Ocean Acidification

Caused by Increased Atmospheric CO_2

And the Effects on Marine Biota

Problem

- CO_2 in the atmosphere reacts with ocean water to form an acid.
- With increasing atmospheric CO_2 levels, the ocean's acidity has been steadily increasing
- An increase in acidity of the ocean can be detrimental to marine life

Anthropogenic CO_2

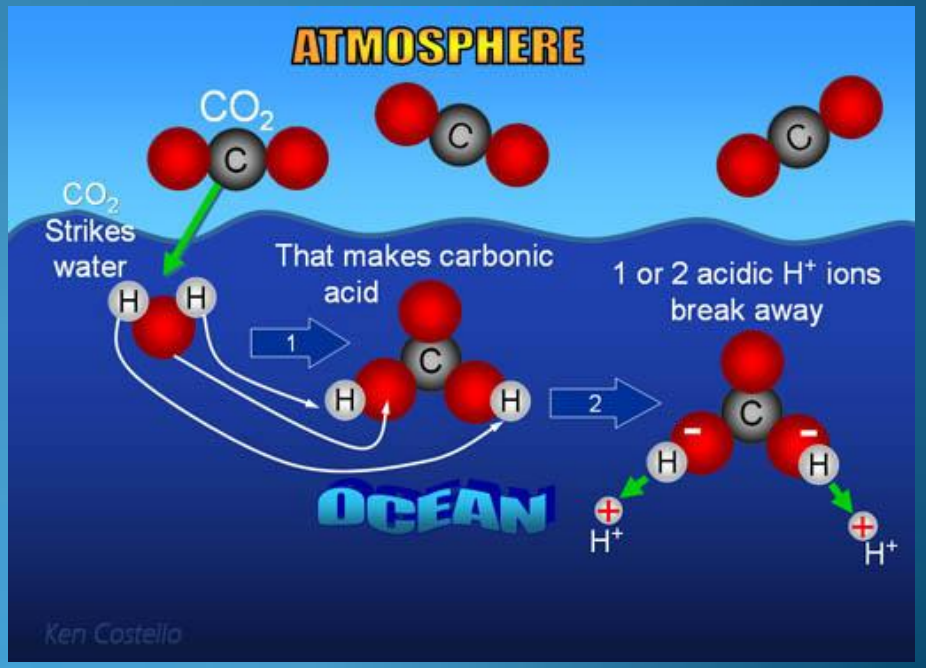
- Oceans serve as an atmospheric carbon sink.
- Since the 1980's, oceans have absorbed about 30% of anthropogenic CO2. (From a 0.1 pH decrease)
- CO2 concentrations are predicted to be between 550-1000 μ atm by 2100. (Which will cause a 0.2-0.5 pH drop)

