# pH FUNDAMENTALS
## CONTINUING EDUCATION COURSE



**Technical Learning College**

# Printing and Saving Instructions

It is recommended that you download this pdf document and assignment to your computer desktop and open it with Adobe Acrobat DC reader.

Adobe Acrobat DC reader is a free computer software program and you can find it at Adobe Acrobat's website.

You can complete the course by viewing the course on your computer or you can print it out.  This course booklet does not have the assignment (the test). Please visit our website and download the assignment (the test).

**Printing Instructions:** Once you have purchased the program, we will give you permission to print this document.  If you are going to print this document, it was designed to be printed double-sided or duplexed but can be printed single-sided.

*You can obtain a printed version from TLC for an additional $79.95 plus shipping charges.*

*Hyperlink to Assignment…*
*http://www.abctlc.com/downloads/PDF/pHFundamentalsASS.pdf*

*State Approval Listing Link*
*http://www.abctlc.com/PDF/CEU%20State%20Approvals.pdf*

**State Approval Listing Link,** check to see if your State accepts or has pre-approved this course.  Not all States are listed. Not all courses are listed.  Do not solely trust our list for it may be outdated.  It is your sole responsibility to ensure this course is accepted for credit.  No refunds.

**Professional Engineers**: Most states will accept our courses for credit but we do not officially list the States or Agencies acceptance or approvals.

**Some States and many employers require the final exam to be proctored.**

**Do not solely depend on TLC's Approval list for it may be outdated.**

Most of our students prefer to do the assignment in Word and e-mail or fax the assignment back to us. We also teach this course in a conventional hands-on class. Call us and schedule a class today.

# pH CHART

## Contributing Editors

**James L. Six** Received a Bachelor of Science Degree in Civil Engineering from the University of Akron in June of 1976, Registered Professional Engineer in the State of Ohio, Number 45031 (Retired), Class IV Water Supply Operator issued by Ohio EPA, Number WS4-1012914-08, Class II Wastewater Collection System Operator issued by Ohio EPA, Number WC2-1012914-94

**Joseph Camerata** has a BS in Management with honors (magna cum laude). He retired as a Chemist in 2006 having worked in the field of chemical, environmental, and industrial hygiene sampling and analysis for 40 years.

**James Bevan**, Water Quality Inspector S.M.E. Twenty years of experience in the environmental field dealing with all aspects of water regulations on the federal, state, and local levels. Teacher and Proctor in Charge for Backflow Certification Testing at the ASETT Center in Tucson for the past 15 years and possess an Arizona Community College, Special Teaching Certificate in Environmental Studies.

**Dr. Pete Greer** S.M.E., Retired biology instructor, chemistry and biological review.

**Jack White**, Environmental, Health, Safety expert, City of Phoenix. Art Credits.

# Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print - based distance educational format. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you to finish the material at your convenience. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams, depending upon your state or employer requirements.

**Flexible Learning**
At TLC there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus-based student. You will work at your own pace, completing assignments in time frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

**Course Structure**
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student-friendly course design allows you the most flexibility in choosing when and where you will study.

**Classroom of One**
TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.

**Satisfaction Guaranteed**

We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none.  This is one reason we have taught more than 20,000 students.
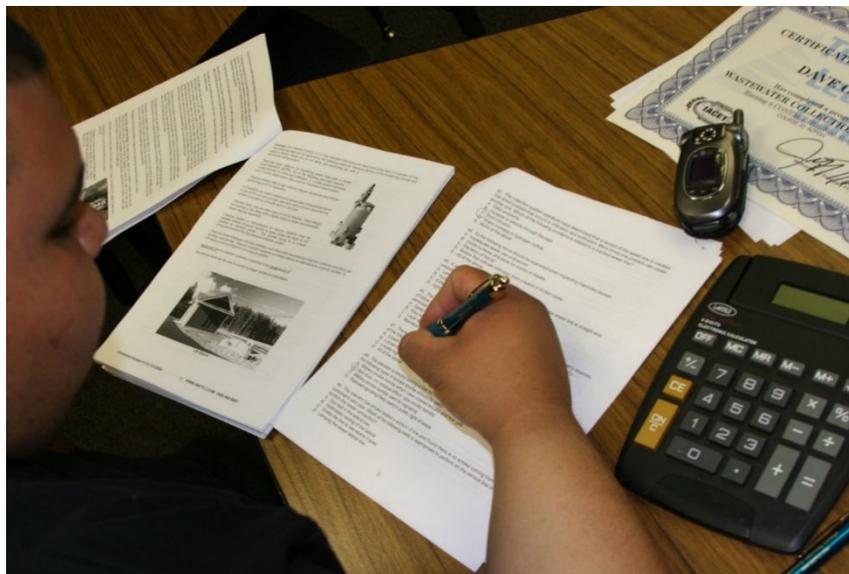


We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail.  If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

## Contact Numbers
## Fax  (928) 468-0675
## Email    Info@tlch2o.com
## Telephone  (866) 557-1746

# CEU COURSE DESCRIPTION

## pH FUNDAMENTALS CEU TRAINING COURSE

This one contact hour continuing education course is a non-lab course that introduces the students to basic pH measurement and reaction principles. Topics covered include the pH scale and measuring techniques. This course will help you to gain a good knowledge of the reactions between acids and bases and understanding pH.

**Target Audience**
Attention Laboratory Analyst, Water Samplers, Wastewater Treatment Operators, Water Distribution Operators, Well Drillers, Pump Installers, and Water Treatment Operators. The target audience for this course is the person interested in working in a water/wastewater treatment or distribution/collections facility and wishing to maintain CEUs for certification license or to learn how to do the job safely and effectively, and/or to meet education needs for promotion.

**Course Statement of Need**
All laboratory personnel/operators need to be able to measure the pH of various compounds and be able to calibrate the pH testing equipment.

**Prerequisite**
Although a background in chemistry is not necessary, a basic knowledge of math, including algebra, is suggested.

**General CEU Training Objectives**
1. The student will understand and describe the principles of pH.

**Specific CEU Course Learning Objectives**
1. The student will understand and describe the principles of pH.
- Acidity and Basicity
- Calculating pH
- Hard Water Section
- pH Measurement
- Strong Acids and Bases

**Final Examination for Credit**
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

**Course Procedures for Registration and Support**
All of Technical Learning College's distance courses have complete registration and support services offered. Delivery of services will include, e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service.

When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request. All students will be tracked by a unique number assigned to the student.

**Instructions for Written Assignments**
The *pH Fundamentals* CEU Training course uses a multiple-choice answer key.

**Feedback Mechanism (examination procedures)**
Each student will receive a feedback form as part of his or her study packet.  You will be able to find this form in the front of the course assignment or lesson.

**Security and Integrity**
All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers.  Any fraud or deceit will result in forfeiture of all fees, and the appropriate agency will be notified.

**Grading Criteria**
TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice. For security purposes, please fax or e-mail a copy of your driver's license and always call us to confirm we've received your assignment and to confirm your identity.

TLC offers students the option of either pass/fail or assignment of a standard letter grade. If a standard letter grade is not requested, a pass/fail notice will be issued. Final course grades are based on the total number of possible points. The grading scale is administered equally to all students in the course. Do not expect to receive a grade higher than that merited by your total points. No point adjustments will be made for class participation or other subjective factors. If TLC is not notified, you will only receive a pass/fail notice. In order to pass your final assignment, you are required to obtain a minimum score of 70% on your assignment.

**Recordkeeping and Reporting Practices**
TLC will keep all student records for a minimum of seven years.  It is the student's responsibility to give the completion certificate to the appropriate agencies.  TLC will not release any records to any party, except to the student self.  We will send the required information to Texas, Indiana and Pennsylvania for your certificate renewals.

**ADA Compliance**
TLC will make reasonable accommodations for persons with documented disabilities.  Students should notify TLC and their instructors of any special needs.  Course content may vary from this outline to meet the needs of this particular group.

**Mission Statement**
Our only product is educational service.  Our goal is to provide you with the best possible education service possible. TLC will attempt to make your learning experience an enjoyable opportunity.

**When the Student finishes this course…**
**At the conclusion of this course:**
The student will understand and describe the principles of pH and understand the difference between acids and bases.

**Educational Mission**
**The educational mission of TLC is:**
*To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,*

*To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,*

*To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,*

*To provide a forum in which students can exchange experiences and ideas related to environmental education,*

*To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.*

# TABLE OF CONTENTS

**All of this material comes from TLC's Water Chemistry and Water/Wastewater Sampling CEU Course.  References in rear of manual.**

| FACTOR | TYPE | SOURCE(S) | PROBLEM |
|--------|------|-----------|---------|
| FECAL COLIFORM BACTERIA | BIOLOGICAL | HUMAN SEWAGE; LIVESTOCK WASTE | POSSIBLE PRESENCE OF PATHOGENIC (DISEASE-CAUSING) ORGANISMS |
| DISSOLVED OXYGEN (DO) | CHEMICAL | AIR; AQUATIC PLANTS | LOW LEVELS CAN KILL AQUATIC ORGANISMS |
| NITROGEN AND PHOSPHORUS | CHEMICAL | FERTILIZERS AND DETERGENTS FROM LAWNS AND RUNOFF | EXCESSIVE ALGAE GROWTH CAN LEAD TO LOW DO |
| ZINC, ARSENIC, LEAD, MERCURY, CADMIUM, NICKEL | CHEMICAL | LANDFILLS; INDUSTRIAL DISCHARGES; RUNOFF | GENETIC MUTATIONS OR DEATH IN FISH & WILDLIFE (HUMAN HEALTH THREATS AS WELL) |
| SALT | CHEMICAL | SALTWATER INTRUSION (IF NEAR OCEAN) | KILLS FRESHWATER SPECIES OF PLANTS AND ANIMALS |
| MUD, SAND, OTHER SOLID PARTICLES (TURBIDITY) | PHYSICAL | EROSION AND RUNOFF FROM DEVELOPMENT; AGRICULTURE | REDUCES PHOTOSYNTHESIS IN AQUATIC VEGETATION; INTERFERES WITH RESPIRATION IN AQUATIC ANIMALS |

