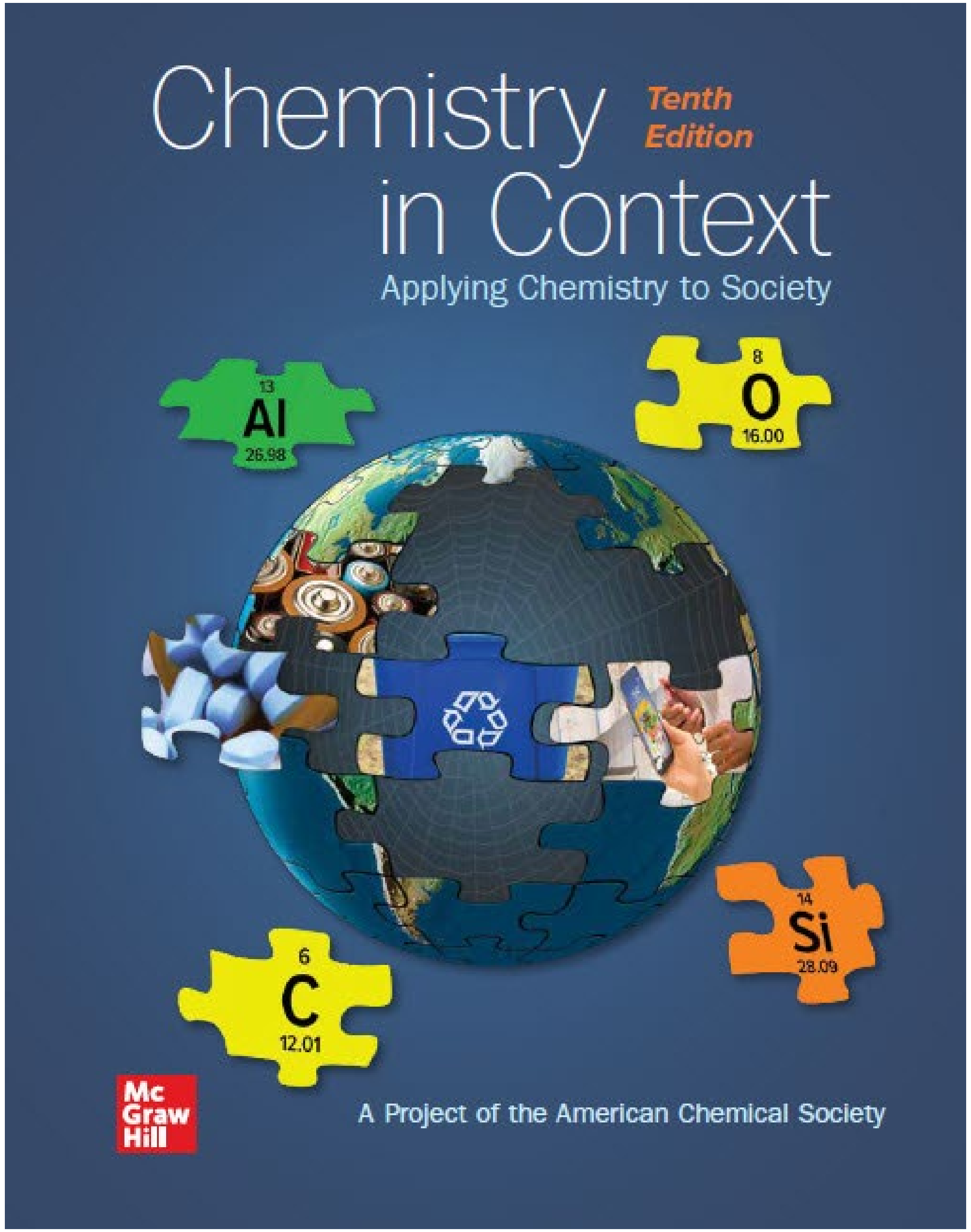
General Chemistry (CH101): Chemistry around Us

Department of Chemistry

KAIST

Chapter 05

Water Everywhere: A Most Precious Resource



Chapter 5
Water Everywhere: A Most Precious Resource

- What are the unique properties of water?
- Where is the water located that we and other lifeforms use?
- How does water interact with other chemicals?
- How do the properties of water change through its interaction with other components?
- How can we improve the quality of water?

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Reflect

Water Everywhere

Watch the chapter opening video and think about the water you drink and use on a daily basis.

a. What substances and impurities are found in this water?

b. Where does this water come from, and where does the wastewater eventually go?

C. How do you think the water habits of a community can affect the natural water Supply?

Chapter 5 video

©Tiago Fioreze

The Water We Drink

Water is ubiquitous in nature:

- It covers 70% of the Earth's surface.
- Composes 60% of the human body; 50% of our blood; 77% of the brain.

Water is essential for life; humans can only go a few days without water.

- Loss of 2% of your body's water leads to thirst.
- 5% loss gives rise to headaches and fatigue.
- 10 – 15% loss leads to muscle spasms and delusion.
- >15% loss leads to death.

Fresh water is a limited resource!

Your Turn [1]

Your Turn 5.3 keep a Water log

Pick a two-day period that represents typical activities for you. Record all of your activities that involve water by time and activity. While writing down your use of water, record the following:

a. The role that water played in your life. For example, are you consuming it? Are you using it in some process? Is it part of your outdoor experience?

b. The source of the water, the quantity involved, and where it went afterward.

c. The degree to which you made the water dirty.

The Unique Composition of Water

Water is a liquid at standard temperature and pressure (STP): 25°C and 1 atm

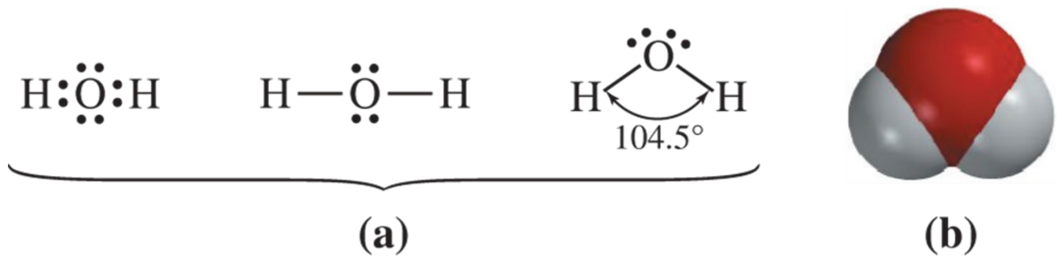
- All other compounds with similar masses are gases under these conditions (O_2, N_2, CO_2).

Water has an anomalously high boiling point (100 °C)

- Liquids with similar molecular structures, such as H_2S (-60 °C), have much lower boiling points.

When water freezes, it expands

- Most other liquids contract when they solidify.



Electronegativity

The **Electronegativity** is a measure of the attraction of an atom for electrons in a chemical bond.

- The greater the electronegativity, the more an atom attracts the electrons in a bond towards itself.

Table 5.1		Electronegativity Values for Selected Elements					
Group 1	**2**	**13**	**14**	**15**	**16**	**17**	**18**
H 2.1							He *
Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne *
Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar *

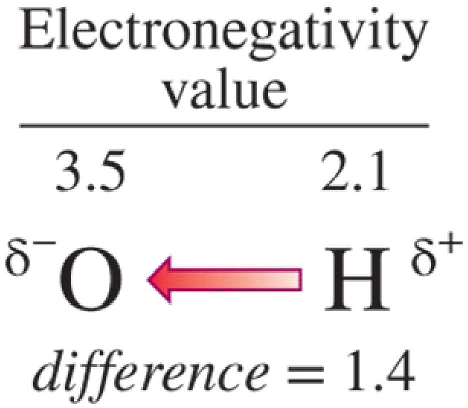
*Noble gases rarely (if ever) bond to other elements, and therefore do not have electronegativity values.

Polar Covalent Compounds

A difference in the electronegativity of the atoms in a covalent bond creates a **polar covalent bond** (a.k.a. polar bond).

- Electrons are not equally shared, but are pulled towards the more electronegative atom.
- Arrows point towards the more electronegative atom; referred to as a bond dipole.

A **nonpolar covalent bond** is found between two atoms of the same element (such as Cl_2, O_2, N_2, etc.).



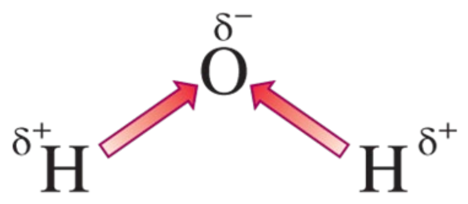
Molecular Polarity

A molecule that contains polar bonds may or may not be polar.

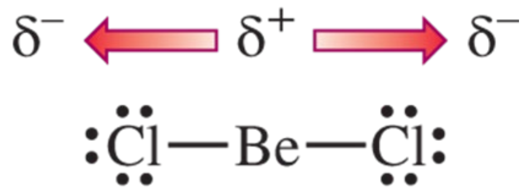
- Depends on both the type of bond AND the shape of the molecule.

Water is polar because it has polar bonds and a bent shape.

- The bond dipoles don’t offset or cancel each other.



- $BeCl_2$ is a nonpolar molecule because its polar bonds cancel.



[Molecule Polarity]

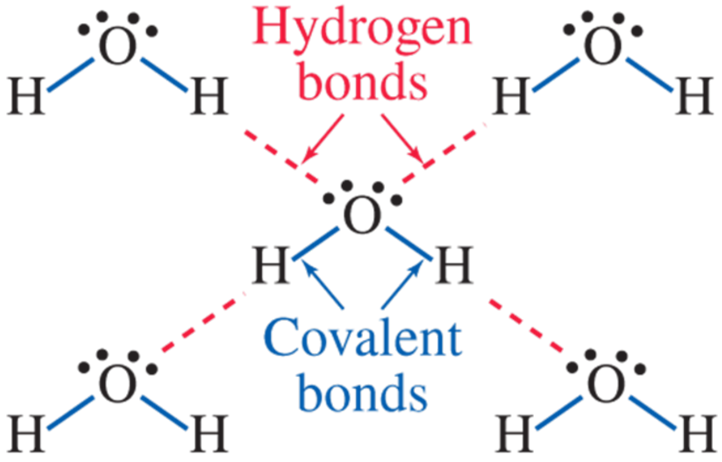
Hydrogen Bonding

A **hydrogen bond** is an electrostatic attraction between a hydrogen atom bonded directly to an atom of N, O, or F and an atom of N, O, or F

1. Hydrogen atom…
2. …bonded to a N, O, or F.
3. N, O, or F in another molecule (could be the same type of molecule).

Hydrogen bonds are *inter*molecular bonds

Covalent bonds are *intra*molecular bonds



The Properties of Water, Explained

- Hydrogen bonds are not as strong as covalent bonds, but they are strong enough to affect the physical properties of a substance.
- The high boiling point of water is due to hydrogen bonds, which must be broken in order to transform water from a liquid to a gas.
- **Chemical changes** are governed by the strengths of intramolecular forces (covalent and polar bonds).
- **Physical changes** are governed by the strengths of intermolecular forces (hydrogen bonds and London dispersion forces).

