

Ocean Acidification: The basic chemistry

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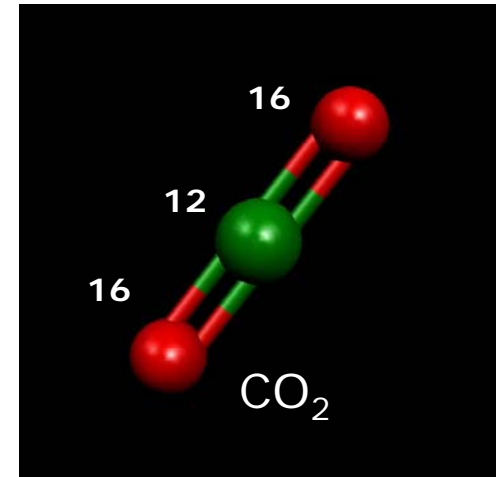
1. Carbon Dioxide Emissions

Current global Emissions (fossil fuels):

About 9 billion tons of carbon per year.

Slight drop in 2009 (economy)

1 ton C \cong 3.7 (44/12) metric tons CO₂

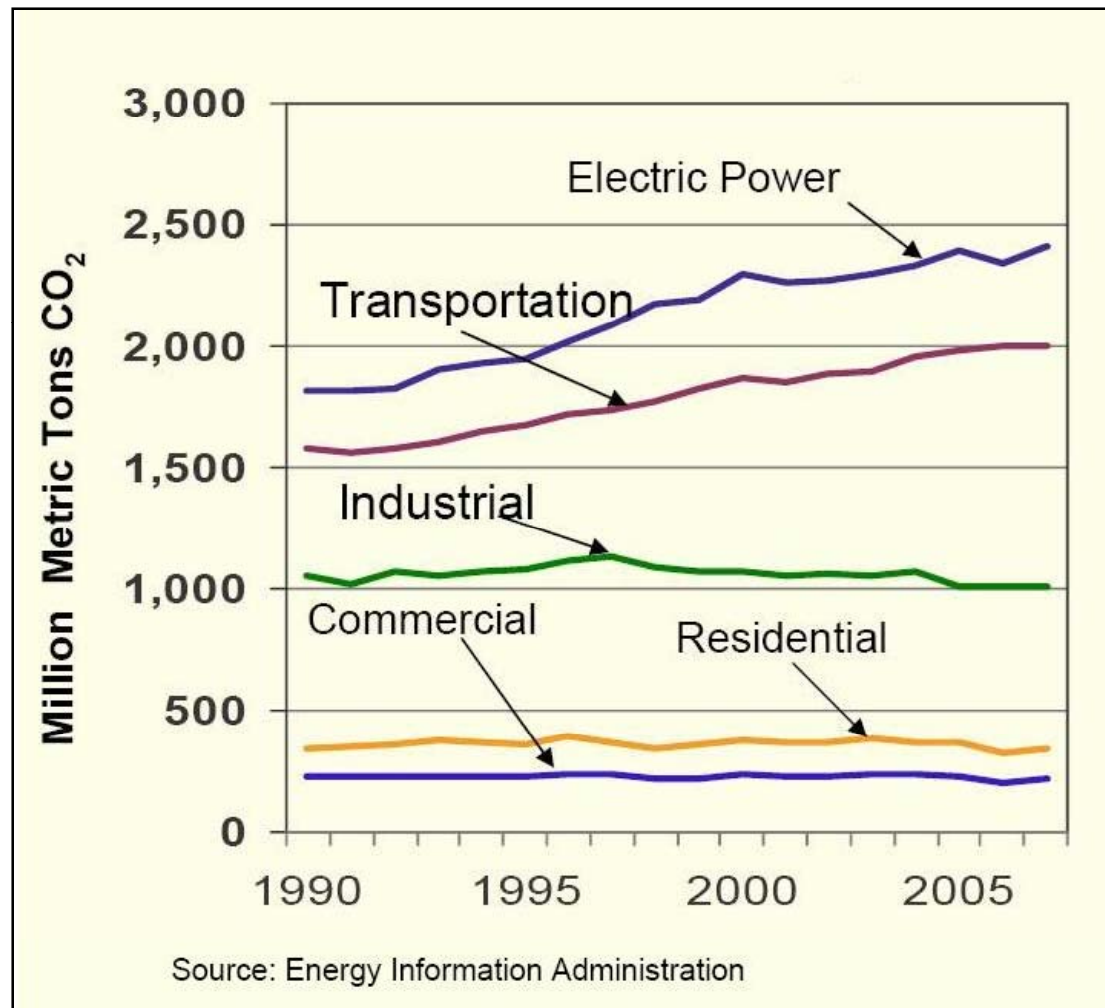


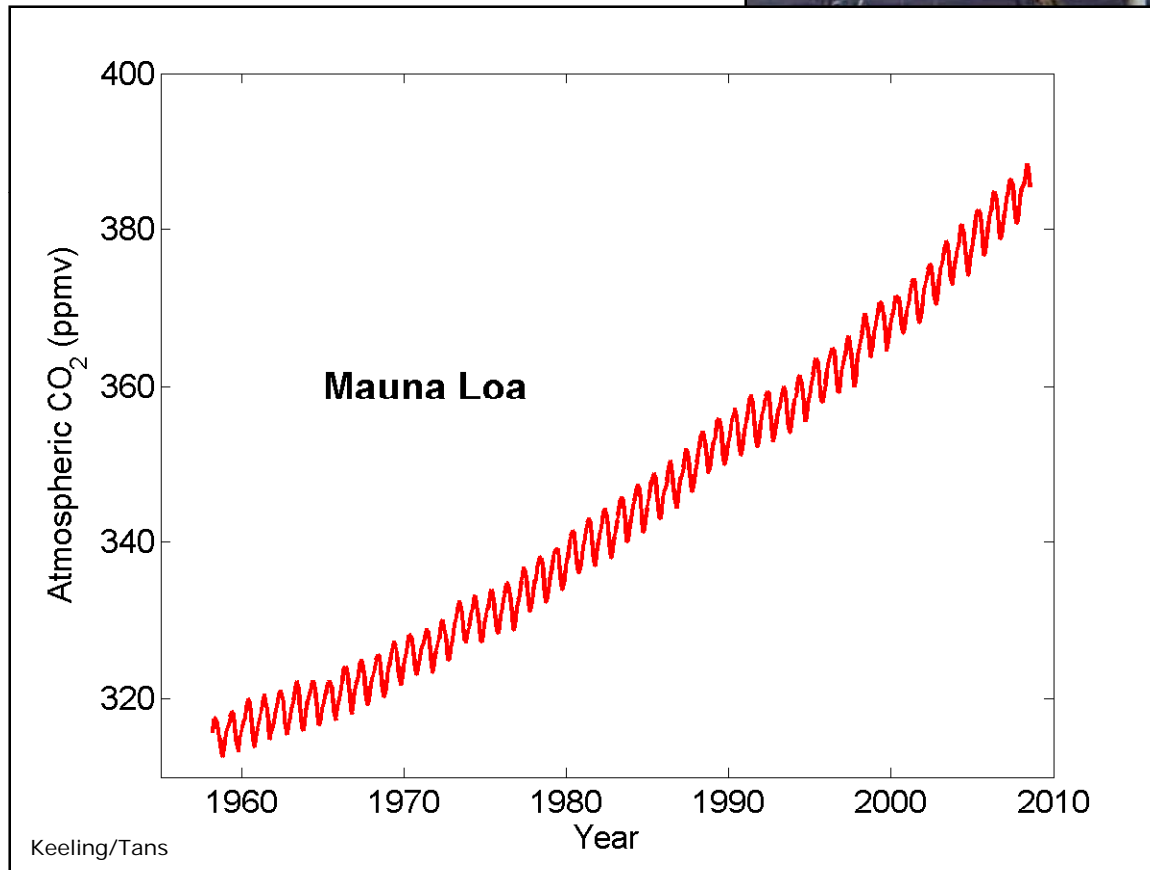
Sources:

- Fossil fuel burning
(petroleum, coal, gas)
- Deforestation
- Cement manufacturing



