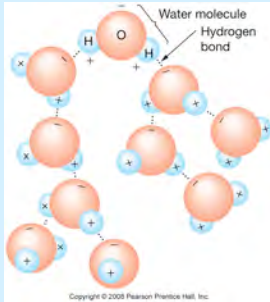


CHAPTER 5 Water and Seawater

H₂O molecule

- One hydrogen H and two oxygen O atoms bonded by sharing electrons
- Both H atoms on same side of O atom
- Dipolar

Hydrogen bonding



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

Fig. 5.3

Hydrogen bonding

- Hydrogen bonds are weaker than covalent bonds but still strong enough to result in
 - High surface tension
 - High solubility of chemical compounds in water
 - Solid, liquid, gas at Earth's surface
 - Unusual thermal properties
 - Unusual density

Water molecules in different states of matter

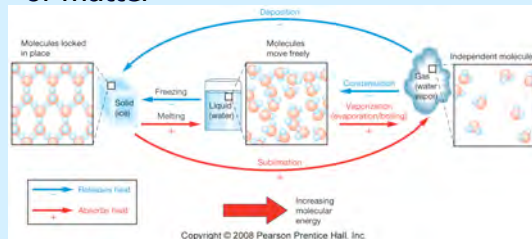


Fig. 5.5

Changes of state due to adding or subtracting heat

- Heat is energy of moving molecules
- Calorie is amount of heat needed to raise the temperature of 1 gram of water by 1° C
- Temperature is measurement of average kinetic energy

Unusual thermal properties of H₂O

- H₂O has high boiling point
- H₂O has high freezing point
- Most H₂O is in the form of water (liquid) on Earth's surface (good for life)
- High **latent (hidden) heats** of
 - Vaporization/condensation
 - Melting/freezing
 - Evaporation

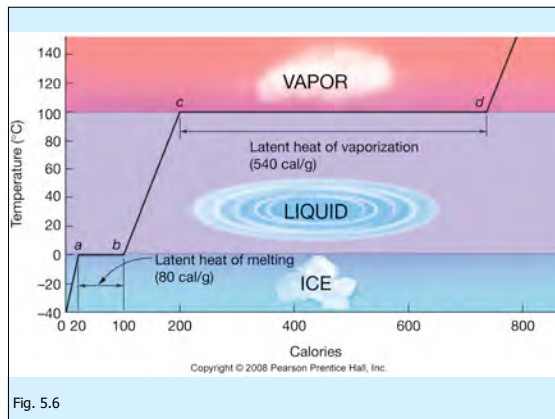


Fig. 5.6

Unusual thermal properties of H₂O

- Water high **heat capacity**
 - Amount of heat required to raise the temperature of 1 gram of any substance 1° C
 - Water can take in/lose lots of heat without changing temperature
- Rocks low heat capacity
 - Rocks quickly change temperature as they gain/lose heat

Global thermostatic effects

- Moderate temperature on Earth's surface
 - Equatorial oceans (hot) don't boil
 - Polar oceans (cold) don't freeze solid
- **Marine effect**
 - Oceans moderate temperature changes day/night; different seasons
- **Continental effect**
 - Land areas have greater range of temperatures day/night and during different seasons

Density of water

- Density of water increases as temperature decreases
- Density of ice is less than density of water
- From 4°C to 0°C density of water decreases as temperature decreases

Density of water

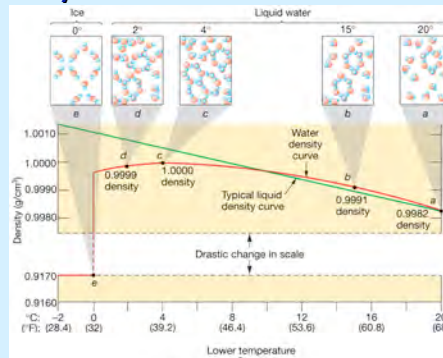


Fig. 5.10

Salinity

- Total amount of solid material dissolved in water- *Traditional definition*
- Typical salinity is 3.5% or 35‰

