

Acid/Base Homeostasis (Part 2)

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- The stomach contains an aqueous solution of hydrochloric acid, which is the only example of a strong acid found in the body.
 - Note that as soon as this strong acid hits the water, it completely dissociates into hydrogen ion and chloride ion which are found in the stomach.
 - Remember that strong acids are substances that release all their hydrogen ion. The pink color is from an indicator which has been added.

8. Weak Acid: Carbonic Acid

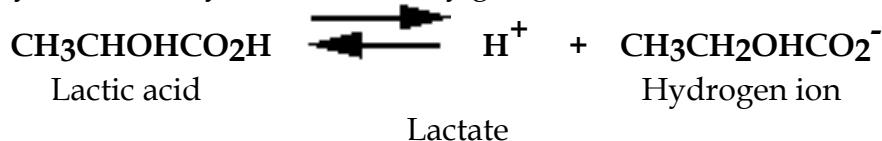
- Unlike strong acids, when weak acids, such as carbonic acid, are added to water it does not completely dissociate. Carbonic acid is formed when we bubble carbon dioxide through water.



- Remember that pH measures of the free hydrogen ion in solution. Because not much hydrogen ion is released when carbonic acid is added to water, this acid is weak, and it has a higher pH than a strong acid. The pink color is from an indicator which has been added.

9. Weak Acid: Lactic Acid

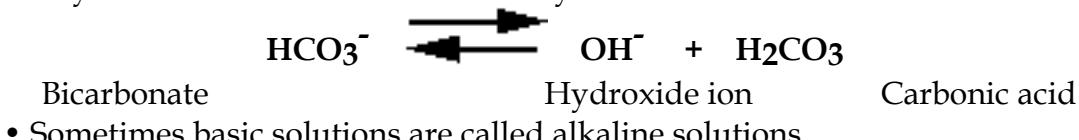
- When you exercise, your muscles may generate lactic acid.



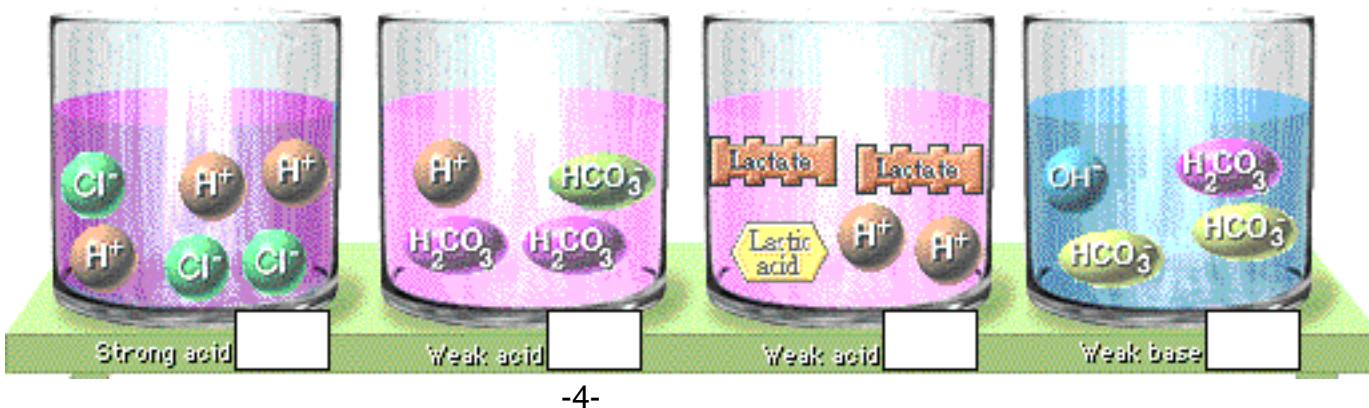
- Notice that more hydrogen ions are released from the lactic acid than were released from the carbonic acid. Again, the pink color is from an indicator which has been added to show that this is a weak acid.
 - Although both carbonic acid and lactic acid are weak acids, lactic acid releases more hydrogen ion and is therefore a stronger weak acid.

10. Weak Base: Bicarbonate

- Bases take up hydrogen ion. While there are both strong and weak bases, only weak bases are found in the body.



