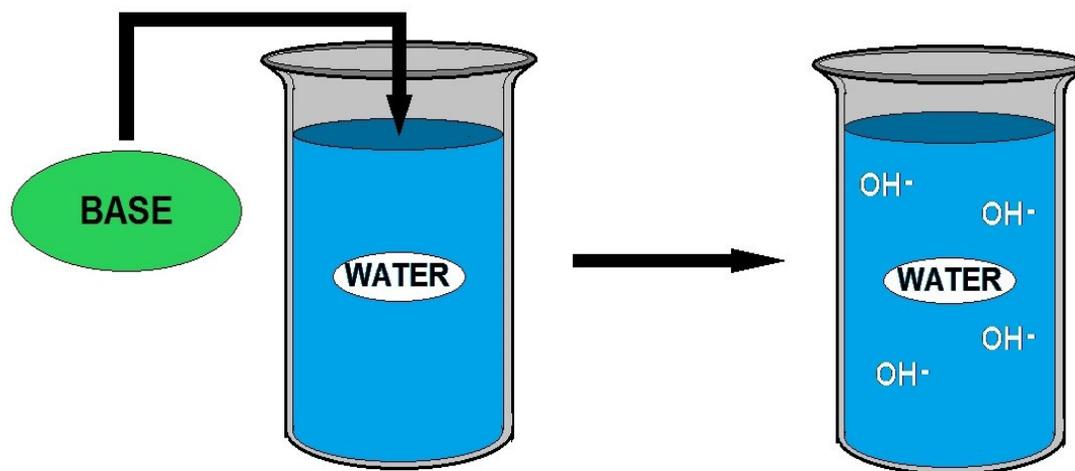
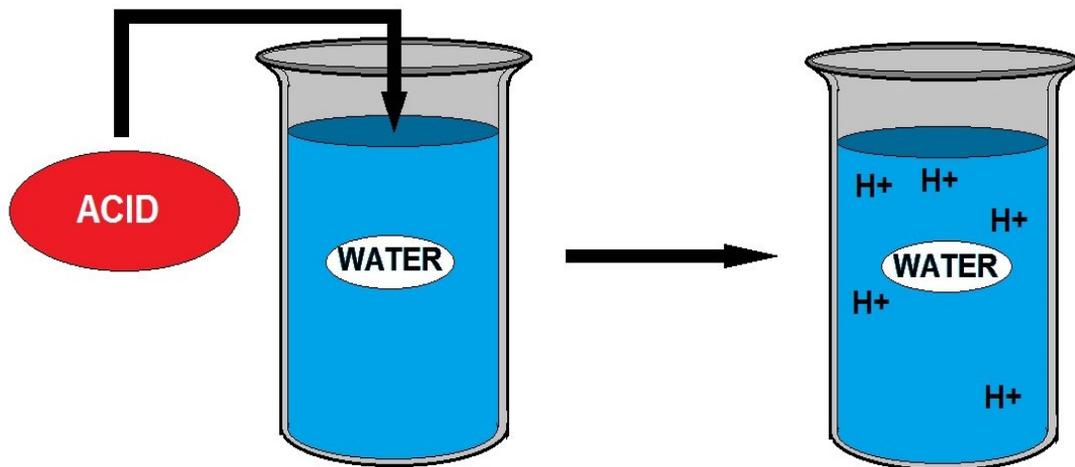


# BASIC CHEMISTRY

PROFESIONAL DEVELOPMENT  
CONTINUING EDUCATION COURSE





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

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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.

# 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 do finish the material on your leisure. 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 can 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

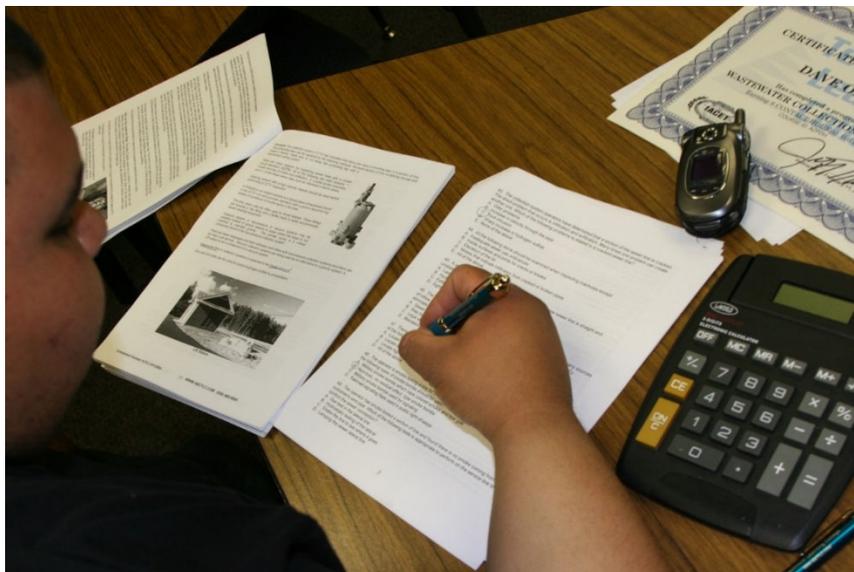
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student friendly course design allows you the most flexibility in choosing when and where you will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

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**Telephone (866) 557-1746**

## **CEU COURSE DESCRIPTION**

### **BASIC CHEMISTRY CEU TRAINING COURSE**

This five hour continuing education course is a non-lab course that introduces the students to basic chemistry principles. Topics covered include the periodic table, atoms and molecules, the pH scale and experimental design and techniques. You will understand atoms and molecules. You will be able to classify elements and compounds. You will learn about chemical bonds including ionic and covalent bonding. This course will help you to gain a good knowledge of the reactions between acids and bases and understanding pH. This course will teach you the meaning of ions, particles, gases, liquids, solids, soluble and insoluble mixtures. You will understand other interesting areas of chemistry.

#### **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 identify different types of matter. Develop an appreciation for development of modern chemistry. Be able to describe the basic structure of the atom, giving specific details for any given element. Develop knowledge of the periodic table and its structure and be able to explain why atoms join together to form different compounds. Build and name simple ionic and covalent chemical compounds

#### **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 basic chemistry.
2. The student will understand and describe the principles of the Period Table, including elements, atoms and molecules.
3. The student will understand and describe the principles of pH.
4. The student will understand and describe the principles of laboratory safety and general laboratory procedures.

#### **Specific CEU Course Learning Objectives**

1. The student will understand and describe the principles of basic chemistry.
  - Basic Chemistry
  - Chemical Compounds
  - Chemistry Subdivisions
  - Commonly Found Chemical Types
  - Inorganic Chemical Section
  - Main Group Elements
  - Principles of Modern Chemistry

- Reactions
- Substances

2. The student will understand and describe the principles of the Period Table, including elements, atoms and molecules.

- Bonding
- Energy
- Molecule Section
- Phase
- Understanding the Atom

3. The student will understand and describe the principles of pH.

- Acidity and Basicity
- Calculating pH
- Hard Water Section
- pH Measurement
- Strong Acids and Bases

4. The student will understand and describe the principles of laboratory safety and general laboratory procedures.

- Chemical Hygiene Plan
- Laboratory Safety Section
- Symbols and Characters

#### **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 *Basic Chemistry* 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 basic chemistry, the principles of the Period Table, including elements, atoms and molecules, the principles of pH, and principles of laboratory safety.



READ THE SAFETY DATA SHEET



WEAR PROPER PPE



HANDLING CHEMICALS

## **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.*

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CARL WILHELM SCHEELE (1742-1786)

By the time he was a teenager, Scheele had learned the dominant theory of gases in the 1770s, the phlogiston theory. Phlogiston, classified as "matter of fire", was supposed to be released from any burning material, and when it was exhausted, combustion would stop. When Scheele discovered oxygen he called it "fire air" because it supported combustion, but he explained oxygen using phlogistical terms because he did not believe that his discovery disproved the phlogiston theory. Before Scheele made his discovery of oxygen, he studied air.

Air was thought to be an element that made up the environment in which chemical reactions took place but did not interfere with the reactions. Scheele's investigation of air enabled him to conclude that air was a mixture of "fire air" and "foul air;" in other words, a mixture of two gases. He performed numerous experiments in which he burned substances such as saltpeter (potassium nitrate), manganese dioxide, heavy metal nitrates, silver carbonate and mercuric oxide. In all of these experiments, he isolated gas with the same properties: his "fire air," which he believed combined with phlogiston to be released during heat-releasing reactions.

However, his first publication, *A Chemical Treatise on Air and Fire*, was not released until 1777, at which time both Joseph Priestley and Lavoisier had already published their experimental data and conclusions concerning oxygen and the phlogiston theory.

## Introduction to Basic Chemistry



### Chemistry

**Chemistry** is a branch of physical science that studies the composition, structure, properties and change of matter. Chemistry is chiefly concerned with atoms and molecules and their interactions and transformations, for example, the properties of the chemical bonds formed between atoms to create chemical compounds. As such, chemistry studies the involvement of electrons and various forms of energy in photochemical reactions, oxidation-reduction reactions, changes in phases of matter, and separation of mixtures. Preparation and properties of complex substances, such as alloys, polymers, biological molecules, and pharmaceutical agents are considered in specialized fields of chemistry.

Chemistry is sometimes called *the central science* because it bridges other natural sciences like physics, geology and biology. Chemistry is a branch of physical science but distinct from physics.

The etymology of the word chemistry has been much disputed. The history of chemistry can be traced to certain practices, known as alchemy, which had been practiced for several millennia in various parts of the world.

#### Definition

In retrospect, the definition of chemistry has changed over time, as new discoveries and theories add to the functionality of the science. The term "chymistry", in the view of noted scientist Robert Boyle in 1661, meant the subject of the material principles of mixed bodies.

In 1663 the chemist Christopher Glaser described "chymistry" as a scientific art, by which one learns to dissolve bodies, and draw from them the different substances on their composition, and how to unite them again, and exalt them to a higher perfection.

The 1730 definition of the word "chemistry", as used by Georg Ernst Stahl, meant the art of resolving mixed, compound, or aggregate bodies into their principles; and of composing such bodies from those principles. In 1837, Jean-Baptiste Dumas considered the word "chemistry" to refer to the science concerned with the laws and effects of molecular forces. This definition further evolved until, in 1947, it came to mean the science of substances: their structure, their properties, and the reactions that change them into other substances - a characterization accepted by Linus Pauling. More recently, in 1998, Professor Raymond Chang broadened the definition of "chemistry" to mean the study of matter and the changes it undergoes.

### **Chemistry Subdisciplines**

Chemistry is typically divided into several major sub-disciplines. There are also several main cross-disciplinary and more specialized fields of chemistry.

- Analytical chemistry is the analysis of material samples to gain an understanding of their chemical composition and structure. Analytical chemistry incorporates standardized experimental methods in chemistry. These methods may be used in all subdisciplines of chemistry, excluding purely theoretical chemistry.
- Biochemistry is the study of the chemicals, chemical reactions and chemical interactions that take place in living organisms. Biochemistry and organic chemistry are closely related, as in medicinal chemistry or neurochemistry. Biochemistry is also associated with molecular biology and genetics.
- Inorganic chemistry is the study of the properties and reactions of inorganic compounds. The distinction between organic and inorganic disciplines is not absolute and there is much overlap, most importantly in the sub-discipline of organometallic chemistry.
- Materials chemistry is the preparation, characterization, and understanding of substances with a useful function. The field is a new breadth of study in graduate programs, and it integrates elements from all classical areas of chemistry with a focus on fundamental issues that are unique to materials. Primary systems of study include the chemistry of condensed phases (solids, liquids, polymers) and interfaces between different phases.
- Neurochemistry is the study of neurochemicals; including transmitters, peptides, proteins, lipids, sugars, and nucleic acids; their interactions, and the roles they play in forming, maintaining, and modifying the nervous system.
- Nuclear chemistry is the study of how subatomic particles come together and make nuclei. Modern Transmutation is a large component of nuclear chemistry, and the table of nuclides is an important result and tool for this field.
- Organic chemistry is the study of the structure, properties, composition, mechanisms, and reactions of organic compounds. An organic compound is defined as any compound based on a carbon skeleton.
- Physical chemistry is the study of the physical and fundamental basis of chemical systems and processes. In particular, the energetics and dynamics of such systems and processes are of interest to physical chemists. Important areas of study include chemical thermodynamics, chemical kinetics, electrochemistry, statistical mechanics, spectroscopy, and more recently, astrochemistry. Physical chemistry has large overlap with molecular physics. Physical chemistry involves the use of infinitesimal calculus in deriving equations. It is usually associated with

- quantum chemistry and theoretical chemistry. Physical chemistry is a distinct discipline from chemical physics, but again, there is very strong overlap.
- Theoretical chemistry is the study of chemistry via fundamental theoretical reasoning (usually within mathematics or physics). In particular the application of quantum mechanics to chemistry is called quantum chemistry. Since the end of the Second World War, the development of computers has allowed a systematic development of computational chemistry, which is the art of developing and applying computer programs for solving chemical problems. Theoretical chemistry has large overlap with (theoretical and experimental) condensed matter physics and molecular physics.

Other disciplines within chemistry are traditionally grouped by the type of matter being studied or the kind of study. These include inorganic chemistry, the study of inorganic matter; organic chemistry, the study of organic (carbon based) matter; biochemistry, the study of substances found in biological organisms; physical chemistry, the study of chemical processes using physical concepts such as thermodynamics and quantum mechanics; and analytical chemistry, the analysis of material samples to gain an understanding of their chemical composition and structure.

Many more specialized disciplines have emerged in recent years, e.g. neurochemistry the chemical study of the nervous system (see subdisciplines).

## Commonly found Chemical Types

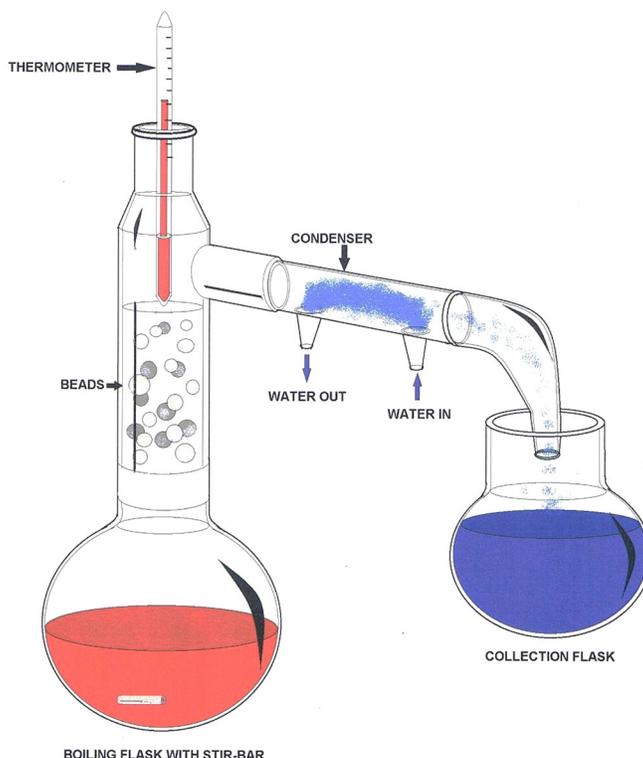
Many chemicals are commonly available in pure form. Others are available as reagents - inexpensive, convenient sources of chemicals with a bit of processing.

This is convenient for both amateur and professional chemistry work. Common reagents include:

- Metal oxides and carbonates (widely used in pottery)
- Organic acids (used for home brewing)
- Solvents and acids (used in cleaning materials and other hardware applications)
- Photographic chemicals, such as silver nitrate
- Single-chemical fertilizers, such as potassium nitrate (used in agricultural supply)
- Chlorinating agents, such as calcium hypochlorite (used in swimming pool and water purification)
- Mordants, such as potassium dichromate (used in arts and crafts)
- A *chemical substance* is a form of matter that has constant chemical composition and characteristic properties. It cannot be separated into components by physical separation methods, i.e. without breaking chemical bonds. Chemical substances can be chemical elements, chemical compounds, ions or alloys.
- Chemical substances are often called 'pure' to set them apart from mixtures. A common example of a chemical substance is pure water; it has the same properties and the same ratio of hydrogen to oxygen whether it is isolated from a river or made in a laboratory. Other chemical substances commonly encountered in pure form are diamond (carbon), gold, table salt (sodium chloride) and refined sugar (sucrose). However, in practice, no substance is entirely pure, and chemical purity is specified according to the intended use of the chemical.
- Chemical substances exist as solids, liquids, gases or plasma, and may change between these phases of matter with changes in temperature or pressure. Chemical reactions convert one chemical substance into another.
- Forms of energy, such as light and heat, are not considered to be matter, and thus they are not "substances" in this regard.
- Chemical substances (also called pure substances) may well be defined as "any material with a definite chemical composition" in an introductory general chemistry textbook. According to this definition a chemical substance can either be a pure chemical element or a pure chemical compound. But, there are exceptions to this definition; a pure substance can also be defined as a form of matter that has both definite composition and distinct properties. The chemical substance index published by CAS also includes several alloys of uncertain composition. Non-stoichiometric compounds are a special case (in inorganic chemistry) that violates the law of constant composition, and for them, it is sometimes difficult to draw the line between a mixture and a compound, as in the case of palladium hydride.
- In geology, substances of uniform composition are called minerals, while physical mixtures (aggregates) of several minerals (different substances) are defined as rocks. Many minerals, however, mutually dissolve into solid solutions, such that a single rock is a uniform substance despite being a mixture in stoichiometric terms. Feldspars are a common example: anorthoclase is an alkali aluminum silicate, where the alkali metal is interchangeably either sodium or potassium.

## Principles of Modern Chemistry

The current model of atomic structure is the quantum mechanical model. Traditional chemistry starts with the study of elementary particles, atoms, molecules, substances, metals, crystals and other aggregates of matter. This matter can be studied in solid, liquid, or gas states, in isolation or in combination. The interactions, reactions and transformations that are studied in chemistry are usually the result of interactions between atoms, leading to rearrangements of the chemical bonds which hold atoms together. Such behaviors are studied in a chemistry laboratory.



The chemistry laboratory stereotypically uses various forms of laboratory glassware. However glassware is not central to chemistry and a great deal of experimental (as well as applied/industrial) chemistry is done without it.

A chemical reaction is a transformation of some substances into one or more different substances. The basis of such a chemical transformation is the rearrangement of electrons in the chemical bonds between atoms. It can be symbolically depicted through a chemical equation, which usually involves atoms as subjects.

The number of atoms on the left and the right in the equation for a chemical transformation is equal. (When the number of atoms on either side is unequal, the transformation is referred to as a nuclear reaction or radioactive decay.) The type of chemical reactions a substance may undergo and the energy changes that may accompany it are constrained by certain basic rules, known as chemical laws.

Energy and entropy considerations are invariably important in almost all chemical studies. Chemical substances are classified in terms of their structure, phase, as well as their chemical compositions. They can be analyzed using the tools of chemical analysis, e.g. spectroscopy and chromatography. Scientists engaged in chemical research are known as chemists. Most chemists specialize in one or more sub-disciplines.

## Matter

In chemistry, matter is defined as anything that has rest mass and volume (it takes up space) and is made up of particles. The particles that make up matter have rest mass as well - not all particles have rest mass, such as the photon. Matter can be a pure chemical substance or a mixture of substances.

