

# Dissolved Oxygen



# Dissolved Oxygen

- Required by all aerobic organisms
- Oxygen affects solubilities of other chemicals



# Solubility

- Air is 21% oxygen and the rest is mostly nitrogen
- Oxygen is more soluble in water than nitrogen, therefore water contains more oxygen than would be expected from concentrations in the air



# Solubility of oxygen in water

- Solubility decreases as temperature increases
  - Change in solubility is nonlinear (parabolic)



# Solubility of oxygen in water

- Solubility increases as pressure increases
  - Pressure is determined by atmospheric and hydrostatic factors
    - Altitude and depth affect solubility
  - Saturation is often defined for a particular depth by adjusting for pressure
  - Pressure reduces the amount of bubble formation



# Solubility of oxygen in water

- Solubility increases as pressure increases
  - Generally oxygen at depths greater than 1 to 4 meters can remain dissolved due to hydrostatic pressure
  - Concentrations of oxygen can be much greater than at the surface and still be at saturation



# Solubility of oxygen in water

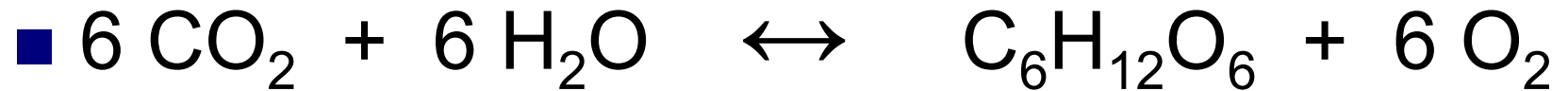
- Solubility decreases exponentially as salinity increases
  - Solubility of oxygen in seawater is 80% of solubility in freshwater

# Solubility of oxygen in water

- Distribution of dissolved oxygen in lakes
  - Diffusion of gases in water is slow
  - Circulation of water is required to establish an equilibrium between air and water
- At turnover, oxygen in the water is at 100% saturation (12 to 13 mg/l at 4°C and near sea level)



# Oxygen profiles



# Orthograde oxygen profile

- In an oligotrophic lake (low nutrient inputs and low organic production), oxygen concentration at depth is regulated by physical processes
- Oxygen concentration is at 100% saturation throughout lake
- Absolute concentrations of oxygen decrease in the warmer waters of the epilimnion and increase in the cooler waters of the metalimnion and hypolimnion



# Clinograde oxygen profile

- In a eutrophic lake (high nutrient inputs and high organic production), oxygen concentration at depth is regulated largely by biological processes

# Clinograde oxygen profile

- Oxidative processes (decomposition and respiration) result in the consumption of oxygen
  - Animals, plants, and microbes consume oxygen
  - Dissolved organic matter is oxidized and oxygen is taken up
    - Purely chemical oxidation
    - Photochemical oxidation by UV light
    - Primary production generates dissolved oxygen
- $6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \leftrightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$



# Clinograde oxygen profile

- Oxidative consumption reduces oxygen concentrations in the hypolimnion and oxygen concentrations are less than 100% saturation
- Circulation and primary production in the epilimnion maintain oxygen at 100% saturation

# Formation of ice in winter

- Ice blocks exchange of oxygen with the atmosphere
- In an oligotrophic lake, oxygen would be at 100% saturation throughout the lake
  - Oxygen concentration would be slightly higher in the colder epilimnetic water during inverse stratification
- In a eutrophic lake, oxygen concentration would be less than 100% saturation due to oxidative consumption of oxygen
  - Oxygen concentrations would be lower in the lower hypolimnetic waters over the sediment



# Metalimnetic oxygen maxima

- Oxygen concentrations may be greatest in the metalimnion during stratification
- A metalimnetic oxygen maximum is called a positive heterograde curve



# Metalimnetic oxygen maxima

- Thermal influence on oxygen solubility in the epilimnion and oxidative consumption in the hypolimnion may result in a positive heterograde curve during summer stratification





# Metalimnetic oxygen maxima

- Certain algae that are adapted to low temperatures and low light intensity may be found in high abundance in the metalimnion (with potentially higher nutrient concentrations) and their photosynthetic activity results in a positive heterograde curve (usually above 100% saturation)



# Metalimnetic oxygen maxima

- When the metalimnion coincides with dense beds of macrophytes in the littoral zone of the lake, metalimnetic maxima for oxygen may occur



# Metalimnetic oxygen minima

- When oxygen concentrations are lowest in the metalimnion, the oxygen versus depth profile is called a metalimnetic oxygen minimum or negative heterograde curve



# Metalimnetic oxygen minima

- Reduced sinking rates of particulates or animals (microcrustaceans) may result in an accumulation in the metalimnion. The oxidative consumption of oxygen associated with this material (microbial respiration or animal respiration) can result in a metalimnetic oxygen minimum



# Metalimnetic oxygen minima

- Senescence and decomposition of macrophytes in the littoral zone associated with the metalimnion may result in a metalimnetic oxygen minimum



# Meromictic lakes

- Extreme clinograde oxygen profiles can occur in lakes that are permanently meromictic
- Organic matter and sulfides in the monimolimnion rapidly deplete any intrusion of oxygen

# Extreme oxygen concentrations

- Aquatic plants are not uniformly distributed throughout the lake basin
- Macrophytes often occur in the highest abundance in the littoral zones around the edge of the lake
  - Oxygen production associated with intense photosynthetic activity may result in localized high concentrations of oxygen
  - Oxygen depletion associated with the decomposition of dying macrophytes may result in localized low concentrations of oxygen
  - In shallow lakes with extensive growth of aquatic macrophytes, decomposition of dying macrophytes in late summer may result in oxygen reduction to near anoxic conditions



# Extreme oxygen concentrations

- Such reductions may cause a catastrophic die-off of animals, a condition termed summerkill
  - Photosynthesis during the day and respiration at night by phytoplankton can result in major changes in oxygen concentrations in the upper waters of the lake over a diel cycle





# Extreme oxygen concentrations

- Ice cover and snow cover on a lake in winter can cause extreme reductions in light. Decomposition and respiration in the ice-covered lake can reduce the oxygen concentrations to near anoxia and cause a catastrophic die-off in the winter, a condition termed winterkill



# Major zones in a lake

- Trophogenic zone - the upper stratum of a lake in which photosynthetic activity predominates
- Tropholytic zone - the aphotic deep stratum of a lake where decomposition of organic matter predominates

# Major zones in a lake

- Photic zone - the upper stratum of a lake which receives light input (generally greater than 1% of surface radiation)
- Aphotic zone - the lower stratum of a lake in which there is no light (generally less than 1% of surface radiation)

