OBJECTIVES
Students will:
- determine the relationship between the pH of a solution and the concentration of H⁺ ions.
- investigate how to change the concentration of H⁺ ions.

1. What is the relationship between the pH of a solution and the concentration of hydrogen ions (H⁺)?

2. What is concentration?

3. What are some everyday items that are in a concentrated form?

Materials Per Lab Group
- 1 test tube rack
- 5 15 mL falcon tubes
- 6 dropper pipettes
- 1 box of pH strips or pH test paper
- 1 pair of forceps
- 1 lab marker
- 1 piece of plastic wrap 30 cm long
- 1 1400 mL beaker containing 100 mL of distilled water
- 1 15 mL falcon tube containing 7 mL of 1 M hydrochloric acid (HCl) colored with red food coloring
- 1 pair goggles per student
- 1 lab apron per student
Lesson One: Serial Dilution of an Acid

1. In this investigation, you will use a technique called serial dilution to dilute an acid 5 times. You will determine the H\(^+\) ion concentration each time by measuring the pH of each of the solutions.

2. Obtain a 400 mL beaker with approximately 100 mL of distilled water and label it “H\(_2\)O”.

STOP AND DISCUSS
3. Obtain a test tube rack with 6 falcon tubes and 6 pipettes. If the falcon tubes are not labeled, use a lab marker and masking tape to label the leftmost falcon tube “HCl”. Label the next falcon tube “1”, the next “2”, and continue until you have labeled the last falcon tube “5”.

4. Obtain a falcon tube with 7 mL of the red colored hydrochloric acid (HCl).

5. Use a second pipette to add 9 mL of distilled water from the 400 mL “H₂O” beaker to falcon tubes 1, 2, 3, 4 and 5. Add water until the volume reaches the 9 mL mark on the side of each falcon tube. Screw the caps back on the falcon tubes and return the dropper pipette to the beaker.

### Background
A less concentrated solution can be made by adding less solute or by diluting a more concentrated solution by adding more solvent. Suppose that you wanted to make a cherry drink with a concentration of

\[
\frac{5 \text{ g of the soft drink powder}}{100 \text{ mL of water}}
\]

but you have no more powder. All you have is a solution with a concentration of

\[
\frac{10 \text{ g of the soft drink powder}}{100 \text{ mL of water}}
\]

You could add 100 mL of water to this solution to dilute it so that now you have 200 mL of solution with a concentration of

\[
\frac{10 \text{ g of the soft drink powder}}{200 \text{ mL of water}} \quad \text{which is the same as} \quad \frac{5 \text{ g of the soft drink powder}}{100 \text{ mL of water}}
\]

You will use a dilution method called serial dilution to prepare a series of different dilutions of hydrochloric acid (HCl). In this method, 1 mL of a solution of the acid is added to 9 mL of water and mixed resulting in a concentration of acid that is 1/10th the original concentration. 1 mL of this solution is added to another 9 mL of water and mixed resulting in a concentration that is 1/100th the original concentration. In this example, each time a dilution is made, each solution is diluted by a dilution factor of 10.

Using a serial dilution, a series of less and less concentrated solutions of HCl can be made.

### STOP AND DISCUSS
6. Use the following diagram to help you with your serial dilutions.

**Note:** Hydrochloric acid (HCl) is not normally red. Red food coloring has been added to help you see the differences among your dilutions.

[Diagram showing the dilution process]

a. Use a clean dropper pipette to transfer 1 mL of the HCl from the falcon tube labeled “HCl” to tube 1. The volume should reach the 10 mL mark on the side of the tube.

b. Return all excess hydrochloric acid (HCl) in the dropper pipette to the falcon tube labeled “HCl” and screw the cap on. Place the dropper pipette off to the side.

c. Screw the cap back onto tube 1 and turn it upside down then upright again three times to mix the contents.

b. Use a clean dropper pipette to transfer 1 mL of the solution from tube 1 to tube 2. The volume should reach the 10 mL mark on the side of the tube. Return any excess solution to tube 1 and screw the cap on.

d. Screw the cap back onto tube 2 and turn it upside down then upright again three times to mix the contents.

e. Repeat this procedure as shown in the diagram until the dilutions have been prepared for tubes 3, 4 and 5.