# Periodic Table of the Elements

Alkali metals  
Alkaline earth metals  
Transition metals  
Lanthanide series  
Actinide series  
Poor metals  
Nonmetals  
Noble gases  
Solid  
Liquid  
Gas  
Synthetic

1 IA  
2 IIA  
3 IIIB  
4 IVB  
5 VB  
6 VIB  
7 VIIB  
8 VIII  
9 VIII  
10 VIII  
11 IB  
12 IIB  
13 IIIA  
14 IVA  
15 VA  
16 VIA  
17 VIIA  
18 VIIIA

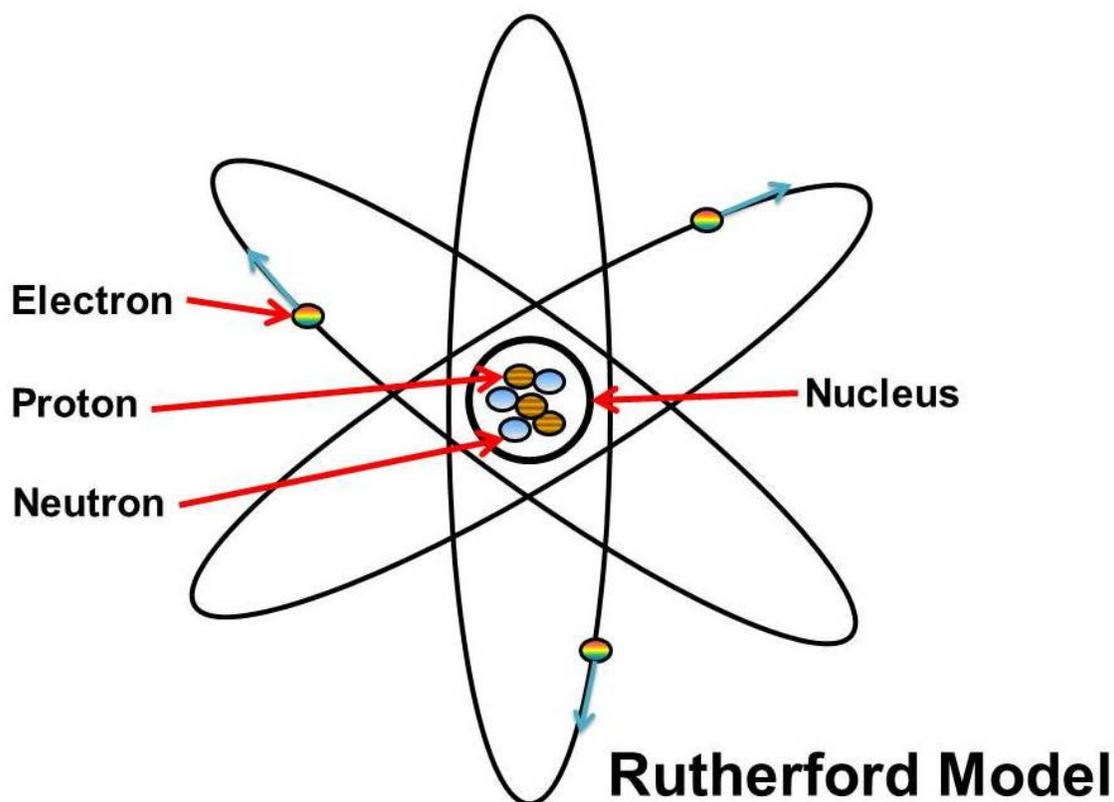
1 H Hydrogen (1.00784)  
2 He Helium (4.002602)  
3 Li Lithium (6.941)  
4 Be Beryllium (9.012182)  
5 B Boron (10.811)  
6 C Carbon (12.0107)  
7 N Nitrogen (14.0064)  
8 O Oxygen (15.9994)  
9 F Fluorine (18.9984032)  
10 Ne Neon (20.1797)  
11 Na Sodium (22.989770)  
12 Mg Magnesium (24.3050)  
13 Al Aluminum (26.981538)  
14 Si Silicon (28.0855)  
15 P Phosphorus (30.973761)  
16 S Sulfur (32.06)  
17 Cl Chlorine (35.45)  
18 Ar Argon (39.948)  
19 K Potassium (39.0983)  
20 Ca Calcium (40.078)  
21 Sc Scandium (44.955910)  
22 Ti Titanium (47.867)  
23 V Vanadium (50.9415)  
24 Cr Chromium (51.9961)  
25 Mn Manganese (54.938045)  
26 Fe Iron (55.845)  
27 Co Cobalt (58.933200)  
28 Ni Nickel (58.6934)  
29 Cu Copper (63.546)  
30 Zn Zinc (65.409)  
31 Ga Gallium (69.723)  
32 Ge Germanium (72.64)  
33 As Arsenic (74.92160)  
34 Se Selenium (78.96)  
35 Br Bromine (79.904)  
36 Kr Krypton (83.796)  
37 Rb Rubidium (85.4678)  
38 Sr Strontium (87.62)  
39 Y Yttrium (88.90585)  
40 Zr Zirconium (91.224)  
41 Nb Niobium (92.90638)  
42 Mo Molybdenum (95.94)  
43 Tc Technetium (98)  
44 Ru Ruthenium (101.07)  
45 Rh Rhodium (102.90550)  
46 Pd Palladium (106.42)  
47 Ag Silver (107.8682)  
48 Cd Cadmium (112.411)  
49 In Indium (114.818)  
50 Sn Tin (118.710)  
51 Sb Antimony (121.760)  
52 Te Tellurium (127.6)  
53 I Iodine (126.90547)  
54 Xe Xenon (131.29)  
55 Cs Cesium (132.90545)  
56 Ba Barium (137.327)  
57-71 Lanthanide series  
58 Ce Cerium (140.12)  
59 Pr Praseodymium (140.90765)  
60 Nd Neodymium (144.24)  
61 Pm Promethium (145)  
62 Sm Samarium (150.36)  
63 Eu Europium (151.964)  
64 Gd Gadolinium (157.25)  
65 Tb Terbium (158.92534)  
66 Dy Dysprosium (162.50)  
67 Ho Holmium (164.93032)  
68 Er Erbium (167.259)  
69 Tm Thulium (168.93421)  
70 Yb Ytterbium (173.04)  
71 Lu Lutetium (174.967)  
72 Hf Hafnium (178.49)  
73 Ta Tantalum (180.9479)  
74 W Tungsten (183.84)  
75 Re Rhenium (186.207)  
76 Os Osmium (190.23)  
77 Ir Iridium (192.22)  
78 Pt Platinum (195.078)  
79 Au Gold (196.96655)  
80 Hg Mercury (200.59)  
81 Tl Thallium (204.3833)  
82 Pb Lead (207.2)  
83 Bi Bismuth (208.98039)  
84 Po Polonium (209)  
85 At Astatine (210)  
86 Rn Radon (222)  
87 Fr Francium (223)  
88 Ra Radium (226)  
89-103 Actinide series  
89 Ac Actinium (227)  
90 Th Thorium (232.0381)  
91 Pa Protactinium (231.03688)  
92 U Uranium (238.02891)  
93 Np Neptunium (237)  
94 Pu Plutonium (244)  
95 Am Americium (243)  
96 Cm Curium (247)  
97 Bk Berkelium (247)  
98 Cf Californium (251)  
99 Es Einsteinium (252)  
100 Fm Fermium (257)  
101 Md Mendelevium (258)  
102 No Nobelium (259)  
103 Lr Lawrencium (260)  
104 Rf Rutherfordium (261)  
105 Db Dubnium (262)  
106 Sg Seaborgium (266)  
107 Bh Bohrium (264)  
108 Hs Hassium (265)  
109 Mt Meitnerium (268)  
110 Ds Darmstadtium (271)  
111 Rg Roentgenium (272)  
112 Uub Ununbium (285)  
113 Uut Ununtrium (284)  
114 Uuq Ununquadium (289)  
115 Uup Ununpentium (288)  
116 Uuh Ununhexium (289)  
117 Uus Ununseptium (289)  
118 Uuo Ununoctium (289)

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

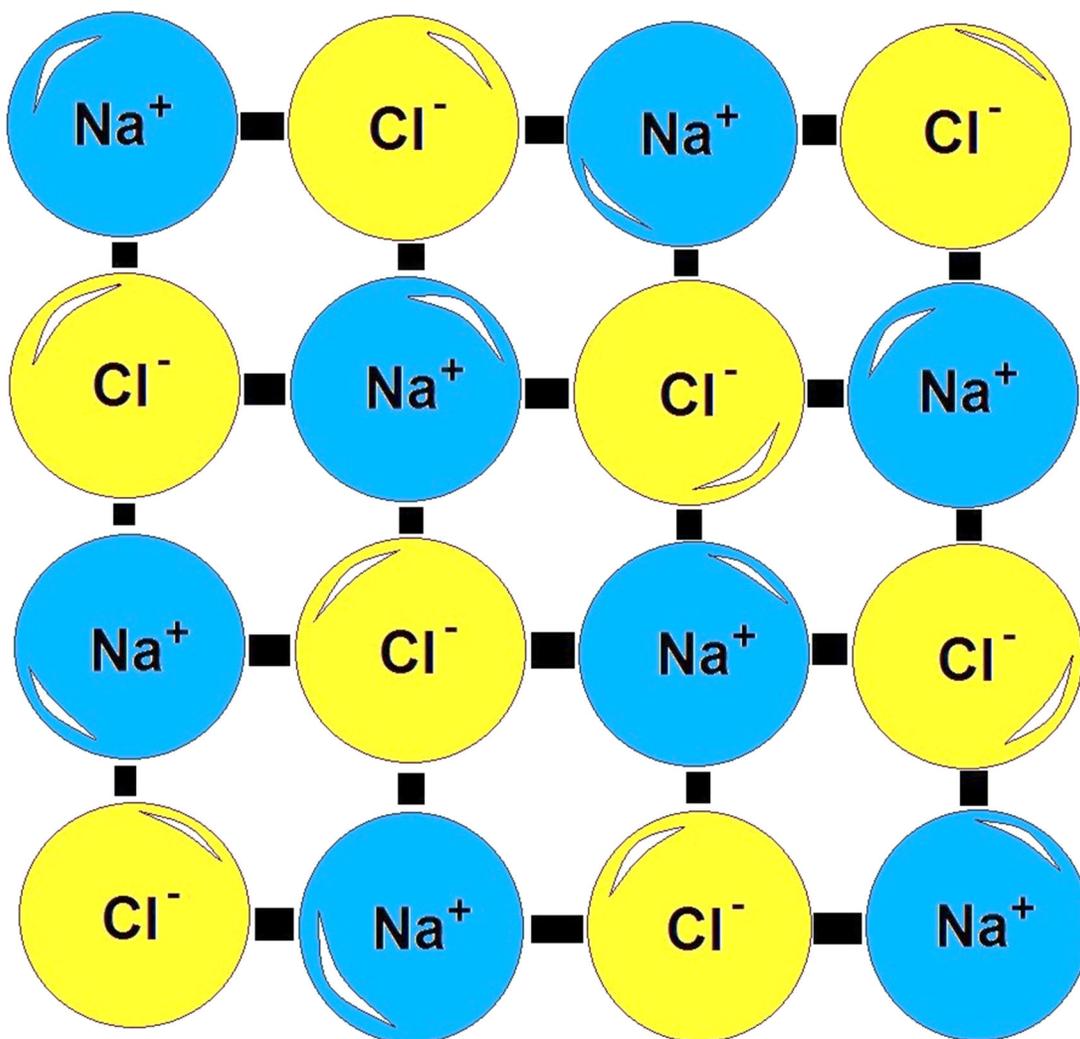
Note: The subgroup numbers 1-18 were adopted in 1994 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

## Basic Chemical Structure

At the turn of the twentieth century the theoretical underpinnings of chemistry were finally understood due to a series of remarkable discoveries that succeeded in probing and discovering the very nature of the internal structure of atoms. In 1897, J. J. Thomson of Cambridge University discovered the electron and soon after the French scientist Becquerel as well as the couple Pierre and Marie Curie investigated the phenomenon of radioactivity. In a series of pioneering scattering experiments Ernest Rutherford at the University of Manchester discovered the internal structure of the atom and the existence of the proton, classified and explained the different types of radioactivity and successfully transmuted the first element by bombarding nitrogen with alpha particles.

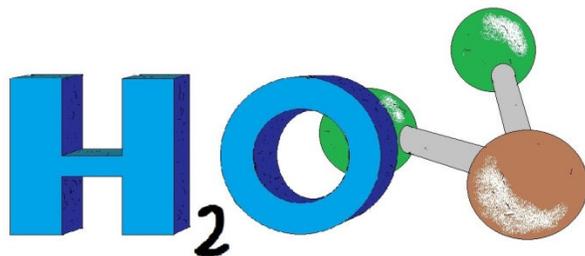


His work on atomic structure was improved on by his students, the Danish physicist Niels Bohr and Henry Moseley. The electronic theory of chemical bonds and molecular orbitals was developed by the American scientists Linus Pauling and Gilbert N. Lewis.



**CRYSTAL LATTICE OF NaCl (Table Salt)**

## What is a Compound?



Water (H<sub>2</sub>O), an example of a chemical compound

A *compound* is a pure chemical substance composed of more than one element. The properties of a compound bear little similarity to those of its elements. The standard nomenclature of compounds is set by the International Union of Pure and Applied Chemistry (IUPAC). Organic compounds are named according to the organic nomenclature system. Inorganic compounds are named according to the inorganic nomenclature system. In addition the Chemical Abstracts Service has devised a method to index chemical substances. In this scheme each chemical substance is identifiable by a number known as its CAS registry number.

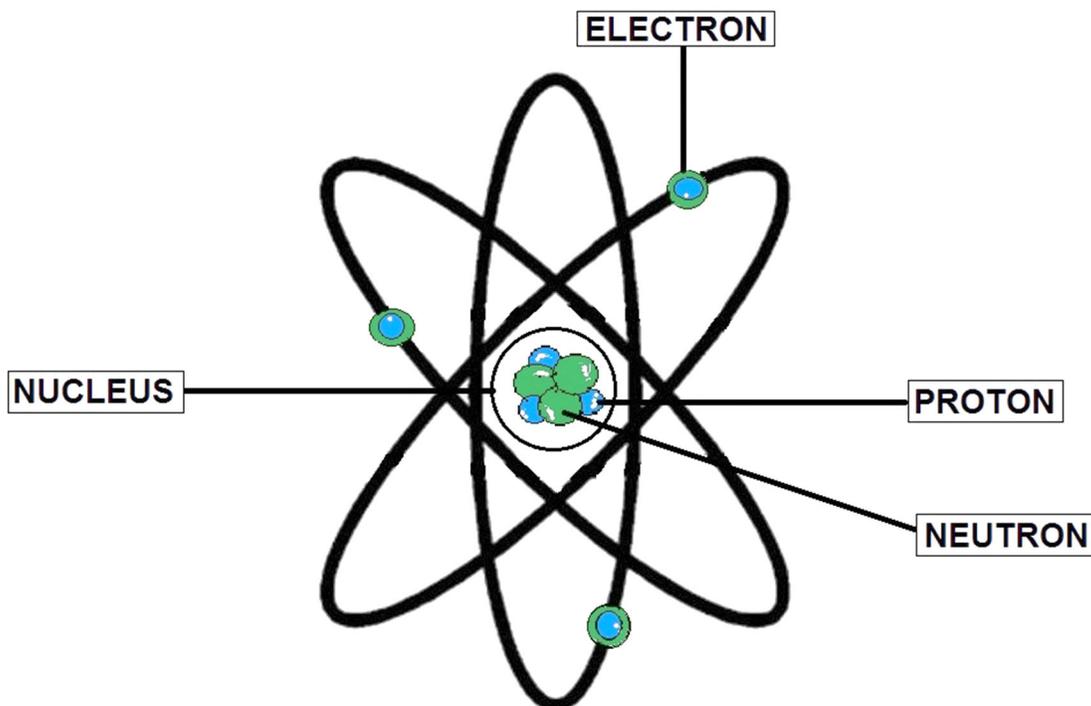
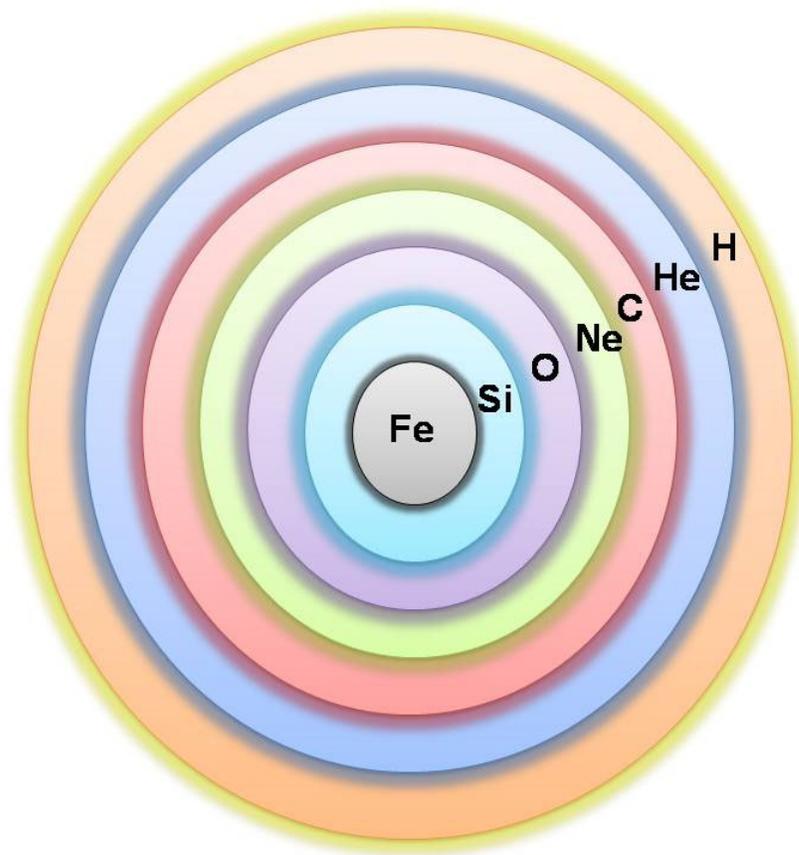


DIAGRAM OF AN ATOM



**Fe: Iron**

**Si: Silicon**

**O: Oxygen**

**Ne: Neon**

**C: Carbon**

**He: Helium**

**H: Hydrogen**

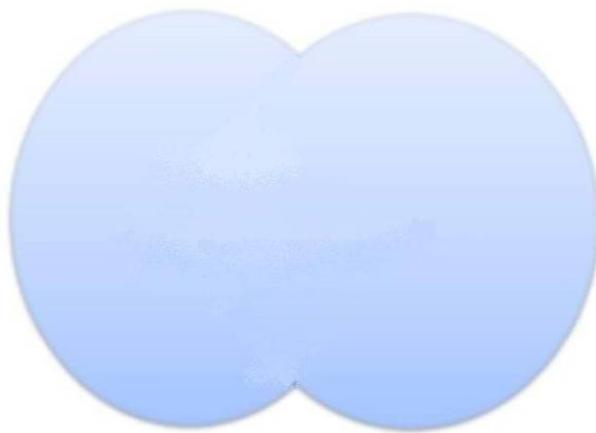
Elements of a Star

## Chemical Compounds

A pure chemical compound is a chemical substance that is composed of a particular set of molecules or ions. Two or more elements combined into one substance through a chemical reaction form a chemical compound. All compounds are substances, but not all substances are compounds.

A chemical compound can be either atoms bonded together in molecules or crystals in which atoms, molecules or ions form a crystalline lattice. Compounds based primarily on carbon and hydrogen atoms are called organic compounds, and all others are called inorganic compounds. Compounds containing bonds between carbon and a metal are called organometallic compounds.