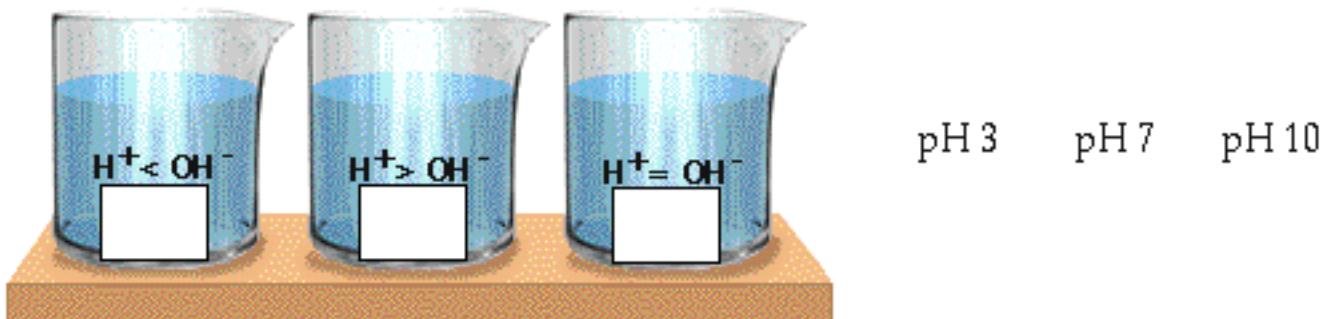
- Note that there would have to be a positive ion, such as sodium, with the bicarbonate on the shelf.
- A small percentage of the bicarbonate ions take up hydrogen ions from the water. When water molecules lose hydrogen ion, hydroxide ion remains, which increases the pH. Again, the pink color is from an indicator which has been added.
- Indicate the pH's of these solutions:



-4-

11. Match the pH to the Beaker

- A neutral solution has a pH of 7 because the hydrogen ion and hydroxide ion concentrations are equal.
- Indicate the pH's on the appropriate beakers.



- At pH 7 the concentrations of hydrogen ion and hydroxide ion are equal and the solution is neutral.
- At pH 3 the concentrations of hydrogen ion is greater than hydroxide ion and the solution is acidic.
- At pH 10 the concentrations of hydrogen ion is less than hydroxide ion and the solution is basic.

*Now is a good time to go to quiz question 1:

- Click the Quiz button on the left side of the screen.
- Work through all parts of question 1.
- After answering question 1, click on the Back to Topic button on the left side of the screen.
- To get back to where you left off, click on the scrolling page list at the top of the screen.
- Choose "12. Electrolytes as Weak Acids and Bases."

12. Electrolytes as Weak Acids and Bases

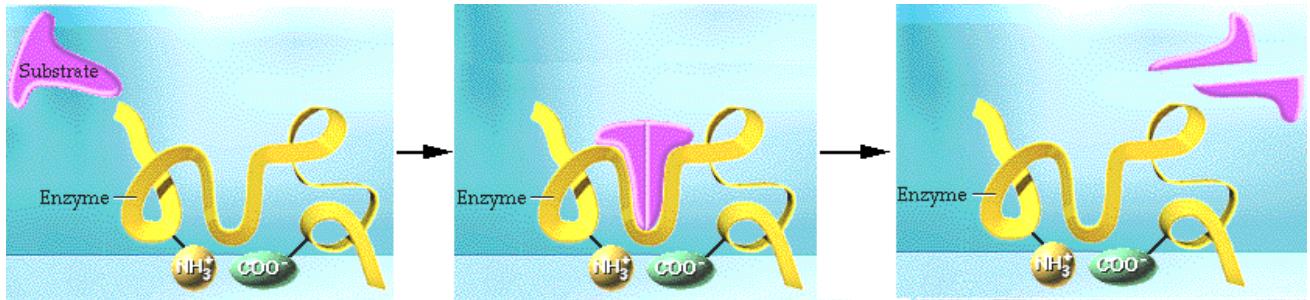
- Some electrolytes normally found in plasma can act as weak acids and bases.
- Bicarbonate, hydrogen phosphate, sulfate, and anions of organic acids all serve as bases in the body.
- Dihydrogen phosphate is an acid in the body.
- In addition proteins have acidic and basic side groups.
- Indicate the acids and bases on the chart below:

Electrolytes

<u>Major Positive Ions (Cations)</u>		<u>Major Negative Ions (Anions)</u>
 Sodium Ion		 Chloride Ion
 Potassium Ion		 Bicarbonate Ion
 Calcium Ion		 Phosphate Ions
 Magnesium Ion		 Sulfate Ions
		 Organic Acids
		 Proteins

13. Normal Globular Protein

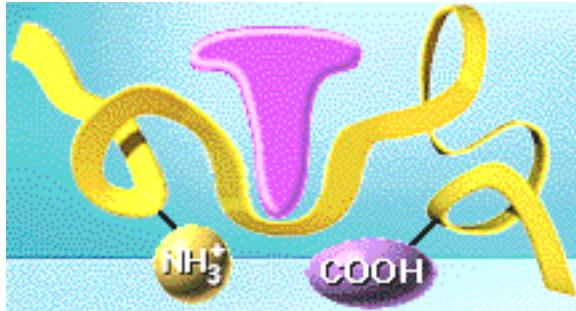
- Maintaining the pH of body fluids is very important because many proteins cannot function at an altered pH. Many globular proteins have specific functions in the body and their shape is crucial for their function.
- The protein shown is an enzyme. Enzymes have active sites with a specific shape. If for some reason the shape of the protein changes, this enzyme would no longer be able to function.
- Because this enzyme functions within the cytoplasm of the cell, it operates best at pH 7.0.



- Proteins have positive and negative charges that will determine, to some extent, the shape, or tertiary structure, of the protein. These positive and negative charges are present because of acidic and basic amino acid side chains.
- This protein is shown with only one positive and negative charge, but remember that proteins have many charges.

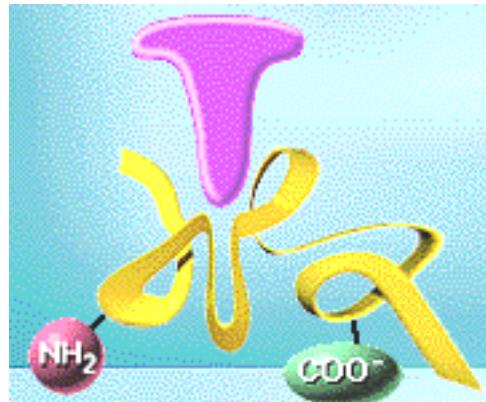
14. Effect of Acid on Globular Protein

- If pH is altered, globular proteins lose their shape or denature and cannot function properly. Clinical symptoms will result. For example, when lactic acid is generated in large quantities by muscle, muscles can no longer perform to their maximum.



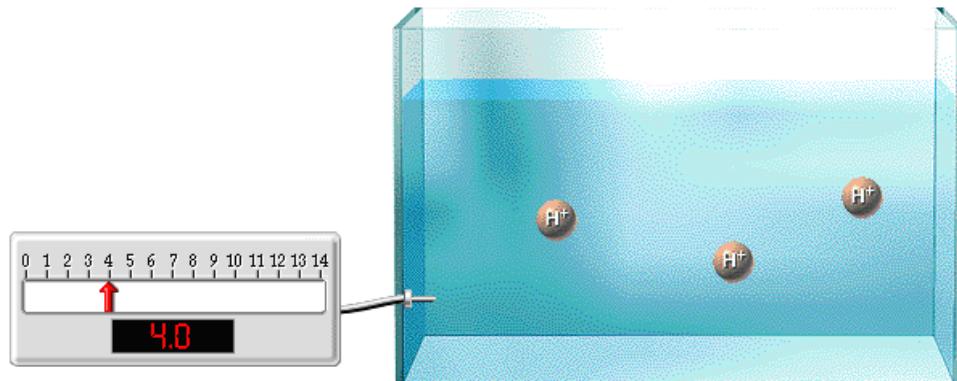
15. Effect of Base on Globular Protein

- Now let's see what happens when we add base to this enzyme.
- Again, if base is added, globular proteins denature and cannot function properly.
- To summarize, proteins can release and accept hydrogen ion. however, If the pH of the body fluid changes too much, proteins, such as enzymes and hormones, will no longer function.



