Chapter 5:
The Water We Drink

Water

70% of the Earth's surface is covered by water

The human body is 50-75% water

The human brain is 75% water

Blood is 83% water

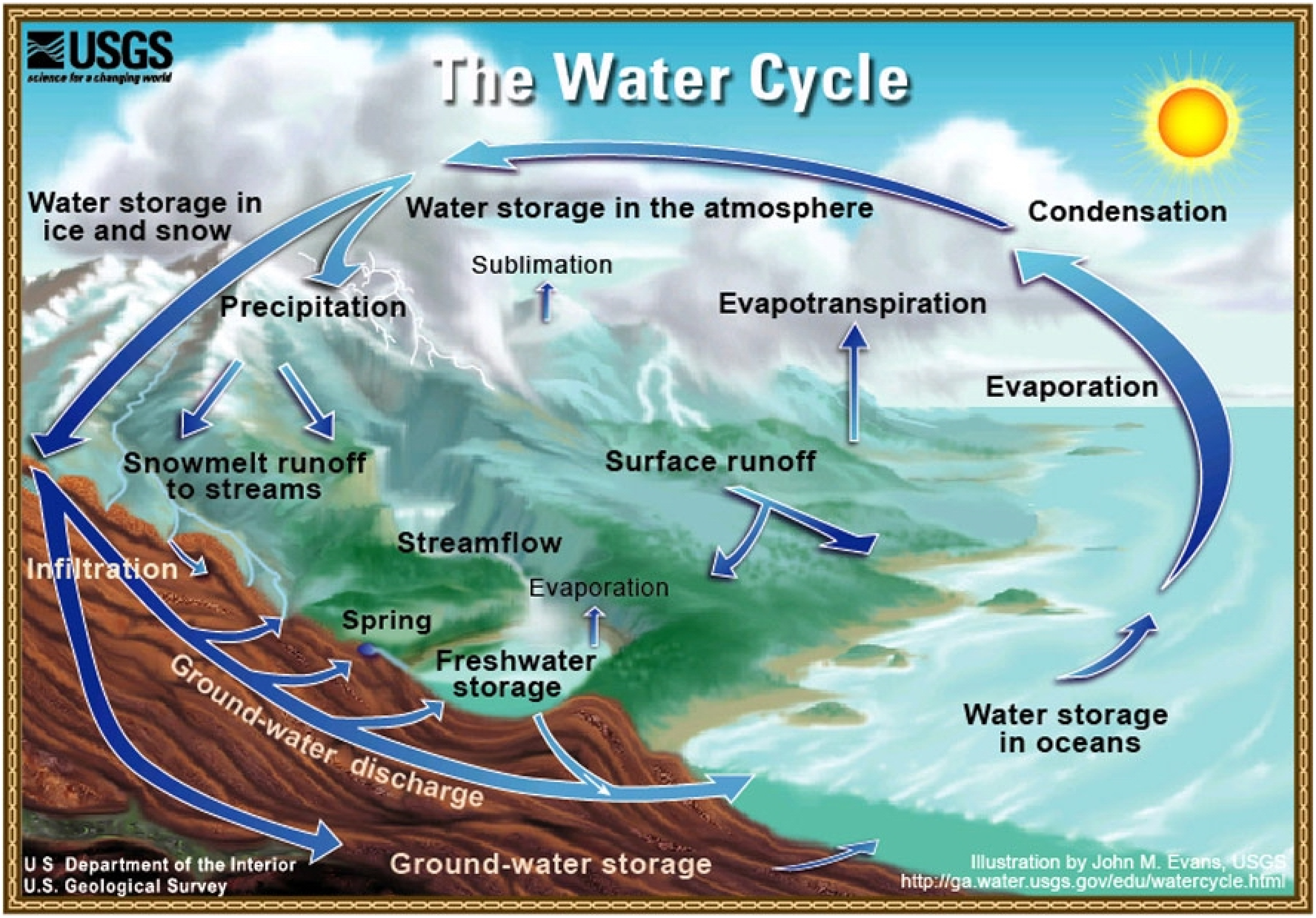
Lungs are 90% water

