Explain with supporting evidence the observed phenomena of using an antacid to neutralize an acidic stomach (group research on acid reflux, acids, bases, etc).
2. Design an investigation to explore the chemical properties of acids and bases and relate these macroscopic observations to infer the structure of the particles on the microscopic level.
3. Analyze data to classify unknown substances as acidic, basic or neutral and provide supporting evidence from the investigation to back this argument.
4. Develop a particulate diagram or model, based on research and experimentation, to explain the differences between a weak acid and a strong acid (or base) in an aqueous solution.
5. Formulate questions to research and construct an explanation for the color changes that occurred when hydrochloric acid was added to a solution of antacid with universal indicator.
6. Design a titration investigation in order to collect evidence to support this explanation for acid-base neutralization at the particulate level.
7. Develop a particulate diagram model and explanation paragraph to communicate the process of acid-base neutralization.

Additional notes on student supports

Materials

Teacher Demo-Neutralization Reaction of an Antacid

Magnesium hydroxide (laxatives containing magnesium hydroxide may be used); 3M Hydrochloric acid (HCl); Universal indicator; 1 L Beaker; Ice; pipet; and magnetic stir plate (or stirring rod).

Neutralization Investigation:

Burette (or droppers/pipettes); 0.1 M Sodium hydroxide (NaOH); 0.15 M Hydrochloric acid (HCl); Phenolphthalein or other suitable indicator; pH probes (or universal pH paper); and Erlenmeyer flask.

Safety: ANSI Z87.1 chemical splash-proof goggles, aprons and gloves

Student Investigation - Acid-base chemical properties

Substances to analyze (vinegar, lemon juice, 1 M Hydrochloric acid (HCl), 1 M Sodium hydroxide (NaOH), deionized water, baking soda ($NaHCO_3$) solution, juice or soda drinks, hydrogen peroxide (H_2O_2), potassium

iodide (KI) solution); Indicators (Universal pH paper, litmus paper and any liquid indicator such as bromothymol blue, thymol blue, methyl red, phenol red, etc); **Testing equipment** - metal shavings, powdered calcium chloride ($CaCl_2$), conductivity tester, reaction well plates, pipettes, splints, small beakers; unknown substances - antacid, sports drink, 0.1M Hydrochloric acid (HCl)	
Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.	
Engaging Learners	**Phenomenon** **Teacher Demo:** Neutralization Reaction of an Antacid Students observe how the addition of HCl to magnesium hydroxide solution and universal indicator solution results in a variety of color changes.
	Obtaining 1. Students individually record their observations and come up with questions that they would like to answer based on their observation. 2. Class discussion on what questions should be researched. *Some suggestions:* ○ *What causes acid reflux?* ○ *What acid is involved?* ○ *What type of substance is magnesium hydroxide?* ○ *How does adding a base to an acid help reflux?* ○ *What are the differences in structure between acids and bases?* ○ *What are some models of acid and bases? (Limit students to just the Arrhenius model and the Bronsted-Lowry Model. Please note Lewis Model is not in the curriculum).* 3. In groups, students obtain information about their question (*Teacher may need to guide to make sure question is relevant to curriculum.*) on acids and bases (online resources or textbooks).
	Evaluating In groups, students will write a paragraph on a shared document (electronically) or platform that summarizes their research. This sharing allows the teacher to evaluate the information and correct misconceptions or guide the students to further research, if needed. **Teacher Tips for ALL discussions during lesson:** ● *Very important to get students to write down their explanations. When they know their words will be read, it makes them more thoughtful about their research and analysis and they will spend more time on it.* ● *Sometimes ask adjacent students to read explanations as students are tempted to change their words based on prior students' explanations.* ● *Ask questions so you can address misconceptions.* ● *Can get students to keep tally of responses on board, if relevant to the activity.*