16. Buffers

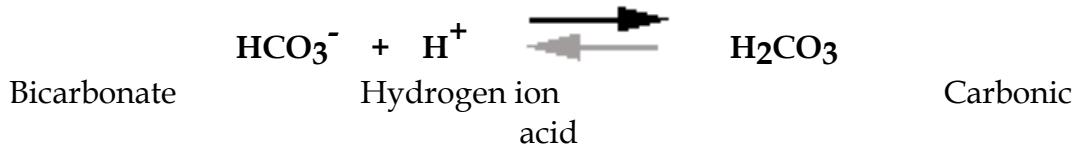
- The body has three ways of maintaining a normal pH range:
 - Chemical buffer systems
 - Respiratory controls
 - Renal mechanisms
- First we'll describe chemical buffers. They act within seconds to help the body control pH.
- Notice the large drop in pH, which is typical when acid is added to an unbuffered solution.



- Most buffers are composed of weak acid and weak base pairs which are sometimes called conjugate acid/base pairs. The purpose of a buffer is to help the body maintain a relatively constant pH.
- There are three important buffer systems in the body:
 - Carbonic acid/bicarbonate buffer system
 - Phosphate buffer system
 - Protein buffers

17. Carbonic Acid/Bicarbonate Buffer

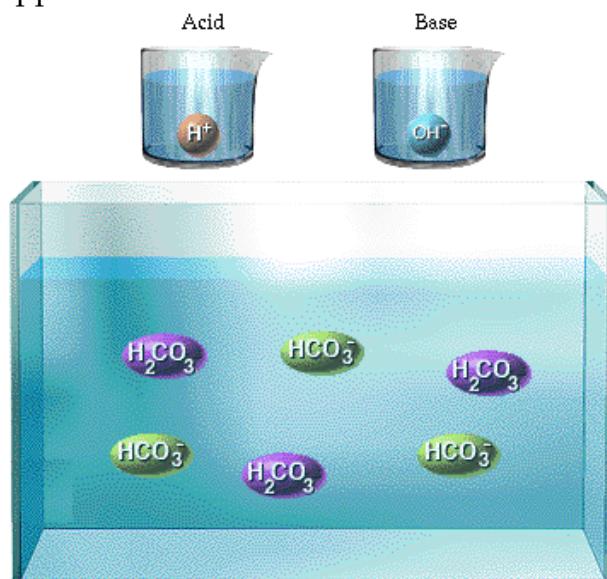
- First let's discuss the carbonic acid/bicarbonate buffer system. The weak acid is carbonic acid, H_2CO_3 , and the weak base is bicarbonate, HCO_3^- .
- When acid is added, the hydrogen ion attaches to the weak base, bicarbonate, to form a weak acid, carbonic acid:



- Because the hydrogen ion attaches and is not free in solution, the pH will not change dramatically. The weak acid that forms will not dissociate into hydrogen ions to any great extent.
 - When base is added, the hydroxide pulls a hydrogen ion off of carbonic acid, forming water and bicarbonate:



- Because the hydroxide pulled a hydrogen ion off of the carbonic acid and formed water, the hydroxide did not significantly increase the pH of the solution.
 - Show what happens when both acid and base are added to this solution:



18. Phosphate Buffer

- Now let's take what we learned about the carbonic acid/bicarbonate buffer system and apply it to the phosphate buffer system.
 - Which of these is the weak acid? _____ H_2PO_4^- or _____ $\text{HPO}_4^{=}$
 - Dihydrogen phosphate is the weak acid. You can tell because it contains more hydrogen ion.
 - When acid is added: The hydrogen ion adds to the weak base, hydrogen phosphate.