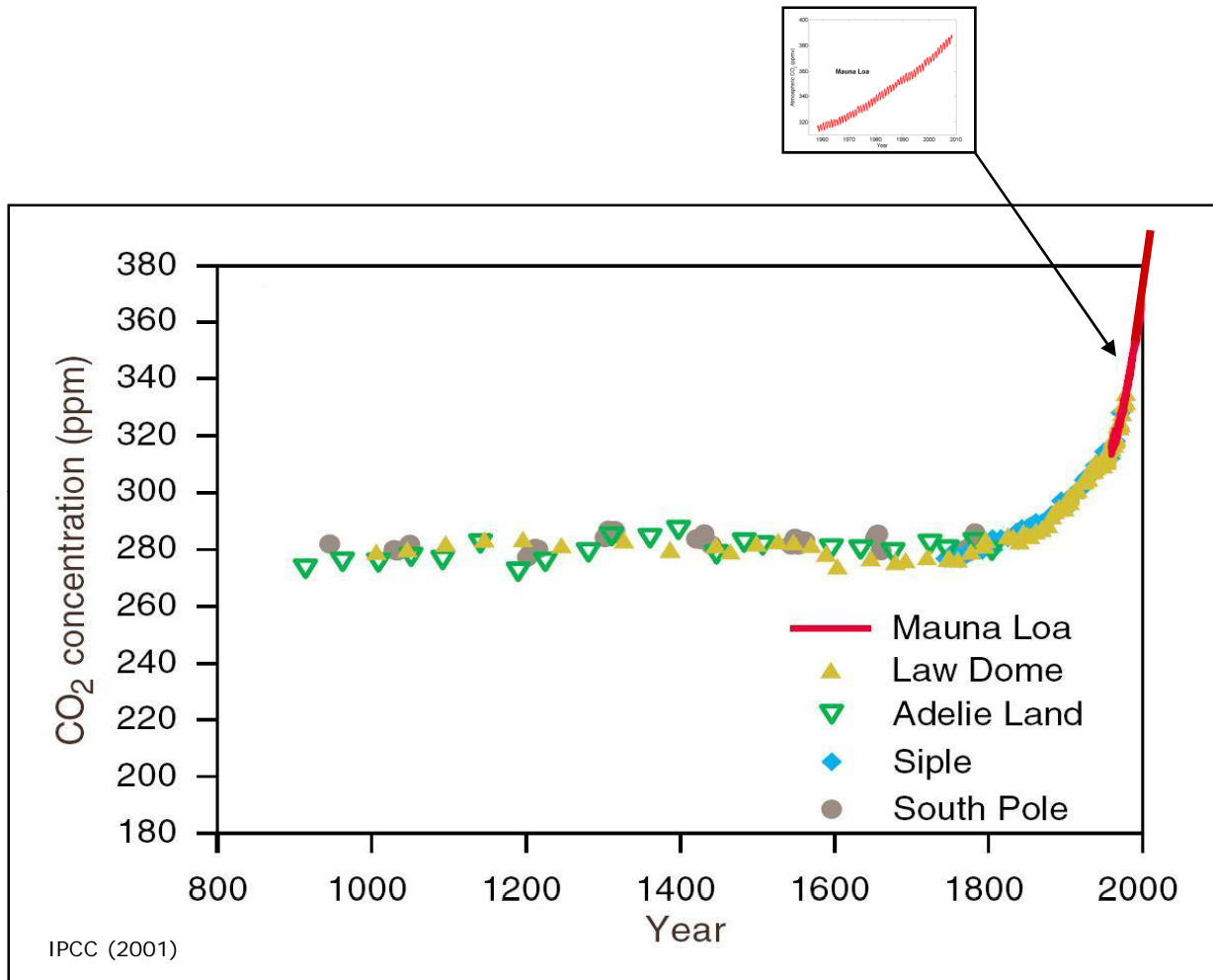
Fossil fuel burning (US)





Carbon Dioxide

Atmosphere