	Communicating The research collection is shared with all students so they can all have access to the class research. Alternatively, the information could be recorded on the board or whiteboards allowing groups to present the information to the class.
Exploring	*Obtaining* 1. The teacher asks the students (*in groups of 2-3)* to design an investigation to gather evidence to support their research. Students will investigate the chemical properties of acids and bases and link this behavior to a particulate model of the structure of acids and bases. 2. Students are asked to first identify a variety of household materials (*sample list included in table below*) as acids, bases or neutral solutions. They are provided with testing materials such as indicators, conductivity testers, calcium carbonate powder, and powdered metal shavings. (Magnesium is recommended.) *To ensure safe laboratory practices, the teacher should give the students instructions on handling acids and bases as well as testing techniques.* a. *Students need to wear ANSI Z87.1 chemical splash-proof goggles, aprons and gloves. Acids and bases can be toxic by ingestion and inhalation and are corrosive to the skin and eyes.* *b. A few drops of each solution to be tested is placed in well plates. Each sample is investigated by conducting the following tests:* *i. Recording observations when a few pieces of metal shavings are dropped into solution.* *ii. Recording color change when a few drops of liquid indicator are dropped into the solution.* *iii. Recording the color changes when paper indicators strips are immersed into the solution.* *iv. Recording observations when a pea-sized amount of calcium carbonate is dropped into the solution.* *v. Recording the level of conductivity when a conductivity probe is immersed into the solution.* 3. Students, in groups of 2-3, will develop a data table to collect their data. 4. The students will analyze their data and determine what chemical properties are important in characterizing acids and bases. 5. The teacher will give the students three unknown solutions to test and classify based on their data and characterization of acids and bases. 6. The students, individually, will develop an argument to support their claims of whether the substance is acid, base or neutral.
	Communicating • Students will communicate their data in student-developed data tables. • Students will share their data tables and conclusions with other groups allowing them to revise and modify their investigation as

they see fit.
- Students will individually write an argument as to whether each unknown solution is acidic, basic or neutral and will supply evidence to support their claim from their investigation.
- Each group will come up with questions they would like to answer based on their data. *Examples of such questions include:*
    - *Why do some acids react more vigorously than others to metal and carbonates?*
    - *Why are some acids or bases stronger conductors?*
    - *What is the meaning of the numbers that the pH colors correspond to? How does this relate to the structure of the acid and the base?*

Evaluating
Here is a link to a student version of this lesson which will guide students and can be submitted or reviewed by the teacher as the investigation progresses.
EXPLORING ACIDS and BASES - Student Handout
Teachers should encourage student groups to evaluate each other's data tables and paragraph supporting students' claims. A Sample Data Table is included.

Substance	Indicator	pH paper	Litmus	Reaction with metal	Reaction with carbonate	Conductor	Acid, base, or neutral?
Vinegar							
Lemon juice							
Water							
Baking soda solution							
Soft drink solution							
Diluted drain cleaner (use 1M NaOH)							
1.0 M HCl							
Hydrogen peroxide							
KI solution							

<table>
<tr>
<td></td>
<td>
A sample analysis table is shown below but students could choose other properties to characterize substance, based on their data.
<table>
<tr><th>Unknown</th><th>pH paper</th><th>Carbonate reaction</th><th>Metal reaction</th><th>Acid, base, or neutral?</th></tr>
<tr><td>A</td><td></td><td></td><td></td><td></td></tr>
<tr><td>B</td><td></td><td></td><td></td><td></td></tr>
<tr><td>C</td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
</tr>
<tr>
<td rowspan="3">Explaining
Finalizing Model</td>
<td>Obtaining
Students, in groups, conduct more research and use data from their investigation to come up with a particulate diagram that models the behavior of weak and strong acids (or bases) in an aqueous solution.</td>
</tr>
<tr>
<td>Evaluating
Students, in groups of 2-3, should utilize their research, data and their prior knowledge of making particle diagrams to draw a cross-sectional particulate diagram of a weak acid and a strong acid (or base).
Diagrams should include the following:
Strong acid:

10 or more circles representing H^+ ions
10 or more circles representing the anion ex. Cl^-
2 circles joined representing a solitary HCl molecule
White background may be used to indicate water molecules in all diagrams.

