39.4B: Transport of Carbon Dioxide in the Blood

Dissolution, hemoglobin binding, and the bicarbonate buffer system are ways in which carbon dioxide is transported throughout the body.

Learning Objectives

• Explain how carbon dioxide is transported from body tissues to the lungs

Key Points

• Carbon dioxide is more soluble in blood than is oxygen; about 5 to 7 percent of all carbon dioxide is dissolved in the plasma.
• Carbon dioxide has the ability to attach to hemoglobin molecules; it will be removed from the body once they become dissociated from one another.
• In the bicarbonate buffer system, the most common form of carbon dioxide transportation in the blood, carbon dioxide is finally expelled from the body through the lungs during exhalation.
• Importantly, the bicarbonate buffer system allows little change to the pH of the body system; it allows for people to travel and live at high altitudes because the system can adjust itself to regulate carbon dioxide while maintaining the correct pH in the body.

Key Terms

• carbaminohemoglobin: a compound made up of hemoglobin and carbon dioxide; one of the forms in which carbon dioxide exists in the blood
• **carbonic anhydrase**: a family of enzymes that catalyze the rapid interconversion of carbon dioxide and water to bicarbonate and protons

• **carbon monoxide**: a colorless, odourless, flammable, highly toxic gas

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**Transport of Carbon Dioxide in the Blood**

Carbon dioxide molecules are transported in the blood from body tissues to the lungs by one of three methods:

1. Dissolution directly into the blood
2. Binding to hemoglobin
3. Carried as a bicarbonate ion

Several properties of carbon dioxide in the blood affect its transport. First, carbon dioxide is more soluble in blood than is oxygen. About 5 to 7 percent of all carbon dioxide is dissolved in the plasma. Second, carbon dioxide can bind to plasma proteins or can enter red blood cells and bind to hemoglobin. This form transports about 10 percent of the carbon dioxide. When carbon dioxide binds to hemoglobin, a molecule called carbaminohemoglobin is formed. Binding of carbon dioxide to hemoglobin is reversible. Therefore, when it reaches the lungs, the carbon dioxide can freely dissociate from the hemoglobin and be expelled from the body.

Third, the majority of carbon dioxide molecules (85 percent) are carried as part of the bicarbonate buffer system. In this system, carbon dioxide diffuses into the red blood cells. Carbonic anhydrase (CA) within the red blood cells quickly converts the carbon dioxide into carbonic acid (H₂CO₃). Carbonic acid is an unstable, intermediate molecule that immediately dissociates into bicarbonate ions (HCO₃⁻) and hydrogen (H⁺) ions. Since carbon dioxide is quickly converted into bicarbonate ions, this reaction allows for the continued uptake of carbon dioxide into the blood, down its concentration gradient. It also results in the production of H⁺ ions. If too much H⁺ is produced, it can alter blood pH. However, hemoglobin binds to the free H⁺ ions, limiting shifts in pH. The newly-synthesized bicarbonate ion is transported out of the red blood cell into the liquid component of the blood in exchange for a chloride ion (Cl⁻); this is called the chloride shift. When the blood reaches the lungs, the bicarbonate ion is transported back into the red blood cell in exchange for the chloride ion. The H⁺ ion dissociates from the hemoglobin and binds to the bicarbonate ion. This produces the carbonic acid intermediate, which is converted back into carbon dioxide through the enzymatic action of CA. The carbon dioxide produced is expelled through the lungs during exhalation.

The benefit of the bicarbonate buffer system is that carbon dioxide is “soaked up” into the blood with little change to the pH of the system. This is important because it takes only a small change in the overall pH of the body for severe injury or death to result. The presence of this bicarbonate buffer system also allows for people to travel and live at high altitudes. When the partial pressure of oxygen and carbon dioxide change at high altitudes, the bicarbonate buffer system adjusts to regulate carbon dioxide while maintaining the correct pH in the body.

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**Carbon Monoxide Poisoning**

While carbon dioxide can readily associate and dissociate from hemoglobin, other molecules, such as carbon monoxide (CO), cannot. Carbon monoxide has a greater affinity for hemoglobin than does oxygen. Therefore, when carbon...
monoxide is present, it binds to hemoglobin preferentially over oxygen. As a result, oxygen cannot bind to hemoglobin, so very little oxygen is transported throughout the body. Carbon monoxide is a colorless, odorless gas which is difficult to detect. It is produced by gas-powered vehicles and tools. Carbon monoxide can cause headaches, confusion, and nausea; long-term exposure can cause brain damage or death. Administering 100 percent (pure) oxygen is the usual treatment for carbon monoxide poisoning as it speeds up the separation of carbon monoxide from hemoglobin.

![Graph showing oxygen saturation of hemoglobin at different CO levels](http://cnx.org/content/m44799/latest/Figure_39_04_01.jpg)

**Figure 39.1**: Carbon monoxide poisoning: When carbon monoxide (CO) in the body increases, the oxygen saturation of hemoglobin decreases since hemoglobin will bind more readily to CO than to oxygen. Therefore, CO exposure leads to death due to a decreased transportation of oxygen in the body.

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