## WATER QUALITY FACTORS



**MICROBIOLOGICAL**
- BACTERIA
- VIRUSES
- PROTOZOA

**CHEMICAL**
- ORGANIC / INORGANIC
- NATURALLY OCCURING
- ANTHROPAGENIC

**PHYSICAL AESTHETIC**
- TURBIDITY
- ODOR
- TASTE
- SMELL
- APPEARANCE
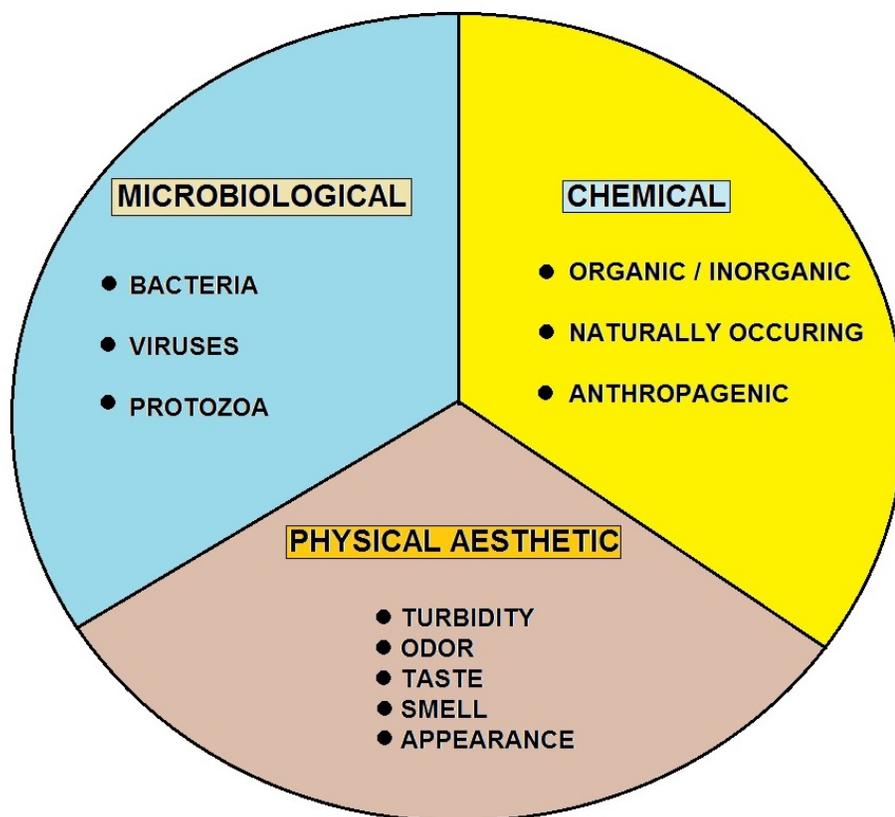
## WATER QUALITY BROKEN DOWN INTO 3 BROAD CATEGORIES

# Hydrogen Molecules
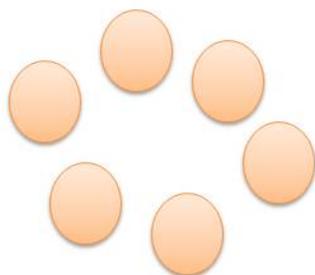


# Oxygen Molecules
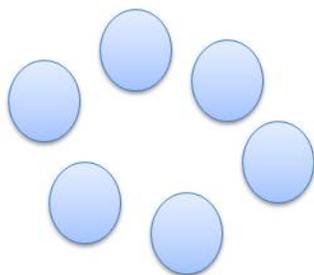


# Water Molecules
# $H_2O$
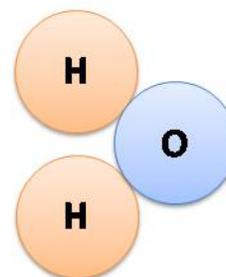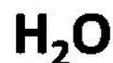


## What is Water?

Water is the chemical substance with chemical formula $H_2O$: one molecule of water has two hydrogen atoms covalently bonded to a single oxygen atom. Water is a tasteless, odorless liquid at ambient temperature and pressure, and appears colorless in small quantities, although it has its own intrinsic very light blue hue. Ice also appears colorless, and water vapor is essentially invisible as a gas.

Water is primarily a liquid under standard conditions, which is not predicted from its relationship to other analogous hydrides of the oxygen family in the periodic table, which are gases such as hydrogen sulfide.

The elements surrounding oxygen in the periodic table, nitrogen, fluorine, phosphorus, sulfur and chlorine, all combine with hydrogen to produce gases under standard conditions. The reason that water forms a liquid are that oxygen is more electronegative than all of these elements with the exception of fluorine.

Oxygen attracts electrons much more strongly than hydrogen, resulting in a net positive charge on the hydrogen atoms, and a net negative charge on the oxygen atom. The presence of a charge on each of these atoms gives each water molecule a net dipole moment.

Electrical attraction between water molecules due to this dipole pulls individual molecules closer together, making it more difficult to separate the molecules and therefore raising the boiling point.

**Sample Station commonly found at most water or wastewater treatment plants.**
This tap will allow the operator to obtain Grab Samples for pH, Temperature, COD, Bacterial, ORP, OUP, Organics and Inorganic field parameters.



**TESTING THE pH OF WATER**

pH Fundamentals ©TLC  7/18/2022   TLC (928) 468-0665 Fax (928) 468-0675
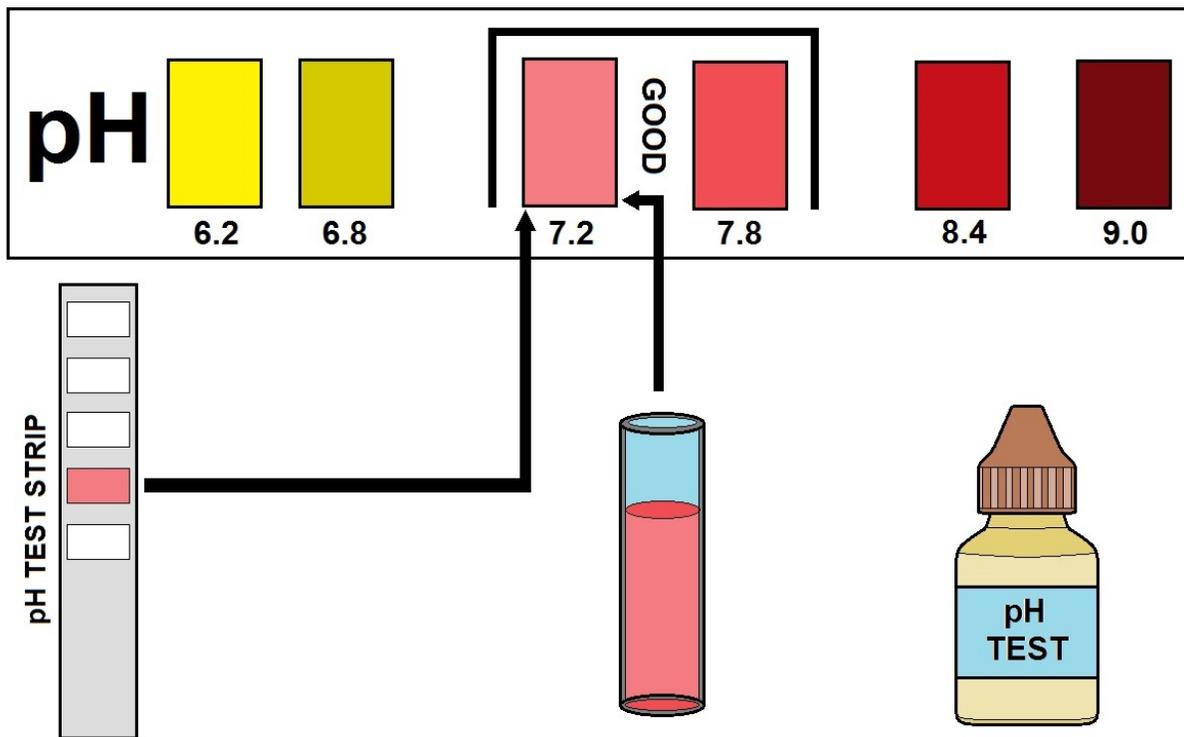
## Chemical Reaction

*We will start with the basics….*
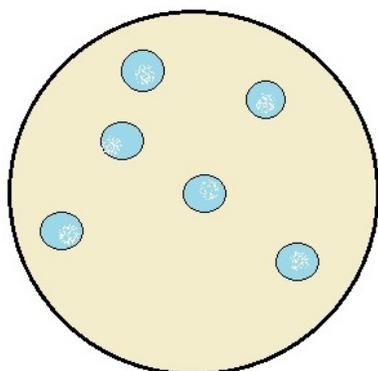


ATOMS OF AN ELEMENT
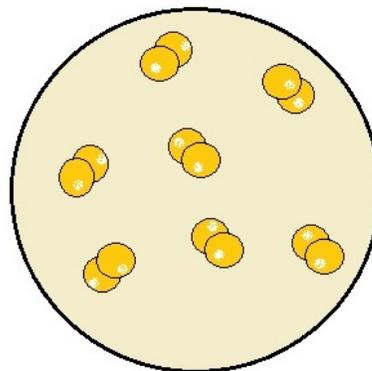
MOLECULES OF AN ELEMENT
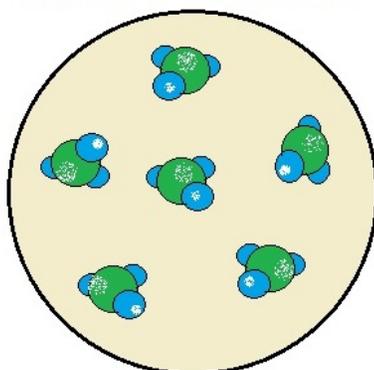
MOLECULES OF A COMPOUND
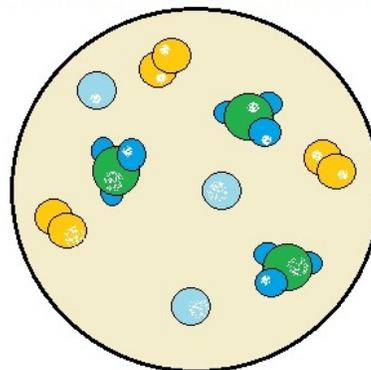
MIXTURE OF TWO ELEMENTS AND A COMPOUND

## Chemical Reactions

During chemical reactions, bonds between atoms break and form, resulting in different substances with different properties. In a blast furnace, iron oxide, a compound, reacts with carbon monoxide to form iron, one of the chemical elements, and carbon dioxide.

When a chemical substance is transformed as a result of its interaction with another substance or with energy, a chemical reaction is said to have occurred.

A *chemical reaction* is therefore a concept related to the "reaction" of a substance when it comes in close contact with another, whether as a mixture or a solution; exposure to some form of energy, or both. It results in some energy exchange between the constituents of the reaction as well as with the system environment, which may be designed vessels—often laboratory glassware.

Chemical reactions can result in the formation or dissociation of molecules, that is, molecules breaking apart to form two or smaller molecules, or rearrangement of atoms within or across molecules. Chemical reactions usually involve the making or breaking of chemical bonds. Oxidation, reduction, dissociation, acid-base neutralization and molecular re-arrangement are some of the commonly used kinds of chemical reactions.

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A chemical reaction can be symbolically depicted through a chemical equation. While in a non-nuclear chemical reaction the number and kind of atoms on both sides of the equation are equal, for a nuclear reaction this holds true only for the nuclear particles viz. protons and neutrons.

The sequence of steps in which the reorganization of chemical bonds may be taking place in the course of a chemical reaction is called its mechanism. A chemical reaction can be envisioned to take place in a number of steps, each of which may have a different speed. Many reaction intermediates with variable stability can thus be envisaged during the course of a reaction. Reaction mechanisms are proposed to explain the kinetics and the relative product mix of a reaction. Many physical chemists specialize in exploring and proposing the mechanisms of various chemical reactions. Several empirical rules, like the Woodward–Hoffmann rules often come in handy while proposing a mechanism for a chemical reaction.

According to the IUPAC gold book, a chemical reaction is "a process that results in the interconversion of chemical species." Accordingly, a chemical reaction may be an elementary reaction or a stepwise reaction. An additional caveat is made, in that this definition includes cases where the interconversion of conformers is experimentally observable. Such detectable chemical reactions normally involve sets of molecular entities as indicated by this definition, but it is often conceptually convenient to use the term also for changes involving single molecular entities (i.e. 'microscopic chemical events').

**Ions and Salts**
An *ion* is a charged species, an atom or a molecule, which has lost or gained one or more electrons. When an atom loses an electron and thus has more protons than electrons, the atom is a positively charged ion or cation. When an atom gains an electron and thus has more electrons than protons, the atom is a negatively charged ion or anion. Cations and anions can form a crystalline lattice of neutral salts, such as the $Na^+$ and $Cl^-$ ions forming sodium chloride, or NaCl.

