OCEANOGRAPHY

5. Water and Seawater

part I

notes from textbook, integrated with original contributions

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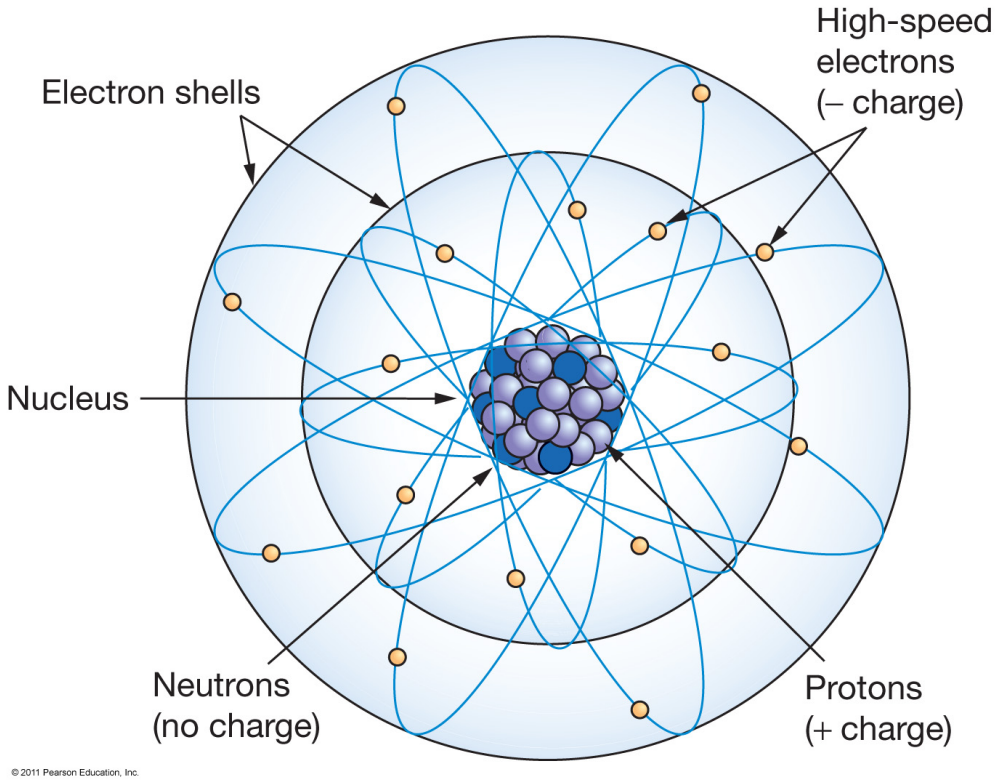
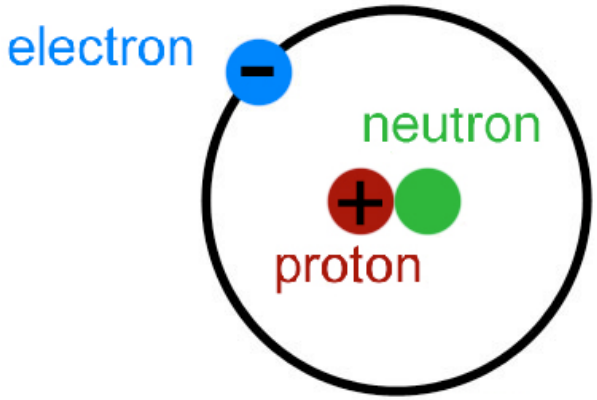
5.1 – Why Does Water Have Such Unusual Chemical Properties?

- Atoms – building blocks of all matter
- Subatomic particles
  - Protons
  - Neutrons
  - Electrons
- Number of protons distinguishes chemical elements



atomic structure

- Atomic Number
- Atomic Mass
- Conditions for elements' stability
- Concept of molecule
- Chemical Bonds



How do things stay together?

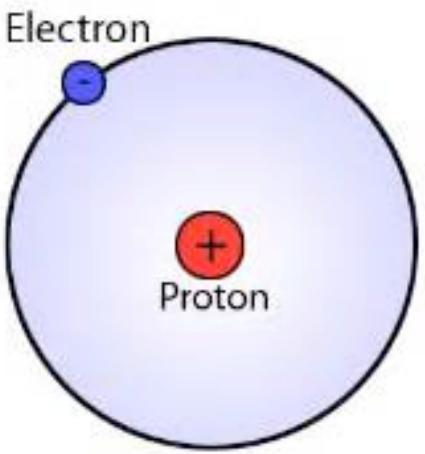
- All substances are made by atoms of elements
- Atoms are made by protons, neutrons, electrons (subatomic particles)
- Protons and neutrons reside in the nucleus
- Electrons orbit around the nucleus in “shells”
- Depending on how many electrons are found in shells, different kinds of chemical bonds occur (covalent, ionic, metallic)

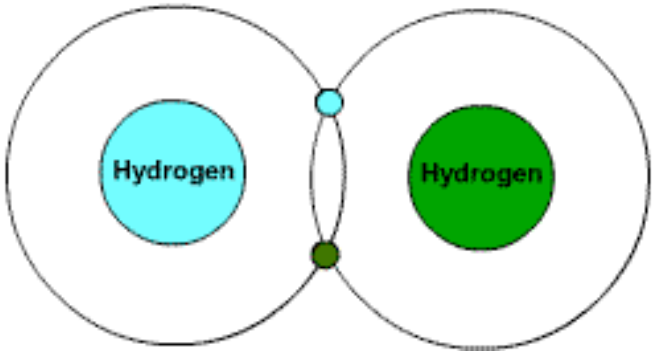
chemical bonds

- **Covalent** Bond
  - when atoms share electrons
- **Ionic** Bond
  - when atoms exchange electrons
- **Metallic** Bond
  - electrons are free to move throughout a metal
- **Van der Waals** Bond
  - weak electrostatic bond