Bones (!) are 22% water

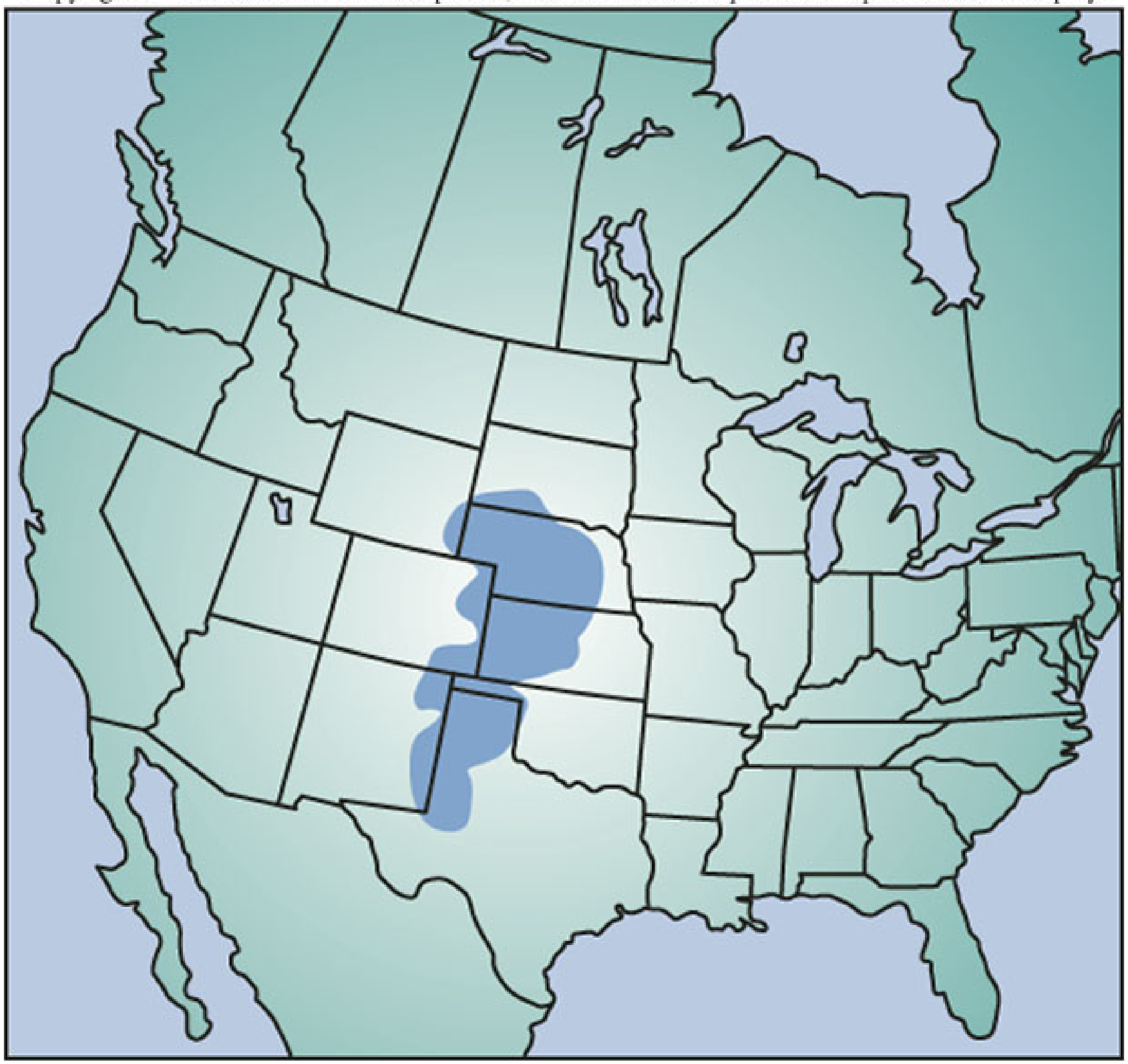
And yet, we take water for granted

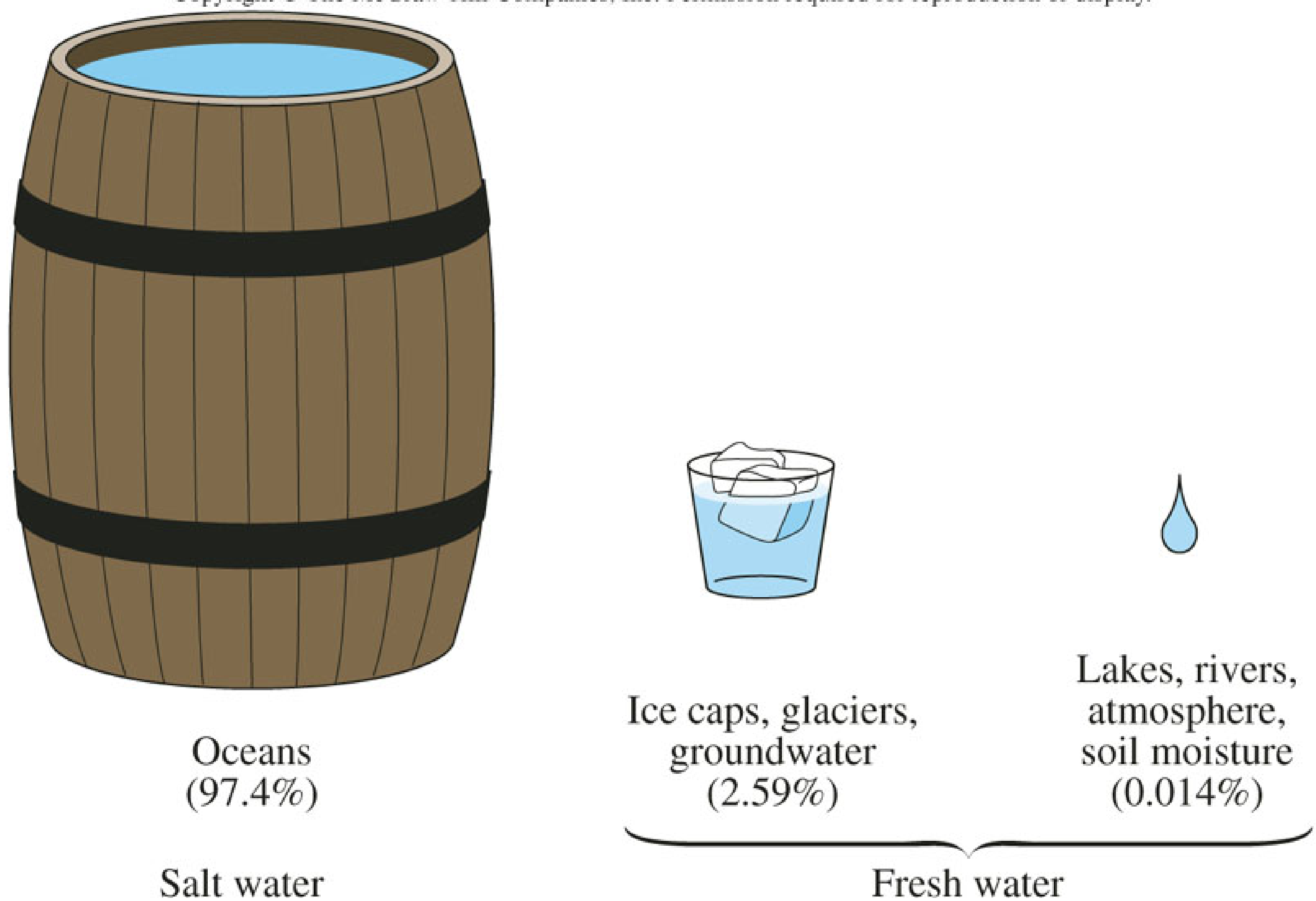
What goes in to the water we drink? And where does it come from in the first place?

