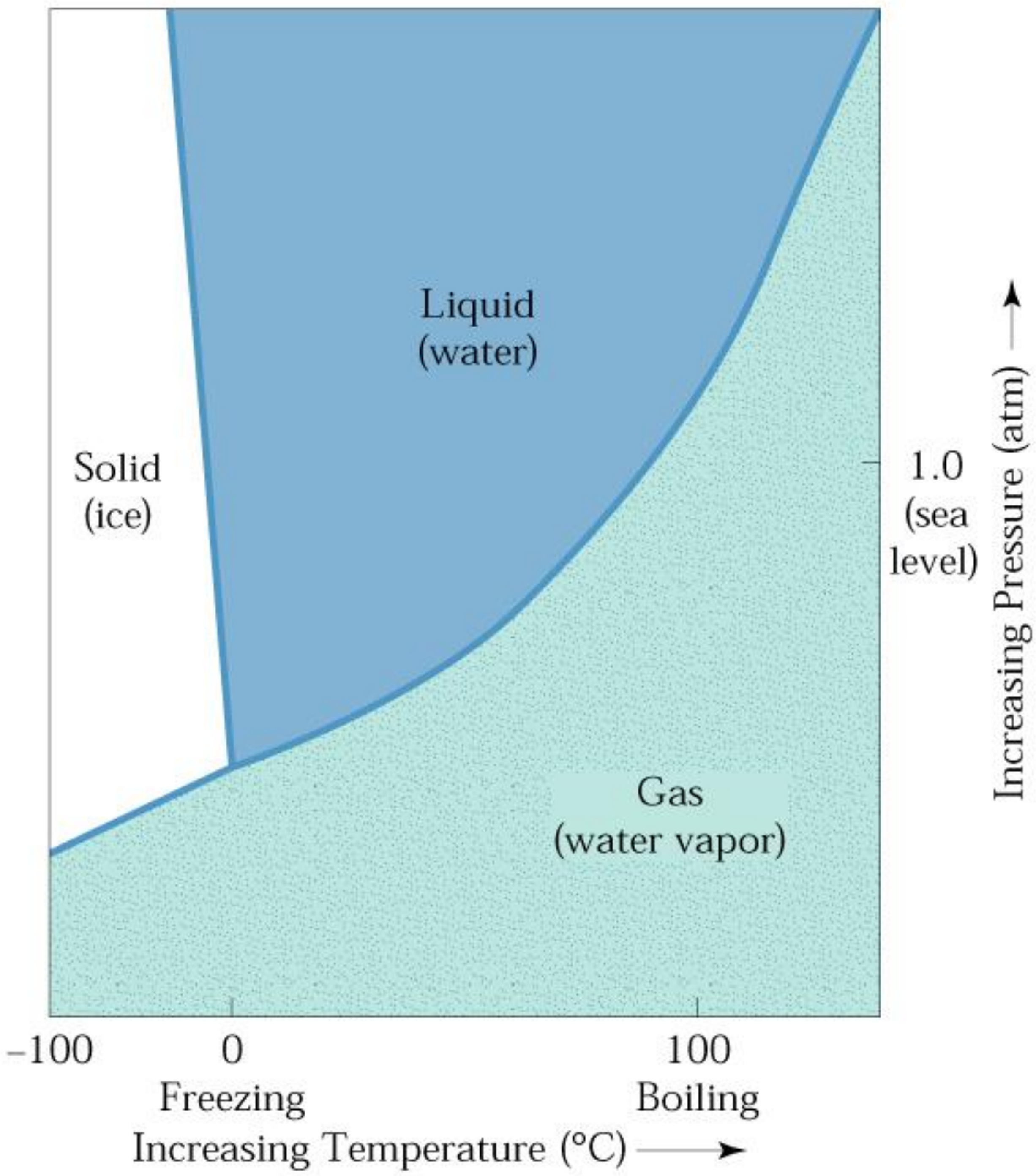
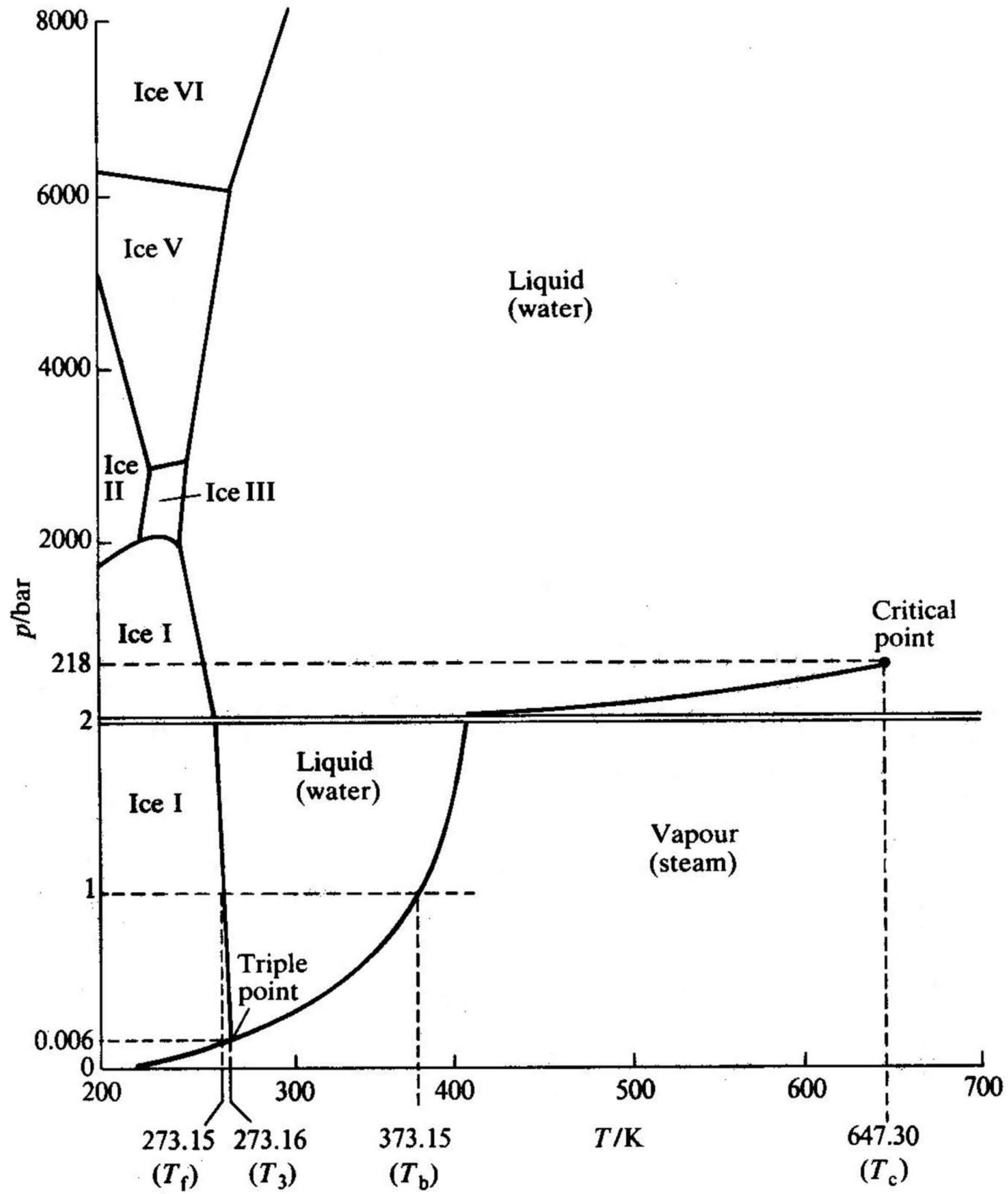


