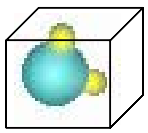
CAL WATER

Industrial Water Purification
(800) CAL-WATER

Water
The Universal Solvent

Molecular Weight:	18.016	
Freezing Point:	0 °C	-32 °F
Boiling Point:	100 °C	212 °F
Density:	1 g/cc (Def. of 1 gram)	
Specific Gravity:	1 (Basis of)	
Specific Heat:	1 (Basis of)	
Electrical Resistance:	18.3 Megohms/cc (Pure, At STP)	
pH:	7.0	

The Molecule:



H_2O

Water is the common name applied to the liquid state of the hydrogen-oxygen compound H_2O. The ancient philosophers regarded water as a basic element typifying all liquid substances. Scientists did not discard that view until the latter half of the 18th century.

In 1781 the British chemist Henry Cavendish synthesized water by detonating a mixture of hydrogen and air. However, the results of his experiments were not clearly interpreted until two years later, when the French chemist Lavoisier proved that water was not an element but a compound of oxygen and hydrogen.

In a scientific paper presented in 1804, the French chemist Gay-Lussac and the German naturalist Alexander von Humboldt demonstrated jointly that water consisted of two volumes of hydrogen to one of oxygen, as expressed by the present-day formula H_2O.

Properties

Pure water is an odorless, tasteless liquid. It has a bluish tint, which may be detected, however, only in layers of considerable depth. Under standard atmospheric pressure (760 mm of mercury, the freezing point of water is 0° C (32° F) and its boiling point is 100° C (212° F).

Water attains its maximum density at a temperature of 4° C (39° F) and unlike most substances, expands upon freezing. Water can exist in a super-cooled state; that is, it may remain as a liquid although its temperature is below its freezing point. Water can easily be cooled to about -25° C (-13° F) without freezing, either under laboratory conditions or in the atmosphere itself. Super-cooled water will freeze if it is disturbed, if the temperature is lowered further, or if an ice crystal or other particle is added to it.

Its physical properties are used as standards to define the calorie and specific and latent heat and in the metric system for the original definition of the unit of mass, the gram. Water is one of the best-known ionizing agents.

Most substances are at least somewhat soluble in water. Water combines with certain salts to form hydrates. It reacts with metal oxides to form acids. It acts as a catalyst in many important chemical reactions. Water will dissolve more substances than sulfuric acid. For these reasons water is frequently called "**The Universal Solvent**."

Occurrence

Water is the only substance that occurs at ordinary temperatures in all three states of matter, that is, as a solid, a liquid, and a gas. As a solid, or ice, it is found as glaciers and ice caps, on water surfaces in winter, as snow, hail, and frost, and as clouds formed of ice crystals. It occurs in the liquid state as rain clouds formed of water droplets, and on vegetation as dew; in addition, it covers three-quarters of the surface of the earth in the form of swamps, lakes, rivers, and oceans. As gas, or water vapor, it occurs as fog, steam, and clouds.

Atmospheric vapor is measured in terms of relative humidity, which is the ratio of the quantity of vapor actually present to the greatest amount possible at a given temperature.

Water occurs as moisture in the upper portion of soil, in which it is held by capillary action to the particles of soil. In this state, it is called bound water and has different characteristics from free water. Under the influence of gravity, water accumulates in rock interstices beneath the surface of the earth as a vast groundwater reservoir supplying wells and springs and sustaining the flow of some streams during periods of drought.

Natural Water Cycle

Hydrology is the science concerned with the distribution of water on the earth, its physical and chemical reactions with other naturally occurring substances, and its relation to life on earth; the continuous movement of water between the earth and the atmosphere is known as the hydrological cycle. Under several influences, of which heat is predominant, water is evaporated from both water and land surfaces and is transpired from living cells. This vapor circulates through the atmosphere and is precipitated in the form of rain or snow.

On striking the surface of the earth, the water follows two paths. In amounts determined by the intensity of the rain and the porosity, permeability, thickness, and previous moisture content of the soil, one part of the water, termed surface runoff, flows directly into rills and streams and on into oceans or landlocked bodies of water; the remainder infiltrates into the soil. A part of the infiltrated water becomes soil moisture, which may be evaporated directly or may move upward through the roots of vegetation to be transpired from leaves. The portion of the water that overcomes the forces of cohesion and adhesion in the soil profile percolates downward, accumulating in the so-called zone of saturation to form the groundwater reservoir, the surface of which is known as the water table. Under natural conditions, the water table rises intermittently in response to replenishment, or recharge, and then declines as a result of continuous drainage into natural outlets such as springs.

