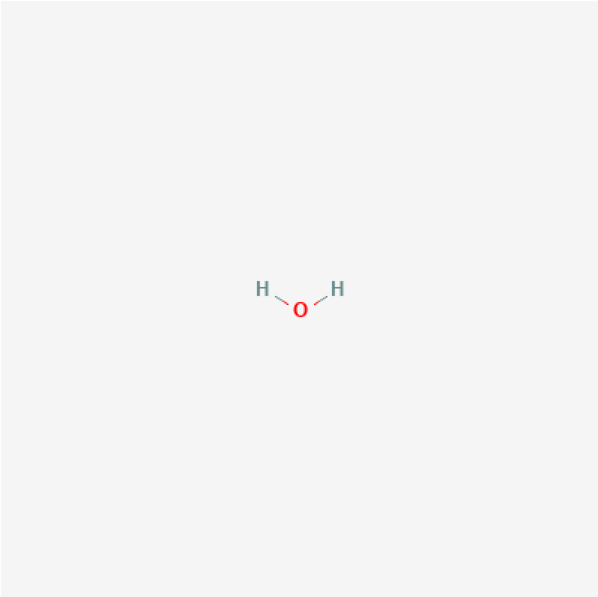
Properties of Water



Water (H_2O) Forms a V shaped molecule with the H ends having a partial positive charge and the O ends having a partial negative charge.

Defintion

Hydrogen Bonding
A relatively strong intermolecular force.
The positive charge of the H is attracted to the negative charges of other molecules. In the case of water, the negative charge is on the O side.

In liquid water, a hydrogen bond is about **1/20th** as strong as a covalent bond

The Four Emergent Properties of Eater

1. Cohesion
2. Moderation of Temperature
3. Floating of Ice on Water
4. The Solvent of Life

Cohesion

Def

Cohesion
The bonds that hold a substance together.

In water, Hydrogen bonds act as the cohesion force.

Surface Tension
The difficulty of stretching or puncturing the surface of a liquid

Since water's cohesion force is Hydrogen Bonding (a relatively strong intermolecular force), its surface tension is also high. Additionally, the Hydrogen bonds do *not* bond with the surrounding air, increasing its surface tension

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Adhesion
The bonds that hold a substance to something else.

Water also has a relatively strong adhesive force to certain materials because of its polarity and Hydrogen bonding.

Cohesion and Surface Tension help support Life

- High surface tension allows things to float easily
- Adhesion allows plants to transport water up its roots and stem against the gravity

Moderation of Temperature

Def

Thermal Energy
The *total* amount of kinetic energy a certain amount of particles have.
The faster the particles move, the more kinetic energy it has, meaning more thermal energy, meaning higher **Temperature**

Temperature
The *average* amount of kinetic energy in a substance.

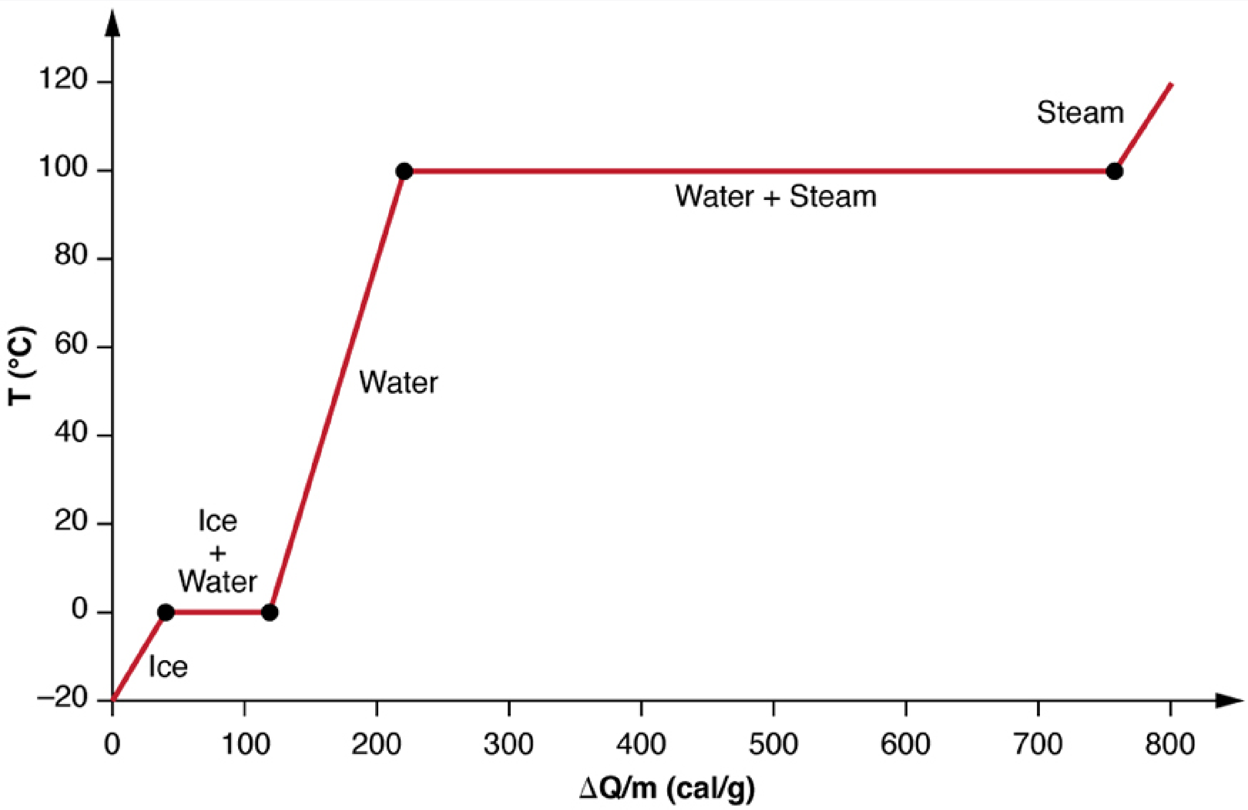
Specific Heat
The amount of energy required to raise the temperature of 1g of a substance by 1 degree C.