Examples of polyatomic ions that do not split up during acid-base reactions are hydroxide ($OH^-$) and phosphate ($PO_4^{3-}$).

Plasma is composed of gaseous matter that has been completely ionized, usually through high temperature.



**SODIUM CHLORIDE**

## Acidity and Basicity

**HYDROCHLORIC ACID**

$H^+$  $Cl^-$  →  $-$  $Cl^-$  $+$  $+$  $H^+$

**SODIUM HYDROXIDE**

$Na^+$  $O$  $H$  →  $Na^+$  $+$  $O$  $H$
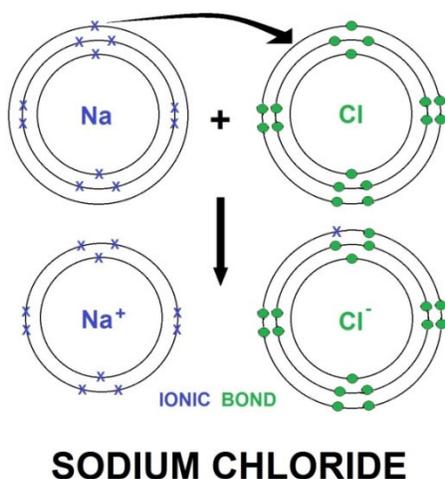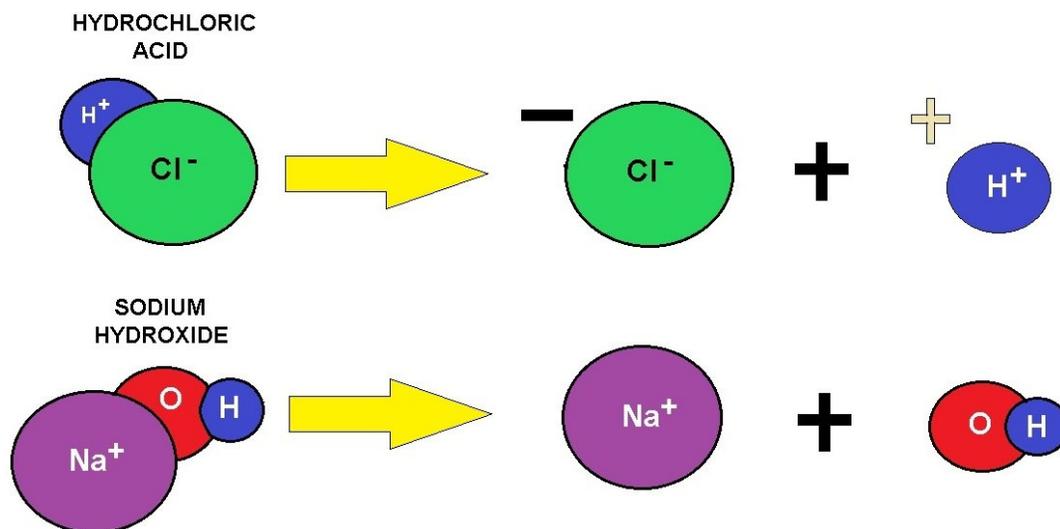
## ACIDS AND BASES
### (comparison)

A substance can often be classified as an acid or a base. There are several different theories which explain acid-base behavior. The simplest is Arrhenius theory, which states than an acid is a substance that produces hydronium ions when it is dissolved in water, and a base is one that produces hydroxide ions when dissolved in water. According to Brønsted–Lowry acid–base theory, acids are substances that donate a positive hydrogen ion to another substance in a chemical reaction; by extension, a base is the substance which receives that hydrogen ion.

A third common theory is Lewis acid-base theory, which is based on the formation of new chemical bonds. Lewis theory explains that an acid is a substance which is capable of accepting a pair of electrons from another substance during the process of bond formation, while a base is a substance which can provide a pair of electrons to form a new bond. According to this theory, the crucial things being exchanged are charges. There are several other ways in which a substance may be classified as an acid or a base, as is evident in the history of this concept.

Acid strength is commonly measured by two methods.

One measurement, based on the Arrhenius definition of acidity, is pH, which is a measurement of the hydronium ion concentration in a solution, as expressed on a negative logarithmic scale. Thus, solutions that have a low pH have a high hydronium ion concentration and can be said to be more acidic.

The other measurement, based on the Brønsted–Lowry definition, is the acid dissociation constant ($K_a$), which measures the relative ability of a substance to act as an acid under the Brønsted–Lowry definition of an acid. That is, substances with a higher $K_a$ are more likely to donate hydrogen ions in chemical reactions than those with lower $K_a$ values.

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**Redox**

Redox (*red*uction-*ox*idation) reactions include all chemical reactions in which atoms have their oxidation state changed by either gaining electrons (reduction) or losing electrons (oxidation). Substances that have the ability to oxidize other substances are said to be oxidative and are known as oxidizing agents, oxidants or oxidizers. An oxidant removes electrons from another substance. Similarly, substances that have the ability to reduce other substances are said to be reductive and are known as reducing agents, reductants, or reducers.
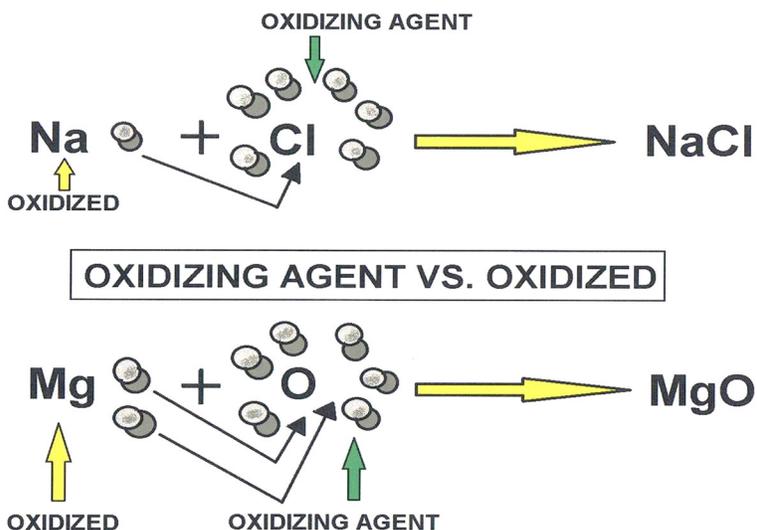


A reductant transfers electrons to another substance and is thus oxidized itself. And because it "donates" electrons it is also called an electron donor. Oxidation and reduction properly refer to a change in oxidation number—the actual transfer of electrons may never occur. Thus, oxidation is better defined as an increase in oxidation number, and reduction as a decrease in oxidation number.



Commonly found conductivity, temperature and pH measuring equipment.  As a sampler, you will use this equipment on a daily basis.  Make sure to date the pH buffers and calibrate your equipment every morning.

**REDUCING AGENTS** | **OXIDIZING AGENTS**

A LOSES ELECTRONS | B GAINS ELECTRONS

A IS OXIDIZED | B IS REDUCED
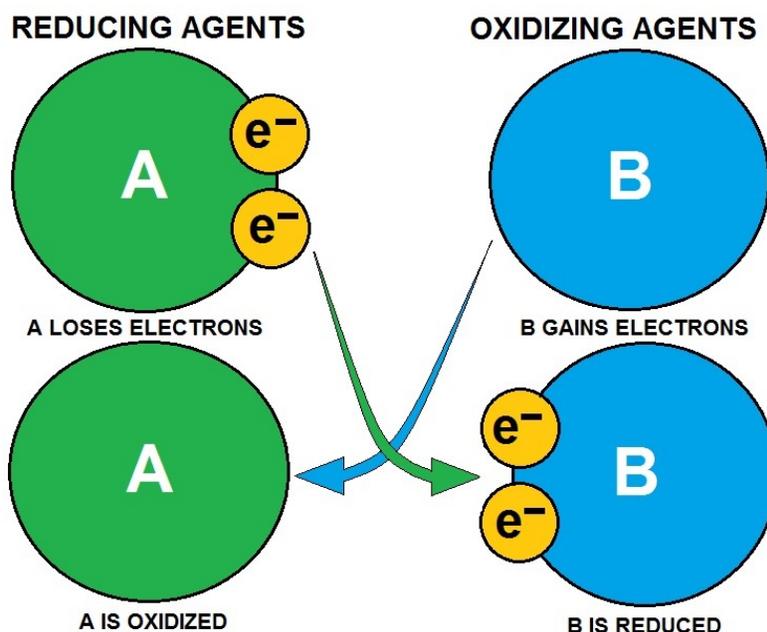
**Equilibrium**

Although the concept of equilibrium is widely used across sciences, in the context of chemistry, it arises whenever a number of different states of the chemical composition are possible, as for example, in a mixture of several chemical compounds that can react with one another, or when a substance can be present in more than one kind of phase. A system of chemical substances at equilibrium, even though having an unchanging composition, is most often not static; molecules of the substances continue to react with one another thus giving rise to a dynamic equilibrium. Thus, the concept describes the state in which the parameters such as chemical composition remain unchanged over time.