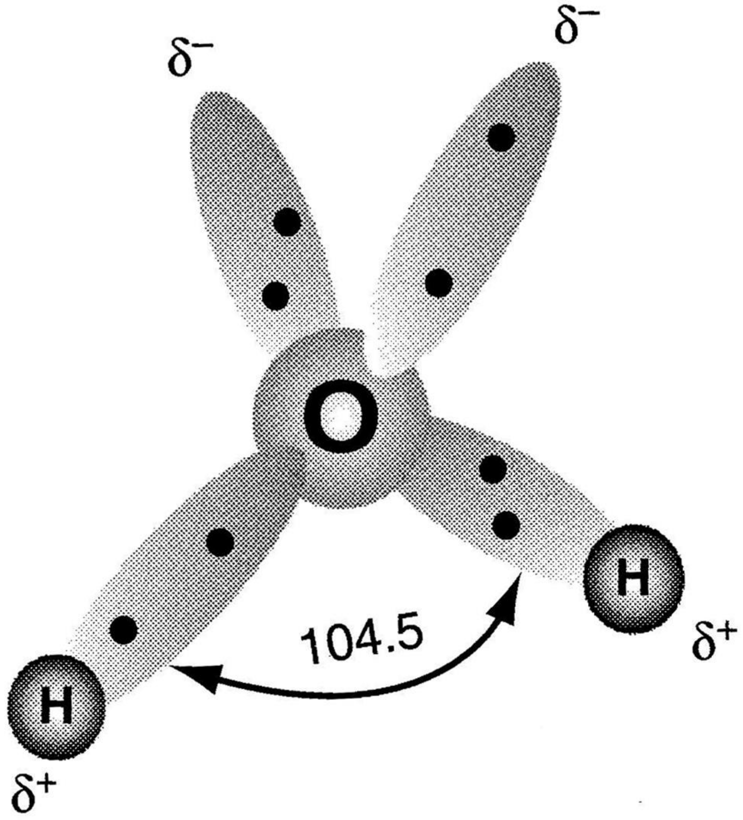
Simple Phase Diagram of Water

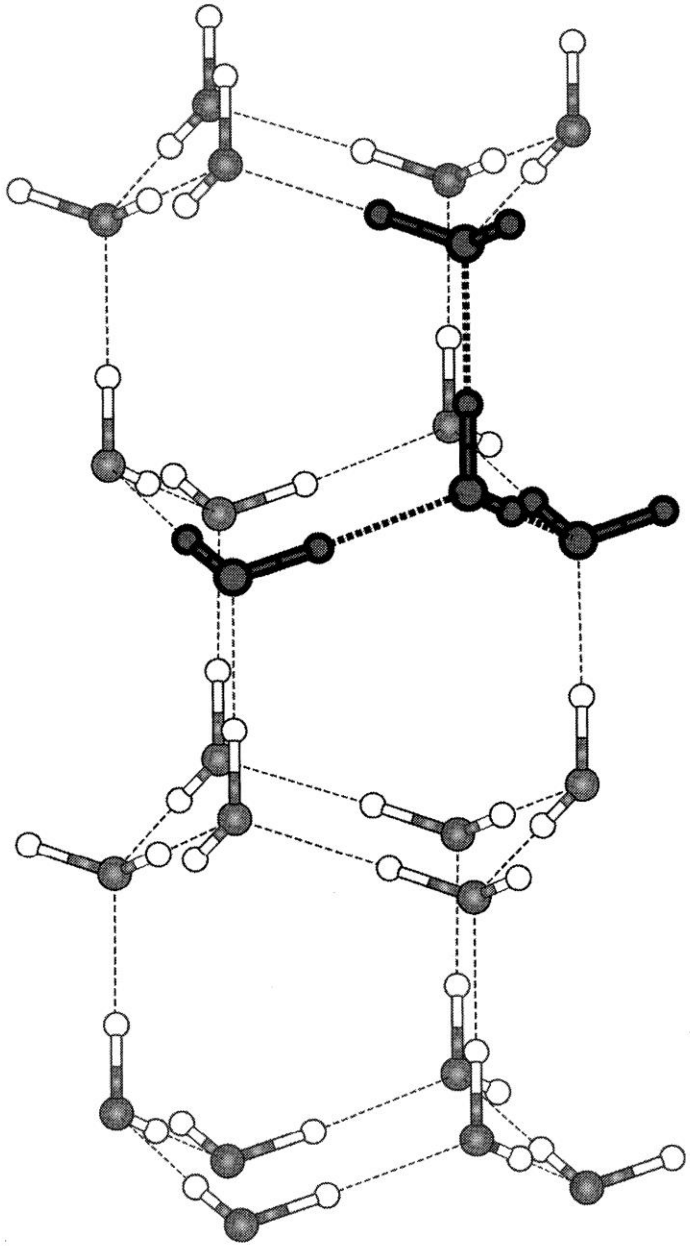
(Wiley 1999)



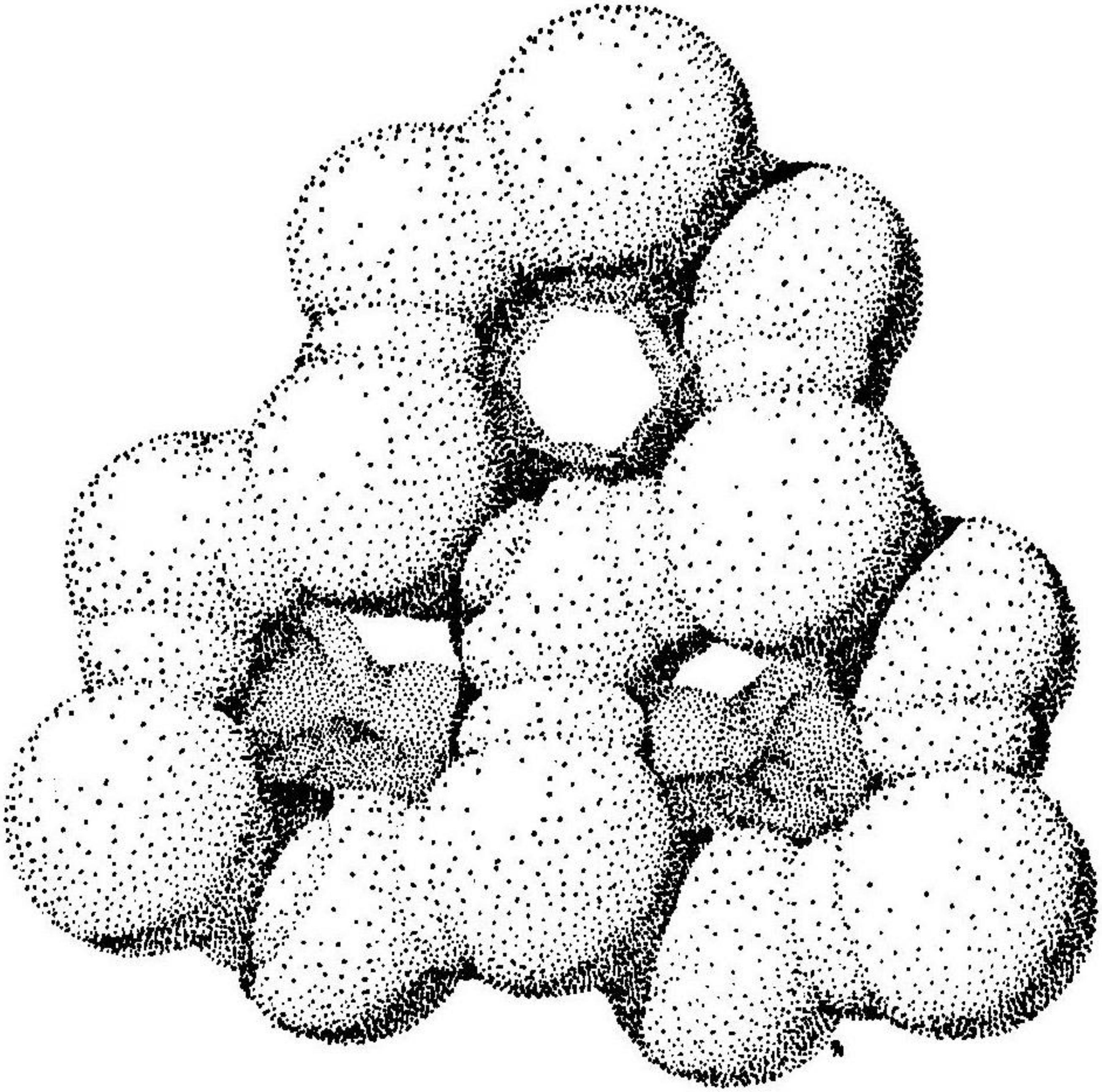
Detailed Phase Diagram of Water Showing Forms of Ice