Composition

Because of its capacity to dissolve numerous substances in large amounts, pure water rarely occurs in nature. During condensation and precipitation, rain or snow absorbs from the atmosphere varying amounts of carbon dioxide and other gases, as well as traces of organic and inorganic material. In addition, precipitation carries radioactive fallout to the earth's surface. In its movement on and through the earth's crust, water reacts with minerals in the soil and rocks. The principal dissolved constituents of surface and groundwater are sulfates, chlorides, and bicarbonates of sodium and potassium and the oxides of calcium and magnesium. Surface waters may also contain domestic sewage and industrial wastes.

Water in Life

Water is the major constituent of living matter. From 50 to 90 percent of the weight of living organisms is water.

Protoplasm, the basic material of living cells, consists of a solution in water of fats, carbohydrates, proteins, salts, and similar chemicals. Water acts as a solvent, transporting, combining, and chemically breaking down these substances. Blood in animals and sap in plants consist largely of water and serve to transport food and remove waste material. Water also plays a key role in the metabolic breakdown of such essential molecules as proteins and carbohydrates. This process, called hydrolysis, goes on continually in living cells.

Impurities

Properly treated municipal water though safe to drink contains a variety of extraneous matter that could adversely affect aqueous manufacturing processes. The three major categories of impurities that are found in city water are organics, suspended solids and dissolved solids.

Ground waters from shallow wells may contain large quantities of nitrogen compounds and chlorides derived from human and animal wastes. Waters from deep wells generally contain only minerals in solution such as calcium, magnesium and sodium salts. Almost all supplies of natural drinking water contain fluorides in varying amounts. The proper proportion of fluorides in drinking water has been found to reduce tooth decay.

Seawater contains, in addition to concentrated amounts of sodium chloride, or salt, many other soluble compounds, as the impure waters of rivers and streams are constantly feeding the oceans. At the same time, pure water is continually lost by the process of evaporation, and as a result the proportion of the impurities that give the oceans their saline character is increased.

Organic Contamination

Organic contamination is anything living, previously living, and/or anything that contains carbon except carbon dioxide. Biological contaminants include bacteria, algae, molds, amoeba, and any other microorganism. Non-living organic compounds include all the three letter carcinogens such as THM, TCE, etc., plus thousands of others.

Particulate Matter

City water contains suspended solids in the form of turbidity. While all city water normally contains some turbidity, the problem is aggravated anytime there is a heavy water use out of the city water main, up or down stream. If, for example, there is a fire anywhere in the area, the velocity increases through the main line to the hydrant(s) being used, which kicks up all the settled solids in the city main which in turn causes water users in the area to receive heavily turbid water.

Particulate impurities come in all shapes, sizes and materials, such as silt, clay, colloids, organic material, and anything else that won't dissolve in water.

Dissolved Solids

Most of the dissolved solids in water are salts of common metals. These solids become ionized. Ions are electrically charged atoms or groups of atoms that may be positively or negatively charged Examples: ions of metals such as calcium Ca^{++}, magnesium Mg^{++}, sodium Na^{+} and of hydrogen H^{+} are positively charged and are called CATIONS. Their charges are balanced by negatively charged ANIONS such as chloride Cl- and sulfate SO4=.

Hardness

Hardness of natural waters is caused largely by calcium and magnesium salts and to a small extent by iron, aluminum, and other metals. Hardness resulting from the bicarbonates and carbonates of calcium and magnesium is called temporary hardness and can be removed by boiling, which also sterilizes the water. The residual hardness is known as non-carbonate, or permanent, hardness. The methods of softening non-carbonate hardness includes the addition of sodium carbonate and lime and filtration through natural or artificial ion exchange media which absorb the hardness-producing metallic ions and release sodium ions to the water.

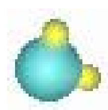
Sequestering agents in detergents serve to inactivate the substances that make water hard. Iron, which causes an unpleasant taste in drinking water, may be removed by aeration and sedimentation or by passing the water through Manganese Green sand filters, or the iron may be stabilized by addition of such salts as polyphosphates.

Measuring Impurities
Most impurities in water are described by the weight of the impurity verses the weight of a specific volume of water. They are typically measured in either parts per million (ppm) or grains per gallon (gpg).