Why Does Ice Float?

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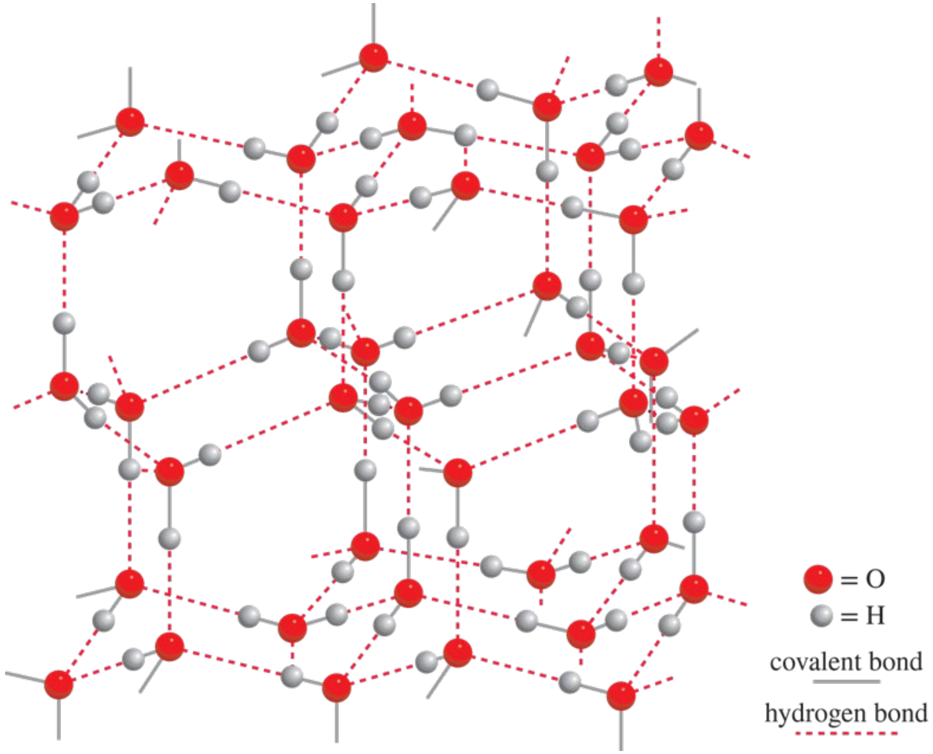
Paraffin wax and ice in water

Why Does Ice Float?

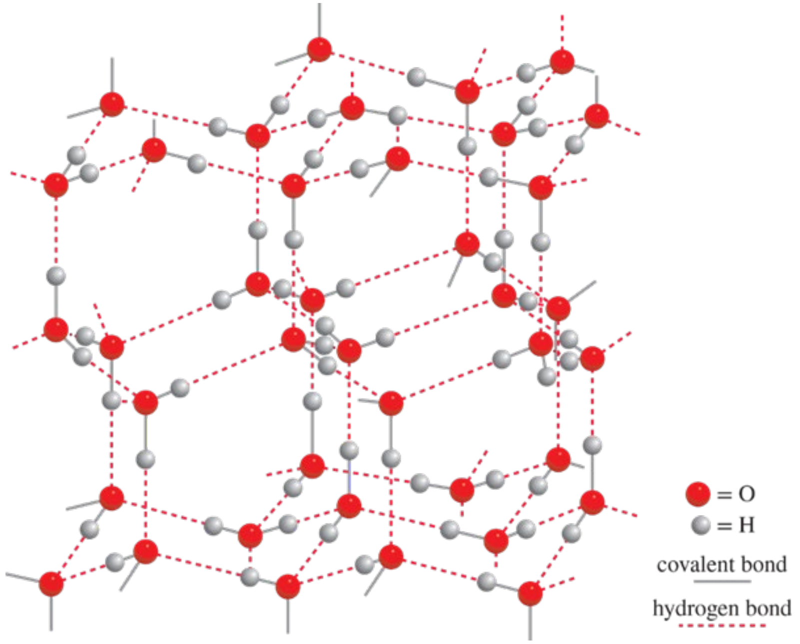
- Due to hydrogen bonding, the structure of ice is porous. This results in a lower density for solid water than liquid. Pipes burst on freezing!
- The solid phase of most substance is denser than its liquid.
- Aquatic plants and fish can live in a freshwater lake during cold winter because the lake doesn't freeze from the bottom up.



[Connected Chemistry - American Chemical Society (acs.org)]

What Else is Special About Water?

- **Specific heat** (1.00 cal/g°C) – a lot of energy required to change the temperature; moist air stores heat energy.
- **Heat of fusion** – released when the liquid freezes to a solid; spray crops to prevent freezing.
- **Heat of vaporization** – released when the gas condenses into a liquid; huge temperature swing during a thunderstorm.



Energy is required to break the intermolecular hydrogen bonds during a phase change

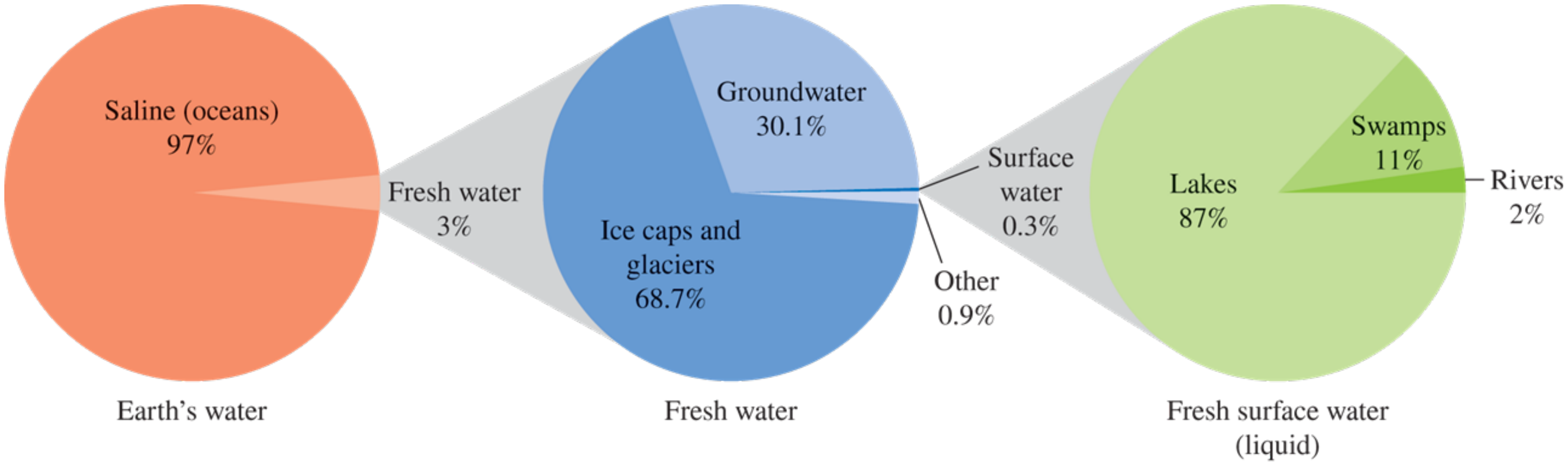
Fresh Water: A Rare and Precious Resource!

Only 3% of water found on Earth is freshwater.

- 68% of freshwater is in glaciers, ice caps, snowfields.
- 30% of freshwater is found underground and must be pumped to the surface.
- 0.3% of freshwater is in lakes, rivers, and wetlands.

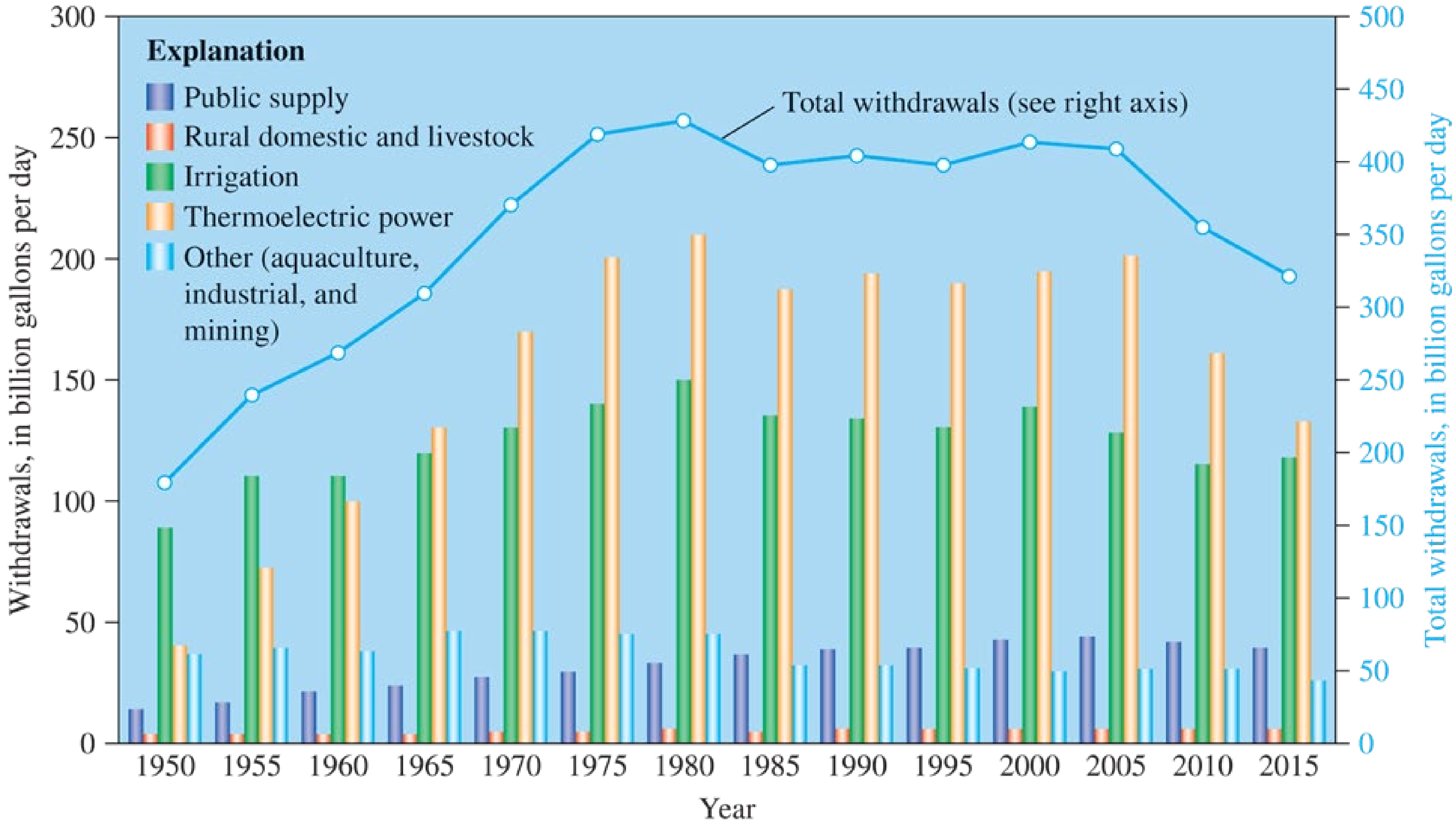
If all the water on our planet fit into a 2-liter bottle, only 60 mL would be freshwater.