### Oxygen – O<sub>2</sub> Molecule

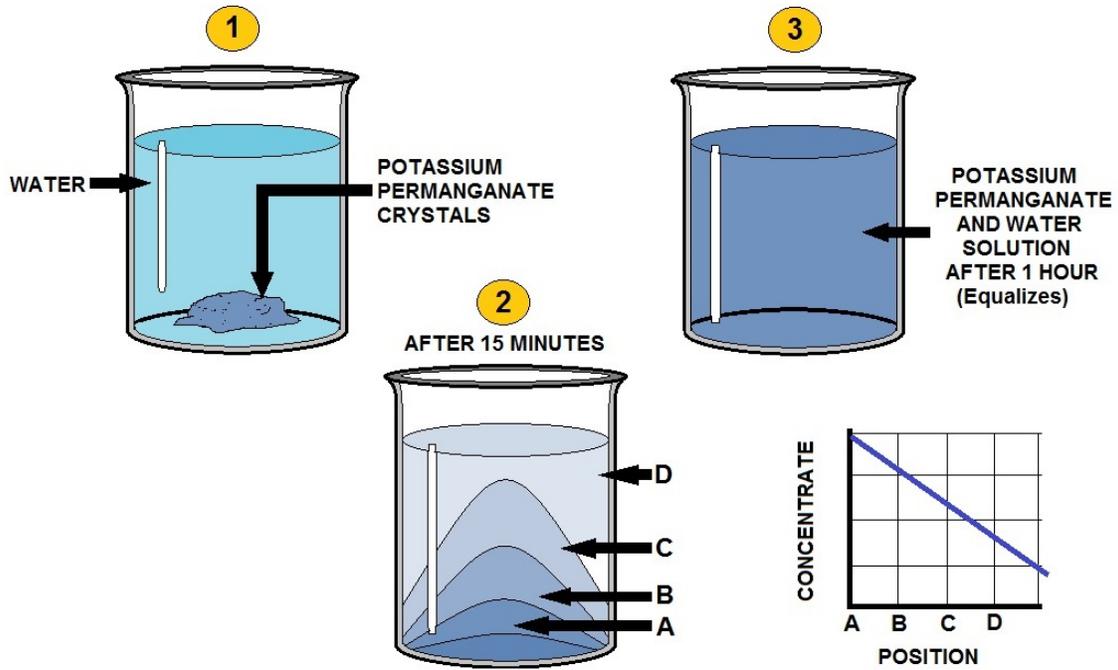


Compounds in which components share electrons are known as covalent compounds. Compounds consisting of oppositely charged ions are known as ionic compounds, or salts.

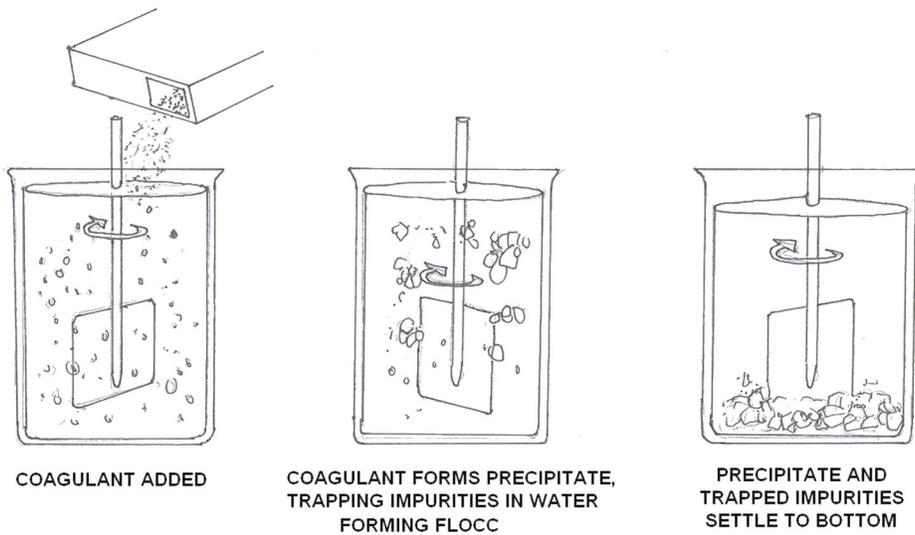
In organic chemistry, there can be more than one chemical compound with the same composition and molecular weight. Generally, these are called isomers. Isomers usually have substantially different chemical properties, may be isolated and do not spontaneously convert to each other.

A common example is glucose vs. fructose. The former is an aldehyde, the latter is a ketone. Their interconversion requires either enzymatic or acid-base catalysis. However, there are also tautomers, where isomerization occurs spontaneously, such that a pure substance cannot be isolated into its tautomers.

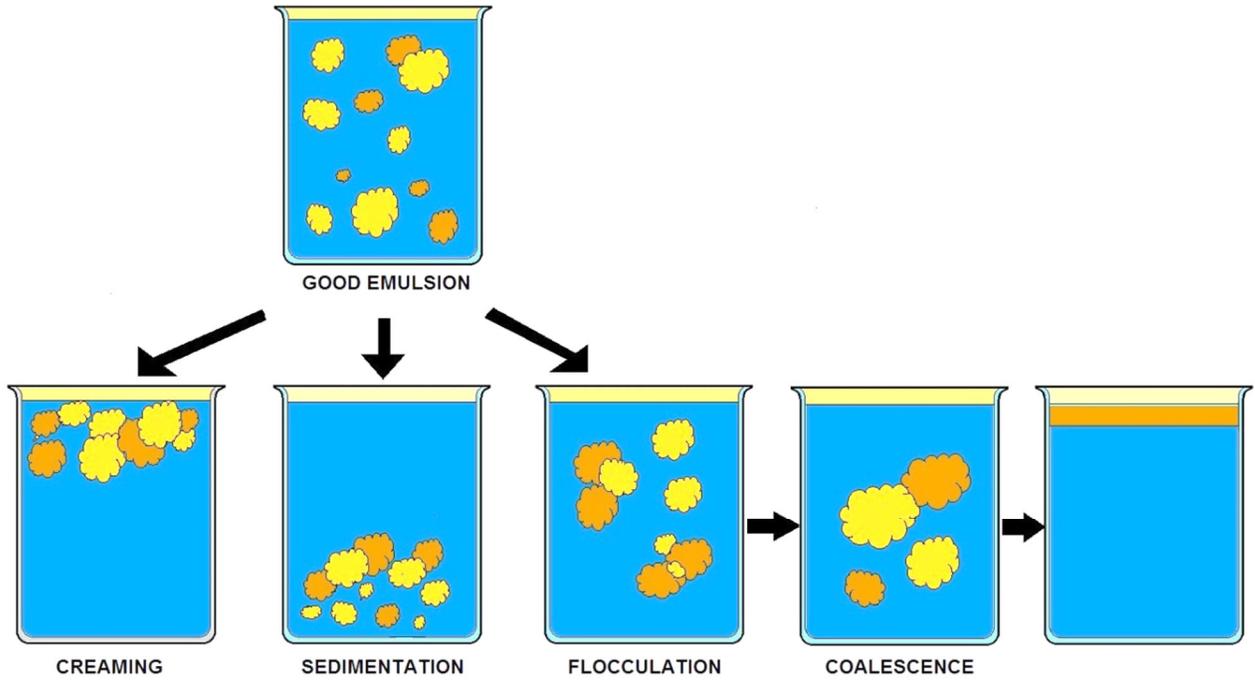
A common example is glucose, which has open-chain and ring forms. One cannot manufacture pure open-chain glucose because glucose spontaneously cyclizes to the hemiacetal form. Materials may also comprise other entities such as polymers. These may be inorganic or organic and sometimes a combination of inorganic and organic.



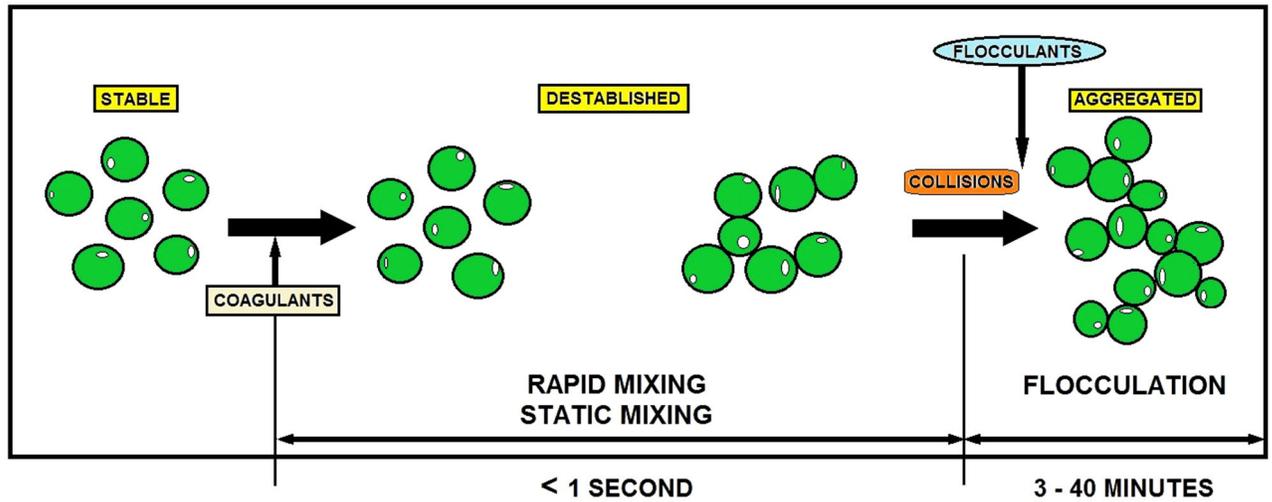
## DIFFUSION OF POTASSIUM PERMANGANATE IN WATER



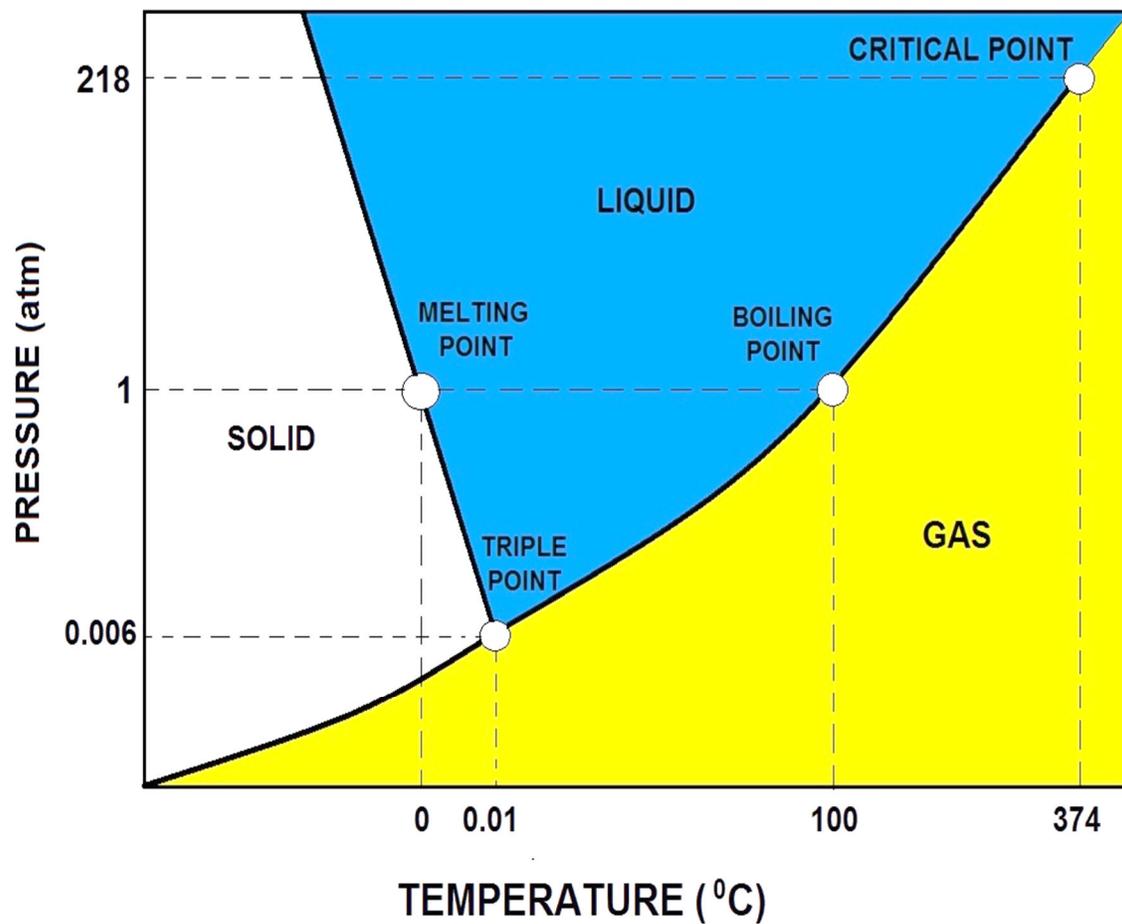
## BASICS OF COAGULATION



**MECHANISMS OF EMULSION INSTABILITY**



**BASIC COAGULATION / FLOCCULATION DEFINITIONS**

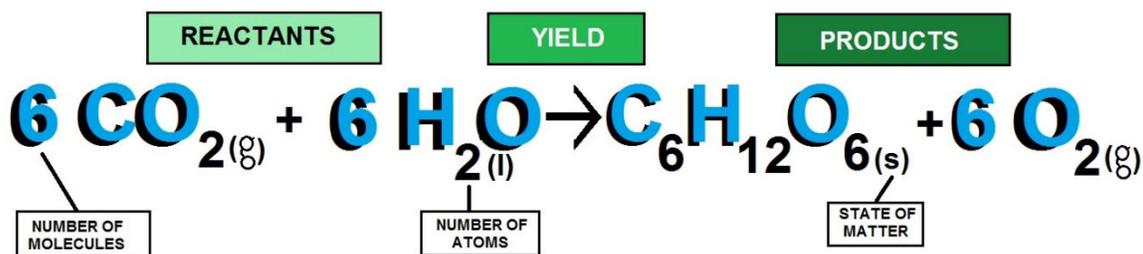


## WATER PHASE DIAGRAM

## Common Water Treatment Chemicals

Chemical Name	Common Name	Chemical Formula
Aluminum hydroxide		Al(OH) <sub>3</sub>
Aluminum sulfate	Alum, liquid	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> · 14(H <sub>2</sub> O)
Ammonia		NH <sub>3</sub>
Ammonium		NH <sub>4</sub>
Bentonitic clay	Bentonite	
Calcium bicarbonate		Ca(HCO <sub>3</sub> ) <sub>2</sub>
Calcium carbonate	Limestone	CaCO <sub>3</sub>
Calcium chloride		CaCl <sub>2</sub>
Calcium Hypochlorite	HTH	Ca(OCl) <sub>2</sub> · 4H <sub>2</sub> O
Calcium hydroxide	Slaked Lime	Ca(OH) <sub>2</sub>
Calcium oxide	Unslaked (Quicklime)	CaO
Calcium sulfate	Gypsum	CaSO <sub>4</sub>
Carbon	Activated Carbon	C
Carbon dioxide		CO <sub>2</sub>
Carbonic acid		H <sub>2</sub> CO <sub>3</sub>
Chlorine gas		Cl <sub>2</sub>
Chlorine Dioxide		ClO <sub>2</sub>
Copper sulfate	Blue vitriol	CuSO <sub>4</sub> · 5H <sub>2</sub> O
Dichloramine		NHCl <sub>2</sub>
Ferric chloride	Iron chloride	FeCl <sub>3</sub>
Ferric hydroxide		Fe(OH) <sub>3</sub>
Ferric sulfate	Iron sulfate	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>
Ferrous bicarbonate		Fe(HCO <sub>3</sub> ) <sub>2</sub>
Ferrous hydroxide		Fe(OH) <sub>2</sub>
Ferrous sulfate	Copperas	FeSO <sub>4</sub> · 7H <sub>2</sub> O
Hydrofluorosilicic acid		H <sub>2</sub> SiF <sub>6</sub>
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		H <sub>2</sub> S
Hypochlorous acid		HOCl
Magnesium bicarbonate		Mg(HCO <sub>3</sub> ) <sub>2</sub>
Magnesium carbonate		MgCO <sub>3</sub>
Magnesium chloride		MgCl <sub>2</sub>
Magnesium hydroxide		Mg(OH) <sub>2</sub>
Magnesium dioxide		MgO <sub>2</sub>
Manganous bicarbonate		Mn(HCO <sub>3</sub> ) <sub>2</sub>
Manganous sulfate		MnSO <sub>4</sub>

Monochloramine		NH <sub>2</sub> Cl
Potassium bicarbonate		KHCO <sub>3</sub>
Sodium chloride	Salt	NaCl
Sodium chlorite		NaClO <sub>2</sub>
Sodium fluoride		NaF
Sodium fluorsilicate		Na <sub>2</sub> SiF <sub>6</sub>
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium Metaphosphate	Hexametaphosphate	NaPO <sub>3</sub>
Sodium phosphate	Disodium phosphate	Na <sub>3</sub> PO <sub>4</sub>
Sodium sulfate		Na <sub>2</sub> SO <sub>4</sub>
Sulfuric acid		H <sub>2</sub> SO <sub>4</sub>



## CHEMICAL EQUATION (How to balance)

Number	Element	Valence
1	Hydrogen	(-1), +1
2	Helium	0
3	Lithium	+1
4	Beryllium	+2
5	Boron	-3, +3
6	Carbon	(+2), +4
7	Nitrogen	-3, -2, -1, (+1), +2, +3, +4, +5
8	Oxygen	-2
9	Fluorine	-1, (+1)
10	Neon	0
11	Sodium	+1
12	Magnesium	+2
13	Aluminum	+3
14	Silicon	-4, (+2), +4
15	Phosphorus	-3, +1, +3, +5
16	Sulfur	-2, +2, +4, +6
17	Chlorine	-1, +1, (+2), +3, (+4), +5, +7
18	Argon	0
19	Potassium	+1
20	Calcium	+2
21	Scandium	+3
22	Titanium	+2, +3, +4
23	Vanadium	+2, +3, +4, +5
24	Chromium	+2, +3, +6
25	Manganese	+2, (+3), +4, (+6), +7
26	Iron	+2, +3, (+4), (+6)
27	Cobalt	+2, +3, (+4)
28	Nickel	(+1), +2, (+3), (+4)
29	Copper	+1, +2, (+3)
30	Zinc	+2
31	Gallium	(+2), +3
32	Germanium	-4, +2, +4
33	Arsenic	-3, (+2), +3, +5
34	Selenium	-2, (+2), +4, +6
35	Bromine	-1, +1, (+3), (+4), +5
36	Krypton	0
37	Rubidium	+1
38	Strontium	+2
39	Yttrium	+3
40	Zirconium	(+2), (+3), +4
41	Niobium	(+2), +3, (+4), +5
42	Molybdenum	(+2), +3, (+4), (+5), +6
43	Technetium	+6
44	Rubidium	(+2), +3, +4, (+6), (+7), +8
45	Rhodium	(+2), (+3), +4, (+6)
46	Palladium	+2, +4, (+6)
47	Silver	+1, (+2), (+3)

48	Cadmium	(+1), +2
49	Indium	(+1), (+2), +3
50	Tin	+2, +4
51	Antimony	-3, +3, (+4), +5
52	Tellurium	-2, (+2), +4, +6
53	Iodine	-1, +1, (+3), (+4), +5, +7
54	Xenon	0
55	Cesium	+1
56	Barium	+2
57	Lanthanum	+3
58	Cerium	+3, +4
59	Praseodymium	+3
60	Neodymium	+3, +4
61	Promethium	+3
62	Samarium	(+2), +3
63	Europium	(+2), +3
64	Gadolinium	+3
65	Terbium	+3, +4
66	Dysprosium	+3
67	Holmium	+3
68	Erbium	+3
69	Thulium	(+2), +3
70	Ytterbium	(+2), +3
71	Lutetium	+3
72	Hafnium	+4
73	Tantalum	(+3), (+4), +5
74	Tungsten	(+2), (+3), (+4), (+5), +6
75	Rhenium	(-1), (+1), +2, (+3), +4, (+5), +6, +7
76	Osmium	(+2), +3, +4, +6, +8
77	Iridium	(+1), (+2), +3, +4, +6
78	Platinum	(+1), +2, (+3), +4, +6
79	Gold	+1, (+2), +3
80	Mercury	+1, +2
81	Thallium	+1, (+2), +3
82	Lead	+2, +4
83	Bismuth	(-3), (+2), +3, (+4), (+5)
84	Polonium	(-2), +2, +4, (+6)
85	Astatine	?
86	Radon	0
87	Francium	?
88	Radium	+2
89	Actinium	+3
90	Thorium	+4
91	Protactinium	+5
92	Uranium	(+2), +3, +4, (+5), +6

Reference: Lange's Handbook of Chemistry, 8th Ed., Norbert A. Lange (Ed.), Handbook Publishers, Inc. 1952.