Where does water come from?



Aquifers – can be large or small




Oceans
(97.4%)
Salt water
Ice caps, glaciers,
groundwater
(2.59%)
Lakes, rivers,
atmosphere,
soil moisture
(0.014%)
Fresh water

Water is the “Universal Solvent”

- **Solvent** – a substance capable of dissolving other substances
- **Solute** – the substance(s) that dissolves in a solvent
- **Solution** – the resulting homogeneous mixture of uniform composition
- ***Aqueous* Solution** – solutions in which water is the solvent

Which dissolve in water?

- Table salt
- Sugar
- Chalk
- Diet Pepsi
- Olive oil
- Tylenol

Table 5.1 Importance of Water as a Solvent

In our bodies:

- Blood plasma is an aqueous solution containing a variety of life-supporting substances.
- Inhaled oxygen dissolves in blood plasma in the lungs allowing O_2 to combine with hemoglobin.
- Blood plasma carries dissolved CO_2 to the lungs to be exhaled.
- Blood plasma transports nutrients into all the cells and organs.
- Water helps to maintain a chemical balance by carrying wastes away.

In the environment:

- Water can transport toxic substances into, within, and out of living organisms.
- Water-soluble toxic substances, such as some pesticides, lead ions, and mercury ions, can be widely distributed.
- Water may reduce the concentrations of pollutants to safe levels by dilution or by carrying them away (or both).
- Rainwater carries substances, including those responsible for acid rain, from the atmosphere down to Earth.

Table 5.2 Mineral Composition of Tap Water, mg/L

Calcium	66	Sulfates	42
Magnesium	24	Chlorides	48
Sodium	18	Nitrates	6
		Fluorides	1

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Table 5.3 Mineral Composition of Evian, mg/L

Calcium	78	Bicarbonates	357
Magnesium	24	Sulfates	10
Silica	14	Chlorides	4
		Nitrates (N)	1

Solute Concentration

- Concentration – the ratio of the amount of ‘ingredient’ to the amount of water
- Recall that in the atmosphere...
  - 78% N_2 means that for every 100 air molecules, 78 of them (on average) are N_2.
  - 370 ppm CO_2 (up from 280 ppm) means that for every 1,000,000 air molecules, 370 of them (on average) are CO_2
  - In the atmosphere, the solvent is N_2, it is what there is the most of.

Percent, %

- Weight Percent – $\dfrac{grams\ of\ \ solute}{grams\, of\ \ water} \times 100\%$

- Example, 5 g of NaCl dissolved in 100 g of water makes an aqueous solution that is 5 % NaCl by weight .

$$\frac{5\, g\ NaCl}{100\, g\ H_2O} \times 100\% = 5\%$$

ppm

- Again, by weight, so $1\,ppm = \dfrac{1\,g\ solute}{1{,}000{,}000\,g\ H_2O}$

- When dealing with so much water, it's a little easier to deal with Volume instead of Mass

  The density of water is 1g/mL.

  1,000,000 g H_2O = 1,000,000 mL H_2O

  1,000 mL = 1 L

  1,000,000 mL H_2O = 1,000 L H_2O

$$1\,ppm = \frac{1\,g\ solute}{1{,}000{,}000\,g\ H_2O} = \frac{1\,g\ solute}{1{,}000\,L\ H_2O} = \frac{1{,}000\,mg\ solute}{1{,}000\,L\ H_2O} = \frac{1\,mg\ solute}{1\,L\ H_2O}$$

