LECTURE №8

WATER AND ITS PROPERTIES

28.03.2016

LESSON OBJECTIVES:

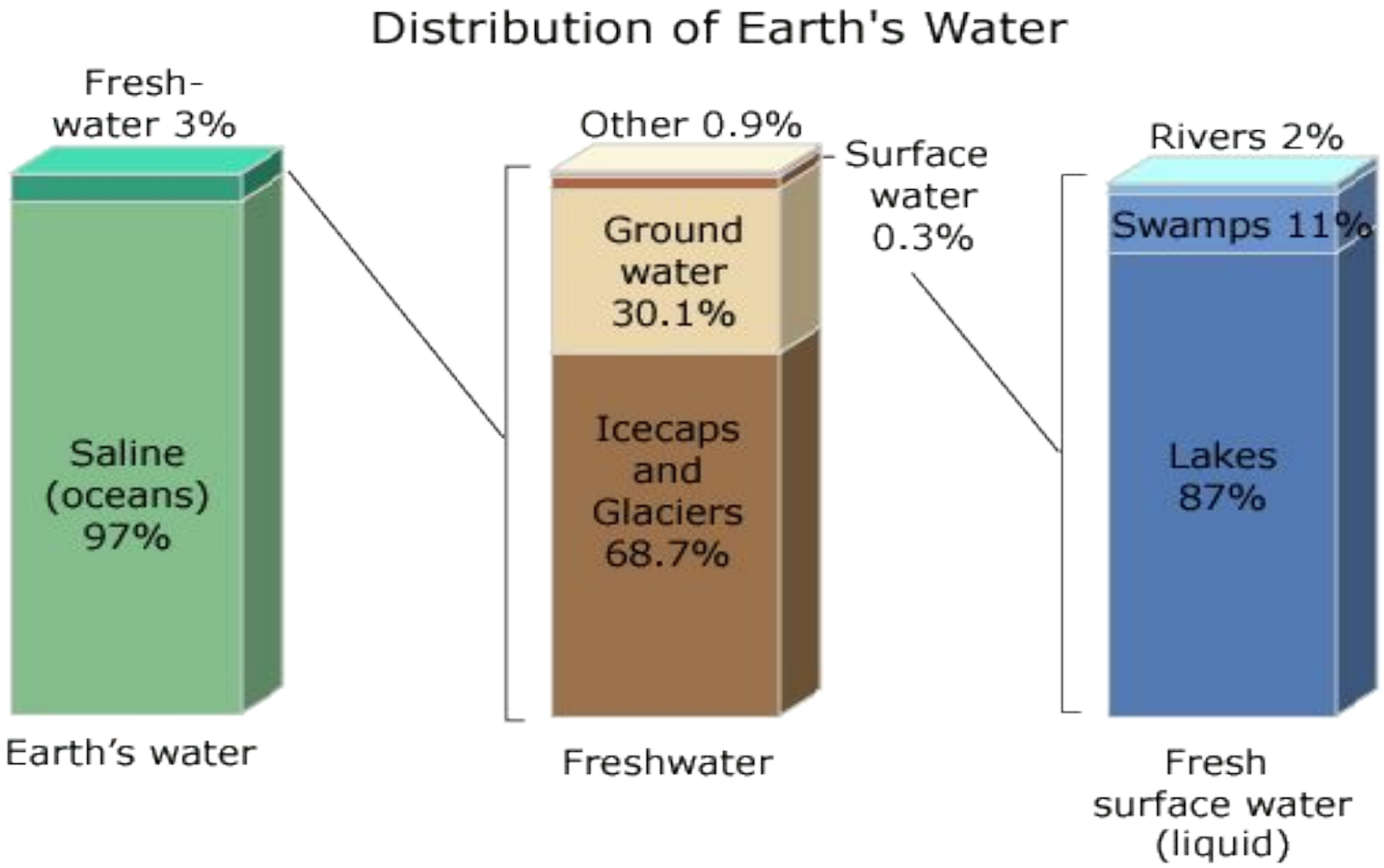
1) Water and its structure

1) To explore the unique properties of water as the cohesion, adhesion, capillary water and surface tension

1) Chemical properties of water as solvent

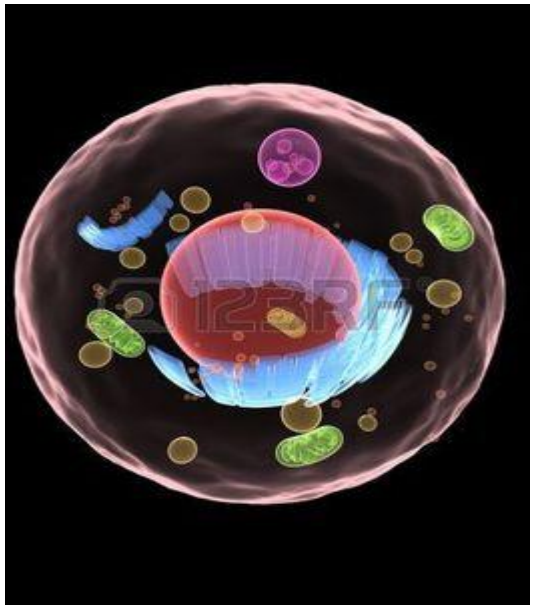
1) Water Hardness

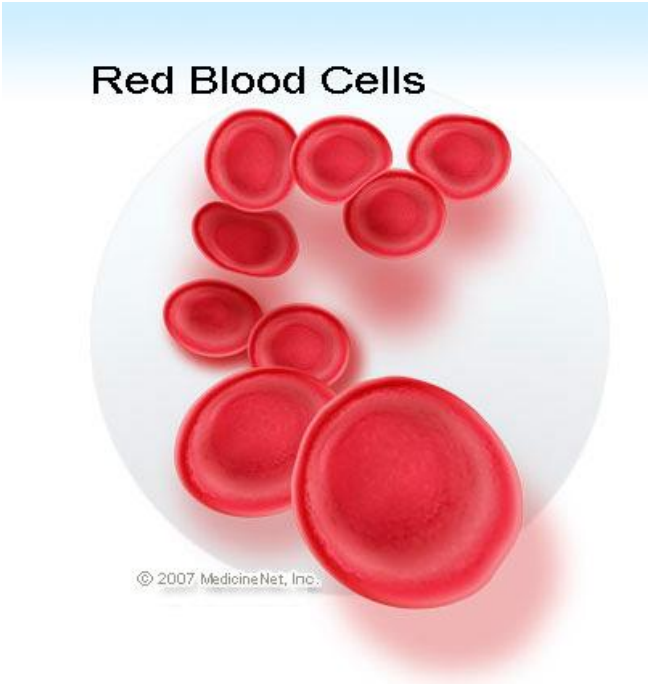
Water is a transparent fluid which forms the world's streams, lakes, oceans and rain, and is the major constituent of the fluids of living things.



Water helps to hydrate the body:

Our cells are composed of roughly 75% water.





Our blood is composed of roughly 90% water.

Water is a buffer that regulates body temperature (through sweating and vasoconstriction)

Water is a liquid at standard ambient temperature and pressure, but it often co-exists on Earth with its solid state, ice; and gaseous state, steam (water vapor). It also exists as snow, fog, dew and cloud.