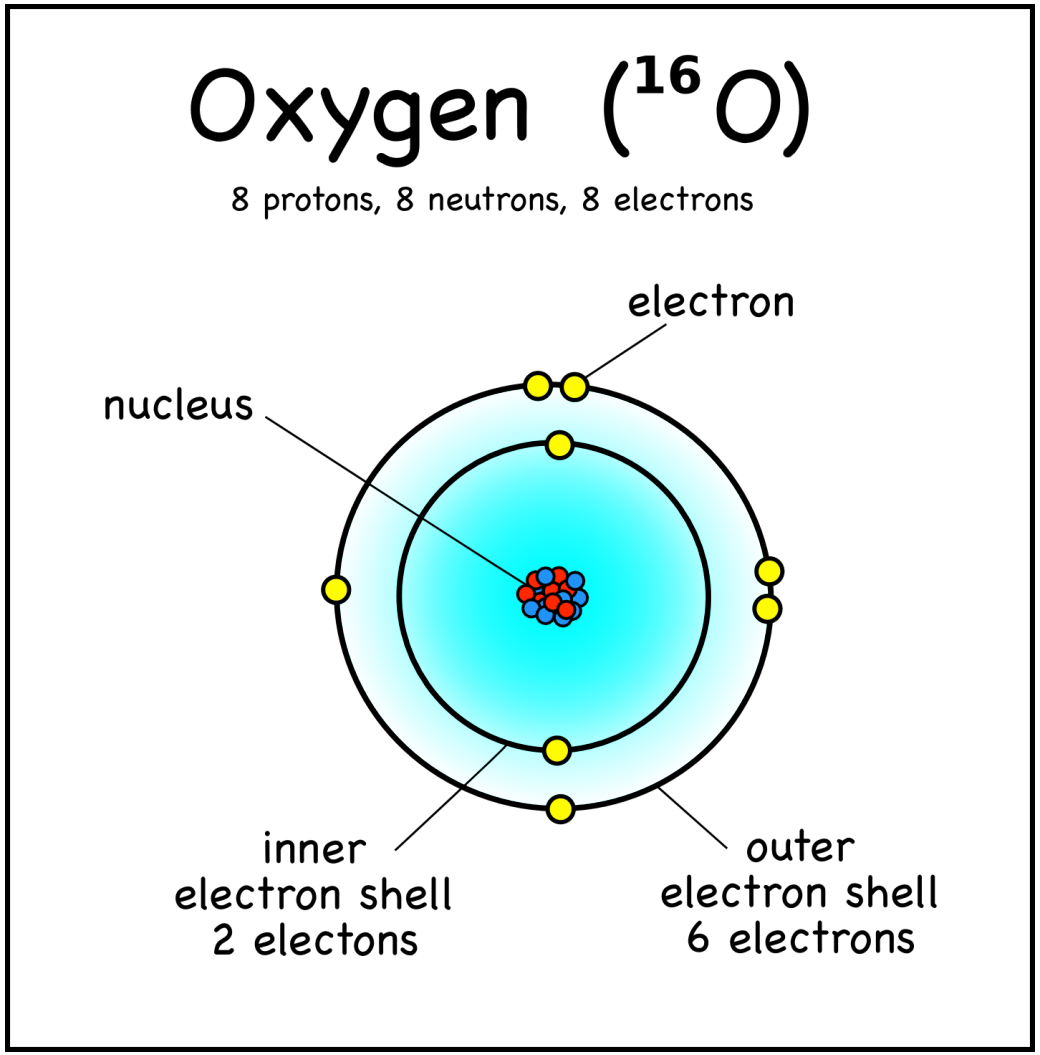
chemical bonds: covalent bonds

- Covalent Bonds: electrons are shared
  - the case of hydrogen
  - atom vs. molecule





the case of oxygen



The outer shell of an atom has space for 8 electrons.

Oxygen only has 6 electrons in the outer shell.

With two more electrons it would reach the stage of “full shell”.

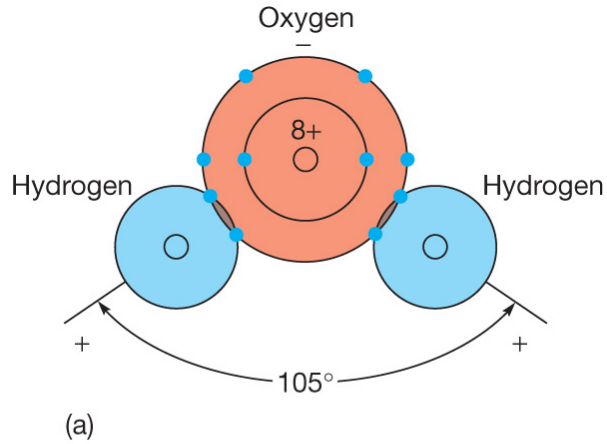
But, if we have two extra electrons, the atom would have a charge, and that is not possible, unless it bonds with one or more other atoms.

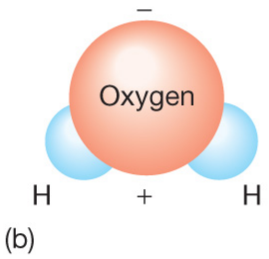
So, Oxygen would only bond with atoms that would provide it with two extra electrons.