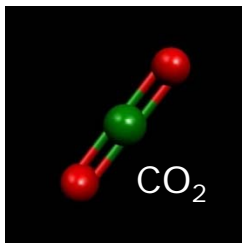
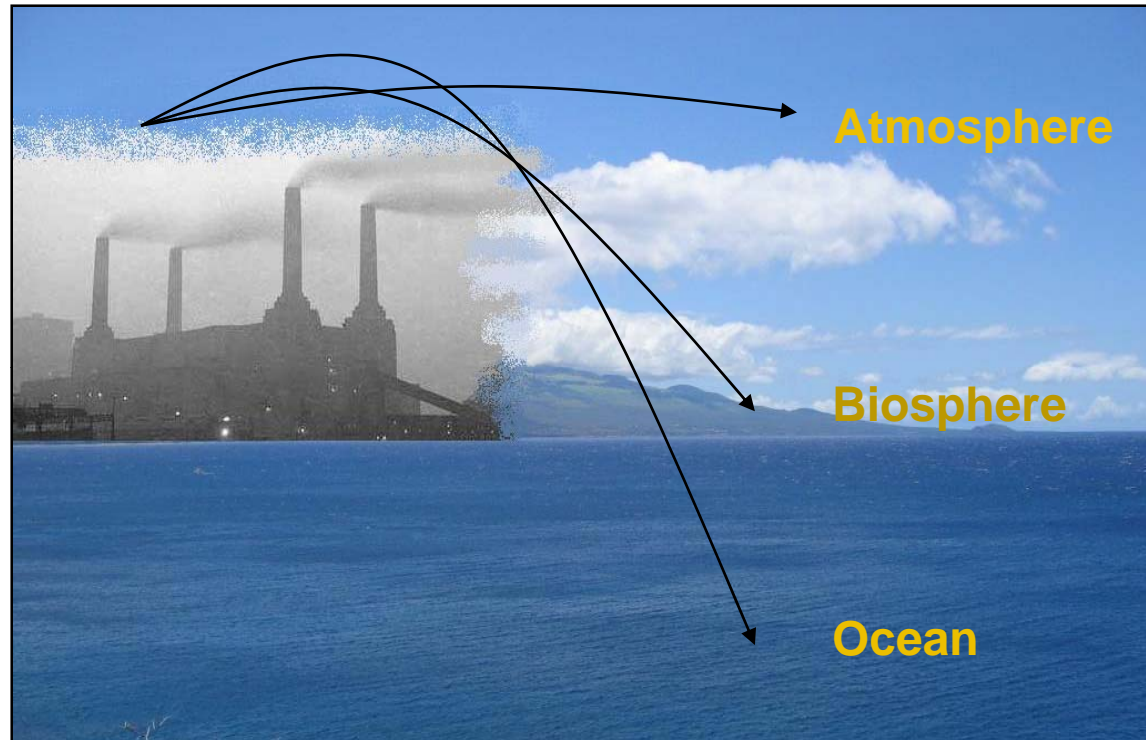
About 40% increase.