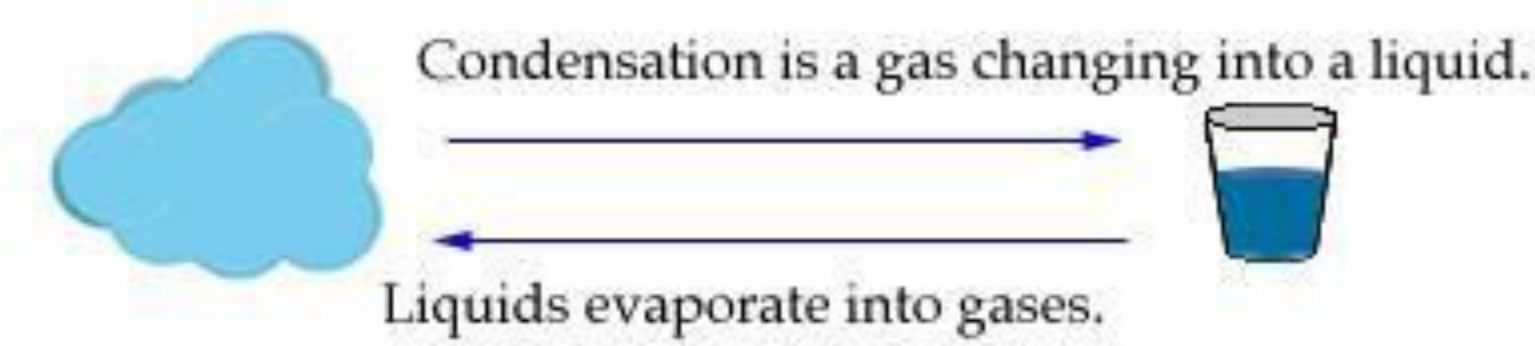
snow

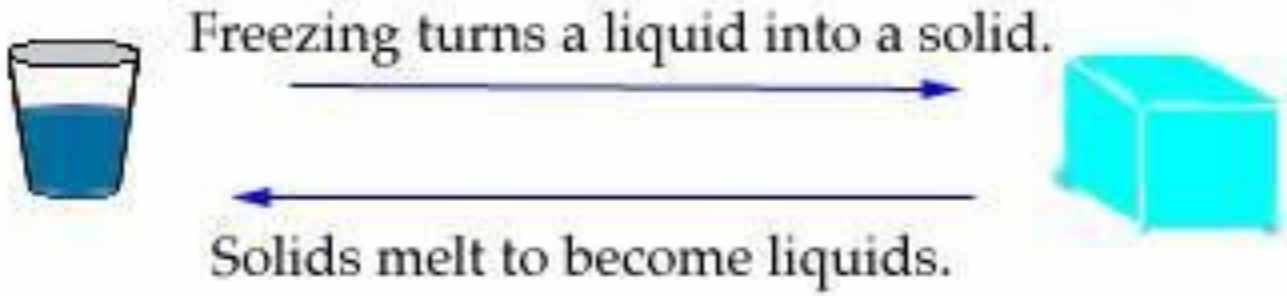
fog

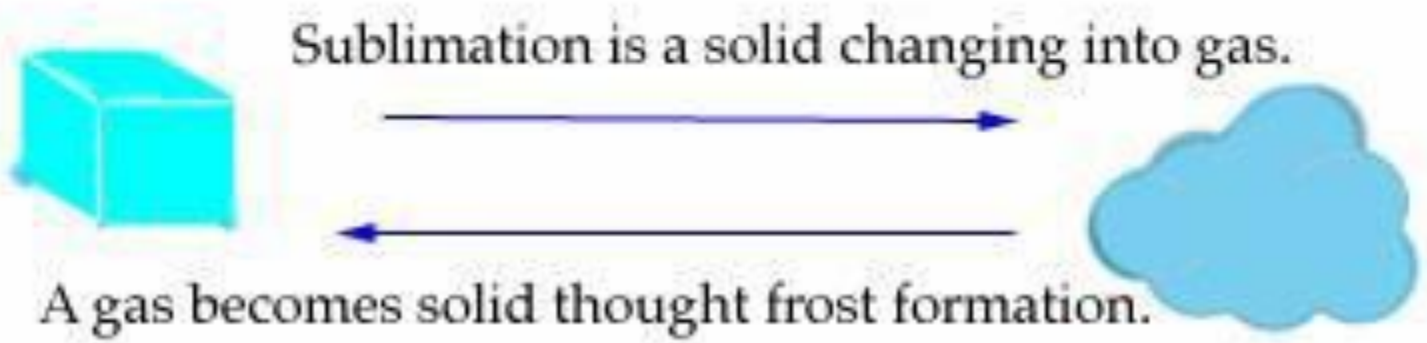
clouds

dew

WATER PHASES CHANGES



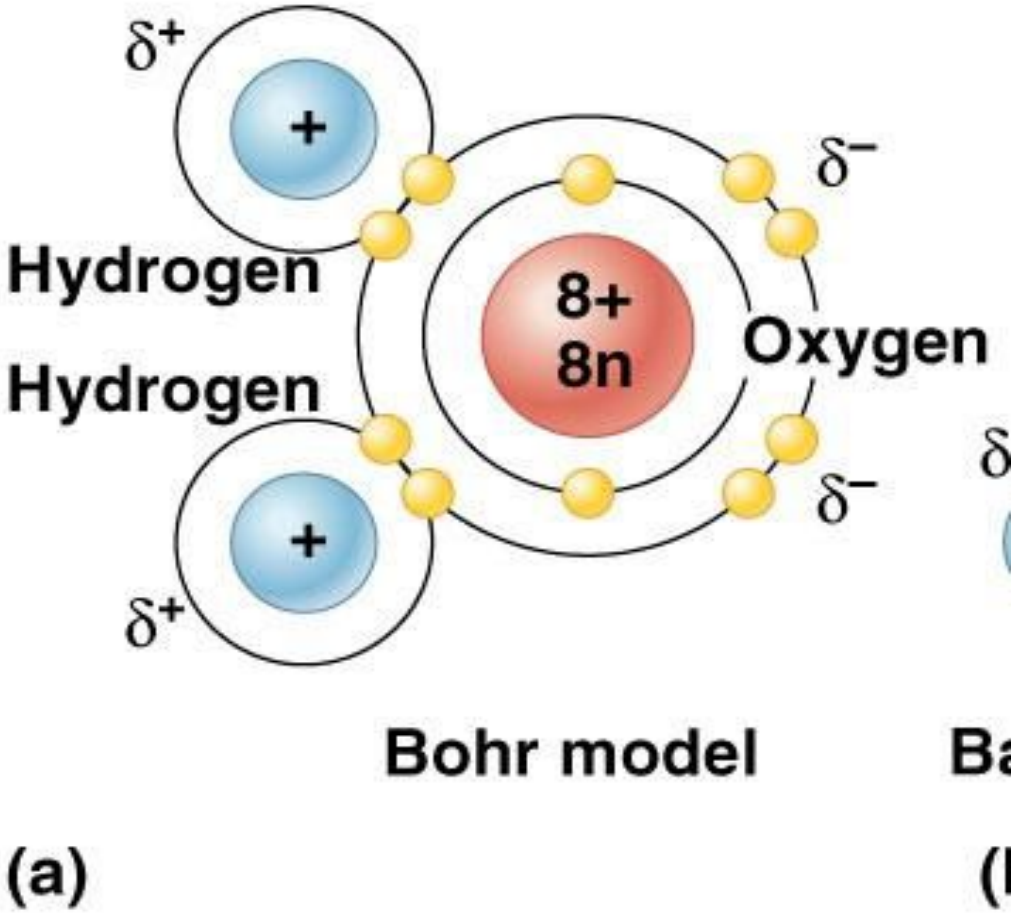




As a chemical compound, a water molecule contains one oxygen and two hydrogen atoms that are connected by **covalent** bonds.

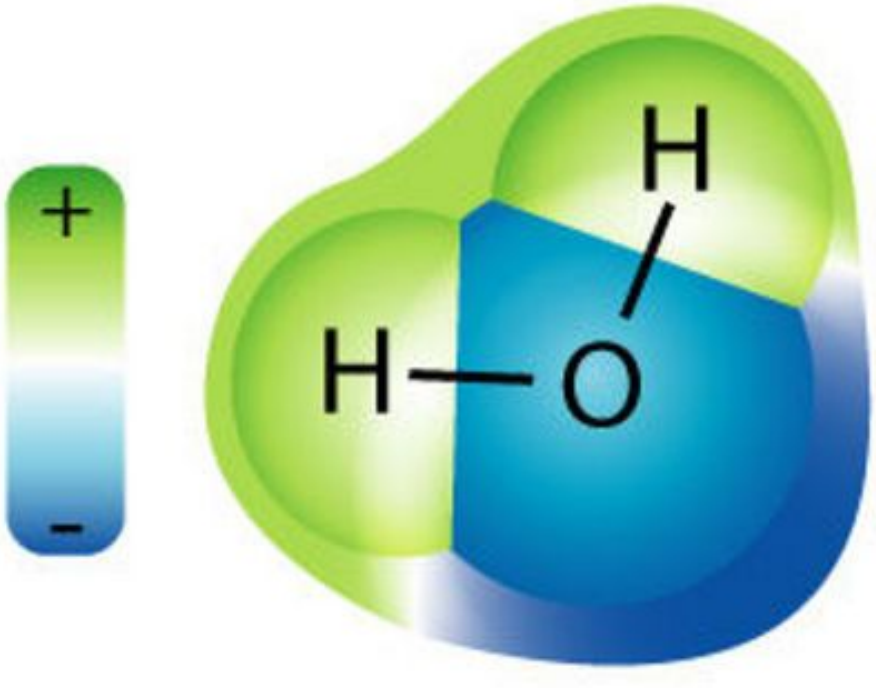
Water is:

- **Composed of two hydrogen atoms and one oxygen atoms**
- **H_2O**
- **Polar Molecule has oppositely charged ends**



Unevenly distributed charges due to unequal forces placed on bonding electrons:

- **Oxygen ends slightly negative**
- **Hydrogen end slightly positive**



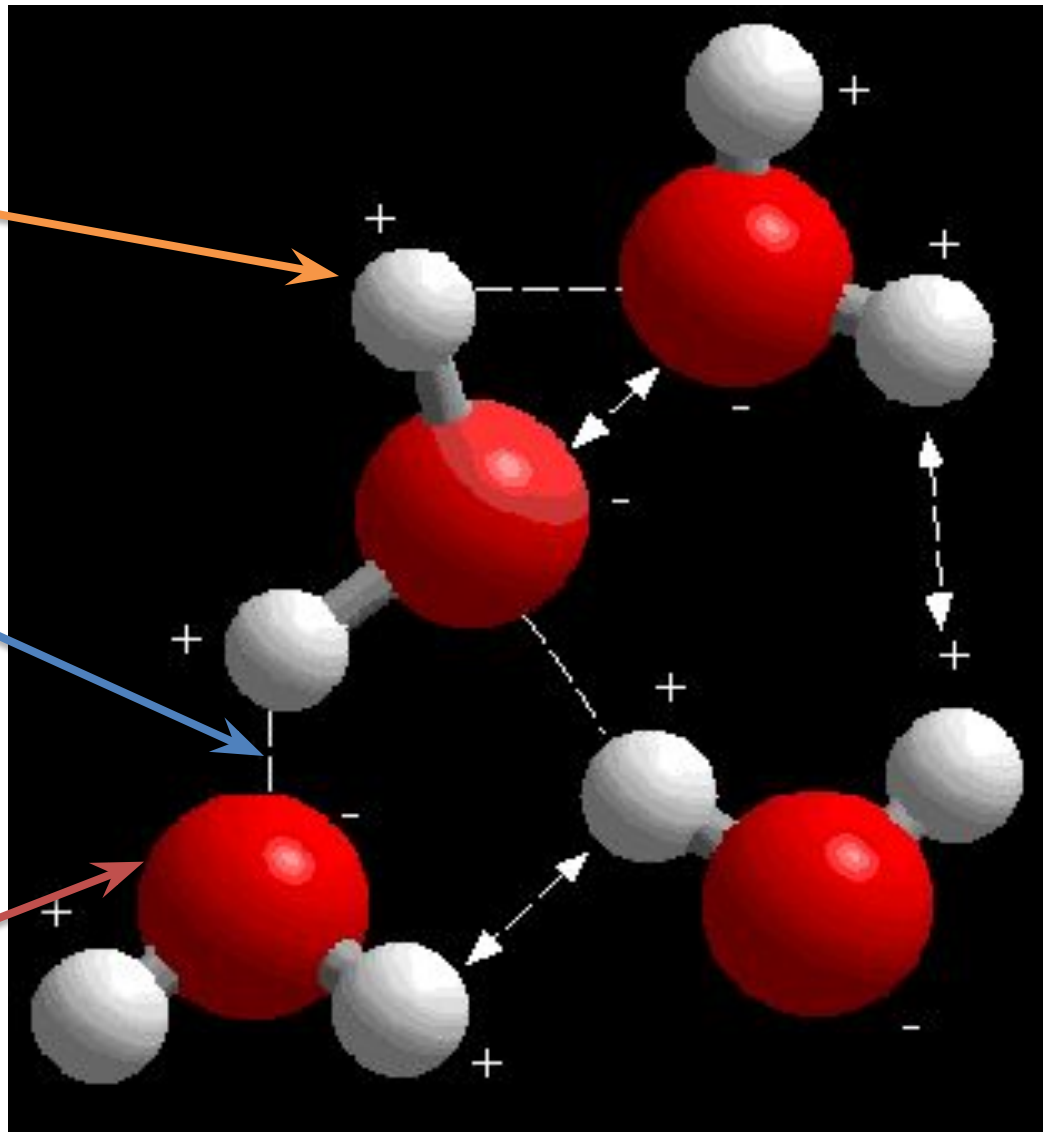
Water molecule is a polar and a dipole

As result of polarity water molecules form Hydrogen bonds:

slightly positive charge

Charge hydrogen bond between (+) and (-) areas of different water molecules

slightly negative charge



PHYSICAL PROPERTIES OF WATER:

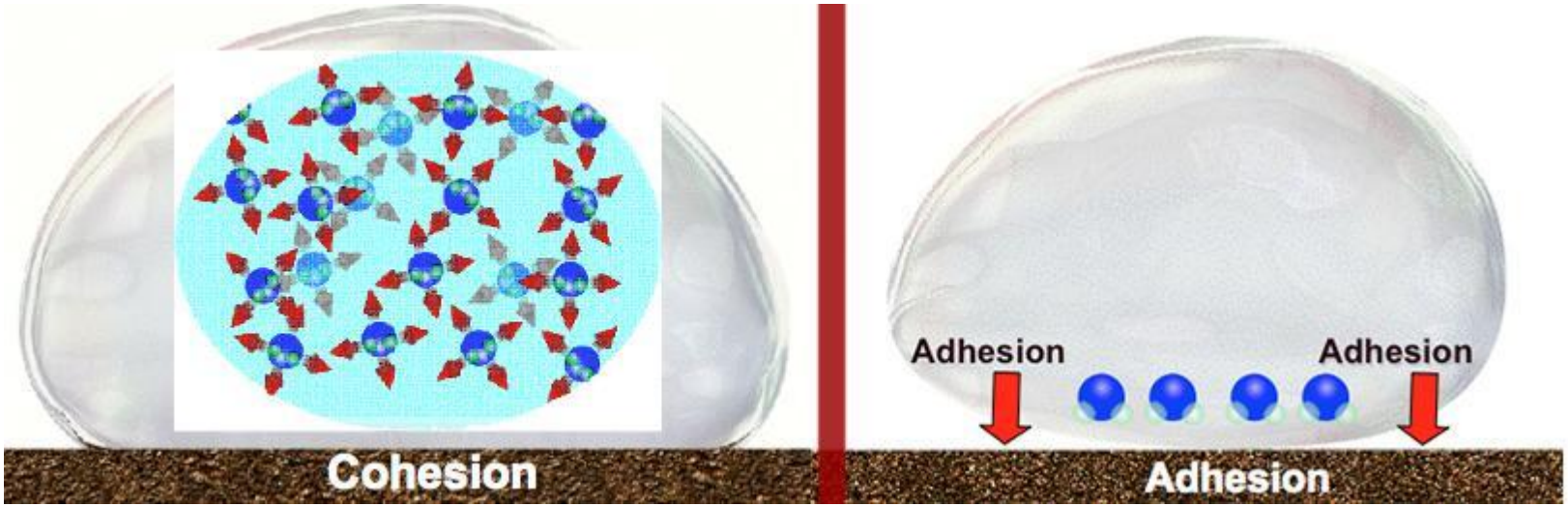
1. Water has a high specific heat.
2. Water in a pure state has a neutral pH. As a result, pure water is neither acidic nor basic. Water changes its pH when substances are dissolved in it.
3. Water conducts heat more easily than any liquid except mercury.
4. Water molecules exist in liquid form over an important range of temperature from 0 - 100° Celsius.
5. Water has a high surface tension.
6. Water is a universal solvent.

COHESION

- Water is attracted to water
- is a various intermolecular forces that hold solids and liquids together
- hydrogen bonding locks molecules together.

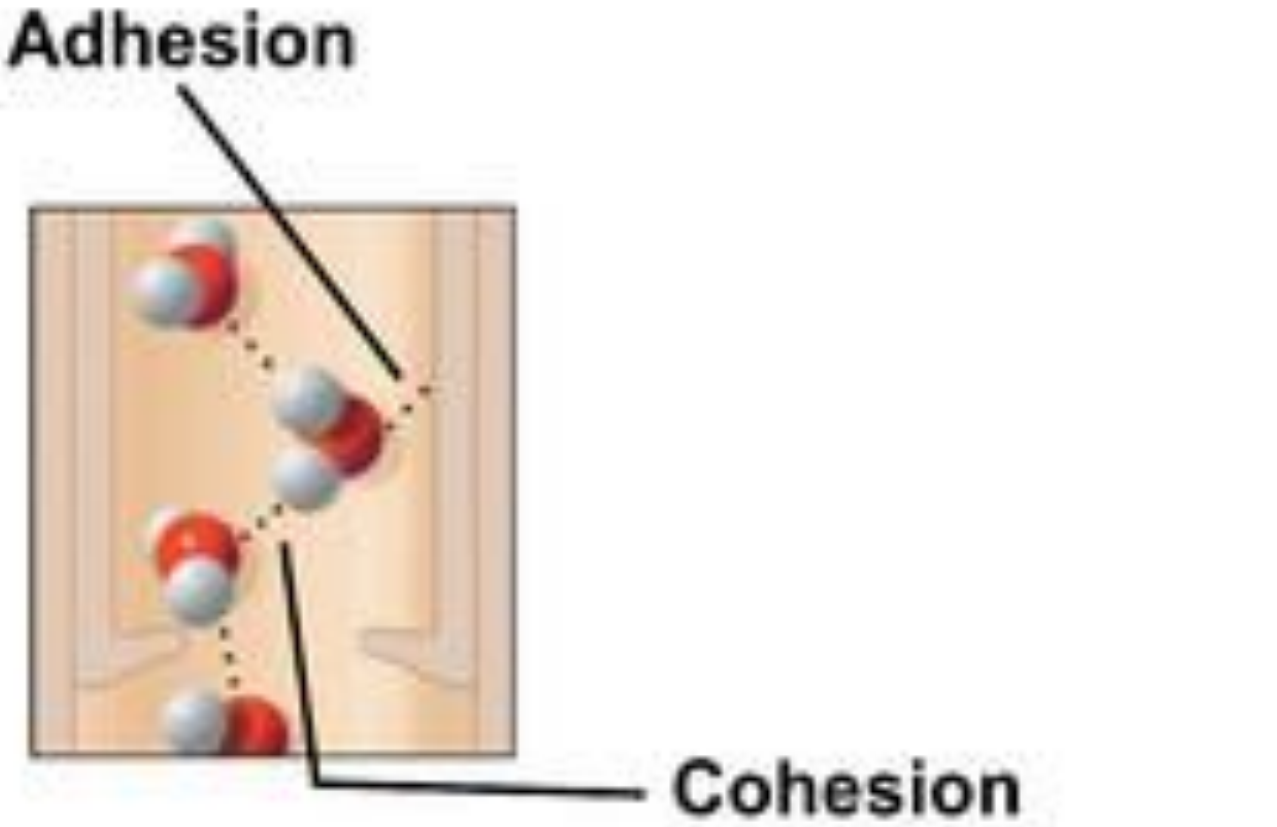
ADHESION

- Water is attracted to other substances
- Water is adhesive to any substance with which it can form hydrogen bonds.



Thus the forces between molecules in a drop of water are cohesive, while the mutual attraction between water and glass represents adhesion.

Water and plant cell wall

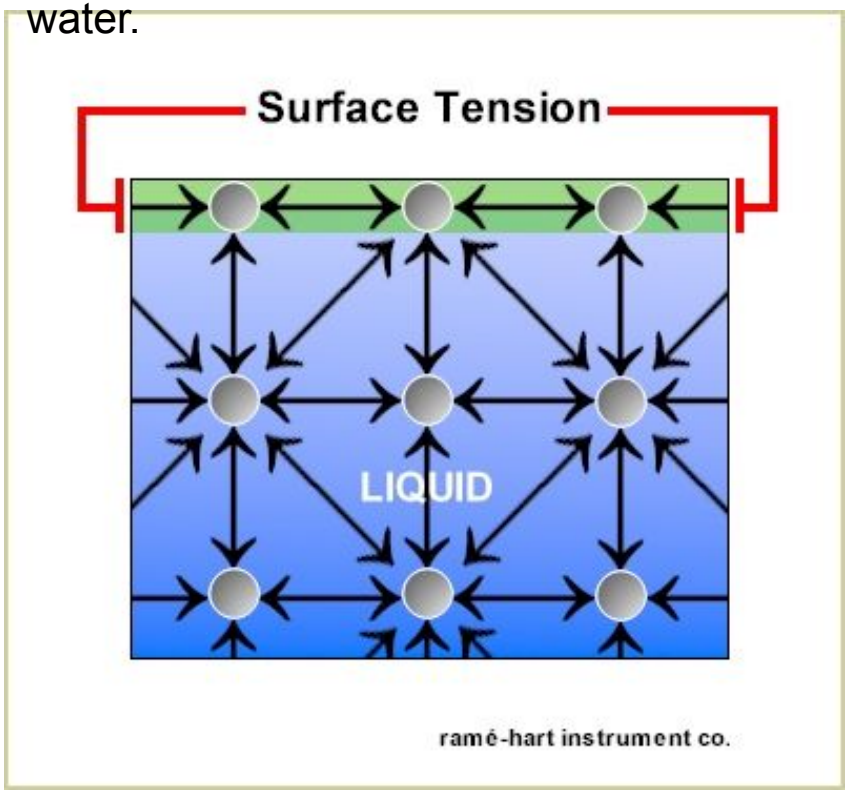


H bonds between water molecules

Surface Tension

Is a property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of the water molecules.

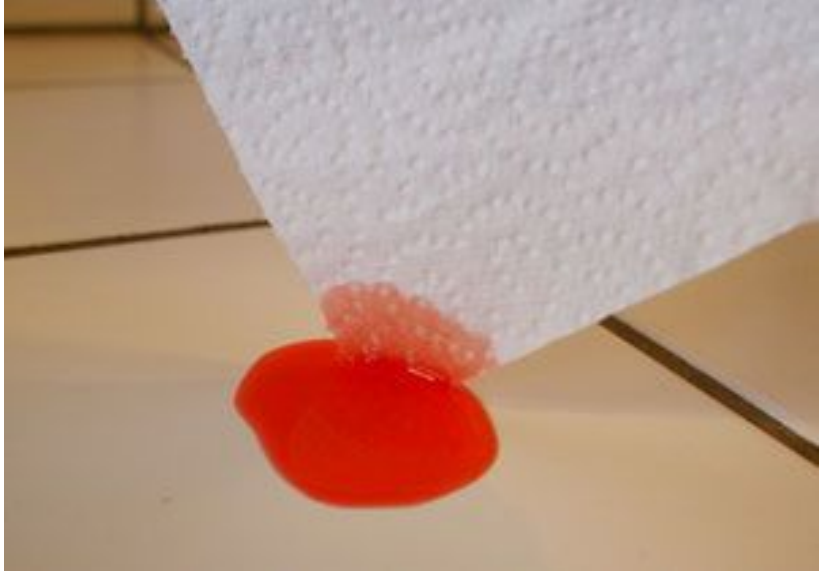
Water molecules want to cling to each other. At the surface, however, there are fewer water molecules to cling to since there is air above (thus, no water molecules). This results in a stronger **hydrogen bond** between those molecules that actually do come in contact with one another, and a layer of strongly bonded water (see diagram). This surface layer (held together by surface tension) creates a considerable barrier between the atmosphere and the water.