(Atkins 1990)


δ⁻
δ⁻
O
H
H
104.5
δ⁺
δ⁺



Structure of Ice 1h with water pentamer highlighted (Emerson & Hedges Fig 3.4, page 67)

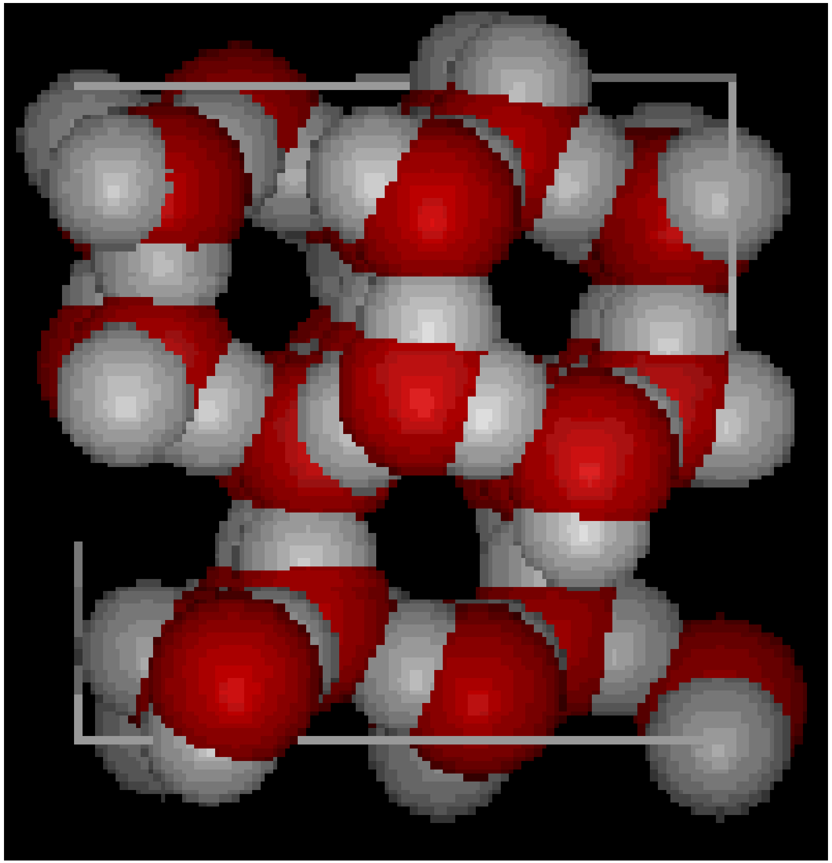


Structure of Ice 1h, Hexagonal with Space Giving Low Density

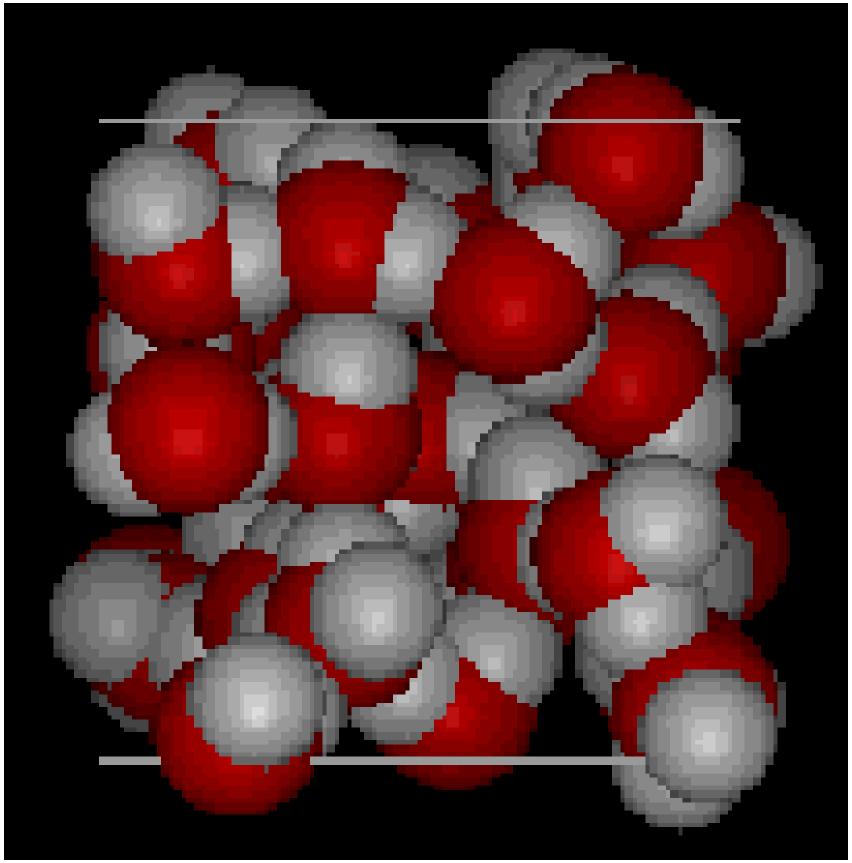
(Pilson 1998)

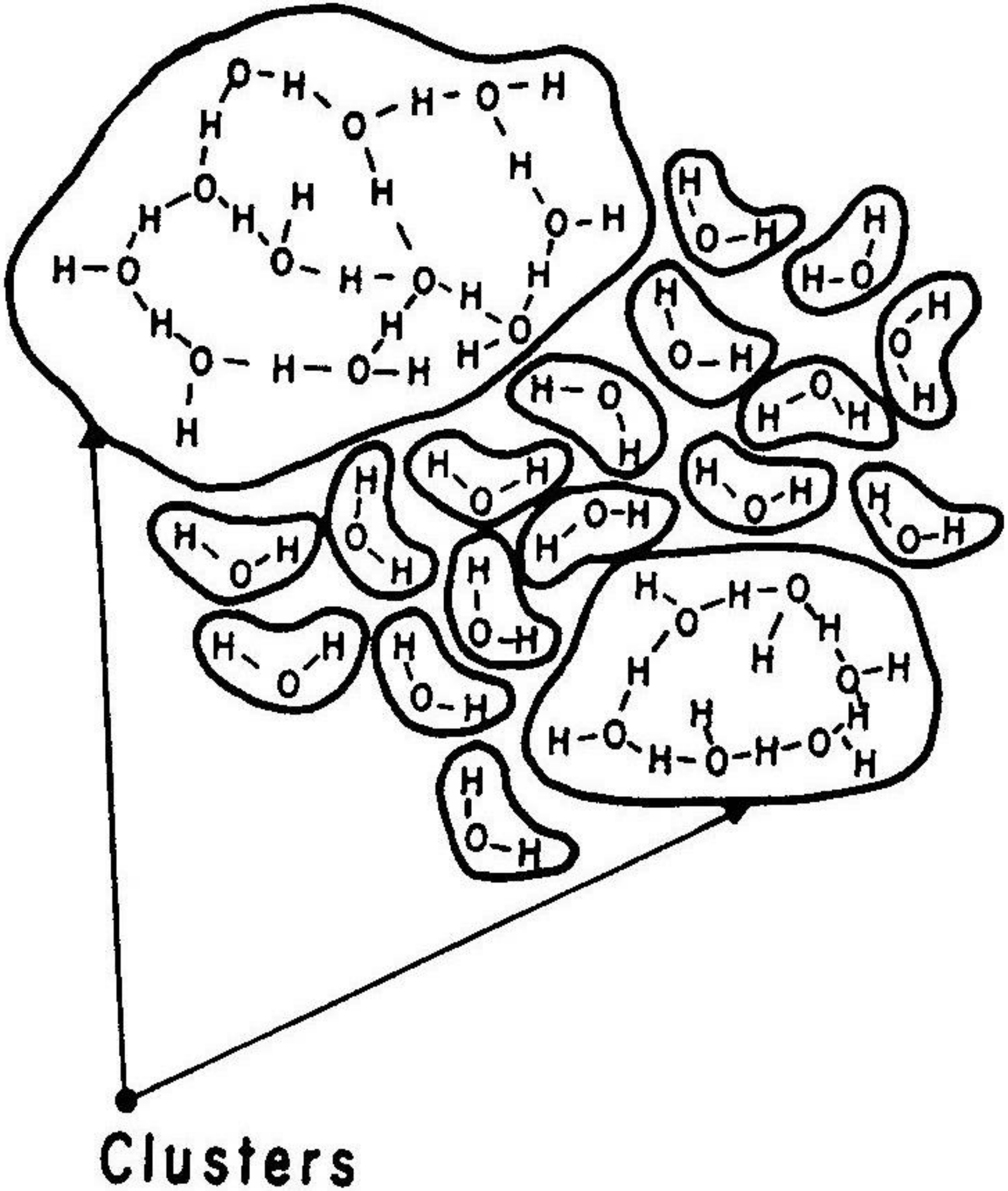
Comparison of Ice and Liquid Water Structures (NYU-SVL)