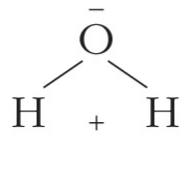
That would imply that Oxygen is looking for two negative charges (-2), and that is how its Oxidation Number is calculated

the water molecule

- Strong covalent bonds between one hydrogen (H) and two oxygen (O) atoms
- Both H atoms on same side of O atom
- Dipolar



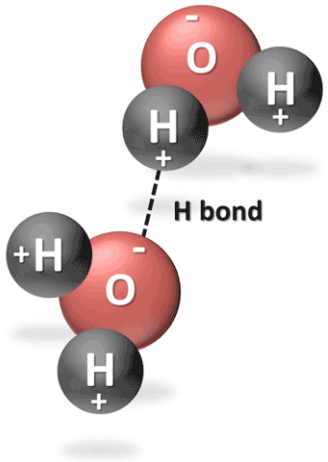


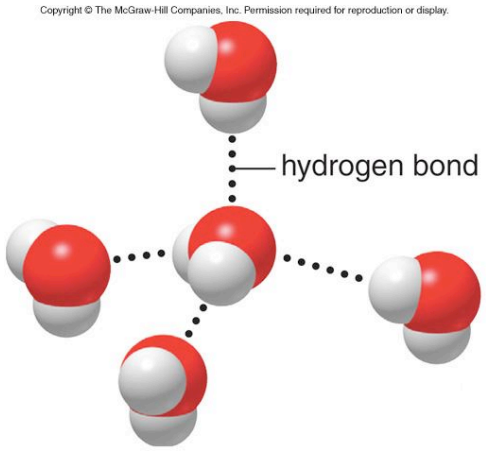


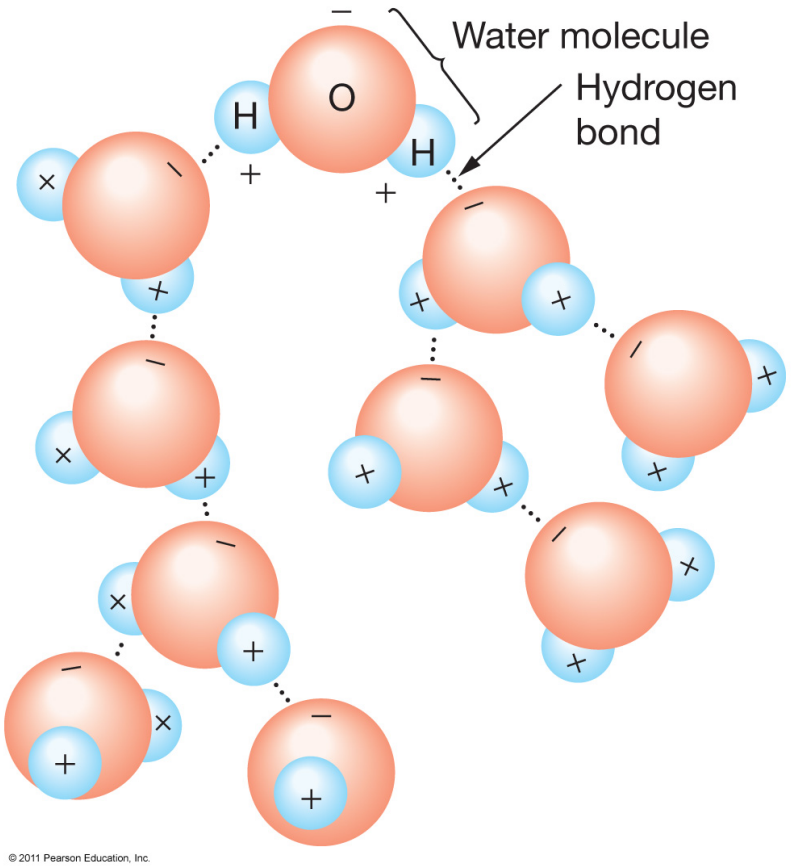
hydrogen bonds

(not a chemical bond, but a molecular bond)

- Polarity means small negative charge at O end
- Small positive charge at H end
- Attraction between positive and negative ends of water molecules to each other or other ions







hydrogen bonds

Hydrogen bonds are weaker than covalent bonds but still strong enough to result in:

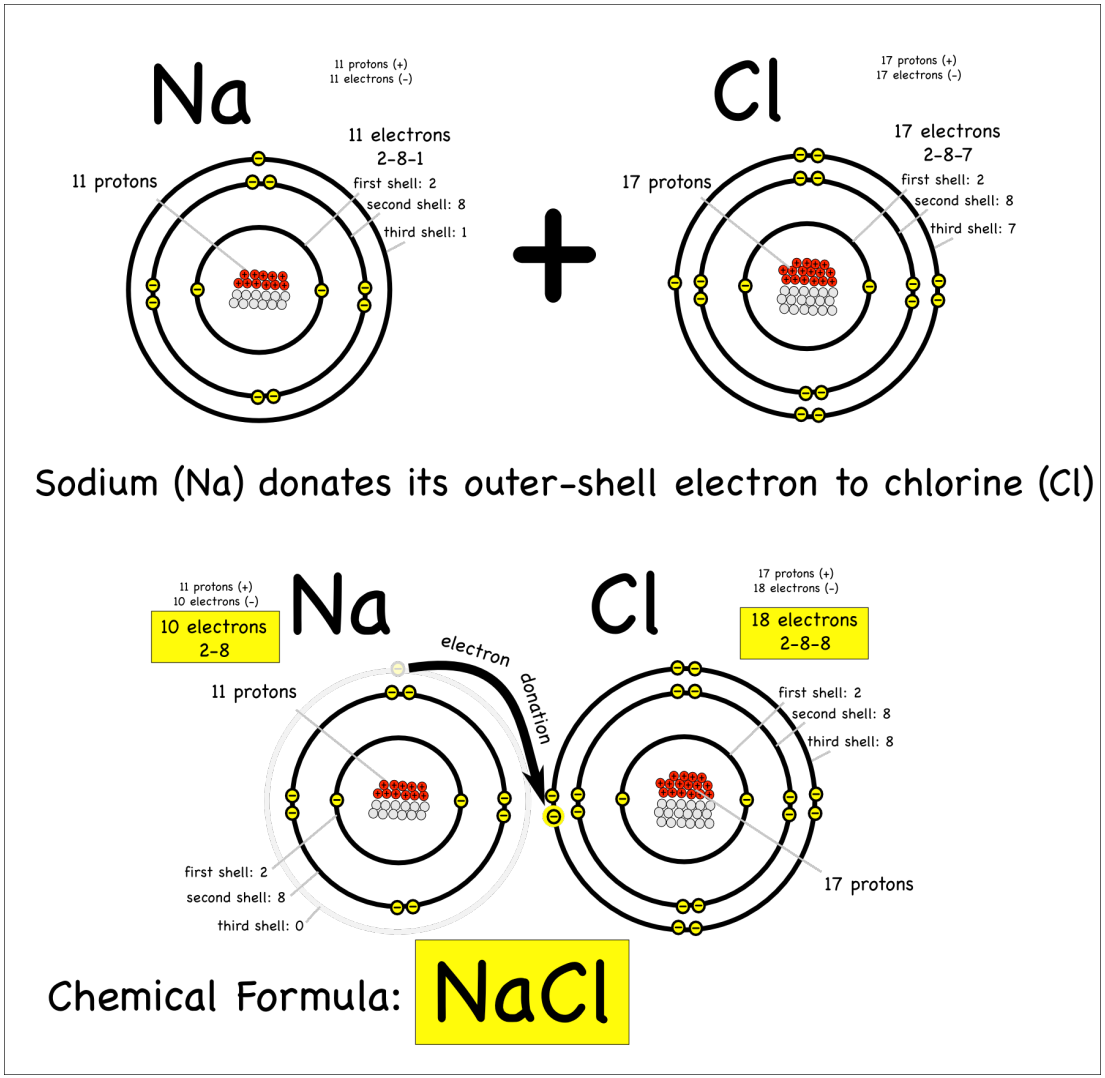
- High water surface tension
- High solubility of chemical compounds in water
- Unusual thermal properties of water
- Unusual density of water



chemical bonds: ionic bonds

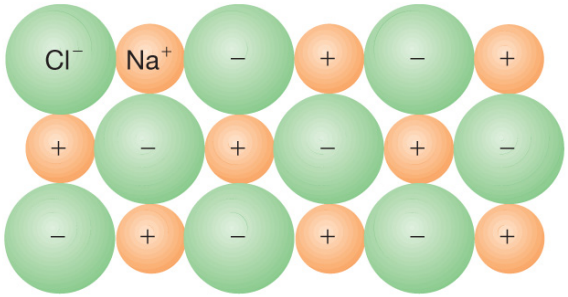
- Ionic Bonds: electrons are exchanged

- ions have a charge but can only exist if that charge is neutralized
  - either by an opposite counterpart
  - or by molecules of water

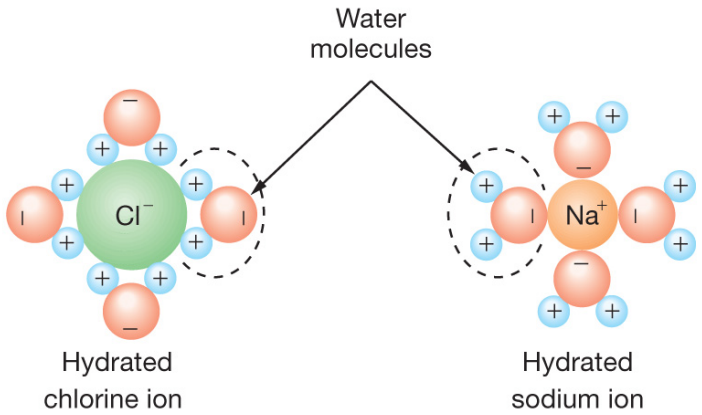


water as a solvent

- Water molecules stick to other polar molecules and ions (ions have a charge!)
- Water can reduce the attraction between ions of opposite charge by as much as 80 times
- Consequently, water can dissolve almost anything.
- Hydration of the ions: the surrounding of ions by water