1 ppm = 1mg solute / L of water

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$$\frac{18\,mg\ sodium}{1\,L\ H_2O}\times\frac{1\,L\ H_2O}{1{,}000\,mL\ H_2O}=\frac{1.8\times10^{-2}\,mg\ sodium}{1\,mL\ H_2O}$$

$$\frac{1.8\times10^{-2}\,mg\ sodium}{1\,mL\ H_2O}\times\frac{1\,mL\ H_2O}{1\,g\ H_2O}=\frac{1.8\times10^{-2}\,mg\ sodium}{1\,g\ H_2O}$$

$$\frac{1.8\times10^{-2}\,mg\ sodium}{1\,g\ H_2O}\times\frac{1\,g\ sodium}{1{,}000\,mg\ sodium}=\frac{1.8\times10^{-5}\,g\ sodium}{1\,g\ H_2O}$$

$$\frac{1.8\times10^{-5}\,g\ sodium}{1\,g\ H_2O}\times\frac{1{,}000{,}000}{1{,}000{,}000}=\frac{18\,g\ sodium}{1{,}000{,}000\,g\ H_2O}$$

$$\frac{18\,mg\ sodium}{1\,L\ H_2O}=\frac{18\,g\ sodium}{1{,}000{,}000\,g\ H_2O}=18\ ppm$$

ppb

- Again, by weight, so $$1\,ppb = \frac{1\,g\ solute}{1{,}000{,}000{,}000\,g\ H_2O}$$

- As with ppm, it's easier to deal with volume than mass

  The density of water is 1g/mL.

  1,000,000,000 g H_2O = 1,000,000,000 mL H_2O

  1,000 mL = 1 L

  1,000,000,000 mL H_2O = 1,000,000 L H_2O

  1 g = 1000 mg = 1,000,000 μg

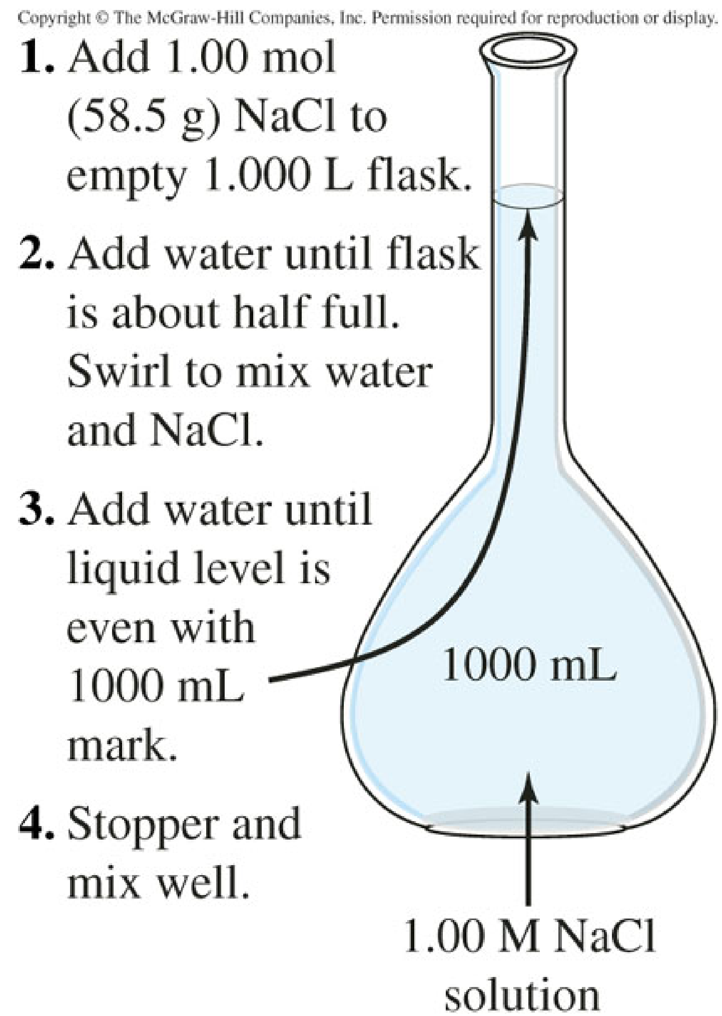
$$1\,ppb = \frac{1\,g\ solute}{1{,}000{,}000{,}000\,g\ H_2O} = \frac{1{,}000{,}000\,\mu g\ solute}{1{,}000{,}000\,L\ H_2O} = \frac{1\,\mu g\ solute}{1\,L\ H_2O}$$

1 ppb = 1μg/L

- The maximum **lead** concentration in drinking water allowed by the federal government is 15 ppb.
- This means that for every 1,000,000,000 g of water (1,000,000 L) only 15 g of Pb is allowed.
- This corresponds to 15 μg Pb/L

Molarity

$$M = \frac{moles\ of\ solute}{liters\ of\ solution}$$



- Counting chemical units, so it is easier to compare one compound to another

- If we dissolve 17 g $NaNO_3$ in enough water to create 1L of solution, what is the molarity of this solution?

$$molar\ mass\ of\ NaNO_3$$

$$\frac{23\,g\ Na}{mol}+\frac{14\,g\ N}{mol}+3\left(\frac{16\,g\ O}{mol}\right)=\frac{85\,g\ NaNO_3}{mol}$$

$$\frac{17\,g\ NaNO_3}{1L\ solution}\times\frac{1\,mol\ NaNO_3}{85\,g\ NaNO_3}=\frac{0.2\,mol\ NaNO_3}{1L\ solution}$$

$$\frac{0.2\,mol\ NaNO_3}{1L\ solution}=0.2\,M\ NaNO_3\ solution$$

- For this same 0.20 M $NaNO_3$ solution, what is the concentration of sodium?