‰ or parts per thousand (ppt) = grams of salt per kilogram of water g/Kg

Six elements make up 99% of dissolved solids in seawater

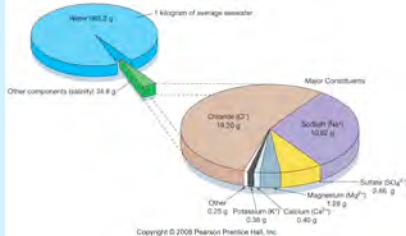


Fig. 5.12

Measuring salinity

- **Evaporation**
- **Chemical analysis - titration**
 - Principle of constant proportions
 - Major dissolved constituents in same proportion regardless of total salinity
 - Measure amount of *halogens (Cl, Br, I, F)* (chlorinity)
 - $Salinity = 1.80655 * Chlorinity (ppt)$
- **Electrical conductivity**
 - Salinometer

Pure water vs. seawater

TABLE 5.4 Comparison of selected properties of pure water and seawater

Property	Pure water	35% seawater
Color (light transmission)	Clear (high transparency)	Same as for pure water
• Small quantities of water	Clear (high transparency)	Same as for pure water
• Large quantities of water	Blue-green because water molecules scatter blue and green wavelengths best	Same as for pure water
Odor	Odorless	Distinctly marine
Taste	Tasteless	Distinctly salty
pH	7.0 (neutral)	Surface waters range = 8.0–8.3; average = 8.1 (slightly alkaline)
Density at 4°C (39°F)	1.000 g/cm ³	1.028 g/cm ³
Freezing point	0°C (32°F)	-1.9°C (28.6°F)
Boiling point	100°C (212°F)	100.6°C (213.1°F)

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Salinity variations

- Open ocean salinity 33 to 38 ‰
- Coastal areas salinity varies more widely
 - Influx of freshwater lowers salinity or creates **brackish** conditions
 - Greater rate of evaporation raises salinity or creates **hypersaline** conditions
 - Salinity may vary with seasons (dry/rain)

How to change salinity

- Add water
- Remove water
- Add dissolved substances
- Remove dissolved substances

Processes that add/subtract water from oceans

Salinity decreases through:

- Precipitation (rain or snow)
- Runoff (river flow)
- Melting icebergs
- Melting sea ice

Salinity increases through:

- Evaporation
- Formation of sea ice

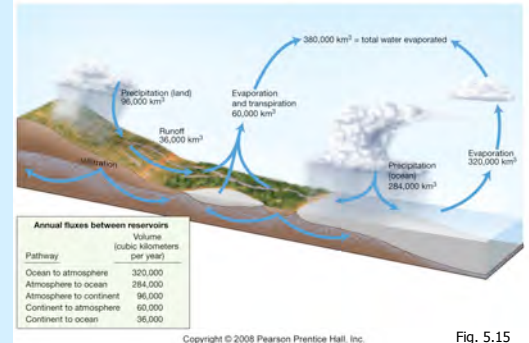
Processes that add/subtract water

TABLE 5.5 Processes affecting seawater salinity

Process	How accomplished	Adds or removes	Effect on salt in seawater	Effect on H ₂ O in seawater	Salinity increase or decrease?	Source of freshwater from the sea?
Precipitation	Rain, sleet, hail, or snow falls directly on the ocean	Adds very fresh water	None	More H ₂ O	Decrease	—
Runoff	Streams carry water to the ocean	Adds mostly fresh water	Negligible addition of salt	More H ₂ O	Decrease	—
Icebergs melting	Glaciers ice calves into the ocean and melts	Adds very fresh water	None	More H ₂ O	Decrease	Yes, icebergs from Antarctic have been traced to South America
Sea ice melting	Sea ice melts in the ocean	Adds mostly fresh water and some salt	Adds a small amount of salt	More H ₂ O	Decrease	Yes, sea ice can be melted and is better than drinking seawater
Sea ice freezing	Seawater freezes in cold ocean areas	Removes mostly fresh water	30% of salts in seawater are retained in ice	Less H ₂ O	Increase	Yes, through multiple freezings, called brine rejection
Evaporation	Seawater evaporates in hot climates	Removes very pure water	None (essentially all salts are left behind)	Less H ₂ O	Increase	Yes, through evaporation of seawater and condensation of water vapor, called distillation

