Lesson Summary

This lesson contains six activities that offer an extensive overview of the Brønsted-Lowry and Lewis theories of acids and bases. Following a Connecting Activity, teachers can demonstrate how to use a submicroscopic simulation to differentiate the theories. In this simulation, the user can switch between the Brønsted-Lowry view of an acid-base reaction and the Lewis view of the same reaction. Students continue the lesson by creating working definitions of these two theories and further explore other reactions via computer simulations to better understand the different acid-base perspectives. Students create detailed sketches and record observations. Students apply the theories to identify different substances. In the final activity, students complete a Venn diagram of the theories as well as a final review of the limitations of each model.

SWBAT (Students Will Be Able To)

- Compare and contrast the Arrhenius, Brønsted-Lowry, and Lewis theories of acids
- Know that the Arrhenius theory states that acids generate $\text{H}^+$ ($\text{H}_3\text{O}^+$) ions and bases generate $\text{OH}^-$ ions in water
- Know that according to the Brønsted-Lowry theory of acids, acids donate protons and bases accept protons
- Know that the Lewis acids are electron acceptors and bases are electron donors

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

Do not forget to follow the CCC sketching observation protocol. When appropriate, include the location, motion, interaction, and appearance of molecules in your written observations.

- Ions will have halos in the simulation. When drawing keys for sketches, make sure to include halos only for ions.
- Hydroxide and hydronium are easily confused when naming ions. Hydroxide ions are OH\(^{-}\) and hydronium ions are H\(_3\)O\(^{+}\).
- This lesson includes activities that involve writing complete and net ionic equations. Review your notes from the Solutions and Reactions Units for help with writing equations.
- In Simulation 2, the Brønsted-Lowry view focuses on the submicroscopic level. For the Lewis view, you will focus on the subatomic level. You will be able to view the electrons on the subatomic level.
- A Venn diagram is a group of circles that overlap to compare and contrast ideas. Similarities are placed in the area where the circles overlap. Differences are placed on the areas where the circles do not overlap.

Notes

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Homework

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Upcoming Quizzes/Tests

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Acids & Bases - Lesson 2: Brønsted-Lowry and Lewis Theories

Activity 1: Connecting

1. In your own words, define an acid and a base.

Introduction to Brønsted-Lowry and Lewis Theories

The Arrhenius theory of acids and bases was a milestone in the history of chemistry. However, this theory is quite specific and does not account for all situations. There are three limitations with Arrhenius theory. First, Arrhenius defined an acid as a substance that produces free protons (H\(^+\)) in water. However, free protons do not exist for long in aqueous solutions since they form hydronium (H\(_3\)O\(^+\)) ions almost immediately with water.

Second, Arrhenius theory only explains the acidic or basic nature of substances that are soluble in water. The theory cannot explain whether substances that are insoluble in water or substances dissolved in solvents other than water are acidic or basic. For example, hydrochloric acid (HCl) is defined as an acid when it is dissolved in water according to Arrhenius theory. But when HCl is dissolved in a solvent other than water, it cannot produce hydronium ions because there are no water molecules present to react with H\(^+\) ions. In this case, it becomes unclear how to define HCl as an acid.

Finally, Arrhenius theory indicates that acids and bases must produce hydronium (H\(_3\)O\(^+\)) ions or hydroxide (OH\(^-\)) ions, respectively. However, some substances, such as aluminum trichloride (AlCl\(_3\)), do not contain hydrogen atoms of their own, yet still have acidic properties! Similarly, ammonia (NH\(_3\)) and a few other substances behave as bases even though they contain no hydroxide ions. Since the Arrhenius definition of an acid and base limits how a chemist classifies acids and bases, a new theory for classification was needed. Two new theories of acids and bases were proposed that are more general than the Arrhenius theory. These theories can account for the acidic and basic properties of many more substances.

