

Chapter 1 : FAQ: Water and the temperature scale

Scale deposits are a typical indicator of hard water. Hard water is a common quality of water which contains dissolved compounds of calcium and magnesium and, sometimes, other divalent and trivalent metallic elements.

The water cycle known scientifically as the hydrologic cycle refers to the continuous exchange of water within the hydrosphere, between the atmosphere, soil water, surface water, groundwater, and plants. Water moves perpetually through each of these regions in the water cycle consisting of following transfer processes: Precipitation, at a rate of T_t per year over land, has several forms: Water runoff often collects over watersheds flowing into rivers. A mathematical model used to simulate river or stream flow and calculate water quality parameters is a hydrological transport model. Some water is diverted to irrigation for agriculture. Rivers and seas offer opportunity for travel and commerce. Through erosion, runoff shapes the environment creating river valleys and deltas which provide rich soil and level ground for the establishment of population centers. A flood occurs when an area of land, usually low-lying, is covered with water. It is when a river overflows its banks or flood comes from the sea. A drought is an extended period of months or years when a region notes a deficiency in its water supply. This occurs when a region receives consistently below average precipitation.

Fresh water storage Main article: Water resources The Bay of Fundy at high tide left and low tide right Some runoff water is trapped for periods of time, for example in lakes. At high altitude, during winter, and in the far north and south, snow collects in ice caps, snow packs and glaciers. Water also infiltrates the ground and goes into aquifers. This groundwater later flows back to the surface in springs, or more spectacularly in hot springs and geysers. Groundwater is also extracted artificially in wells. This water storage is important, since clean, fresh water is essential to human and other land-based life. In many parts of the world, it is in short supply.

Sea water and tides Main articles: Seawater and Tides Sea water contains about 3. The physical properties of sea water differ from fresh water in some important respects. The salinity of water in major seas varies from about 0. Tides are the cyclic rising and falling of local sea levels caused by the tidal forces of the Moon and the Sun acting on the oceans. Tides cause changes in the depth of the marine and estuarine water bodies and produce oscillating currents known as tidal streams. The changing tide produced at a given location is the result of the changing positions of the Moon and Sun relative to the Earth coupled with the effects of Earth rotation and the local bathymetry. The strip of seashore that is submerged at high tide and exposed at low tide, the intertidal zone, is an important ecological product of ocean tides. Effects on life An oasis is an isolated water source with vegetation in a desert. Overview of photosynthesis and respiration. Water at right, together with carbon dioxide CO_2 , form oxygen and organic compounds at left, which can be respired to water and CO_2 . From a biological standpoint, water has many distinct properties that are critical for the proliferation of life. It carries out this role by allowing organic compounds to react in ways that ultimately allow replication. All known forms of life depend on water. Metabolism is the sum total of anabolism and catabolism. In anabolism, water is removed from molecules through energy requiring enzymatic chemical reactions in order to grow larger molecules e. In catabolism, water is used to break bonds in order to generate smaller molecules e. Without water, these particular metabolic processes could not exist. Water is fundamental to photosynthesis and respiration. Hydrogen is combined with CO_2 absorbed from air or water to form glucose and release oxygen [citation needed]. Water is also central to acid-base neutrality and enzyme function. Water is considered to be neutral, with a pH the negative log of the hydrogen ion concentration of 7. Acids have pH values less than 7 while bases have values greater than 7. Aquatic life forms Some of the biodiversity of a coral reef Some marine diatoms " a key phytoplankton group Earth surface waters are filled with life. The earliest life forms appeared in water; nearly all fish live exclusively in water, and there are many types of marine mammals, such as dolphins and whales. Some kinds of animals, such as amphibians, spend portions of their lives in water and portions on land. Plants such as kelp and algae grow in the water and are the basis for some underwater ecosystems. Plankton is generally the foundation of the ocean food chain. Aquatic vertebrates must obtain oxygen to survive, and they do so in various ways. Fish have gills instead of lungs, although some species of fish, such as the lungfish, have both. Marine mammals, such as dolphins, whales,

otters , and seals need to surface periodically to breathe air. Some amphibians are able to absorb oxygen through their skin. Invertebrates exhibit a wide range of modifications to survive in poorly oxygenated waters including breathing tubes see insect and mollusc siphons and gills Carcinus. However as invertebrate life evolved in an aquatic habitat most have little or no specialisation for respiration in water. Effects on human civilization This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. May Water fountain Civilization has historically flourished around rivers and major waterways; Mesopotamia , the so-called cradle of civilization, was situated between the major rivers Tigris and Euphrates ; the ancient society of the Egyptians depended entirely upon the Nile. Rome was also founded on the banks of the Italian river Tiber. Islands with safe water ports, like Singapore, have flourished for the same reason. In places such as North Africa and the Middle East, where water is more scarce, access to clean drinking water was and is a major factor in human development. Health and pollution An environmental science program â€” a student from Iowa State University sampling water Water fit for human consumption is called drinking water or potable water. Water that is not potable may be made potable by filtration or distillation , or by a range of other methods. Water that is not fit for drinking but is not harmful for humans when used for swimming or bathing is called by various names other than potable or drinking water, and is sometimes called safe water , or "safe for bathing". Chlorine is a skin and mucous membrane irritant that is used to make water safe for bathing or drinking. Its use is highly technical and is usually monitored by government regulations typically 1 part per million ppm for drinking water, and 1â€”2 ppm of chlorine not yet reacted with impurities for bathing water. Water for bathing may be maintained in satisfactory microbiological condition using chemical disinfectants such as chlorine or ozone or by the use of ultraviolet light. In the US, non-potable forms of wastewater generated by humans may be referred to as greywater , which is treatable and thus easily able to be made potable again, and blackwater , which generally contains sewage and other forms of waste which require further treatment in order to be made reusable. These terms may have different meanings in other countries and cultures. This natural resource is becoming scarcer in certain places, and its availability is a major social and economic concern. Currently, about a billion people around the world routinely drink unhealthy water. Most countries accepted the goal of halving by the number of people worldwide who do not have access to safe water and sanitation during the G8 Evian summit. Poor water quality and bad sanitation are deadly; some five million deaths a year are caused by polluted drinking water. The World Health Organization estimates that safe water could prevent 1.