0. Carbon Dioxide

1750-2004:

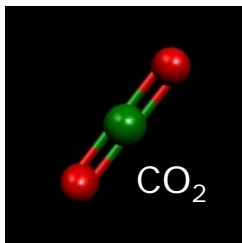
<u>Emissions</u>	<u>Oceans</u>
~1,200	~500

(billion metric tons CO₂)



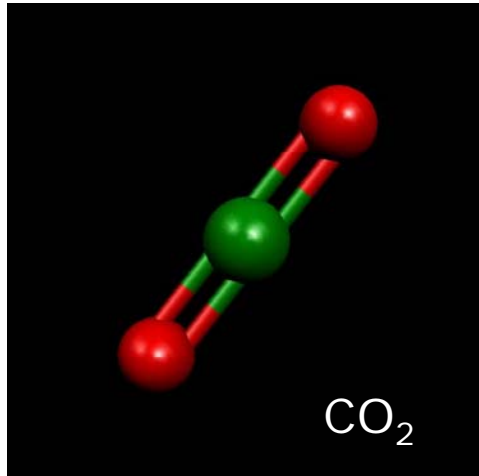
0. Carbon Dioxide

500 billion tons CO₂ equivalent in weight to 140 cm of water across Malaysia.

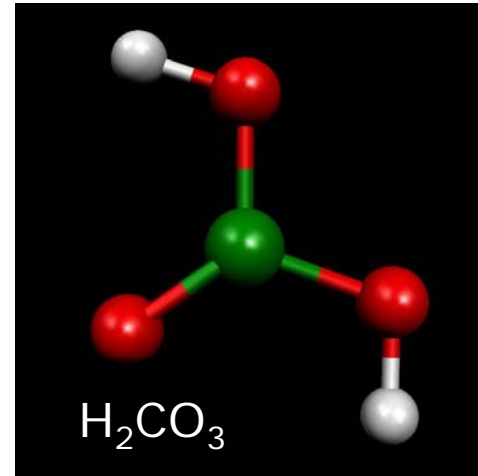


2. Carbon Dioxide in the Ocean

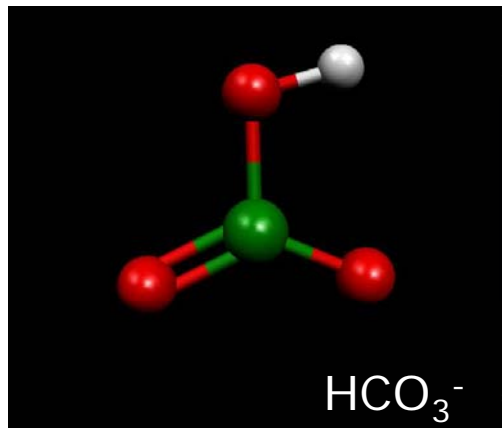
Carbon Dioxide



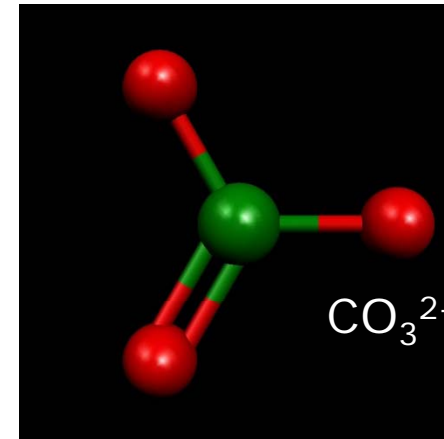
Carbonic Acid

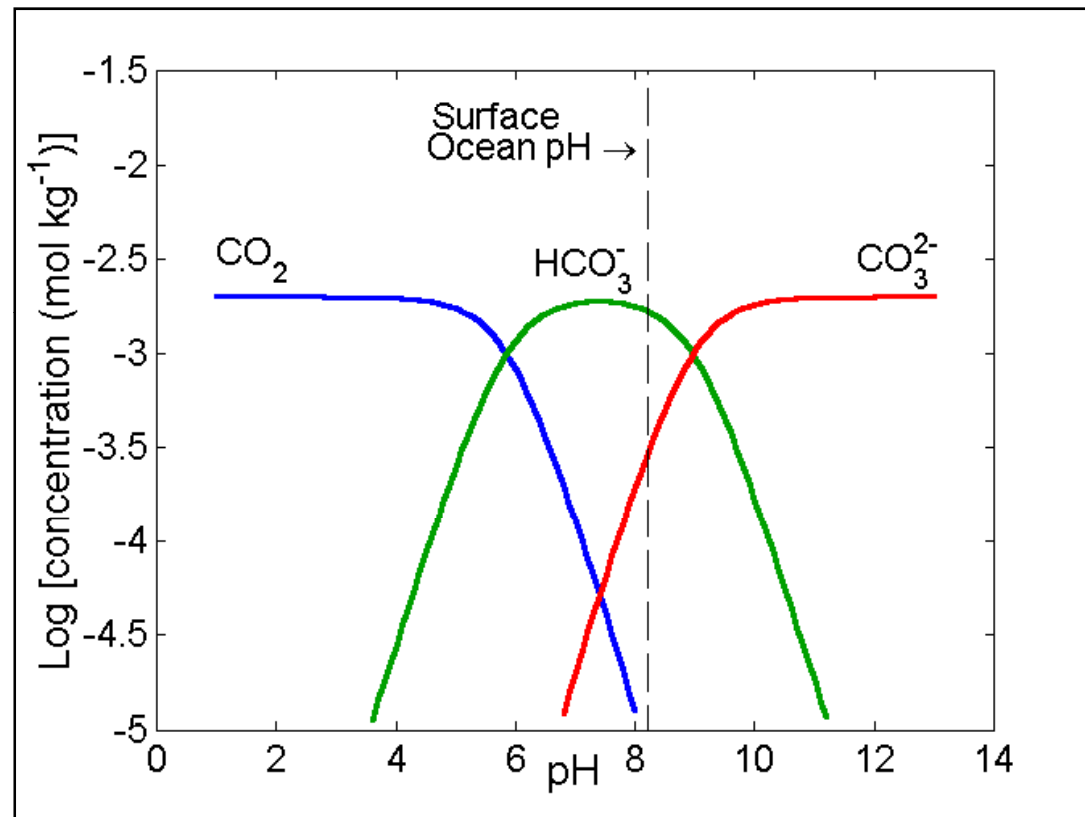


Bicarbonate Ion



Carbonate Ion



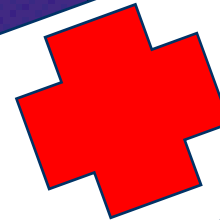


Zeebe and Wolf-Gladrow (2001)