(a) Sodium chloride, solid crystal structure



(b) Sodium chloride, in solution

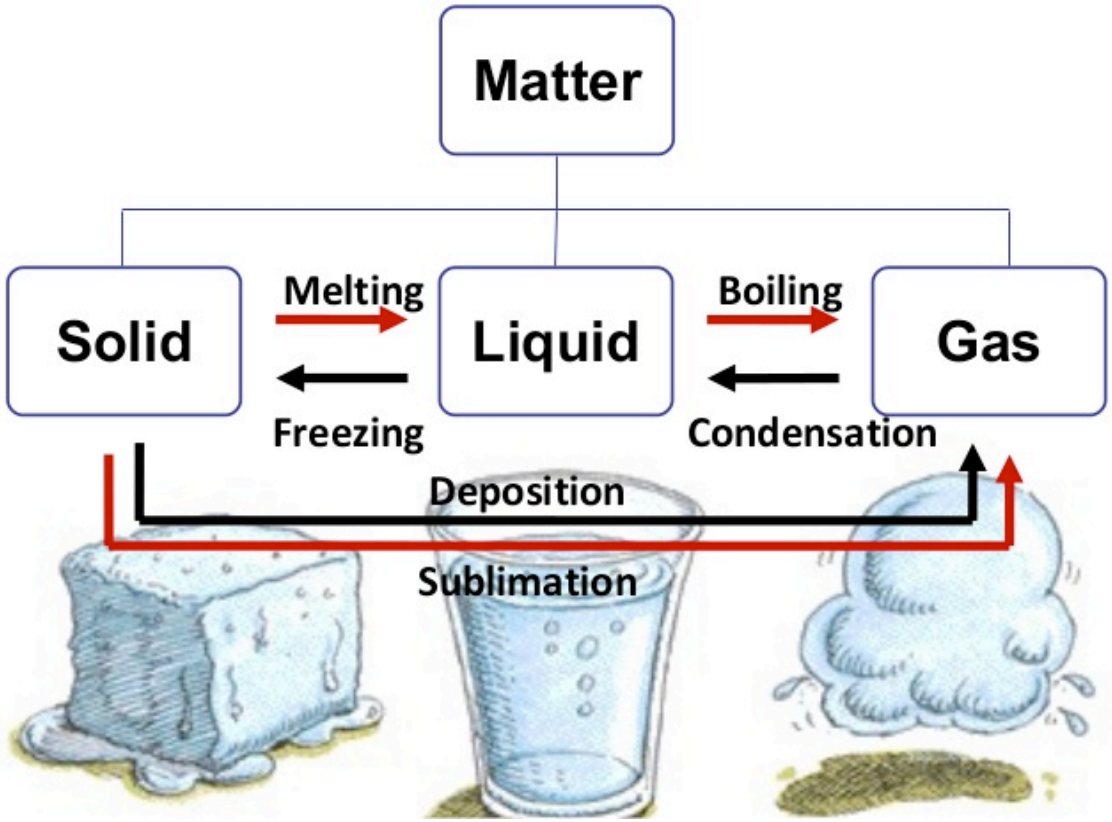
5.2 – What Important Physical Properties Does Water Possess?

- Thermal properties
  - freezing and boiling points
  - heat capacity and specific heat
  - latent heat
    - latent heat of melting, vaporization, evaporation, condensation, freezing
  - global thermostatic effects

- Water's density as a result of thermal contraction

5.2.1 - Water's Thermal Properties

- Water is solid, liquid, and gas at Earth's surface.
- Water influences Earth's heat budget
- Van der Waals forces
- Energy (heat) must be added for molecules to overcome attractions



