Connected Chemistry

Acids & Bases Unit

Lesson 1: Arrhenius Theory

Student's Lesson at a Glance

Lesson Summary

This lesson contains four activities that overview the Arrhenius theory of acids and bases. Following a Connecting Activity, the teacher performs a demonstration on two unknown clear liquids to determine the pH before and after mixing. During this time, students make predictions about what they think is happening on a submicroscopic level. Students explore three sets of reactions via the computer simulations. Students are asked to create sketches and record observations. The lesson concludes with a teacher-facilitated discussion of the limitations of Arrhenius theory.

SWBAT (Students Will Be Able To)

- Know that the Arrhenius theory states that acids generate H^+ ions (H_3O^+) and bases generate OH^- ions in water
- Apply Arrhenius theory to simulated reactions and identify the theory's limitations

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in **bold**. Additional words that will expand your scientific vocabulary are in *italics*.

CCC Reminder

- Don't forget to follow the CCC sketching observation protocol. When appropriate in your written observations, include the location, motion, interaction, and appearance of molecules.
- Ions will have halos in the simulation. When drawing keys for sketches, make sure to include halos for ions only.
- Hydroxide and hydronium are easily confused when naming ions. Hydroxide ions are OH^- and hydronium ions are H_3O^+.
- You will need to know how to write ionic equations. Review your notes in Solutions and Reactions unit for help.

Notes

Homework

Upcoming Quizzes/Tests

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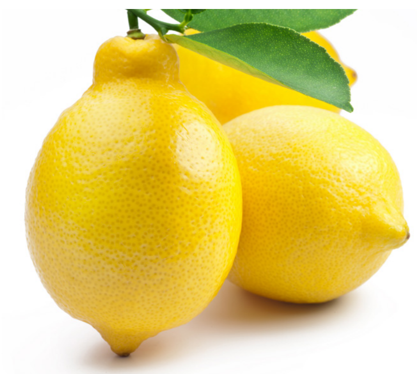
Activity 1: Connecting

1. What do you think is the difference between an acid and a base?

2. What characteristics do you think are common in foods that are acidic?

3. Why is it nearly impossible to measure the concentration of hydrogen ions (H^+) in a solution?

Acids and bases are everywhere in our daily lives. Oranges and lemons contain citric acid, while antacids contain magnesium hydroxide. Recall that the definition of acids and bases has a relationship with the concentration of hydronium ions (H_3O^+). In this lesson, we will explore the behavior and definition of acid and base molecules at the submicroscopic level.



Many years ago, chemists attempted to define acids and bases on the submicroscopic level by proposing three major theories that explained macroscopic observations in the laboratory. In the next two lessons, you will examine these theories – the Arrhenius, Brønsted-Lowry and Lewis theories – of acids and bases. Your observations of teacher demonstrations, formulas, and simulations will help you learn the differences and relationships among these three theories according to the submicroscopic behavior of acidic and basic substances.

In 1884, Svante Arrhenius proposed a theory that defined acids and bases from his study of ion formation in aqueous solutions. He studied the dissociation of ionic compounds in water. Recall that dissociation is the process by which ionic compounds separate into their component ions. Arrhenius constructed definitions for acids and bases from his data:

- An **acid** is a substance that dissociates in water to produce one or more hydrogen ions (H^+).
- A **base** is a substance that dissociates in water to produce

one or more hydroxide ions (OH^-).

Recall that today, chemists have discovered that H^+ ions only exist for very extremely short time periods before forming H_3O^+ ions in water in the following equilibrium reaction.

$$H^+ (aq) + H_2O (l) \rightleftharpoons H_3O^+ (aq)$$

Given this, modern version of the Arrhenius' definition is as follows:

- An **acid** is a substance that dissociates in water to produce one or more hydronium ions (H_3O^+).
- A **base** is a substance that dissociates in water to produce one or more hydroxide ions (OH^-).