In 1923 on nearly the same date, two chemists, Johannes Nicolaus Brønsted, a scientist from Denmark, and Thomas Martin Lowry, a scientist from England, published nearly identical theories about acids and bases. Because of this, both of the scientists are recognized as the discoverers of the Brønsted-Lowry theory of acids and bases. In formulating the theory, Brønsted stated that “... acids and bases are substances that are capable of splitting off or taking up hydrogen ions, respectively.” In other words, the Brønsted-Lowry theory defines acids as proton...
donors and bases as proton acceptors.

Sometime later, Gilbert Lewis recognized that there were limitations to the Brønsted-Lowry theory similar to the limitations of Arrhenius theory. Specifically, Lewis argued that the Brønsted-Lowry theory could not account for acidic or basic substances that did not have protons in their molecular structure. In 1938, he presented a theory that included substances that contained no protons. The Lewis theory classified acids and bases on the movement of pairs of electrons rather than the movement of protons. Lewis’ theory focuses on the subatomic level and defined acids as electron pair acceptors and bases as electron pair donors.

2. What is the difference between a Brønsted-Lowry acid and a Brønsted-Lowry base?

________________________________________________________________________

________________________________________________________________________

3. What is the difference between a Lewis acid and a Lewis base?

________________________________________________________________________

________________________________________________________________________

4. What do you think the relationship is between the Brønsted-Lowry and Lewis theories of acids and bases?

________________________________________________________________________

________________________________________________________________________

5. What are the limitations of the Brønsted-Lowry and Lewis theories?

________________________________________________________________________

________________________________________________________________________
Activity 2: Brønsted-Lowry and Lewis Theories

Demonstration: Use Simulation 2, Set 1

This simulation highlights the differences between the Brønsted-Lowry and Lewis theories on the submicroscopic level.

- Before your teacher plays the simulation, predict the products of the reaction in the chemical equation. Be sure to include phases.
- Your teacher will first select “Brønsted-Lowry” to demonstrate the theory.
- Before the reaction plays in the simulation, create a submicroscopic sketch of what you observe. Be sure to include a key.
- Your teacher will then play the reaction in the simulation.
- After the reaction stops, create a submicroscopic sketch of what you observed. Be sure to include a key.
- Your teacher will then change the view to “Lewis” to demonstrate acid and base behavior. You should repeat the procedure of sketching and recording your observations as you did with the Brønsted-Lowry view.
### View #1: Brønsted-Lowry theory

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
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</thead>
<tbody>
<tr>
<td><strong>Submicroscopic Sketch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chemical Equation</strong></td>
<td>( \text{NaOH} (s) + \text{HCl} (g) \rightarrow )</td>
<td></td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Key</strong></td>
<td></td>
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</tbody>
</table>
**View # 2: Lewis theory**

<table>
<thead>
<tr>
<th>Submicroscopic Sketch</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Equation</td>
<td>NaOH (s) + HCl (g) → ______________</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td></td>
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<tr>
<td>Key</td>
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</tbody>
</table>

*Chemical Equation* (same as previous page)

\[ \text{NaOH (s) + HCl (g)} \rightarrow \text{______________} \]
6. Which reactant donated a proton? *Explain your answer.*

___________________________________________________________________________________

___________________________________________________________________________________

7. Which reactant accepted a proton? *Explain your answer.*

___________________________________________________________________________________

___________________________________________________________________________________

8. Which reactant donated an electron pair? *Explain your answer.*

___________________________________________________________________________________

___________________________________________________________________________________

9. Which reactant accepted an electron pair? *Explain your answer.*

___________________________________________________________________________________

___________________________________________________________________________________

In the following two questions, circle all answers that are applicable.