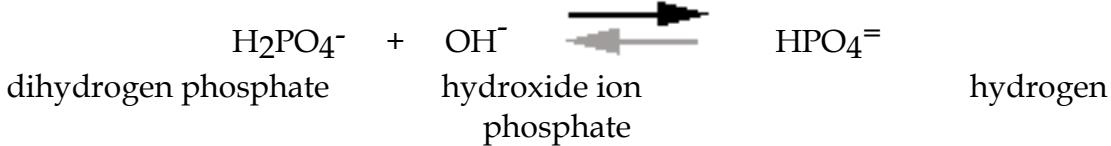


hydrogen phosphate

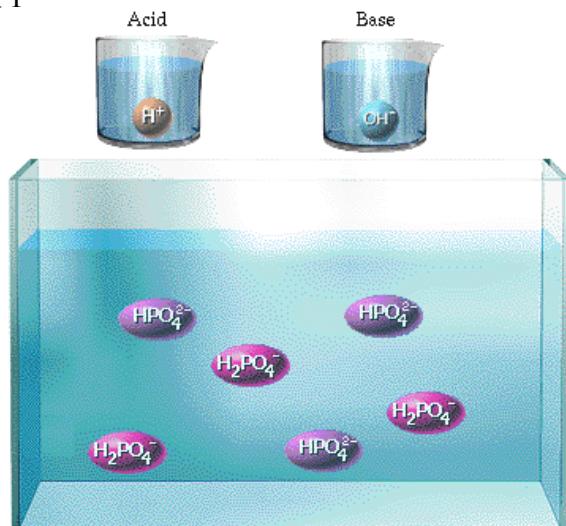
hydrogen ion
phosphate

dihydrogen

- When base is added: The hydroxide ion pulls a hydrogen ion off of dihydrogen phosphate to form water and hydrogen phosphate.

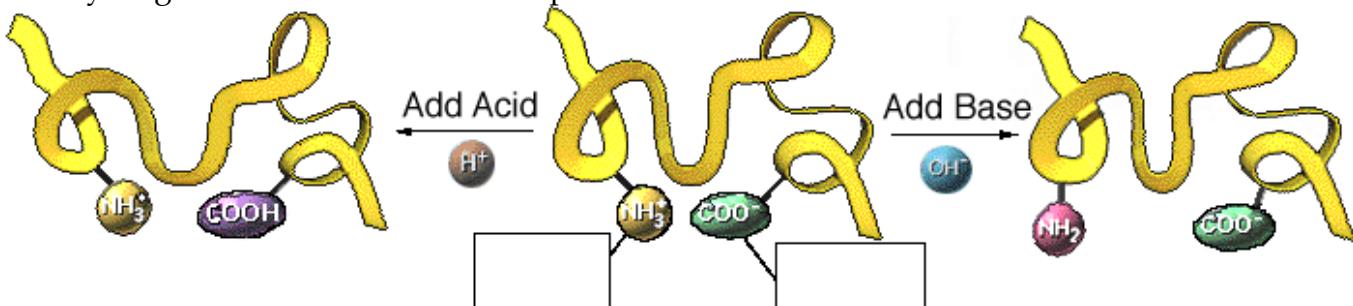


- Show what happens when both acid and base are added to this solution:



19. Protein Buffers

- Remember that proteins have side chains which can act as weak acids or weak bases, allowing proteins to serve as buffers.
 - When acid is added when there is excess hydrogen ion in the body fluids.
 - When there is too much acid in the body, proteins take up hydrogen ion onto side chains that are weak bases. pH does not change much because the hydrogen ions are attached to the protein and not free in solution.



- Now let's see what happens when base is added to the protein.
 - When there is excess base in the body, proteins release hydrogen ion from side chains that are weak acids.

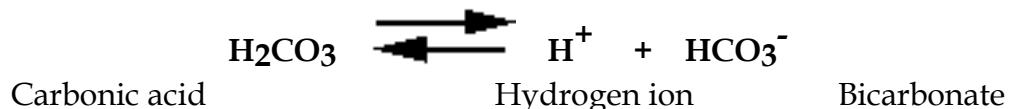
- Notice that the shape of the protein did not change much here because only small amounts of acid or base were added. If the pH increases or decreases too much, the proteins may become denatured and not function properly.

*Now is a good time to go to quiz question 2:

- Click the Quiz button on the left side of the screen.
 - Work through all parts of question 2.
 - After answering question 2, click on the Back to Topic button on the left side of the screen.
 - To get back to where you left off, click on the scrolling page list at the top of the screen.
 - Choose "20. Dynamic Equilibrium."

20. Dynamic Equilibrium

- This chemical equation expresses the relationship between the weak acid and weak base of a buffer.