4. Using the modern Arrhenius' definition of an acid, identify the acid in the following reaction:

$$HNO_3 (aq) + H_2O (l) \rightarrow H_3O^+ (aq) + NO_3^- (aq)$$

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5. Arrhenius' definition of acids and bases was partially incorrect. In science, it is common for scientists to later revise their explanations or solutions to a problem. Why is the process of trial and error important in scientific research?

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Activity 2: Demonstration

Demonstration: *Your teacher will run a series of demonstrations that involve acidic and basic solutions. Answer the following questions as your teacher conducts each demonstration.*

Clear liquid #1	**Clear liquid #2**
6. What is the pH of this solution? **acidic or basic**	9. What is the pH of this solution? **acidic or basic**
7. What color is the litmus paper when it touches the liquid? ____________________	10. What color is the litmus paper when it touches the liquid? ____________________
8. What happens when the indicator is added to the solution? ____________________ ____________________ ____________________ ____________________	11. What happens when the indicator is added to the solution? ____________________ ____________________ ____________________ ____________________

Mixture of liquid #1 and liquid #2

12. What is the pH of this solution? **acidic or basic**

13. What is the color of the litmus paper when it touches the liquid?

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14. What happens when the indicator is added to the solution?

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15. Sketch how you think each solution appears at the submicroscopic level before and after mixing. Be sure to include a key.

	Before Mixing	**After Mixing**
Submicroscopic Sketches	**HCl (aq)**	
	NaOH (aq)	
	Key	

16. Why might it be difficult to classify different substances as acids or bases based only on how they appear on the macroscopic level?

Activity 3: Simulation of Arrhenius Theory

Set 1: *Use Simulation 1, **Set 1***

For each of the following sets:

- *Create a submicroscopic sketch before the reaction is started.*
- *Play the simulation for 15 seconds, pause the simulation, and create a submicroscopic sketch.*
- *Record your observations and create a key.*

	Before (at time 0 seconds)	**After** (at time 15 seconds)
Submicroscopic Sketch		
Complete Ionic Equation		
Observations		
Key		

Using your sketches and observations, answer the following questions.

17. Were hydronium ions (H_3O^+) produced when HCl dissociated in water? If so, which substance in water created the H_3O^+ ions?

18. Were hydroxide ions (OH-) produced when HCl dissociated in water? If so, which substance in water produced the OH- ions?

19. Why is water included in the chemical equation?

20. Is HCl an Arrhenius acid or an Arrhenius base? *Support your claim with evidence.*

Set 2: *Use Simulation 1, **Set 2***

	Before (at time 0 seconds)	**After** (at time 15 seconds)
Submicroscopic Sketch		
Complete Ionic Equation		
Observations		
Key		

Using your sketches and observations, answer the following questions.

21. Were hydronium ions (H_3O^+) produced when NaOH dissociated in water? If so, which substance in water created the H_3O^+ ions?

22. Were hydroxide ions (OH^-) produced when NaOH dissociated in water? If so, which substance in water produced the OH^- ions?

23. Why is water included in the chemical equation?

24. Is NaOH an Arrhenius acid or Arrhenius base? *Support your claim with evidence.*

Set 3: *Use Simulation 1, **Set 3***

	Before (at time 0 seconds)	After (at time 15 seconds)
Submicroscopic Sketch		
Complete Ionic Equation		
Observations		
Key		

Using your sketches and observations, answer the following questions.

25. Were hydronium ions (H_3O^+) produced in the reaction? If so, which substance in water created the H_3O^+ ions?

26. Were hydroxide ions (OH^-) produced in the reaction? If so, which substance in water produced the OH^- ions?

27. What would you expect the final pH of the solution to be after mixing? *Support your claim with evidence.*

Activity 4: Teacher Facilitated Discussion

28. How are the reactions in set 1 and 2 different from the reaction in set 3 above?

29. In the reaction in set 3 above, if you evaporate all of the water from the solution that forms "after mixing," what compound would be left behind as a solid?

30. Do you think that all acids and bases dissociate in the exact same way when they are dissolved in water? *Support your claim with evidence.*

Lesson Reflection Question

31. What are the limitations of the Arrhenius theory?