10. In the reaction, HCl is a:
    a. Brønsted-Lowry acid
    b. Brønsted-Lowry base
    c. Lewis Acid
    d. Lewis Base
    *Support your answer with evidence.*

___________________________________________________________________________________

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11. In the reaction, NaOH is a:
    a. Brønsted-Lowry acid
    b. Brønsted-Lowry base
    c. Lewis Acid
    d. Lewis Base
    *Support your answer with evidence.*

___________________________________________________________________________________

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___________________________________________________________________________________
Part 1: Use Simulation 2, Set 2

For each of the following sets:

- Predict the products of the reaction in the chemical equation space below the sketching area.
- For both Brønsted-Lowry and Lewis views, complete before and after sketches. Record your observations as you did during the demonstration in Activity 2. Make sure to include a key.
- Use your sketches and observations to answer the analysis questions.

View #1: Brønsted-Lowry perspective

<table>
<thead>
<tr>
<th>Submicroscopic Sketch</th>
<th>Chemical Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>HCl (g) + NH₃ (g) →</td>
</tr>
</tbody>
</table>

Observations

Key
<table>
<thead>
<tr>
<th>Submicroscopic Sketch</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Chemical Equation (same as previous page)</th>
<th>HCl (g) + NH₃ (g) → ______________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td></td>
</tr>
</tbody>
</table>

| Key                                      |                                          |
12. Which reactant donated a proton? Explain your answer.

13. Which reactant accepted a proton? Explain your answer.


15. Which reactant accepted an electron pair? Explain your answer.

For the following questions, circle all answers that are applicable.

16. In the reaction, HCl is a:
   a. Brønsted-Lowry acid
   b. Brønsted-Lowry base
   c. Lewis Acid
   d. Lewis Base
   Support your answer with evidence.

17. In the reaction, NH₃ is a:
   a. Brønsted-Lowry acid
   b. Brønsted-Lowry base
   c. Lewis Acid
   d. Lewis Base
   Support your answer with evidence.
**Part 2:** *Use Simulation 2, Set 3*

**View #1: Brønsted-Lowry perspective**

<table>
<thead>
<tr>
<th>Submicroscopic Sketch</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Equation</strong></td>
<td>$\text{CN}^- (g) + \text{HBr} (g) \rightarrow$</td>
<td></td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Key</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### View #2: Lewis perspective

<table>
<thead>
<tr>
<th>Submicroscopic Sketch</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Equation</strong> (same as previous page)</td>
<td>CN⁻(g) + HBr(g) →</td>
<td></td>
</tr>
</tbody>
</table>

**Observations**

**Key**
18. Which reactant donated a proton? *Explain your answer.*

________________________________________________________________________

________________________________________________________________________

19. Which reactant accepted a proton? *Explain your answer.*

________________________________________________________________________

________________________________________________________________________

20. Which reactant donated an electron pair? *Explain your answer.*

________________________________________________________________________

________________________________________________________________________

21. Which reactant accepted an electron pair? *Explain your answer.*

________________________________________________________________________

________________________________________________________________________

*For the following questions, circle all answers that are applicable.*

22. In the reaction, HBr is a:
   a. Brønsted-Lowry acid
   b. Brønsted-Lowry base
   c. Lewis Acid
   d. Lewis Base

*Support your answer with evidence.*

________________________________________________________________________

23. In the reaction, CN\(^-\) is a:
   a. Brønsted-Lowry acid
   b. Brønsted-Lowry base
   c. Lewis Acid
   d. Lewis Base

*Support your answer with evidence.*

________________________________________________________________________
Activity 4: Demonstration

Demonstration: Use Simulation 2, Set 4

For the following sets:
- Your teacher will demonstrate the simulation.
- Complete sketches, create a key, and record your observations as you did in the previous activity.
- Use your sketches and observations to answer the analysis questions.

View #1: Brønsted-Lowry perspective

<table>
<thead>
<tr>
<th>Submicroscopic Sketch</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
</table>

Chemical Equation

\[ \text{BCl}_3 (g) + \text{Cl}^- (g) \rightarrow \text{________} \]

Observations

Key
24. At a glance, what do you notice about the reaction above that is different from the previous three sets?