The higher the specific heat, the more resistant to temperature change the substance is.

Heat
Amount of thermal energy being *transferred* from one body of matter to another.

Calorie
Defined as the Specific heat of Liquid Water.

Heat of Vaporization
The amount of energy needed to convert a liquid into gas.



Temperature vs Absorbed Heat for Water

Un-intuitively, the temperature of the substance will actually stop increasing while undergoing a phase change until enough energy is absorbed to finish the phase change.

Water's High Specific Heat

Water has a very high Specific Heat in comparison to most other materials. This means that it can absorb a lot of energy before increasing its Temperature.

For comparison, Water's specific heat is **10x** that of Iron.

Water's High Heat of Vaporisation

Water also has a high heat of vaporisation. This allows water to absorb a lot of energy once it is at boiling point before actually changing into a gas.

Def

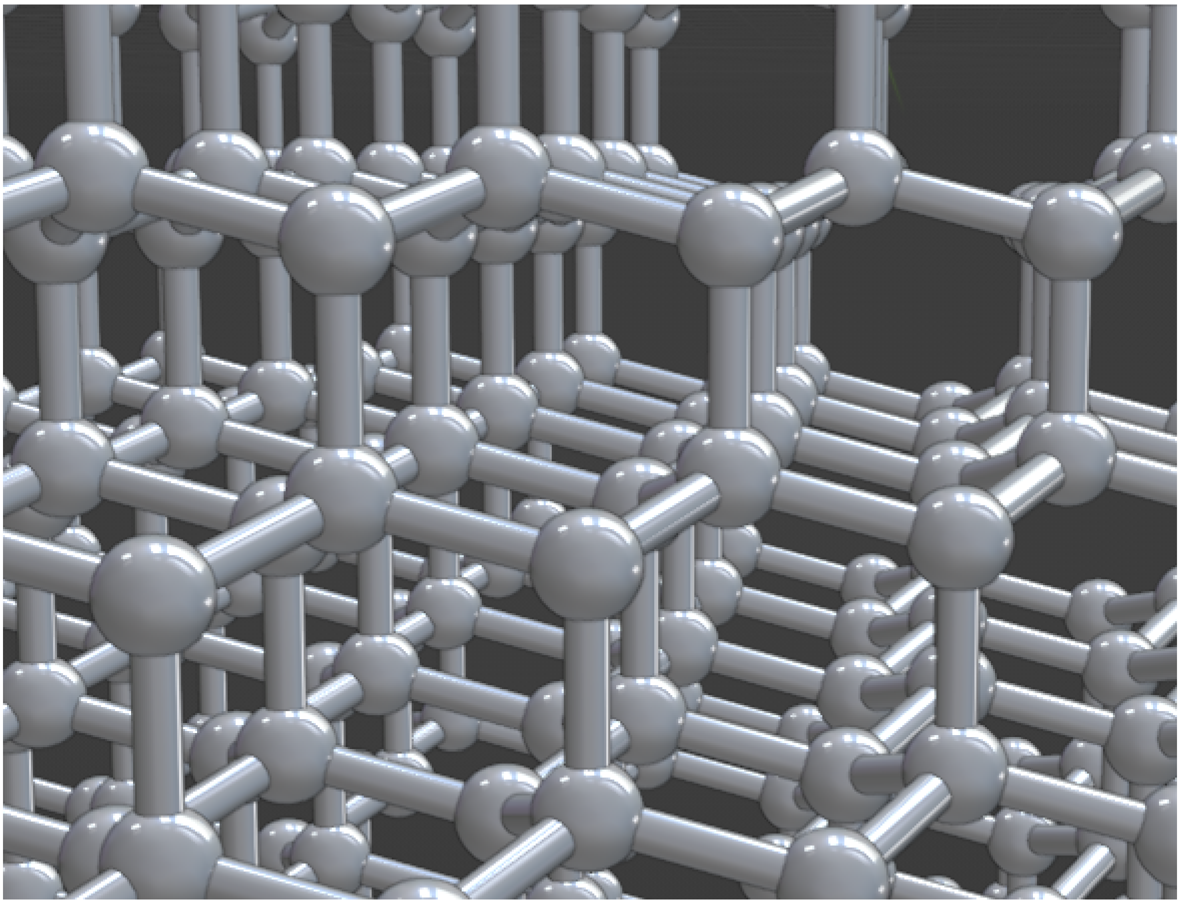
Evaporative Cooling
When hotter molecules are more likely to evaporate, leaving the average temperature of the remaining liquid cooler.