$$\frac{0.2\,mol\ NaNO_3}{1\,L\ water} \times \frac{1\,mol\ Na^+}{1\,mol\ NaNO_3} = 0.2\,M\ \ Na^+$$

$$\frac{0.2\,mol\ Na^+}{1\,L\ water} \times \frac{23\,g\ Na^+}{1\,mol\ Na^+} = \frac{4.6\,g\ Na^+}{1\,L\ water}$$

$$\frac{4.6\,g\ Na^+}{1\,L\ water} \times \frac{1000\,mg}{1\,g} = \frac{4,600\,mg\ Na^+}{1\,L\ water}$$

$$\frac{4,600\,mg\ Na^+}{1\,L\ water} = 4,600\ ppm$$

- The concentration of the solution we made by dissolving 17 g of NaNO3 in enough water to make 1 L of solution is:

0.20 M $NaNO_3$

0.20 M Na^+

0.20 M NO_3^-

1.7 wt % $NaNO_3$

4,600 ppm Na^+

12,400 ppm NO_3^-

Interesting properties of water

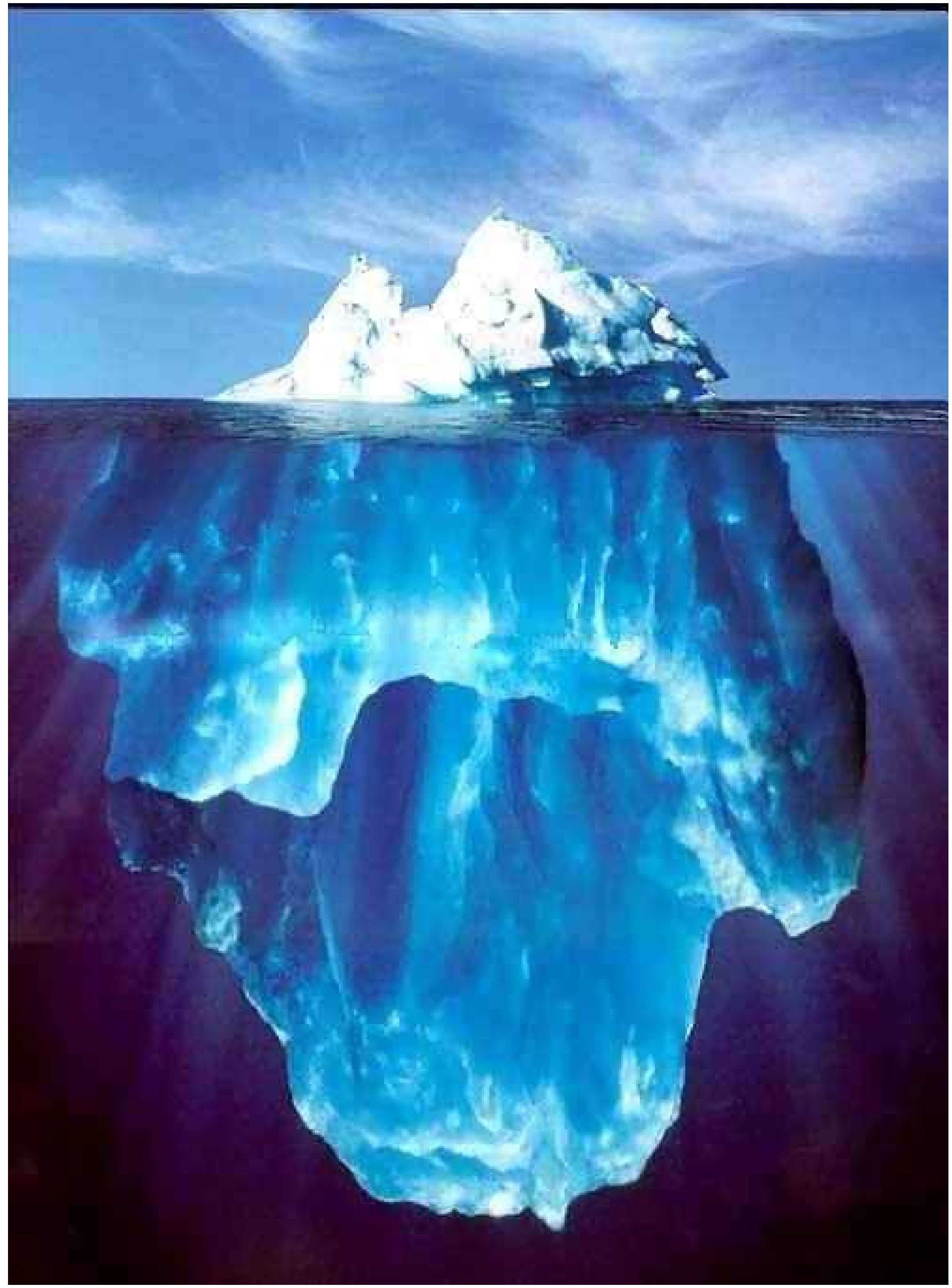
- It is a liquid under standard conditions
- H_2O boils at 100°C and freezes at 0°C
  - Other similar molecules such as NH_3, HF, and H_2S are all gases at room temperature. H_2O has a molar mass of 18g/mol
  - Molecules with similar masses such as N_2 (28g/mol), O_2 (32g/mol), and CO_2 (44g/mol) are all gases at room temperature
- What makes water different?

When water freezes, it expands.

The density of solid water is less than the density of liquid water.

Ice floats

Why?