25. Why are the reactants BCl$_3$ (g) and Cl$^-$ (g) assigned as acidic and basic, respectively, in the Brønsted-Lowry theory? Explain your reasoning.

26. Identify the Lewis acid and Lewis base in the reaction BCl$_3$ + Cl$^-$ → ____________.

27. In the Lewis perspective, what is the role of the electron pair donor (Lewis base)?

28. In the Lewis perspective, what is the role of the electron pair acceptor (Lewis acid)?

29. Compare and contrast the Brønsted-Lowry and Lewis theories of acids and bases. How do they differ in terms of defining acids and bases?
25. Which reactant donated a proton? Explain your answer.

__________________________________________________________________________

__________________________________________________________________________

26. Which reactant accepted a proton? Explain your answer.

__________________________________________________________________________

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27. Which reactant donated an electron pair? Explain your answer.

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29. In the reaction, BCl₃ is a:

   a. Brønsted-Lowry acid
   b. Brønsted-Lowry base
   c. Lewis Acid
   d. Lewis Base

   Support your answer with evidence.

__________________________________________________________________________

__________________________________________________________________________

30. In the reaction, Cl⁻ is a:

   a. Brønsted-Lowry acid
   b. Brønsted-Lowry base
   c. Lewis Acid
   d. Lewis Base

   Support your answer with evidence

__________________________________________________________________________

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### Activity 5: Putting It All Together

#### Applying Different Acid and Base Theories

Look at the following reactions and determine which theory (Arrhenius, Brønsted-Lowry, or Lewis) can describe the reactants. More than one theory may apply!

**Teacher Example**

\[
\text{HNO}_3 \text{(aq)} + \text{H}_2\text{O} \text{(l)} \rightarrow \text{H}_3\text{O}^+ \text{(aq)} + \text{NO}_3^- \text{(aq)}
\]

*For the following questions, circle all answers that are applicable.*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>31. In the reaction, HNO₃ is a:</td>
<td>32. In the reaction, H₂O is a:</td>
</tr>
<tr>
<td>a. Arrhenius acid</td>
<td>a. Arrhenius acid</td>
</tr>
<tr>
<td>b. Arrhenius base</td>
<td>b. Arrhenius base</td>
</tr>
<tr>
<td>c. Brønsted-Lowry acid</td>
<td>c. Brønsted-Lowry acid</td>
</tr>
<tr>
<td>d. Brønsted-Lowry base</td>
<td>d. Brønsted-Lowry base</td>
</tr>
<tr>
<td>e. Lewis acid</td>
<td>e. Lewis acid</td>
</tr>
<tr>
<td>f. Lewis base</td>
<td>f. Lewis base</td>
</tr>
</tbody>
</table>

*Support your answer with evidence.*

\[
\text{HCl} \text{(aq)} + \text{NaSCN} \text{(s)} \rightarrow \text{HSCN} \text{(aq)} + \text{NaCl} \text{(g)}
\]

33. In the reaction, SCN⁻ is a:

| a. Arrhenius acid |
| b. Arrhenius base |
| c. Brønsted-Lowry acid |
| d. Brønsted-Lowry base |
| e. Lewis acid |
| f. Lewis base |

*Support your answer with evidence.*

34. In the reaction, HCl⁻ is a:

| a. Arrhenius acid |
| b. Arrhenius base |
| c. Brønsted-Lowry acid |
| d. Brønsted-Lowry base |
| e. Lewis acid |
| f. Lewis base |

*Support your answer with evidence.*
For the following questions, circle all answers that are applicable.

**LiCN (aq) + H₂O (l) → HCN (aq) + LiOH (aq)**

35. In the reaction, H₂O is a:
   a. Arrhenius acid
   b. Arrhenius base
   c. Brønsted-Lowry acid
   d. Brønsted-Lowry base
   e. Lewis acid
   f. Lewis base
   Support your answer with evidence.