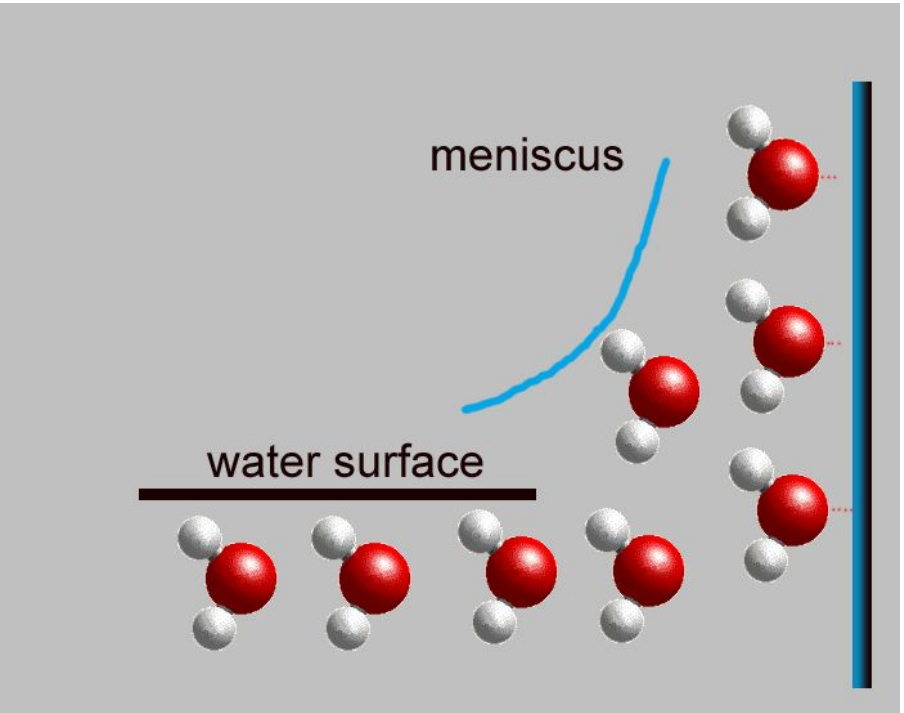


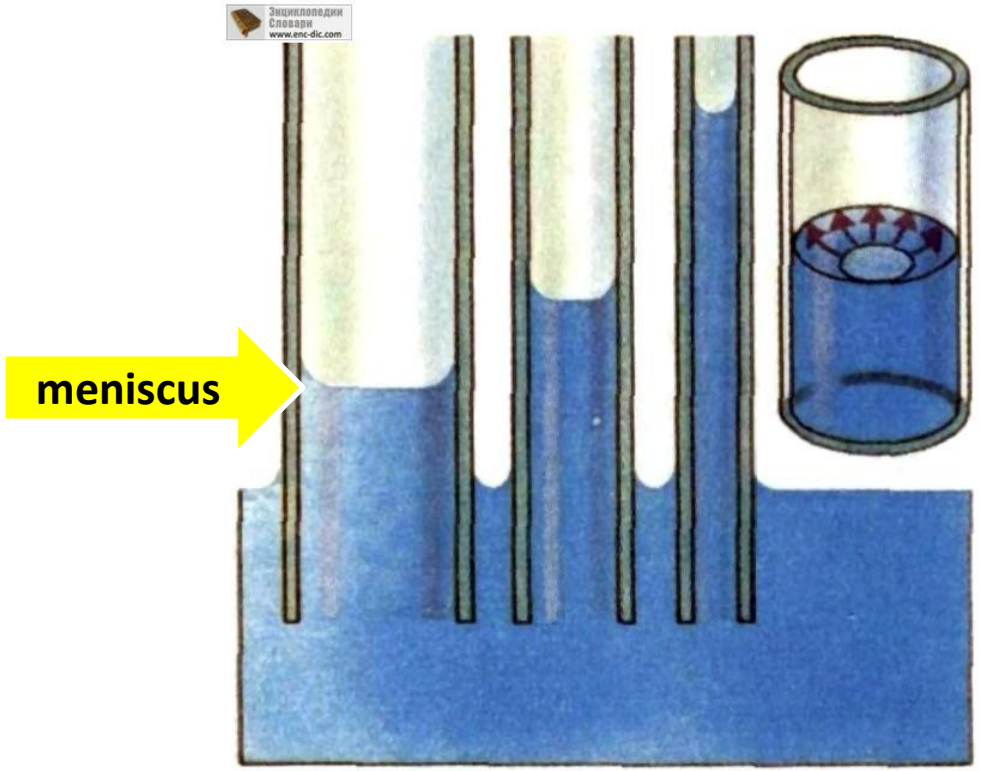
Surface tension allows insects to float and stride on a water surface.

Capillary Action:

Capillary action is important for moving water (and all of the things that are dissolved in it) around. It is defined as the movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.

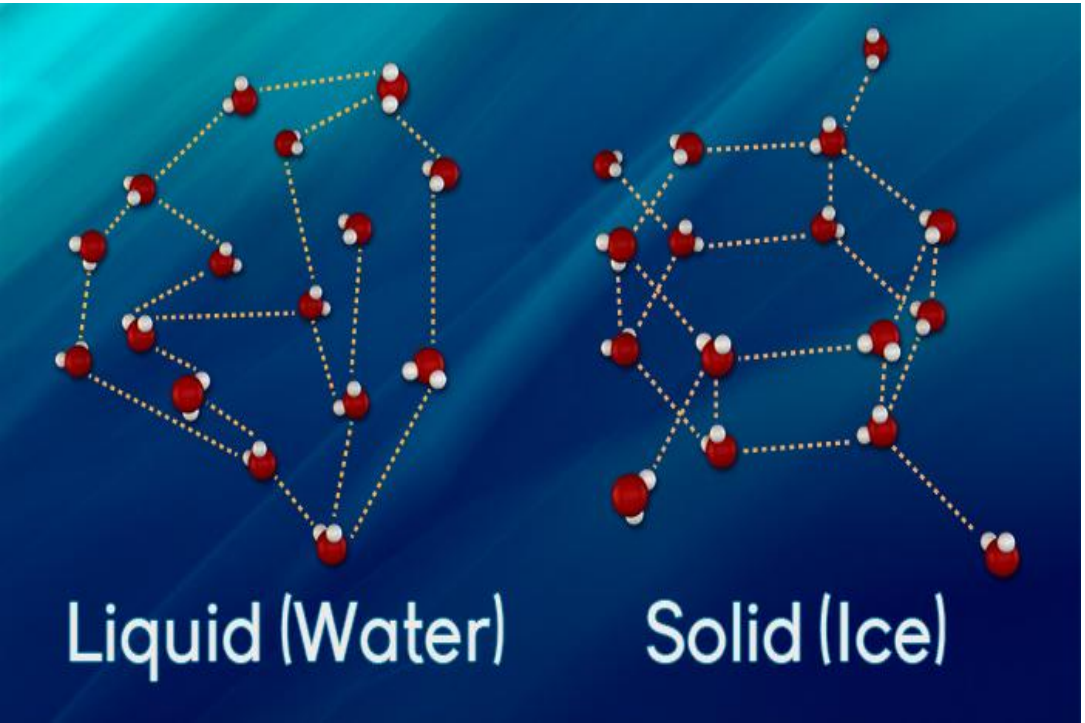






Density:

- Water has a density of 1g/mL at 4 °C
- Water is the one of the few substances that is less dense as a solid than liquid
- Due to hydrogen bonding and resultant pockets



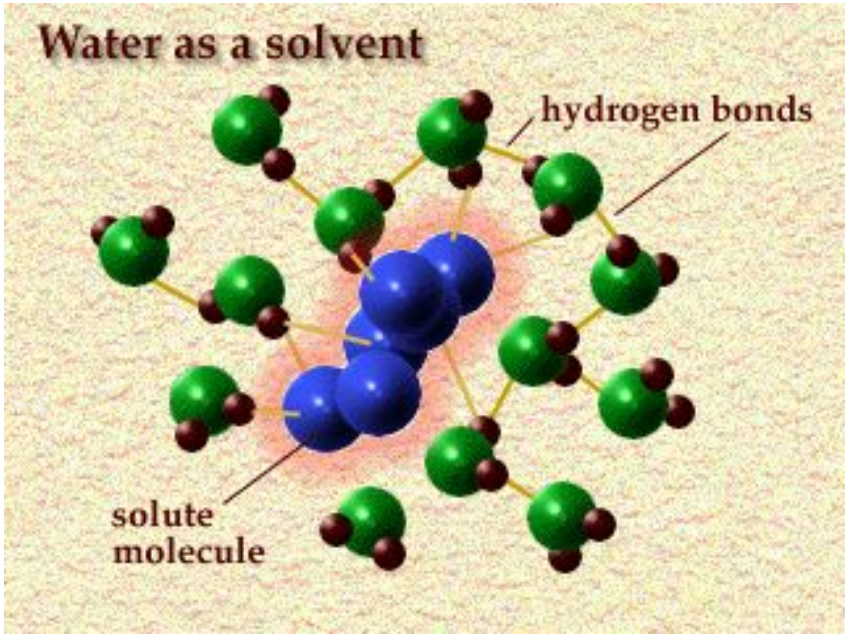
ice floats on water because it is less dense

Properties of Water

- At sea level, pure water boils at 100 °C and freezes at 0 °C.
- The boiling temperature of water decreases at higher elevations (lower atmospheric pressure).
- For this reason, an egg will take longer to boil at higher altitudes

Water is Universal Solvent:

- Ions and polar molecules readily dissolve in water
- Substances such as salt are pulled apart by attraction of opposite charges due to polar structures



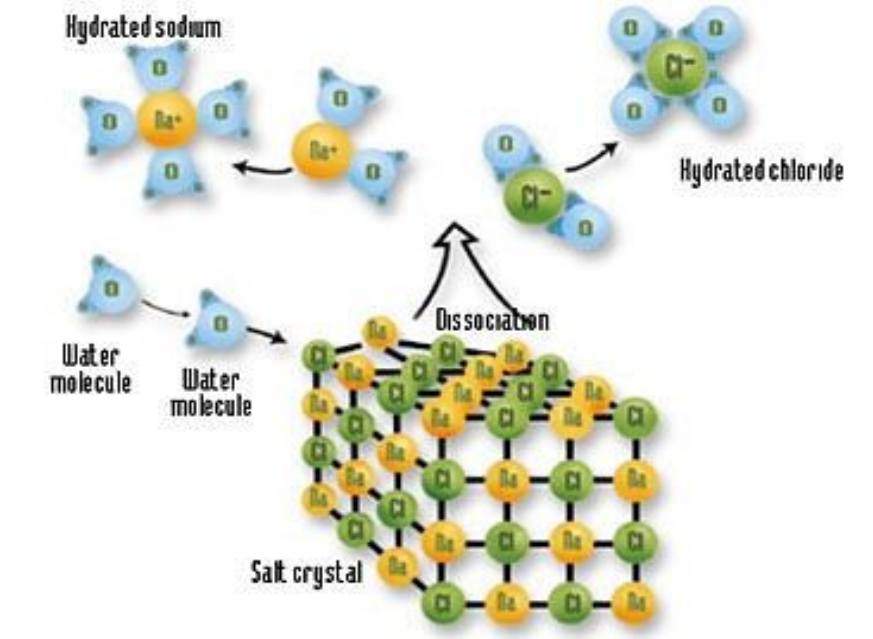


Figure 3: Salt crystal dissolving in water. Sodium and chloride atoms are "pulled" (dissociated) from the salt crystal and surrounded by water molecules (hydrated).

