Exploring the Lime Cycle: Limewater CO_2 Experiment

Instructions: Limewater is a saturated solution of calcium hydroxide (hydrated lime). When carbon dioxide is added to limewater, a precipitate is formed, demonstrating a portion of the lime cycle. The addition of dry ice (solid CO_2) adds excess carbon dioxide to the solution, forming a new compound and changing the pH of the solution.

Materials:

- Calcium hydroxide ($Ca(OH)_2$)
- Dry Ice
- Distilled water
- Beakers (500 mL)
- Straws
- Universal indicator solution
- Goggles
- Heavy gloves
- Apron

Safety Precautions:

- Calcium hydroxide is a skin irritant. Wear gloves when handling solid calcium hydroxide.
- The limewater solution is a weak base. Avoid ingestion of the limewater solution.
- Dry ice must be handled with heavy gloves as it will burn unprotected skin.
- Chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron are recommended for this experiment.

Preparation:

1. Create the limewater solution. Add 5 grams of calcium hydroxide to 2 liters of distilled water and stir. Add to a sealable, screw top bottle and label the bottle accordingly. Invert the solution several times to mix periodically for a couple of days. Ensure the solution is clear and not cloudy. Decant the solution after the solid has settled.

2. Add 200 mL of limewater to a beaker for each group.

Lab Procedure:

1. Add the universal indicator to test the pH of the solution. Record the pH/color in your lab notebook.

2. Place the straw in the limewater solution and blow into the solution through the straw. After about 20-30 seconds, the solution should become cloudy from the formation of a precipitate.

3. Using gloves, add a chunk of dry ice to the solution (remember that dry ice is solid CO_2). Observe the reaction. After a few minutes, the reaction should subside. Record what you observed in your lab notebook.

4. As the reaction subsides, record the pH/color of the universal indicator in your lab notebook.

5. When finished with the procedure, answer the discussion questions on the next page.

Discussion:

1. What was the pH of the solution after Step 1? What does this mean?

2. What chemical compound was formed after blowing into limewater (Step 2)? Why did the solution turn cloudy? Consider what you have learned so far about the lime cycle.

3. What portion of the lime cycle does this reaction relate to? What is this process called?

4. Write the chemical equation of the reaction observed in Step 2. Write down the number of atoms for each element. Is the equation balanced?

5. What did you observe during Step 3? How did the solution change from Step 2?

6. What was the pH of the solution after Step 4? What does this mean?

7. What chemical compound was formed by bubbling CO_2 into the limewater solution? Bonus: Write out the chemical equation for this reaction.

8. Write the chemical equation of the reaction observed between the precipitate formed in Step 2 and the compound formed in Step 3. Write down the number of atoms for each element. Is the equation balanced?

Answers:

1. What was the pH of the solution after Step 1? What does this mean?
   The universal indicator (or pH test strip) should be blue, indicating a pH around 12. This means the solution is an alkali.

2. What chemical compound was formed after blowing into limewater (Step 2)? Why did the solution turn cloudy? Consider what you have learned so far about the lime cycle.
   Calcium carbonate ($CaCO_3$). The solution turned cloudy due to the formation of a calcium carbonate precipitate from a reaction between limewater and carbon dioxide.

3. What portion of the lime cycle does this reaction relate to? What is this process called?
   The final portion of the lime cycle, carbonation.

4. Write the chemical equation of the reaction observed in Step 2. Write down the number of atoms for each element. Is the equation balanced?

   $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$

C = 1	C = 1
O = 4	O = 4
Ca = 1	Ca = 1
H = 2	H = 2

   Yes, the equation is balanced.

5. What did you observe during Step 3? How did the solution change from Step 2?
   Addition of dry ice to water causes carbon dioxide to rapidly become a gas (sublimination). Cold CO_2 gas causes water vapor in the air to condense into small water droplets or clouds. The additional dissolution of CO_2 in the solution results in the formation of carbonic acid. This acid dissolves the calcium carbonate precipitate formed in Step 2, causing the solution to turn from cloudy to clear. The formation of carbonic acid also causes the universal indicator to change from blue to light green/yellow.

6. What was the pH of the solution after Step 4? What does this mean?
   The universal indicator (or pH test strip) should be light green/yellow, indicating a pH around 4. This means the solution is an acid.

7. What chemical compound was formed by bubbling CO_2 into the limewater solution? Bonus: Write out the chemical equation for this reaction.

   Carbonic acid
   $H_2O + CO_2 \rightarrow H_2CO_3$

8. Write the chemical equation of the reaction observed between the precipitate formed in Step 2 and the compound formed in Step 3. Write down the number of atoms for each element. Is the equation balanced?

   $CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$

C = 2	C = 2
O = 6	O = 6
Ca = 1	Ca = 1
H = 2	H = 2

   Yes, the equation is balanced.