- Only 4 drops would represent the water in lakes and rivers!



Water Use Trends

- 322 billion gallons of water are withdrawn daily in the US.
- 86% freshwater and 14% saltwater.
- Thermoelectric power and irrigation represent the largest uses of water.
- Agriculture accounts for 30% of global water consumption.



Water Footprints

- A **water footprint** is an estimate of the volume of freshwater used to produce particular goods or provide services.

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Table 5.2 Water Footprints for Meats and Grains

Food (1 kg)	Water footprint (L, global average)
corn (maize)	1,200
wheat	1,800
soybeans	2,100
rice	2,500
chicken	4,300
pork	6,000
sheep	8,700
beef	15,400

Source: Water Footprint Network, 2012

Water Footprints

- A **water footprint** is an estimate of the volume of freshwater used to produce particular goods or provide services.

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Table 5.3 Water Footprints for Various Products

Product	Water footprint (L, global average)
1 cup of coffee (250 mL)	260
1 cup of tea (250 mL)	27
1 banana (200 g)	160
1 orange (150 g)	80
1 glass of orange juice (200 mL)	200
1 egg (60 g)	200
1 chocolate bar (100 g)	1700
1 cotton T-shirt (250 g)	2500

Source: Water Footprint Network, 2012

Your Turn

Your Turn 5.15 Differences in Water Footprints

Based on the data in Table 5.2, how do crops compare to meat, in terms of water usage? What are some reasons for this?

Global Climate Change

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(b)

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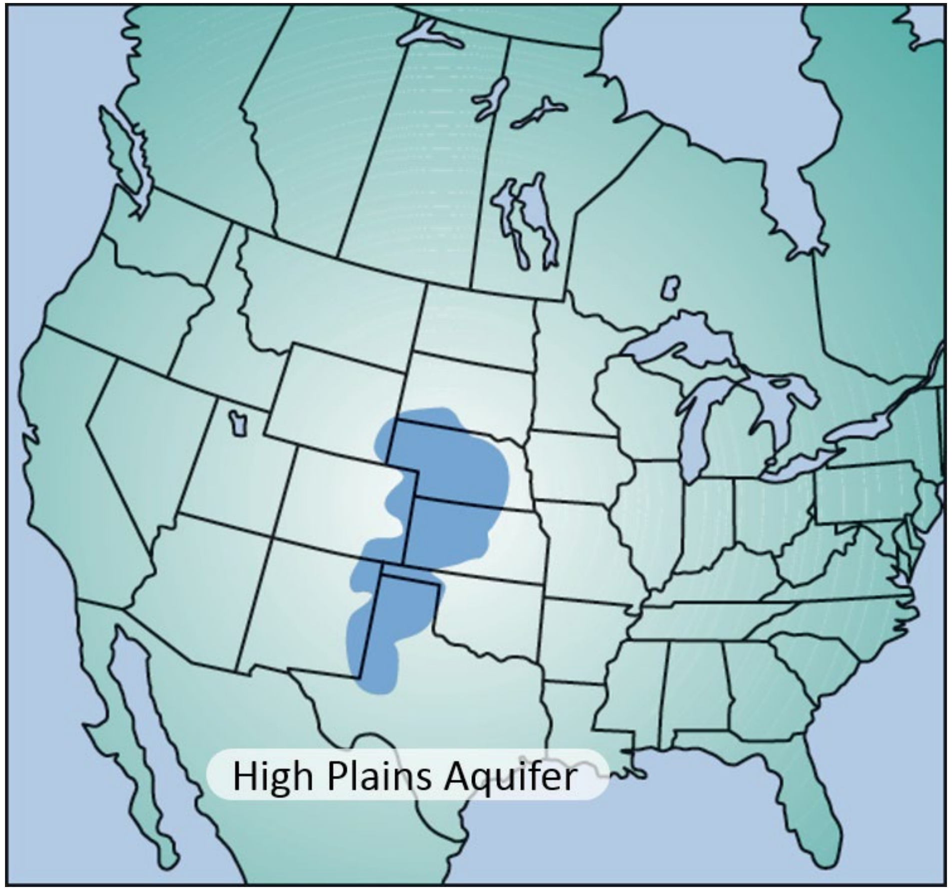
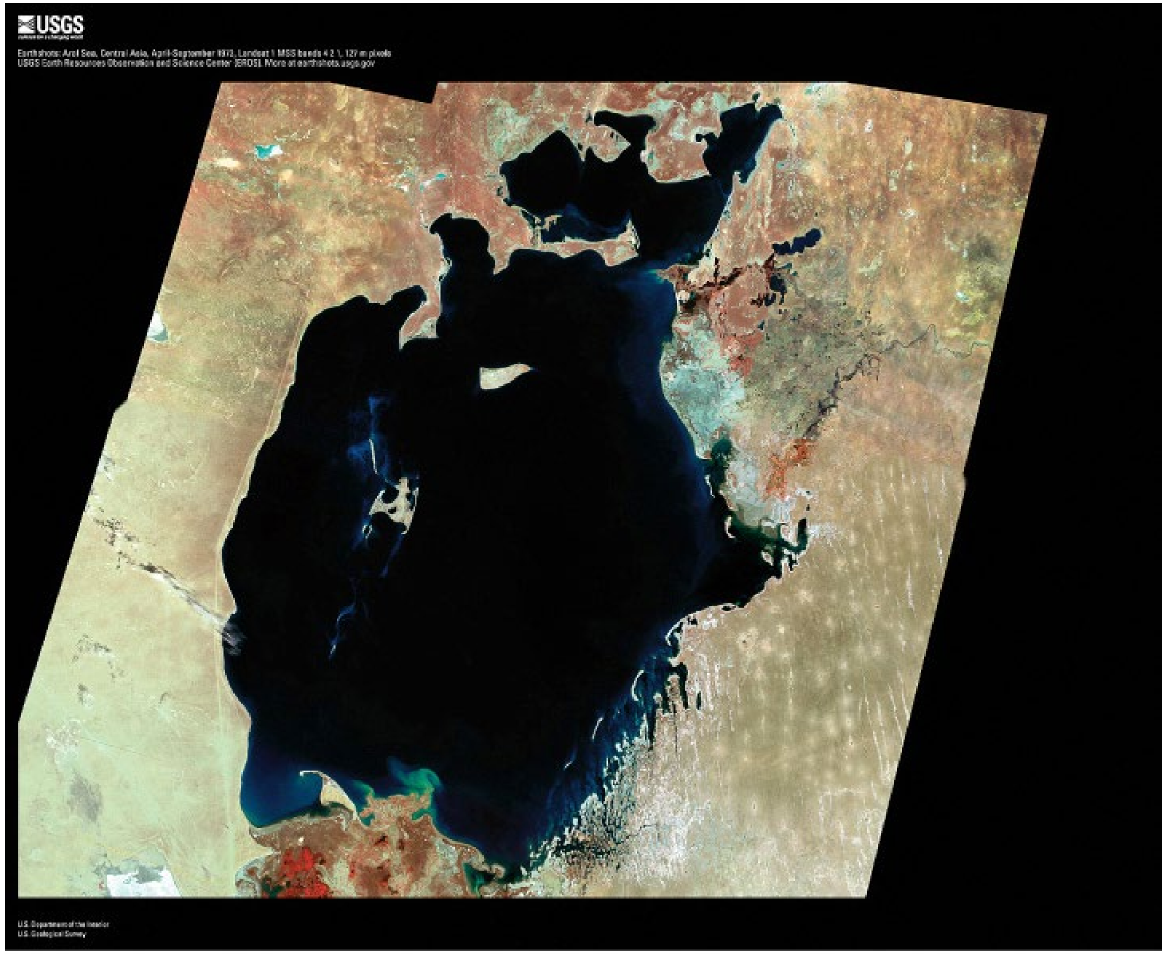
Water Pollution [1]

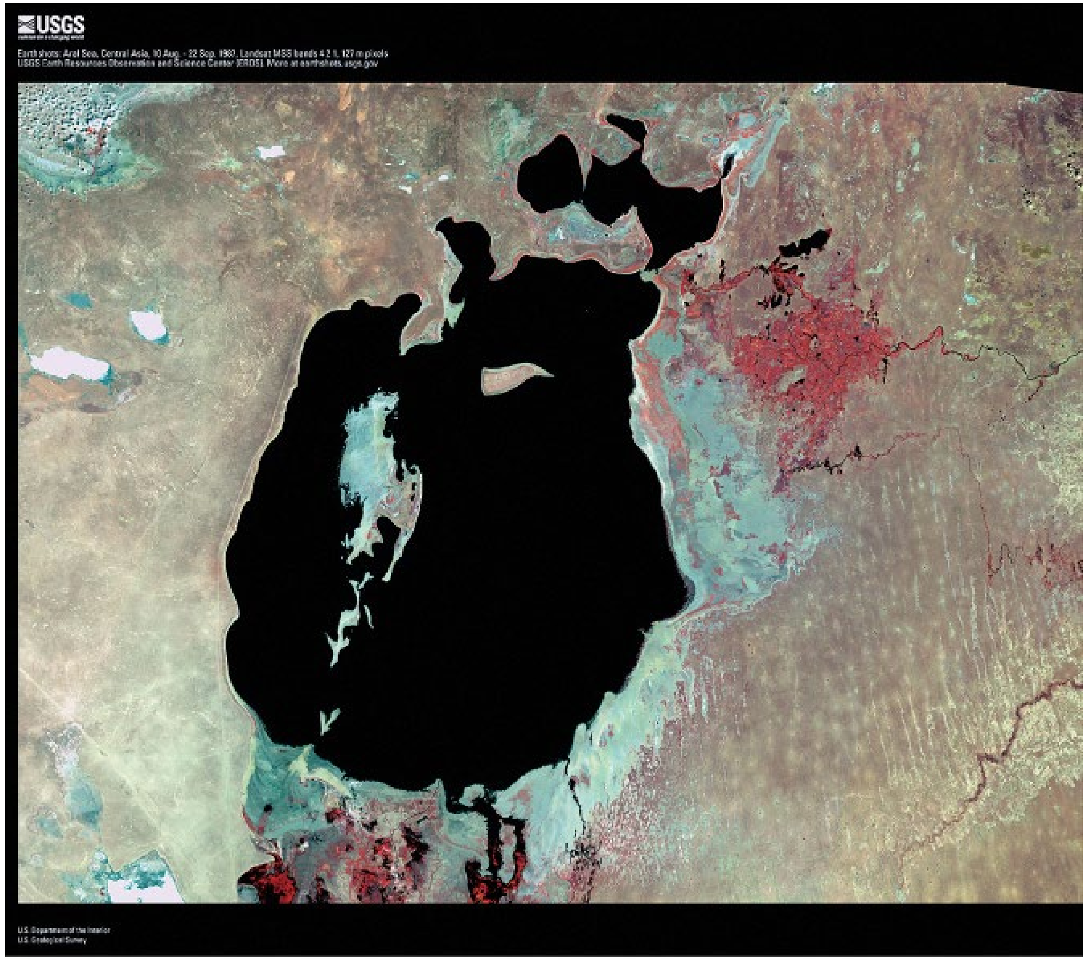
- The average American uses about 100 gallons of water per day.
- Nearly ¾ of the water entering our homes goes down the drain.
- Much of our water comes from underground aquifers.