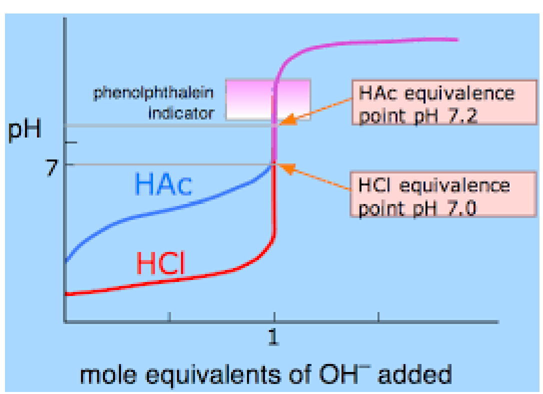
Weak Acid:

1 circle representing H^+ ions
1 circle representing anion ex. F^-
10 circle pairs representing the HF molecule

Strong base

10 or more circles representing OH^- ions
10 or more circles representing the cation ex.Na^+
2 circles joined representing a solitary NaOH molecule

</td>
</tr>
<tr>
<td>Communicating
Groups will share their models with each other and individually write a paragraph explaining how their models explain differences in pH and conductivity between weak and strong acids.</td>
</tr>
<tr>
<td>Elaborating</td>
<td>Phenomenon</td>
</tr>
</table>

Applying Model to Solve a Problems	Color changes were observed in initial demonstration when HCl was added to the magnesium hydroxide solution. Students now know that color changes imply that pH is changing. Questions to initiate discussion: ● What changes are happening within your model of a strong base to cause the color change in the demonstration? ● What changes are specifically occurring on the molecular level with the acid and the base? ● What mathematical relationship exist to quantify the observed changes and what does it represent? ● Why does the system change back to the original color repeatedly and then eventually stop with excess acid? ● What model of particles could be used to explain your observation?
	Obtaining Give students 0.10 M Sodium hydroxide (NaOH) and 0.15 M Hydrochloric acid (HCl) along with indicator (phenolphthalein) and either universal pH paper or pH meters to investigate the changes that occur when strong bases are added to strong acids. This will allow students to gather evidence to support their model of neutralization. *If burettes are not available, teacher could use pipettes/droppers). Follow all safety rules when using strong acids and bases.* Two websites with articles to help teachers and/or students with performing titrations: [Acid-base Titration] OR [Chem Teacher-- Titration]
	Evaluating Students evaluate their data and use it to graph a pH curve, construct an explanation for the shape of the pH curve and relate that curve to rearrangements on the molecular level. Students will draw a model to represent the neutralization at a molecular level. Teachers will evaluate the pH curve and particulate model of neutralization. *A sample titration curve is shown below to help with teacher evaluation. In the diagram, the red curve represents the titration of HCl with NaOH. Millimeters or drops of NaOH should be represented on the X-axis with pH of the solution in the Erlenmeyer on the Y-axis.* *[Sample pH Curve and Particulate Model of Neutralization]*  *("File:Weak.png." Wikimedia Commons, the free media repository. 8*

	Mar 2014, 21:41 UTC.)
	Communicating Students individually communicate their arguments and evidence using google docs. They use their model to illustrate and support their explanation.
Evaluation	***Assessment of Student Learning***
	• *Data table identifying unknown substances as acidic, basic or neutral along with an argument and evidence to back this claim. This table is shown in an earlier evaluation step.* • *Model or particle drawing of a weak and strong acid (base). Sample criteria for this are also given in an earlier evaluation step. This should reference percent dissociation of the molecules.* • *Titration curve - also shown in earlier evaluation stage.* • *Particulate diagram showing major species in solution during the neutralization of a strong acid with a strong base. This diagram should include - H+, OH- and H2O.* • *Individual narrative which describes the process of acid/base neutralization. This should reference pH and show a conceptual understanding of pH (the curriculum does not require relating this to the negative logarithm of the hydrogen ion concentration).* *Include samples of formative, summative, and worksheet/journal ideas. Remind teachers about when and what is for a grade and when and what is for teacher information to guide lessons.*
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Developing and using models • Using mathematical and computational thinking • Asking questions and defining problems • Planning and carrying out investigations
Crosscutting Concepts	• Cause and effect • Systems and system models • Scale, proportion and quantity • Structure and function
Disciplinary Core Ideas	From a ***K-12 Framework for K-12 Science:*** • PS1.A: Structure and Properties of Matter • PS1.B: Chemical Reactions • PS2.B: Types of Interactions