ADD ACID TO WATER | NEVER ADD WATER TO ACID
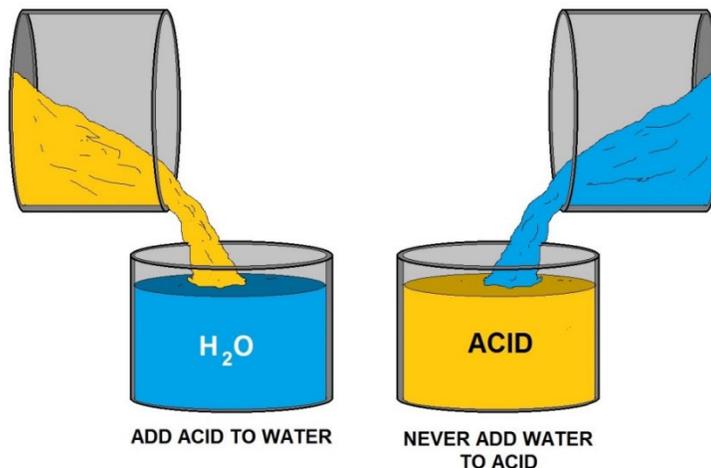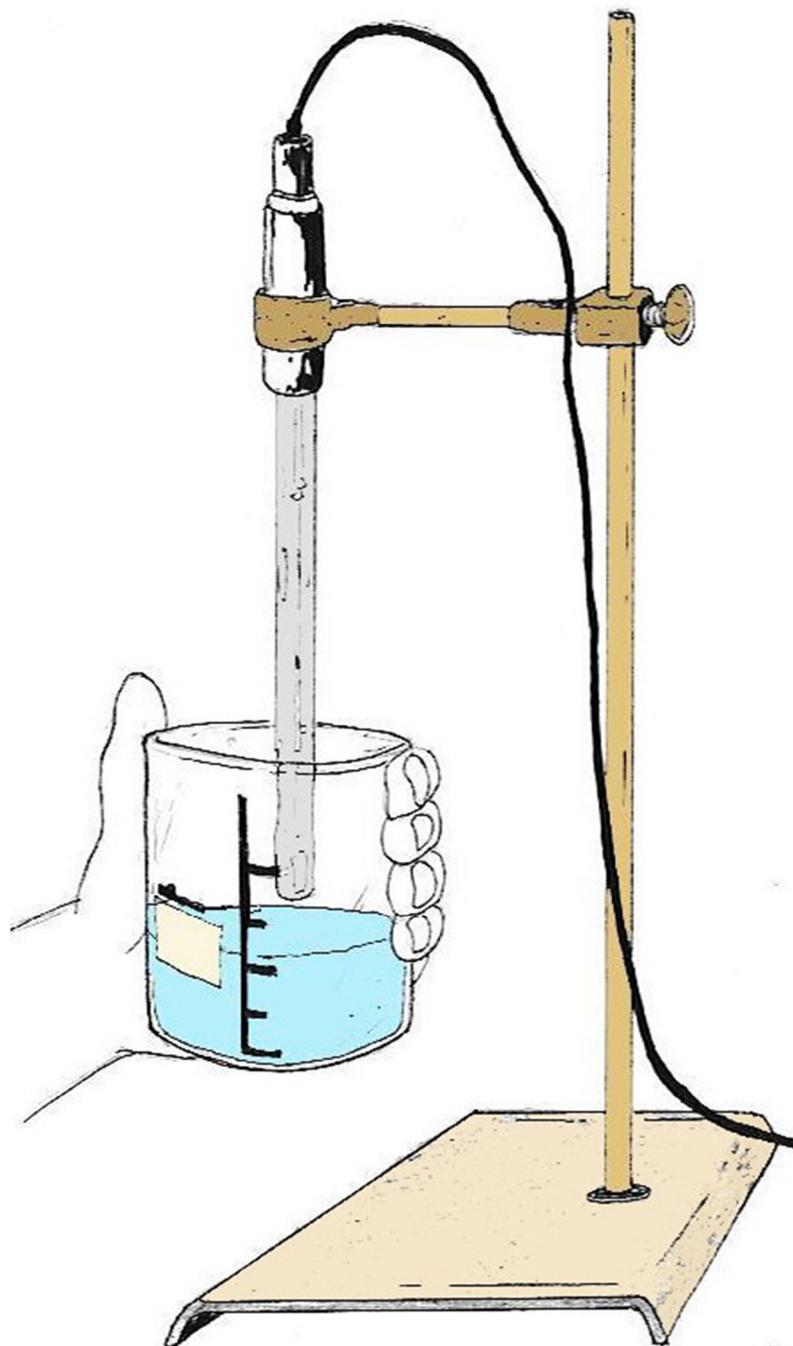
**USING A CONDUCTIVITY PROBE TO TEST pH**

# Substances versus Mixtures

All matter consists of various elements and chemical compounds, but these are often intimately mixed together. Mixtures contain more than one chemical substance, and they do not have a fixed composition. In principle, they can be separated into the component substances by purely mechanical processes. Butter, soil and wood are common examples of mixtures.

Grey iron metal and yellow sulfur are both chemical elements, and they can be mixed together in any ratio to form a yellow-grey mixture. No chemical process occurs, and the material can be identified as a mixture by the fact that the sulfur and the iron can be separated by a mechanical process, such as using a magnet to attract the iron away from the sulfur.

In contrast, if iron and sulfur are heated together in a certain ratio (1 atom of iron for each atom of sulfur, or by weight, 56 grams (1 mol) of iron to 32 grams (1 mol) of sulfur), a chemical reaction takes place and a new substance is formed, the compound iron(II) sulfide, with chemical formula FeS. The resulting compound has all the properties of a chemical substance and is not a mixture. Iron (II) sulfide has its own distinct properties such as melting point and solubility, and the two elements cannot be separated using normal mechanical processes; a magnet will be unable to recover the iron, since there is no metallic iron present in the compound.

**Chemicals versus Chemical Substances**
While the term *chemical substance* is a precise technical term that is synonymous with "chemical" for professional chemists, the meaning of the word *chemical* varies for non-chemists within the English-speaking world or those using English. For industries, government and society in general in some countries, the word *chemical* includes a wider class of substances that contain many mixtures of such chemical substances, often finding application in many vocations. In countries that require a list of ingredients in products, the "chemicals" listed would be equated with "chemical substances".

Within the chemical industry, manufactured "chemicals" are chemical substances, which can be classified by production volume into bulk chemicals, fine chemicals and chemicals found in research only:
- Bulk chemicals are produced in very large quantities, usually with highly optimized continuous processes and to a relatively low price.
- Fine chemicals are produced at a high cost in small quantities for special low-volume applications such as biocides, pharmaceuticals and specialty chemicals for technical applications.
- Research chemicals are produced individually for research, such as when searching for synthetic routes or screening substances for pharmaceutical activity. In effect, their price per gram is very high, although they are not sold.

The cause of the difference in production volume is the complexity of the molecular structure of the chemical. Bulk chemicals are usually much less complex. While fine chemicals may be more complex, many of them are simple enough to be sold as "building blocks" in the synthesis of more complex molecules targeted for single use, as named above.

The *production* of a chemical includes not only its synthesis but also its purification to eliminate by-products and impurities involved in the synthesis.

The last step in production should be the analysis of batch lots of chemicals in order to identify and quantify the percentages of impurities for the buyer of the chemicals. The required purity and analysis depends on the application, but higher tolerance of impurities is usually expected in the production of bulk chemicals.  Thus, the user of the chemical in the US might choose between the bulk or "technical grade" with higher amounts of impurities or a much purer "pharmaceutical grade" (labeled "USP", United States Pharmacopeia).

**Naming and Indexing**
Every chemical substance has one or more systematic names, usually named according to the IUPAC rules for naming. An alternative system is used by the Chemical Abstracts Service (CAS).

Many compounds are also known by their more common, simpler names, many of which predate the systematic name. For example, the long-known sugar glucose is now systematically named 6-(hydroxymethyl) oxane-2,3,4,5-tetrol. Natural products and pharmaceuticals are also given simpler names, for example the mild pain-killer Naproxen is the more common name for the chemical compound (S)-6-methoxy-α-methyl-2-naphthaleneacetic acid.

Chemists frequently refer to chemical compounds using chemical formulae or molecular structure of the compound. There has been a phenomenal growth in the number of chemical compounds being synthesized (or isolated), and then reported in the scientific literature by professional chemists around the world. An enormous number of chemical compounds are possible through the chemical combination of the known chemical elements.

CAS provides the abstracting services of the chemical literature, and provides a numerical identifier, known as CAS registry number to each chemical substance that has been reported in the chemical literature (such as chemistry journals and patents). This information is compiled as a database and is popularly known as the Chemical substances index. Other computer-friendly systems that have been developed for substance information, are: SMILES and the International Chemical Identifier or InChI.

HYDROGEN ($H_2$)   OXYGEN ($O_2$)   NITROGEN ($N_2$)   CHLORINE ($Cl_2$)

NITROGEN OXIDE (NO)   WATER ($H_2O$)   NITROGEN DIOXIDE ($NO_2$)   CARBON DIOXIDE ($CO_2$)
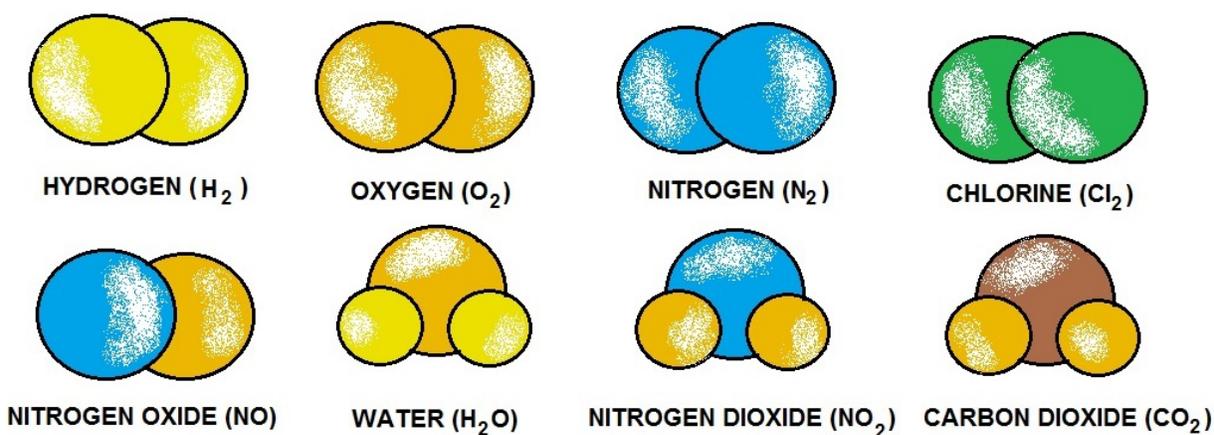
# Understanding the Molecule

A *molecule* is the smallest indivisible portion of a pure chemical substance that has its unique set of chemical properties, that is, its potential to undergo a certain set of chemical reactions with other substances. However, this definition only works well for substances that are composed of molecules, which is not true of many substances (see below). Molecules are typically a set of atoms bound together by covalent bonds, such that the structure is electrically neutral and all valence electrons are paired with other electrons either in bonds or in lone pairs.



**BARE CALCIUM ION**
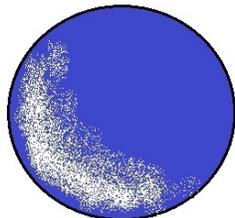
**HYDRATED CALCIUM ION**

$H_2O$
**WATER MOLECULE**

Thus, molecules exist as electrically neutral units, unlike ions. When this rule is broken, giving the "molecule" a charge, the result is sometimes named a molecular ion or a polyatomic ion. However, the discrete and separate nature of the molecular concept usually requires that molecular ions be present only in well-separated form, such as a directed beam in a vacuum in a mass spectrometer. Charged polyatomic collections residing in solids (for example, common sulfate or nitrate ions) are generally not considered "molecules" in chemistry.

The "inert" or noble gas elements (helium, neon, argon, krypton, xenon and radon) are composed of lone atoms as their smallest discrete unit, but the other isolated chemical elements consist of either molecules or networks of atoms bonded to each other in some way. Identifiable molecules compose familiar substances such as water, air, and many organic compounds like alcohol, sugar, gasoline, and the various pharmaceuticals.

However, not all substances or chemical compounds consist of discrete molecules, and indeed most of the solid substances that make up the solid crust, mantle, and core of the Earth are chemical compounds without molecules. These other types of substances, such as ionic compounds and network solids, are organized in such a way as to lack the existence of identifiable molecules *per se*. Instead, these substances are discussed in terms of formula units or unit cells as the smallest repeating structure within the substance.

Examples of such substances are mineral salts (such as table salt), solids like carbon and diamond, metals, and familiar silica and silicate minerals such as quartz and granite.

One of the main characteristics of a molecule is its geometry often called its structure. While the structure of diatomic, triatomic or tetra atomic molecules may be trivial, (linear, angular pyramidal etc.) the structure of polyatomic molecules, that are constituted of more than six atoms (of several elements) can be crucial for its chemical nature.

### Substance and Mixture
A chemical substance is a kind of matter with a definite composition and set of properties. A collection of substances is called a mixture. Examples of mixtures are air and alloys.

### Mole and Amount of Substance
The mole is a unit of measurement that denotes an amount of substance (also called chemical amount). The mole is defined as the number of atoms found in exactly 0.012 kilogram (or 12 grams) of carbon-12, where the carbon-12 atoms are unbound, at rest and in their ground state. The number of entities per mole is known as the Avogadro constant and is determined empirically to be approximately $6.022 \times 10^{23}$ mol$^{-1}$. Molar concentration is the amount of a particular substance per volume of solution and is commonly reported in moldm$^{-3}$.