Electronegativity – a measure of an atom's attraction for the electrons it shares in a covalent bond.

Table 5.4 Electronegativity Values, Arranged by Group Number

1A	2A	3A	4A	5A	6A	7A	8A
H							He
2.1							—
Li	Be	B	C	N	O	F	Ne
1.0	1.5	2.0	2.5	3.0	3.5	4.0	—
Na	Mg	Al	Si	P	S	Cl	Ar
0.9	1.2	1.5	1.8	2.1	2.5	3.0	—

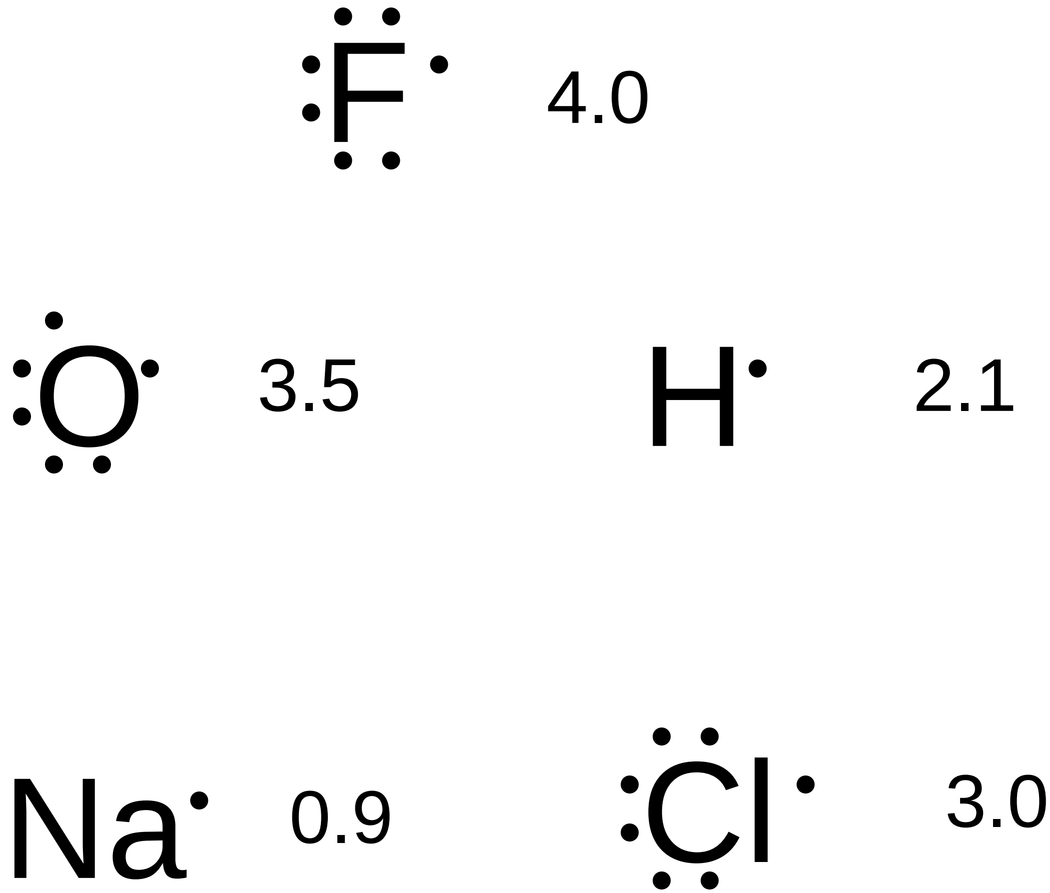

F 4.0
O 3.5
H 2.1
Na 0.9
Cl 3.0

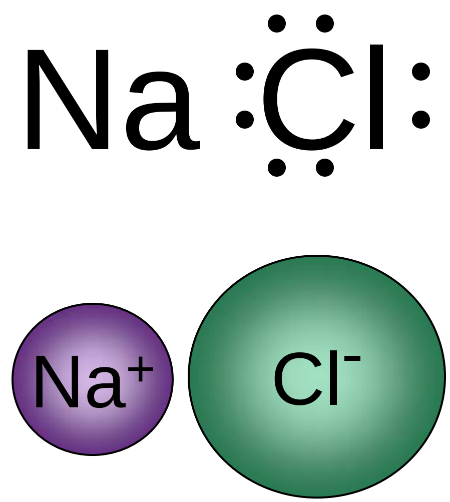
Table 5.5 Comparison of a Sodium Atom with a Sodium Ion

