Dissolved Gases in Seawater

Ghana Summer School

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Outline

- Nitrogen, Carbon dioxide, Oxygen
- Dalton's Law, Henry's Law and Estimation of Concentrations
- Distribution of Gases in the ocean
- Factors controlling the distribution of Gases in the ocean

Relevance of GE in the Ocean

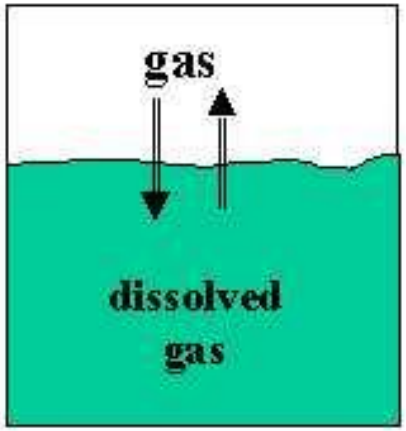
- Photosynthesis and Respiration: CO_2 and O_2
- Climate regulation: CO_2, N_2O, CH_4
- Building of calcium carbonate shells: CO_2
- Paleoenvironmental Reconstruction

GASES IN AIR AND DISSOLVED IN SEA WATER AT EQUILIBRIUM WITH AIR

The percentage of gases in sea water is based on the total gases dissolved in sea water at equilibrium with air.

Gas	Chemical Symbol	Percentage in Air	Percentage in Sea Water
Nitrogen	N_2	78.08	62.6
Oxygen	O_2	20.95	34.3
Argon	Ar	0.934	1.6
Carbon Dioxide	CO_2	0.033	1.4
Neon	Ne	0.0018	0.00097
Helium	He	0.00052	0.00023
Methane	CH_4	0.00020	0.00038
Krypton	Kr	0.00011	0.00038
Carbon Monoxide	CO	0.000015	0.000017
Nitrous Oxide	N_2O	0.000050	0.0015
Xenon	Xe	0.0000087	0.000054

Gas Solubility



At equilibrium:

$$Gas_{(g)} \Leftrightarrow Gas_{(aq)}$$

Equilibrium constant:

$$K_{eq} = \frac{[Gas]aq}{[Gas]g}$$

Can solve for $[Gas]_g$ using Ideal Gas Law...

- $[Gas]_g$ is usually expressed as a partial pressure P_A

Gas Law Fundamentals -

Dalton's Law

$$P_{Total} = \sum \text{Partial Pressures}$$

Ideal Gas Equation

$$P_{Total} = \frac{n_{total} R T}{V} = (n_a + n_b + n_c + \ldots)\frac{(RT)}{V}$$

Chemical Constituents of the Atmosphere

Major Gases (> ppm)	% By Volume
N_2	78.08
O_2	20.95
Ar	0.93
CO_2	0.04
(H_2O	Variable)

Trace Gases (≤ppm)	ppmv
Ne	18
He	5.2
CH_4	1.7
Kr	1.1
H	0.5
O_3	0.05-6
N_2O	0.4-1
NO	0-0.5
SO_2	0-0.5
CO	0.05-2.0

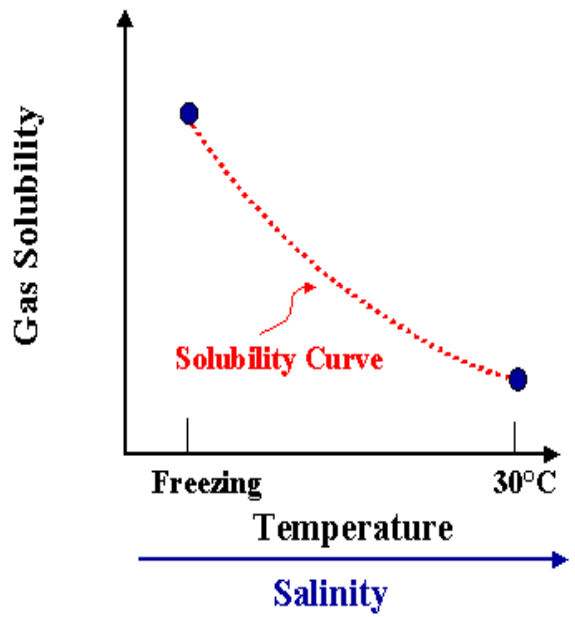
And many more less concentrated....