The Physics

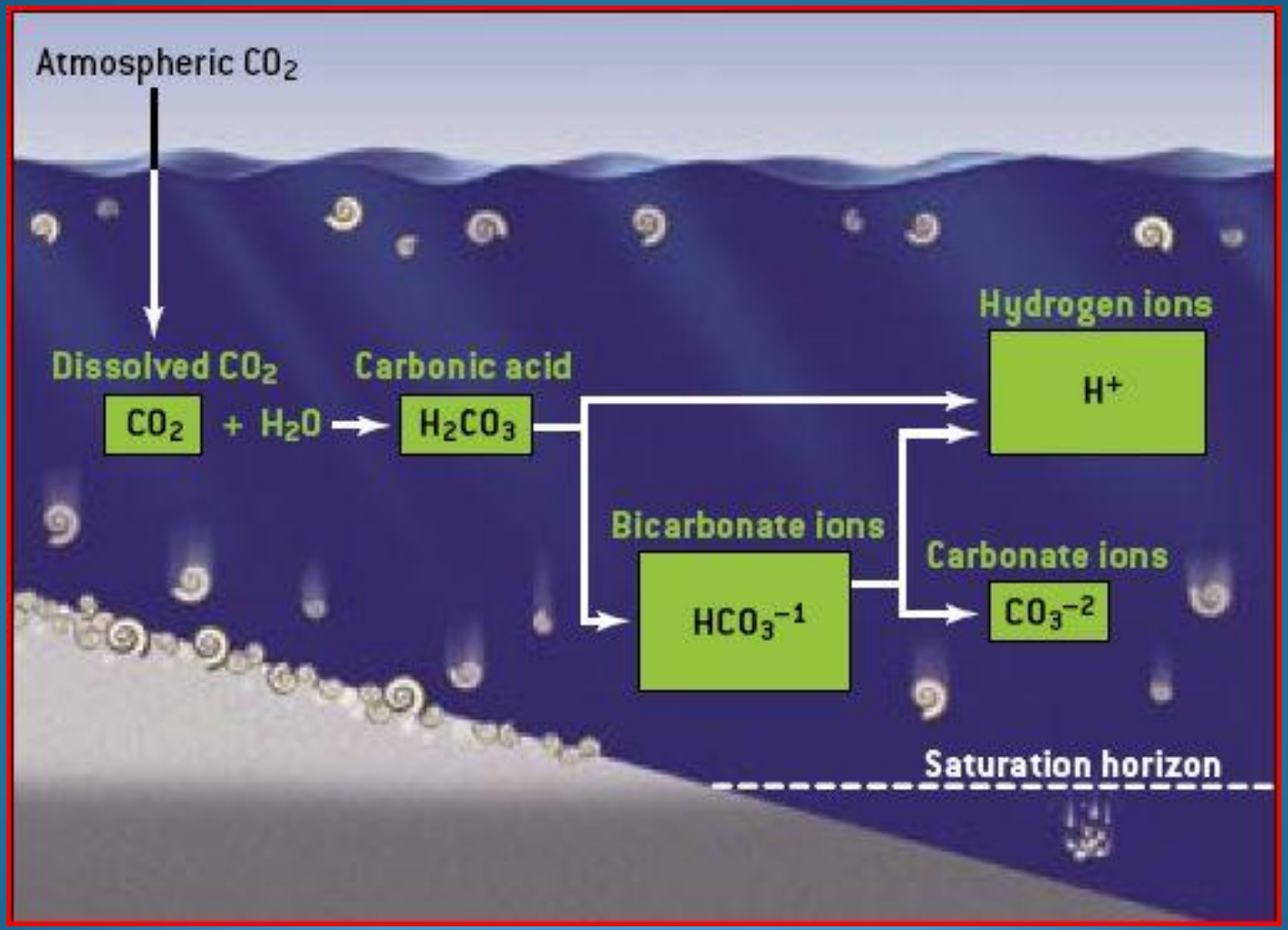
- Fast moving molecules of a gas strike the ocean surface and dissolve

- Mixing of the ocean and atmosphere:
  - -Waves
  - -Eddy/wind interaction
  - -Marine Life