# Periodic Table of the Elements



Atomic masses in parentheses are those of the most stable or common isotope.

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

# pH Section
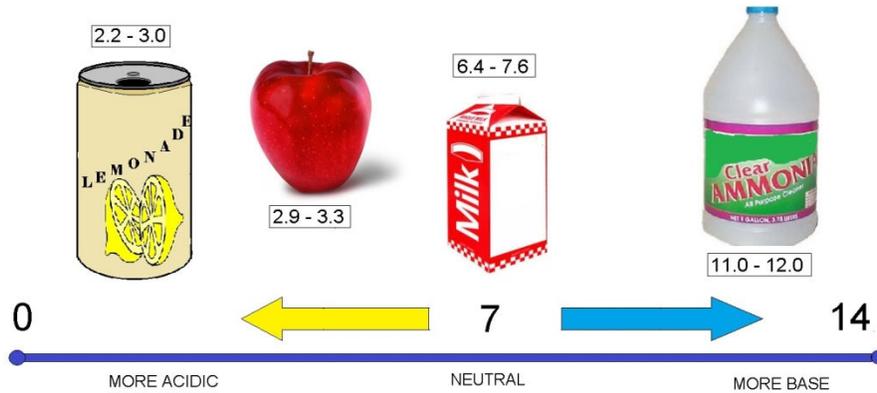


## pH SCALE

In water and wastewater processes, **pH** is a measure of the acidity or basicity of an aqueous solution. Solutions with a pH greater than 7 are basic or alkaline and solution or samples with a pH less than 7 are said to be acidic. Pure water has a pH very close to 7.

Primary pH standard values are determined using a concentration cell with transference, by measuring the potential difference between a hydrogen electrode and a standard electrode such as the silver chloride electrode. The pH scale is traceable to a set of standard solutions whose pH is established by international agreement.

Measurement of pH for aqueous solutions can be done with a glass electrode and a pH meter or using indicators like strip test paper.

pH measurements are important in water and wastewater processes (sampling) but also in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering, chemical engineering, nutrition, water treatment & water purification, and many other applications.



## pH - VALUE
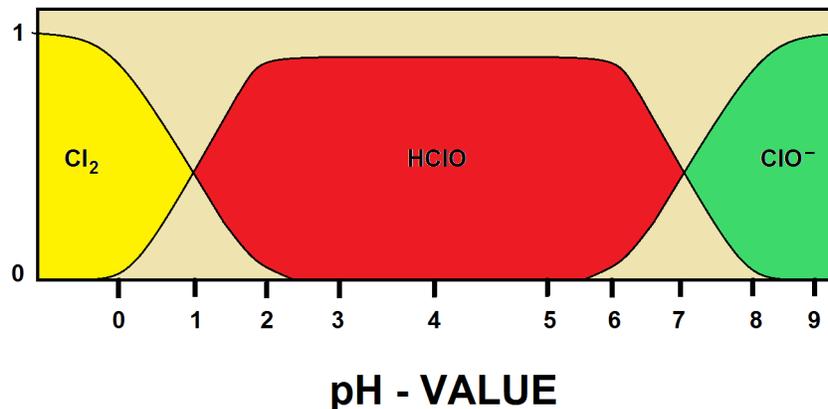
Mathematically, pH is the measurement of hydroxyl ion activity and expressed as the negative logarithm of the activity of the (solvated) hydronium ion, more often expressed as the measure of the hydronium ion concentration.
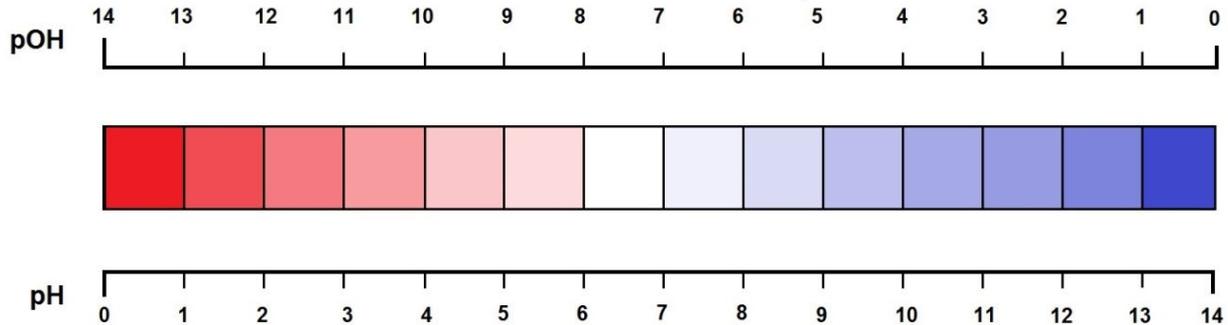


IN RELATION BETWEEN p(OH) AND p(H) (red= ACIDIC / blue= BASIC)

## Contents
## History
The scientific discovery of the p[H] concept of was first introduced by Danish chemist Søren Peder Lauritz Sørensen at the Carlsberg Laboratory back in 1909 and revised to the modern pH in 1924 to accommodate definitions and measurements in terms of electrochemical cells. In the first papers, the notation had the "H" as a subscript to the lowercase "p", as so: pH.

## Alkalinity
Alkalinity is the quantitative capacity of an aqueous solution to neutralize an acid. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It is one of the best measures of the sensitivity of the stream to acid inputs. There can be long-term changes in the alkalinity of rivers and streams in response to human disturbances.
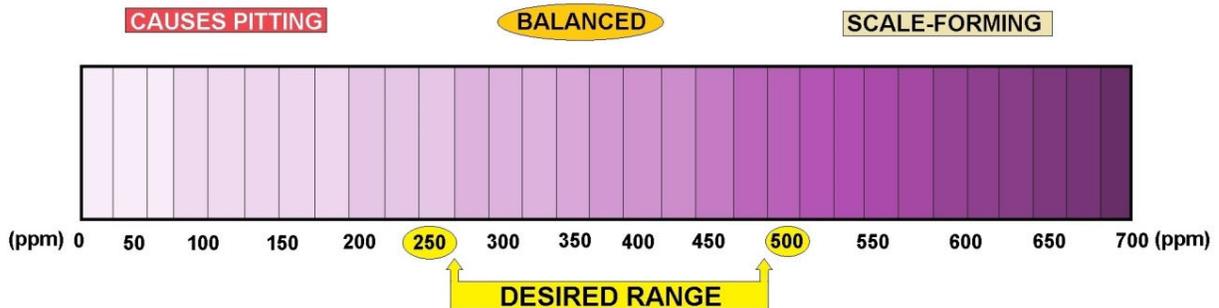


## CALCIUM HARDNESS MEASUREMENT

*Reference. Bates, Roger G. Determination of pH: theory and practice. Wiley, 1973.*

## pH Definition and Measurement

| CONCENTRATION OF HYDROGEN IONS COMPARED TO DISTILLED H2O | | | | EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH |
|---|---|---|---|---|
| | 1/10,000,000 | 14 | LIQUID DRAIN CLEANER CAUSTIC SODA | |
| | 1/1,000,000 | 13 | BLEACHES OVEN CLEANERS | |
| | 1/100,000 | 12 | SOAPY WATER | |
| | 1/10,000 | 11 | HOUSEHOLD AMMONIA (11.9) | |
| | 1/1,000 | 10 | MILK OF MAGNESIUM (10.5) | |
| | 1/100 | 9 | TOOTHPASTE (9.9) | |
| | 1/10 | 8 | BAKING SODA (8.4) / SEA WATER EGGS | |
| | 0 | 7 | "PURE" WATER (7) | |
| | 10 | 6 | URINE (6) / MILK (6.6) | |
| | 100 | 5 | ACID RAIN (5.6) BLACK COFFEE (5) | |
| | 1000 | 4 | TOMATO JUICE (4.1) | |
| | 10,000 | 3 | GRAPEFRUIT & ORANGE JUICE SOFT DRINK | |
| | 100,000 | 2 | LEMON JUICE (2.3) VINEGAR (2.9) | |
| | 1,000,000 | 1 | HYDROCHLORIC ACID SECRETED FROM STOMACH LINING (1) | |
| | 10,000,000 | 0 | BATTERY ACID | |

### pH Scale

**Technical Definition of pH**
In technical terms, pH is defined as the decimal logarithm of the reciprocal of the hydrogen ion activity, $a$H+, in a solution.

$$ pH = -\log_{10}(a_H+) = \log_{10}\left(\frac{1}{a_H+}\right) $$

Ion-selective electrodes are often used to measure pH, respond to activity.

In this calculation of electrode potential, $E$, follows the Nernst equation, which, for the hydrogen ion can be written as

$$ E = E^0 + \frac{RT}{F} \ln(a_H+) = E^0 - \frac{2.303RT}{F}pH $$

where $E$ is a measured potential, $E^0$ is the standard electrode potential, $R$ is the gas constant, $T$ is the temperature in kelvin, $F$ is the Faraday constant. For H+ number of electrons transferred is one. It follows that electrode potential is proportional to pH when pH is defined in terms of activity.

International Standard ISO 31-8 is the standard for the precise measurement of pH as follows: A galvanic cell is set up to measure the electromotive force (EMF) between a reference electrode and an electrode sensitive to the hydrogen ion activity when they are both immersed in the same aqueous solution.

The reference electrode may be a silver chloride electrode or a calomel electrode. The hydrogen-ion selective electrode is a standard hydrogen electrode.

Reference electrode | concentrated solution of KCl || test solution | $H_2$ | Pt

Firstly, the cell is filled with a solution of known hydrogen ion activity and the emf, $E_S$, is measured. Then the emf, $E_X$, of the same cell containing the solution of unknown pH is measured.

$$pH(X) = pH(S) + \frac{E_s - E_x}{Z}$$

The difference between the two measured emf values is proportional to pH. This method of calibration avoids the need to know the standard electrode potential. The proportionality constant, *1/z* is ideally equal to $\frac{1}{2.303 RT/F}$ the "Nernstian slope".

If you were to apply this practice the above calculation, a glass electrode is used rather than the cumbersome hydrogen electrode. A combined glass electrode has an in-built reference electrode. It is calibrated against buffer solutions of known hydrogen ion activity. IUPAC has proposed the use of a set of buffer solutions of known $H^+$ activity.

Two or more buffer solutions should be used in order to accommodate the fact that the "slope" may differ slightly from ideal.

The electrode is first immersed in a standard solution and the reading on a pH meter is adjusted to be equal to the standard buffer's value, to implement the proper calibration. The reading from a second standard buffer solution is then adjusted, using the "slope" control, to be equal to the pH for that solution. Further details are given in the IUPAC recommendations.

When more than two buffer solutions are used the electrode is calibrated by fitting observed pH values to a straight line with respect to standard buffer values. Commercial standard buffer solutions usually come with information on the value at 25 °C and a correction factor to be applied for other temperatures. The pH scale is logarithmic and pH is a dimensionless quantity.

**pH Indicators**
Visual comparison of the color of a test solution with a standard color chart provides a means to measure pH accurate to the nearest whole number. Indicators may be used to measure pH, by making use of the fact that their color changes with pH. More precise measurements are possible if the color is measured spectrophotometrically, using a colorimeter of spectrophotometer. Universal indicator consists of a mixture of indicators such that there is a continuous color change from about pH 2 to pH 10. Universal indicator paper is made from absorbent paper that has been impregnated with universal indicator.