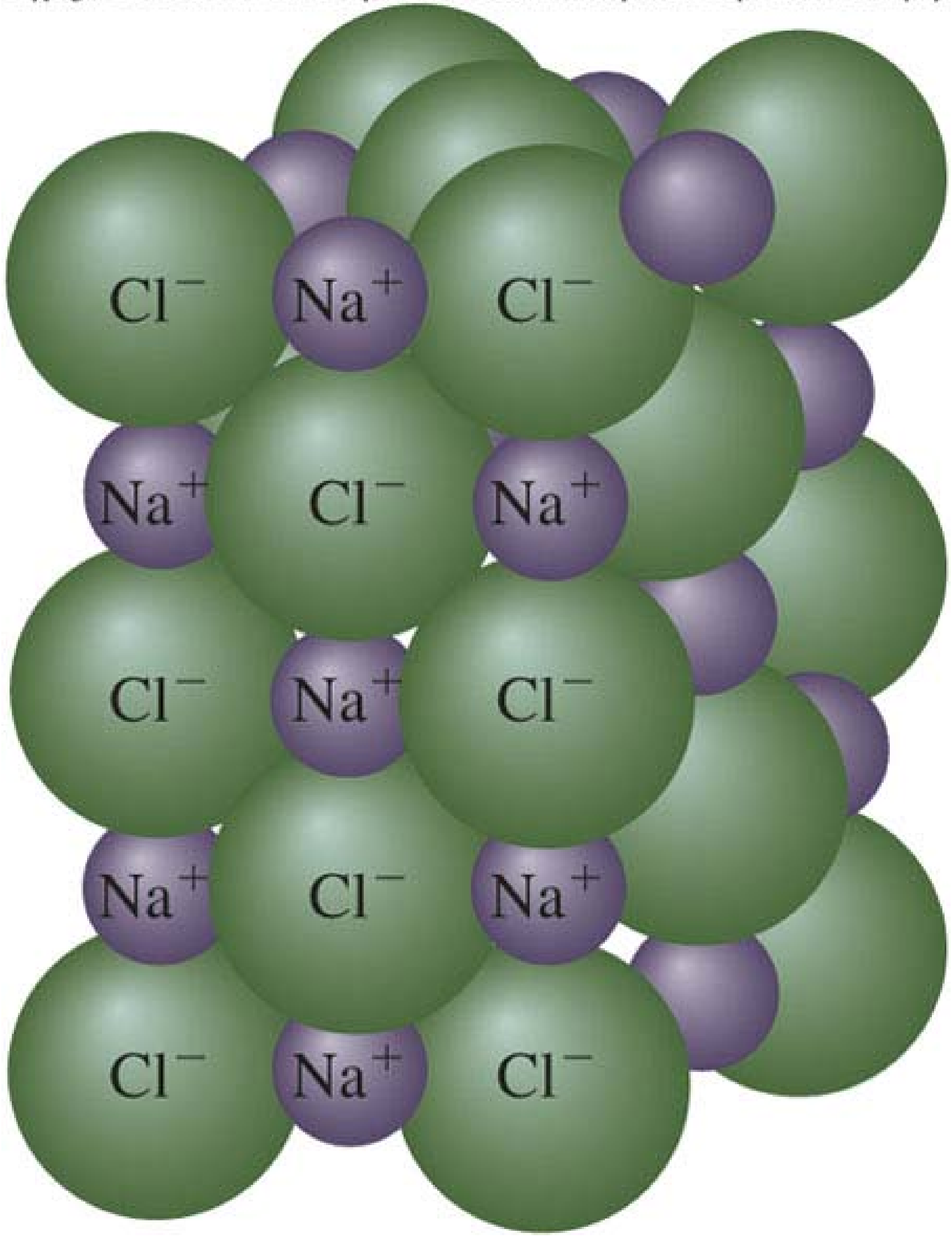
	Sodium Atom		Sodium Ion
$Na\cdot$	Na 11 protons 11 electrons *Net* charge: zero	Na	Na^{+} 11 protons 10 electrons *Net* charge: 1+

Table 5.6 Comparison of a Chlorine Atom with a Chloride Ion

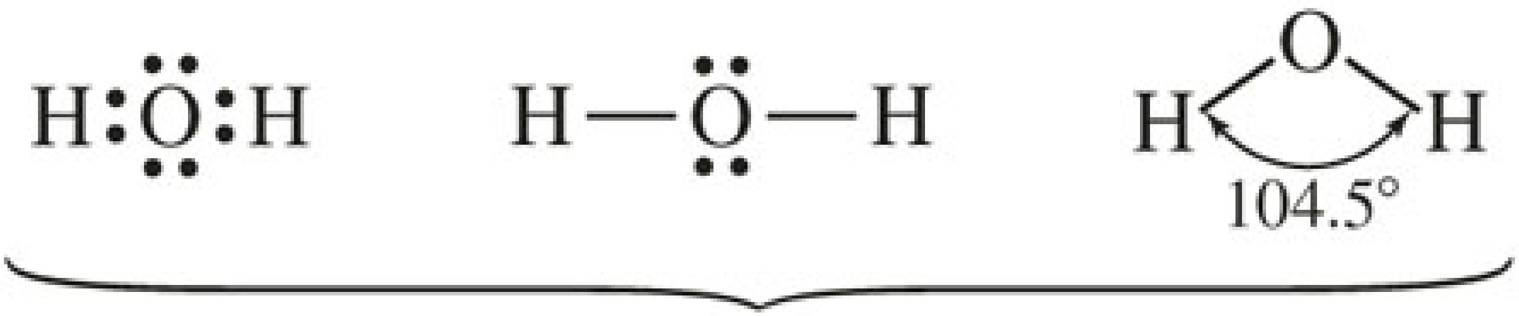
	Chlorine Atom		Chloride Ion
$:\ddot{\underset{\cdot\cdot}{Cl}}\cdot$	Cl 17 protons 17 electrons *Net* charge: zero	$:\ddot{\underset{\cdot\cdot}{Cl}}:$	Cl^{-} 17 protons 18 electrons *Net* charge: 1−