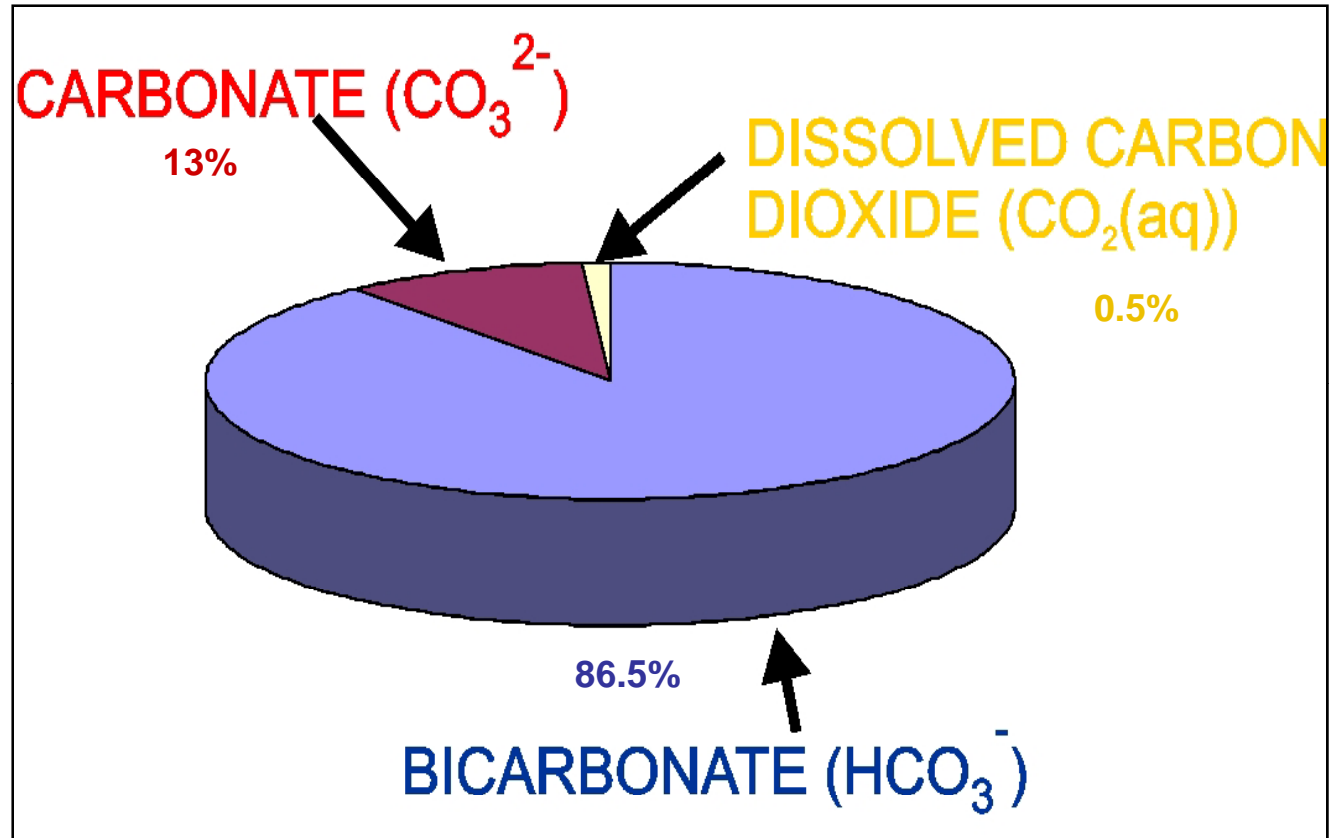
RICHARD E. ZEEBE and DIETER A. WOLF-GLADROW

**CO₂ IN SEAWATER:
EQUILIBRIUM, KINETICS,
ISOTOPES**

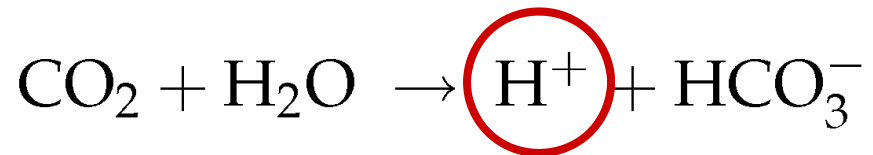
The CO₂ survival kit



ELSEVIER OCEANOGRAPHY SERIES



Dissolution of CO₂ lowers pH:

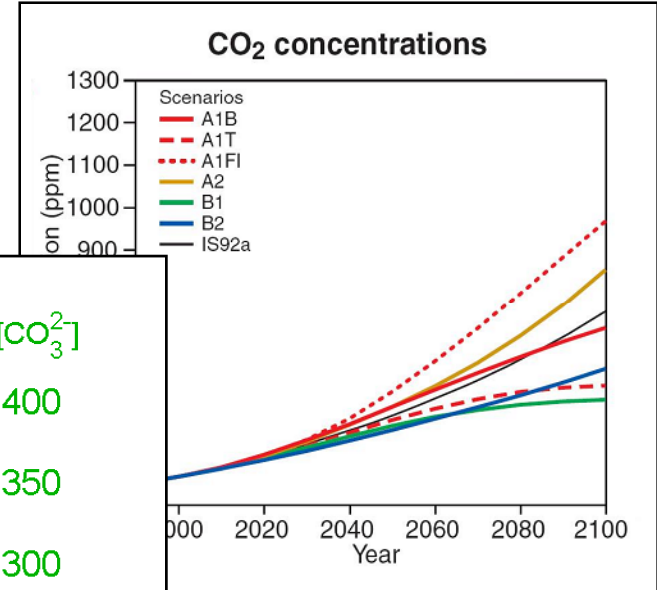
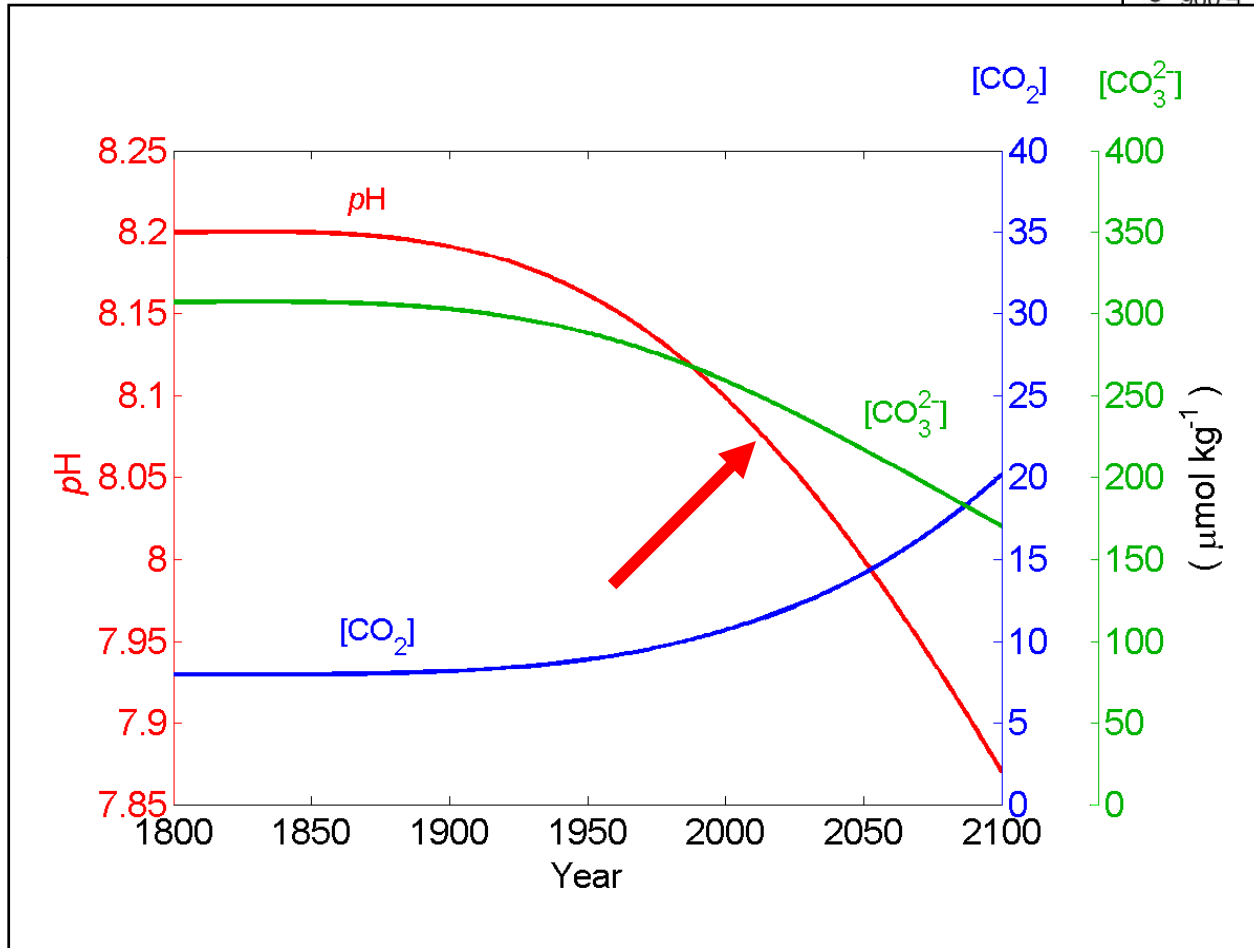


Logarithmic scale!
(Richter scale)

$$\text{pH} = -\log([\text{H}^+])$$

pH = 0	Battery acid, strong hydrofluoric acid
pH = 1	Hydrochloric acid secreted by stomach lining
pH = 2	Lemon juice, gastric acid, vinegar
pH = 3	Grapefruit, orange juice, soda
pH = 4	Tomato juice, acid rain
pH = 5	Soft drinking water, black coffee
pH = 6	Urine, saliva
pH = 7	"Pure" water
pH = 8	Seawater
pH = 9	Baking soda
pH = 10	Great Salt Lake, milk of magnesia
pH = 11	Ammonia solution
pH = 12	Soapy water
pH = 13	Bleach, oven cleaner
pH = 14	Liquid drain cleaner

Ocean Acidification



$$10^{-7.9} / 10^{-8.2} \simeq 2$$

Zeebe & Wolf-Gladrow, 2001.