Chapter 2 : Water - Wikipedia

The stochastic modeling of water demand requires knowledge of the statistical features of the demand time series at different spatial and temporal aggregations. The observation of real data has revealed the presence of a nontrivial scaling of the second-order moments with the number of customers.

Cohesion refers to the fact that water sticks to itself very easily. Adhesion means that water also sticks very well to other things, which is why it spreads out in a thin film on certain surfaces, like glass. When water comes into contact with these surfaces, the adhesive forces are stronger than the cohesive forces. Instead of sticking together in a ball, it spreads out. Water also has a high level of surface tension. These molecules cohere to each other strongly but adhere to the other medium weakly. One example of this is the way that water beads up on waxy surfaces, such as leaves or waxed cars. Surface tension makes these water drops round so they cover the smallest possible surface area. Capillary action is also a result of surface tension. As we mentioned, this happens in plants when they "suck up" water. This makes the water rise and cohere to itself again, a process that continues until enough water builds up to make gravity begin pulling it back down. Ice is less dense than water because water molecules form crystalline structures at freezing 32 degrees Fahrenheit or 0 degrees Celsius temperatures. The thermal properties of water are also linked to its hydrogen bonds. Water has a very high specific heat capacity, which is the amount of heat per unit mass required to raise its temperature by one degree Celsius. The energy required to raise the temperature of water by one degree Celsius is 4. Water also has a high heat of vaporization, which means that it can take a lot of heat without its temperature rising much. This plays a huge part in the climate, because it means that oceans take a long time to warm up. Water is often known as the universal solvent, which means that many substances dissolve in it. Substances that dissolve in water are hydrophilic. Salt and sugar are both polar, like water, so they dissolve very well in it. Substances that do not dissolve in water are hydrophobic. The presence of these minerals is the difference between hard water and soft water. Hard water usually contains a lot of calcium and magnesium, but may also contain metals. It can also cause lime scale deposits in pipes, water heaters and toilets. Others claim that it forms an entirely new structure. For lots more information about water and related topics, check out the links below.

Chapter 3 : Hard water - Wikipedia

The stochastic modeling of water demand requires knowledge of the statistical features of the demand time series at different spatial and temporal aggregations. The observation of real data has.

Scaling Scaling in boilers Boiler scale is caused by impurities being precipitated out of the water directly on heat transfer surfaces or by suspended matter in water settling out on the metal and becoming hard and adherent. Evaporation in a boiler causes impurities to concentrate. This interferes with heat transfers and may cause hot spots. Leading to local overheating. The deposition of crystalline precipitates on the walls of the boiler interferes with heat transfer and may cause hot spots, leading to local overheating. The less heat they conduct, the more dangerous they are. Common feed water contaminants that can form boiler deposits include calcium , magnesium , iron , aluminum , and silica. Scale is formed by salts that have limited solubility but are not totally insoluble in boiler water. These salts reach the deposit site in a soluble form and precipitate. The values corresponding to their thermal conductivity are: A carbonate deposit is usually granular and sometimes of a very porous nature. The crystals of calcium carbonate are large but usually are matted together with finely divided particles of other materials so that the scale looks dense and uniform. Dropping it in a solution of acid can easily identify a carbonate deposit. Bubbles of carbon dioxide will effervesce from the scale. A sulphate deposit is much harder and more dense than a carbonate deposit because the crystals are smaller and cement together tighter. A Sulphate deposit is brittle, does not pulverize easily, and does not effervesce when dropped into acid. A high silica deposit is very hard, resembling porcelain. The crystal of silica are extremely small, forming a very dense and impervious scale. This scale is extremely brittle and very difficult to pulverize. It is not soluble in hydrochloric acid and is usually very light coloured. Iron deposits, due either to corrosion or iron contamination in the water, are very dark coloured. Iron deposits in boilers are most often magnetic. They are soluble in hot acid giving a dark brown coloured solution. If unchecked, scaling causes progressive lowering of the boiler efficiency by heat retardation, acting as an insulator. Eventually, scale built-up will cause the tube to overheat and rupture. Boiler deposits can also cause plugging or partial obstruction of corrosive attack underneath the deposits may occur. In general, boiler deposits can cut operating efficiency, produce boiler damage, cause unscheduled boiler outages, and increase cleaning expense. The first anti-scaling preventative measure is to supply good quality demineralised water as make-up feed water. The purer the feed water is, the weaker the driving mechanism to form scale. Scale-forming minerals that do enter the boiler can be rendered harmless by internal chemical treatment. A long-established technique is to detach the hardness cations, magnesium and calcium, from the scale forming minerals and to replace them with sodium ions. Presence of Silica Silica can vaporize into the steam at operating pressures as low as 28 bars. Its solubility in steam increases with increased temperature; therefore, silica becomes more soluble as steam is superheated. The conditions under which vaporous silica carryover occurs have been thoroughly investigated and documented. Researchers have found that for any given set of boiler conditions using demineralized or evaporated quality make-up water, silica is distribute between the boiler water and the steam in a definite ratio. This ratio depends on two factors: The value of the ratio increases almost logarithmically with increasing pressure and decreases with increasing pH. If the silica enters the boiler water, the usual corrective action is to increase boiler blowdown, to decrease it to acceptable levels and then to correct the condition that caused the silica contamination. For further information check our web page about silica scaling in boilers. Find information about the other main problems occurring in boilers: Check also our web page about boiler water treatment , in particular through deaeration deaerating heaters or membrane contractors.

