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INTERACTIONS BETWEEN OPERATIONAL RESEARCH AND ENVIRONMENTAL CHEMISTRY

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ABSTRACT

Water is abundant in all living things and, consequentially, is in almost all foods, unless steps have been taken to remove it. It is essential for life, even though it contributes no calories to the diet. Water also greatly affects the texture of foods, as can be seen when comparing grapes and raisins (dried grapes), or fresh and wilted lettuce. It gives crisp texture or turgor to fruits and vegetables, and it also affects perception of the tenderness of meat. For some food products, such as potato chips, salt, or sugar, lack of water is an important aspect of their quality, and keeping water out of such foods is important to maintain quality.

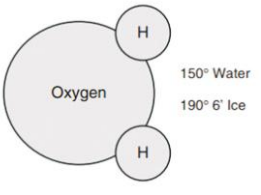
Almost all food processing techniques involve the use of water or modification of water in some form: freezing, drying, emulsification (trapping water in droplets or trapping oil in a water phase to give salad dressings their characteristic mouth feel), breadmaking, thickening of starch, and making pectin gels are a few examples. Further, because bacteria cannot grow without water, the water content has a significant effect on maintaining quality of the food. This explains why freezing, dehydration, or concentration of foods increases shelf life and inhibits bacterial growth.

KEYWORDS: *water, Chemistry of water, food products, breadmaking.*

INTRODUCTION:

The chemical formula for water is H2O. Water contains strong covalent bonds that hold the two hydrogen atoms and one oxygen atom together. The oxygen can be regarded to be at the center of a tetrahedron, with a bond angle of 105 o between the two hydrogen atoms in liquid water and a larger angle of 109o 6` between the hydrogens in ice.

The bonds between oxygen and each hydrogen atom are polar bonds, having a 40 % partial ionic character. This means that the outer-shell electrons are unequally shared between the oxygen and hydrogen atoms, the oxygen atom attracting them more strongly than each hydrogen atom. As a result, each hydrogen atom is slightly positively charged and each oxygen atom is slightly negatively charged. Therefore they are able to form hydrogen bonds.



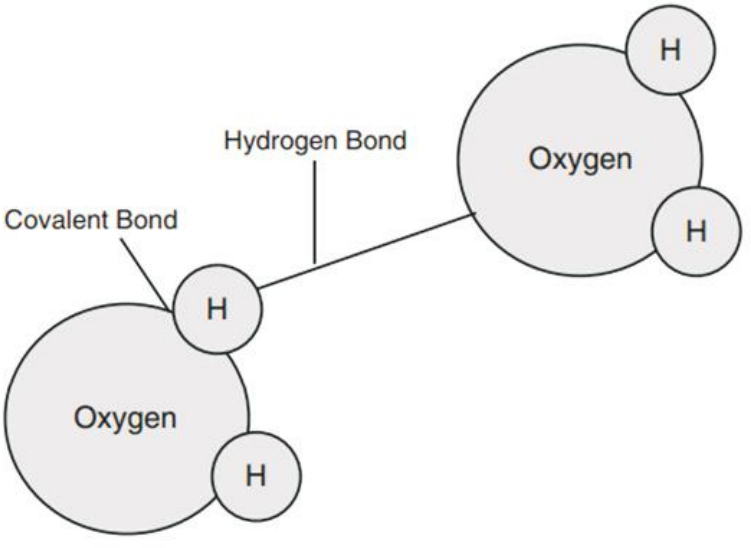
Bond angle of water and ice

A hydrogen bond is a weak bond between polar compounds where a hydrogen atom of one molecule is attracted to an electronegative atom of another molecule. It is a weak bond relative to other types of chemical bonds such as covalent or ionic bonds, but it is very important because it usually occurs in large numbers and, therefore, has a significant cumulative effect on the

properties of the substance in which it is found. Water can form up to four hydrogen bonds (oxygen can hydrogen bond with two hydrogen atoms).

Water would be expected to be gas at room temperature if compared with similar compounds in terms of their positions in the periodic table, yet due to the many hydrogen bonds it contains, it is liquid. Hydrogen bonds between hydrogen and oxygen are common, not just between water molecules, although between many other types of molecules that are important in foods, such as sugars, starches, pectins, and proteins.