**pOH**
pOH is sometimes used as a measure of the concentration of hydroxide ions, $OH^-$, or alkalinity. pOH values are derived from pH measurements. The concentration of hydroxide ions in water is related to the concentration of hydrogen ions by

$$[OH^-] = \frac{K_W}{[H^+]}$$

where $K_W$ is the self-ionization constant of water. Taking logarithms

$$pOH = pK_W - pH$$

So, at room temperature pOH ≈ 14 − pH. However, this relationship is not strictly valid in other circumstances, such as in measurements of soil alkalinity.

**Extremes of pH**
Measurement of pH below about 2.5 (ca. 0.003 mol dm$^{-3}$ acid) and above about 10.5 (ca. 0.0003 mol dm$^{-3}$ alkali) requires special procedures because, when using the glass electrode, the Nernst law breaks down under those conditions.

Extreme pH measurements imply that the solution may be concentrated, so electrode potentials are affected by ionic strength variation. At high pH the glass electrode may be affected by "alkaline error", because the electrode becomes sensitive to the concentration of cations such as $Na^+$ and $K^+$ in the solution. Specially constructed electrodes are available which partly overcome these problems. Runoff from industrial outfalls, restaurant grease, mines or mine tailings can produce some very low pH values.

**Non-aqueous Solutions**
Hydrogen ion concentrations (activities) can be measured in non-aqueous solvents. pH values based on these measurements belong to a different scale from aqueous pH values, because activities relate to different standard states. Hydrogen ion activity, $a_{H^+}$, can be defined as:

$$a_{H+} = \exp\left(\frac{\mu_{H^+} - \mu_{H^+}^{\ominus}}{RT}\right)$$

where $\mu_{H^+}$ is the chemical potential of the hydrogen ion, $\mu^e_{H^+}$ is its chemical potential in the chosen standard state, $R$ is the gas constant and $T$ is the thermodynamic temperature. Therefore, pH values on the different scales cannot be compared directly, requiring an intersolvent scale which involves the transfer activity coefficient of hydrolyonium ion.

pH is an example of an acidity function. Other acidity functions can be defined. For example, the Hammett acidity function, $H_0$, has been developed in connection with superacids.

The concept of "Unified pH scale" has been developed on the basis of the absolute chemical potential of the proton. This scale applies to liquids, gases and even solids.

**Applications**

Water has a pH of $pK_w/2$, so the pH of pure water is about 7 at 25 °C; this value varies with temperature. When an acid is dissolved in water, the pH will be less than that of pure water. When a base, or alkali, is dissolved in water, the pH will be greater than that of pure water.

A solution of a strong acid, such as hydrochloric acid, at concentration 1 mol $dm^{-3}$ has a pH of 0. A solution of a strong alkali, such as sodium hydroxide, at concentration 1 mol $dm^{-3}$, has a pH of 14. Thus, measured pH values will lie mostly in the range 0 to 14, though negative pH values and values above 14 are entirely possible.

Since pH is a logarithmic scale, a difference of one pH unit is equivalent to a tenfold difference in hydrogen ion concentration.

The pH of an aqueous solution of pure water is slightly different from that of, a salt such as sodium chloride even though the salt is neither acidic nor basic. In this case, the hydrogen and hydroxide ions' activity are dependent on ionic strength, so $K_w$ varies with ionic strength. The pH of pure water decreases with increasing temperatures. One example is the pH of pure water at 50 °C is 6.55.

**Seawater**

The pH of seawater plays an important role in the ocean's carbon cycle, and there is evidence of ongoing ocean acidification caused by carbon dioxide emissions. pH measurement can be complicated by the chemical properties of seawater, and several distinct pH scales exist in chemical oceanography.

As part of its operational definition of the pH scale, the IUPAC defines a series of buffer solutions across a range of pH values (often denoted with NBS or NIST designation).

These solutions have a relatively low ionic strength (~0.1) compared to that of seawater (~0.7), and, as a consequence, are not recommended for use in characterizing the pH of seawater, since the ionic strength differences cause changes in electrode potential.

To resolve this problem, an alternative series of buffers based on artificial seawater was developed. This new series resolves the problem of ionic strength differences between samples and the buffers.  The newest pH scale is referred to as the **total scale**, often denoted as **$pH_T$**.

# Calculations of pH

The calculation of the pH of a solution containing acids and/or bases is an example of a chemical speciation calculation, that is, a mathematical procedure for calculating the concentrations of all chemical species that are present in the solution.

The complexity of the procedure depends on the nature of the solution.

If the pH of a solution contains a weak acid requires the solution of a quadratic equation.

If the pH of a solution contains a weak base may require the solution of a cubic equation.

For strong acids and bases no calculations are necessary except in extreme situations.

The general case requires the solution of a set of non-linear simultaneous equations.

A complicating factor is that water itself is a weak acid and a weak base. It dissociates according to the equilibrium

$$2H_2O \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$
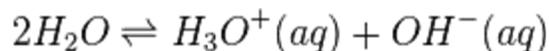
with a dissociation constant, $K_w$ defined as

$$K_w = [H^+][OH^-]$$

where [H⁺] represents for the concentration of the aquated hydronium ion and [OH⁻] stands for the concentration of the hydroxide ion. $K_w$ has a value of about $10^{-14}$ at 25 °C, so pure water has a pH of approximately 7.

This equilibrium needs to be considered at high pH and when the solute concentration is extremely low.

SOLIDIFICATION

MELT

CONDENSATE

EVAPORATE

SOLID          LIQUID          GAS

SOLID          LIQUID          GAS          PLASMA

MATTER CHANGED BY ADDING HEAT
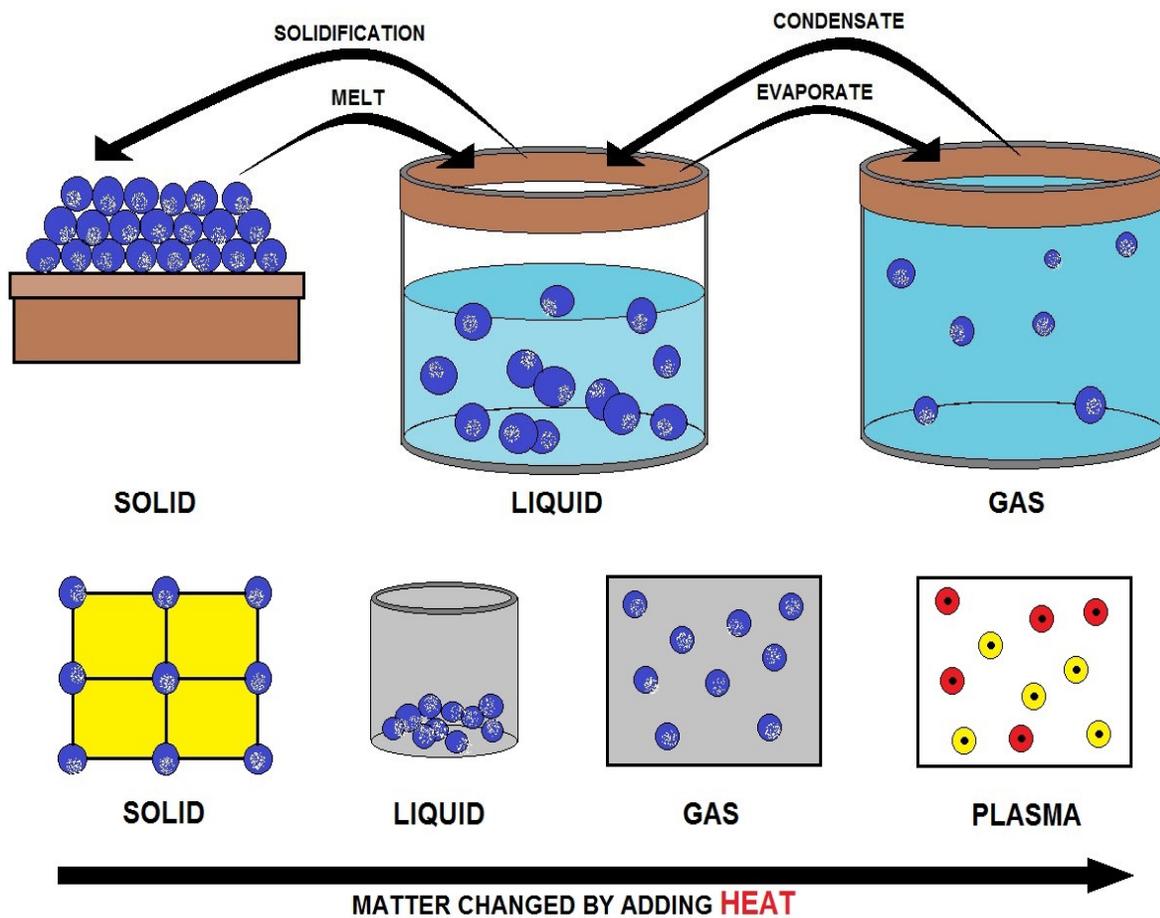
# STATES OF MATTER

## Strong Acids and Bases

$$Cl_2 + H_2O \longrightarrow HOCl + H + Cl$$

**CHLORINE GAS**        **HYPOCHLOROUS ACID**

$$HOCl \longrightarrow OCl + H$$

**HYPOCHLORITE ION**

### Strong Acids and Bases

Strong acids and bases are compounds that, for practical purposes, are completely dissociated in water. Under normal circumstances this means that the concentration of hydrogen ions in acidic solution can be taken to be equal to the concentration of the acid. The pH is then equal to minus the logarithm of the concentration value.

Hydrochloric acid (HCl) is an example of a strong acid. The pH of a 0.01M solution of HCl is equal to $-\log_{10}(0.01)$, that is, pH = 2.

Sodium hydroxide, NaOH, is an example of a strong base. The p[OH] value of a 0.01M solution of NaOH is equal to $-\log_{10}(0.01)$, that is, p[OH] = 2.

From the definition of p[OH] above, this means that the pH is equal to about 12. For solutions of sodium hydroxide at higher concentrations the self-ionization equilibrium must be taken into account.

### Weak Acids and Bases

A weak acid or the conjugate acid of a weak base can be treated using the same formalism.

Acid: $HA \rightleftharpoons H^+ + A^-$

Base: $HA^+ \rightleftharpoons H^+ + A$
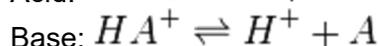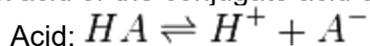
First, an acid dissociation constant is defined as follows. Electrical charges are omitted from subsequent equations for the sake of generality

$$K_a = \frac{[H][A]}{[HA]}$$

and its value is assumed to have been determined by experiment. This being so, there are three unknown concentrations, [HA], [H⁺] and [A⁻] to determine by calculation. Two additional equations are needed.

One way to provide them is to apply the law of mass conservation in terms of the two "reagents" H and A.

$$C_A = [A] + [HA]$$
$$C_H = [H] + [HA]$$

C stands for analytical concentration. In some texts one mass balance equation is replaced by an equation of charge balance. This is satisfactory for simple cases like this one but is more difficult to apply to more complicated cases as those below.