7. Spread the plastic wrap on the table next to the test tube rack.

8. Label the top of a pH paper strip with “HCl.” Label 5 additional strips with the numbers 1, 2, 3, 4 and 5.
9. Using forceps grasp the top of the strip labeled “HCl.” Dip the pH strip into the liquid in the tube labeled “HCl.”

10. Place the pH paper strip just inside the lower left corner of the plastic wrap. Fold the excess plastic wrap down over the strip.

11. Match the color of the pH strip with the pictures on the box. Estimate the pH of the HCl that most closely corresponds to the color of the pictures. Find the pH to the nearest half of a pH unit, for example, 3.0, 3.5 or 4.0.

12. Record the pH value in Table A.

13. Dip pH strip 1 into the liquid in tube 1. Remove the pH paper strip and place it to the right of strip labeled “HCl.”

14. Repeat the procedure as described in steps 10-13, until you have lined up all 6 pH paper strips on the plastic wrap as shown in the picture. Fold the excess plastic wrap down over the strips.

Table A: The Effect of HCl Concentration on Solution pH

<table>
<thead>
<tr>
<th>Falcon Tube</th>
<th>HCl</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl Concentration (N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.1</td>
<td>0.01</td>
<td>0.001</td>
<td>0.001</td>
<td>0.0001</td>
<td>0.00001</td>
</tr>
<tr>
<td>Dilution Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1/10</td>
<td>1/100</td>
<td>1/1,000</td>
<td>1/10,000</td>
<td>1/100,000</td>
<td></td>
</tr>
<tr>
<td>Times Diluted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Analysis

Graph: Use the grid below to draw a graph that compares the pH of the solutions and the number of times you diluted the original solution of HCl. Use the data from Table A to draw the graph.

a. Determine the independent variable in the experiment.
b. Determine the dependent variable in the experiment
c. Number the axes after determining the proper scale.
d. Draw a line of best fit through the data points.
1. **Question:** What solvent did you use to dilute your solutions as you performed your serial dilutions?

2. **Question:** Look at the solutions in the falcon tubes. As you diluted the original red solution of hydrochloric acid (HCl), what happened to the color of the hydrochloric acid (HCl)? Which solutions displayed a shade of red or pink and which solutions were colorless?

3. **Question:** Based on your observations of the color of the solutions, what happened to the concentration of the red food coloring you diluted the original red solution of hydrochloric acid (HCl)?

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**Background**

To describe the concentration of a solute, the concentration must have units. In Table A, the hydrochloric acid (HCl) concentration is described by the unit “N” for Normal. This is one of several different units used to describe concentration.

To make solution 1, you added 1 mL of hydrochloric acid (HCl) to 9 mL of water for a total of 10 mL. To make solution 2, you added 1 mL of solution 1 to 9 mL of water. You continued until you had made solution 5. Each new solution had a concentration that was 10 times less than the previous, since you added 1 mL to 9 mL of water for a total of 10 mL.

In Table A, the concentration of solutions 1-5 was 10 times less than the previous solution. The concentration of hydrochloric acid (HCl) was 1 N, the concentration of solution 1 was 0.1 N, the concentration of solution 2 was 0.01 N, etc.

Each time the pH of a solution increased by 1 pH unit, the concentration of hydrogen ions (H\(^+\)) was diluted 10 times, so the concentration is 10 times less.
1. What other solute in addition to the food coloring were you diluting and measuring as you performed your serial dilutions?

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2. Look at your graph. As the undiluted hydrochloric acid (HCl) was diluted from 1 to 5 times with water, what happened to the pH?

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________________________________________________________________________

3. As the original hydrochloric acid (HCl) was diluted from 1 to 5 times with water, what happened to the hydrogen ion (H⁺) concentration?

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________________________________________________________________________

STOP AND DISCUSS

1. Look at Table A. Solution 1 was how many times less concentrated than the hydrochloric acid (HCl)? How could you use a decimal to show this change?

________________________________________________________________________

2. Look at Table A. Solution 2 was how many times less concentrated than the original solution of HCl? How could you use a decimal to show this change?

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3. Each solution was how many times less concentrated than the previous one?
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________________________________________________________________________

4. How can the concentration of hydrogen ions (H⁺) be changed?
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5. You want to save money on fruit drink mix. You need to know what is the least amount of powdered fruit drink mix you can use in a liter of water, while still maintaining an appealing taste. You are given a liter of water mixed with one cup of the powdered mix. What would you do to determine if a half cup of fruit drink mix would be enough to make the drink and it still keep an appealing taste?
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