Chapter 4 : Scaling and antiscalants - Lenntech

neous in space and stationary in time, the following expression This brief review shows that the spatial and temporal scaling can be written: properties of water demand represents a key point for a correct n stochastic modeling of water consumption.

Fouling Deposit accumulations in cooling water systems reduce the efficiency of heat transfer and the carrying capacity of the water distribution system. In addition, the deposits cause oxygen differential cells to form. These cells accelerate corrosion and lead to process equipment failure. Deposits range from thin, tightly adherent films to thick, gelatinous masses, depending on the depositing species and the mechanism responsible for deposition. Deposit formation is influenced strongly by system parameters, such as water and skin temperatures, water velocity, residence time, and system metallurgy. With the introduction of high-efficiency film fill, deposit accumulation in the cooling tower packing has become an area of concern see Figure Deposits are broadly categorized as scale or foulants. SCALE Scale deposits are formed by precipitation and crystal growth at a surface in contact with water. Precipitation occurs when solubilities are exceeded either in the bulk water or at the surface. The most common scale-forming salts that deposit on heat transfer surfaces are those that exhibit retrograde solubility with temperature. Although they may be completely soluble in the lower-temperature bulk water, these compounds e. Scaling is not always related to temperature. Calcium carbonate and calcium sulfate scaling occur on unheated surfaces when their solubilities are exceeded in the bulk water see Figure Metallic surfaces are ideal sites for crystal nucleation because of their rough surfaces and the low velocities adjacent to the surface. Corrosion cells on the metal surface produce areas of high pH, which promote the precipitation of many cooling water salts. Once formed, scale deposits initiate additional nucleation, and crystal growth proceeds at an accelerated rate. Scale control can be achieved through operation of the cooling system at subsaturated conditions or through the use of chemical additives. Operational Control The most direct method of inhibiting formation of scale deposits is operation at subsaturation conditions, where scale-forming salts are soluble. However, in most cases, high blowdown rates and low pH are required so that solubilities are not exceeded at the heat transfer surface. In addition, it is necessary to maintain precise control of pH and concentration cycles. Minor variations in water chemistry or heat load can result in scaling see Figure Chemical Additives Scaling can be controlled effectively by the use of sequestering agents and chelates , which are capable of forming soluble complexes with metal ions. The precipitation properties of these complexes are not the same as those of the metal ions. Classic examples of these materials are ethylenediaminetetraacetic acid EDTA for chelating calcium hardness, and polyphosphates for iron Figure This approach requires stoichiometric chemical quantities. Therefore, its use is limited to waters containing low concentrations of the metal. Deposit control agents that inhibit precipitation at dosages far below the stoichiometric level required for sequestration or chelation are called "threshold inhibitors. Threshold inhibitors function by an adsorption mechanism. As ion clusters in solution become oriented, metastable microcrystallites highly oriented ion clusters are formed. At the initial stage of precipitation, the microcrystallite can either continue to grow forming a larger crystal with a well defined lattice or dissolve. Threshold inhibitors prevent precipitation by adsorbing on the newly emerging crystal, blocking active growth sites. This inhibits further growth and favors the dissolution reaction. The precipitate dissolves and releases the inhibitor, which is then free to repeat the process. Threshold inhibitors delay or retard the rate of precipitation. Crystals eventually form, depending on the degree of supersaturation and system retention time. After stable crystals appear, their continued growth is retarded by adsorption of inhibitor. The inhibitor blocks much of the crystal surface, causing distortions in the crystal lattice as growth continues. The distortions defects in the crystal lattice create internal stresses, making the crystal fragile. Tightly adherent scale deposits do not form, because crystals that form on surfaces in contact with flowing water cannot withstand the mechanical force exerted by the water. The adsorbed inhibitor also disperses particles, by virtue of its electrostatic charge, and prevents the formation of strongly bound agglomerates. The most commonly used scale inhibitors are low molecular weight acrylate polymers and organophosphorus compounds phosphonates.