Ice 1h



Liquid Water

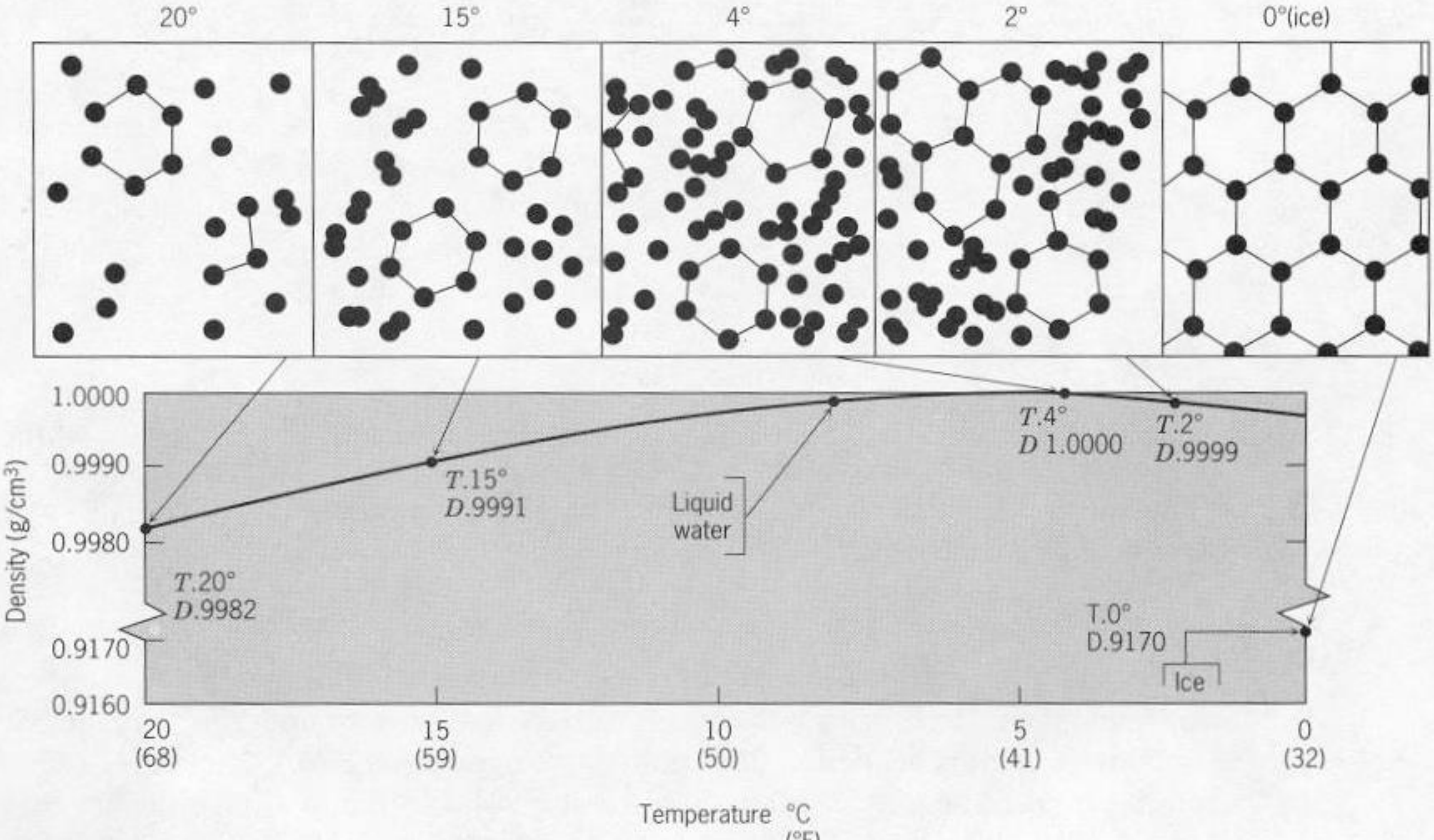




Water Clusters Dynamically Form, Break and Re-form

(Millero 2006)

Structure or Association of Water Molecules Versus Temperature and Affect on Density (Libes 1992)



What happens when we add solutes to water?

“Water, water, every where,
Nor any drop to drink.”