- Metals and Non-metals create **IONIC BONDS**
  - Ionic bonds are **not** characterized by sharing of electrons, but by the attraction of oppositely charged ions
  - The further away from each other on the periodic table the two elements are, the more likely the bond is ionic

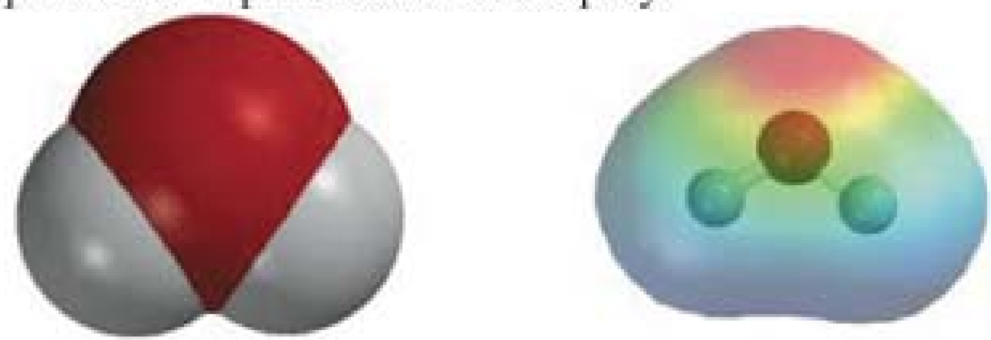




Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻



(a)

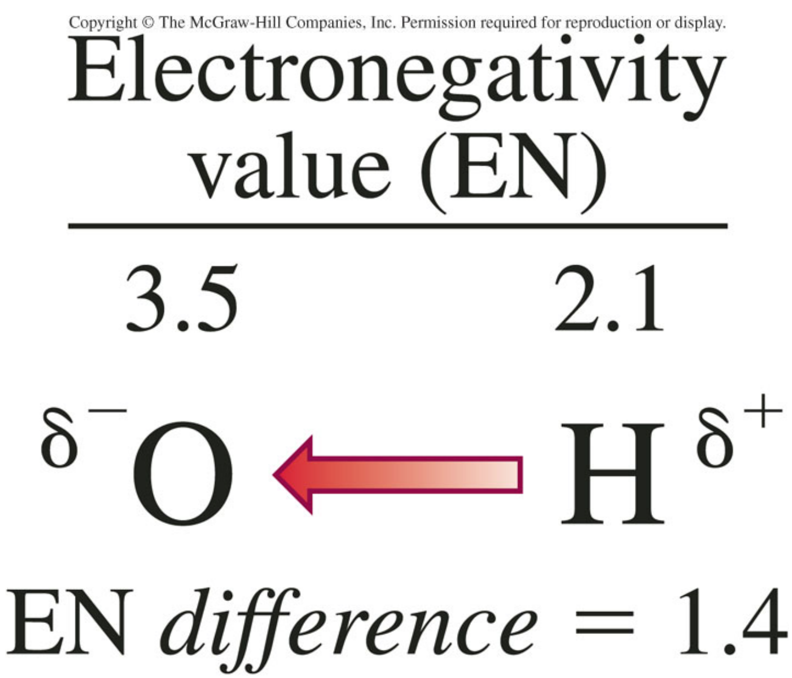


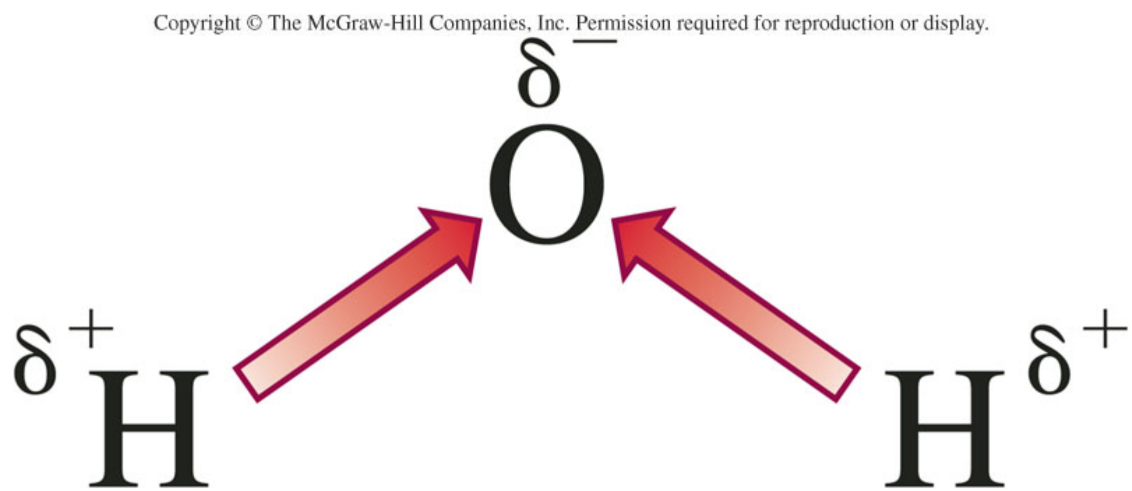
(b) (c)

Water is "Polar"

The bonds in water SHARE the electrons, but the electrons are not shared equally.

The O-H bond is a **polar covalent bond**





Non-Polar Molecules

Note! CO_2 is a special case. Each **bond** is polar – ΔEN = 1.0. But because the molecule is symmetric, the end result is **non**polar.