Both classes of materials function as threshold inhibitors; however, the polymeric materials are more effective dispersants. Selection of a scale control agent depends on the precipitating species and its degree of supersaturation. The most effective scale control programs use both a precipitation inhibitor and a dispersant. In some cases this can be achieved with a single component e. Langelier, published in , deals with the conditions at which a water is in equilibrium with calcium carbonate. An equation developed by Langelier makes it possible to predict the tendency of calcium carbonate either to precipitate or to dissolve under varying conditions. The equation expresses the relationship of pH, calcium, total alkalinity, dissolved solids, and temperature as they relate to the solubility of calcium carbonate in waters with a pH of 6. Their values for any given condition can be computed from known thermodynamic constants. Both the calcium ion and the alkalinity terms are the negative logarithms of their respective concentrations. The calcium content is molar, while the alkalinity is an equivalent concentration i . The calculation of the pHs has been simplified by the preparation of various nomographs. A typical one is shown in Figure This index is a qualitative indication of the tendency of calcium carbonate to deposit or dissolve. If the LSI is positive, calcium carbonate tends to deposit. If it is negative, calcium carbonate tends to dissolve. If it is zero, the water is at equilibrium. The LSI measures only the directional tendency or driving force for calcium carbonate to precipitate or dissolve. It cannot be used as a quantitative measure. Two different waters, one of low hardness corrosive and the other of high hardness scale-forming , can have the same Saturation Index. The Stability Index developed by Ryzner makes it possible to distinguish between two such waters. This index is based on a study of actual operating results with waters having various Saturation Indexes. Where the Stability Index exceeds 7. As the Stability Index rises above 7. Use of the LSI together with the Stability Index contributes to more accurate prediction of the scaling or corrosive tendencies of a water. Fouling mechanisms are dominated by particle-particle interactions that lead to the formation of agglomerates. At low water velocities, particle settling occurs under the influence of gravity see Figure Parameters that affect the rate of settling are particle size, relative liquid and particle densities, and liquid viscosity. The most important factor affecting the settling rate is the size of the particle. Because of this, the control of fouling by preventing agglomeration is one of the most fundamental aspects of deposition control. Foulants enter a cooling system with makeup water, airborne contamination, process leaks, and corrosion. Most potential foulants enter with makeup water as particulate matter, such as clay, silt, and iron oxides see Figure Insoluble aluminum and iron hydroxides enter a system from makeup water pretreatment operations. Some well waters contain high levels of soluble ferrous iron that is later oxidized to ferric iron by dissolved oxygen in the recirculating cooling water. Because it is very insoluble, the ferric iron precipitates. The steel corrosion process is also a source of ferrous iron and, consequently, contributes to fouling. Both iron and aluminum are particularly troublesome because of their ability to act as coagulants. Also, their soluble and insoluble hydroxide forms can each cause precipitation of some water treatment chemicals, such as orthophosphate. Airborne contaminants usually consist of clay and dirt particles but can include gases such as hydrogen sulfide, which forms insoluble precipitates with many metal ions. Process leaks introduce a variety of contaminants that accelerate deposition and corrosion. Foulants, such as river water silt, enter the system as finely dispersed particles, which can be as small as nm. The particles carry an electrostatic charge, which causes similarly charged particles to repel each other, favoring their dispersion. The net charge a particle carries depends on the composition of the water. Cycling of cooling water increases the concentration of counter-charged ions capable of being electrostatically attracted to and adsorbed onto a charged particle. As counterions adsorb, the net charge of the particle decreases. Particles begin to agglomerate and grow in size as their repulsive forces are diminished. Settling occurs when the energy imparted by fluid velocity can no longer suspend the particle, due to agglomeration and growth. After particles have settled, the nature of the deposit depends on the strength of the attractive forces between the particles themselves agglomerate strength and between the particles and the surface they contact. If attractive forces between particles are strong and the particles are not highly hydrated, deposits are dense and well structured; if the forces are weak, the deposits are soft and pliable. Deposition continues as long as the shear strength of the deposit exceeds the shear stress of the flowing water. Methods of fouling control are discussed in the following sections. Particulate removal can also be accomplished by filtration of recirculating

cooling water. These methods do not remove all of the suspended matter from the cooling water. The level of fouling experienced is influenced by the effectiveness of the particular removal scheme employed, the water velocities in the process equipment, and the cycles of concentration maintained in the cooling tower. High Water Velocities The ability of high water velocities to minimize fouling depends on the nature of the foulant. Clay and silt deposits are more effectively removed by high water velocities than aluminum and iron deposits, which are more tacky and form interlocking networks with other precipitates. Operation at high water velocities is not always a viable solution to clay and silt deposition because of design limitations, economic considerations, and the potential for erosion corrosion. Dispersants Dispersants are materials that suspend particulate matter by adsorbing onto the surface of particles and imparting a high charge. Electrostatic repulsion between like-charged particles prevents agglomeration, which reduces particle growth.

Chapter 5 : Scaling in boilers - Lenntech

Abstract. Variability of saturated hydraulic conductivity, k_{sat} , increases when sample size decreases implying that saturated water flow might be a scaling blog.quintoapp.com moments of scaling distributions observed at different resolutions can be related by a power-law function, with the exponent being a single value (simple scaling) or a function (multiscaling).

Scaling and Antiscalants Scaling and Antiscalants Scaling means the deposition of particles on a membrane, causing it to plug. Without some means of scale inhibition, reverse osmosis RO membranes and flow passages within membrane elements will scale due to precipitation of sparingly soluble gas, such as calcium carbonate, calcium sulfate, barium sulfate and strontium sulfate. Most natural waters contain relatively high concentrations of calcium, sulfate and bicarbonate ions. In membrane desalination operations at high recovery ratios, the solubility limits of gypsum and calcite exceed saturation levels leading to crystallization on membrane surfaces. The surface blockage of the scale results in permeate flux decline, reducing the efficiency of the process and increasing of operation costs. The effects of scale on the permeation rate of RO systems is illustrated in the following figure. Following an induction period, plant flow decrease rapidly. The length of this period varies with the type of scale and the degree of super saturation of the sparingly soluble salt. As it is evident from the graph, the induction period for calcium carbonate is much shorter than that for sulfate scales, such as calcium sulfate. It is economically preferable to prevent scaling formation, even if there are effective cleaners for scale. Scale often plugs RO element feed passages, making cleaning difficult and very time consuming. There is also the risk that scaling will damage membrane surface. There are three methods of scale control commonly employed: This is very effective in preventing the precipitation of calcium carbonate, but ineffective in preventing other types of scale. Additional disadvantages include the corrosivity of the acid, the cost of tanks and monitoring equipment and the fact that acid lowers the pH of the RO permeate. When all the sodium ions have been replaced by calcium and magnesium, the resin must be regenerated with a brine solution. Ion exchange softening eliminates the need for continuous feed of either acid or antiscalant. As a crystal begin to form at the submicroscopic level, negative groups located on the antiscalant molecule attack the positive charges on scale nuclei interrupting the electronic balance necessary to propagate the crystal growth. When treated with crystal modifiers, scale crystals appear distorted, generally more oval in shape, and less compact. The high anionic charge also separates particles from fixed anionic charges present on the membrane surface. Threshold Mechanism Dispersancy During the past two decades new generations of antiscalants have emerged commercially, in which the active ingredients are mostly proprietary mixtures of various molecular weight polycarboxylates and polyacrylates. Calculation procedures exist for predicting the likelihood of scale formation. Use of these predictors depends upon an up-to-date water analysis and a knowledge of system design parameters. The ions contained in the feed water concentrate through the RO system, the point of maximum scale potential is the concentrate stream. Antiscalant type and dosage is therefore based upon the mineral analysis at this point. It is important to find the optimization of antiscalant treatment with respect to type and dosage, identifying the proper antiscalant to use and the dosage-induction type relationship for the extended level of super saturation. Lenntech can help you in the selection of the best antiscalant for your particular application. Economical analysis Acid addition is not very cost effective because of the cost of acid, tanks and monitoring equipment. Unless removed by degasification, excess of carbon dioxide contained in the permeate of acid-fed systems increases the cost of ion exchange regeneration. Antiscalants are relatively cheap products and have no additional costs. When compared to either acid or antiscalant addition, the main disadvantage to softening is cost factoring in equipment costs. Through a present worth analysis there is no level of hardness in which softening competes economically with antiscalants addition. Footnote Skid mounted softeners, containing 40 ft³ 1,2m³ of resin each. Antiscalant equipment consists of feed tank and pumps. Antiscalant dosages range from 2 to 5 ppm.