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should consider giving students an organizer for observations, questions and then research.
2. The teacher should consider giving students question stems to help with question generation.
3. The teacher should have clear and consistent guidelines for class discussions. This should make students feel more comfortable and be more likely to participate.
4. The teacher can help students determine which questions are most related to the standard and the lesson.
5. The teacher should consider giving students sources to guide their research.
6. The teacher should provide multiple ways for students to express their knowledge. These formats could include in writing, drawing or designing a play.
7. The teacher should consider options for students to share information. These options could include electronically, presentations or gallery walks.

8. The teacher should consider a formative assessment. Then the teacher can review, re-teach or enrich as needed.

Exploring:

1. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
2. The teacher should consider providing students with an organizer to assist in planning their investigation.
3. The teacher should discuss with students what might constitute evidence in this lab activity.
4. The teacher should review lab safety rules with students.
5. The teacher should consider providing a data table as necessary for the students.
6. The teacher may need to explicitly go over how to record data in the data table.
7. The students should be allowed to compare their identifications of the solutions. The students should be sure to use evidence when talking to another group about how they classified a solution.
8. The teacher should provide multiple ways for students to express their knowledge. These formats could include in writing, drawing or designing a play.
9. Students may need additional time to develop their argument.

Explaining:

1. The teacher should use intentional and flexible grouping to group students. Best practices is to use data to drive student grouping.
2. The teacher should provide multiple ways for students to express their knowledge. These formats could include in writing, drawing or designing a play.
3. The teacher may need to explicitly teach how to draw a particulate diagram of an acid or base. The teacher may need to draw a diagram to show students, then have the students practice within their groups and then have them practice individually.
4. The teacher should consider format options for sharing. These formats could include sharing electronically, gallery walks or presenting.

Elaborating:

1. The teacher should have clear and consistent guidelines for class discussions. This should make students feel more comfortable and more likely to participate.
2. The teacher should remind students of lab safety procedures.
3. The teacher should consider providing an organizer for data, observations and research.
4. The teacher should consider providing sources to students to use in their research.
5. The teacher should consider showing students how to analyze data. The teacher can use an unrelated data set and have students draw conclusions based on the data set provided. Then have the students try it within their group with the data that they gathered in the lab.
6. The teacher should provide multiple ways for students to express their knowledge. These formats could include in writing, drawing or designing a play.
7. The teacher should consider showing students a pH curve to compare their pH curve to after they have constructed it.

Evaluating:

1. The teacher should consider providing multiple ways for students to communicate their knowledge of the material. These formats could include writing, drawing or designing a presentation.
2. Students may need additional time to complete their assignments.

EXPLORING ACIDS & BASES - Student Handout

1. **Phenomenon:** What changes result when hydrochloric acid is added to magnesium hydroxide solution (laxatives containing this compound may be used)?

Observations:

Questions: *Formulate questions to research and develop an understanding of the chemistry behind this phenomenon.*

Research to answer class questions:

2. Investigation:

Your Task:

Many household materials are acids or bases. Develop, analyze and generate an acid-base classification chart using household materials that allows you to learn more about their chemical properties and also to categorize an unknown substance as acid or base based on observable chemical properties.

Phenomenon: Students observe chemical changes (such as color change and bubbles) in reactions characteristic of acid and bases.

Guiding Question:

How can the chemical properties of an aqueous solution be used to classify the substance as an acid or base?