Together with the equation defining $K_a$, there are now three equations in three unknowns. When an acid is dissolved in water $C_A = C_H = C_a$, the concentration of the acid, so $[A] = [H]$. After some further algebraic manipulation an equation in the hydrogen ion concentration may be obtained.

$$[H]^2 + K_a[H] - K_aC_a = 0$$

CONCENTRATED
HYDROCHLORIC
ACID

POTASSIUM
MANGANATE

CHLORINE
GAS

34
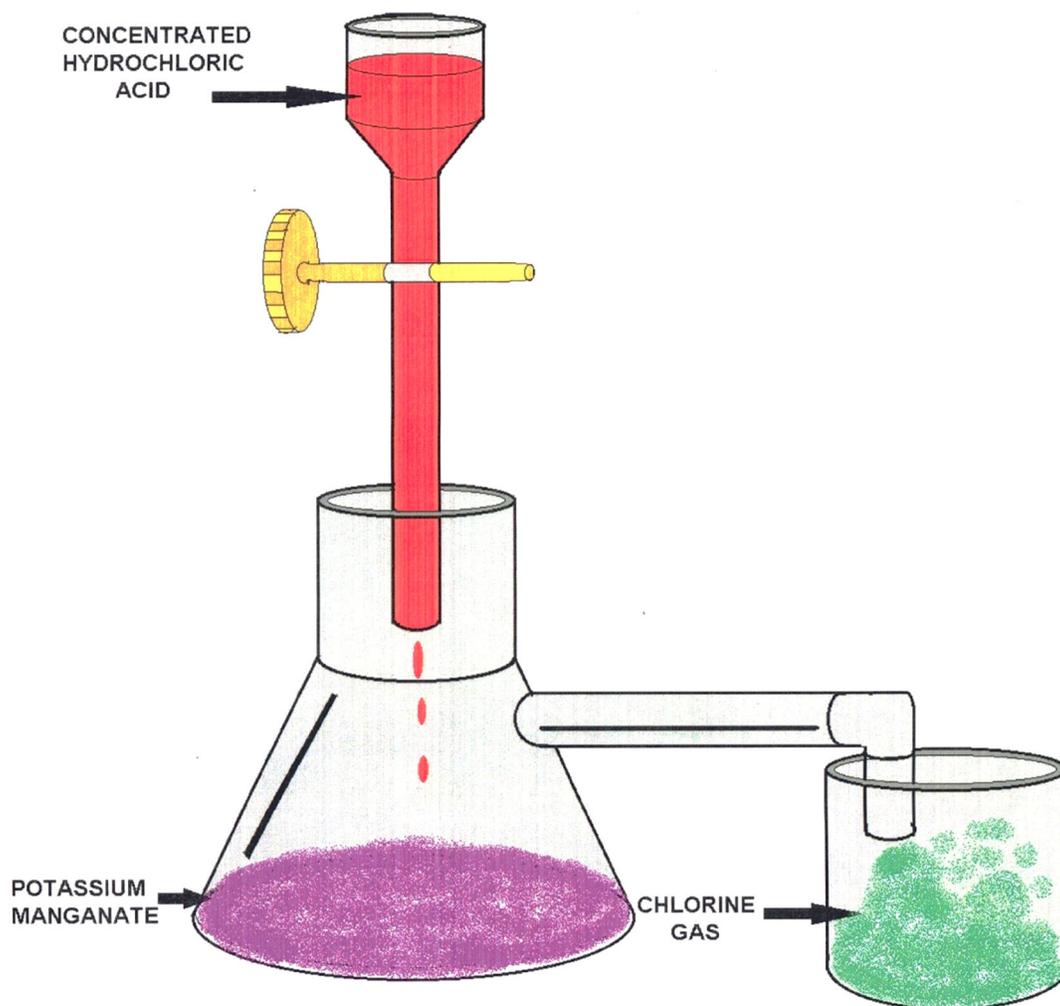
# Alkalinity Section

**Introduction**

Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titratable bases. The measured value may vary significantly with the end-point pH used. Alkalinity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known.

Alkalinity is significant in many uses and treatments of natural waters and wastewaters. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate, and hydroxide content, it is taken as an indication of the concentration of these constituents. The measured values also may include contributions from borates, phosphates, silicates or other bases if these are present. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes.

**Titration Method**
**a. Principle**

Hydroxyl ions present in a sample, as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Alkalinity thus depends on the end-point pH used.

**b. Reagents**

i) Standard Hydrochloric Acid – 0.02 N.
ii) Methyl Orange Indicator – Dissolve 0.1 g of methyl orange in distilled water and dilute to 1 liter.
iii) Sodium carbonate solution, 0.02 N : Dry 3 to 5 g primary standard $Na_2CO_3$ at 250$^o$C for 4 h and cool in a desiccator. Weigh 1.03 gm. (to the nearest mg), transfer to a 1-L volumetric flask, fill flask to the mark with distilled water, dissolve and mix reagent. Do no keep longer than 1 week.

**c. Procedure**

Titrate over a white surface 100 ml of the sample contained in a 250-ml conical flask with standard hydrochloric acid using two or three drops of methyl orange Indicator.
(**NOTE** – If more than 30 ml of acid is required for the titration, a smaller suitable aliquot of the sample shall be taken.)

**d. Calculation**
**Total alkalinity** (as $CaCO_3$), mg/l = 10 V or NxVx50x1000

T.A. (as $CaCO_3$) = ----------------------
                     Sample Amount
Where N = Normality of HCl used
    V = volume in ml of standard hydrochloric acid used in the titration.

**Alkalinity to Phenolphthalein**

The sample is titrated against standard acid using phenolphthalein indicator.

### a. Reagents
i) Phenolphthalein Indicator Solution :
Dissolve 0.1 g of phenolphthalein in 60 ml of ETHANOL and dilute with Distilled water to 100 ml.
ii) Standard hydrochloric Acid – 0.02 N.

### b. Procedure
Add 2 drops of phenolphthalein indicator solution to a sample of suitable size, 50 or 100 ml, in a conical flask and titrate over a while surface with standard hydrochloric acid.

### c. Calculation

**Alkalinity to phenolphthalein (as CaCO₃)**, mg/l $= \dfrac{1000 \, V_1}{V_2}$

Where
$V_1$ = volume in ml of standard hydrochloric acid used in the titration , and
$V_2$ = Volume in ml of the sample taken for the test.

### Caustic Alkalinity
### a. General
Caustic alkalinity is the alkalinity corresponding to the hydroxides present in water and is calculated from total alkalinity (T) and alkalinity to phenolphthalein (P).

| b. Procedure<br>Determine total alkalinity and alkalinity to phenolphthalein and calculate caustic alkalinity as shown in Table below.<br>Result of Titration Caustic Alkalinity or Hydroxide Alkalinity as  CaCO₃<br>Carbonate Alkalinity as CaCO₃<br>Bicarbonate Concentration<br>as   CaCO₃<br>**Result of Titration** | Caustic Alkalinity or Hydroxide Alkalinity as CaCO₃ | Carbonate Alkalinity as CaCO₃ | Bicarbonate Concentration as CaCO₃ |
|---|---|---|---|
| P=0 | 0 | 0 | 0 |
| P<1/2T | 0 | 2P | T-2P |
| P=1/2T | 0 | 2P | 0 |
| P>1/2T | 2P-T | 2(T-P) | 0 |
| P=T | T | 0 | 0 |

The alkalinity of water is a measure of its capacity to neutralize acids.  The alkalinity of natural water is due to the salts of carbonate, bicarbonate, borates, silicates and phosphates along with the hydroxyl ions in free state.

However, the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate, and bicarbonates which may be ranked in order of their association with high pH values. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation and softening.

# Alkalinity (Total)

References: ASTM D 1067-92, Acidity or Alkalinity of Water.
APHA Standard Methods, 19th ed., p. 2-26, method 2320B (1995).
EPA Methods for Chemical Analysis of Water and Wastes, method 310.1 (1983).

The alkalinity of water is a measurement of its buffering capacity or ability to react with strong acids to a designated pH. Alkalinity of natural waters is typically a combination of bicarbonate, carbonate, and hydroxide ions. Sewage and wastewaters usually exhibit higher alkalinities either due to the presence of silicates and phosphates or to a concentration of the ions from natural waters.

Alkalinity inhibits corrosion in boiler and cooling waters and is therefore a desired quality which must be maintained. It is also measured as a means of controlling water and wastewater treatment processes or the quality of various process waters. In natural waters, excessive alkalinity can render water unsuitable for irrigation purposes and may indicate the presence of industrial effluents.

*The Titrimetric Method.* CHEMetrics' tests determine total or "M" alkalinity using an acid titrant and a pH indicator. The end point of the titration occurs at pH 4.5. Results are expressed as ppm (mg/L) CaCO3.

## Hardness (calcium)

Reference: West, T. S., DSC, Ph.D., Complexometry with EDTA and Related Reagents, 3rd ed., p. 46, 164 (1969).

Originally described as water's capacity to precipitate soap, hardness is one of the most frequently determined qualities of water. It is a composite of the calcium, magnesium, strontium, and barium concentrations in a sample. The current practice is to assume total hardness refers to the calcium and magnesium concentrations only.

Completely de-hardened water, resulting from sodium zeolite or other suitable ion exchange treatment, is required for various processes-including power generation, printing and photo finishing, pulp and paper manufacturing, and food and beverage processing.

Hard water can cause scale formation on heat exchange surfaces, resulting in decreased heat transfer and equipment damage.

The Titrimetric Method. This method is specific for calcium hardness. The EGTA titrant in alkaline solution is employed with zincon indicator. Results are expressed as ppm (mg/L) $CaCO_3$.

Shelf-life. 8 months. Although the reagent itself is stable, the end point indicator has a limited shelf-life. We recommend stocking quantities that will be used within 7 months.