Chapter 6 : Water Properties | HowStuffWorks

Water can moderate temperature because of the two properties: high-specific heat and the high heat of vaporization. High-specific heat is the amount of energy that is absorbed or lost by one gram of a substance to change the temperature by 1 degree celsius.

Yes, we start with the atom, and then go on to the rules governing the kinds of structural units that can be made from them. We are taught early on to predict the properties of bulk matter from these geometric arrangements. And then we come to H₂O, and are shocked to find that many of these predictions are way off, and that water and by implication, life itself should not even exist on our planet! But we soon learn that this tiny combination of three nuclei and eight electrons possesses special properties that make it unique among the more than 15 million chemical species we presently know. When we stop to ponder the consequences of this, chemistry moves from being an arcane science to a voyage of wonder and pleasure as we learn to relate the microscopic world of the atom to the greater world in which we all live. In water, each hydrogen nucleus is bound to the central oxygen atom by a pair of electrons that are shared between them; chemists call this shared electron pair a covalent chemical bond. In H₂O, only two of the six outer-shell electrons of oxygen are used for this purpose, leaving four electrons which are organized into two non-bonding pairs. The four electron pairs surrounding the oxygen tend to arrange themselves as far from each other as possible in order to minimize repulsions between these clouds of negative charge. This would ordinarily result in a tetrahedral geometry in which the angle between electron pairs and therefore the H-O-H bond angle is 109.5 degrees. However, because the two non-bonding pairs remain closer to the oxygen atom, these exert a stronger repulsion against the two covalent bonding pairs, effectively pushing the two hydrogen atoms closer together. Because molecules are smaller than light waves, they cannot be observed directly, and must be "visualized" by alternative means. This computer-generated image comes from calculations that model the electron distribution in the H₂O molecule. The outer envelope shows the effective "surface" of the molecule as defined by the extent of the cloud of negative electric charge created by the eight electrons. Hydrogen bonding The H₂O molecule is electrically neutral, but the positive and negative charges are not distributed uniformly. This is illustrated by the gradation in color in the schematic diagram here. This charge displacement constitutes an electric dipole, represented by the arrow at the bottom; you can think of this dipole as the electrical "image" of a water molecule. As we all learned in school, opposite charges attract, so the partially-positive hydrogen atom on one water molecule is electrostatically attracted to the partially-negative oxygen on a neighboring molecule. This process is called somewhat misleadingly hydrogen bonding. This means that it is considerably weaker; it is so weak, in fact, that a given hydrogen bond cannot survive for more than a tiny fraction of a second. See here for much more about hydrogen bonding. The anomalous properties of water Water has long been known to exhibit many physical properties that distinguish it from other small molecules of comparable mass. Chemists refer to these as the "anomalous" properties of water, but they are by no means mysterious; all are entirely predictable consequences of the way the size and nuclear charge of the oxygen atom conspire to distort the electronic charge clouds of the atoms of other elements when these are chemically bonded to the oxygen. Water is one of the few known substances whose solid form is less dense than the liquid. The other widely-cited anomalous property of water is its high boiling point. Notice that H-bonding is also observed with fluorine and nitrogen. The water strider takes advantage of the fact that the water surface acts like an elastic film that resists deformation when a small weight is placed on it. If you are careful, you can also "float" a small paper clip or steel staple on the surface of water in a cup. This is all due to the surface tension of the 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. This drawing highlights two H₂O molecules, one at the surface, and the other in the bulk of the liquid. As a consequence, a

