**WATER CHEMISTRY**

**Introduction**

Water is the only substance on the Earth that occurs in all three physical states simultaneously (solid/ice, liquid/water, and gas/water vapor). It is an essential material for life: living systems consist of water and its amount is about 70–80% (w/w). Water possesses many chemical and physical properties that make it useful to cells and organisms.

Some important functions of water in human body;

* A primary function of water is to serve as a lubricant. For example, it is found in saliva and is a substantial component in the fluid surrounding joints.
* Water is also in and surrounding body structures such as the brain, spinal cord and eyes. The water layer helps protect and cushion these vulnerable areas from shock and trauma that could otherwise cause significant damage.
* Water is an important agent in body temperature regulation.
* Water is essential in the body's transportation system.
* It is a medium for the majority of biochemical reactions.

Muscle consists of 75% water

Brain consists of 90% of water

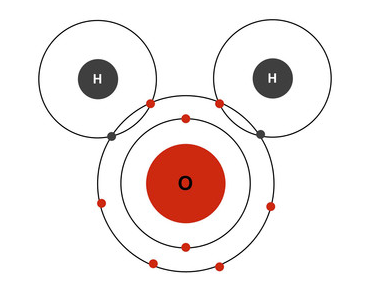
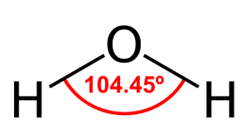
Bone consists of 22% of water

Blood consists of 83% water

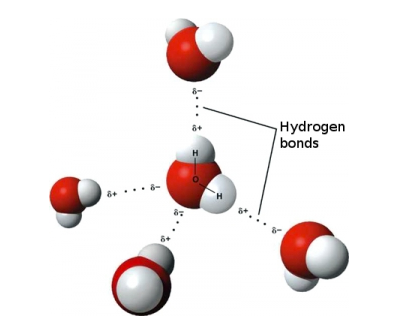
Water plays many critical roles within the field of agriculture, food, and feed science, technology, and engineering. Water is the main components of drinking water, beverages and most of foodstuffs. Water content of fresh fruits, vegetables, meats, and sea foods exceeds 50%.Water is used as a good medium to cook foods. In addition, steam is the basic working medium of heat (as a feed for boiler) and power engineering in food processing. In food chains, water is not just a medium for reactions, but is also an active ingredient used to control reactions, food texture, and physical and biological behavior. Food may pick up moisture from the environment or lose moisture to the environment during storage. The percent of loss of fresh foods can be significantly reduced by controlling their water activity during storage. These changes may influence the texture and organoleptic properties of foodstuffs. Many operations in food processing (concentration, drying, dehydration, thawing, salting, and freezing) use physico-chemical properties of water and its state transition properties.

**Chemical Structure**

Chemical formula of water is H2O. A water molecule contains two hydrogen atoms each sharing a pair of electrons with an oxygen atom. When atoms share electrons in this way, a covalent bond is created. The molecule oriented along H–O–H linkage with an average angle of 104.5°.

The H2O molecule is electrically neutral, but the positive and negative charges are not distributed uniformly. Since positive and negative charges attract each other, polar water molecules align when they approach each other—the positive hydrogen end of one molecule is attracted to the negative oxygen end of a second molecule. This attraction is called a hydrogen bond and makes water molecule strongly polar. Water molecules are loosely bound together by weak hydrogen bonds, which gives water its liquid property.



Water described as the "universal solvent" for its ability to dissolve many substances. Polarity of water allows it to separate ions in salts and strongly bond to other polar substances such as alcohols and acids, thus dissolving them. Its hydrogen bonding causes its many unique properties, such as having a solid form less dense than its liquid form, a relatively high boiling point of 100 °C for its molar mass, and a high heat capacity.

**Properties of Water**

**Solvent:** Water is a universal solvent as well as a solvent for many substances because of strong interactions between water and other substances, its high dipole moment, and its ability to donate and accept protons for formation of hydrogen bonds. These properties make it an excellent solvent, especially for electrolytes and polar compounds (salts, acids, sugars, alcohols, carbonyl compounds, etc. More than half of known elements in the periodic table can be found in natural water, some in high concentrations, and others only in trace amounts. Water is used as a solvent or diluents in preparation of beverages and foodstuffs.

**Cohesion and Adhesion:** Water molecules stay close to each other (cohesion), due to the collective action of hydrogen bonds between water molecules. These hydrogen bonds are constantly breaking, with new bonds being formed with different water molecules; but at any given time in a sample of liquid water, a large portion of the molecules are held together by such bonds. Water also has high adhesion properties because of its polar nature. On extremely clean/smooth glass the water may form a thin film because the molecular forces between glass and water molecules (adhesive forces) are stronger than the cohesive forces. In biological cells and organelles, water is in contact with membrane and protein surfaces that are hydrophilic; that is, surfaces that have a strong attraction to water.

**Surface Tension:** Water has an unusually high surface tension, which is caused by the strength of the hydrogen bonding between water molecules. This allows insects to walk on water. A molecule within the bulk of a liquid experiences attractions to neighboring molecules in all directions, but since these average out to zero, there is no net force on the molecule. For a molecule that finds itself at the surface, the situation is quite different; it experiences forces only sideways and downward, and this is what creates the stretched-membrane effect. The distinction between molecules located at the surface and those deep inside is especially prominent in H2O, owing to the strong hydrogen-bonding forces. The difference between the forces experienced by a molecule at the surface and one in the bulk liquid gives rise to the liquid's surface tension.