Water's Moderation of Temperature helps support Life

- Allows water to absorb a lot of energy without gaining a lot of temperature, such as the oceans absorbing a lot of energy from the Sun without heating up throughout the day.
- Allows organisms too cool themselves down with the help of a high heat of vaporisation as well as evaporative cooling.

Floating of Ice on Water

Water is one of the few substances that are less dense as a solid than a liquid. This allows Ice to float on Water.



When water is locked into this kind of lattice, it has more empty space than when it is a liquid, making it less dense.

Floating Ice's importance to Life

- Floating Ice protects ponds and other bodies of water from completely freezing over. Since ice floats, the water remains underneath the ice.

The Solvent of Life

Def

Dissolution
The act of dissolving a solute into a solvent to form a solution

Happens when the solvent creates bonds with with the solute.

Example

When water dissolves table salt (NaCl),

1. The negative side of the water molecules (O) bonds with the positively charged Sodium (Na)
2. The positive side of water (H) bonds with the negatively charged Chlorine (Cl)

Other non-ionic molecules can also be dissolved if water can create hydrogen bonds with the surface of the molecule (for example sugar)

Aqueous Solution
A solution where the solvent is water.

Hydration Shell
A sphere of water molecules surrounding a molecule.

Strong solvent properties

Since Water is strongly partially charged with and can Hydrogen Bond, it can easily bond to other charged substances as well, dissolving them easily.

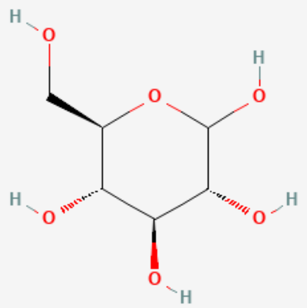
Hydrophilic and Hydrophobic Substances

Def

Hydrophilic
A substance attracted to water

Example

Since **Cotton** is hydrophilic, as it is made of large chains of cellulose, it can easily bond with water.
This allows cotton to easily absorb water, making it good towels. Since Cellulose is a large molecule, it does not get dissolved by water and can maintain its structure.



D-Glucose ($C_6H_{12}O_6$), the monomer of Cellulose.

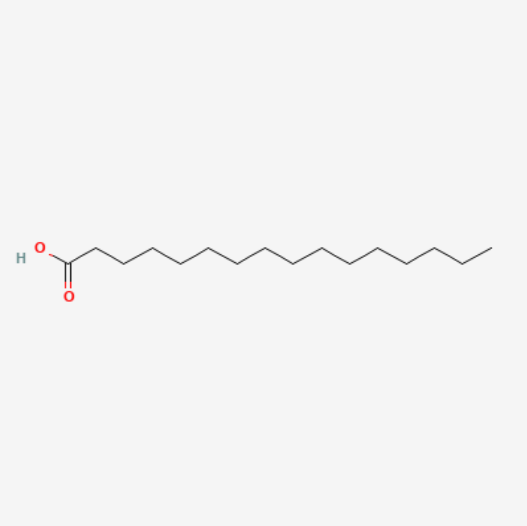
Cellulose will be made up of hundreds or thousands of these molecules in a chain.

Hydrophobic
A substance repelled by water.

Example

Kitchen oil repels water because it is non-polar and doesn't have charges. This makes oil stick to oil and repel water when they are forcefully mixed.

