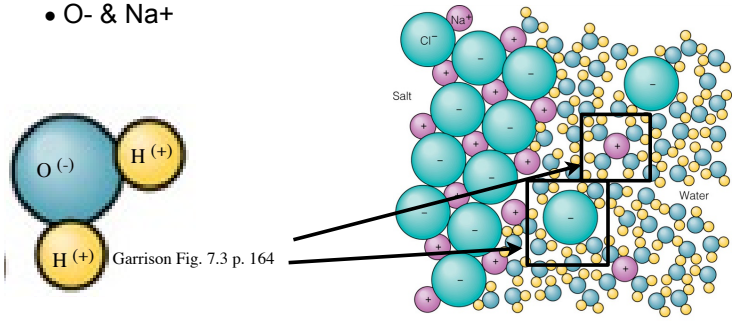
What is Salinity?

- What are salts?
  - Molecules that break apart easily in water solution
  - Atoms separate from each other to form ions
- What are ions?
  - Electrically charged atoms
  - Gain or lose one or more electrons in solution
- What is salinity?
  - Salinity = grams salts per kilogram sea water
- What is an approximate global average salinity?
  - Average = 35 g/kg = 3.5%

Why are Sea Salts Soluble?

- Ionic molecules dissolve easily in water
  - Water molecule H_2O has electrical polarity
  - Water molecules attract salt ions
    - H+ & Cl-
    - O- & Na+



Garrison Fig. 7.3 p. 164

What are the Big 6 Salt Ions?

- Chloride (Cl^-) ~ 55% of salts
- Sodium (Na^+) ~ 31% of salts
- Sulfate (SO_4^{2+}) ~ 3% of salts
- Magnesium (Mg^{2+}) ~ 1% of salts
- Calcium (Ca^{2+}) ~0.4% of salts
- Potassium (K^+) ~0.4% of salts
- Bicarbonate (HCO_3^-) ~0.15% of salts

Why is the Sea Salty?

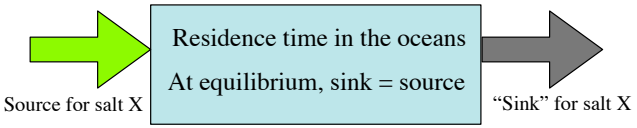
- Salts enter the ocean from various sources:
  - Erosion of land, transport by rivers
  - "Excess volatiles"
    - Ions delivered as gases rather than dissolved solids
    - Terrestrial volcanoes
    - Hydrothermal vents at rift valleys

Why is the Sea not more Salty?

- Salts leave the ocean via various "sinks:"
  - Inorganic (non-biogenous) sediments
  - Organic (biogenous) sediments
  - Evaporation
    - Salt does not evaporate
    - But when seas evaporate they leave salt deposits
    - Mediterranean 5.5 million years ago
  - Hydrothermal vents

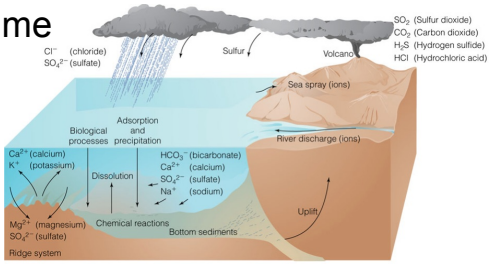
What is Residence Time?

- The length of time a salt ion spend in the ocean between source & sink
- What determines residence time?
  - Solubility of the salt
  - Big 6 are all very soluble & have long residence
- What is chemical equilibrium?
  - Inputs are equaled by outputs
    - Sources = Sinks



Residence Time

- Residence time (years) =
  - Amount in ocean ÷ amount entering/leaving per year
- Long residence time
  - Large amount in ocean
  - Very soluble
- Short residence time
  - Small amount in ocean
  - Poorly soluble



What is Conservative?