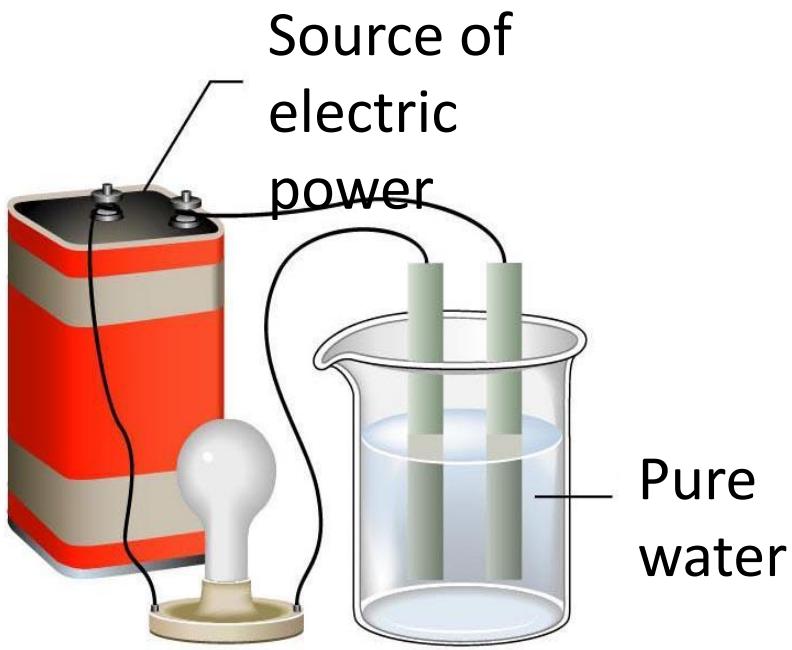
A substance that can behave as either an acid or a base is called, ***amphoteric (ampholyte):***

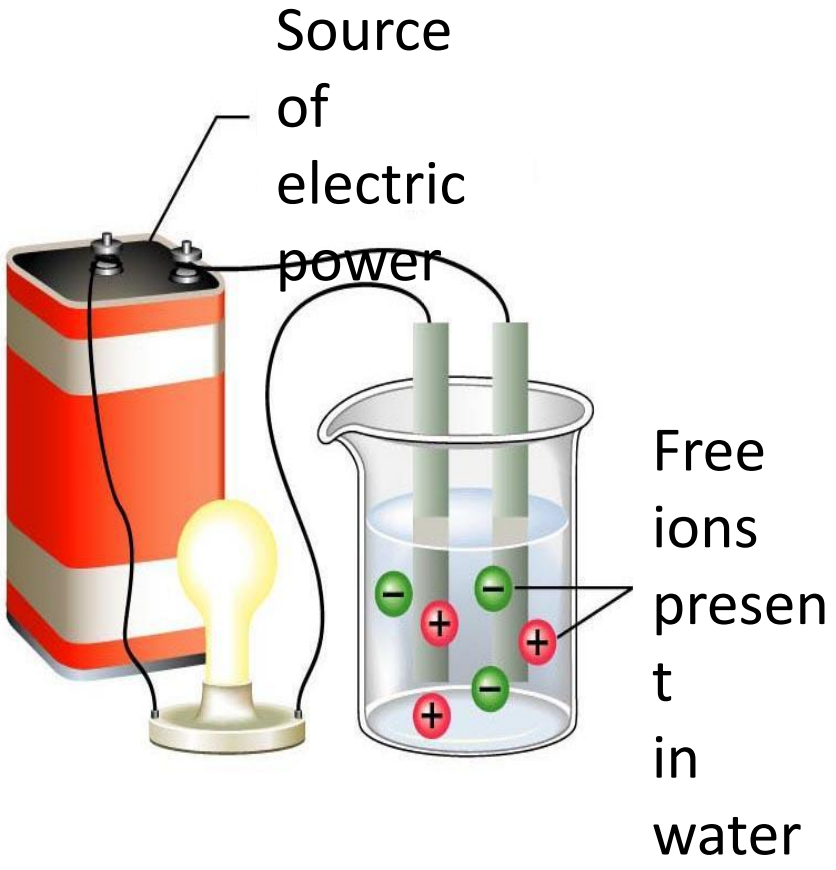
$$HOH \Leftrightarrow H^+ + OH^-$$

ampholyte **acid** **base**

All the major components in cells (proteins, DNA and polysaccharides) are also dissolved in water.

Pure water has a low electrical conductivity, but this increases significantly with the dissolution of a small amount of ionic material such as sodium chloride.





CHEMICAL PROPERTIES OF WATER:

1. pH (activity acidity)
2. Total Acidity
3. Alkalinity
4. **Total Hardness**
5. Chemical reactivity: water can participate in chemical reactions. Example: involvement of water molecules in dehydration synthesis and hydrolysis, electrolysis.
6. Metals – Iron, Manganese, Zinc, Copper, Chromium, Lead
7. Nitrate/ Nitrite
8. Arsenic, Selenium, Fluoride
9. Chloride
10. Total and Free Chlorine

In practice, the chemical properties of water are determined by analytical methods.

REACTION OF WATER WITH METALS

- Not all metals react with water.
- Metals of Group 1 (IA or alkali) react vigorously with cold water forming hydroxide and hydrogen gas:

$$2Na + H_2O \longrightarrow 2NaOH + H_2 \uparrow$$

- Metals from magnesium to iron in the activity series of metals, react with steam (but not H_2O) to form the metal oxide and hydrogen gas:

Magnesium + Steam ⟶ Magnesium oxide + Hydrogen

$$Mg + H_2O \longrightarrow MgO + H_2 \uparrow$$

- Noble metals, such as gold and silver, do not react with water at all.

DISSOLVING ELECTROLYTES IN WATER

Solid electrolytes are composed of ions which are held together by electrostatic forces of attraction. When an electrolyte is dissolved in water, these forces are weakened and the electrolyte undergoes dissociation into ions. The ions are solvated.

The process of splitting of the molecules into ions of an electrolyte is called dissociation .

acid: $HCl_{(g)} + H_2O_{(aq)} = H^+_{(aq)} + Cl^-_{(aq)}$

base: $NaOH_{(s)} + H_2O_{(aq)} = Na^+_{(aq)} + OH^-_{(aq)}$

salt: $NaCl_{(s)} + H_2O_{(aq)} = Na^+_{(aq)} + Cl^-_{(aq)}$

HYDROLYSIS

Is a chemical process in which a molecule is cleaved into two parts by the addition of a molecule of water ("chemical decomposition by water," 1880, formed in English from ***hydro-*** + Greek ***lysis*** "a loosening, a dissolution," from ***lyein*** "to loosen, dissolve").

$$AB + \text{H-}\mathbf{OH} \rightleftharpoons A\text{-H} + B\text{-}\mathbf{OH}$$

TOTAL HARDNESS

One important indicators of water quality is its hardness. **General hardness (GH) is caused by the presence of a certain concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in 1 liter of water**:

$$GH = \frac{m_{Ca^{2+}}}{20,04} + \frac{m_{Mg^{2+}}}{12,16} = mmol \cdot eq / L$$

These "hardness ions" cause two major kinds of problems. First, the metal cations react with soaps, causing them to form an unsightly precipitate – the familiar "bathtub ring".

More seriously, the calcium and magnesium carbonates tend to precipitate out as adherent solids on the surfaces of pipes and especially on the hot heat exchanger surfaces of boilers. The resulting scale buildup can impede water flow in pipes.

In boilers, the deposits act as thermal insulation that impedes the flow of heat into the water; this not only reduces heating efficiency, but allows the metal to overheat, which in pressurized systems can lead to catastrophic failure.

TYPES / CLASSIFICATION OF HARDNESS

GENERAL HARDNESS:

GH = TH + PH

Temporary (carbonate) hardness:

$Ca(HCO_3)_2$,

$Mg(HCO_3)_2$

Permanent (non-carbonate) hardness:

$CaCl_2$, $CaSO_4$
$MgCl_2$, $MgSO_4$

TEMPORARY HARDNESS

Temporary hardness is due to the presence of bi-carbonates of calcium and magnesium. It can be removed by easy means like boiling. When temporary hard water is boiled, the carbonates decompose with liberation of carbon-dioxide and precipitation of the insoluble Carbonates which are reformed:

$$Ca(HCO_3)_2 \rightarrow CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$

$$Mg(HCO_3)_2 \rightarrow MgCO_3 \downarrow + CO_2 \uparrow + H_2O$$

$MgCO_3$ is slightly soluble in water but heating will cause its hydrolysis into the much less soluble $Mg(OH)_2$

$$MgCO_3 + H_2O \rightarrow Mg(OH)_2 + CO_2 \uparrow$$

So simple boiling and filtering of water remove temporary hardness.

PERMANENT HARDNESS

It is due to the presence of chlorides and sulphates of calcium and magnesium. These salts do not decompose on boiling. So permanent hardness can't be removed easily. It can be removed by soda (Na_2CO_3), surfactants (Na_3PO_4) or lime ($Ca(OH)_2$) when $MgSO_4$ is responsible for hardness:

$$CaSO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + CaCO_3 \downarrow$$

$$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaSO_4$$

Surfactant a substance that tends to reduce the surface tension of a liquid in which it is dissolved.