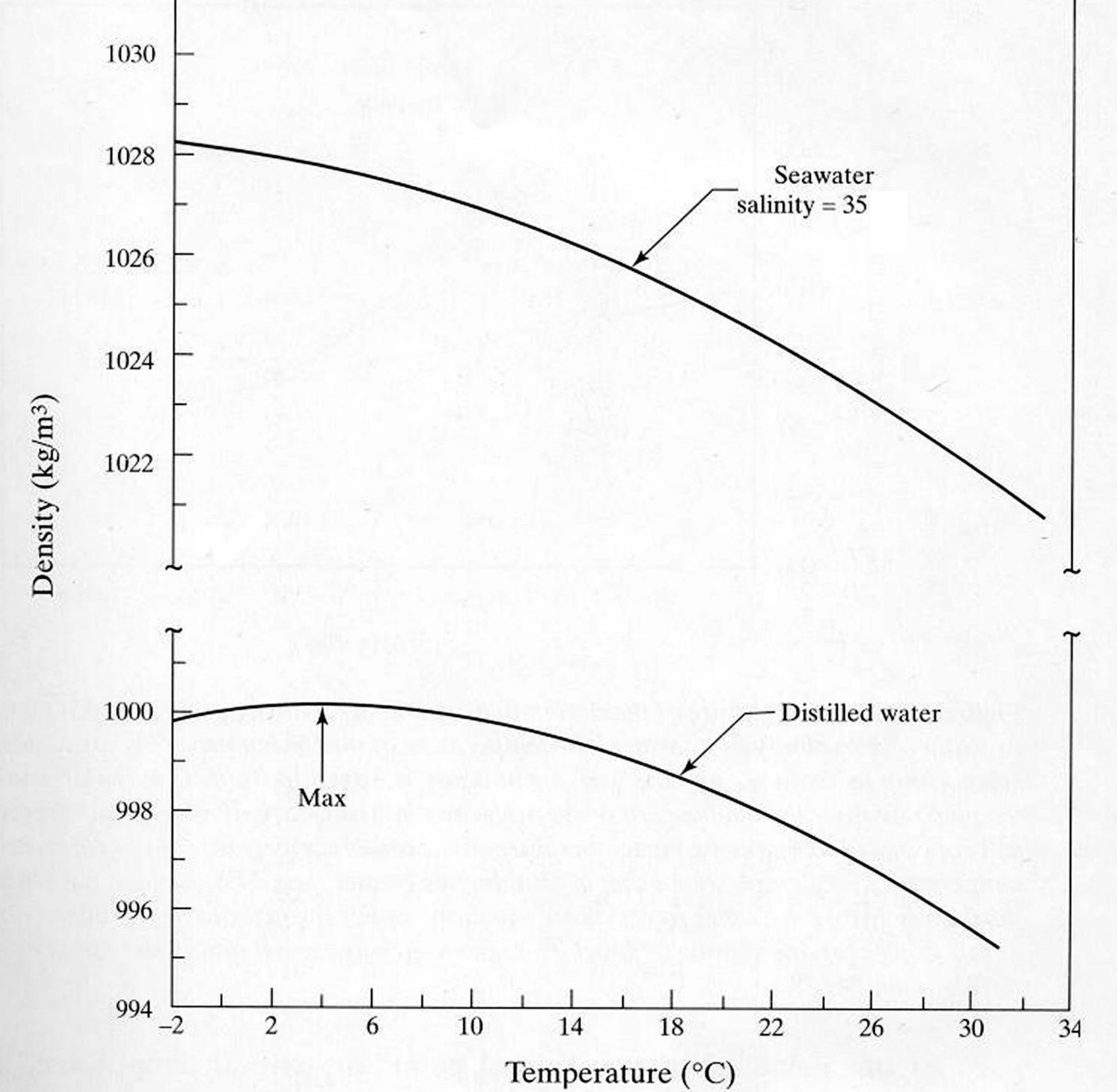
The Rime of the Ancient Mariner

Samuel Taylor Coleridge

Circa 1798

Solutes (Particularly Ions) are Structure Breakers

- More accurately they form new structures
- Reorient some water molecules
- Cause new associations
- Modify properties
- Alter much of the Physical Chem. (Physicochemical Properties)



Temperature Density Diagram for Pure Water & Seawater at 35 PSU

(Pilson 1998)

TABLE 2.2

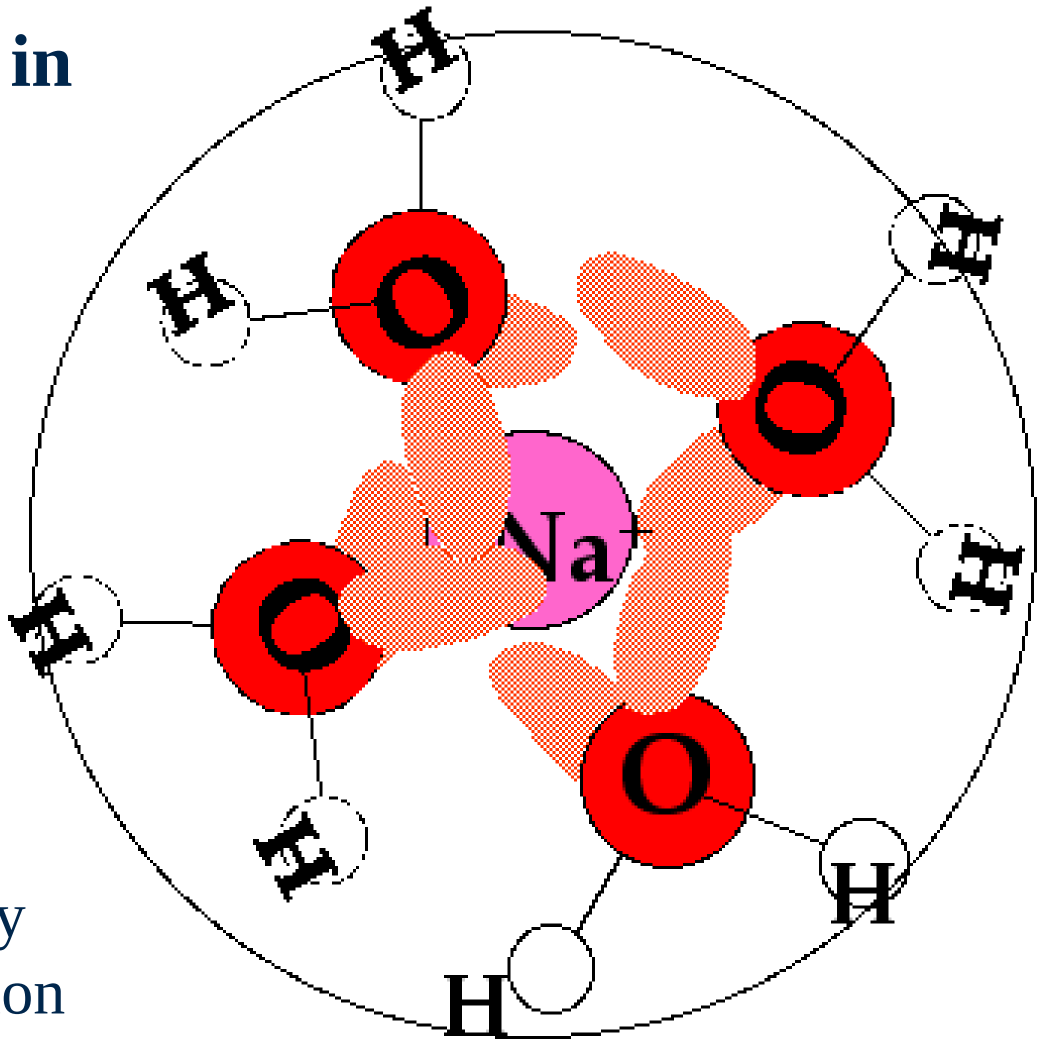
Comparison of Pure Water and Seawater Properties

Property	*Seawater, 35‰ S*	*Pure Water*
Density, g/cm^3, 25°C	1.02412	1.0029
Equivalent conductivity, 25°C, $cm^2\ ohm^{-1}\ equiv^{-1}$	—	—
Specific conductivity, 25°C, $ohm^{-1}\ cm^{-1}$	0.0532	—
Viscosity, 25°C, millipoise	9.02	8.90
Vapor pressure, mm Hg at 20°C	17.4	17.34
Isothermal compressibility, 0°C, unit vol/atm	46.4×10^{-6}	50.3×10^{-6}
Temperature of maximum density, °C	−3.52	+3.98
Freezing point, °C	−1.91	0.00
Surface tension, 25°C, dyne/cm	72.74	71.97
Velocity of sound, 0°C, m/s	1450	1407
Specific heat, 17.5°C, $J\ g^{-1}\,°C^{-1}$	3.898	4.182

Source: From *Marine Chemistry*, R. A. Horne, copyright © 1969 by John Wiley & Sons, Inc., New York, p. 57. Reprinted with permission.