- P = pressure
- V = volume of gas
- n = number of moles of gas present
- T = absolute temp. K (= C + 273.15)
- R = gas constant

Henry's Law

It states: "At a constant temperature, the amount of a given gas that dissolves in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid."

$$[A_{(aq)}] = (K_{eq}/RT)P_A$$



$[A_{(aq)}]$ = concentration of gas G in solution

P_A = partial pressure of the gas

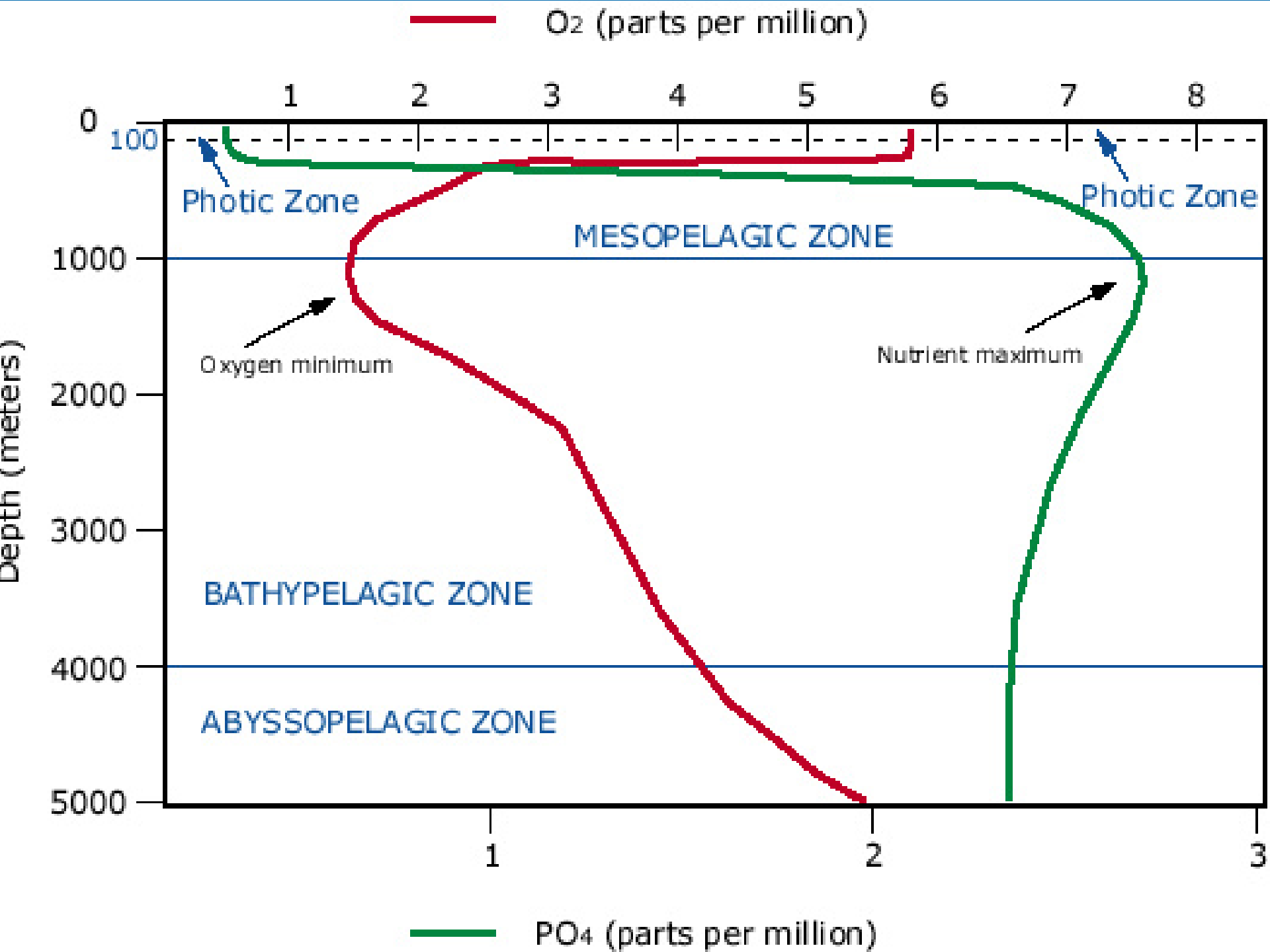
K_{eq} = Henry's law constant for gas A, this is a function of temp. and salinity

R and T are the usuals

DISTRIBUTION OF GASES IN THE OCEAN

- The surface layer is usually saturated in atmospheric gases due to the direct exchange with the atmosphere.