Ocean Acidification

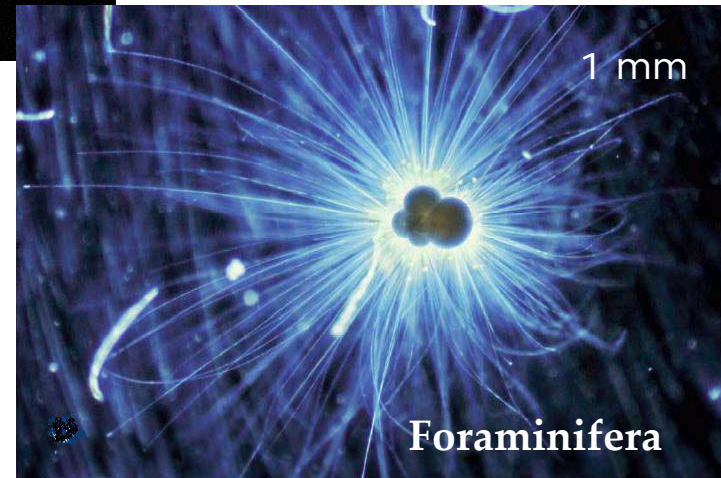
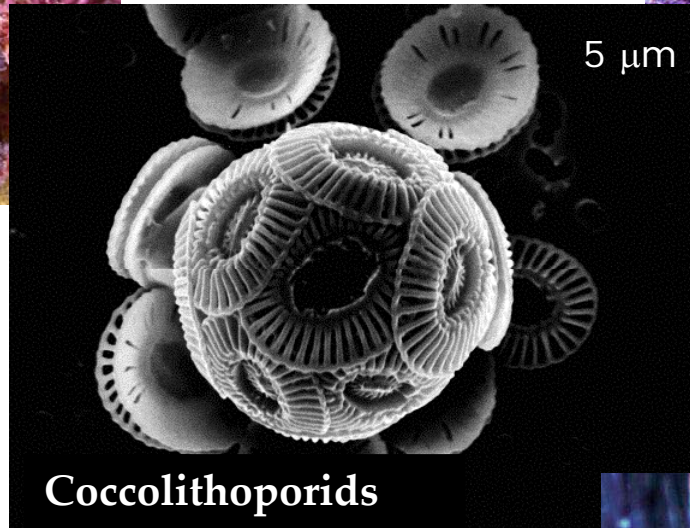


Dissolution of CaCO_3 neutralizes the acid:



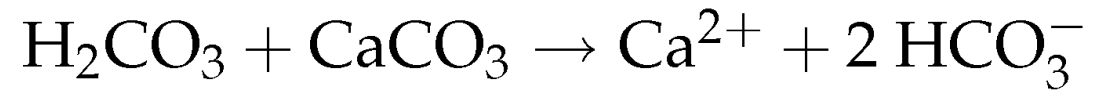
FAST ACTING Supreme Tasting	
Drug Facts	
Active ingredients (in each 5 mL teaspoon)	Purposes
Calcium carbonate 400 mg.....	Antacid
Magnesium hydroxide 135 mg.....	Antacid

Ocean Acidification



Ocean Acidification

Dissolution of CaCO_3 neutralizes the acid:

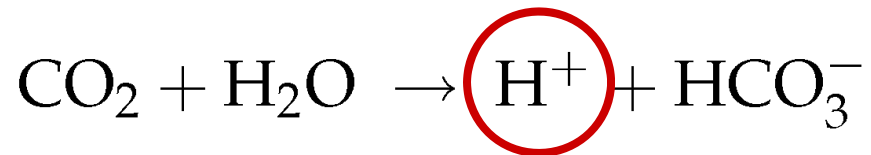


Anthropogenic
 CO_2

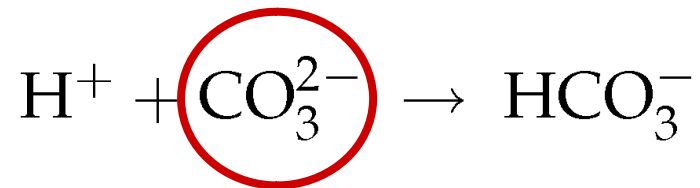


Just an illustration!

Dissolution of CO₂ lowers pH:



and carbonate mineral saturation:



$$\text{pH} = -\log([\text{H}^+])$$

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Ocean Acidification

Saturation State



Ocean Acidification

Saturation State