Overconsumption



Aral Sea 1973

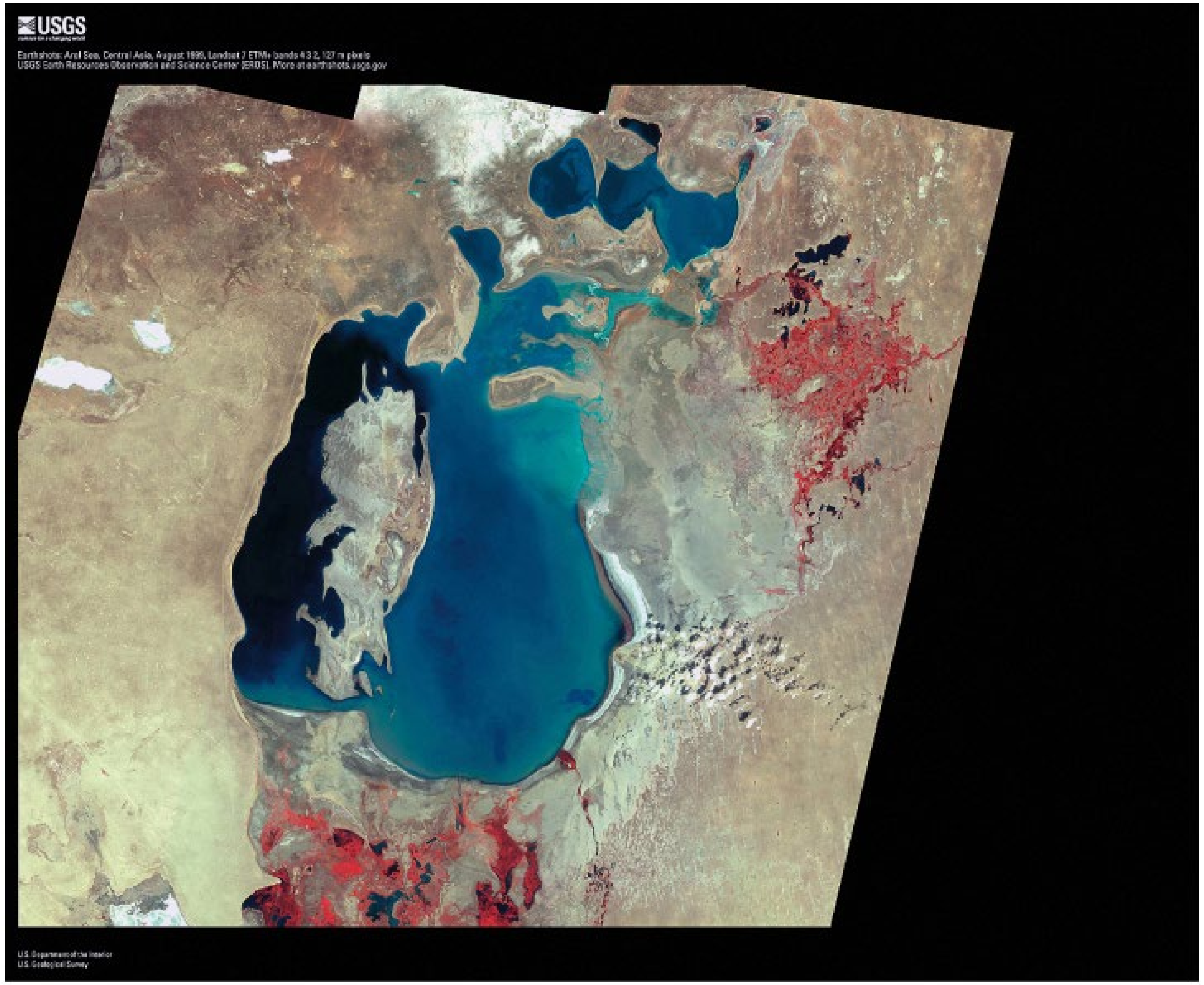


Aral Sea 1987

Source: U.S. Geological Survey (USGS)

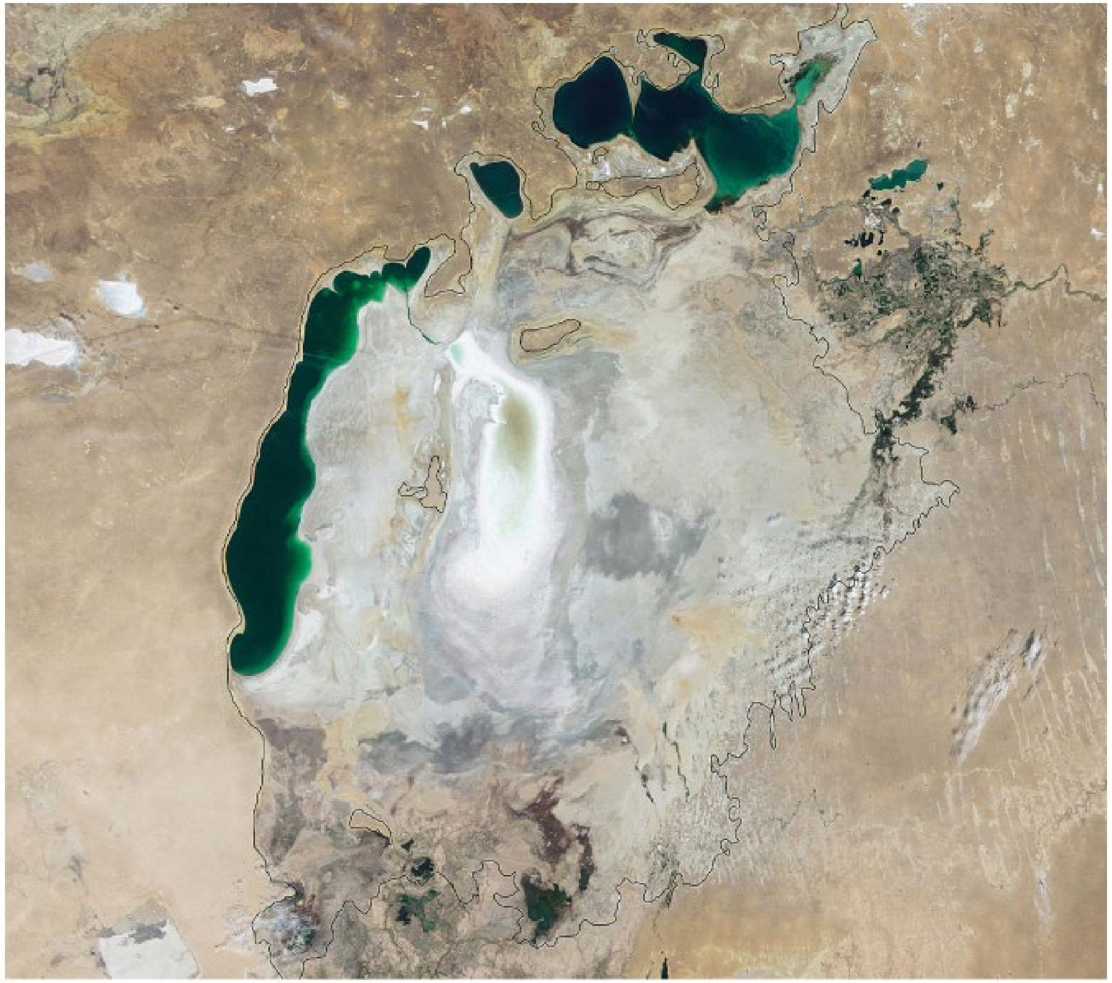
Source: U.S. Geological Survey (USGS)

Overconsumption: Tragedy of the Commons



Aral Sea 1999

Source: U.S. Geological Survey (USGS)



Aral Sea 2009

Source: NASA image created by Jesse Allen

Water Pollution 2

While normally free of pollutants, groundwater can be contaminated by a number of sources:

- Abandoned mines.
- Runoff from fertilized fields poorly constructed landfills and septic systems.
- Household chemicals poured down the drain or on the ground.

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Solutions

A **solution** is a homogeneous mixture of uniform composition.

Solutions are made up of **solvents** and **solutes**.

- The majority component of a mixture; dissolves the others.
- Minority components of a mixture; dissolved in the solvent.

When water is the solvent, you have an **aqueous solution.**

Concentrations of Solutions

Parts per hundred (percent): 20 g of NaCl in 100 g of aqueous solution (water + solutes masses) is a 20% NaCl solution

Parts per million (ppm):

$$97\,\text{ppm Ca} = \frac{97\,\text{g Ca}}{1\times10^{6}\ \text{g solution}} \times \frac{1000\,\text{g solution}}{1\,\text{L solution}} \times \frac{1000\,\text{mg Ca}}{1\,\text{g Ca}} = \frac{97\,\text{mg Ca}}{1\,\text{L solution}}$$

Parts per billion (ppb):

$$2\,\text{ppb Hg} = \frac{2\,\text{g Hg}}{1\times10^{9}\ \text{g solution}} \times \frac{1000\,\text{g solution}}{1\,\text{L solution}} \times \frac{1\times10^{6}\,\mu\text{g Hg}}{1\,\text{g Hg}} = \frac{2\,\mu\text{g Hg}}{1\,\text{L solution}}$$

Molarity

Molarity is a commonly used unit of concentration in chemistry

$$\text{Molarity, } M = \frac{\text{moles of solute (mol)}}{\text{L of solution (L)}}$$

Square brackets [ ] are used to indicate “concentration of” in units of M

[NaCl] = 1.0 M means there is 1.0 moles of NaCl per liter of solution

[Concentration - Solutions | Concentration | Saturation - PhET Interactive Simulations (colorado.edu)]

Molarity Example Calculation

How many grams of NaCl are in one liter of 2.0 M NaCl?

$$\frac{2.0 \text{ moles NaCl}}{1\text{L solution}} \times 1\text{L solution} \times \frac{58.44\text{g NaCl}}{1\text{mole NaCl}} = 106.9\text{g NaCl}$$