molecule at the surface will tend to be drawn into the bulk of the liquid. But since there must always be some surface, the overall effect is to minimize the surface area of a liquid. The geometric shape that has the smallest ratio of surface area to volume is the sphere, so very small quantities of liquids tend to form spherical drops. As the drops get bigger, their weight deforms them into the typical tear shape. You will probably observe that the water does not cover the inside surface uniformly, but remains dispersed into drops. The same effect is seen on a dirty windshield; turning on the wipers simply breaks hundreds of drops into thousands. By contrast, water poured over a clean glass surface will wet it, leaving a uniform film. When a liquid is in contact with a solid surface, its behavior depends on the relative magnitudes of the surface tension forces and the attractive forces between the molecules of the liquid and of those comprising the surface. If an H₂O molecule is more strongly attracted to its own kind, then surface tension will dominate, increasing the curvature of the interface. This is what happens at the interface between water and a hydrophobic surface such as a plastic mixing bowl or a windshield coated with oily material. A clean glass surface, by contrast, has -OH groups sticking out of it which readily attach to water molecules through hydrogen bonding; this causes the water to spread out evenly over the surface, or to wet it. The value of this contact angle can be predicted from the properties of the liquid and solid separately. If we want water to wet a surface that is not ordinarily wettable, we add a detergent to the water to reduce its surface tension. A detergent is a special kind of molecule in which one end is attracted to H₂O molecules but the other end is not, so these ends stick out above the surface and repel each other, cancelling out the surface tension forces due to the water molecules alone. Water the liquid The nature of liquid water and how the H₂O molecules within it are organized and interact are questions that have attracted the interest of chemists for many years. There is probably no liquid that has received more intensive study, and there is now a huge literature on this subject. The following facts are well established: H₂O molecules attract each other through the special type of dipole-dipole interaction known as hydrogen bonding a hydrogen-bonded cluster in which four H₂O's are located at the corners of an imaginary tetrahedron is an especially favorable low-potential energy configuration, but A variety of techniques including infrared absorption, neutron scattering, and nuclear magnetic resonance have been used to probe the microscopic structure of water. The information garnered from these experiments and from theoretical calculations has led to the development of around twenty "models" that attempt to explain the structure and behavior of water. More recently, computer simulations of various kinds have been employed to explore how well these models are able to predict the observed physical properties of water. This work has led to a gradual refinement of our views about the structure of liquid water, but it has not produced any definitive answer. There are several reasons for this, but the principal one is that the very concept of "structure" and of water "clusters" depends on both the time frame and volume under consideration. Thus questions of the following kinds are still open: How do you distinguish the members of a "cluster" from adjacent molecules that are not in that cluster? Since individual hydrogen bonds are continually breaking and re-forming on a picosecond time scale, do water clusters have any meaningful existence over longer periods of time? In other words, clusters are transient, whereas "structure" implies a molecular arrangement that is more enduring. Can we then legitimately use the term "clusters" in describing the structure of water? The possible locations of neighboring molecules around a given H₂O are limited by energetic and geometric considerations, thus giving rise to a certain amount of "structure" within any small volume element. It is not clear, however, to what extent these structures interact as the size of the volume element is enlarged. And as mentioned above, to what extent are these structures maintained for periods longer than a few picoseconds? Current views of water structure The present thinking, influenced greatly by molecular modeling simulations beginning in the s, is that on a very short time scale less than a picosecond , water is more like a "gel" consisting of a single, huge hydrogen-bonded cluster. On a sec time scale, rotations and other thermal motions cause individual hydrogen bonds to break and re-form in new configurations, inducing ever-changing local discontinuities whose extent and influence depends on the temperature and pressure. This computer-generated nanoscale view of liquid water is from the lab of Gene Stanley of Boston University [source]. While this might prolong their lifetimes, it does not appear that they remain intact long enough to detect as directly observable entities in ordinary bulk water at normal pressures. It must be emphasized that no stable clustered unit or arrangement has ever been isolated or identified in pure

bulk liquid water. A report suggests that a simple tetrahedral arrangement is the only long-range structure that persists at time scales of a picosecond or beyond. But for an interesting and somewhat controversial alternative view, see this PDF article by the late Rustum Roy. Water clusters are of considerable interest as models for the study of water and water surfaces, and many articles on them are published every year. Some notable work reported in extended our view of water to the femtosecond time scale. The principal finding was that 80 percent of the water molecules are bound in chain-like fashion to only two other molecules at room temperature, thus supporting the prevailing view of a dynamically-changing, disordered water structure. Some recent work involving novel experimental and computational techniques has revealed more about water structure: Lawrence Livermore National Laboratory: Revealing the Mysteries of Water Water: Liquid and solid water Ice, like all solids, has a well-defined structure; each water molecule is surrounded by four neighboring H₂O's. The hydrogen bonds are represented by the dashed lines in this 2-dimensional schematic diagram. In reality, the four bonds from each O atom point toward the four corners of a tetrahedron centered on the O atom. This basic assembly repeats itself in three dimensions to build the ice crystal. When ice melts to form liquid water, the uniform three-dimensional tetrahedral organization of the solid breaks down as thermal motions disrupt, distort, and occasionally break hydrogen bonds. The methods used to determine the positions of molecules in a solid do not work with liquids, so there is no unambiguous way of determining the detailed structure of water. The illustration here is probably typical of the arrangement of neighbors around any particular H₂O molecule, but very little is known about the extent to which an arrangement like this gets propagated to more distant molecules. Here are three-dimensional views of a typical local structure of water left and ice right. Notice the greater openness of the ice structure which is necessary to ensure the strongest degree of hydrogen bonding in a uniform, extended crystal lattice. The more crowded and jumbled arrangement in liquid water can be sustained only by the greater amount thermal energy available above the freezing point. This Ice Structure page from U. The stable arrangement of hydrogen-bonded water molecules in ice gives rise to the beautiful hexagonal symmetry that reveals itself in every snowflake. For almost everything there is to know about snowflakes and a lot of nice images , see this SnowCrystals page from CalTech. Why is ice slippery? As the temperature approaches the freezing point, this region of disorder extends farther down from the surface and acts as a lubricant. The distilled or de-ionized water we use in the laboratory contains dissolved atmospheric gases and occasionally some silica, but their small amounts and relative inertness make these impurities insignificant for most purposes. When water of the highest obtainable purity is required for certain types of exacting measurements, it is commonly filtered, de-ionized, and triple-vacuum distilled. But even this "chemically pure" water is a mixture of isotopic species: And to top this off, the two hydrogen atoms in water contain protons whose magnetic moments can be parallel or antiparallel, giving rise to ortho- and para-water, respectively. The amount of the rare isotopes of oxygen and hydrogen in water varies enough from place to place that it is now possible to determine the age and source of a particular water sample with some precision. These differences are reflected in the H and O isotopic profiles of organisms. Thus the isotopic analysis of human hair can be a useful tool for crime investigations and anthropology research. See also this Microbe Forensics page , and this general resource on water isotopes.