Removal of Hardness

1. Boiling
2. Addition of lime
3. Addition of sodium carbonates
4. Base exchange process

Temporary Hardness

1. Addition of Sodium carbonate
2. Base exchange process:

- Sodium Permutit is used ($Na_2Al_2Si_2OH_2O$)
- Exchange Na ions for Ca and Mg ions
- Ca and Mg Permutit is formed .
- Removes 100% hardness
- Some raw water is added to protect against corrosive action of 100% soft water

Permanent Hardness

Measurement of Hardness

Expressed as millimole equivalents of Ca^{2+} and Mg^{2+} cations in 1 liter of the water (*mmole-Eq/L*).

On scale hardness distinguishes:

Value of hardness (mmol-eq/L)	Water hardness	Example
H > 1,5	Very soft	Most soft water is rain, snow and iceberg (0.1 mmol-eq/L)
H = 1,5 – 4,0	Soft	Rain water
H = 4,0 – 8,0	Moderately hard	Drinking water
H = 8,0 – 12	Hard	
H > 12,0	Very hard	The most hard - water of oceans (up to 130 mmol-eq/L)

ESTIMATION OF WATER HARDNESS

Water hardness can be determined by the following 2 analytical methods:

1. **By titration with HCl**: In this method temporary hardness can be measured.
2. **By titration with EDTA**: In this method general hardness can be measured.

ESTIMATION OF TEMPORARY HARDNESS BY TITRATION WITH HCL:

For determining temporary hardness: 100 ml hard water is taken into a 250 ml conical flask. Then few 3-4 drops of methyl orange is added in it as an indicator. Now titration is carried out by adding 0.1N cold HCl until the **yellow color** of methyl orange turns **red**.

Here, each meal 0.1N HCl is equivalent to 0.005 gm of $CaCO_3$. The associated reactions are as follows:

$$Ca(HCO_3)_2 + 2HCl \rightarrow CaCl_2 + 2CO_2 \uparrow + 2H_2O$$

$$Mg(HCO_3)_2 + 2HCl \rightarrow MgCl_2 + 2CO_2 \uparrow + 2H_2O$$

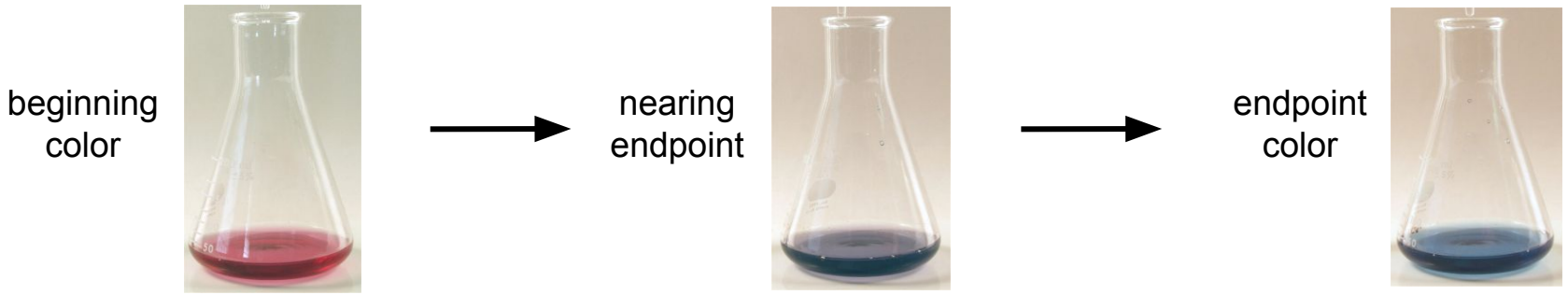
$$TH = \frac{V_{HCl} \cdot N_{HCl}}{V_{H_2O}} \cdot 1000 = mmol / L$$

ESTIMATION OF GENERAL HARDNESS BY TITRATION WITH EDTA:

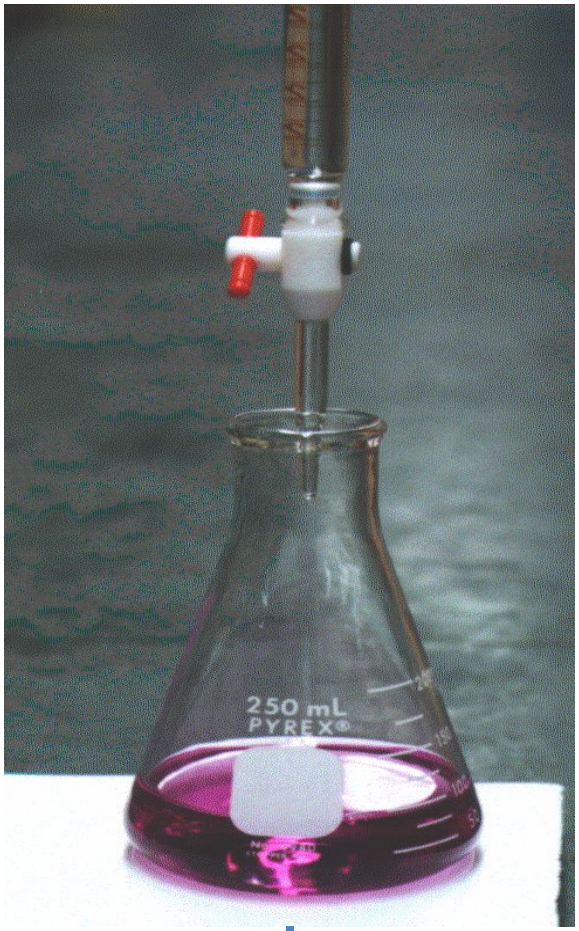
Add 1ml of buffer solution (NH_4OH+NH_4Cl) to 100 ml of the original water sample. Add 3-4 drops of Eriochrome Black T indicator. Titrate against 0.05N prepared EDTA solutions in burette until the color charges from **wine red** (or **violet**) to **pure blue** (or **turquoise**) with no reddish tone; then calculate the general hardness:

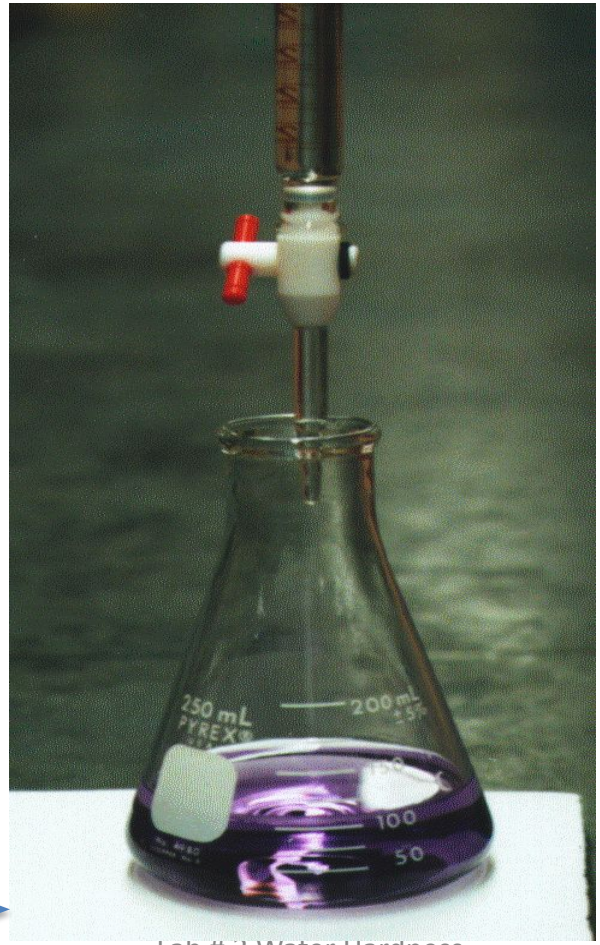
$$GH = \frac{V_{EDTA} \cdot N_{EDTA}}{V_{H_2O}} \cdot 1000 = mmol / L$$

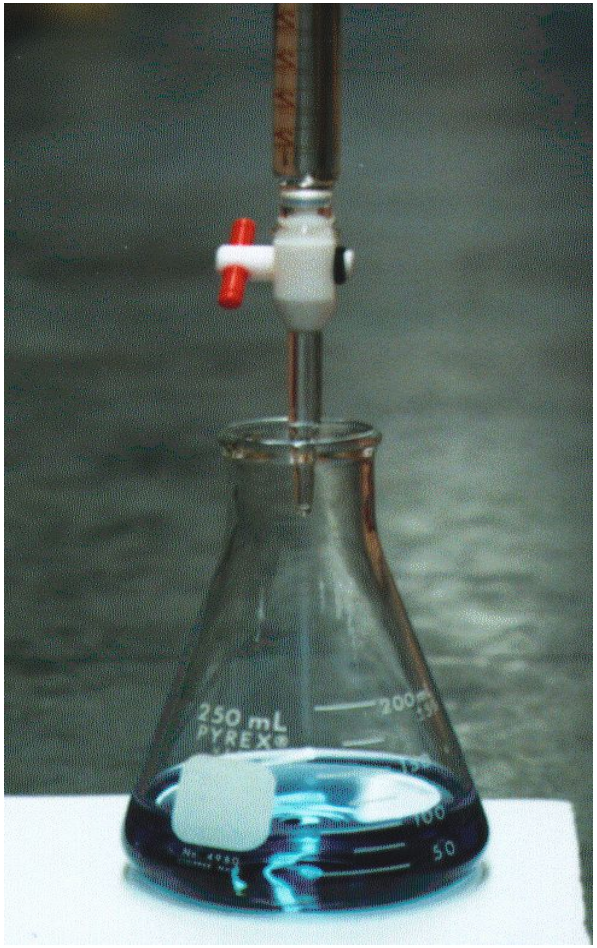
- As you near the endpoint, the solution will turn purple. Continue to slowly add EDTA until the solution turns blue, with no trace of red.



Eriochrome Black Indicator reacted with metal ions in water and changed its color:







Permanent hardness can be found by deducting the temporary hardness from total hardness i.e.