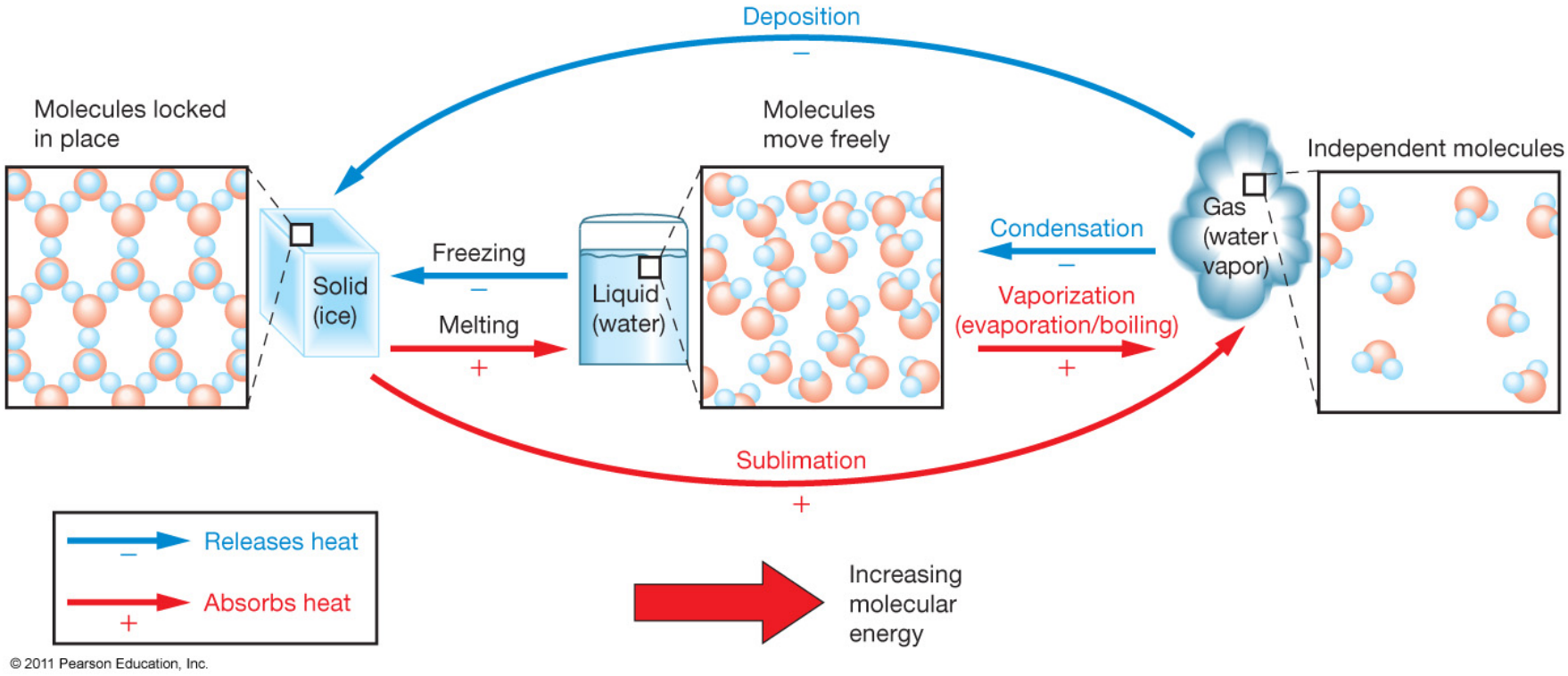
heat vs. temperature

- **heat**: amount of energy transferred from one body to another due to a difference in temperature
- heat is proportional to kinetic energy of molecules in a body
- heat can be generated by chemical reactions (including combustion), by friction, by radioactivity
- heat can be transferred by radiation, convection, conduction

- heat can be also summarized as the “energy of moving molecules”

- Calorie is the amount of heat needed to raise the temperature of 1 gram of water by 1°C
  - note that familiar “calories” used in food are actually kilocalories

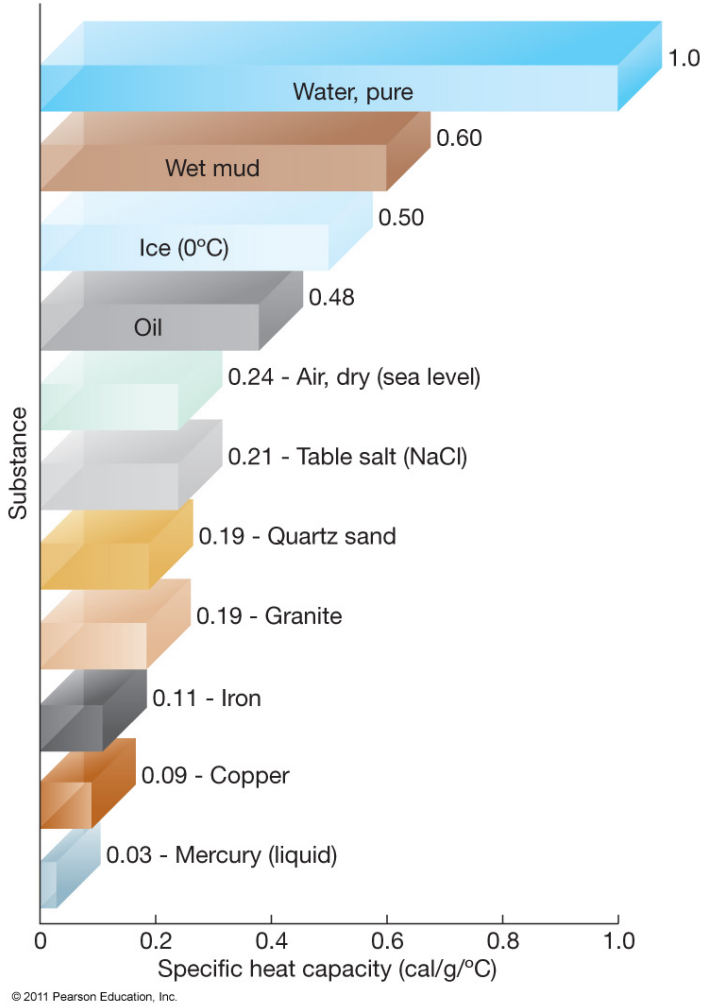
- Temperature is a measurement of average kinetic energy of the molecules that make up a substance
  - temperature changes when heat is added or subtracted to a substance
  - temperature is measured in degrees centigrade (°C), also known as Celsius
  - degrees Fahrenheit (°F) are a non-scientific scale only used popularly (not scientifically) in the USA, Bahamas, Belize, and Palau



- Freezing point = melting point: 0°C (32°F)
- Boiling point = condensation point: 100°C (212°F)
- Freezing and boiling points of water unusually high (thanks to hydrogen bonds and Van der Waals forces)
- If water behaved like other similar compounds, oceans would be frozen and life as we know it – which is water-based – would not exist