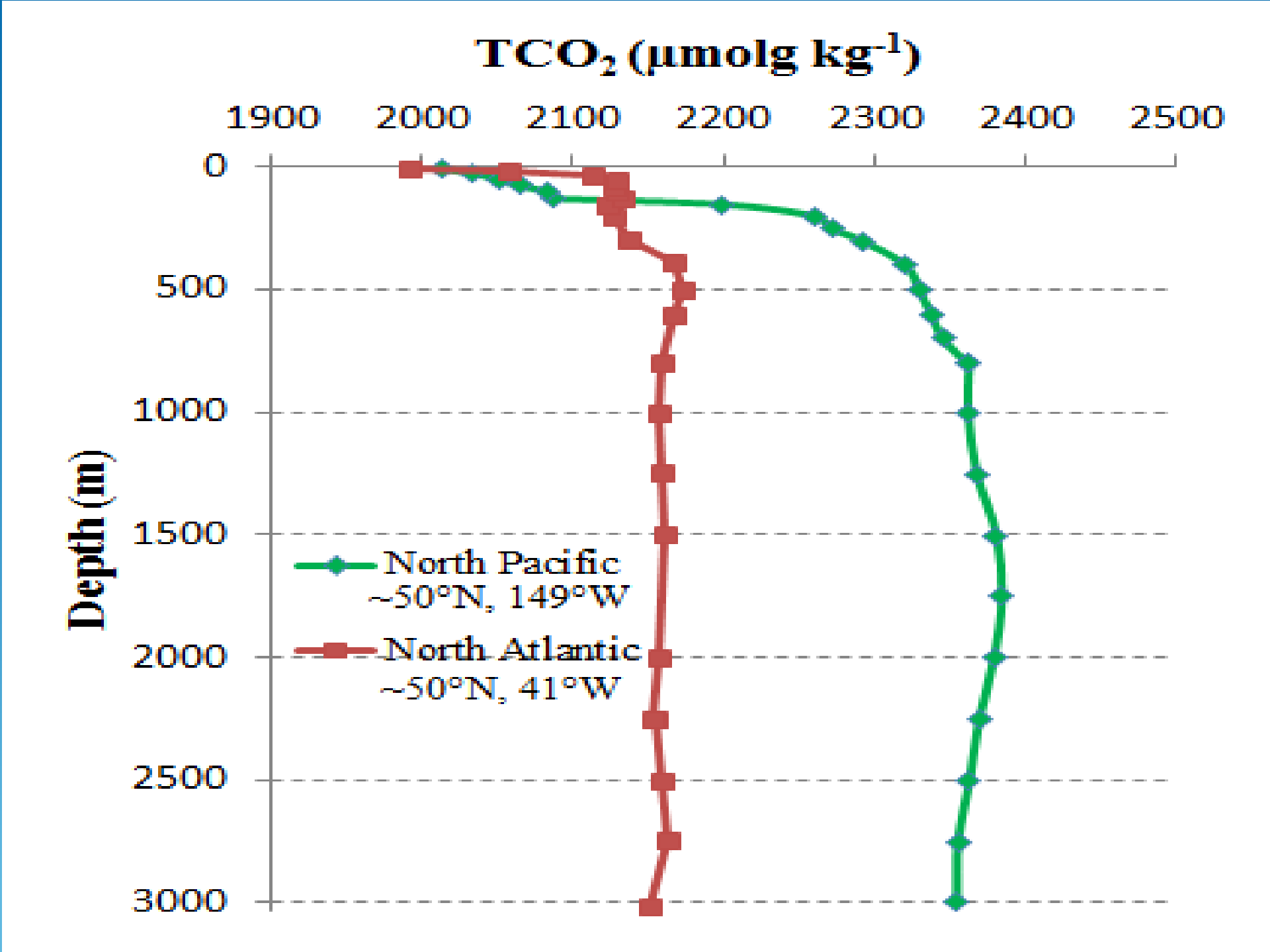
- Below the surface layer, gas content reflects relative importance of:
- Respiration,
- Photosynthesis,
- Decay and
- Gases released from volcanic vents.


O2 (parts per million)
1
2
3
4
5
6
7
8
0
100
1000
2000
3000
4000
5000
Depth (meters)
Photic Zone
Photic Zone
MESOPELAGIC ZONE
Oxygen minimum
Nutrient maximum
BATHYPELAGIC ZONE
ABYSSOPELAGIC ZONE
1
2
3
PO4 (parts per million)

Gases in Seawater: O_2

Oxygen tends to be abundant in the surface layer and deep layer bottom, but lowest in the pycnocline.

- **Surface layer is rich in oxygen because of photosynthesis and contact with the atmosphere.**
- **Oxygen minimum layer occurs at about 150 to 1500m below the surface and coincides with the pycnocline.**
  - *Sinking food particles settle into this layer and become suspended in place because of the greater density of the water below.*
  - *The food draws large numbers of organisms which respire, consuming oxygen.*
  - *Decay of uneaten material consumes additional oxygen.*
  - *Density difference prevents mixing downward of oxygen-rich water from the surface or upwards from the deep layer.*
- **The deep layer is rich in oxygen because its water is derived from the cold surface waters which sank (convect) to the bottom. Consumption is low because there are fewer organisms and less decay consuming oxygen.**
- **Anoxic waters contain no oxygen and are inhabited by anaerobic organisms (bacteria).**


TCO_2 (µmolg kg^{-1})
1900
2000
2100
2200
2300
2400
2500
0
500
1000
1500
2000
2500
3000
Depth (m)
North Pacific
~50°N, 149°W
North Atlantic
~50°N, 41°W

CO_2 IN THE OCEAN

- The vertical distribution of ΣCO_2 in the ocean is a result of the biological and physical carbon pumps.
- Uptake of carbon into organic matter and production of $CaCO_3$ in the surface ocean, the transport to deeper layers, and the remineralization at depth (biological pump) reduces ΣCO_2 in surface waters while ΣCO_2 in deep water increases