<b>Common Used Products</b>	<b>Chemical Name</b>
acetone	dimethyl ketone
acid of sugar	oxalic acid
alcohol, grain	ethyl alcohol
alcohol, wood	methyl alcohol
alum	aluminum potassium sulfate
alumina	aluminum oxide
antichlor	sodium thiosulfate
aqua ammonia	aqueous solution of ammonium hydroxide
aqua regia	nitrohydrochloric acid
aqua fortis	nitric acid
aromatic spirit of ammonia	ammonia in alcohol
asbestos	magnesium silicate
aspirin	acetylsalicylic acid
baking soda	sodium bicarbonate
banana oil (artificial)	isoamyl acetate
benzol	benzene
bichloride of mercury	mercuric chloride
black copper oxide	cupric oxide
black lead	graphite (carbon)
bleaching powder	chlorinated lime
blue vitriol	copper sulfate
bluestone	copper sulfate
borax	sodium borate
brimstone	sulfur
brine	aqueous sodium chloride solution
butter of antimony	antimony trichloride
butter of tin	anhydrous stannic chloride
calomel	mercury chloride
carbolic acid	phenol
carbonic acid gas	carbon dioxide
caustic potash	potassium hydroxide
caustic soda	sodium hydroxide
chalk	calcium carbonate
Chile saltpeter	sodium nitrate
chrome, alum	chromic potassium sulfate
chrome, yellow	lead (VI) chromate
copperas	ferrous sulfate
cream of tartar	potassium bitartrate
crocus powder	ferric oxide
emery powder	impure aluminum oxide
Epsom salts	magnesium sulfate
ethanol	ethyl alcohol
fluorspar	natural calcium fluoride
formalin	aqueous formaldehyde solution
French chalk	natural magnesium silicate
galena	natural lead sulfide
Glauber's salt	sodium sulfate
gypsum	natural calcium sulfate

hydrocyanic acid	hydrogen cyanide
hypo (photography)	sodium thiosulfate solution
lime	calcium oxide
limewater	aqueous solution of calcium hydroxide
lunar caustic	silver nitrate
magnesia	magnesium oxide
mercury oxide, black	mercurous oxide
methanol	methyl alcohol
methylated spirits	methyl alcohol
muriatic acid	hydrochloric acid
oil of vitriol	sulfuric acid
oil of wintergreen (artificial)	methyl salicylate
Paris green	copper acetoarsenite
Paris white	powdered calcium carbonate
pear oil (artificial)	isoamyl acetate
pearl ash	potassium carbonate
plaster of Paris	calcium sulfate
plumbago	graphite
potash	potassium carbonate
potassa	potassium hydroxide
Prussic acid	hydrogen cyanide
pyro	tetrasodium pyrophosphate
quicklime	calcium oxide
quicksilver	mercury
red lead	lead tetraoxide
Rochelle salt	potassium sodium tartrate
rouge, jeweler's	ferric oxide
rubbing alcohol	isopropyl alcohol
sal ammoniac	ammonium chloride
sal soda	sodium carbonate
salt, table	sodium chloride
salt of lemon	potassium binoxalate
salt of tartar	potassium carbonate
saltpeter	potassium nitrate
silica	silicon dioxide
soda ash	sodium carbonate
soda lye	sodium hydroxide
soluble glass	sodium silicate
spirit of hartshorn	ammonium hydroxide solution
sugar, table	sucrose
talc or talcum	magnesium silicate
vinegar	impure dilute acetic acid
vitamin C	ascorbic acid
washing soda	sodium carbonate
water glass	sodium silicate

## 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- $\alpha$ -methyl-2-naphthaleneacetic acid.

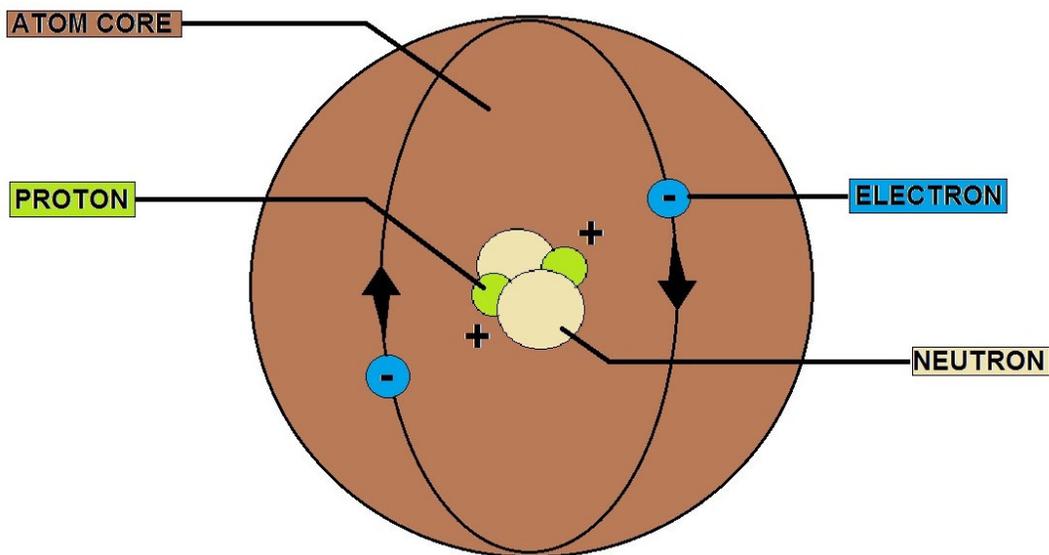
Chemists frequently refer to chemical compounds using chemical formulae or molecular structure of the compound. There has been a phenomenal growth in the number of chemical compounds being synthesized (or isolated), and then reported in the scientific literature by professional chemists around the world.

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.

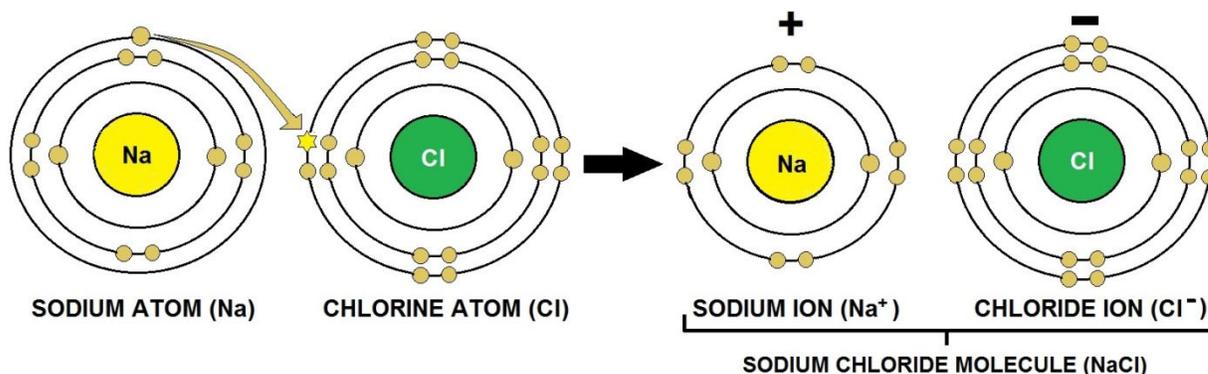
## Understanding the Atom

The atom is the basic unit of chemistry. It consists of a dense core called the atomic nucleus surrounded by a space called the electron cloud.

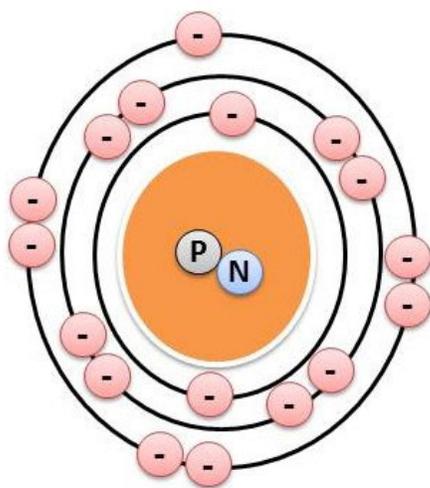


## BASICS OF AN ATOM

The nucleus is made up of positively charged protons and uncharged neutrons (together called nucleons), while the electron cloud consists of negatively-charged electrons which orbit the nucleus. In a neutral atom, the negatively-charged electrons balance out the positive charge of the protons. The nucleus is dense; the mass of a nucleon is 1,836 times that of an electron, yet the radius of an atom is about 10,000 times that of its nucleus.



The atom is also the smallest entity that can be envisaged to retain the chemical properties of the element, such as electronegativity, ionization potential, preferred oxidation state(s), coordination number, and preferred types of bonds to form (e.g., metallic, ionic, covalent).



-  ELECTRONS = 17
-  PROTONS = 17
-  NEUTRONS = 18
-  NUCLEUS

# CHLORINE

## Element

Standard form of the periodic table of chemical elements. The colors represent different categories of elements.

A chemical element is a pure substance which is composed of a single type of atom, characterized by its particular number of protons in the nuclei of its atoms, known as the atomic number and represented by the symbol  $Z$ .

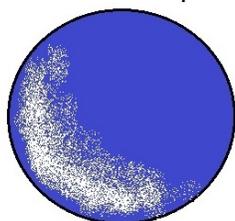
The mass number is the sum of the number of protons and neutrons in a nucleus. Although all the nuclei of all atoms belonging to one element will have the same atomic number, they may not necessarily have the same mass number; atoms of an element which have different mass numbers are known as isotopes.

For example, all atoms with 6 protons in their nuclei are atoms of the chemical element carbon, but atoms of carbon may have mass numbers of 12 or 13.

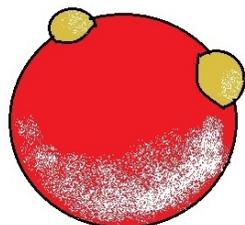
The standard presentation of the chemical elements is in the periodic table, which orders elements by atomic number. The periodic table is arranged in groups, or columns, and periods, or rows. The periodic table is useful in identifying periodic trends.

## Molecule Section

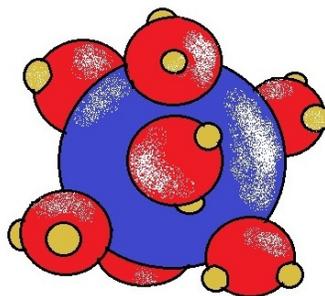
A *molecule* is the smallest indivisible portion of a pure chemical substance that has its unique set of chemical properties, that is, its potential to undergo a certain set of chemical reactions with other substances. However, this definition only works well for substances that are composed of molecules, 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**



**H<sub>2</sub>O**  
**WATER MOLECULE**



**HYDRATED CALCIUM ION**

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.

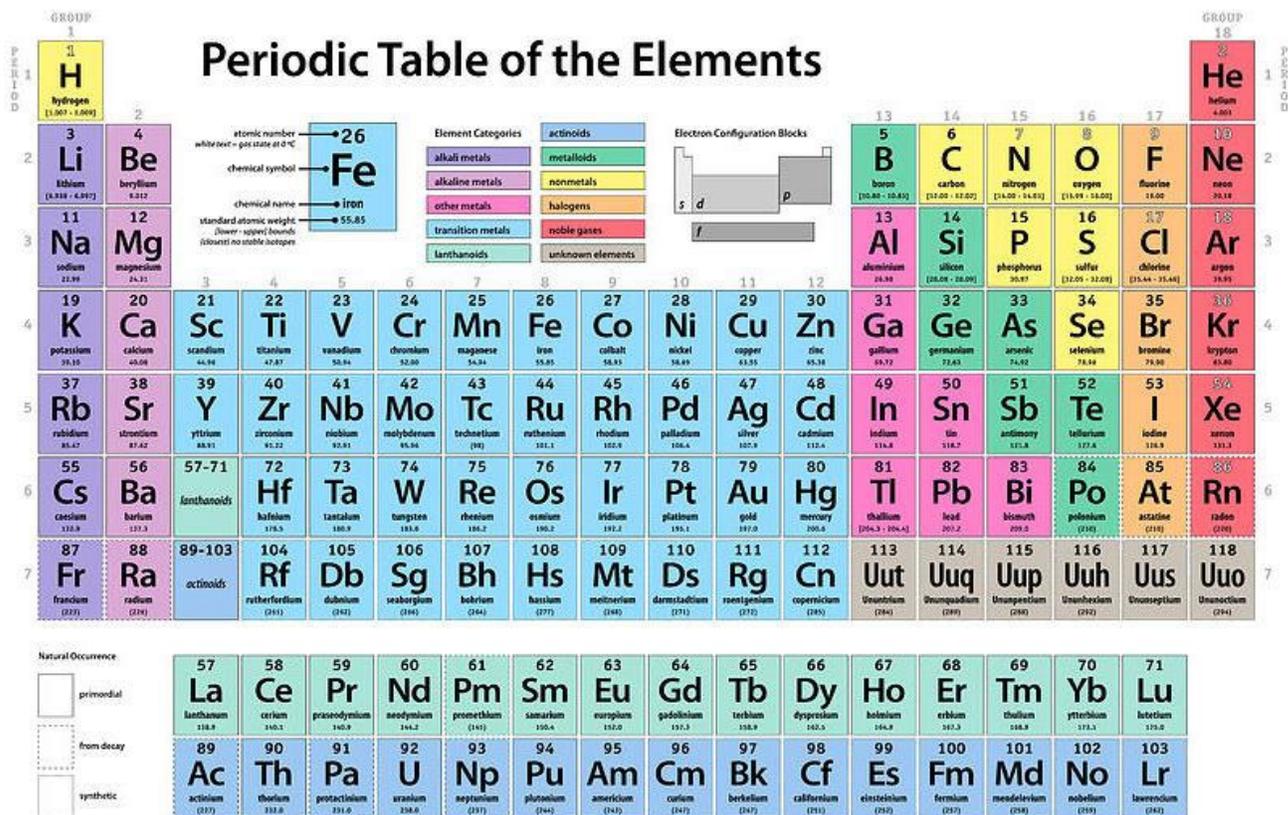
One of the main characteristics of a molecule is its geometry often called its structure. While the structure of diatomic, triatomic or tetra atomic molecules may be trivial, (linear, angular pyramidal etc.) the structure of polyatomic molecules, that are constituted of more than six atoms (of several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

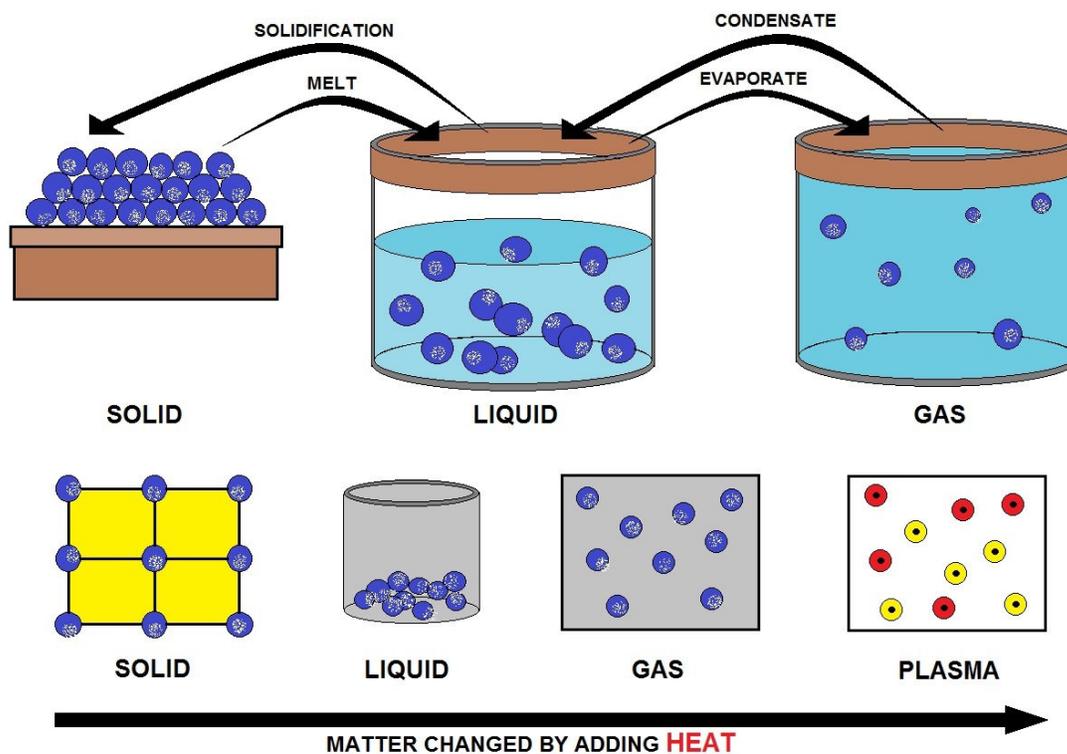
### Mole and Amount of Substance

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  $6.022 \times 10^{23} \text{ mol}^{-1}$ . Molar concentration is the amount of a particular substance per volume of solution, and is commonly reported in  $\text{mol dm}^{-3}$ .



## Phase

In addition to the specific chemical properties that distinguish different chemical classifications, chemicals can exist in several phases. For the most part, the chemical classifications are independent of these bulk phase classifications; however, some more exotic phases are incompatible with certain chemical properties. A *phase* is a set of states of a chemical system that have similar bulk structural properties, over a range of conditions, such as pressure or temperature.



## STATES OF MATTER

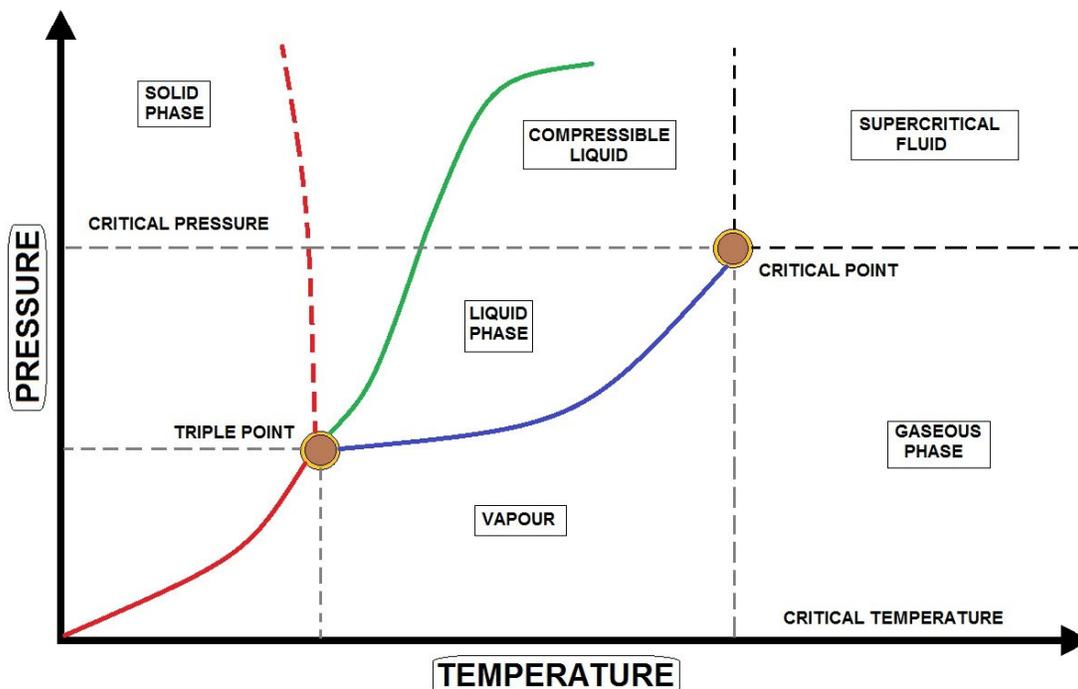
Physical properties, such as density and refractive index tend to fall within values characteristic of the phase. The phase of matter is defined by the *phase transition*, which is when energy put into or taken out of the system goes into rearranging the structure of the system, instead of changing the bulk conditions.