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Hydrologic cycle describes recycling of water near Earth's surface



Processes that add/subtract dissolved substances

Salinity increases through:

- River flow
- Volcanic eruptions
- Atmosphere
- Biologic interactions

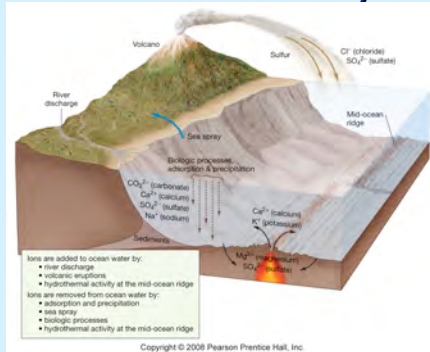
Salinity decreases through:

- Salt spray
- Chemical reactions at seawater-sea floor interface
- Biologic interactions
- Evaporite formation
- Adsorption

Residence time

- Average length of time a substance remains dissolved in seawater
- Ions with long residence time are in high concentration in seawater
- Ions with short residence time are in low concentration in seawater
- Steady state condition

Residence time and steady state



Acidity and alkalinity

- Acid releases H⁺ when dissolved in water
- Alkaline (or base) releases OH⁻
- pH scale measures *the hydrogen ion concentration*
 - Low pH value, acid
 - High pH value, alkaline (basic)
 - pH 7 = neutral

Carbonate buffering

- Keeps ocean pH about same (8.1)
- pH too high, carbonic acid releases H+
- pH too low, bicarbonate combines with H+
- Precipitation/dissolution of calcium carbonate CaCO_3 buffers ocean pH
- Oceans can absorb CO_2 from atmosphere without much change in pH

Carbonate buffering

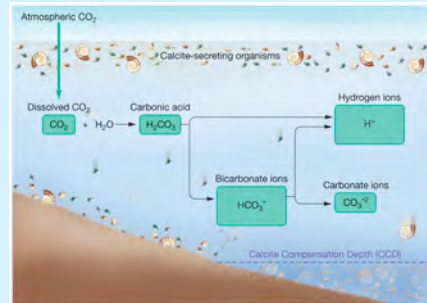


Fig. 5.18

If seawater too basic: $\text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+$; pH drops
 If seawater too acidic: $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$; pH rises
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Surface ocean variation of salinity

- Polar regions: salinity lower, lots of rain/snow and runoff
- Mid-latitudes: salinity higher, high rate of evaporation
- Equator: salinity lower, lots of rain
- Thus, salinity at surface varies primarily with latitude

Surface ocean variation of salinity

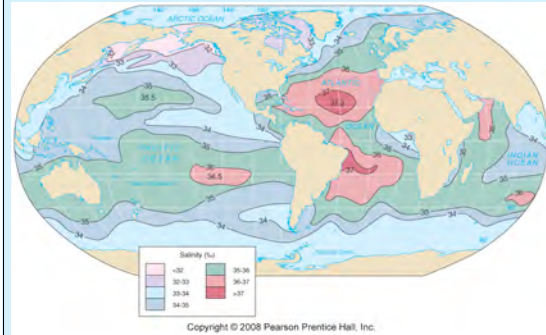


Fig. 5.21

Deep ocean variation of salinity

- Surface ocean salinity is variable
- Deeper ocean salinity is nearly the same (polar source regions for deeper ocean water)
- Halocline**, rapid change of salinity with depth