Chapter 7 : Presaging Scale Formation Properties of Water

Water activities are an excellent way to get fit and get well. The unique physical properties of water provide an ideal healing environment for exercise and therapy and can have several advantages over land-based programs.

These ions enter a water supply by leaching from minerals within an aquifer. Common calcium -containing minerals are calcite and gypsum. A common magnesium mineral is dolomite which also contains calcium. Rainwater and distilled water are soft , because they contain few ions. Rain containing dissolved carbon dioxide can react with calcium carbonate and carry calcium ions away with it. The calcium carbonate may be re-deposited as calcite as the carbon dioxide is lost to atmosphere, sometimes forming stalactites and stalagmites. Calcium and magnesium ions can sometimes be removed by water softeners. Carbonate hardness Temporary hardness is a type of water hardness caused by the presence of dissolved bicarbonate minerals calcium bicarbonate and magnesium bicarbonate. The presence of the metal cations makes the water hard. However, unlike the permanent hardness caused by sulphate and chloride compounds , this "temporary" hardness can be reduced either by boiling the water, or by the addition of lime calcium hydroxide through the process of lime softening. Permanent hardness[edit] Permanent hardness is hardness mineral content that cannot be removed by boiling. Ions causing permanent hardness of water can be removed using a water softener, or ion exchange column. A major component of such scum is calcium stearate , which arises from sodium stearate , the main component of soap: Synthetic detergents do not form such scums. A portion of the ancient Roman Eifel aqueduct in Germany. Hard water also forms deposits that clog plumbing. This precipitation formation of an insoluble solid is principally caused by thermal decomposition of bicarbonate ions but also happens in cases where the carbonate ion is at saturation concentration. In boilers, the deposits impair the flow of heat into water, reducing the heating efficiency and allowing the metal boiler components to overheat. In a pressurized system, this overheating can lead to failure of the boiler. The softening of hard water by ion exchange does not increase its corrosivity per se. Similarly, where lead plumbing is in use, softened water does not substantially increase plumbo -solvency. Calcium and magnesium hydroxides are both soluble in water. The solubility of the hydroxides of the alkaline-earth metals to which calcium and magnesium belong group 2 of the periodic table increases moving down the column. Aqueous solutions of these metal hydroxides absorb carbon dioxide from the air, forming the insoluble carbonates, giving rise to the turbidity. Hence, a common solution to the problem is, while maintaining the chlorine concentration at the proper level, to lower the pH by the addition of hydrochloric acid, the optimum value being in the range of 7. Water softening It is often desirable to soften hard water. Most detergents contain ingredients that counteract the effects of hard water on the surfactants. For this reason, water softening is often unnecessary. Where softening is practised, it is often recommended to soften only the water sent to domestic hot water systems so as to prevent or delay inefficiencies and damage due to scale formation in water heaters. Washing soda sodium carbonate - Na_2CO_3 is easily obtained and has long been used as a water softener for domestic laundry, in conjunction with the usual soap or detergent. Health considerations[edit] The World Health Organization says that "there does not appear to be any convincing evidence that water hardness causes adverse health effects in humans". The World Health Organization has reviewed the evidence and concluded the data was inadequate to allow for a recommendation for a level of hardness. However, no meaningful difference in symptom relief was found between children with access to a home water softener and those without. Although water hardness usually measures only the total concentrations of calcium and magnesium the two most prevalent divalent metal ions , iron , aluminium , and manganese can also be present at elevated levels in some locations. The presence of iron characteristically confers a brownish rust -like colour to the calcification, instead of white the color of most of the other compounds. The table below shows conversion factors between the various units.

Chapter 8 : Water Purification Handbook Chapter 25 Deposit and Scale Control-Cooling System

The amount of dissolved calcium and magnesium in the water The simple definition of water hardness is the amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals, both calcium and magnesium. You may have felt the effects of hard water, literally, the last.

How are water properties related to the temperature scale and to other fundamental SI units? Because water is commonly available in fairly pure form, it has historically been used as a reproducible standard for defining physical quantities. Most of those old standards using water have been superseded by more precise standards. However, it is still interesting and instructive to trace the ways in which water has been used as a measurement standard. Probably the most familiar such use of water is in connection to the temperature scale. The Celsius sometimes called Centigrade, though use of that term is no longer considered correct temperature scale was originally defined so that the freezing point and boiling point of pure water, both at one atmosphere pressure, were 0 and degrees, respectively. This definition ceased to be valid with the adoption of a new International Temperature Scale in The thermodynamic definition of temperature is based solely on the behavior of an ideal gas; also one fixed point is needed to set the size of the degree. The temperature of the triple point of water is defined to be exactly While this completely determines the thermodynamic temperature scale, temperature measurements require approximating the thermodynamic temperature by a "practical" scale that contains other fixed points at which instruments can be calibrated. Temperatures are assigned to these points based on the best scientific estimate of their true thermodynamic temperatures, and procedures are specified for interpolating between the fixed points. While previous temperature scales used the atmospheric boiling point of water as a fixed point assigning it On ITS, the atmospheric boiling temperature of water turns out to be approximately So, have the properties of water changed? What has changed is our ability to precisely determine temperatures in closer approximation to the true thermodynamic temperature. It is sometimes asked why one could not redefine the temperature scale so that the familiar 0 and degrees Celsius would still hold for the freezing and boiling points of water. This could be done, but it would require changing the size of the degree; this would distort another familiar relationship because the difference between absolute temperature in kelvins and the Celsius scale would have to become approximately In this way, water is still an important part of defining the temperature scale, but it is the triple point, rather than the freezing and boiling points, that is used. Of course for most practical uses, it is an adequate approximation to think of water as boiling at degrees Celsius rather than The other important historical use of water as a measurement standard has been in the definition of mass. The gram was originally defined as the mass of one cubic centimeter of water at some standard condition. This is advantageous because it is independent of the standard of length and because a solid is easier to weigh precisely than a liquid. Updated June 15,