Sometimes the distinction between phases can be continuous instead of having a discrete boundary, in this case the matter is considered to be in a supercritical state. When three states meet based on the conditions, it is known as a triple point and since this is invariant, it is a convenient way to define a set of conditions.

The most familiar examples of phases are solids, liquids, and gases. Many substances exhibit multiple solid phases.

For example, there are three phases of solid iron (alpha, gamma, and delta) that vary based on temperature and pressure.

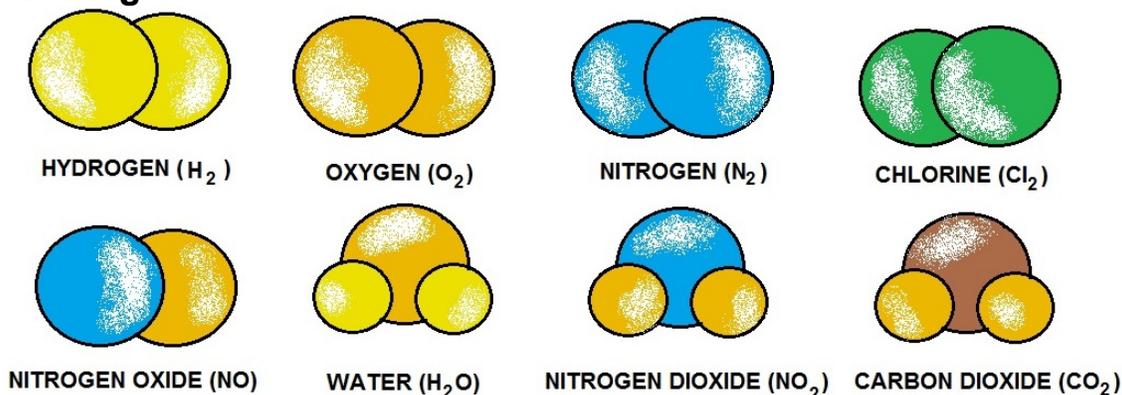
A principal difference between solid phases is the crystal structure, or arrangement, of the atoms. Another phase commonly encountered in the study of chemistry is the *aqueous* phase, which is the state of substances dissolved in aqueous solution (that is, in water).



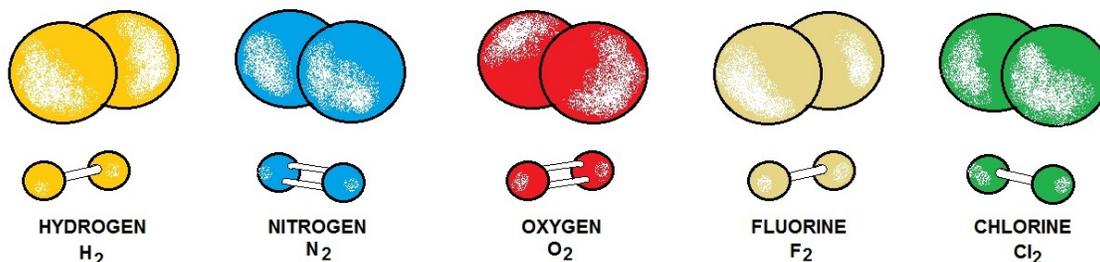
### TRIPLE AND CRITICAL POINTS OF A SUBSTANCE

Less familiar phases include plasmas, Bose–Einstein condensates and fermionic condensates and the paramagnetic and ferromagnetic phases of magnetic materials. While most familiar phases deal with three-dimensional systems, it is also possible to define analogs in two-dimensional systems, which has received attention for its relevance to systems in biology.

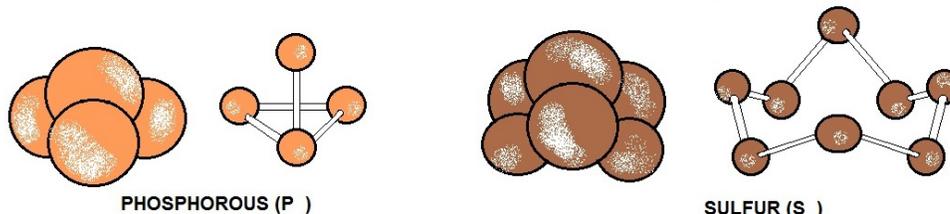
## Bonding



Atoms sticking together in molecules or crystals are said to be bonded with one another. A chemical bond may be visualized as the multipole balance between the positive charges in the nuclei and the negative charges oscillating about them. More than simple attraction and repulsion, the energies and distributions characterize the availability of an electron to bond to another atom.



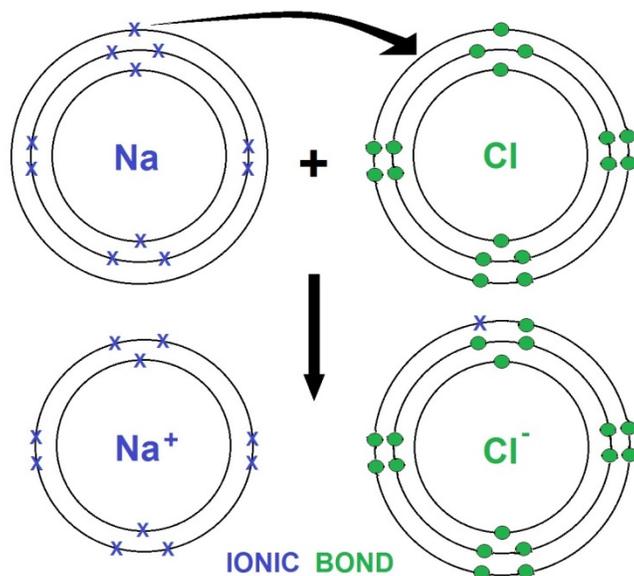
### ELEMENTS THAT EXIST AS DIATOMIC MOLECULES



### ELEMENTS THAT EXIST AS POLYATOMIC MOLECULES

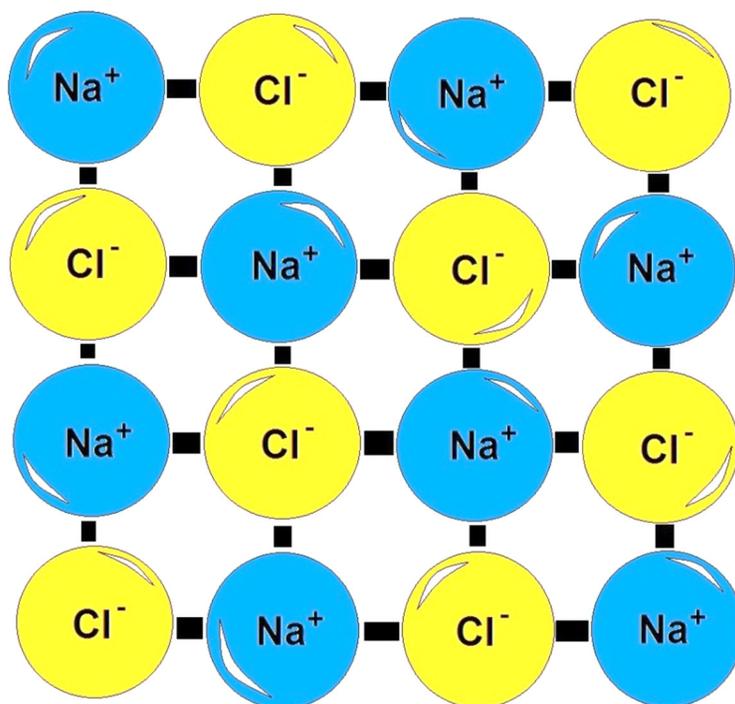
A chemical bond can be a covalent bond, an ionic bond, a hydrogen bond or just because of Van der Waals force. Each of these kinds of bonds is ascribed to some potential. These potentials create the interactions which hold atoms together in molecules or crystals. In many simple compounds, valence bond theory, the Valence Shell Electron Pair Repulsion model (VSEPR), and the concept of oxidation number can be used to explain molecular structure and composition.

An ionic bond is formed when a metal loses one or more of its electrons, becoming a positively charged cation, and the electrons are then gained by the non-metal atom, becoming a negatively charged anion.

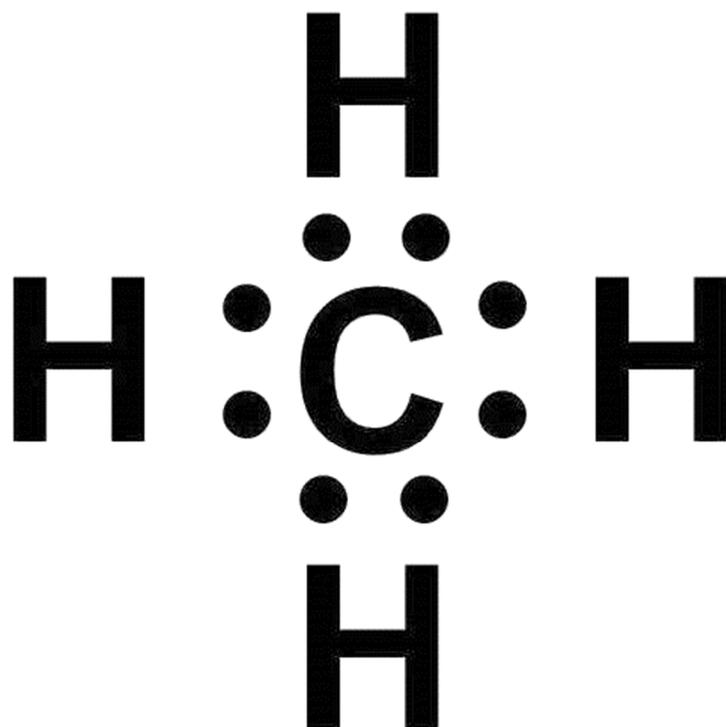


## SODIUM CHLORIDE

The two oppositely charged ions attract one another, and the ionic bond is the electrostatic force of attraction between them. For example, sodium (Na), a metal, loses one electron to become an  $\text{Na}^+$  cation while chlorine (Cl), a non-metal, gains this electron to become  $\text{Cl}^-$ . The ions are held together due to electrostatic attraction, and that compound sodium chloride ( $\text{NaCl}$ ), or common table salt, is formed.



**CRYSTAL LATTICE OF NaCl (Table Salt)**



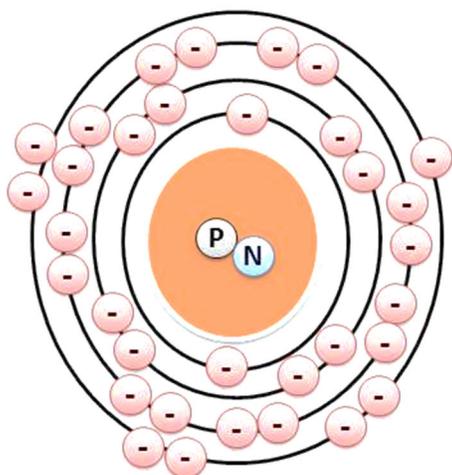
## Methane molecule (CH<sub>4</sub>)

In the methane molecule (CH<sub>4</sub>), the carbon atom shares a pair of valence electrons with each of the four hydrogen atoms. Thus, the octet rule is satisfied for C-atom (it has eight electrons in its valence shell) and the duet rule is satisfied for the H-atoms (they have two electrons in their valence shells).

In a covalent bond, one or more pairs of valence electrons are shared by two atoms: the resulting electrically neutral group of bonded atoms is termed a molecule. Atoms will share valence electrons in such a way as to create a noble gas electron configuration (eight electrons in their outermost shell) for each atom.

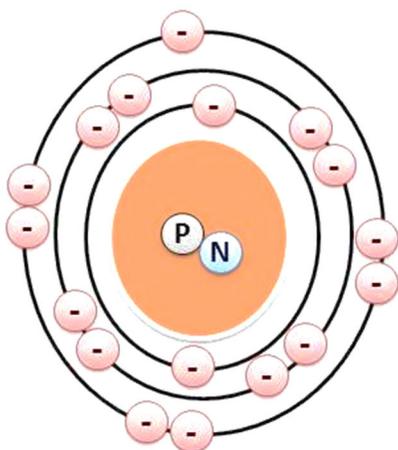
Atoms that tend to combine in such a way that they each have eight electrons in their valence shell are said to follow the octet rule. However, some elements like hydrogen and lithium need only two electrons in their outermost shell to attain this stable configuration; these atoms are said to follow the *duet rule*, and in this way they are reaching the electron configuration of the noble gas helium, which has two electrons in its outer shell.

Similarly, theories from classical physics can be used to predict many ionic structures. With more complicated compounds, such as metal complexes, valence bond theory is less applicable and alternative approaches, such as the molecular orbital theory, are generally used.



-  ELECTRONS = 35
-  PROTONS = 35
-  NEUTRONS = 45
-  NUCLEUS

## BROMINE



-  ELECTRONS = 17
-  PROTONS = 17
-  NEUTRONS = 18
-  NUCLEUS

## CHLORINE

## Energy

In the context of chemistry, energy is an attribute of a substance as a consequence of its atomic, molecular or aggregate structure. Since a chemical transformation is accompanied by a change in one or more of these kinds of structures, it is invariably accompanied by an increase or decrease of energy of the substances involved. Some energy is transferred between the surroundings and the reactants of the reaction in the form of heat or light; thus the products of a reaction may have more or less energy than the reactants.

A reaction is said to be exergonic if the final state is lower on the energy scale than the initial state; in the case of endergonic reactions the situation is the reverse. A reaction is said to be exothermic if the reaction releases heat to the surroundings; in the case of endothermic reactions, the reaction absorbs heat from the surroundings.

Chemical reactions are invariably not possible unless the reactants surmount an energy barrier known as the activation energy. The *speed* of a chemical reaction (at given temperature T) is related to the activation energy E, by the Boltzmann's population factor - that is the probability of a molecule to have energy greater than or equal to E at the given temperature T.

$$e^{-E/kT}$$

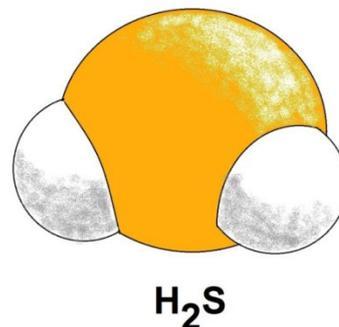
This exponential dependence of a reaction rate on temperature is known as the Arrhenius equation. The activation energy necessary for a chemical reaction to occur can be in the form of heat, light, electricity or mechanical force in the form of ultrasound.

A related concept free energy, which also incorporates entropy considerations, is a very useful means for predicting the feasibility of a reaction and determining the state of equilibrium of a chemical reaction, in chemical thermodynamics. A reaction is feasible only if the total change in the Gibbs free energy is negative, if it is equal to zero the chemical reaction is said to be at equilibrium.

$$\Delta G \leq 0$$

There exist only limited possible states of energy for electrons, atoms and molecules. These are determined by the rules of quantum mechanics, which require quantization of energy of a bound system. The atoms/molecules in a higher energy state are said to be excited. The molecules/atoms of substance in an excited energy state are often much more reactive; that is, more amenable to chemical reactions.

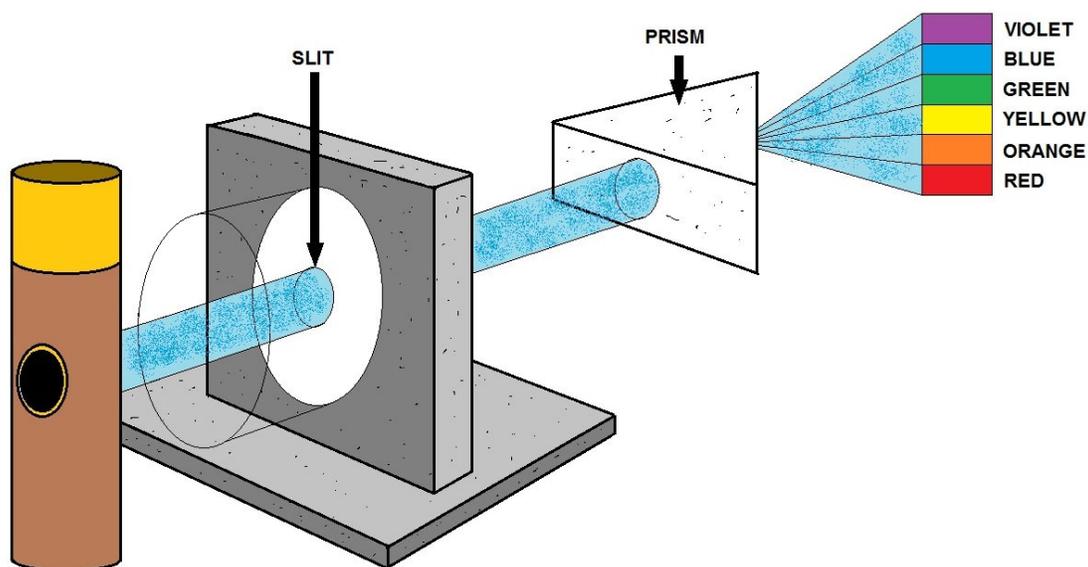
The phase of a substance is invariably determined by its energy and the energy of its surroundings. When the intermolecular forces of a substance are such that the energy of the surroundings is not sufficient to overcome them, it occurs in a more ordered phase like liquid or solid as is the case with water (H<sub>2</sub>O); a liquid at room temperature because its molecules are bound by hydrogen bonds.



Whereas hydrogen sulfide (H<sub>2</sub>S) is a gas at room temperature and standard pressure, as its molecules are bound by weaker dipole-dipole interactions.

The transfer of energy from one chemical substance to another depends on the *size* of energy quanta emitted from one substance. However, heat energy is often transferred more easily from almost any substance to another because the phonons responsible for vibrational and rotational energy levels in a substance have much less energy than photons invoked for the electronic energy transfer.

Thus, because vibrational and rotational energy levels are more closely spaced than electronic energy levels, heat is more easily transferred between substances relative to light or other forms of electronic energy. For example, ultraviolet electromagnetic radiation is not transferred with as much efficacy from one substance to another as thermal or electrical energy.

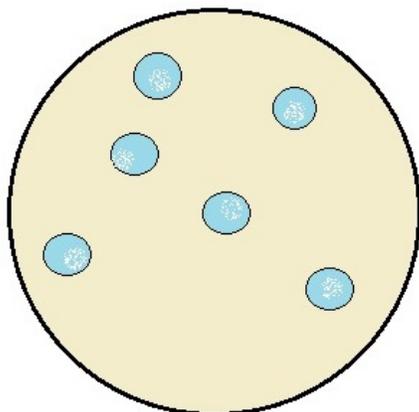


## SPECTROSCOPY

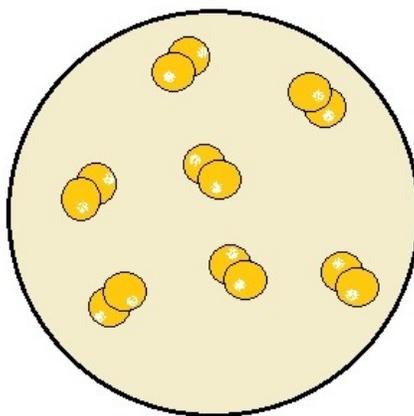
The existence of characteristic energy levels for different chemical substances is useful for their identification by the analysis of spectral lines. Different kinds of spectra are often used in chemical spectroscopy, e.g. IR, microwave, NMR, ESR, etc. Spectroscopy is also used to identify the composition of remote objects - like stars and distant galaxies - by analyzing their radiation spectra.

The term chemical energy is often used to indicate the potential of a chemical substance to undergo a transformation through a chemical reaction or to transform other chemical substances.