Salinity versus depth

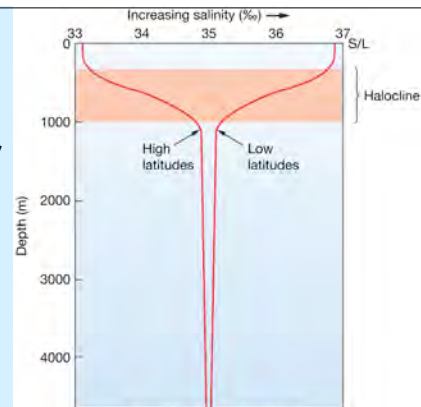


Fig. 5.22

Density of seawater

- 1.022 to 1.030 g/cm³ surface seawater
- Ocean layered according to density
- Density seawater controlled by temperature, salinity, and pressure
 - Most important influence is temperature
 - Density increases with decreasing temperature

Density of seawater

- Salinity greatest influence on density in polar oceans
- Polar ocean is isothermal

Density versus depth

- Density differences cause a layered ocean
- **Pycnocline**, abrupt change of density with depth
- **Thermocline**, abrupt change of temperature with depth

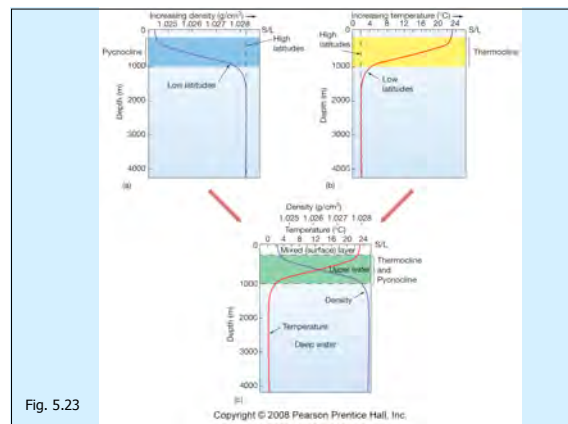


Fig. 5.23

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Layered ocean

- Mixed surface water
- Pycnocline and thermocline
- Deep water
- High latitude oceans
 - Isothermal
 - Isopycnal

Desalination processes

- Remove salt from seawater
- Distillation--most common process
- Electrolysis
- Reverse osmosis
- Freeze separation

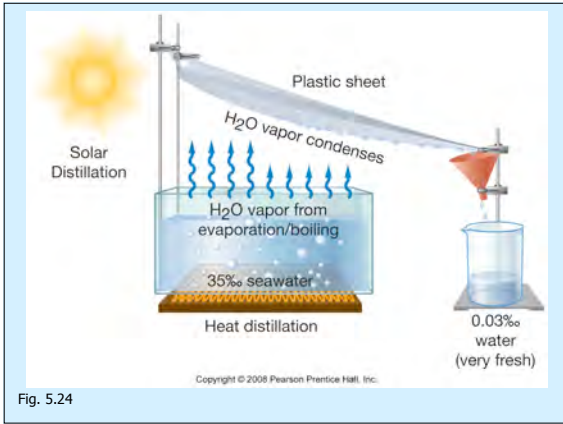


Fig. 5.24

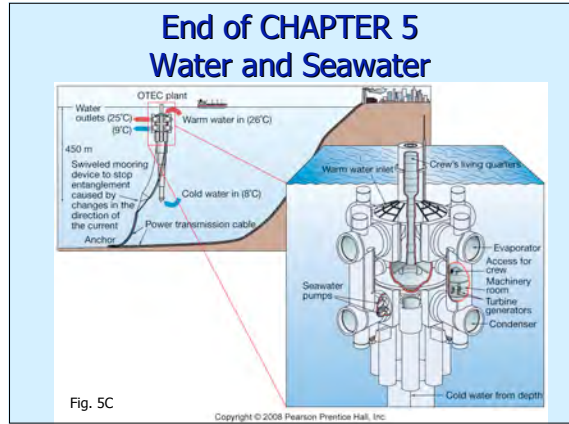


Fig. 5C