36. In the reaction, CN⁻ is a:
   a. Arrhenius acid
   b. Arrhenius base
   c. Brønsted-Lowry acid
   d. Brønsted-Lowry base
   e. Lewis acid
   f. Lewis base
   Support your answer with evidence.

With your knowledge of the different acid/base theories, try the following questions independently.

**HBr (aq) + H₂O (l) → H₃O⁺ (aq) + Br⁻ (aq)**

37. In the reaction, is HBr an acid or base?

38. In the reaction, is H₂O an acid or base?

Consider the reverse of the reaction.

**H₃O⁺ (aq) + Br⁻ (aq) → HBr (aq) + H₂O (l)**

39. In the reaction, is H₃O⁺ an acid or base?

40. In the reaction, is Br⁻ an acid or base?

**H₂SO₄ (aq) + NH₃ (l) → NH₄⁺ (aq) + HSO₄⁻ (aq)**

41. In the reaction, is H₂SO₄ an acid or base?

42. In the reaction, is NH₃ an acid or base?

Consider the reverse of the reaction.

**NH₄⁺ (aq) + HSO₄⁻ (aq) → H₂SO₄ (aq) + NH₃ (l)**

43. In the reaction, is HSO₄⁻ an acid or base?

44. In the reaction, is NH₄⁺ an acid or base?
As you have learned, there are three major theories that explain the behavior of acids and bases. These theories all focus on how acids and bases interact on the submicroscopic level. If we rely solely on the macroscopic level to explain acids and bases, we can determine the acidity or basicity of a compound either by measuring the pH, using litmus paper for a solution, or identifying specific reactions with known reactants. The macroscopic level only allows for observations and does not provide reasons why these observations occur.

On the submicroscopic level, we can better understand why certain compounds act either as a base or acid. The determination of acidity and basicity is examined through many factors, such as how the compounds react when added to water, how the molecules donate or receive protons, and how the molecules accept or donate electron pairs.

45. In your own words describe the Arrhenius theory of acids and bases.

46. Compare and contrast the Brønsted-Lowry theory with the Lewis theory using the Venn Diagram below.

Determine whether the submicroscopic images are an example of an Arrhenius acidic solution, an Arrhenius basic solution, or a neutral solution.

47. Label each diagram as acidic, basic, or neutral.

A__________________  B__________________  C__________________
48. Provide two reactions that can be explained for each of the acid-base theories listed below.

**Arrhenius**

________________________________________________________________________
________________________________________________________________________

**Brønsted-Lowry**

________________________________________________________________________
________________________________________________________________________

**Lewis**

________________________________________________________________________
________________________________________________________________________

49. Select one of the reactions below. Identify whether it can be classified as a Arrhenius, Brønsted-Lowry, or Lewis reaction. Provide evidence to support your claim.

\[ \text{NaHCO}_3 (aq) + \text{H}_2\text{O} (l) \rightarrow \text{H}_2\text{CO}_3 (aq) + \text{NaOH} (aq) \]

________________________________________________________________________
________________________________________________________________________

\[ \text{CH}_3\text{CO}_2\text{H} (aq) + \text{H}_2\text{O} (l) \rightarrow \text{CH}_3\text{CO}_2^- (aq) + \text{H}_3\text{O}^+ (aq) \]

________________________________________________________________________
________________________________________________________________________

\[ \text{I}_2 (g) + \text{I}^- (g) \rightarrow \text{I}_3^- (g) \]

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Lesson Reflection Question

50. Compare and contrast each of the acid-base theories and their limitations in the table below.

<table>
<thead>
<tr>
<th>Theory</th>
<th>Definition</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arrhenius</strong></td>
<td>Acid:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base:</td>
<td></td>
</tr>
<tr>
<td><strong>Lewis</strong></td>
<td>Acid:</td>
<td></td>
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<tr>
<td></td>
<td>Base:</td>
<td></td>
</tr>
<tr>
<td><strong>Brønsted-Lowry</strong></td>
<td>Acid:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base:</td>
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</table>