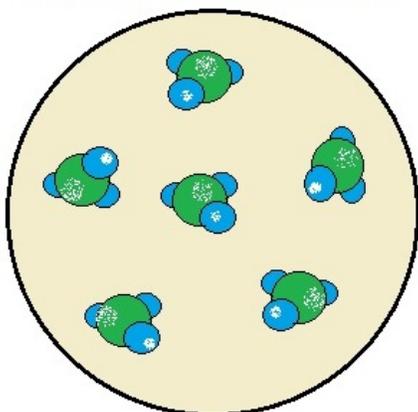
## Reaction



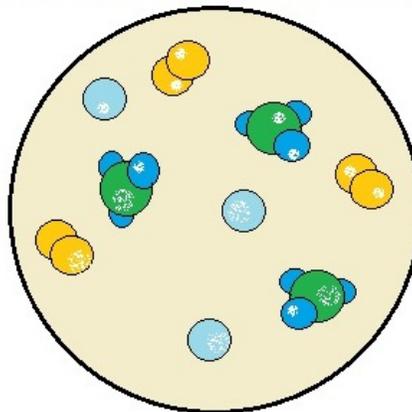
**ATOMS OF AN ELEMENT**



**MOLECULES OF AN ELEMENT**



**MOLECULES OF A COMPOUND**



**MIXTURE OF TWO ELEMENTS  
AND A COMPOUND**

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.

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').

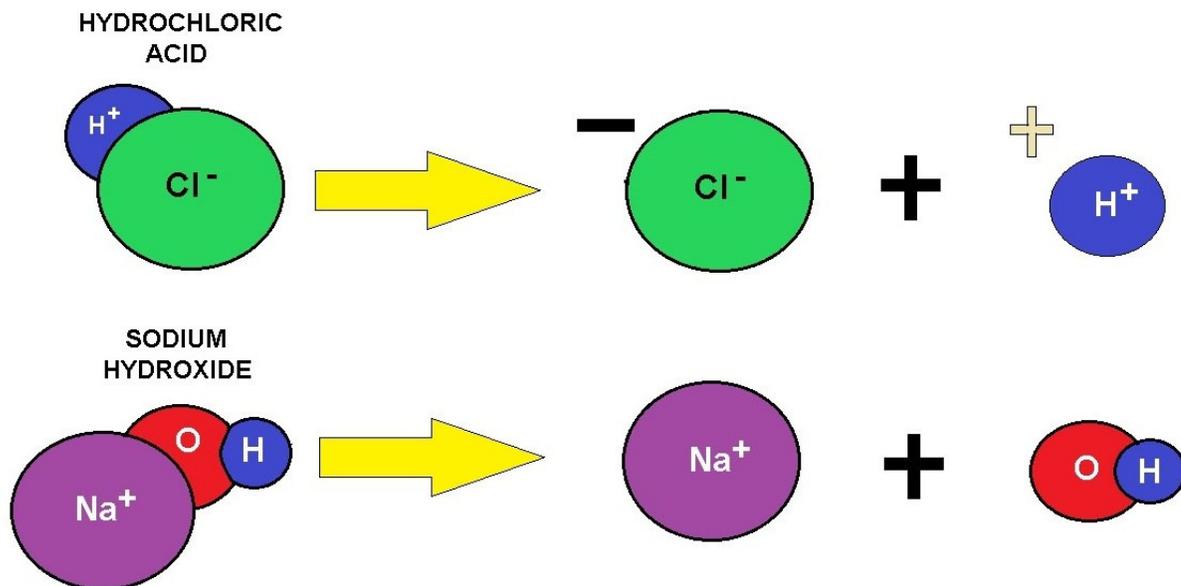
### **Ions and Salts**

An *ion* is a charged species, an atom or a molecule, that 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  $\text{Na}^+$  and  $\text{Cl}^-$  ions forming sodium chloride, or  $\text{NaCl}$ .

Examples of polyatomic ions that do not split up during acid-base reactions are hydroxide ( $\text{OH}^-$ ) and phosphate ( $\text{PO}_4^{3-}$ ).

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

## Acidity and Basicity



## 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 that 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.

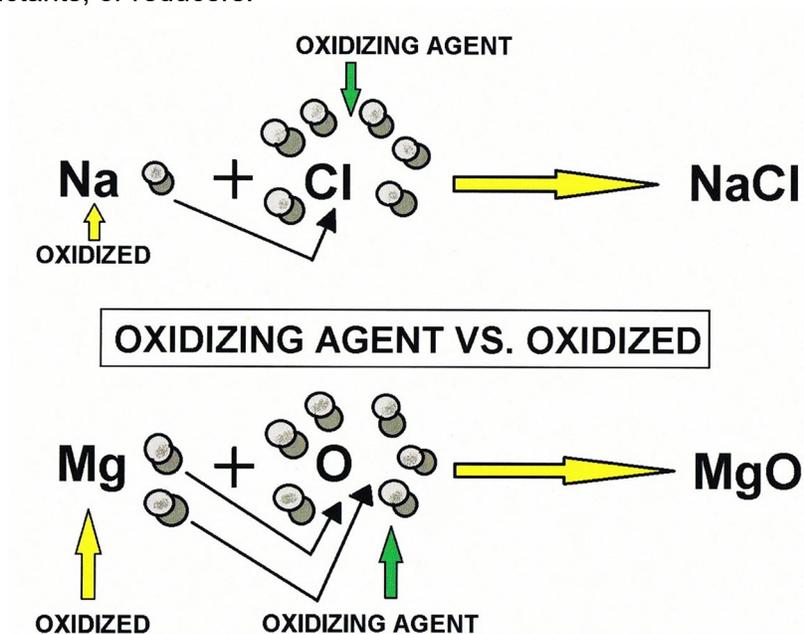
One measurement, based on the Arrhenius definition of acidity, is pH, which is a measurement of the hydronium ion concentration in a solution, as expressed on a negative logarithmic scale. Thus, solutions that have a low pH have a high hydronium ion concentration, and can be said to be more acidic.

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.

### Redox

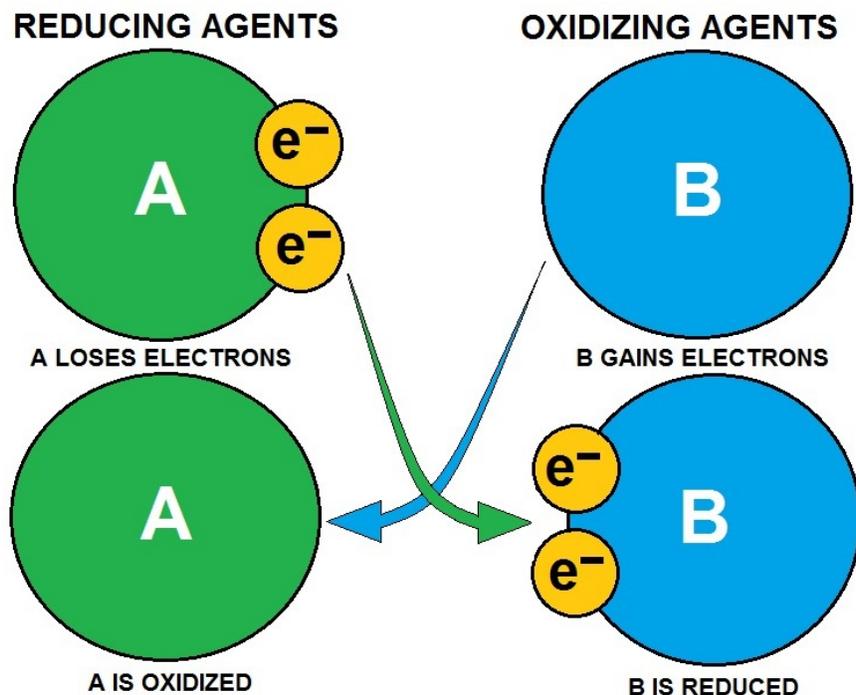
Redox (*reduction-oxidation*) reactions include all chemical reactions in which atoms have their oxidation state changed by either gaining electrons (reduction) or losing electrons (oxidation). Substances that have the ability to oxidize other substances are said to be oxidative and are known as oxidizing 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.



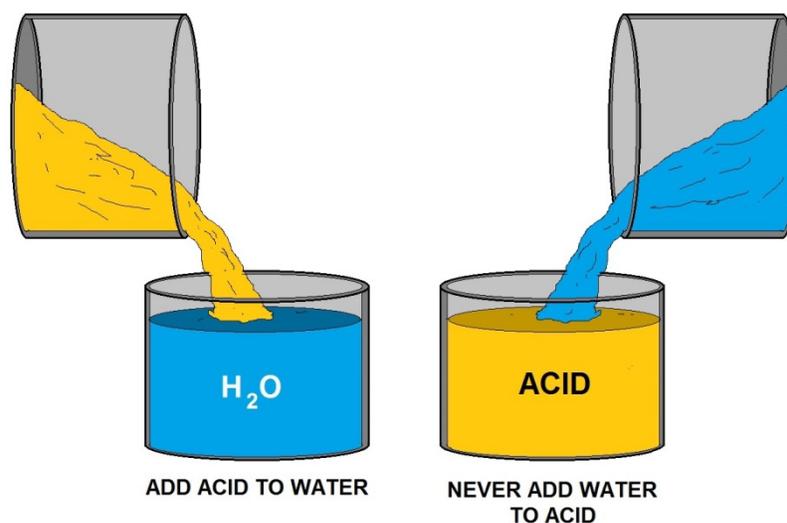
A reductant transfers electrons to another substance, and is thus oxidized itself. And because it "donates" electrons it is also called an electron donor.

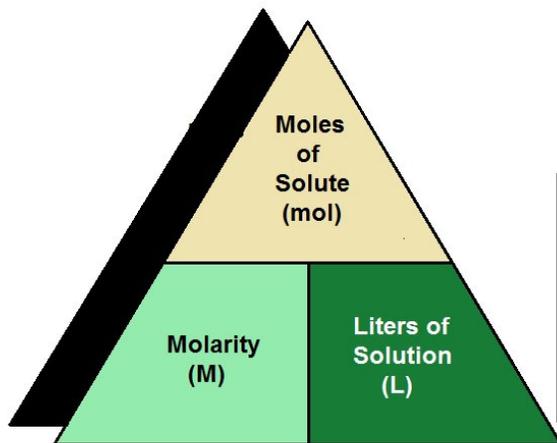
Oxidation and reduction properly refer to a change in oxidation number—the actual transfer of electrons may never occur. Thus, oxidation is better defined as an increase in oxidation number, and reduction as a decrease in oxidation number.



### 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.





**CALCULATING MOLARITY**

$$\text{Moles} = \text{Molarity} \times \text{Liters}$$

$$\text{Molarity} = \text{Moles} / \text{Liters}$$

$$\text{Liters} = \text{Moles} / \text{Molarity}$$

$$\text{MOLARITY} = \frac{\text{Number of Moles}}{\text{Liters of Solution}}$$

OR

$$M = n/v = \frac{\text{Number of Moles}}{\text{Volume}}$$

## CHEMICAL MOLARITY

## Solute – Solution

A solute is a substance that can be dissolved by a solvent to create a solution. A solute can come in many forms. It can be gas, liquid, or solid. The solvent, or substance that dissolves the solute, breaks the solute apart and distributes the solute molecules equally. This creates a *homogenous mixture*, or solution that is equal throughout.

Solutes in solution are measured by their *concentration*. The concentration of a solute is the amount of solute divided by the total volume of solution. A solvent can dilute various amounts of solute, depending on how strong of a solvent is used and how easily the solute molecules come apart. This property of solutes to dissolve in a solvent is known as *solubility*.

### Oxygen in Seawater

An example of a gaseous solute is oxygen. Every fish in the ocean, from the strange creatures in the deepest parts of the ocean to the common coral-dwelling fish that scuba divers love, rely on oxygen dissolved in the water to live. The oxygen, which exists as O<sub>2</sub>, is a polar molecule. As such, the polar water molecules have a natural tendency to attract the oxygen. As the waves mix air into the ocean and the surface of the ocean and atmosphere interact, oxygen is dissolved into the water. The process of diffusion carries the oxygen through the water column, delivering oxygen to organisms throughout the ocean.

In some situations, the organisms in the ocean can use the oxygen in the water faster than it can be diffused into the water. This can happen when excess nutrient runoff from humans runs into the ocean. The nutrients, which are another solute in water, allow huge *algal blooms* to grow. These blooms contain far too many algae. The algae in the lower layers start to die, and bacteria start to consume them. Between the algae and the bacteria, all of the oxygen gets used up. This creates a dead zone in the water column. If fish start to swim through this column, they could suffocate from lack of oxygen.

## Mole

The **mole** (symbol: **mol**) is the unit of measurement for amount of substance in the International System of Units (SI). It is defined as exactly  $6.02214076 \times 10^{23}$  constitutive particles, which may be atoms, molecules, ions, or electrons.

The definition was adopted in November 2018 as one of the seven SI base units, revising the previous definition that specified it as the number of atoms in 12 grams of carbon-12 (<sup>12</sup>C), an isotope of carbon.

The number  $6.02214076 \times 10^{23}$  (the Avogadro number) was chosen so that the mass of one mole of a chemical compound, in grams, is numerically equal (for all practical purposes) to the average mass of one molecule of the compound, in daltons. Thus, for example, one mole of water contains  $6.02214076 \times 10^{23}$  molecules, whose total mass is about 18.015 grams – and the mean mass of one molecule of water is about 18.015 daltons.

The mole is widely used in chemistry as a convenient way to express amounts of reactants and products of chemical reactions. For example, the chemical equation  $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$  can be interpreted to mean that 2 mol dihydrogen (H<sub>2</sub>) and 1 mol dioxygen (O<sub>2</sub>) react to form 2 mol water (H<sub>2</sub>O). The mole may also be used to represent the number of atoms,

ions, or other entities in a given sample of a substance. The concentration of a solution is commonly expressed by its molarity, defined as the amount of dissolved substance per unit volume of solution, for which the unit typically used is moles per liter (mol/l), commonly abbreviated M.

The term **gram-molecule** (g mol) was formerly used for "mole of molecules", and **gram-atom** (g atom) for "mole of atoms". For example, 1 mole of  $\text{MgBr}_2$  is 1 gram-molecule of  $\text{MgBr}_2$  but 3 gram-atoms of  $\text{MgBr}_2$

## Molarity- Molar Mass -Concentration

Molarity is a chemical term that refers to the amount of a substance, usually a solute or solvent, that exists in a given volume of solution, and is more commonly known by terms such as molar mass or simply concentration. The reference is based on the basic molecular unit of the mol, mole, or gram molecule, which is loosely defined as the molecular weight of a chemical element or compound expressed in grams. Molecular weights vary from substance to substance as they are based upon the sum of the weight of all of the atoms that bind together to make up basic molecules for the substance.

Calculating molarity in most instances in chemistry uses a base number of 12 as a reference point, with the isotope carbon-12 being the foundation for an atomic mass unit. A simple molarity formula as an example would be a combination of two hydrogen atoms that bind together in nature to form hydrogen-2, or deuterium, which has a molarity of two. Since the formula to calculate molarity must take into account the three dimensions present in a volume, molarity is expressed either as mols per cubic meter in standard international units, or as mols per liter, and a basic molar mass is defined as one mol per liter.

## Normality or N

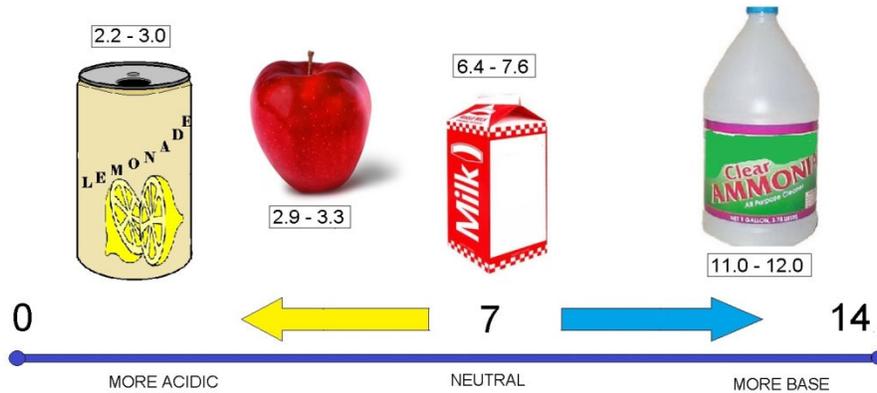
The normality of a solution is the gram equivalent weight of a solute per liter of solution. It may also be called the equivalent concentration. It is indicated using the symbol N, eq/L, or meq/L (= 0.001 N) for units of concentration.

For example, the concentration of a hydrochloric acid solution might be expressed as 0.1 N HCl. A gram equivalent weight or equivalent is a measure of the reactive capacity of a given chemical species (ion, molecule, etc.). The equivalent value is determined using the molecular weight and valence of the chemical species. Normality is the only concentration unit that is reaction dependent.

Examples of how to calculate the normality of a solution.

- Normality is a unit of concentration of a chemical solution expressed as gram equivalent weight of solute per liter of solution. A defined equivalence factor must be used to express concentration.
- Common units of normality include N, eq/L, or meq/L.
- Normality is the only unit of chemical concentration that depends on the chemical reaction being studied.
- Normality is not the most common unit of concentration, nor is its use appropriate for all chemical solutions. Typical situations when you might use normality include acid-base chemistry, redox reactions, or precipitation reactions. For most other situations, molarity or molality are better options for units.

## pH Section



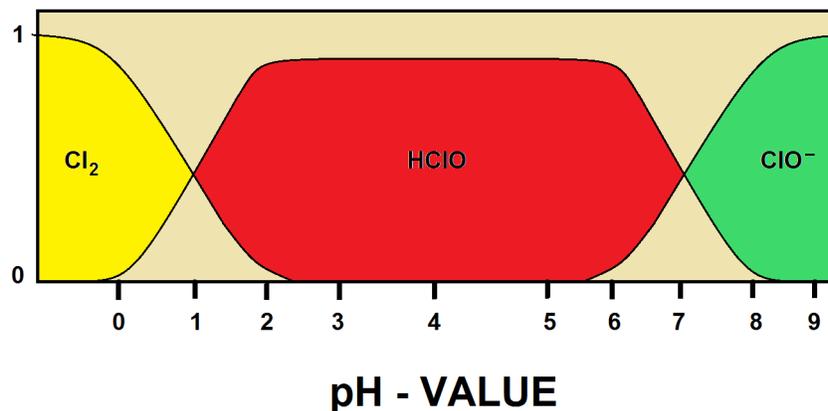
## pH SCALE

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.