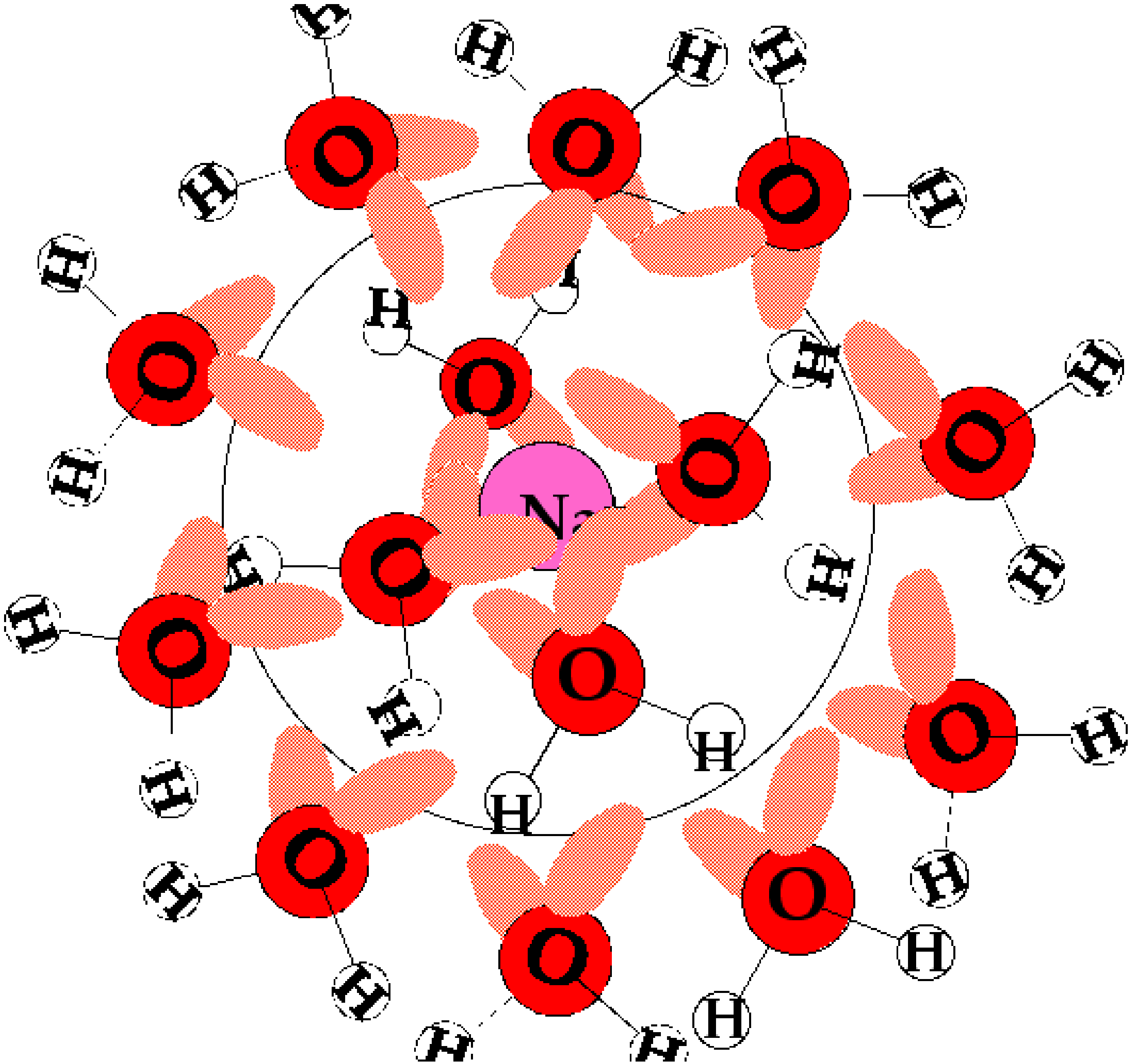
Some Properties Undergo Dramatic Changes

Adding an Ion Like Sodium (Na^+) Changes Some Things in H_2O



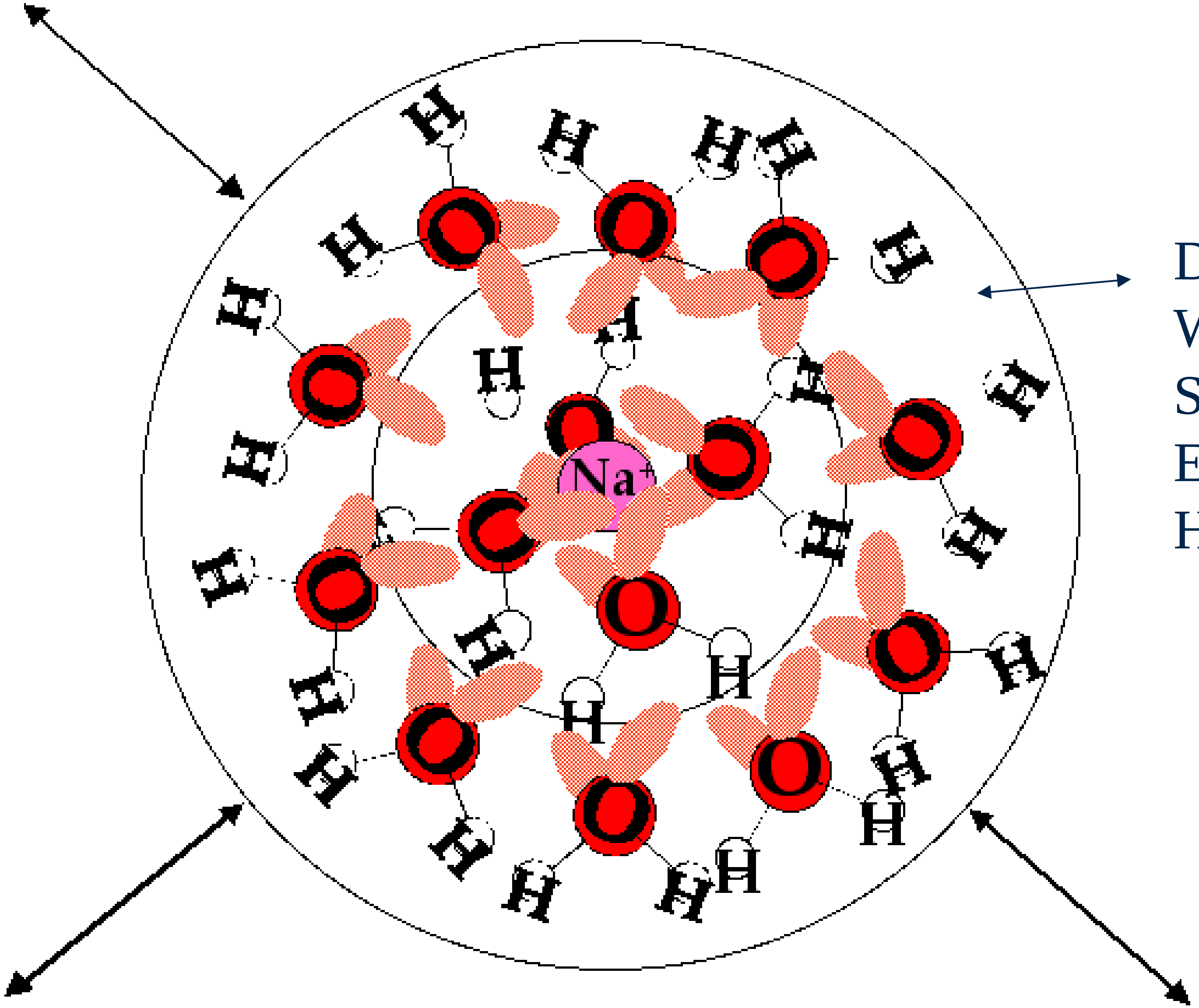
Primary Solvation Shell of H_2O

Polarity, High Dielectric Constant Result in Strong Solvation or Hydration of Na^+ by H_2O