Palmitic acid, a common lipid found in olive oil, a common cooking oil that repels water

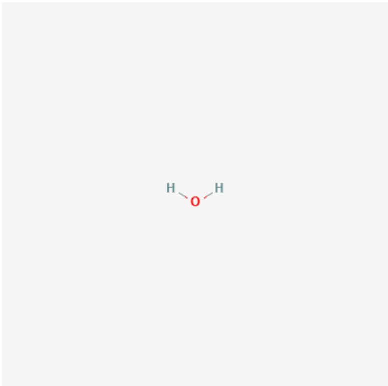


Acidity

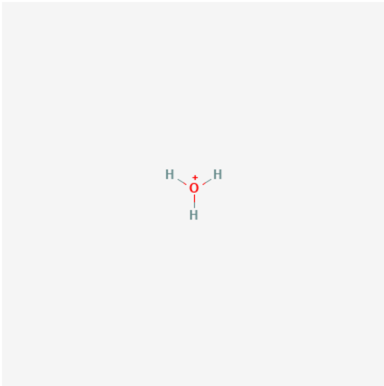
Occasionally, two molecules of water may accidentally exchange a hydrogen ion, making one Hydronium and one Hydroxide
Hydronium is commonly abbreviated from H_3O^+ to H^+

Hydroxide (OH^-)

Water (H_2O)



Hydronium (H^+)



Def

Water Dissociation Constant (K_w)
Is equal to 10^{-14}

Is defined as the concentration of **Hydroxide** (OH^-) multiplied by the concentration of **Hydronium** (H^+) of any aqueous solution at 25^oC

Formula

$$K_w = [H^+][OH^-] = 10^{-14}$$

This remains constant no matter the acidity of the solution

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pH (potential of Hydrogen)
Is a scale from **0 to 14**

0	**7**	**14**
Acidic	***Neutral***	**Basic**
$[H^+] > [OH^-]$	$[H^+] = [OH^-]$	$[H^+] < [OH^-]$

Formula

$$pH = -\log{[H^+]}$$

pH

- pH is a logarithmic scale meaning that to get from pH 7 to 6, it is 10x more acidic.
- Since pH is defined as $-\log{[H^+]}$, the more H^+ there is the more acidic it will be

Calculating pH

Example

Prompt

Given that the concentration of $[OH^-] = 10^{-3}$ find the pH.
Assume the solution is at 25^oC

1. Calculate the concentration of $[H^+]$ by using the Water Dissociation Constant

1. $[OH^-] = 10^{-3}$
2. $[H^+][OH^-] = 10^{-14}$
3. $[H^+] * 10^{-3} = 10^{-14}$
4. $[H^+] = 10^{-11}$

2. Calculate the pH using the definition of pH

5. $pH = -\log{[H^+]}$
6. $pH = -\log{10^{-11}}$
7. $pH = -(-11)$
8. $pH = 11$

Conclusion

We can conclude that the pH of this solution is **11**, which is moderately-highly **Basic**.

Prompt

Given that the concentration of $[H^+]$ is **10000** times more than the concentration of $[OH^-]$, what is the pH
Assume the solution is at 25^oC

1. Calculate the concentration of $[H^+]$ by using the Water Dissociation Constant
   1. $[H^+] = 10000 * [OH^-]$
   2. $[H^+] = 10^4 * [OH^-]$
   3. $[OH^-] = 10^{-4} * [H^+]$
   4. $[H^+][OH^-] = 10^{-14}$
   5. $[H^+] * 10^{-4} * [H^+] = 10^{-14}$
   6. $[H^+]^2 * 10^{-4} = 10^{-14}$
   7. $[H^+]^2 = 10^{-10}$
   8. $[H^+] = 10^{-5}$
2. Calculate the pH using the definition of pH
   5. $pH = -\log[H^+]$
   6. $pH = -\log 10^{-5}$
   7. $pH = -(-5)$
   8. $pH = 5$

Conclusion

We can conclude that the pH of this solution is **5**, which is moderately **Acidic**.

Acidity Buffers

Most living cells operate at a pH close to 7 (neutral), and any deviation from this pH can cause large issues for for the cell.

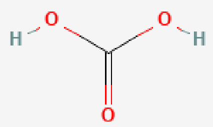
Def

Buffer
A substance that minimises changes in pH in a solution.

Buffers can absorb hydrogen ions when the pH is too low (acidic) and also release hydrogen ions when the pH is too high (basic).

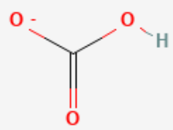
Example

Carbonic acid (H_2CO_3)



When the solution is too basic, Carbonic Acid can release a Hydrogen ion to increase the Acidity by turning into Bicarbonate.

Bicarbonate (HCO_3^-)



When the solution is too acidic, Bicarbonate can bond with a Hydrogen ion to decrease the acidity by turning into Carbonic Acid.