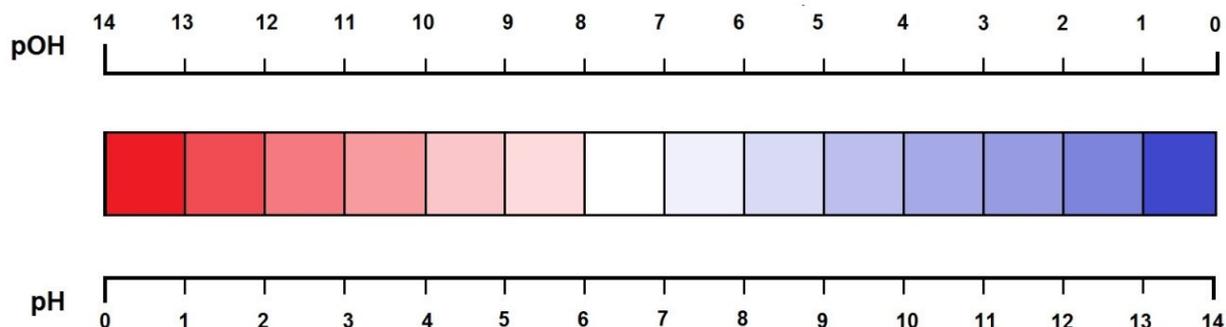
Primary pH standard values are determined using a concentration cell with transference, by measuring the potential difference between a hydrogen electrode and a standard electrode such as the silver chloride electrode. The pH scale is traceable to a set of standard solutions whose pH is established by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



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)

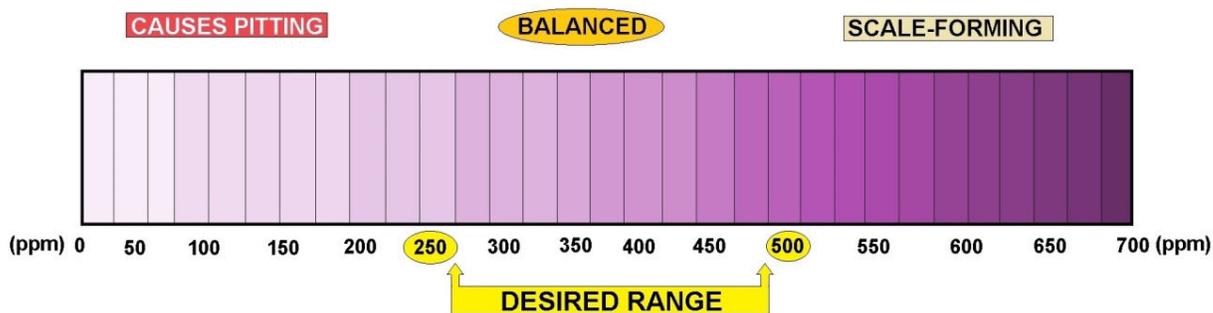
### Contents

#### 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 H <sub>2</sub> O	1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA	EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
	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<sub>2</sub> | 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  $\frac{1}{2.303RT/F}$  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<sup>+</sup> 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 or 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,  $\text{OH}^-$ , 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

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

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

$$\text{pOH} = \text{p}K_w - \text{pH}$$

So, at room temperature  $\text{pOH} \approx 14 - \text{pH}$ . 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.  $0.003 \text{ mol dm}^{-3}$  acid) and above about 10.5 (ca.  $0.0003 \text{ mol dm}^{-3}$  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  $\text{Na}^+$  and  $\text{K}^+$  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,  $a_{\text{H}^+}$ , can be defined as:

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

where  $\mu_{\text{H}^+}$  is the chemical potential of the hydrogen ion,  $\mu_{\text{H}^+}^\ominus$  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<sup>-3</sup> has a pH of 0. A solution of a strong alkali, such as sodium hydroxide, at concentration 1 mol dm<sup>-3</sup>, 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 is 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<sub>T</sub>**.

## 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.

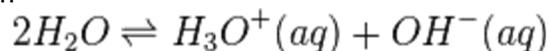
If the pH of a solution contains a weak acid requires the solution of a quadratic equation.

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

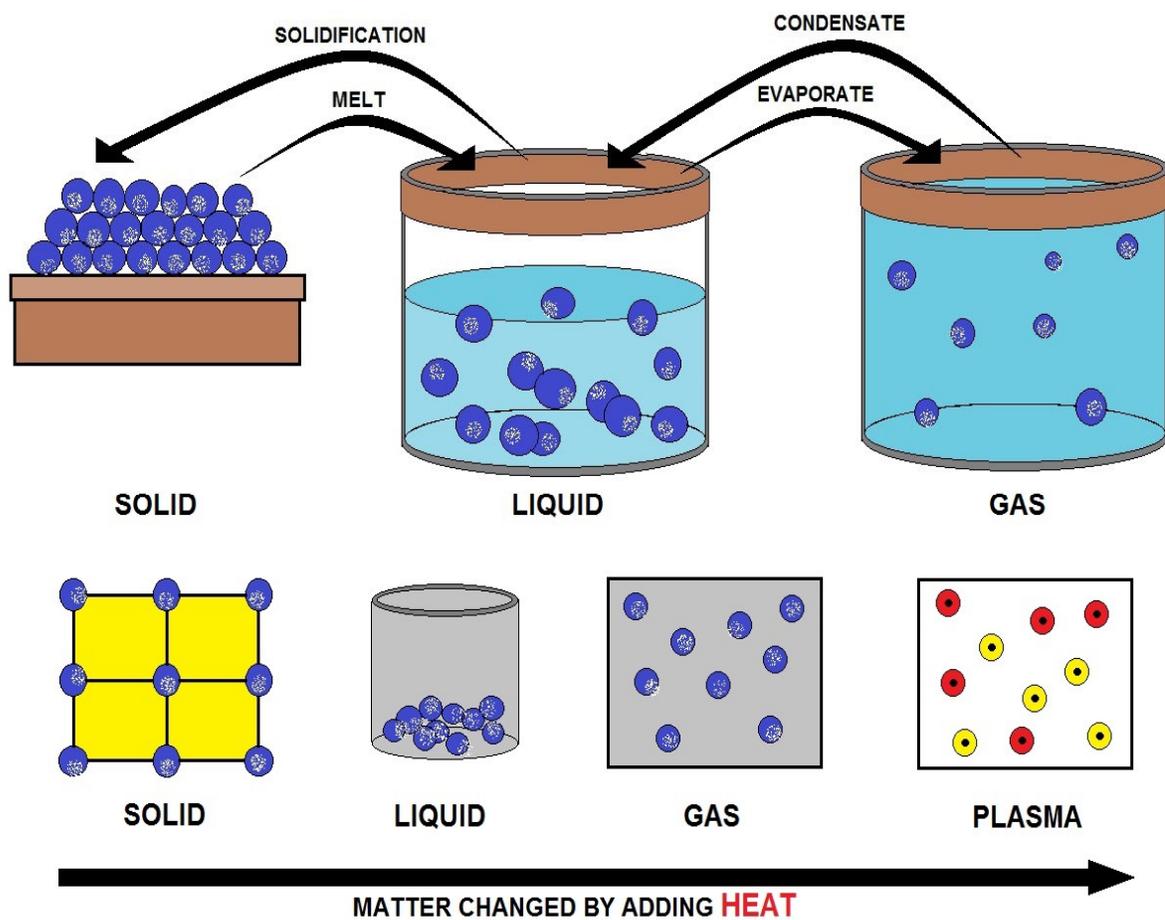


with a dissociation constant,  $K_w$  defined as

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

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.



# STATES OF MATTER

## Strong Acids and Bases



### 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.

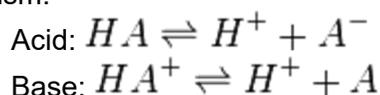
Hydrochloric acid (HCl) is an example of a strong acid. The pH of a 0.01M solution of HCl is equal to  $-\log_{10}(0.01)$ , that is, pH = 2.

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.



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<sup>+</sup>] and [A<sup>-</sup>] to determine by calculation. Two additional equations are needed.

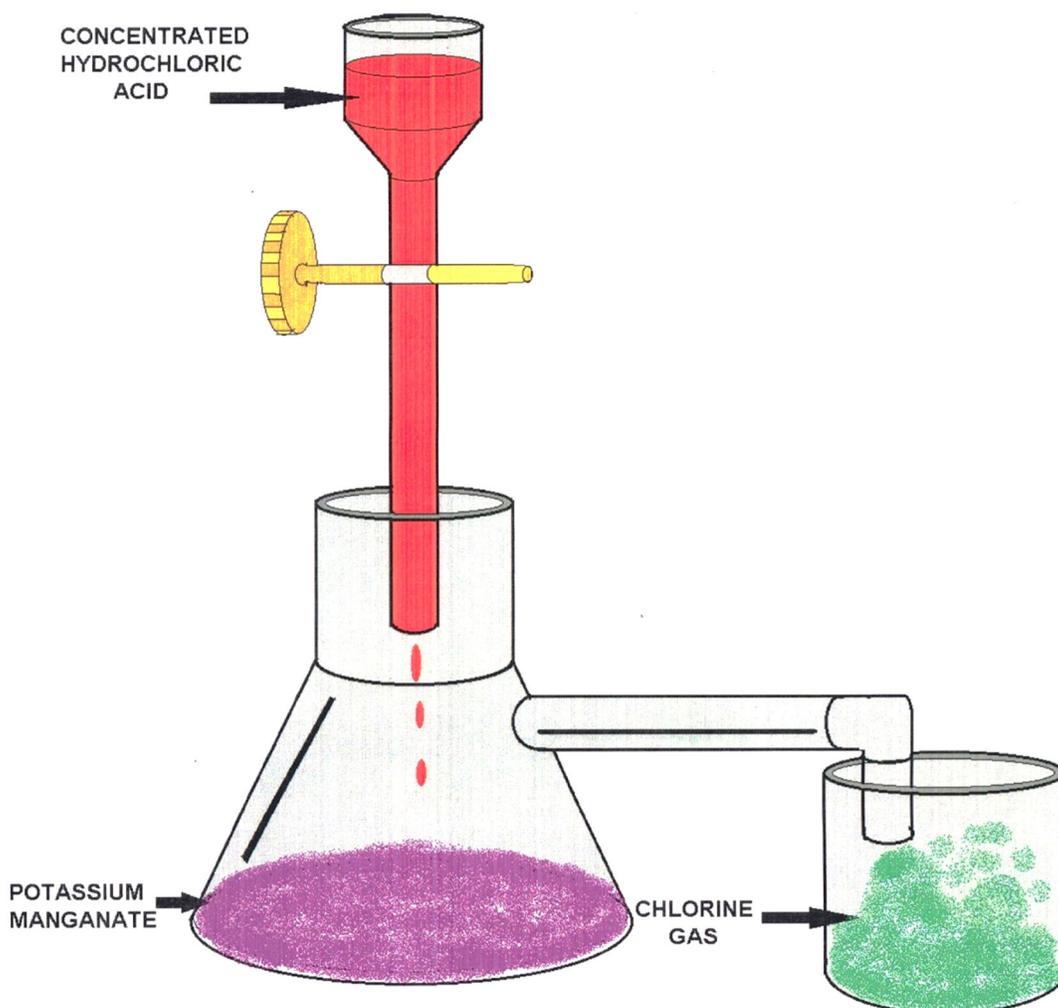
One way to provide them is to apply the law of mass conservation in terms of the two "reagents" H and A.

$$\begin{aligned}C_A &= [A] + [HA] \\C_H &= [H] + [HA]\end{aligned}$$

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.

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



## 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  $\text{Na}_2\text{CO}_3$  at  $250^\circ\text{C}$  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 not 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  $\text{CaCO}_3$ ), mg/l =  $10 V$  or  $N \times V \times 50 \times 1000$

T.A. (as  $\text{CaCO}_3$ ) =  $\frac{\text{Sample Amount}}{\text{Sample Amount}}$

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 white surface with standard hydrochloric acid.

### c. Calculation

$$\text{Alkalinity to phenolphthalein (as CaCO}_3\text{), mg/l} = \frac{1000 V_1}{V_2}$$

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>b. Procedure</b> Determine total alkalinity and alkalinity to phenolphthalein and calculate caustic alkalinity as shown in Table below. Result of Titration Caustic Alkalinity or Hydroxide Alkalinity as $\text{CaCO}_3$ Carbonate Alkalinity as $\text{CaCO}_3$ Bicarbonate Concentration as $\text{CaCO}_3$ <b>Result of Titration</b>	<b>Caustic Alkalinity or Hydroxide Alkalinity as <math>\text{CaCO}_3</math></b>	<b>Carbonate Alkalinity as <math>\text{CaCO}_3</math></b>	<b>Bicarbonate Concentration as <math>\text{CaCO}_3</math></b>
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) CaCO<sub>3</sub>.

### Hardness (calcium)

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

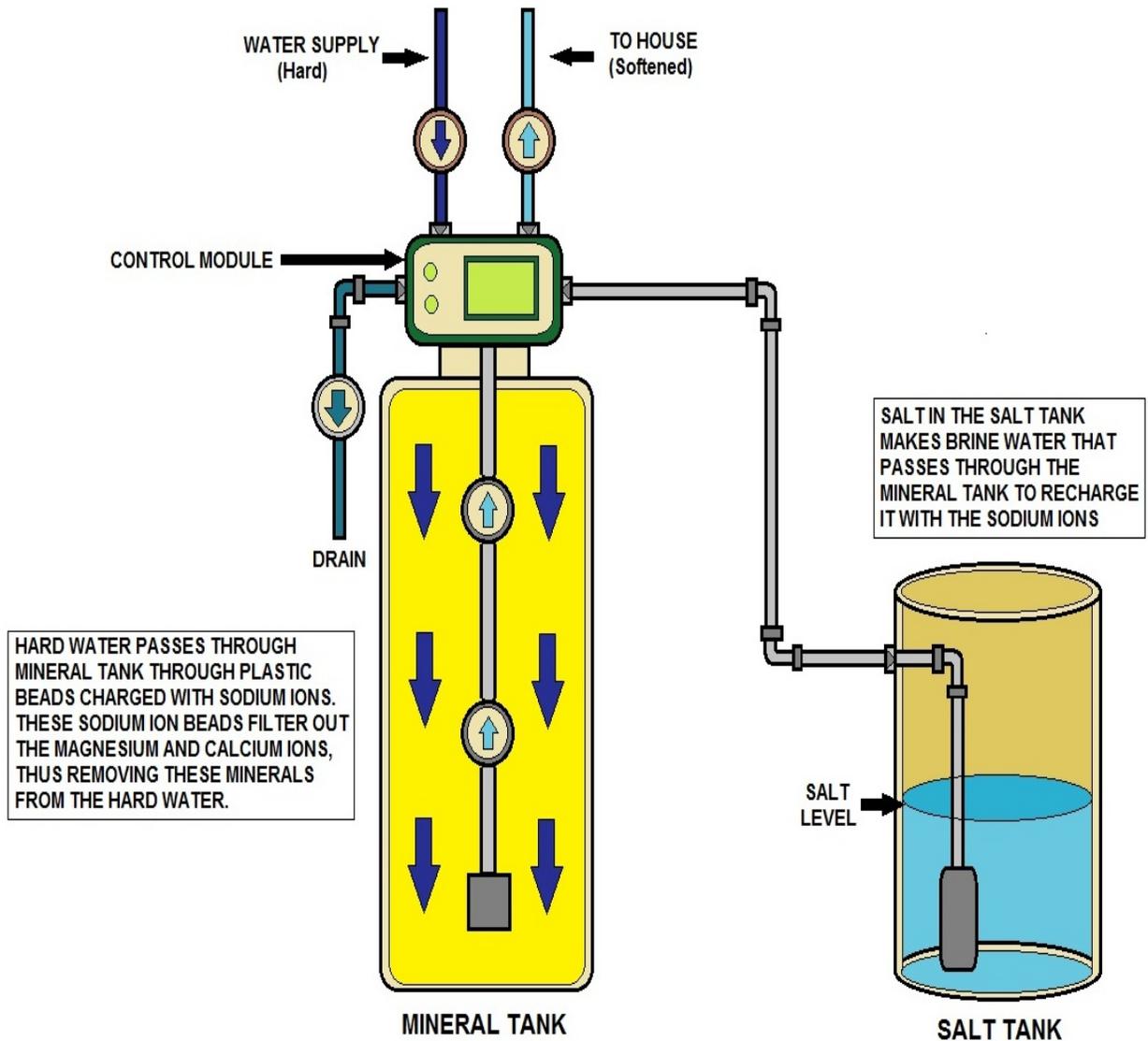
Originally described as water's capacity to precipitate soap, hardness is one of the most frequently determined qualities of water. It is a composite of the calcium, magnesium, strontium, and barium concentrations in a sample. The current practice is to assume total hardness refers to the calcium and 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<sub>3</sub>.

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.



## BASICS OF HOW A WATER SOFTENER WORKS

## Hard Water Section

Water contains various amounts of dissolved minerals, some of which impart a quality known as hardness. Consumers frequently complain about problems attributed to hard water, such as the formation of scale on cooking utensils and hot water heaters. In this document we will examine the occurrence, and effects, of hard water and the hard water treatment or softening process that removes the hardness-causing minerals. The precipitation process most frequently used is generally known as the lime process or lime soda process. Because of the special facilities required and the complexity of the process, it is generally applicable only to medium- or large-size water systems where all treatment can be accomplished at a central location. This process will provide softened water at the lowest cost. Lime softening can be used for treatment of either groundwater or surface water sources.

The other commonly used method of softening involves the ion exchange process. This process has the advantages of a considerably lower initial cost and ease of use by small systems or by large systems at multiple locations. The principal disadvantage is that operating costs are considerably higher. Ion exchange processes can typically be used for direct treatment of ground-water, so long as turbidity and iron levels are not excessive. For treatment of surface water, the process normally must be preceded by conventional treatment. Softening can also be accomplished using membrane technology, electro dialysis, distillation, and freezing. Of these, membrane methods seem to have the greatest potential.



### Distillers

Various sizes of distillers are available for home use. They all work on the principle of vaporizing water and then condensing the vapor. In the process, dissolved solids such as salt, metals, minerals, asbestos fibers, and other particles are removed. Some organic chemicals are also removed, but those that are more volatile are often vaporized and condensed with the product water. Distillers are effective in killing all microorganisms.

The principal problem with a distiller is that a small unit can produce only 2-3 gal (7.5 -11 Lt) a day, and that the power cost for operation will be substantially higher than the operating cost of other types of treatment devices.

Water Distillers have a high energy cost (approximately 20-30 cents per gallon). They must be carbon filtered before and/or after to remove volatile chemicals. It is considered "**dead**" water because the process removes all extra oxygen and energy. It has no taste. It is still second only to reverse osmosis water for health. Diet should be rich in electrolytes, as the aggressive nature of distilled water can "**leach**" electrolytes from the body.



## Occurrence of Hard Water

Hard water is caused by soluble, divalent, metallic cations, (positive ions having valence of 2). The principal chemicals that cause water hardness are calcium (**Ca**) and magnesium (**Mg**). Strontium, aluminum, barium, and iron are usually present in large enough concentrations to contribute significantly to the total hardness.

Water hardness varies considerably in different geographic areas of the contiguous 48 states. This is due to different geologic formations, and is also a function of the contact time between water and limestone deposits. Magnesium is dissolved as water passes over and through dolomite and other magnesium-bearing minerals. Because groundwater is in contact with these formations for a longer period of time than surface water, groundwater is normally harder than surface water.

## Expressing Water Hardness Concentration

Water hardness is generally expressed as a concentration of calcium carbonate, in terms of milligrams per liter as  $\text{CaCO}_3$ . The degree of hardness that consumers consider objectionable will vary, depending on other qualities of the water and on the hardness to which they have become accustomed. We will show two different classifications of the relative hardness of water:

### Comparative classifications of water for softness and hardness

Classification	mg/L as $\text{CaCO}_3$ *	mg/L as $\text{CaCO}_3$ +
Soft	0 – 75	0 – 60
Moderately hard	75 – 150	61 – 120
Hard	150 – 300	121 – 180
Very hard	Over 300	Over 180

*Source: Adapted from Sawyer 1960 and Briggs and Ficke 1977.*

\* Per Sawyer (1960)

+ Per Briggs and Ficke (1977)

## Types of Water Hardness

Hardness can be categorized by either of two methods: calcium versus magnesium hardness and carbonate versus non-carbonate hardness. The calcium-magnesium distinction is based on the minerals involved. Hardness caused by calcium is called calcium hardness, regardless of the salts associated with it, which include calcium sulfate ( $\text{CaSO}_4$ ), calcium chloride ( $\text{CaCl}_2$ ), and others. Likewise, hardness caused by magnesium is called magnesium hardness. Calcium and magnesium are normally the only significant minerals that cause hardness, so it is generally assumed that

$$\text{Total hardness} = \text{calcium hardness} + \text{magnesium hardness}$$

The carbonate-noncarbonate distinction, however, is based on hardness from either the bicarbonate salts of calcium or the normal salts of calcium and magnesium involved in causing water hardness. Carbonate hardness is caused primarily by the bicarbonate salts of calcium and magnesium, which are calcium bicarbonate,  $\text{Ca}(\text{HCO}_3)_2$ , and magnesium bicarbonate  $\text{Mg}(\text{HCO}_3)_2$ . Calcium and magnesium combined with carbonate ( $\text{CO}_3$ ) also contribute to carbonate hardness.