**ALKALINITY**

Bicarbonate
$H_2CO_3$

Carbonic Acid
$HCO_3$

Carbonate
$CO_3$
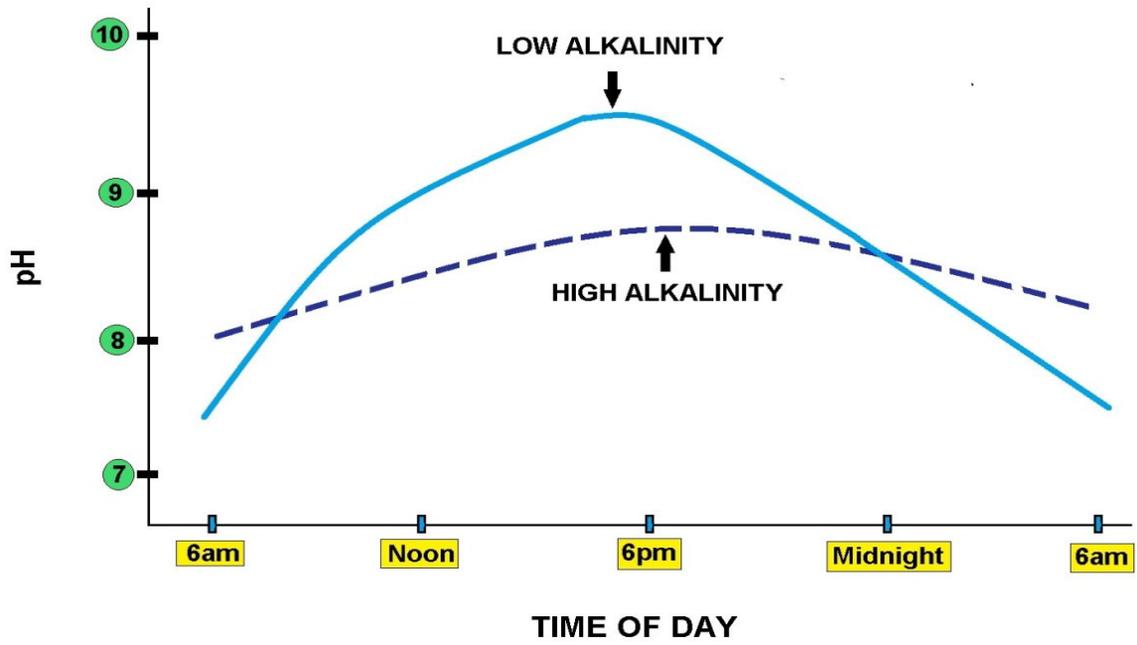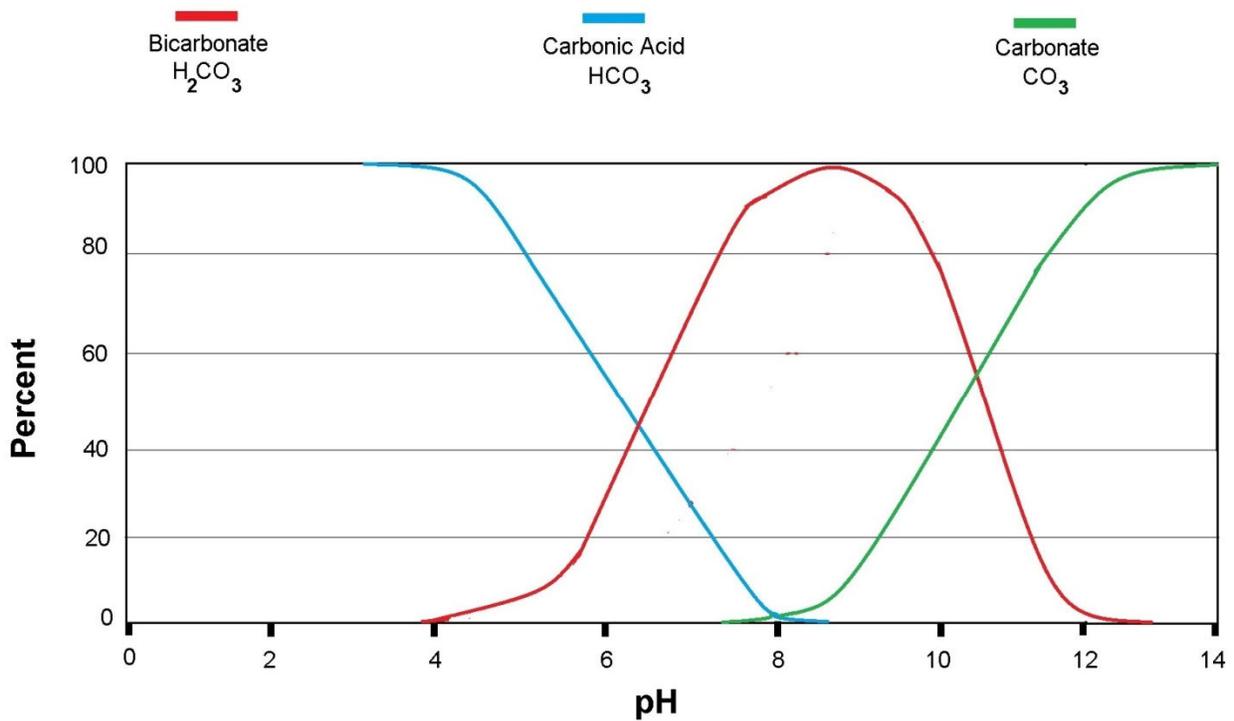


**EFFECTS OF ALKALINITY FROM pH**

# pH Meters

There are several different pH meters on the market. For this course, two types of pH meters will be discussed, the 230A and the 250A models. A two-buffer calibration is used, 7 pH and 10 pH, since most of the tested samples fall within these ranges. Following are the methods presently used in the calibration and measuring techniques of these meters:

**(1)     Calibration of the Orion 230A Model pH Meter**

(a) Two-buffer calibration is used. The first calibration buffer (pH 7) is near the electrode isopotential point, and the second (pH 10) is near the expected sample pH. Choose buffers that are no more than three pH units apart. Use fresh buffers at the beginning of each week.
**This calibration should be done at the beginning of each day and the results entered in the pH logbook.**

(b) Uncover the fill hole. This should always be uncovered when using the meter and checked to make sure it is full of electrolyte solution. Turn on the meter's power. Rinse the electrode with high purity water then place it in the pH 7 buffer.

(c)  Press "cal". **CALIBRATE** and P1 will be displayed.

(d) Wait for the meter to display **READY** with the pH reading flashing. If this is the correct pH, enter "**yes**" and proceed to step "E". If not, press the "**timer**" key and the first digit will start flashing. Pressing the "**timer**" or "**setup**" key ("**timer**" for raising the number or "setup" for decreasing it), correct the digit. When it is correct, press "**yes**." The second digit will start flashing. Repeat the previous steps for the second and third digits.

(e) The display will now show P2, indicating the meter is ready for the second buffer. Rinse the electrode with high purity water and place it in the second buffer (pH 10). Wait for the meter to display **READY** with the pH reading flashing. Use the above procedure for calibrating at this pH.

(f) The electrode slope, in percent, will be displayed (this value must be between 92 to 102 percent) along with the temperature. Record these figures in the logbook.

(g) Rinse the electrode with high purity water and return it to the storage solution. Turn off the power. When the electrode won't be used for a while, cover the fill hole with the rubber sleeve.

**(2)     Calibration of the Orion 250A Model pH Meter**

(a) This procedure is the same as the 230A Model through steps (a) and (b) above.
(b) Press the "**mode**" key until the pH mode indicator is displayed. Place the electrode in the first buffer and press the "**2nd**" key. P1 will be displayed.
(c) Go to step (d) in the calibration of the Orion 230A model and continue with the same set up.

**(3)    Measuring Techniques for pH with Orion Models 230A and 250A**

   (a)  Making sure the fill hole is uncovered, turn on the meter's power.  Rinse the electrode with high purity water.

   (b)  Place the electrode in the sample.

   (c)  When the display is stable and shows **READY**, record the sample pH and temperature.

   (d)  Rinse the electrode, return to the storage solution, and turn the power off. When finished for the day, cover the fill hole.



Common pH measurement equipment and probe rinse agent in plastic bottle.

# Common Symbols and Characters

These symbols and characters are specific to water sampling methods but have been conformed to common usage as much as possible.

**Units of weight and measure and their abbreviations**
**Symbols**
$^\circ$C degrees Celsius
µL microliter
< less than
> greater than
% percent

**Alphabetical characters**
ACUK - Acid chrome violet K
AECL - Alternate enhanced coagulant level
AOC - Assimilable organic carbon
ASDWA - Association of State Drinking Water Administrators
AWWA - American Water Works Association
AWWARF - AWWA Research Foundation
BAC - Biologically active carbon
BAF - Biologically active filtration
BAT - Best Available Technology
BCAA - Bromochloroacetic acid
BDOC - Biodegradable organic carbon
BMP-  Best management practice
BOM - Biodegradable Organic Matter (=BDOC + AOC)
Br- - Bromide ion
$BrO^2$- - Bromite ion
$BrO^3$- - Bromate ion
CI - Confidence interval
$Cl^2$ - Chlorine
$ClO^2$ - Chlorine Dioxide
cm - centimeter
CT - Concentration-Time
CWS - Community Water System
D/DBP - Disinfectants/disinfection byproducts
DBP - Disinfection byproduct
DBPFP - Disinfection byproduct formation potential
DBPP - Disinfection byproduct precursors
DBPR - Disinfectants/disinfection byproducts rule
DBPRAM - DBP Regulatory Assessment Model
DBPs - Disinfection byproducts
DOC-  Dissolved organic carbon
DPD - N,N-diethyl-p-phenylenediamine
DWEL - Drinking Water Equivalent Level
EBCT - Empty bed contact time
EMSL - EPA Environmental Monitoring and Support Laboratory (Cincinnati)
EPA - United States Environmental Protection Agency
ESWTR - Enhanced Surface Water Treatment Rule

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FBR - Filter Backwash Rule
FY - Fiscal year
G - acceleration due to gravity
g - gram
GAC - Granular activated carbon
GWR - Ground Water Rule
GWSS - Ground Water Supply Survey
H2O2 - Hydrogen Peroxide
HAA5 - Haloacetic acids (five)
HOBr - Hypobromous acid
HOCl - Hypochlorous acid
hr - hour
IC- Ion chromatography
ICR- Information Collection Rule
ID - inside diameter
IESWTR- Interim Enhanced Surface Water Treatment Rule
in. - inch
IOA- International Ozone Association
IOC - Inorganic chemical
KMnO4 - Potassium permanganate
L - liter
LOAEL - Lowest observed adverse effect level
LOQ - Limit of quantitation
LT1ESWTR - Long Term Stage 1 Enhanced Surface Water Treatment Rule
m - meter
MCL - Maximum Contaminant Level
MCLG - Maximum Contaminant Level Goal
M-DBP - Microbial and disinfection byproducts
MDL - Method Detection Limit
mg - milligram
mg/L - Milligrams per liter
mgd - Million gallons per day
MIB -Methylisoborneol
mL - milliliter
mm - millimeter
mM - millimolar
MRDL - Maximum Residual Disinfectant Level (as mg/l)
MRDLG - Maximum Residual Disinfectant Level Goal
MRL - Minimum Reporting Level
MX - 3-chloro-4-(dichloromethyl)-5-hydroxyl-2(5H)-furanone
N - normal; gram molecular weight of solute divided by hydrogen equivalent of solute, per liter of solution
NaCl - Sodium chloride
NCI - National Cancer Institute
ND - Not detected
NH$_2$Cl - Monochloramine
NIOSH - National Institute for Occupational Safety and Health
NIPDWR - National Interim Primary Drinking Water Regulation
NOAEL - No Observed Adverse Effect Level
NOM - Natural Organic Matter
NOMS - National Organic Monitoring Survey

NORS - National Organics Reconnaissance Survey for Halogenated Organics
NPDWR - National Primary Drinking Water Regulation
NTNCWS - Nontransient noncommunity water system
NTP - Normal Temperature and Pressure
$O^2$ - Oxygen
$O^3$ - Ozone
OBr- - Hypobromite ion
OCl- - Hypochlorite ion
PCE - Perchloroethylene
PE - Performance evaluation
POE - Point-of-Entry Technologies
POU-  Point-of-Use Technologies
ppb - Parts per billion
ppm - Parts per million
PQL - Practical Quantitation Level
PTA - Packed Tower Aeration
PWS - Public water system
RIA - Regulatory Impact Analysis
RMCL - Recommended Maximum Contaminant Level
RNDB -  Regulations Negotiation Data Base
RSC - Relative Source Contribution
RSD -  relative standard deviation
SDWA - Safe Drinking Water Act, or the "Act," as amended in 1996
SM - Standard Method
SMCL - Secondary Maximum Contaminant Level
SMR - Standardized mortality ratios
SOC - Synthetic Organic Chemical
$s_r$ - standard deviation of recovery
SWTR- Surface Water Treatment Rule
TCE - Trichloroethylene
THM - Trihalomethane
THMFP - Trihalomethane formation potential
TMV - Tobacco mosaic virus
TOC - Total organic carbon
TTHM -  Total trihalomethanes
TWG - Technologies Working Group
UV - Ultraviolet
VOC -  Volatile Organic Chemical
WIDB - Water Industry Data Base
WS - Water supply
X - average percent recovery
XDBPs - Halogenated DBPs

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