Preparing Solutions

Volumetric flasks are used to prepare solutions with concentrations in molarity

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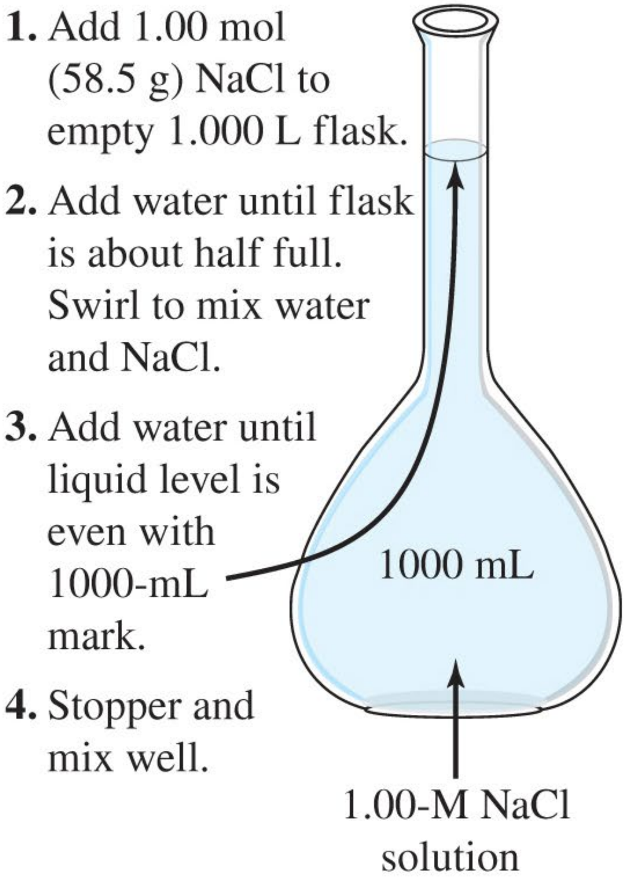

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Your Turn 3

Your Turn 5.25 Moles and Molarity

a. Express a concentration of 16 ppb Hg^{2+} in units of molarity.

b. For 1.5-M and 0.15-M NaCl, how many moles of solute are present in 500 mL of each?

C. A solution is prepared by dissolving 0.50 mol NaCl in enough water to form 250 mL of solution. A second solution is prepared by dissolving 0.60 mol NaCl to form 200 mL of solution. Which solution is more concentrated? Explain.

d. A student was asked to prepare 1.0 L of a 2.0-M $CuSO_4$ solution. The student placed 40.0 g of $CuSO_4$ crystals in a volumetric flask and filled it with water to the 1000-mL mark. Was the resulting solution 2.0 M? Explain.

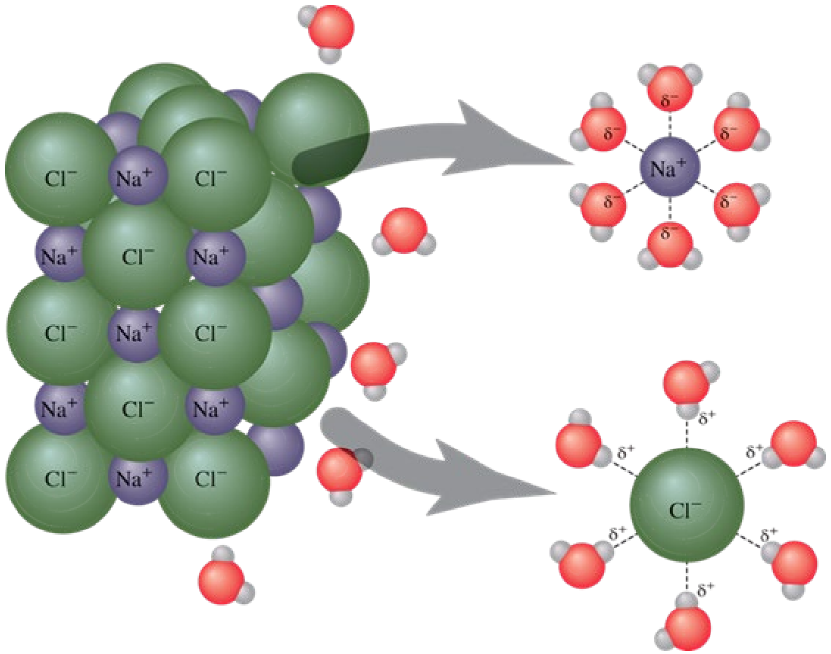
[Molarity (colorado.edu)]

Ionic Compounds

- 97% of water on our planet is found in the saltwater of oceans.
- Since water is **polar**, the partial negative charges on the oxygen atoms are attracted to the positively charged Na^+ ions of the salt crystal.
- Likewise, the partially positive charges on the hydrogen atoms surround the Cl^- ions of the salt.

$$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

- Dissolving the salt to form its component ions is called **dissociation.**



[Dissociation of NaCl (youtube.com)]

Ionic Compounds with Polyatomic Ions

Ionic compounds with polyatomic ions also dissociate, but the polyatomic ions remain intact:

$$Na_2SO_{4(s)} \rightarrow 2Na^+_{(aq)} + SO^{2-}_{4(aq)}$$

Notice the two sodium ions in the compound dissociate from each other as well, forming a total of 3 separate ions for every unit of Na_2SO_4 that dissolves

Ionic Compounds and Water Solubility

- Not all ionic compounds will dissolve in water.
- Simple generalizations about ionic compounds allow us to predict their water solubility.

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Table 5.5 Water Solubility of Ionic Compounds

Ions	Solubility of Compounds	Solubility Exceptions	Examples
Group 1 metals, NH_4^+	all soluble	none	$NaNO_3$ and KBr. Both are soluble.
nitrates	all soluble	none	$LiNO_3$ and $Mg(NO_3)_2$. Both are soluble.
chlorides	most soluble	silver, mercury(I), lead(II)	$MgCl_2$ is soluble. AgCl is insoluble.
sulfates	most soluble	strontium, barium, lead(II), silver(I)	K_2SO_4 is soluble. $BaSO_4$ is insoluble.
carbonates	mostly insoluble*	Group 1 metals, NH_4^+	Na_2CO_3 is soluble. $CaCO_3$ is insoluble.
hydroxides, sulfides	mostly insoluble*	Group 1 metals, NH_4^+	KOH is soluble. $Sr(OH)_2$ is insoluble.

*Insoluble means that the compounds have extremely low solubilities in water (less than 0.01 M). All compounds have at least a very small solubility in water.

Ions and Solubility

Name?	Ion	Soluble?
	$Pb(NO_3)_2$	
	$CaSO_4$	
	Na_3PO_4	
	$Al(OH)_3$	
	$AgBr$	

Ionic Compounds and Electrolytes

- When ions are in aqueous solutions, the solutions are able to conduct electricity.

a)

b)

a) Sugar dissolved in water (nonconducting), a **nonelectrolyte.**

b) NaCl dissolved in water (conducting), an **electrolyte.**

- The dissociated ions (charge) close the circuit gap in the electrolyte solution.

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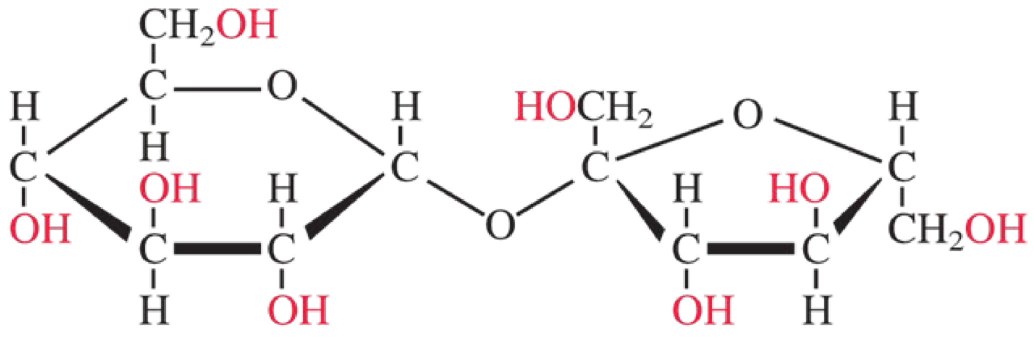
Strong Versus Weak Electrolytes

- If a compound completely dissociates into ions in water, it is a **strong electrolyte** (100% of the substance breaks into its ions).
- If a compound partially dissociates into ions in water, it is a **weak electrolyte** (only some of the substance breaks into ions, the rest remains as a whole uncharged compound).
- If a compound dissolves in water, but does not dissociate into ions, it is a **nonelectrolyte.**
- Table sugar, sucrose, a compound that dissolves in water but does not dissociate.



Rotatable model of sucrose in MolView

"Like Dissolves Like"

- A **polar** compound (for example, ethanol) will dissolve in a **polar** solvent (for example, water).
- A **nonpolar** compound (for example, oil) will dissolve in a **nonpolar** solvent (for example, gasoline).
- A **nonpolar** compound will NOT dissolve in a **polar** solvent, and vice versa.

Narcisopa/Shutterstock

Acids

Acids are historically defined as having sour taste, change the color of an indicator, or react with carbonates.

- Another way to define an acid is as a substance that releases hydrogen ions, H^+, in aqueous solution.
- Since the hydrogen ion has no electron, and only one proton (hence the positive charge), the hydrogen ion is sometimes referred to as a **proton**.

Consider hydrochloric acid, dissolved in water:

$$\mathrm{HCl} \rightarrow \mathrm{H}^+_{(\mathrm{aq})} + \mathrm{Cl}^-_{(\mathrm{aq})}$$

Since HCl dissociates completely into ions, it is a **strong acid**.

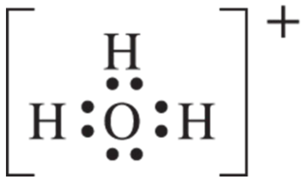
The Hydronium Ion

H^+ ions are much too reactive to exist alone, so they attach to something else, such as water molecules.

When dissolved in water, each HCl donates a proton H^+ to an H_2O molecule, forming H_3O^+, the **hydronium ion.**

- The Cl^- remains unchanged:

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$



Hydronium ion – often we simply write H^+, but understand it to mean H_3O^+ when in aqueous solutions.

Your Turn 4

Your Turn 5.35 Are All Acids Harmful?

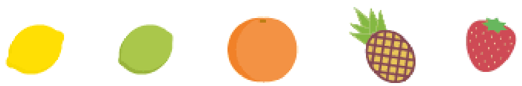
Although the word *acid* may conjure up all sorts of pictures in your mind, every day you eat or drink various acids. Check the labels of foods or beverages and make a list of the acids you find. Speculate on the purpose of each acid.

A Guide to Common Fruit Acids

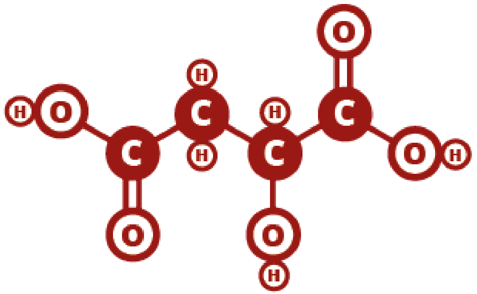
A GUIDE TO COMMON FRUIT ACIDS

Most people probably know that lemons and other citrus fruits contain citric acid – but it's just one of a number of different organic acids that can be found in fruits. Here we look at a number of the most common acids, and the various fruits that they are found in.