**High Heat Capacity:** Another remarkable property of water is its extremely high capacity to absorb heat without a significant increase in temperature. Water is a powerful insulator. When water is heated or cooled, its temperature changes more slowly than other liquids. This resistance to gaining or losing heat is due to the high specific heat of water. Because of water’s unique molecular and bonding structure, heat must first break the hydrogen bonds between the molecules, rather than immediately speeding up the molecules and thereby increasing their temperature. Heat capacity is a useful concept and finds application in heat transfer. The large heat capacity of water makes water as an excellent reservoir and transferer of energy. Water is used as a good coolant in condensers to keep foodstuffs cool from over-heating.

**Change in density:** Water is one of the few known substances whose solid form is less dense than the liquid. As ice, water molecules form four hydrogen bonds that lock them into a rigid crystalline structure. In this state, the water molecules are actually further apart than when they are in a liquid state. This is why water expands as it freezes and is less dense than the surrounding liquid water. Because solid water is less dense, ice floats on the surface of a lake in winter and insulates the water below from freezing, providing a vital benefit to aquatic organisms. If water in its solid form was denser than water in its liquid form, lakes and ponds would freeze solid to the bottom during winter, and no longer provide viable habitats.

**Water in Foods**

Water plays many very important roles in food. It affects texture (dry and brittle versus moist and soft), enables the activity of enzymes and chemical reactions to occur (acts as a solvent), supports the growth of microorganisms, makes it possible for large molecules like polysaccharides and proteins to move about and interact, and conducts heat within food.

Many foods such as meat, poultry, seafood, fruits and vegetables are composed of 75% and more water, so water is the most abundant component in many fresh foods. Other foods such as dairy products, and fresh baked goods also contain high levels of water (about 35% or more). Foods that are high in moisture are at risk of contamination from the growth of microorganisms such as bacteria, yeast, and mold, while dry foods like pasta generally have long shelf lives.

But not all water that occurs in food is alike. Water in foods divided into three forms: **free, adsorbed, and bound**. Free water is the water that can literally be squeezed out of a food, like the juice in an orange, or the water that sometimes separates in sour cream or yogurt. Adsorbed water is water that is attached to the surface of molecules like polysaccharides and proteins. It is not readily squeezed out of the food. Hydration of proteins, such as gluten, and carbohydrates, such as starch, referring to adsorbed water. Bound water is water that is physically trapped within crystals, such as crystalline starch, or other substances in food. The important point is that free and adsorbed water can promote the growth of microorganisms, while bound water can not.

**Water Activity (aw)**

The amount of water that is available for the growth of microorganisms, as well as enzyme and chemical reactions, through a number known as water activity (aw).Water activity is the ratio of the vapor pressure (P) of water in food divided by the vapor pressure of pure water (P0) at the same temperature. The water activity of pure water is equal to 1.0.

Most foods will not support the growth of bacteria if their water activity is less than 0.85, because at this water activity there is not enough water available for the bacteria to grow. However, yeasts can grow at water activities as low as 0.70, while some molds will grow even at water activities as low as 0.60.

Water activity is also related to the texture of food. The amount of moisture in food determines the mobility of molecules in the food, especially large molecules like proteins and polysaccharides that need moisture to move about. Proteins and polysaccharides provide the structure of food. If they are rigid the food will be hard, but if they are flexible the food will be soft. Foods with low moisture content (perhaps 10-20% or less) will be rigid and hard, while moist foods (perhaps 35% or more) will be flexible and soft. When *aw* is low, foods (carbohydrates, lipids, or proteins) behave more like rubbery polymers than crystalline structures.

The rate of certain chemical and biochemical processes are effected by the amount of available water (enzymatic and non-enzymatic browning, oxidative reactions, chemical or biochemical hydrolysis, enzyme-catalyzed flavor changes). One of the effects of reducing the aw in a food product is to reduce the rate of these reactions. Reaction rates are influenced by concentration of solutes.Removal of water from foods in the process of concentration, dehydration, and freezing of foods reduce the rate of deterioration (microbial and enzymatic).

Reducing aw of a food product may be achieved through a number of methods. The most obvious is by partial removal of water in the food product using a variety of unit operations or processes. The concentration of water can also be reduced by the addition of other substances including salt and sugar.

**Heat and Water Relations**

**Specific Heat:** The amount of heat needed to raise the temperature of 1 g water by 1 °C is has its own name, the calorie.

**Heat of vaporization:** Water has a high heat of vaporization, the amount of energy needed to change one gram of a liquid substance to a gas at constant temperature. Water’s heat of vaporization is around 540 cal/g at 100 °C, water's boiling point.

**Latent heat of melting:** Energy needed to change 1 g of ice into liquid phase at 0°C. It is 80 cal at 0 °C.

**Sublimation**: Is the phase transition of a substance directly from the solid to the gas phase without passing through the intermediate liquid phase.

**Boiling:** Some of the molecules at the surface of a liquid have enough kinetic energy to escape into the atmosphere. The **vapor pressure** is the pressure exerted when the molecules leave the surface at the same rate as they return. The pressure of gas above a liquid affects the boiling point. In an open system this is called **atmospheric pressure**. The greater the pressure, the more energy required for liquids to boil, and the higher the boiling point. The boiling point is the temperature in which the vapor pressure of a liquid becomes equal to atmospheric pressure. For water, the boiling point is 100ºC at a pressure of 1 atm. The boiling point of a liquid depends on temperature, atmospheric pressure, and the vapor pressure of the liquid. The vapor pressure of a liquid lowers the amount of pressure exerted on the liquid by the atmosphere. As a result, liquids with high vapor pressures have lower boiling points. Vapor pressure can be increased by heating a liquid and causing more molecules to enter the atmosphere.