Secondary Solvation Shell or a Second Sphere of H_2O is Bound to the First

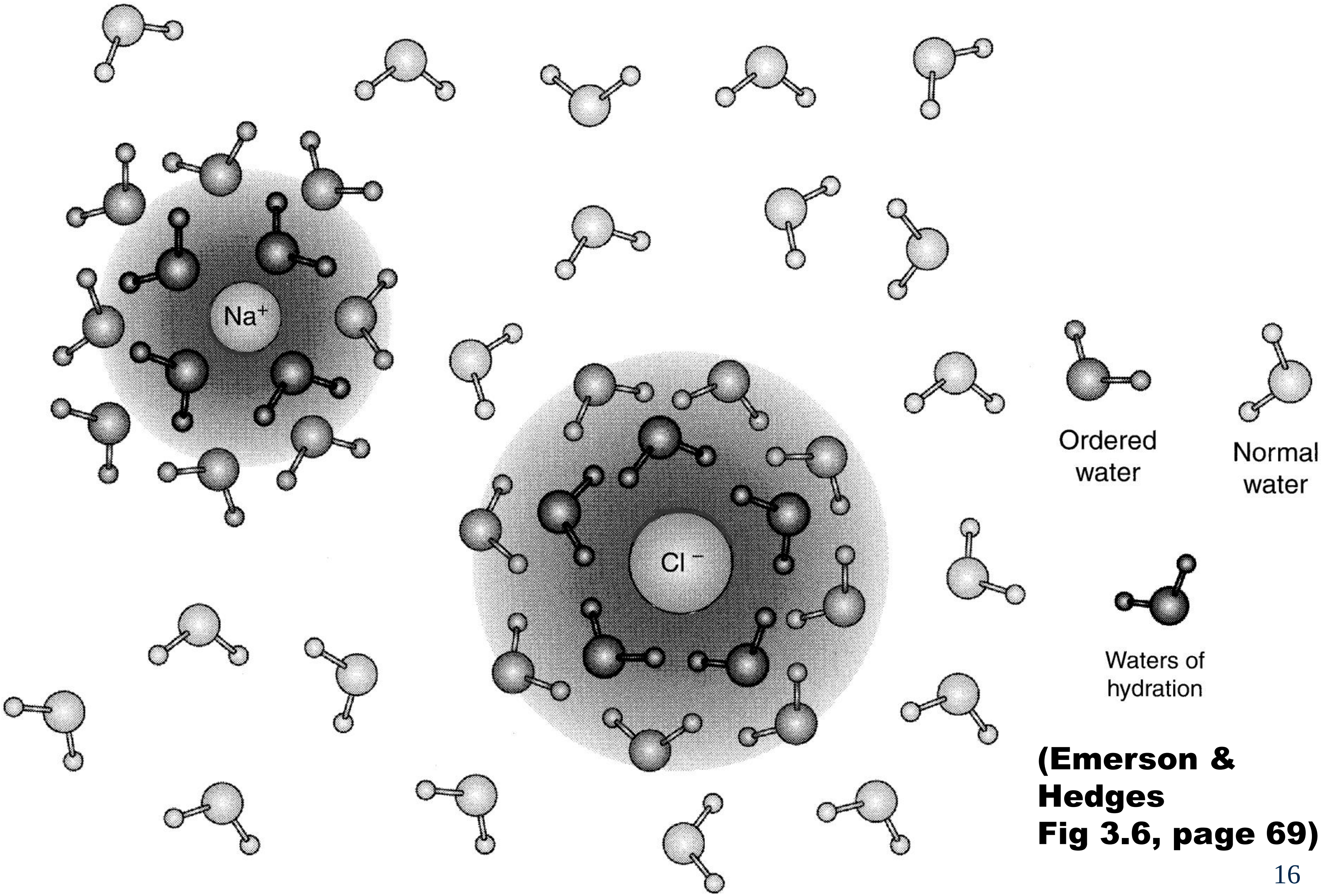
Normal H_2O Structure Exists Out Here for "Bulk" Water