Due to its V-shape, each molecule of water can form up to four hydrogen bonds with its nearest neighbors. Each hydrogen atom can form one hydrogen bond, and the oxygen atom can form two, which results in a threedimensional lattice in ice. The structure of ice—frozen water, is dynamic, and hydrogen bonds are continually breaking and reforming between different water molecules. Liquid water also contains hydrogen bonds and, therefore, has a variety of ordered structures that are continually changing as hydrogen bonds break and re-form. In liquid water, it is estimated that about 80% of water molecules are involved in hydrogen bonding at any one time at 212 F (100°C), whereas 90% are involved in liquid water at 32°F (0° C).



Hydrogen and covalent bonds in water molecules

Specific Heat and Latent Heat of Water

When ice is heated, the temperature increases in proportion to the amount of heat applied. The specific heat of water is the energy (in calories or in joules) required to raise the temperature of 1 g of water by 1oC, and is the same whether heating water or ice. It is relatively high compared to other substances due to the hydrogen bonds. The specific heat of water is 1 o cal/g/C. This means that it takes 100 cal to raise the temperature of 1 g of water from 0 to 100 °C.

Once ice has reached 0oC, energy needs to be put in to break the hydrogen bonds and enable ice to change to the liquid form. Until the ice has been converted to liquid, there is no further change in temperature until liquid water created.

PROPERTIES OF WATER

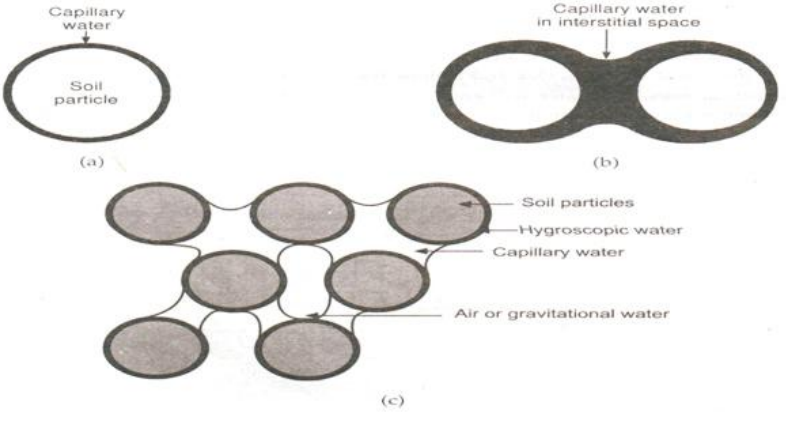
1)Liquid water is colourless, odourless, tasteless and highly incompressible.

2)Water expands when it freezes, on the other hand almost all other substances contract on boiling and freezing. Hence, ice is less dense than liquid water and floats.

3)Water has low molecular weight of 18, like ammonia (MW = 17) or methane MW = 16). But water is in liquid state because of very high attractive forces between water molecules as a result of hydrogen bonds.

4)Water has very high boiling point (100°C) and high heat of vaporization (540 cal/g at 1000C) because of hydrogen bonding. This property of water is highly beneficial to plant life. As the large amount of heat is released from water

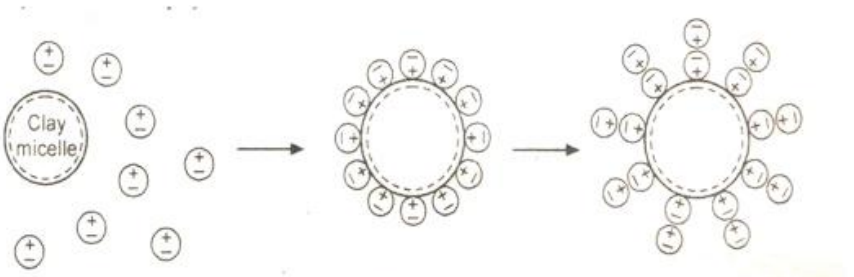
before it freezes and evaporates, it gives considerable cooling effect.
5)The specific heat of water is highest. It has great capacity to absorb heat with very little rise in temperature. Water is relatively slow to heat up and cool down. This property of water is of great significance to plants life. It helps to maintain a stable temperature and stable metabolic rate.
6)Water molecule has high cohesive force. The ability of water molecules in the liquid state to cling to one another tenaciously is called as property of cohesion. This causes continuous flow of water inside the plant. The water makes a unbreakable column in the plants body.
7)Water has highest surface tension except mercury.
8)Water has high adhesive property, Water molecules adhere firmly to the molecules of other substances like glass, wood, clay soil, cellulose protein etc.
9)Water has 'spreading out' property, when water comes with materials such as blotting paper, soil, or a plant cell wall. The tiny fissures, pores and interstices characteristically present in these materials are the spaces through which water moves spontaneously from damp to dry regions. The water molecules thus have 'capillary action' because of hydrogen bonding.
10)Water is one of the most ideal solvent system. Varietyofsubstances get readily dissolved in water. Electrolytes get rapidly dissolved in water. Their positively and negatively charged ions are joined to negative and positive side of the water molecule. Thus, water becomes a good conductor of electricity. Absolutely pure water is poor conductor of electricity.
11)Water is hardly affected by solar radiation. Water absorbs ultraviolet and visible radiation to only a slight extent. Water acts as a good heat insulator since it absorbs red light to a large extent.
12)Water is transparent and colorless, hence enables high transmission of visible light through the sea water or any other bodies of water. This property of water is highly beneficial to the aquatic plant world. They can photosynthesis own if they are submerged at considerable depths. Only blue colour wavelength of light is transmitted through water. Hence, it causes bluish green appearance of sea water.