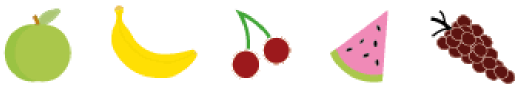
CITRIC ACID



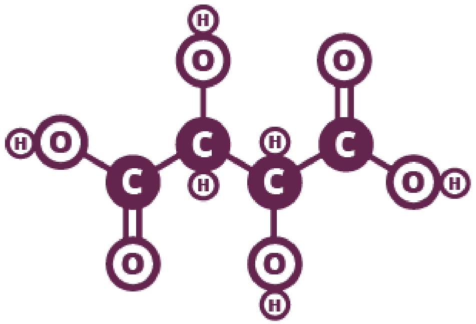
The main acid in citrus fruits is, unsurprisingly, citric acid. Lemons and limes have particularly high levels of this compound. It is also the main acid in a number of berry fruits, including strawberries, raspberries and gooseberries.



MALIC ACID



Malic acid is the main acid in most stone fruits such as cherries, apricots, peaches, and nectarines. It's also found in high amounts in apples, and in lower amounts in bananas. Though watermelons have a low acid content, their principal acid is also malic acid.

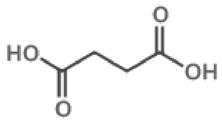


TARTARIC ACID

Tartaric acid is the principal acid in fewer fruits than citric and malic acid. However, it is the main acid in grapes, which also contain malic acid. Red grapes have higher levels of tartaric acid. The main acid of avocado and tamarind is also tartaric acid.

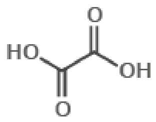
OTHER ORGANIC ACIDS

Citric, malic, and tartaric acids are not the only organic acids present in fruit – a number of other acids are also present, albeit in significantly smaller quantities. To the right, a small selection of these compounds are shown, along with a brief note of some of the fruits in which they're often found.



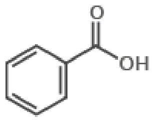
SUCCINIC ACID

Apples and some berries



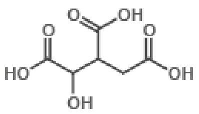
OXALIC ACID

Small amounts in berries



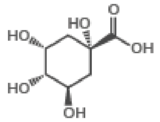
BENZOIC ACID

Present in cranberries



ISOCITRIC ACID

Present in blackberries



QUINIC ACID

Plums & kiwifruit

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Bases

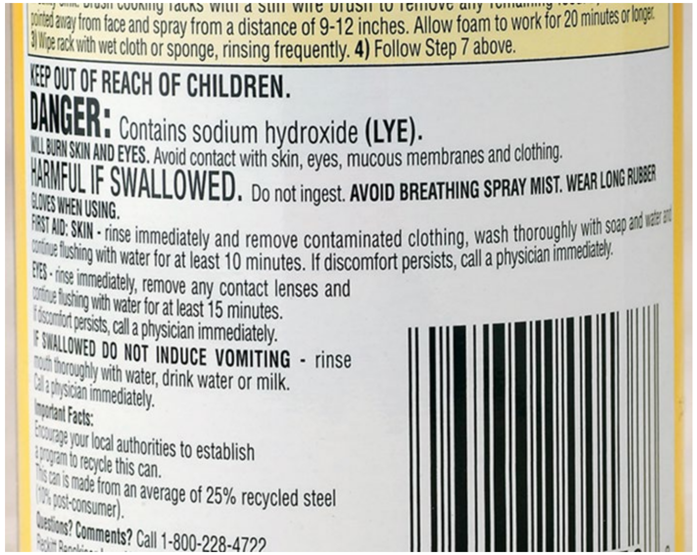
The flip side of the story is the chemical opposite of acids: bases.

A base is any compound that produces hydroxide ions $(OH)^-$ in aqueous solution.

Characteristic properties of bases:

- Bitter taste (not recommended).
- Slippery feel when dissolved in water.
- Turns red litmus paper blue.

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$



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Examples of Bases

Strong bases completely dissociate into OH^- ions in solution

- Examples include Group 1 or Group 2 hydroxides, such as KOH:

$$\mathrm{KOH}_{(aq)} \rightarrow \mathrm{K}^+_{(aq)} + \mathrm{OH}^-_{(aq)}$$

- Calcium hydroxide (and other Group 2 hydroxides) produce two equivalents of OH^- :

$$\mathrm{Ca\,(OH)}_{2(aq)} \rightarrow \mathrm{Ca}^{2+}_{(aq)} + 2\ \mathrm{OH}^-_{(aq)}$$

What about ammonia (NH_3)?

- It is a **weak base**, even though it has no OH^- group :

$$\mathrm{NH}_{3(aq)} + \mathrm{H}_2O_{(l)} \leftrightarrow \mathrm{NH}^+_{4(aq)} + \mathrm{OH}^-_{(aq)}$$

- Since this reaction proceeds in both directions, it’s an **equilibrium reaction**.

Neutralization Reactions

When acids and bases react with each other, we call this a **neutralization reaction.**

- In neutralization reaction, hydrogen ions from an acid combine with hydroxide ions from a base to form molecules of water.
- The other product is a salt (ionic compound).

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(1)}$$

Ionic Equations

This reaction may be represented with a molecule, ionic, or net ionic equation

- **Molecular**:

$$2\ HBr_{(aq)} + Ba(OH)_{2(aq)} \rightarrow BaBr_{2(aq)} + 2\ H_2O_{(l)}$$

- **Ionic**: (all aqueous ionic compounds are dissociated into separate ions).

$$2\ H^{+}_{(aq)} + 2\ Br^{-}_{(aq)} + Ba^{2+}_{(aq)} + 2\ OH^{-}_{(aq)} \rightarrow Ba^{2+}_{(aq)} + 2\ Br^{-}_{(aq)} + 2\ H_2O_{(l)}$$

- **Net ionic**: (cancel common ions from both sides, called "**spectator ions**").

$$2\,H^{+}_{(aq)} + 2\,OH^{-}_{(aq)} \rightarrow 2\,H_2O_{(l)}$$

Divide both sides of the equation by 2 to simplify it:

$$H^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H_2O_{(l)}$$

pH

The pH of a solution is a measure of the concentration of the H^+ ions present in that solution.

The mathematical expression for pH is a log-based scale and is represented as:

$$pH = -\log\left[H^+\right]$$

- If $\left[H^+\right] = 1.0\times10^{-3}$M, the $pH = -\log(1.0\times10^{-3})$, or $-(-3.0) = 3.0$.

Since pH is a log scale based on 10, a pH change of 1 unit represents a power of 10 change in $[H^+]$.

That is, a solution with a pH of 2 has a $\left[H^+\right]$ ten times that of a solution with a pH of 3.

Ion-Product Constant of Water

One useful relationship is the expression:

$$K_w = \left[H^+\right]\left[OH^-\right] = 1.0 \times 10^{-14} \text{(at 25캛)}$$

where K_w is the ion-product constant for water

- Knowing the $[OH^-]$, we can calculate the $[H^+]$ and vice versa.

The three possible aqueous solution situations are:

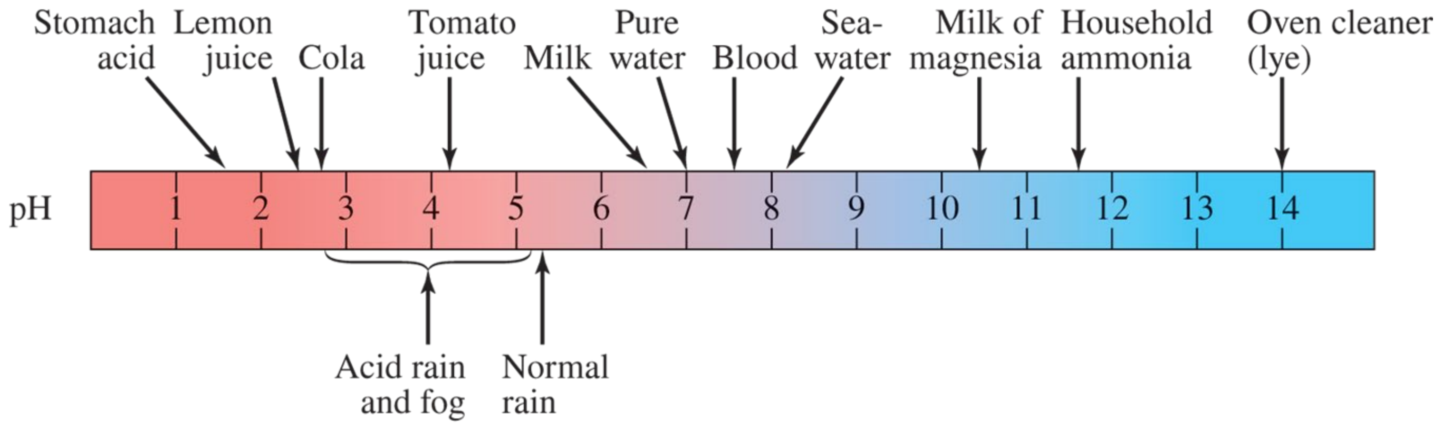
$[H^+] = [OH^-]$ a neutral solution (pH = 7)

$[H^+] > [OH^-]$ an acidic solution (pH < 7)

$[H^+] < [OH^-]$ a basic solution (pH > 7)

The pH Scale

- The pH scale is useful as it is a measure of acid over many orders of magnitude $(\times 10^{-})$.
- Tip: The pH is the power of ten of the [H+] without the negative sign – for $[H+] = 10^{-4}$, the pH is 4.



[Acids, Alkalis, and the pH Scale]

[pH Scale simulation]

Your Turn

Your Turn 5.42 Small Changes, Big Effects

Compare the pairs of samples below. For each, which one is more acidic? Include the relative difference in hydrogen ion concentration between the two pH values.

a. Rainwater, pH = 5.0; lake water, pH = 4.0.

b. Ocean water, pH = 8.3; tap water, pH = 5.3.

c. Tomato juice, pH = 4.5; milk, pH = 6.5.

Why is Rainwater Naturally Acidic?