GH = TH + RH

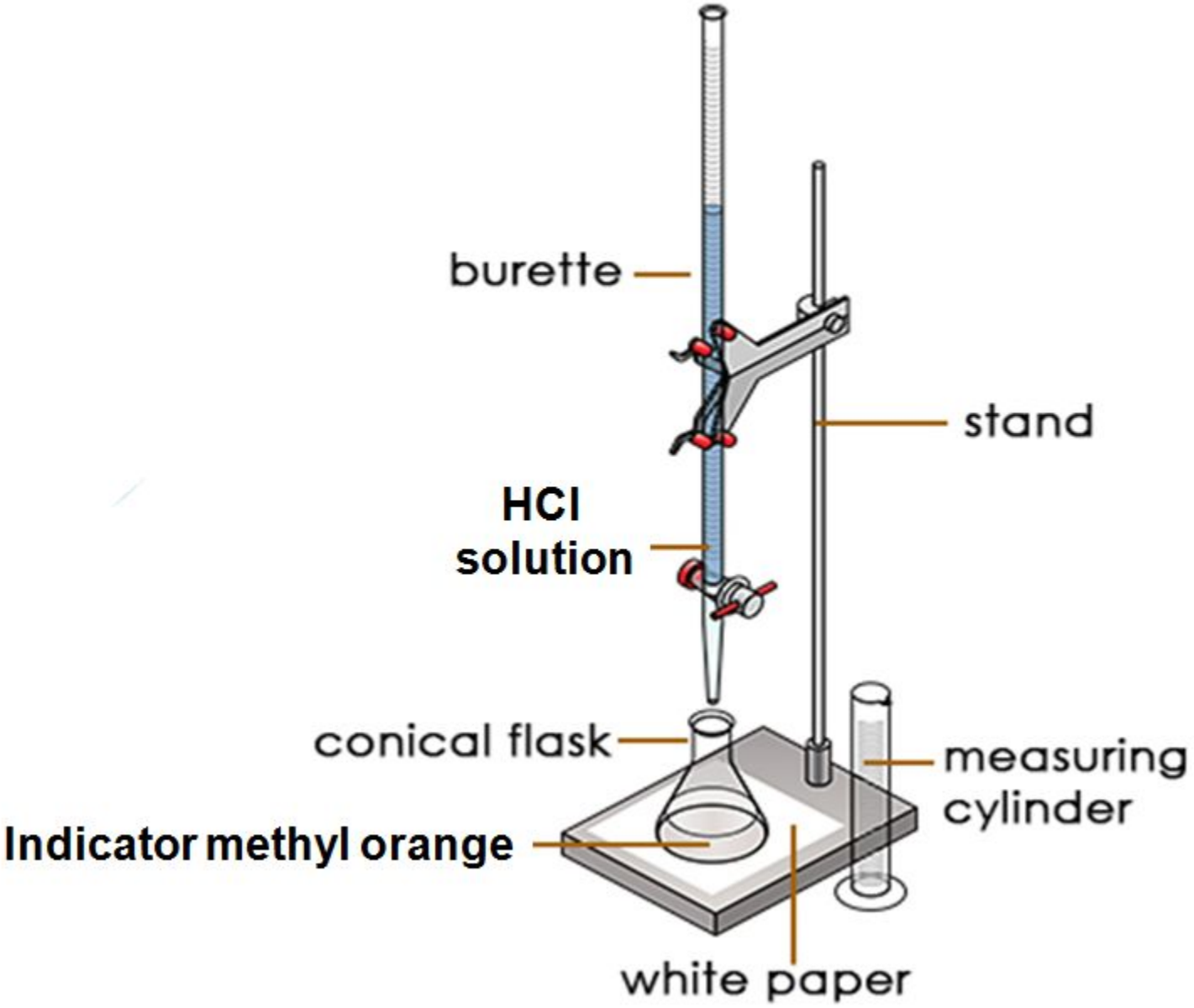
Permanent hardness = General hardness – Temporary hardness

CONCLUSION:

The safe drinking water is recognized water:

- with pH of 7 to 7.5 mmol / L
- hardness not more than 7 mmol / L,
- the total amount of minerals in which not more than 1 g / l,
- harmful chemical impurities do not exceed the maximum allowable concentrations,
- and lacking pathogenic bacteria and viruses.

APPARATUS NEEDED FOR TITRATION



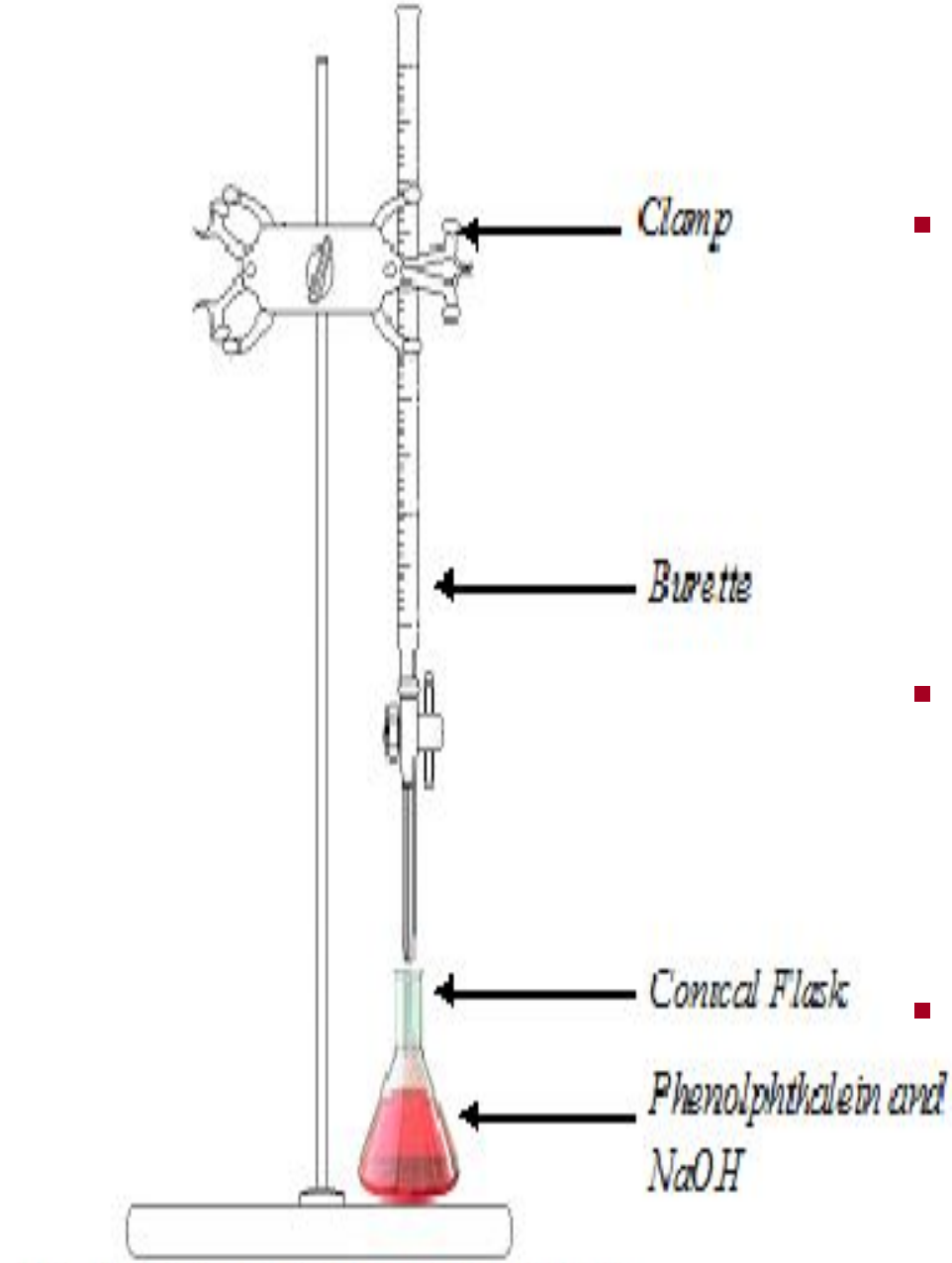
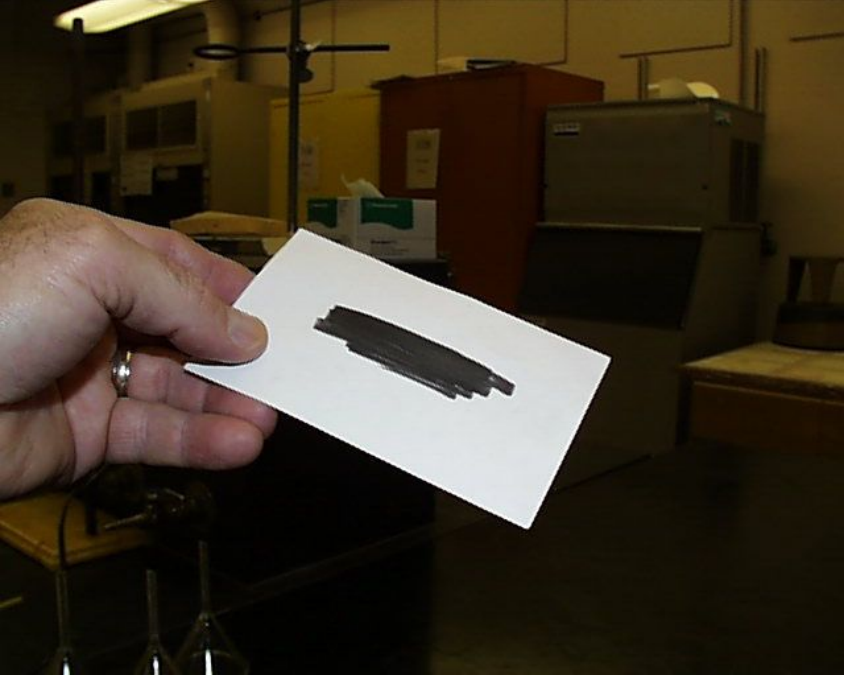


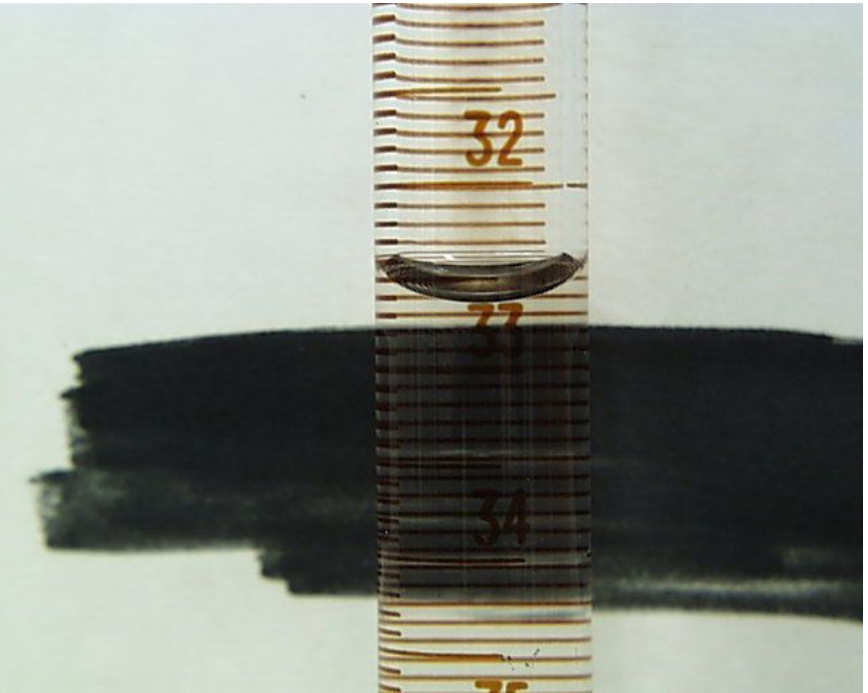
Fig: - Burette and clam with conical flask

RULES OF USING A BURET:

- Clean the buret with a buret brush, water, and a small amount of detergent. Rinse it twice with deionized water. Be sure to drain deionized water through the tip.
- Rinse the buret again with two 10 mL portions of the titrant (HCl or EDTA solutions)
- Fill the buret with titrant and drain a small amount from the buret to dispel any air bubbles that might be in the tip.