A Capillary Water

Water interactions with gases and earth minerals.

Soil obtains its water from rain, snow, dew or irrigation. A amount water hold by the soil in specific atmospheric condition and due to me respective edaphic factors is known as soil water. As soilscontain water.Differentsoils absorbsand retain different quantities of water. Even one and the same soil contains different amount of water at different times. A part of natural water that soaks into the ground (soil) travels down into the layers, wetting the soil through which it passes. A part of this water is drained away and the rest is retained by the soil particles. Some amount of water retained by the soil evaporates and lost forever. Thus, very small fraction of the water that it is soaked into the ground is actually retained in the soil and placed at the disposal of the growing plant.



(a) Clay micelle of free water molecules (b) Clay micelle with water molecules absorbed on it

Microbial transformation of carbon Nitrogen phosphorus, Hydrocarbons & Ion -

Micro-organisms bacteria fungi and algae are living catalysts which help a large number of chemical processes to occur in water and soil. A large number of important chemical reactions in aqueous medium particularly those involving organic matter and redox processes occur through bacterial intermediaries. Algae are the primary producers of biological organic matter (biomass) in water. Micro-organism lead to the formation of many sediment and mineral deposits.

Fungi and bacteria are classified as reduces, which decompose chemical compounds to simpler species and thereby drive the energy requirements for their growth and metabolism. They are regarded as environmental catalyst in aquatic medium. On the other hand, algae are classified as producers. They utilize sunlight and store it as chemical energy, while in the absence of sunlight they use the stored chemical energy for metabolic requirements. Thus, algae serve as aquatic 'solar fuel cells'.

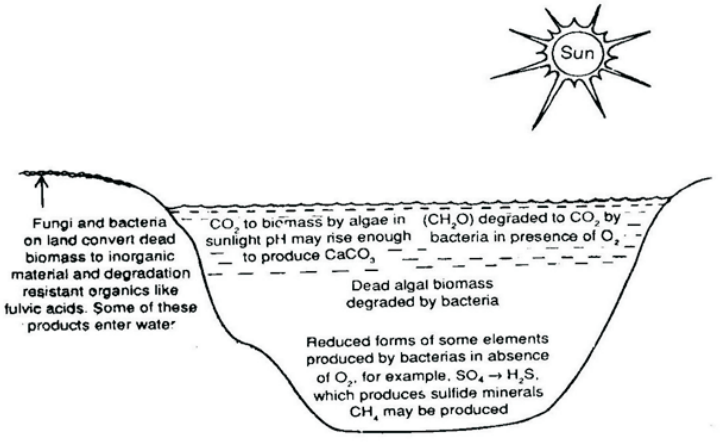


Fig C – Effects of microorganisms on the chemistry of Water (Reprinted by permission on Brooks /Cole publishing Company in 1979.)

Microbial Medicated Redox Reactions

Bacteria mediate a variety of redox reactions and thereby drive the energy needed for then metabolic processes and reproduction. Some environ¬mentally important redox reactions of this category are given below:

$\rightleftharpoons$

Oxidation

$$[CH_2O] + H_20 \rightleftharpoons CO_2 + 4H^+ = 4e\uparrow$$

$$HCOO \rightleftharpoons CO_2 + H^+ + 2e$$

$$HS + 4H_2O \rightleftharpoons SO^2_4 + 9H^+ + 8e$$

$$NH_3 + 3H_2O \rightleftharpoons NO^-_3 + 10H^+ + 8e$$

$$FeCO_3(s) + 2H_2O \rightleftharpoons FeOOH(s) + HCO^-_3 + 2H^+ 8e$$

Reduction

$$O_2\uparrow + 4H^+ + 4e \rightleftharpoons 2H_2O$$

$$NO_3^- + 6H^+ + 5e \rightleftharpoons \tfrac{1}{2}N_2\uparrow + 3H_2O$$

$$CO_2 + 8H^+ + 8e\uparrow \rightleftharpoons CH_4 + 2H_2O$$

Bacteria are involved in many biogeochemical processes in water and soil and in many important elemental cycles in nature, including those of nitrogen, carbon and sulphur. They help in the formation of many mineral deposits including some of those of iron and manganese. Bacteria are also instrumental in the formation of iron and manganese deposits in natural water systems and pipes used to transport water.

Nitrogen Transformations by Bacteria

The nitrogen cycle is one of the most important micro-organism mediated chemical reaction in aquatic and soil environments. It is based four important chemical transformations.

(a) Nitrogen fixation whereby molecular N_2 is fixed as organic nitrogen.

(mainly byRhizobium bacteria):

$$3\{CH_2O\} + 2N_2 + 3H_2O + 4H^+ \rightarrow 3CO_2 + 4NH^+_4$$

(b) Nitrification which is the process of oxidizing $NH_3$to NO^-_3,(by Nitrosamines and Nitrobacterbacteria)

$$NH_3 + 3/2\ O_2 \longrightarrow H^+ + NO^-_2 + H_2O$$

$$NO^-_2 + \tfrac{1}{2}\ O_2 \longrightarrow NO^-_3$$

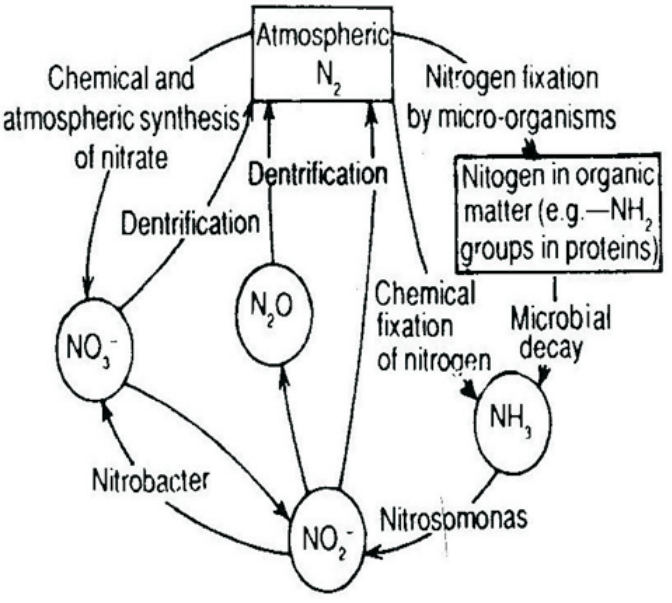
(c) Nitrate reduction

$$\tfrac{1}{2}NO^-_3 + \tfrac{1}{4}\{CH_2O\} \rightarrow \tfrac{1}{2}NO^-_2 + \tfrac{1}{4}H_2O + \tfrac{1}{4}CO_2$$

(d) Denitrificationwhich involves the reduction of NO_3 and NO^-_3 toNO^-_2, followed by recycling of N_2 to the atmosphere:

$$4NO^-_3 + 5\{CH_2O) + 4H^+ \rightarrow 2N_2 + 5CO_2\uparrow + 7H_2O\uparrow$$

The nitrogen cycle, one of nature's most vital dynamic processes, is illustrated in Fig



The nitrogen cycle (Reprinted by permission of Brooks/Cole Publishing Company Monteary, California 93940, U.S.A. from Environmental Chemistry, 3rdedn., S. E. Manahan, 96, 1979. Willard Grant Press, Statler Office Building, Boston, Massachusetts)

CONCLUSION

Water is essential for life and makes up the major part of living tissue. The nature of hydrogen bonds allows water to bond with other water molecules as well as with sugar, starches, pectins, and proteins. Water absorbs energy as it changes from frozen to liquid to vapor state, and is an effective cooling medium. If water is easily extracted from foods by squeezing, or pressing, it is known as free water. Inversely, water that is not easily removed from foods and that is not free to act as a solvent is known as bound water; water in foods imparts freshness. A measure of water activity is the ratio of the vapor pressure of water in a solution to the vapor pressure of pure water. If water is unavailable for pathogenic or spoilage-causing bacteria to multiply, food is better preserved and has a longer shelf life.

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