Disrupted Water Structure Exists in Here

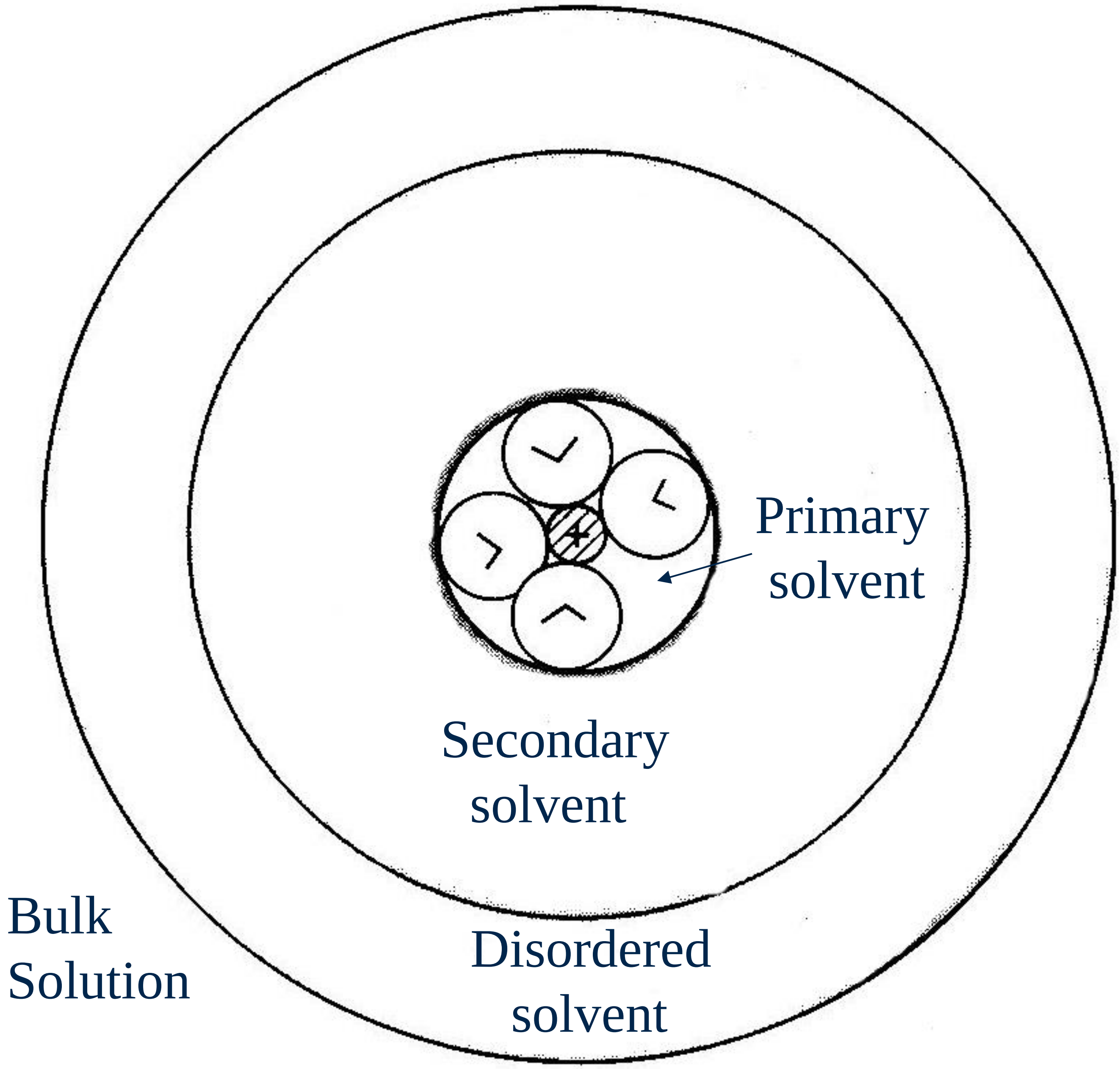
Bulk Water

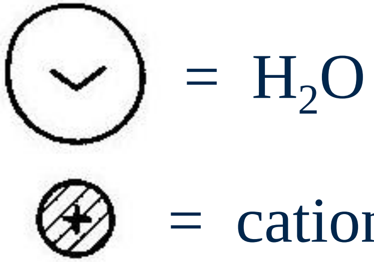
Bulk Water

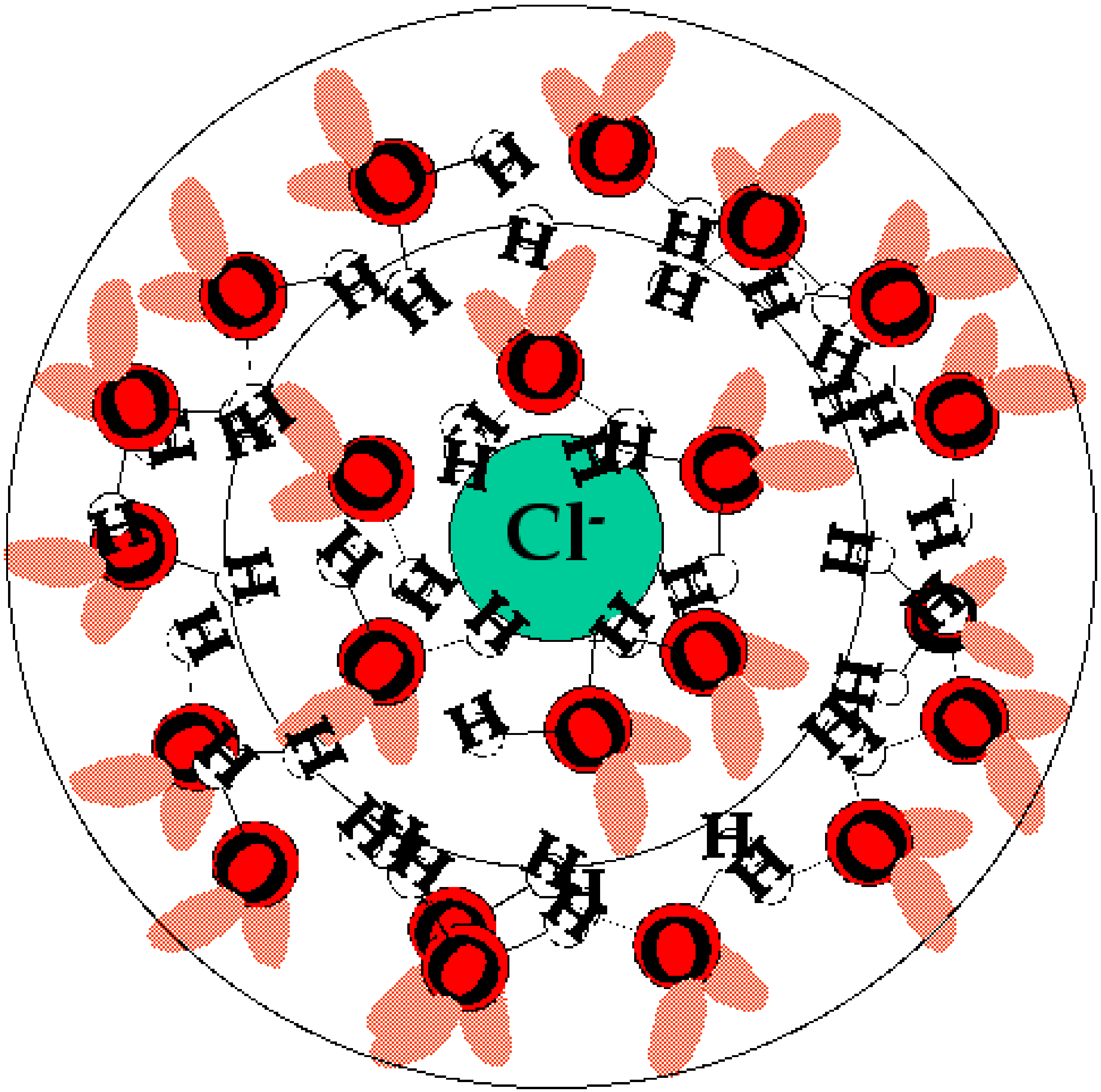


(Emerson & Hedges Fig 3.6, page 69)

Hydrated Ion (Morel 1993)

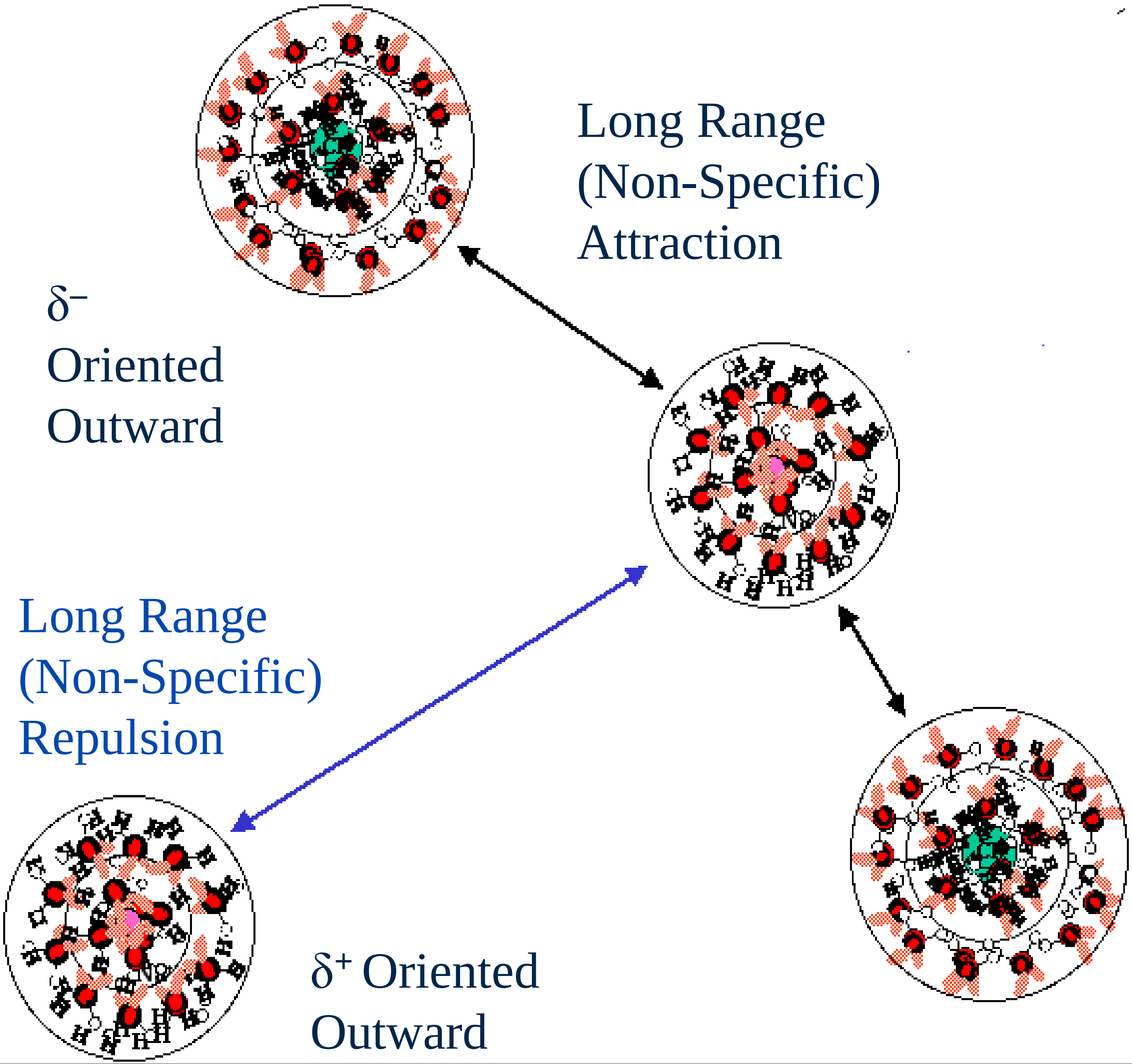






For Anions the Concept is Analogous Only Reversed With Respect to the Orientation of the H_2O

Other Effects Also Occur



Concentration Units

- Salts & other solutes dissolved in water must be specified with respect to their concentration
- Oceanographers generally agree on proper units
- However you will still see every possible unit under the sun being used
- ppm, ppb, ppt, M, mM, µM, nM, mg/L, µg/L, ng/L, pg/L, nmol/kg

Important Points
(see handout posted for last class)

- Use SI units whenever possible
- Chemical Oceanographers should use mol/kg with a prefix due to compressibility
- You must know whether the unit refers to solvent alone or solution as a whole (i.e., molarity vs. molality; ppm as mg/L or mg/kg)