- Carbon dioxide in the atmosphere dissolves to a slight extent in water and reacts with it to produce a slightly acidic solution of carbonic acid.

$$CO_{2(g)} + H_2O_{(1)} \rightarrow H_2CO_{3(aq)}$$

- The carbonic acid dissociates slightly leading to rain with a pH around 5.3.

$$H_2CO_{3(aq)} \rightarrow H^+_{(aq)} \rightarrow HCO^-_{3(aq)}$$

The Chemistry of Acid Rain

- Carbon dioxide is not the only source of H^+ in rain.
- Sulfur oxides (SO_x) and nitrogen oxides (NO_x) compounds also dissolve in water forming acids:

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)} \rightarrow 2H^+_{(aq)} + SO^{2-}_{4(aq)}$$

sulfuric acid

$$4NO_{2(g)} + 2H_2O_{(l)} + O_{2(g)} \rightarrow 4\,HNO_{3(aq)}$$

$$\rightarrow 4H^+_{(aq)} + 4NO^-_{3(aq)}$$

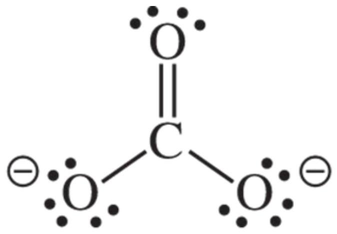
nitric acid

- This acid rain can wreak havoc downwind of **anthropogenic** or natural sources of SO_x and NO_x gases.

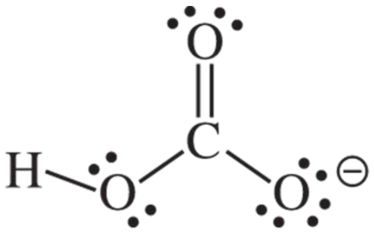
© mrakhr/123RF

Ocean pH

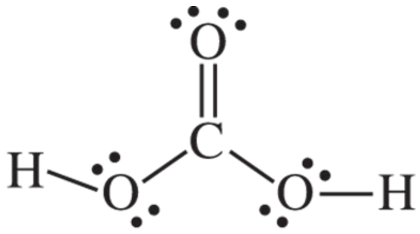
- If rainwater is naturally acidic, why is ocean water basic?
- Three chemical species responsible for maintaining ocean pH:



carbonate ion
CO_3^{2-}



bicarbonate ion
HCO_3^-



carbonic acid
H_2CO_3

Ocean Acidification [1]

- Ocean pH is decreasing due to increased atmospheric carbon dioxide.
- Carbonate ions (CO_3^{2-}) are necessary for marine animal shells and skeletons.
- H^+ produced from the dissociation of carbonic acid reacts with carbonate ion in seawater:

$$H^+_{(aq)} + CO^{2-}_{3(aq)} \rightarrow HCO^-_{3(aq)}$$

- Calcium carbonate in the shells of sea creatures begins to dissolve to maintain the concentration of carbonate ions in seawater:

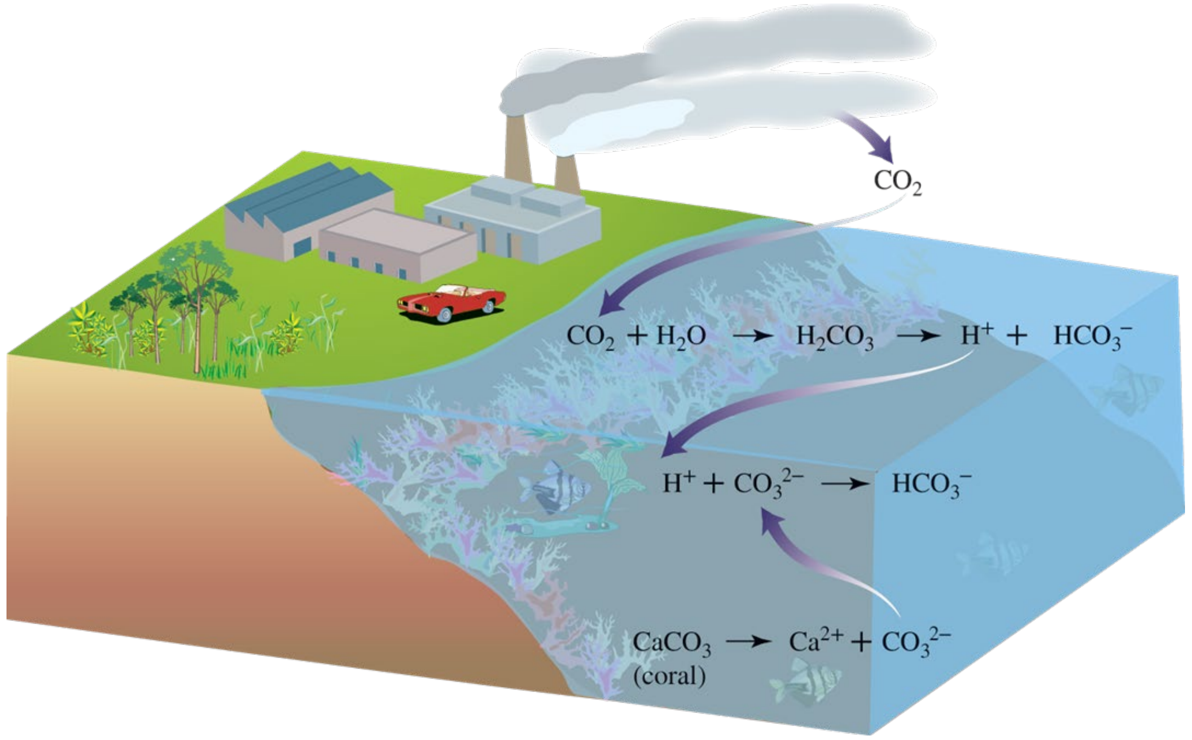
$$CaCO_{3(s)} \rightarrow Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)}$$

[Ocean Acidification: “The Other Carbon Dioxide Problem”]

[Ocean Acidification and Chemical Signalling]

Ocean Acidification [2]

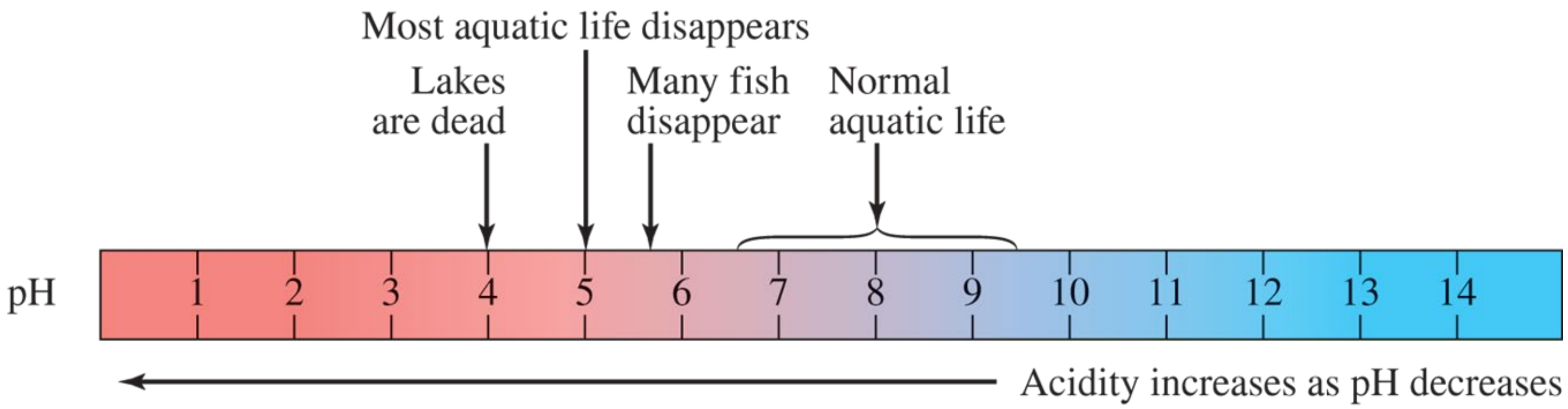
Over the past 200 years, the amount of carbon dioxide in the atmosphere has increased, so more carbon dioxide is dissolving in the ocean and forming carbonic acid.



Aquatic Life and pH

Acidification of waters occurring in lakes and streams, too.

- Midwestern states have considerable limestone ($CaCO_3$) that neutralizes acid (called acid neutralizing capacity, ANC).
- New England states have largely granite, which is much less reactive so the lakes and streams are more sensitive.



Municipal Water Treatment

Screens for filtration of gross particles.

Alum ($Al_2(SO_4)_2$) and lime ($Ca(OH)_2$) to precipitate fine particulates.

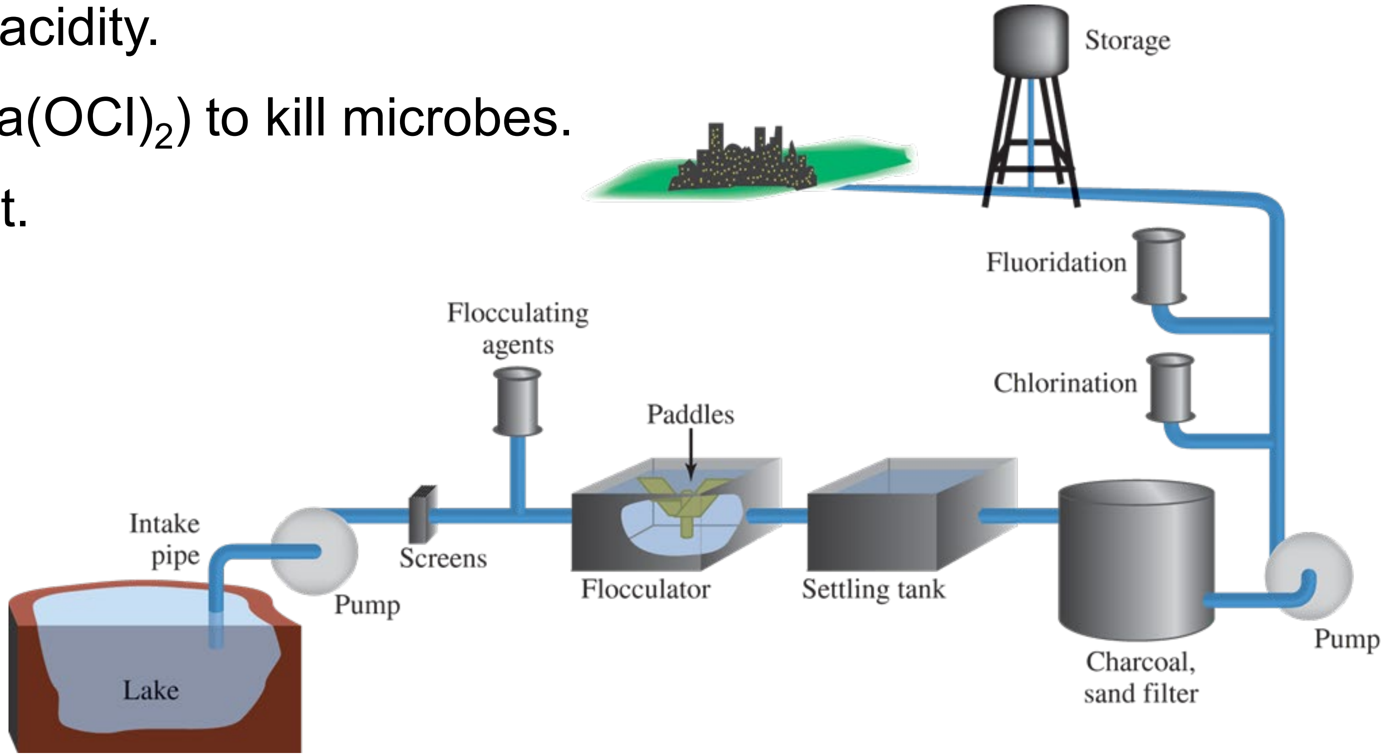
Charcoal or sand for removal of organics.