Gathering/Introduction:

Acids and bases represent two very important classes of chemical compounds. They play an important role in your biology (ex. amino acids; Digestion of food), in atmospheric processes (ex. acid rain); and in geologic processes (cavern formation). Some of the unique chemical properties of acids and bases involve how they interact with metals, carbonates and indicators. An indicator is a dye or pigment that changes color in an acid and/or a base. Cabbage juice is an indicator that you can make at home.

Materials Available:

Household Acids/Bases	Indicators	Equipment/Testing	Unknown Solutions
Vinegar	Thymol Blue	Conductivity tester	A
Lemon Juice	Bromothymol blue	Reaction well plates	B
Deionized water	Phenol Red	Small beakers	C
Baking soda solution	Litmus paper	Pipets	
Soft drink (aqueous solution)		Powdered metal ex Mg shavings (testing)	
Diluted drain cleaner solution (diluted NaOH – 1M)		$CaCO_3$ powder(testing)	
1 M HCl solution		Splints	
Hydrogen peroxide			
Potassium iodide solution			

Safety:

All acids & bases are corrosive and can be toxic. Wear goggles, gloves & apron. Wash hands frequently and when finished in the lab with soap and water. Handle all glassware with care.

Questions to consider in developing your investigation:

- What type of patterns are you observing and how can they be explained?
- How will you minimize error?
- How will you organize your data table?
- How did you analyze your data?
- What type of testing will you need to make?
- How will you identify the unknowns?

3. Data Organization:

Generate a data table to organize the results of your analysis:

4. Analyze your data. Some important questions to consider:

- What properties are important in distinguishing acids, bases and neutral materials?

Generate a data table to collect data on the unknown substances. Decide what properties are important in classifying.

Unknown				
A				
B				
C				

5. Argument for identification of Unknown Substances:

Unknown Substance Classification **Acid, Base or Neutral**	**Argument to Support your Claim** (*Support with data*)
A ___________	
B ___________	
C ___________	

6. Analysis Questions:

1. For A-E below, identify the compounds as "acidic", 'basic" and/or "neutral" based on the properties given:

Compound A does not conduct electricity ___________________

Compound B dissolves metals ___________________

Compound C has a strong, acrid odor ___________________

Compound D turns litmus blue ___________________

Compound E bubbles when baking soda is added ___________________

What questions would you like to answer based on your data?

2. An unknown solution conducts electricity but the indicators thymol blue & bromophenol blue do not change color when they are added to it. Should this solution be classified as an acid or a base. Justify your answer.

3. Choose **<u>either</u>** a strong acid (HCl) OR a strong base (NaOH) and draw a model that represents, from a particulate view, the behavior of the particles in an aqueous solution. Be sure to label all particles. *(Draw in pencil as your model may be revised as you research and communicate with other students.)*

4. HF is a weak acid. Draw another particulate diagram that models the behavior of a weak acid in water. Be sure to take into consideration your research on percent dissociation. Label all particles. *(Draw in pencil as your model may be revised as you research and communicate with other students.)*

Phenomenon: Initial demonstration showing the color changes that resulted when hydrochloric acid was added to magnesium hydroxide solution.

7. Elaborate: Relate the structure of acids & bases to the color changes that are occurring in the demo:

Come up with a model or particulate diagram that shows what is happening in the solution on a molecular level. Some questions to consider in refining your model:

- What mathematical relationship exist to quantify the observed changes and what does it represent?
- Why does the system change back to the original color repeatedly and then eventually stop with excess acid?
- What model of particles could be used to explain your observation?

Return to Instructional Segment

Sample Data Table

Substance	Indicator	pH paper	Litmus	Reaction with metal	Reaction with carbonate	Conductor	Acid, base, or neutral?
Vinegar							
Lemon juice							
Water							
Baking soda solution							
Soft drink solution							
Diluted drain cleaner (use 1M NaOH)							
1.0 M HCl							
Hydrogen peroxide							
KI solution							

Return to Instructional Segment