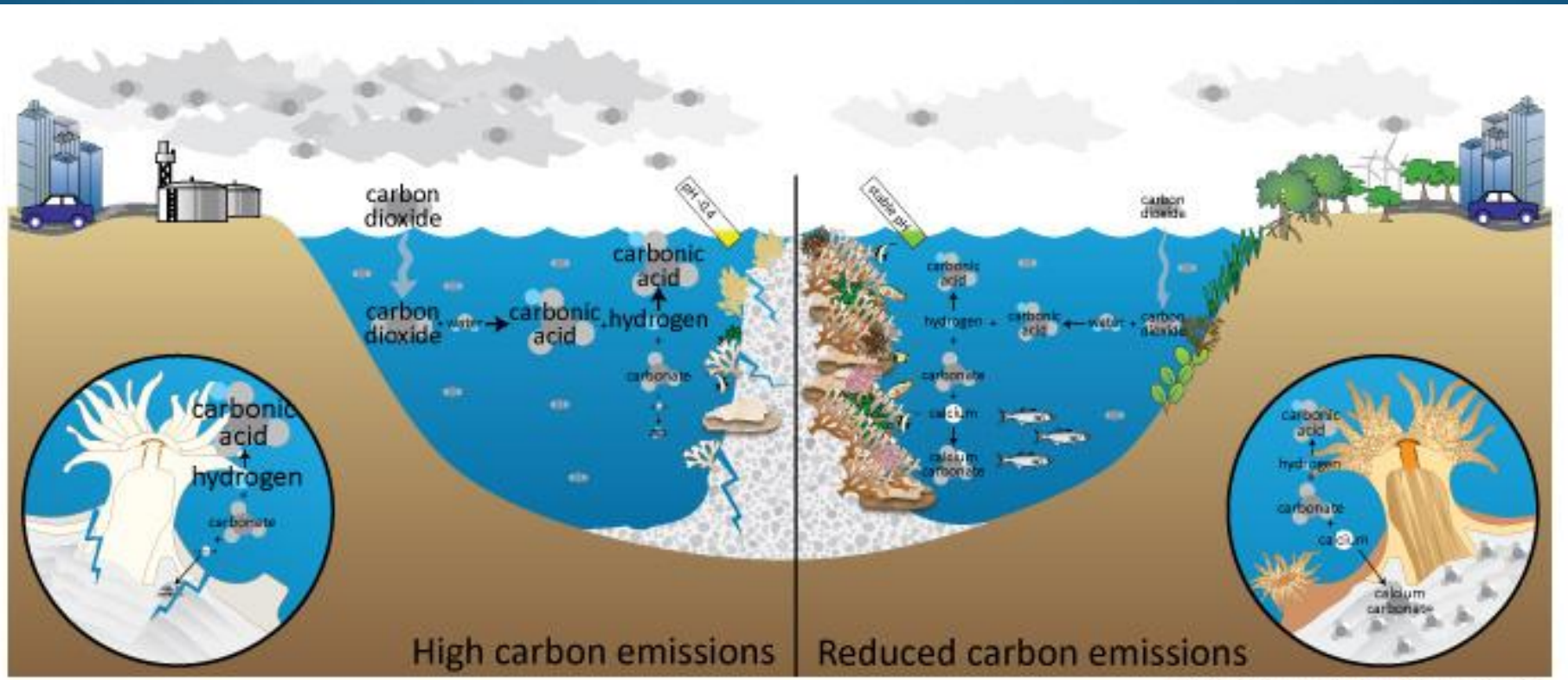
- Mixing increases chance of reaction



The Biology


Atmospheric CO_2
Dissolved CO_2
CO_2 + H_2O
Carbonic acid
H_2CO_3
Hydrogen ions
H^+
Bicarbonate ions
HCO_3^{-1}
Carbonate ions
CO_3^{-2}
Saturation horizon

The Big Picture



The Chemistry

$CO_2 + H_2O \rightarrow HCO_3^- + H^+$

- Carbon dioxide "binds" with water, then breaks up into H^+ to acifify the ocean.

- Though, this just one of the possible reactions CO_2 can take part in at the ocean surface.

The Chemistry

$$CO_2(g) = CO_2(aq) \quad , \qquad (1)$$

$$CO_2(aq) + H_2O(l) = H_2CO_3(aq) \quad , \qquad (2)$$

$$H_2CO_3(aq) = H^+(aq) + HCO_3^-(aq) \quad , \qquad (3)$$

$$HCO_3^-(aq) = H^+(aq) + CO_3^{2-}(aq) \quad ; \qquad (4)$$

- Lower pH means more HCO3- and less dissolved CO2
- Organisms have to expend energy to convert HCO3- to CO2, a reaction which is catalyzed with carbonic anhydrase

Effect on Marine Biota

The Breakdown of Calcareous Shells

$CO_2 + H_2O \rightarrow HCO_3^- + H^+$ excess HCO_3- from CO_2

$H^+ + CO_3^{2-} \rightarrow HCO_3^-$ carbonate combines with H^+

$CaCo_3 \rightarrow Ca^{2+} + CO_3^{2-}$ calcareous shells break down

Net: $H_2O + CO_2 + CO_3 \rightarrow 2HCO_3^-$

Ocean pH

Between 1751 and 1994 surface ocean pH is estimated to have decreased from approximately 8.179 to 8.104 (some other substances in the ocean tend to be basic)

Other ions buffer the changes so that the increase in H+ isn't strictly proportional to the amount of CO_2 (or H_2CO_3) added