Parts Per Million (ppm) is a common unit of measure used to express the number of parts of a substance contained within a million parts of a liquid. Parts per million is interchangeable with "milligrams per liter" in water treatment calculations. The ppm of an impurity is the weight of the impurity, typically measured in milligrams, in a liter of water (mg/l).

Grains Per Gallon (gpg). A grain is a unit of weight measure equivalent to 1/7,000th of a pound. A Grain per gallon is the weight of one grain of impurity per gallon of water. To convert to grains per gallon from parts per million, divide the ppm by 17.1.

Hard Water: Slightly hard = 1 to 3.5 grains per gallon. Moderately hard = 3.5 to 7 grains per gallon. Hard water = 7 to 10.5 grains per gallon. Very hard = 10.5 grains per gallon +.



Water Purification
As seen above, there are a variety of impurities present in naturally occurring water that can make it unsuitable for many purposes.

Objectionable organic and inorganic materials are removed by such methods as screening and sedimentation to eliminate suspended materials; treatment with such compounds as activated carbon to remove tastes and odors; filtration; and chlorination or irradiation to kill infective microorganisms. Modern water treatment can remove all the above with one or more of the following technologies: Chlorination, Activated Carbon Filtration, UV Sterilization and Anion Adsorption.

Industrial high purity water system consists of three steps: 1) Ultraviolet radiation to destroy microorganisms, 2) Filtration to remove particulate material, and 3) Deionization to remove dissolved or ionized solids.

Particle Filtration
The removal of troublesome particles from water is a straightforward process. Particulate impurities can be cheaply and easily removed using mechanical filters. Where high flow rates or heavy particulate loading is expected, sand or multimedia filtration is available which can filter out particles to 10 20 microns in size. Even finer particle filtration can be provided using cartridge filtration, down to a micron and smaller. Membrane filters such as ultrafilter and nanofilter membranes, can remove particles measured in nanometers.

Activated Carbon Filtration
In commercial water treatment, activated carbon is most often used for chlorine removal.

Though all organic impurities can be removed by sufficient activated carbon, any live microorganisms trapped by the carbon can begin reproducing, turning activated carbon into an effective a breeding medium.

Deionization

Deionization of water is accomplished using specifically treated ion exchange resins. Ion exchange resins are plastic beads made out of styrene cross-linked with divynalbenzene. The beads are then either cooked in sulfuric acid to provide sulfite negatively charged sites, or an ammonium salt solution to provide positively charged quaternary ammonium sites. It is the charged sites that give the resin beads their ion exchange properties.

Deionizers remove dissolved solids chemically. Ionized solids by definition have either a positive or negative charge. Cation resin removes positively charged impurities such as calcium (Ca++), magnesium (Mg++), sodium (Na+) and potassium (K+). The impurities attach themselves to sites on the ion exchange resin, eluting off hydrogen (+H). As soon as all the sites are taken up, the resin must be regenerated with an acid such as hydrochloric acid (HCl) or sulfuric acid (H2SO4). NOTE: The cation exchanger should be regenerated with the acid it was designed for. Using the wrong acid will change all the capacity calculations and could ruin the system.

Anion resin removes negatively charged impurities such as chloride (Cl), sulfate (SO4) and carbonate (CO3). The impurities attach themselves to sites on the ion exchange resin, eluting off hydroxyl radical (OH). As soon as all the sites are taken up, the resin must be regenerated with caustic soda (NaOH). NOTE: The anion exchanger must be regenerated using soft water. If hard water is used, the resin can become hardness fouled drastically reducing capacity.

In Mixed bed deionization the two types of resin are mixed after regeneration and placed in the same vessel. The purpose of mixing the resins is to achieve a very high quality deionized water. When the resins are mixed, as the water passes through the resin bed it encounters a cation resin bead, then an anion resin bead, then cation, anion, cation, anion and so forth. The water is deionized then re deionized continually resulting in an ultra high purity product. The regeneration of a mixed bed is expensive and difficult, but the product water is the highest quality obtainable.

Portable exchange (regeneration by others off site) is often selected because of the difficulty of regeneration, the necessity for storing and handling hazardous chemicals and the problem of proper wastewater disposal.

Reverse Osmosis

In the process of reverse osmosis (RO), water is pumped at high pressures from 100 to 600 psi , depending on osmotic backpressure, through a semi permeable membrane leaving dissolved and particulate materials behind. The process works on a percent recovery basis. Typically for every three gallons of product water there will be one gallon of wastewater. The wastewater carries away all the solids that are separated from the product water by the membrane.

