Planet Earth: An Owner’s Manual
The Inorganic Carbon Cycle

Inorganic Carbon Cycle

Carbonic Acid
The most important chemical reaction on Earth!

\[ \text{H}_2\text{O (water)} + \text{CO}_2 \text{ (gas)} = \text{H}^+ \text{ (carbonic acid)} + \text{HCO}_3^- \text{ (bicarbonate)} \]

Rainwater and groundwater are weakly acidic.

The alkalinity of the oceans drives the reaction to favor bicarbonate ion - this allows the oceans to store large quantities of CO2 dissolved from the atmosphere.
Solubility Pump

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

The oceans are capable of storing 50X more CO\(_2\) than the atmosphere.

\[ \text{CO}_2 \text{ dissolved in surface water is transported to deep water by vertical ocean circulation.} \]

Ocean circulation conveyor belt

- COLD AND SALTY DEEP CURRENT
- WARM SHALLOW CURRENT
- GULF STREAM

The ocean circulation conveyor belt plays a key role in the climate of the Earth because of the transport of energy (heat) and matter.

The oceans are currently absorbing about 30% of all human emissions of CO\(_2\).

- Uptake rate is limited by rate of deep ocean circulation
- As oceans warm, they will be able to absorb less and less CO\(_2\)
- As ocean waters absorb CO\(_2\) they become increasingly acidic (pH drops - Acidification)
- Eventually, if atmospheric CO\(_2\) levels begin to fall, the oceans will return their dissolved CO\(_2\) back to the atmosphere.
Hydrolysis of Feldspar

Feldspar + carbon dioxide + water = Ca ions + clay + silica + bicarbonate ion

\[ \text{CaAlSi}_3\text{O}_8 + \text{CO}_2 + \text{H}_2\text{O} = \text{Ca}^{++} + \text{Al}_4\text{Si}_4\text{O}_{10}(\text{OH})_8 + 8\text{SiO}_2 + \text{HCO}_3^- \]

Follow the carbon!

Weathering feldspar in granite
Inorganic Carbon Reservoirs

Atmosphere (CO₂)
Chemical weathering

Earth's Mantle (CO₂)
Oceans (HCO₃⁻)

Rock (CaCO₃)

Questions for Discussion

- What happens to the average rate of chemical weathering as climate warms?
- Where is the weathering of rock most intense?
- How does chemical weathering affect the amount of CO₂ in the atmosphere?
- How might the formation of a mountain range affect global climate?
Carbonate Sedimentary Rock

Limestone - CaCO₃
Dolostone - CaMgCO₃

Sediments precipitated by chemical reaction of bicarbonate ion and calcium ion - usually biologically mediated.
algae, phytoplankton, zooplankton, mollusks, corals, echinoderms (sea urchins, crinoids)

\[ \text{Ca}^{2+} + 2\text{HCO}_3^- \rightarrow \text{CaCO}_3 + \text{H}_2\text{CO}_3 \]
Carbonate mineral

A coral reef is a carbonate mineral factory.
Negative feedback is inherently stable, always driving systems back to an equilibrium.