Chapter 9 : Water and its structure

In domestic settings, hard water is often indicated by a lack of foam formation when soap is agitated in water, and by the formation of limescale in kettles and water heaters. Wherever water hardness is a concern, water softening is commonly used to reduce hard water's adverse effects.

Can you fill in the mixed up numbers in this dilution calculation? Why do people say that water is necessary for life? Why have we never found any living organism that can flourish in a completely dry environment? Why could another liquid not be used? Water has several properties that make it unique amongst compounds and make it possible for all forms of known life to function. It is the only natural substance found in all three physical states at the temperatures that naturally occur on Earth. This means that we see water as a liquid, in rivers and seas, a solid, as snow and ice, and as a gas, as clouds or steam. Can you think of anything else that would be different? Do you think we could still live if water was only a liquid at the temperatures that occur naturally on Earth? Ice is less dense than water This just means that ice floats on water and that lakes freeze from the top down to the bottom. This is clearly important for animals that live on ice, as their habitats would be greatly reduced or not exist at all if ice sank. Similarly, fish and other pond-life would be affected if lakes and ponds froze from the bottom upwards - the layer of frozen water at the top of the pond provides some insulation and prevents the rest of the water getting cold as quickly. It does this by making a barrier between the cold air and the water below. Most substances get progressively more dense as they are cooled. The graph below shows how density of water changes with temperature. Water has a very high melting and boiling point compared to other similar molecules This is what means it is seen as a solid, a liquid and a gas on Earth. If water was not a liquid at most of the temperatures we see on Earth the seas would all be ice, there would be no rain, nothing for plants to collect and animals to drink. Even our cells are filled with liquid water, which would not be possible either. The water in our bodies is mostly contained in our cells, where it gives them a clear shape as well as having billions of useful molecules dissolved in it. Our cells need to be filled with water to work properly because the enzymes inside them only work in solution. Transport in water also occurs on a much smaller scale: For example, if an enzyme needs calcium ions to be activated and start working it will meet these as they move about in the solution inside a cell. The higher the concentration of calcium in the cell, the more likely the enzyme will meet an ion sooner. You may also have learnt about diffusion and osmosis, which are key concepts in understanding how cells function and rely on the presence of water Water has a high specific heat capacity. This is why on a hot day the sand on a beach can be too hot to walk on but the sea still feels cool; the energy from the sun is enough to heat the sand a lot but the water only a little. This has some very important implications, especially for organisms that live in water. Seas, lakes and rivers maintain a much more constant temperature than air, which means that animals can live in water all year round without having to adapt to large temperature changes What do you think would happen if water cooled more easily? What problems might this pose to organisms living in a small pond? Surface tension You might have noticed that if you put a needle on the surface of a bowl of water it floats but if you throw it in it sinks. This is because the needle is denser than water so wants to sink but is held up by the surface tension of the water. You can also see this when you fill a cup to the brim, as the surface of the water will hold together and resist spilling. The high surface tension of water is the reason that some flies can land on its surface without sinking. This concept is also very closely related to another, the idea of capillary action. If you put a very fine tube into a beaker of water you will see that some of the water travels a short way up the tube; this is called capillary action and is caused by the water clinging to the sides of the tube and to other molecules of water, pulling them up the tube with it. Eventually the weight of the water being pulled is too great to be supported and the water stops moving, having reached an equilibrium. All of these properties of water are critical for life as we know it but why does water have them? Does no other substance also do these things? What is it about water that makes it different? To understand the answers to these questions you have to study the molecular structure of water. The chemical formula for water is H_2O , meaning that it contains two hydrogen atoms covalently bonded to one oxygen atom, like this: This diagram represents the bonds as lines, which makes it look like they are the

same at every point? Because oxygen is more electronegative than hydrogen it attracts the electrons in the O-H bond towards itself. If the thickness of the line represents electron density the amount of time electrons spend in that part of the bond, the O-H bond actually looks more like this: This means that the oxygen is slightly negatively charged and that the hydrogens are slightly positively charged. These are called hydrogen bonds. A great deal of energy is required to break down the hydrogen bonds, which is why the melting and boiling points of water are high and why it has a high specific heat capacity. A substance will dissolve in water if it is polar or ionic. This is because it dissolves by forming hydrogen bonds with the water. Oil is not polar, which is why it will not dissolve. Salt, NaCl, does dissolve because it is ionic. Can you think of some other substances that are soluble in water? How do they form hydrogen bonds with it? Can you draw a similar picture to the one below showing why glucose is soluble? Is it more or less soluble in water than salt? Why do you think this is? This is an image of the chemical structure of glucose. There is a C carbon atom at each vertex - this is a common way of drawing organic molecules.