Aeration for volatiles, CaO for acidity.

Chlorination (Cl_2, NaOCl, or $Ca(OCl)_2$) to kill microbes.

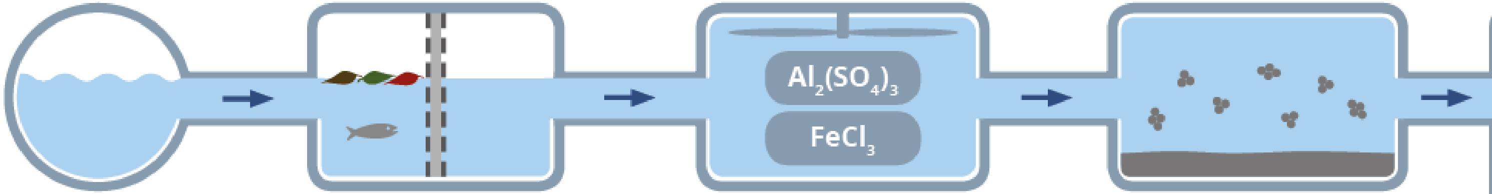
- Alternatives: ozone, UV light.

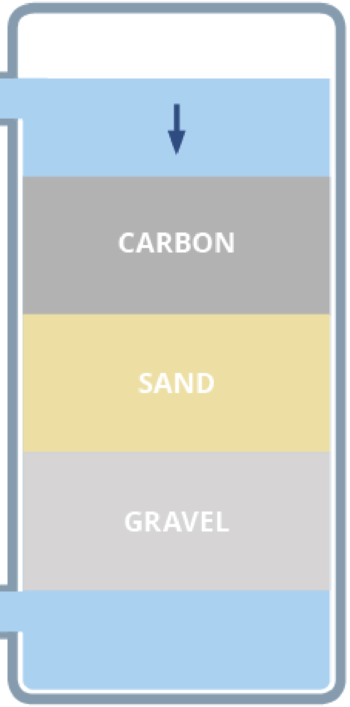
The Chemistry Behind Your Home's Water Supply



WATER TREATMENT – FROM RESERVOIR TO HOME

We take the water coming from our taps for granted – but what happens to it before it gets there? Here's how chemistry helps!





RAW WATER

Water is drawn from lakes, rivers, or reservoirs, or can be drawn from groundwater using boreholes.

SCREENING

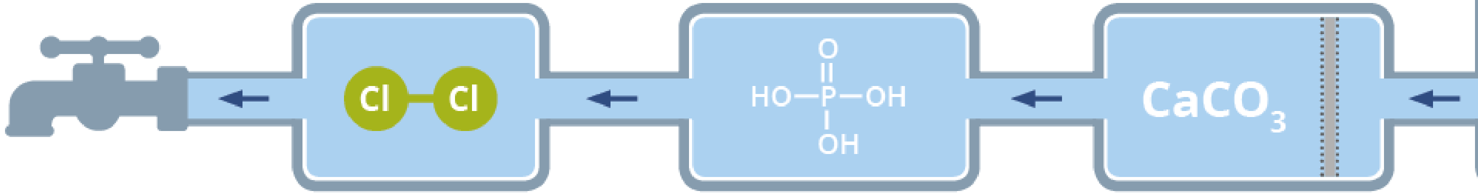
Screening helps to remove large matter from the water, such as leaves and rubbish, using a wire mesh. This prevents the debris from causing obstructions within the facility, making treatment easier.

COAGULANTS ADDED

Coagulants such as aluminium sulfate and ferric chloride are mixed into the water. These make particles of dirt and dissolved substances in the water clump together so that they can be removed.

SEDIMENTATION

Under slow mixing, the clumped particles increase in size, a process called flocculation. Most of them sink to the bottom and form a sludge, which can be removed from the water, treated and disposed of.



TO HOMES

Residual chlorine in the water safeguards against pathogens. Fluoride can be added after chlorination to help to prevent tooth decay.

CHLORINATION

Chlorine is added to water to kill bacteria and viruses, preventing water-borne diseases like cholera and typhoid. Ozone can be used instead of chlorine, and avoids disinfection byproducts.

ANTI-CORROSION AGENTS

Agents such as orthophosphates can be added to the water, particularly in areas with lead pipes. These agents form lead-phosphate complexes on the inside of the pipes, stopping lead getting into the water.

pH CORRECTION

Water that is too acidic can lead to water pipe corrosion. It can be passed through a filter containing crushed limestone (mainly calcium carbonate) to raise pH. Acids can be added if the pH is too high.

FILTRATION

Some particles remain in the water after sedimentation; these are removed by filtration through coal, sand, and gravel beds. They are cleaned by pumping air and water backwards through them.

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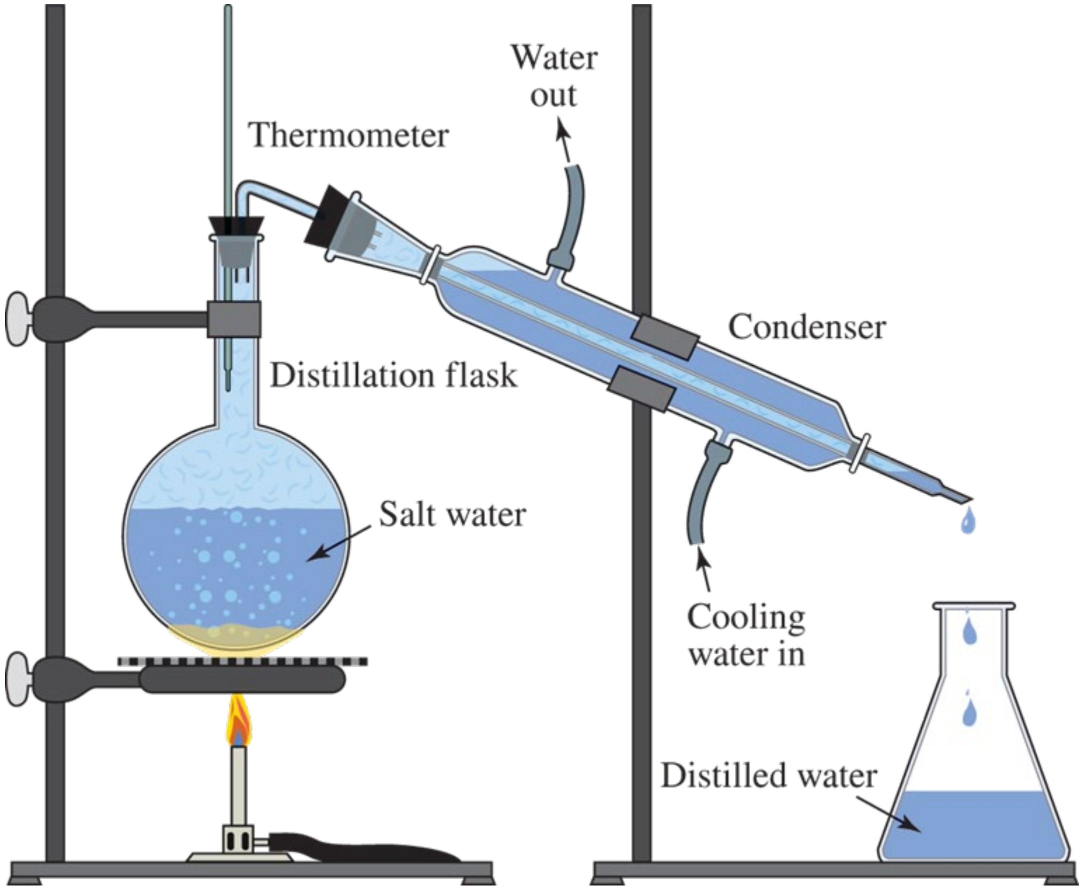
Making Freshwater from Saltwater [1]

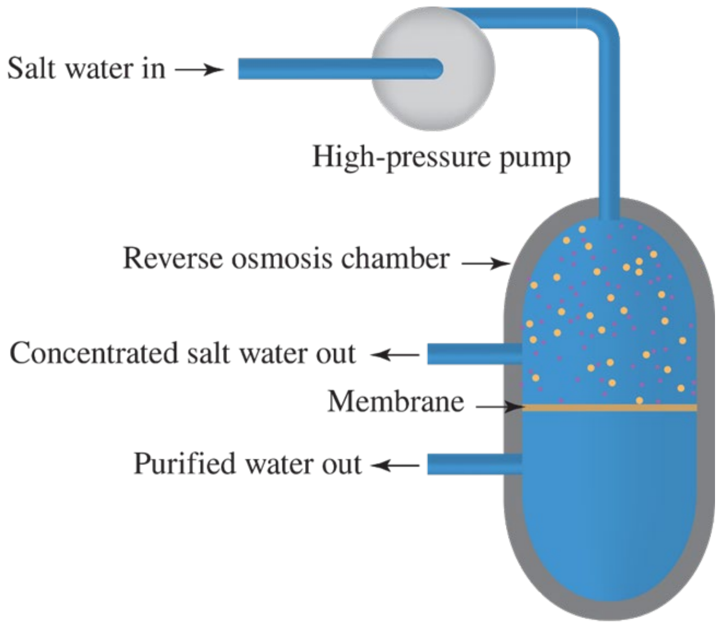
Distillation – a separation process in which a liquid solution is heated and the vapors are condensed and collected.



Making Freshwater from Saltwater 2

Osmosis – the passage of water through a semipermeable membrane from a solution that is less concentrated to a solution that is more concentrated.

Reverse Osmosis – uses pressure to force the movement of water through a semipermeable membrane from a solution that is more concentrated to a solution that is less concentrated



Making Freshwater

[Water Filters & Water Purifiers | LifeStraw – LifeStraw Water Filters & Purifiers]()

[The LifeStraw explained: How it filters water and eradicates disease - YouTube]()

Sewage Water to Beer in Singapore

[Singapore craft beer uses recycled sewage to highlight water scarcity | Singapore | The Guardian]

[The Story of NEWater (youtube.com)]

Example topics that you can delve into further...

1. Describe the comprehensive water treatment system in South Korea.
2. Explain the measures taken to preserve the Great Barrier Reef, the largest coral reef system in the world.
3. Provide a different instance illustrating the concept of "the tragedy of the commons."
4. Analyze the global water supply situation, focusing on countries facing severe water scarcity.
5. Discuss Saudi Arabia's approach to addressing its water shortage, including the technology used for seawater desalination and the volume of seawater purified each year.