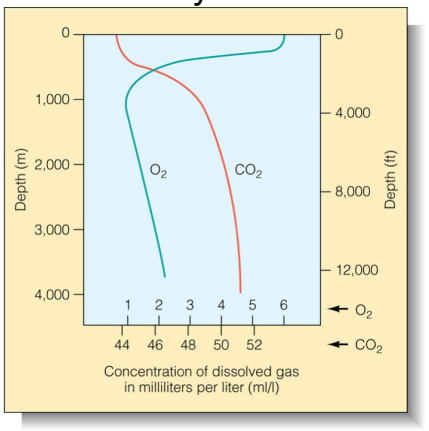
- Conservative constituents not (significantly) affected by biology
  - Maintain a constant ratio to total salinity
  - Na, Cl, Mg, K, SO_4
- What Principle do they obey?
  - Principle of Constant Proportions
    - Fixed ratio of conservative ions
- What are nonconservative constituents?
  - Concentrations depends on biology
  - Ratio to total salinity varies
    - Ca, CO_2 system members, O_2, nutrients

What are Gases in Sea Water?

- Nitrogen (N_2)
- Oxygen (O_2)
- Carbon dioxide (CO_2)
- What are sources & sinks for these gases?
  - Atmosphere
  - Biological activity
    - Photosynthesis
    - Respiration & decomposition
    - Nitrogen fixation, denitrification
    - Nutrient uptake

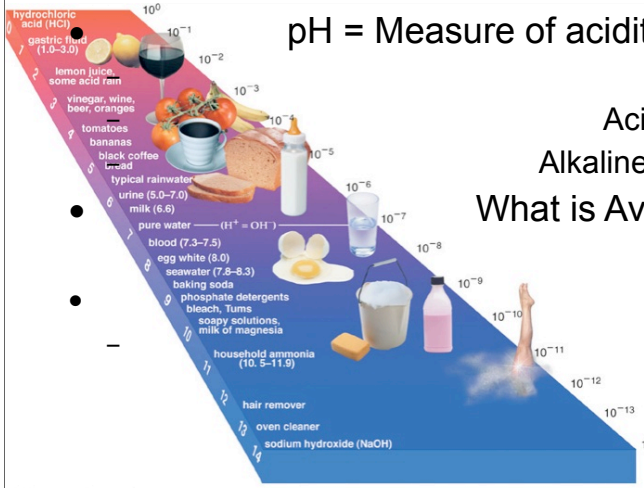
O_2 & CO_2 Depth Changes

- Where is O_2 most abundant & why?
  - At surface
  - Photosynthesis
- Least abundant?
  - Deep water
  - Respiration
- CO_2 least abundant?
  - Surface
  - Photosynthesis
- Most abundant?
  - Deep (respiration)



Garrison Fig. 7.8 p. 172

What is pH?



- pH = Measure of acidity & alkalinity
  - Neutral = 7
  - Acid = less than 7
  - Alkaline = more than 7
- What is Average acidity of ocean?
- Alkaline: ~8
  - range 7.8-8.3

Garrison Fig. 7.9 p. 172

What are Key Forms of CO_2?

- Dissolved CO_2
- Carbonic acid H_2CO_3
- Bicarbonate HCO_3^-
- Carbonate CO_3^{-2}
- Hydrogen ion H^+
- How do these forms change in relative abundance with pH?
  - Lower pH (more acid) = more CO_2/H_2CO_3, less CO_3
  - Higher pH (more alkaline) = less CO_2/H_2CO_3, more CO_3

What are Key Roles of CO_2?

- Controls acidity & alkalinity of sea water
  - "Buffering"
- Source of carbon for photosynthesis
- Source of skeletal material for numerous organisms
  - Calcium carbonate $CaCO_3$
  - Calcareous plankton
  - Bottom-living shellfish: clams, crabs, etc.
  - Coral reefs
- What happens with ocean acidification?
  - Lower pH: less CO_3 for calcareous skeletons

Carbon Dioxide Buffering

- Why does buffering of pH matter?
  - Formation of calcium carbonate $CaCO_3$ skeletons sensitive to pH
- Proportions of CO_2, H_2CO_3, HCO_3^-, CO_3^{-2}, H^+ shift to maintain constant pH
  - Reactions proceed in either direction
- Ocean pH currently decreasing
  - Increasing atmospheric CO_2
  - Mostly decreasing at surface where it enters ocean
  - Pteropods, foraminifera, coccoliths at high latitudes in trouble?

Nutrients

- What are the "macro"-nutrients most likely to be limiting in the ocean?
  - Nitrogen N, phosphorus P, silica Si (diatoms)
  - Could CO_3^{-2} join that group?
- Supply of these nutrients limits primary production under some conditions
  - Often depleted for photosynthesis at the surface