The effectiveness of the rejection of dissolved ionic material is a function of both molecular weight and ionic charge. The larger heavier ions are more completely rejected than smaller lighter ones. Substances with a molecular weight of over 100 will be completely rejected by an R.O. membrane.

Electrodialysis

Electrodialysis, or ED (EDI) takes advantage of the ionization of salt in water. When salt dissolves in water, it splits into charged positive and negative ions. When water passes through an ED column, the charged ions in the water are attracted by perpendicular positively and negatively charges from plates on either side of the flow. As the ions move toward the charged plates they migrate through cation or anion membranes and then are rinsed to waste, the ion free water then passes out of the column as pure water.

Distillation: Perhaps the oldest technique for water purification is the boiling of water. Boiling water killed any organisms present, helped precipitate some of the salts present, drove off carbon dioxide gas, and in short, made water fit to drink.

Distillation
Distillation is the process where water is boiled to steam that is then put through a condenser where it is turned back into water and collected.

The distillation procedure for demineralizing water has been successfully used through the ages as a means to obtain pure water. Until the middle of the 20th century it was the ONLY way to demineralize water.

Distillation as a method of water purification is costly in energy and slow. As distillation proceeds, electrolytes dissolved in water can precipitate out of solution and unless properly controlled by continual wastewater flow, cause deposits and scale on expensive distillation equipment. Single distilled water isn't all that pure. Some electrolytes aerosol over into the distillate yielding a less-than-pure water. Any substance in the water with a vapor pressure equal to or greater than that of water goes over as well. Multiple distillations are required to get a truly reagent grade of water.

With the notable exception of vacuum distillation and similar technologies for desalination, about the best thing that can be said about distillation is that it is traditional.

Ultraviolet Sterilization
Ultraviolet radiation is used primarily to kill any microorganisms present. The subject water is exposed to electro magnetic radiation of a wavelength of 2537 angstroms. The quantity of radiation necessary is 30,000 to 40,000 microwatts seconds per square centimeter. It will kill bacteria, viruses, fungi and any other type of microorganism.

Since UV acts as an oxidizing agent, especially at a wavelength of 185 nm, with sufficient exposure it will break up non-living organics thereby reducing the Total Organic Carbon (TOC) in the water.

The variables associated with UV are flow rate, water clarity, tube clarity and the quantity of the proper wavelength radiation available.

Aeration
In aeration, or the saturation of water with air, water is brought into contact with air in such a manner as to produce maximum diffusion, usually by spraying water into the air in fountains. Aeration removes odors and taste caused by decomposing organic matter, and also industrial wastes such as phenols and volatile gases such as chlorine. It also converts dissolved iron and manganese compounds into insoluble hydrated oxides of the metals that may then be readily settled out.

Desalination of Seawater
The-increasing demand for fresh water has fueled research on efficient methods of removing salt from seawater and brackish waters. Drinking water is potable if it contains 500 parts per million or less of dissolved solids. Understandably, the process of desalting seawater from 35,000 parts per million down to 500 parts per million is a challenge.

The two primary process used in desalination, (AKA, desalinization) today are modern distillation and reverse osmosis.

Distillation

As noted above, the process of distillation for water purification has been known for centuries. The problem has always been the cost. Boiling seawater, then condensing the resultant steam into fresh water takes large amounts of energy. But scientists and engineers have come up with some very clever ways to distill water very efficiently. Multiple-effect evaporation, vapor-compression distillation, and flash evaporation are some examples. Currently flash evaporation is the most widely used and involves heating seawater and pumping it into lower-pressure tanks, where the water abruptly vaporizes (flashes) into steam. The steam then condenses and is drawn off as pure water.

Reverse Osmosis

In reverse osmosis, seawater is pumped through a semi-permiable membrane at high pressure, 400-800 psi, that forces water through the membrane, but not the salt.

A Matter of Economics

Drought is largely a Matter of Economics. Water from conventional sources, such as wells and reservoirs, currently costs about 25 cents per 100 cubic feet for potable use, and about 5 cents per 100 cubic feet for crop irrigation.

Using conventional technology and fuels, plants with a capacity of 1 million gallons per day can produce water at a cost of about 75 cents per 100 cubic feet. With advances in technology, seawater-desalting plants are being designed to produce fresh water for between 30 and 50 cents per 100 cubic feet. But even with these advances, the costs associated with desalinization plants limits their use to arid areas where the people have money. The bottom line is that, we can have all the fresh water we want, if we can pay for it.

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