CARBON

- Most carbon exists as equilibrium products of carbonic acid
- Small amounts as dissolved/detrital organic C
- Small amount as living biota

- $\text{CO}_2$ in air = about 3.2% (increasing)
- Highly soluble in water (200 x > than $\text{O}_2$)
- 1.1 mg/L at 0°C → 0.4 mg/L at 30°C:
\[
\text{CO}_2 \text{(air)} \leftrightarrow \text{CO}_2 \text{(dissolved)} + \text{H}_2\text{O}
\]

Then, \(\text{CO}_2\) hydrates to form carbonic acid:

\[
\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3
\]

Then, bicarbonate \((\text{H}_2\text{CO}_3)\) disassociates:

\[
\text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-
\]

\[
\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \leftrightarrow 2\text{H}^+ + \text{CO}_3^{2-}
\]

Also:

\[
\text{HCO}_3^- + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 + \text{OH}^-
\]

\[
\text{CO}_3^{2-} + \text{H}_2\text{O} \leftrightarrow \text{HCO}_3^- + \text{OH}^-
\]

\[
\text{H}_2\text{CO}_3 \leftrightarrow \text{H}_2\text{O} + \text{CO}_2
\]

These reactions act as a buffer to resist changes in pH (Fig 11-1)

→ absorb \(\text{H}^+\) as long as \(\text{CO}_3^{2-}\) reserves remain

→ absorb \(\text{OH}^-\) as long as \(\text{HCO}_3^-\) reserves remain
ALKALINITY = quantity and kinds of compounds present that shift pH up

- e.g. HCO$_3^-$, CO$_3^{2-}$, OH$^-$

Alkalinity aka *acid neutralizing capacity* (ANC)

- total alkalinity = amount of acid needed / L to neutralize all these ions
- usually expressed as mg/L CaCO$_3$ (which assumes that alkalinity results only from CaCO$_3$ and HCO$_3^-$)
HARDNESS = Ca and Mn salts of CO$_3$ and HCO$_3$ and also SO$_4$, Cl, etc

- often expressed as mg/L CaCO$_3$ in USA
- elsewhere other systems are used (Table)
pH

- ranges from 2 to 12 in lakes
- *Sphagnum* bogs ~ pH 3.3-4.5
- endorheic regions can have very high pH
- most lakes in the 6 to 9 range (HCO$_3^-$)
Interaction of C with pH

- the dominant C species depends on pH
- pH < 5 → free CO$_2$ dominates; pH 6 to 9.5 → HCO$_3^-$ dominates
- pH > 9.5 → CO$_3^{2-}$ dominates
Interaction of C with Ca

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \]

- water from runoff, percolating through soil:
  \[ \text{H}^+ + \text{CaCO}_3 \rightarrow \text{Ca(HCO}_3^-)_2 \]

- an important source of C in watersheds over limestone (CaCO$_3$)
  \[ \text{Ca(HCO}_3^-)_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2 \]

- as \text{CO}_2 is consumed by photosynthesis, [CaCO$_3$] exceeds solubility \[ \rightarrow \text{CaCO}_3 \downarrow \]