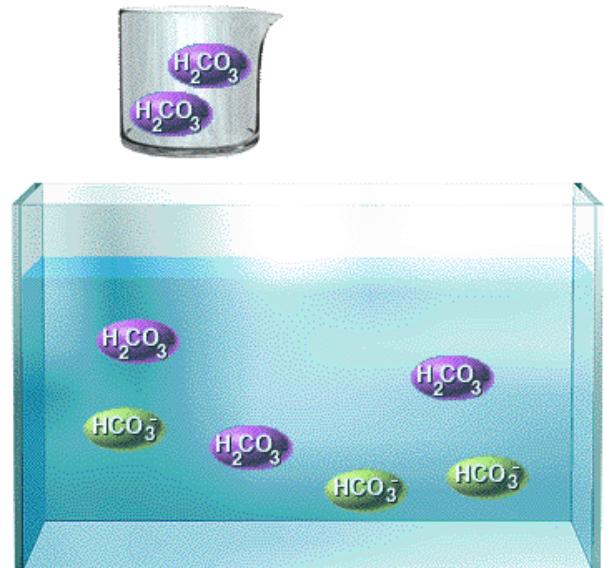
- Many reactions that occur in the body, such as this one, are reversible.
 - The reaction can go either in the forward direction or the reverse direction.
 - The double arrows indicate that reaction can go either in the forward direction or the reverse direction.
 - When the body is in acid/base homeostasis, carbonic acid is constantly forms bicarbonate and hydrogen ion.
 - Bicarbonate and hydrogen ion constantly come back together again to reform carbonic acid.
 - This is a dynamic equilibrium reaction since both the forward and reverse reactions are occurring simultaneously but there is no change in the concentrations of the weak acid and weak base.

21. Adding Carbonic Acid

- Now lets use this equation to explain what happens when the body is not in homeostasis and there is too much carbonic acid in the body fluids.

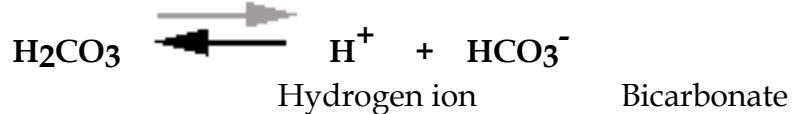


- Adding more carbonic acid forces the reaction to form more bicarbonate and hydrogen ion.
 - What is this change in equilibrium called?
 - ___ shift to the right
 - ___ shift to the left
 - Because we have added more carbonic acid the reaction proceeds to the right.
 - Show what happens when the carbonic acid is added:

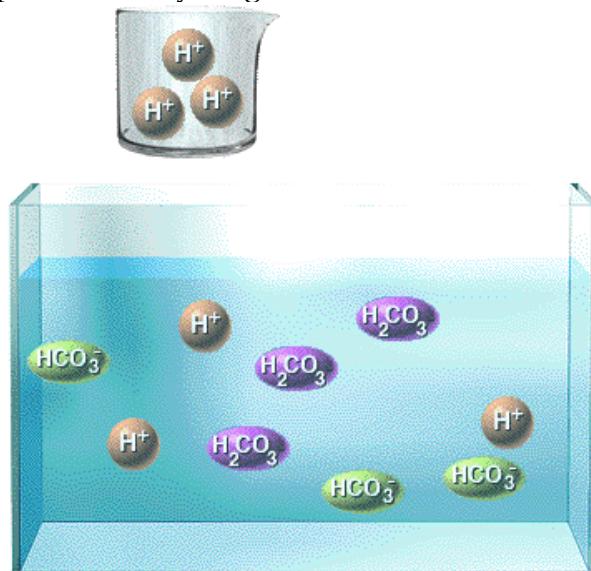


22. Adding Hydrogen Ion

- Now let's consider what happens if we add more bicarbonate or hydrogen ion to the right side of the equation. Which direction will the reaction proceed?
 - ___ Reaction will shift to the right.
 - ___ Reaction will shift to the left
 - The reaction will shift to the left and most of the excess acid will be taken up, allowing the pH to remain fairly constant.

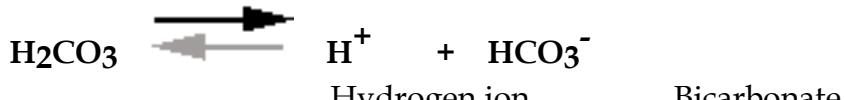


- Show what happens when hydrogen ion is added:



23. Removing Hydrogen Ion

- Now let's show what happens when there's not enough acid in the body.
 - As hydrogen ion is taken away, more hydrogen ion is generated by the buffer system, allowing the pH to remain fairly constant.