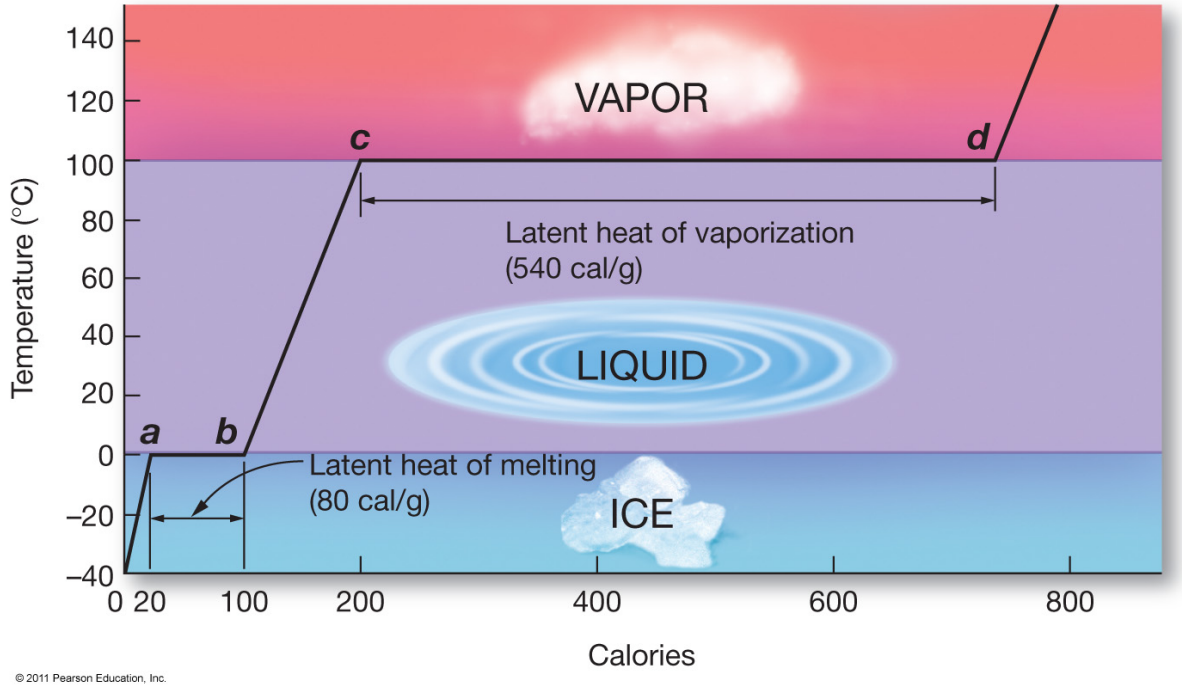
Water's Heat Capacity and Specific Heat

- Heat Capacity – amount of heat required to raise the temperature of 1 gram of any substance by 1°C
- Specific Heat – heat capacity per unit mass
- Water has a high heat capacity: 1 calorie per gram (that is, the specific heat of water is used at the unit of heat quantity, the calorie)
- Water can take in or lose much heat without changing temperature



Water's Latent Heat

- During a change of state, a large amount of heat is absorbed or released by water
- That heat is called latent heat



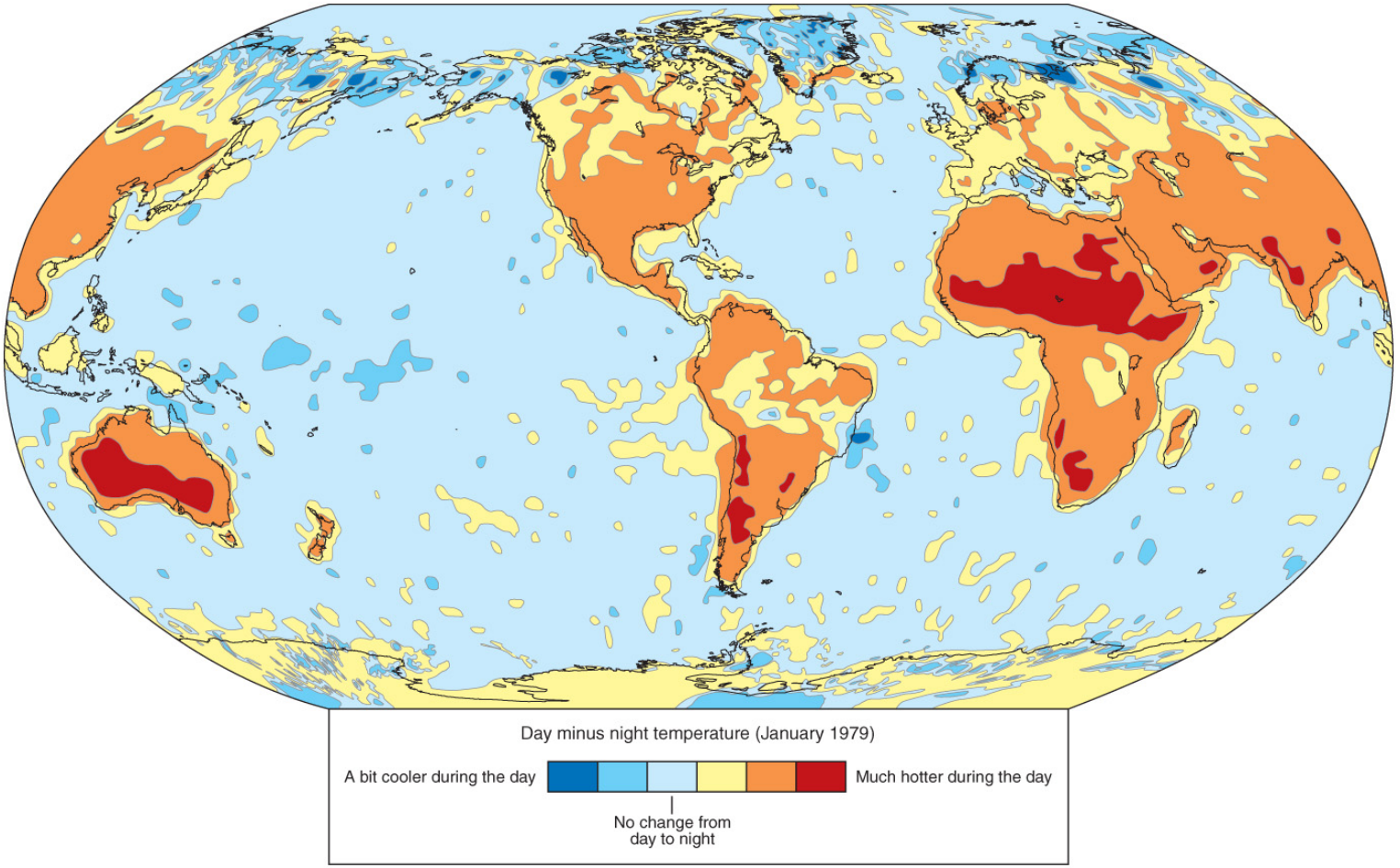
latent heat of evaporation

- while we can easily understand the latent heat of melting (and freezing) and the latent heat of vaporization (and condensation), how do we explain liquids converting to gas below boiling temperature?
- or, how does ocean water evaporate if it does not boil over?
- for an individual ocean water molecule to evaporate, it has to capture heat from surrounding molecules
- so, molecules left behind LOSE energy to the one that evaporates
- consequently, the ocean cools when water evaporates