*makes for a difficult calculation

Decreasing Calcification Rate

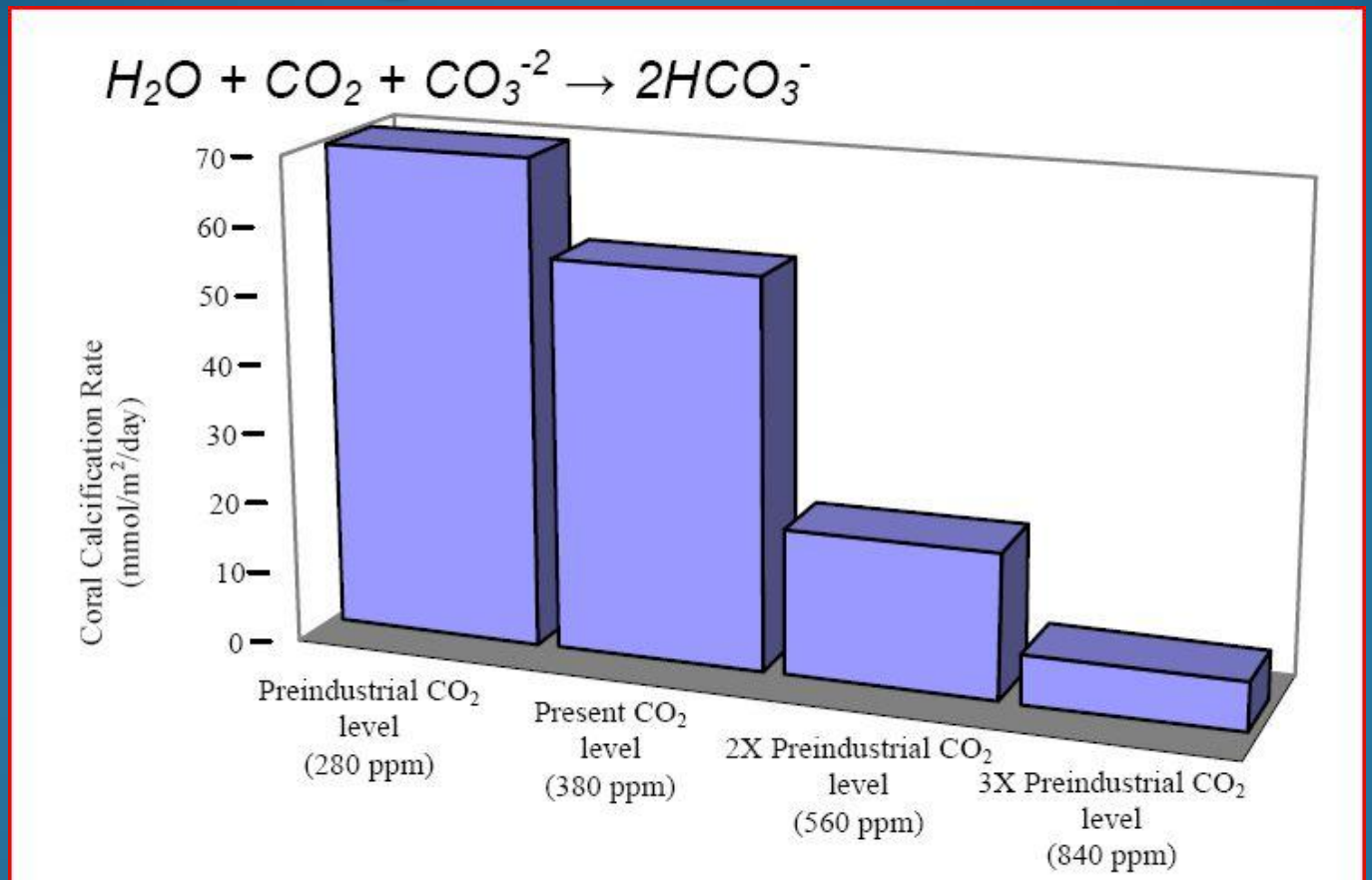


***Figure 1**. Potential impact of rising atmospheric CO_2 on coral reef calcification rate.*

Reaching the Limit

- When atmospheric CO_2 reaches 450 ppm (projected to occur between 2030-2038), aragonite undersaturation is induced
- Species with aragonite (carbonate) shells cannot survive

Limacina helicina

Why is this Important?

- Plankton provide nearly 50% of the world's oxygen
- Hypercapnia (acidification of body fluids)of sea creatures
- US fishery landings for calcifiers such as mussels, clams, and scallops were valued at $675 million in 2006 alone
- Talked about as solution for reducing CO_2 emissions

Correlation with ocean temperature?

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