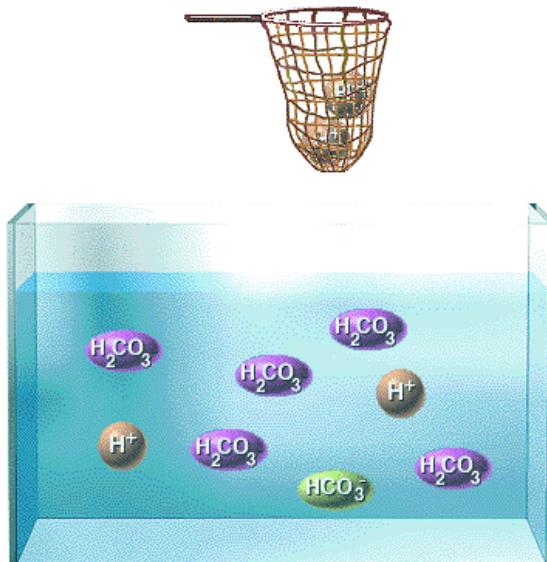


- What do you think we call this change in equilibrium?

- shift to the right
- shift to the left

- It is a shift to the right because the reaction proceeds to the right.

- Show what happens when hydrogen ion is removed:



24. Introduction to Respiratory Control

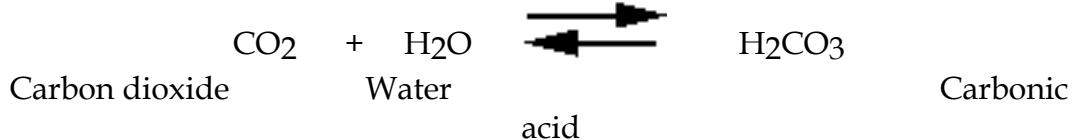
- We have looked at the role of chemical buffers in acid/base balance, now let's look at the role of the respiratory system in regulation of acid/base balance.
 - Note that respiratory control occurs rapidly, but not as rapidly as chemical buffering.
 - Cell metabolism generates carbon dioxide which is eliminated from the body by the lungs.



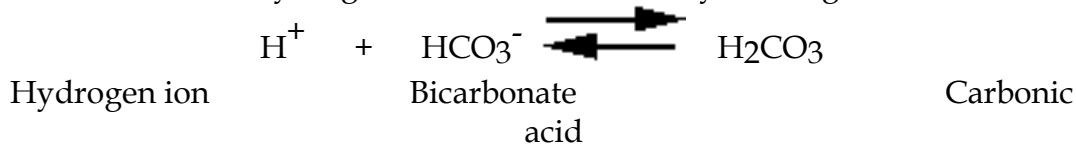
- When we breathe more deeply and quickly, more carbon dioxide leaves the body.
 - When we breathe more slowly or more shallowly, less carbon dioxide leaves the body.

25. Role of Bicarbonate Buffer

- Within the body fluids carbon dioxide and water are constantly coming together to form carbonic acid.
 - Bicarbonate and hydrogen ion are also constantly forming carbonic acid.
 - Inside red blood cells and other cells the enzyme carbonic anhydrase, combines the carbon dioxide with water to form carbonic acid.

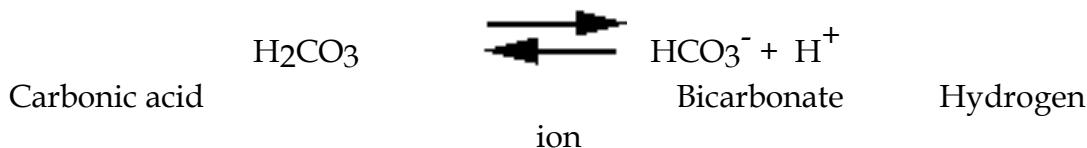


- This is a reversible reaction and carbonic acid will break down to carbon dioxide and water.
 - Note that this reaction can occur outside of cells without the enzyme, but the reaction time is slower.
 - Bicarbonate and hydrogen ion are also constantly forming carbonic acid:

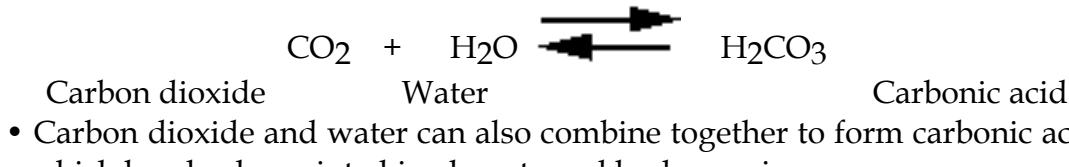


26. Role of Carbon Dioxide/Carbonic Acid Equilibrium

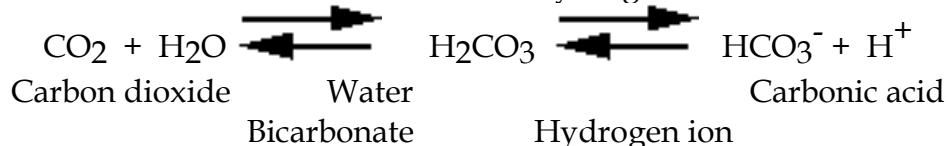
- As you remember, this is the equation for the carbonic acid/bicarbonate buffer.



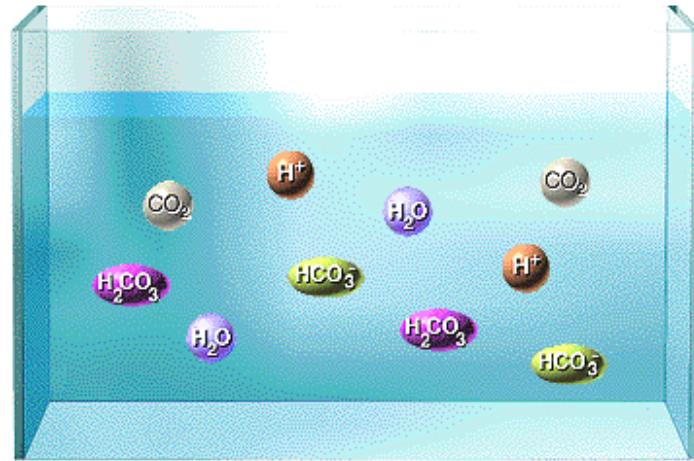
- Now let's expand the equation to see how the entire respiratory system works to regulate pH. Carbonic acid can break down into carbon dioxide and water.



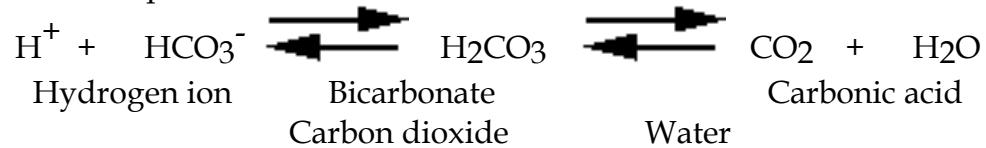
- Carbon dioxide and water can also combine together to form carbonic acid, which breaks down into bicarbonate and hydrogen ion.



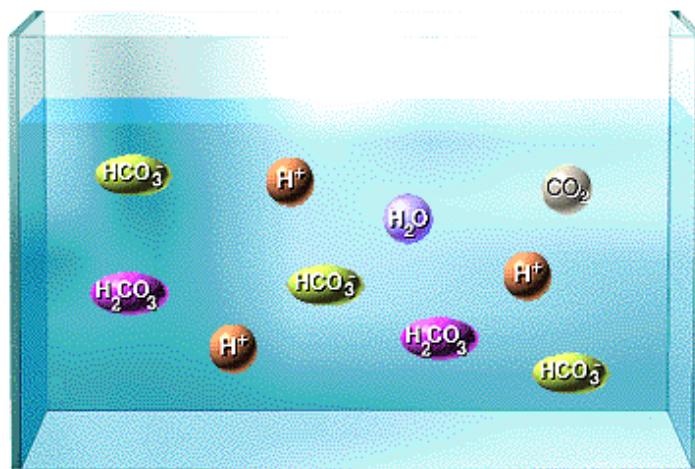
- Show what happens in this tank:



- Bicarbonate and hydrogen ion can also come together to form carbonic acid which splits into carbon dioxide and water.



- Show what happens in this tank:



Continue to Acid/Base Homeostasis – Part III
 (Separate Document)