Global Thermostatic Effects

- Moderate temperature on Earth's surface
  - Equatorial oceans do not boil
  - Polar oceans do not freeze solid
- Marine effect
  - Oceans moderate temperature changes from day to night and during different seasons
- Continental effect
  - Land areas have greater range of temperatures from day to night and during different seasons

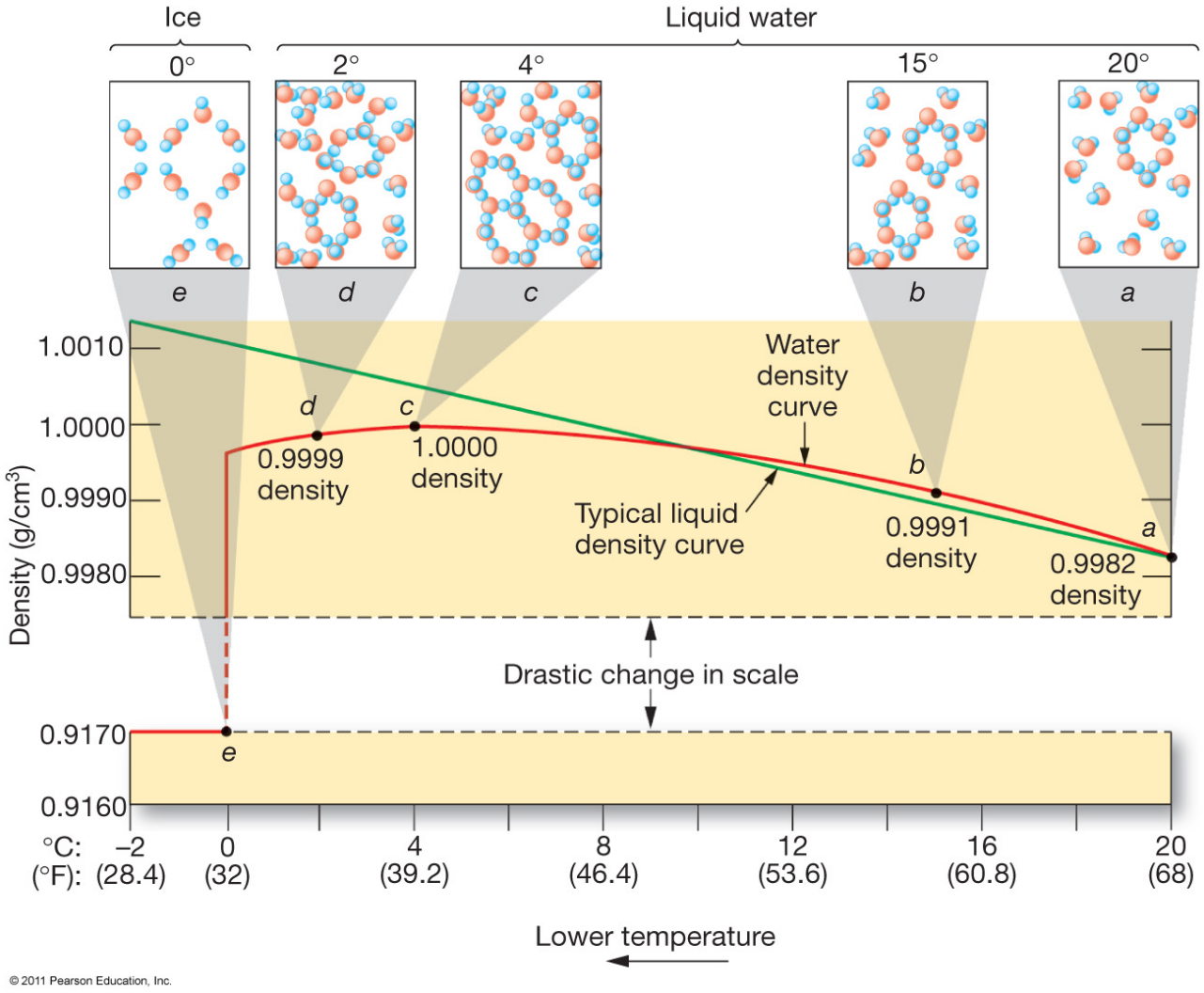
Day/Night Temperature Differences



5.2.2 - Water Density

- Density of all substances increases as temperature decreases
- This is called thermal contraction
- Water behaves in the same way but only down to a temperature of 4°C
- Below 4°C (from 4°C to 0°C), water expands (and density decreases) as temperature decreases
- This is highly unusual and it is the reason why ice floats
- Normally a solid sinks in its own fluid, but ice floats instead
- Ice is less dense than water:
  - Changes in molecular packing
  - Water expands as it freezes

Water Density and Temperature



Pressure and Dissolved Solids in Water change its temperature of maximum density and its freezing point

- Increasing pressure reduces the space for the formation of ice crystals
  - at the bottom of the ocean, at a depth of 5000 m, where the highest density is reached, the temperature is 2°C (and not 4°C)

- Adding dissolved substances inhibits the formation of hydrogen bonds, necessary for ice formation

- In both cases, lower temperatures are necessary to form ice from liquid water

  - Most seawater never freezes