- Use a marker pen to create a black area on a white note card. This will be used to help locate the bottom of the meniscus when reading the buret.



- Place the note card with the black mark behind the buret and just below the meniscus. This will make the bottom of the meniscus much easier to see. Record the volume reading to the nearest 0.01 mL.

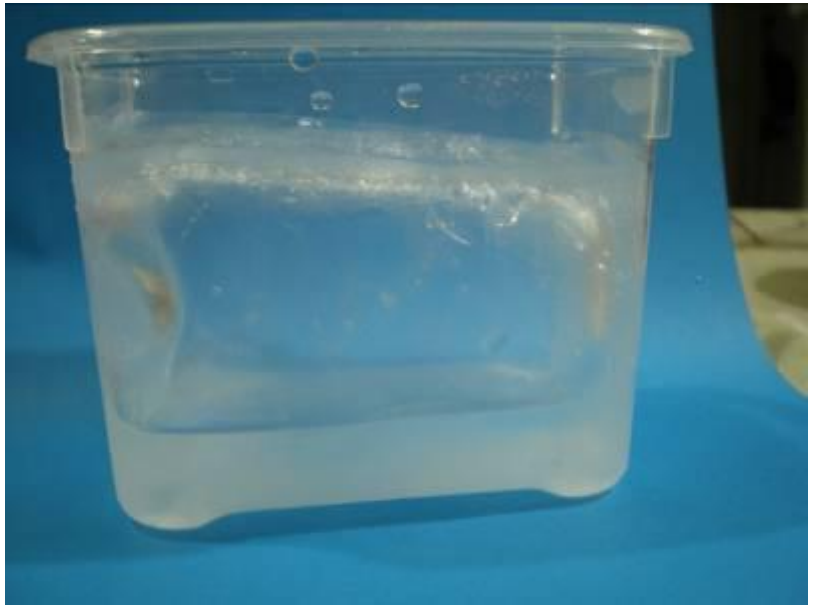
- If you need to dispense less than a full drop of titrant, open the stopcock slightly to allow a small amount of titrant to accumulate on the tip of the buret.

- Rinse the titrant on the tip into the flask using deionized water from your wash bottle.

КИПЯЧЕНИЕ ВОДЫ

Жесткость снижается на 30 - 40%.

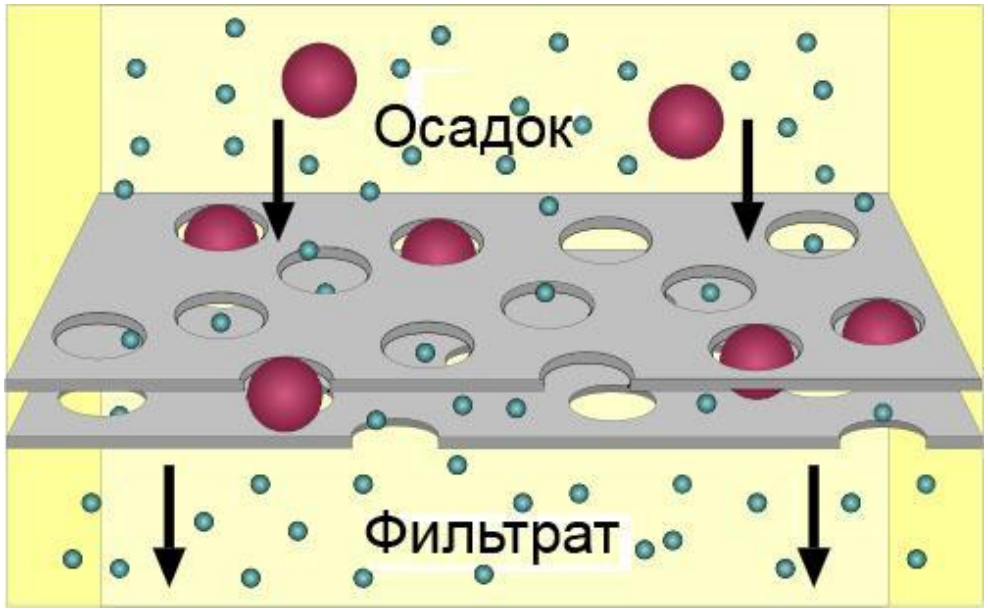
ВЫМОРАЖИВАНИЕ ВОДЫ

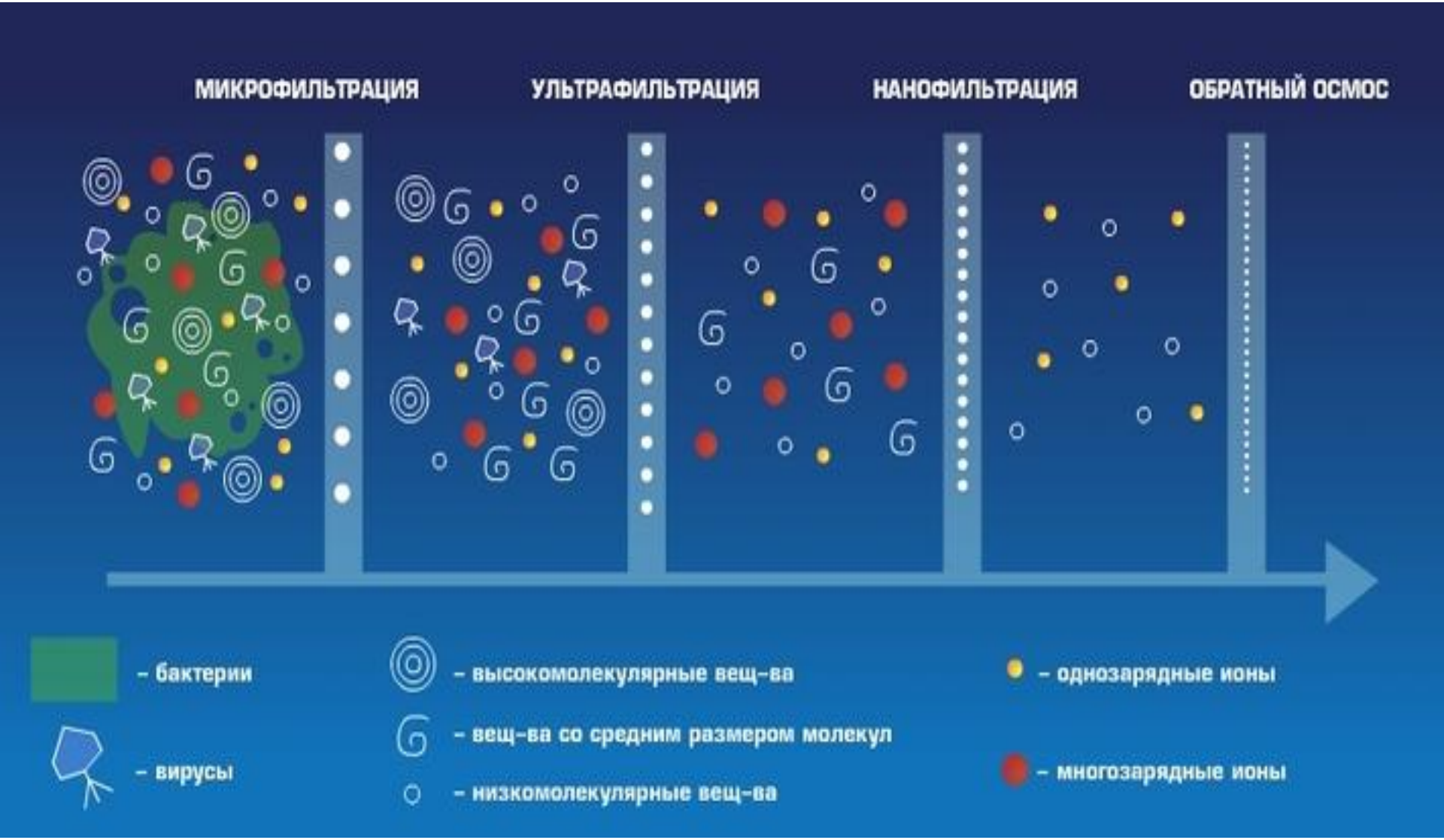


Общая жесткость снижается на 70-80%.

ФИЛЬТРАЦИЯ

Общая жесткость понижается на 80%.




МИКРОФИЛЬТРАЦИЯ
УЛЬТРАФИЛЬТРАЦИЯ
НАНОФИЛЬТРАЦИЯ
ОБРАТНЫЙ ОСМОС
– бактерии
– вирусы
– высокомолекулярные вещ-ва
– вещ-ва со средним размером молекул
– низкомолекулярные вещ-ва
– однозарядные ионы
– многозарядные ионы

Что такое бытовой фильтр?

Внутри картриджа фильтра содержится смесь из активированного угля (черные частицы) и катионообменники (гранулы смолы белого цвета).

Уголь адсорбирует вредные органические вещества и хлориды.

Катионообменники снижают общую жесткость.

УМЯГЧИТЕЛИ ВОДЫ

GLOSSARY

Adhesion – the ability of a substance to stick to an unlike substance.

Cohesion – various intermolecular forces that hold solids and liquids together.

Buffer is a solution composed of a weak acid and its conjugate base that can be used to stabilize the pH of a solution

Density is a measure of the amount of matter contained by a given volume.

Hydrophobic – lacking an affinity for water; unable to absorb, or be wetted by water

Hydrophilic – having an affinity for water; able to absorb, or be wetted by water

Polarity – The intermolecular forces between the slightly positively-charged end of one molecule to the negative end of another or the same molecule.

Specific heat is the amount of heat, in calories, needed to raise the temperature of 1 gram of water by 1 degree Celsius

Heat capacity – the capability of a substance to absorb heat energy

Surface tension is the property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of its molecules.