Noncarbonate hardness is a measure of calcium and magnesium salts other than carbonate and bicarbonate salts. These salts are calcium sulfate, calcium chloride, magnesium sulfate ( $\text{MgSO}_4$ ), and magnesium chloride ( $\text{MgCl}_2$ ). Calcium and magnesium combined with nitrate may also contribute to noncarbonate hardness, although it is a very rare condition. For carbonate and noncarbonate hardness,

$$\text{Total hardness} = \text{carbonate hardness} + \text{noncarbonate hardness}$$

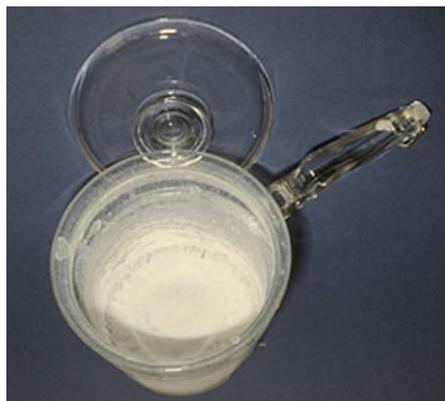
When hard water is boiled, carbon dioxide ( $\text{CO}_2$ ) is driven off, and Bicarbonate salts of calcium and magnesium then settle out of the water to form calcium and magnesium carbonate precipitates. These precipitates form the familiar chalky deposits on teapots. Because it can be removed by heating, carbonate hardness is sometimes called “*Temporary hardness.*” Because noncarbonated hardness cannot be removed or precipitated by prolonged boiling, it is sometimes called “*permanent hardness.*”

## Objections to Hard Water

### Scale Formation

Hard water forms scale, usually calcium carbonate, which causes a variety of problems. Left to dry on the surface of glassware and plumbing fixtures, including showers doors, faucets, and sink tops; hard water leaves unsightly white scale known as water spots. Scale that forms on the inside of water pipes will eventually reduce the flow capacity or possibly block it entirely. Scale that forms within appliances and water meters causes wear on moving parts.

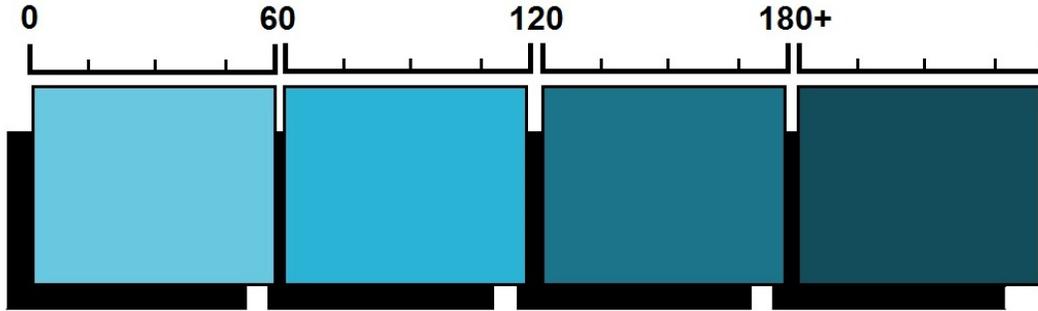
When hard water is heated, scale forms much faster. In particular, when the magnesium hardness is more than about 40 mg/l (as  $\text{CaCO}_3$ ), magnesium hydroxide scale will deposit in hot water heaters that are operated at normal temperatures of 140-150°F (60-66°C). A coating of only 0.04 in. (1 mm) of scale on the heating surfaces of a hot water heater creates an insulation effect that will increase heating costs by about 10 percent.



### Effect on Soap

The historical objection to hardness has been its effect on soap. Hardness ions form precipitates with soap, causing unsightly “curd,” such as the familiar bathtub ring, as well as reduced efficiency in washing and laundering. To counteract these problems, synthetic detergents have been developed and are now used almost exclusively for washing clothes and dishes.

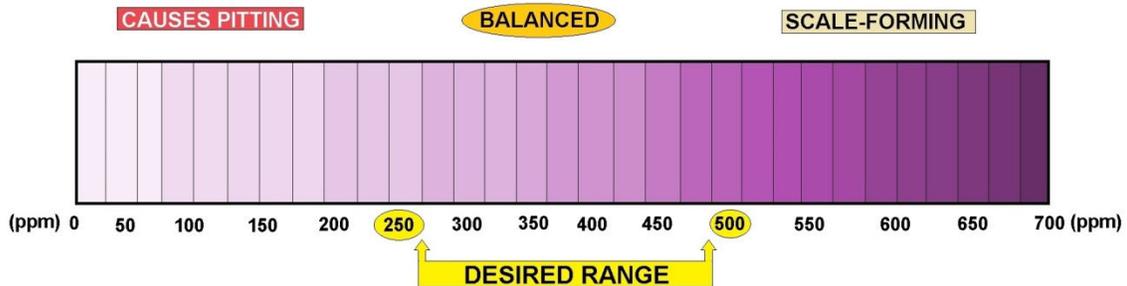
These detergents have additives known as sequestering agents that “tie up” the hardness ions so that they cannot form the troublesome precipitates. Although modern detergents counteract many of the problems of hard water, many customers prefer softer water. These customers can install individual softening units or use water from another source, such as a cistern, for washing.



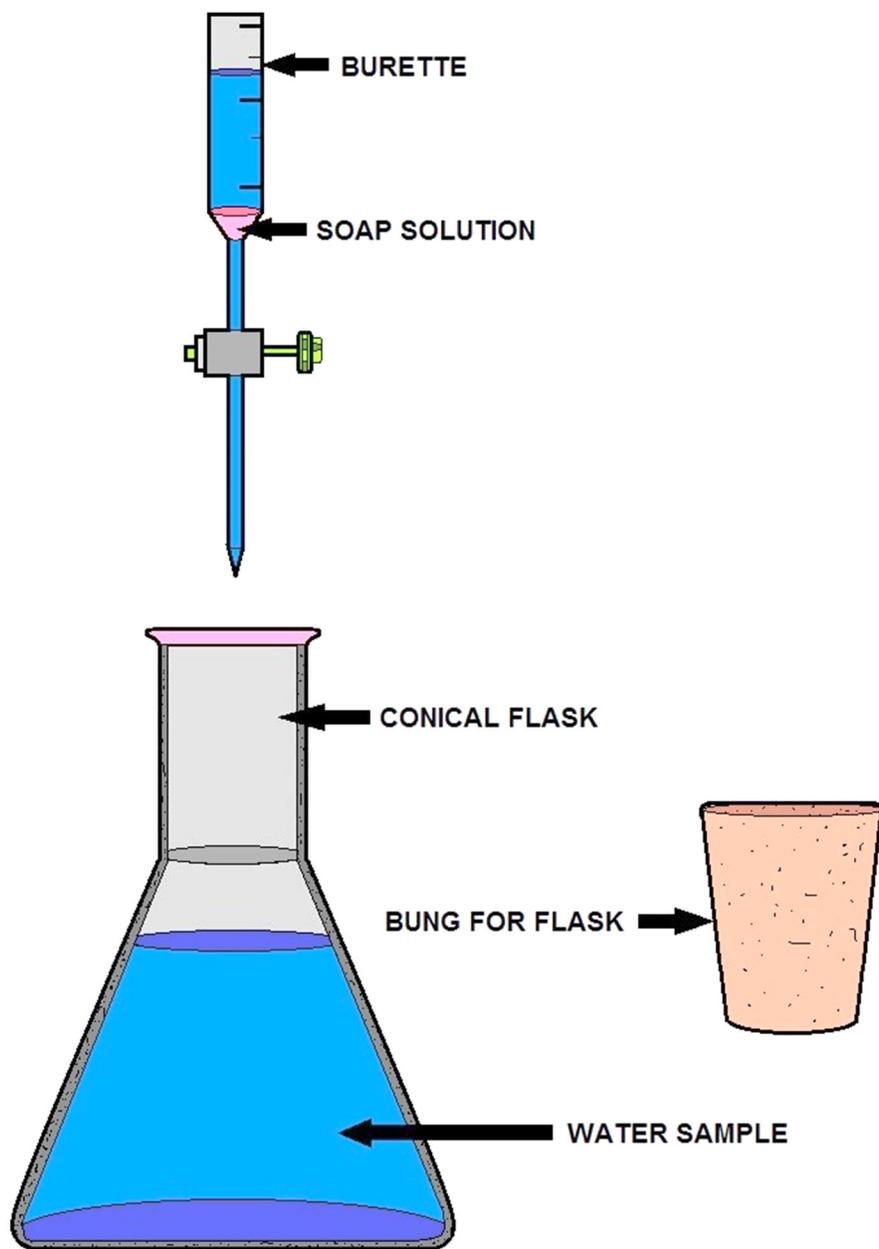
MEASURING HARDNESS OF WATER (Calcium Ions Present)

WATER HARDNESS SCALE		
Grains/Gal.	mg/L or PPM	Classification
LESS THAN 1	LESS THAN 17.1	SOFT
1 - 3.5	17.1 - 60	SLIGHTLY HARD
3.5 - 7	60 - 120	MODERATELY HARD
7 - 10	120 - 180	HARD
Over 10	Over 180	VERY HARD

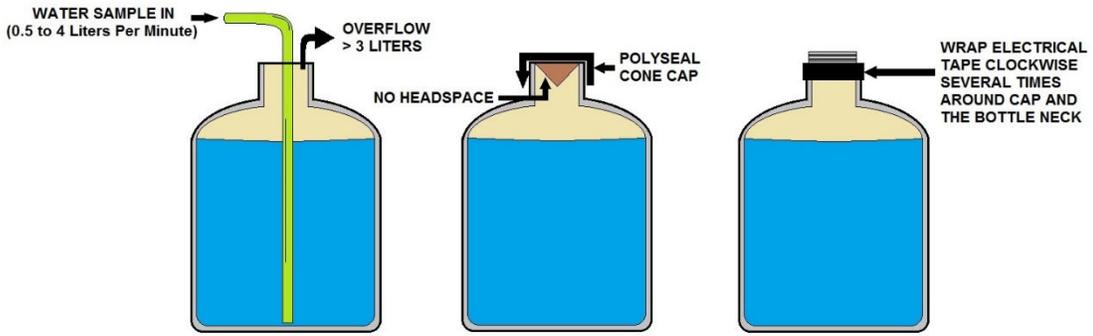
1 gpg = 17.1 mg/L = 17.1 ppm



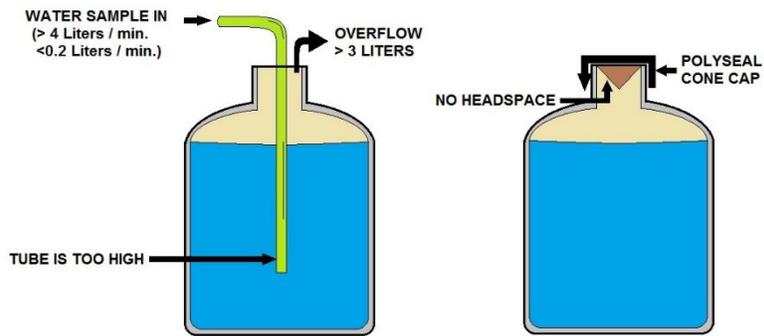
CALCIUM HARDNESS MEASUREMENT



## TESTING FOR THE HARDNESS OF WATER

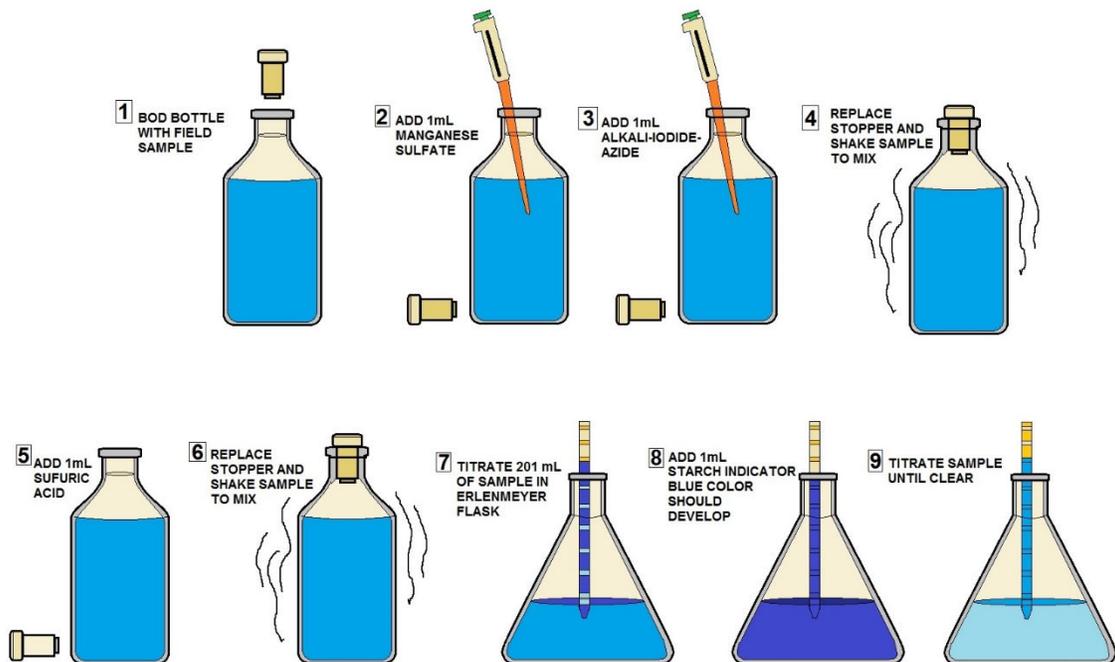


**WILL PRODUCE GOOD RESULTS**



**DO NOT DO THIS. WILL PRODUCE INACCURATE RESULTS**

### WATER SAMPLING PROCEDURES



**HOW TO MEASURE DISSOLVED OXYGEN IN A WATER SAMPLE**

## Inorganic Chemical Section

### What are Inorganic Compounds?

**Inorganic compounds** are of inanimate, not biological origin. Inorganic compounds lack carbon and hydrogen atoms and are synthesized by the agency of geological systems. In contrast, the synthesis of organic compounds in biological systems incorporates carbohydrates into the molecular structure.

Organic chemists traditionally refer to any molecule containing carbon as an organic compound and by default this means that inorganic chemistry deals with molecules lacking carbon. However, biologists may distinguish organic from inorganic compounds in a different way that does not hinge on the presence of a carbon atom.

Pools of organic matter, for example, that have been metabolically incorporated into living tissues persist in decomposing tissues, but as molecules become oxidized into the open environment, such as atmospheric  $\text{CO}_2$ , this creates a separate pool of inorganic compounds.

The distinction between inorganic and organic compounds is not always clear when dealing with open and closed systems, because everything is ultimately connected to everything else on the planet. Some scientists, for example, view the open environment (i.e., the ecosphere) as an extension of life and from this perspective may consider atmospheric  $\text{CO}_2$  as an organic compound. IUPAC, an agency widely recognized for defining chemical terms, does not offer definitions of inorganic or organic.

Inorganic compounds are rather simple chemicals present in ground water. These chemicals are generally described as mineral in nature and usually exist as ions (chemical substances with a positive or negative charge) when dissolved in water. Typical examples include sodium, iron, calcium, magnesium, manganese, nitrate, chloride, sulfate, and zinc. Many of these chemicals are naturally occurring minerals that are dissolved from the rock/soil which make up the aquifer or water-bearing rock formations below the soil surface.

However, some of these compounds may be introduced into ground water by human activities. Nitrate (an agricultural fertilizer) and sodium chloride (road salt) are two examples.

Water purveyors need to test for 30 different inorganic compounds including all arsenic, barium, cadmium, lead, mercury, selenium, and thallium.



- ✓ **Organic compounds** - these are once living, or are living and can bring life to cells. These contain carbon, and their electrons spin clockwise, just like those of the human body. Additionally, these cells can form an ionic bond with the body and can easily break down into materials to help with bodily function, such as tissue repair.
- ✓ **Inorganic compounds**- these were never living, without carbon and cannot bring life to cells. The body treats these metals like toxins and are tightly held together; they cannot be easily broken down. And, their electrons spin counterclockwise, out of sync with the rest of the body.

### **Drinking Water Standards**

The US Environmental Protection Agency is responsible for establishing maximum contaminant levels for drinking water. These standards are expressed as MCL (Maximum Contaminant Level). In most cases, this measurement is expressed as milligrams per liter of water (mg/l) or as parts per million (ppm).

In general terms, inorganic compounds are those materials that do not contain carbon. These compounds are often able to be dissolved in water. For example, dissolved gases such as nitrogen, oxygen, radon, and methane can be classified as inorganic compounds.

In addition to dissolved gases, some metals may be present in water as well. Some of these metals can be hazardous to human health, and may be introduced into water either naturally or through man-made activities.

Some of the more common metals include arsenic and aluminum which the EPA has established a MCL of no more than .05. Lead with a MCL of .015. Mercury MCL of .002. In addition, zinc, calcium, sodium, magnesium, potassium, and copper, all with a 1.3 MCL.

Lead, mercury, and arsenic can be dangerous to human health even at low concentrations, and as mentioned above can be introduced to our water from a variety of sources, including old pipes and lead solder. Conversely, some of the other inorganic compounds such as sodium, potassium, calcium, and magnesium are important to our overall health and well-being.

Another class of inorganic compounds are known as negative ions. These include substances such as fluoride: MCL 4.0 PPM (parts per million). Chloride and nitrate: MCL 10.0 ppm. Nitrite MCL 1.0. Sulfate, phosphate, carbonate, and cyanide: MCL 0.2

### **Inorganic Chemistry**

**Inorganic chemistry** is the study of the synthesis and behavior of inorganic and organometallic compounds. This field covers all chemical compounds except the myriad organic compounds (carbon based compounds, usually containing C-H bonds), which are the subjects of organic chemistry.

The distinction between the two disciplines is far from absolute, and there is much overlap, most importantly in the sub-discipline of organometallic chemistry. It has applications in every aspect of the chemical industry—including catalysis, materials science, pigments, surfactants, coatings, medicine, fuel, and agriculture.

## Subdivisions of Inorganic Chemistry

Many inorganic compounds are ionic compounds, consisting of cations and anions joined by ionic bonding. Examples of salts (which are ionic compounds) are magnesium chloride  $\text{MgCl}_2$ , which consists of magnesium cations  $\text{Mg}^{2+}$  and chloride anions  $\text{Cl}^-$ ; or sodium oxide  $\text{Na}_2\text{O}$ , which consists of sodium cations  $\text{Na}^+$  and oxide anions  $\text{O}^{2-}$ .

In any salt, the proportions of the ions are such that the electric charges cancel out, so that the bulk compound is electrically neutral. The ions are described by their oxidation state and their ease of formation can be inferred from the ionization potential (for cations) or from the electron affinity (anions) of the parent elements.

Important classes of inorganic salts are the oxides, the carbonates, the sulfates and the halides. Many inorganic compounds are characterized by high melting points. Inorganic salts typically are poor conductors in the solid state. Another important feature is their solubility in water, e.g., and ease of crystallization. Where some salts (e.g.,  $\text{NaCl}$ ) are very soluble in water, others (e.g.,  $\text{SiO}_2$ ) are not.

The simplest inorganic reaction is double displacement when in mixing of two salts the ions are swapped without a change in oxidation state. In redox reactions one reactant, the *oxidant*, lowers its oxidation state and another reactant, the *reductant*, has its oxidation state increased. The net result is an exchange of electrons.

Electron exchange can occur indirectly as well, e.g., in batteries, a key concept in electrochemistry.

When one reactant contains hydrogen atoms, a reaction can take place by exchanging protons in acid-base chemistry. In a more general definition, an acid can be any chemical species capable of binding to electron pairs is called a Lewis acid; conversely any molecule that tends to donate an electron pair is referred to as a Lewis base. As a refinement of acid-base interactions, the HSAB theory takes into account polarizability and size of ions.

Inorganic compounds are found in nature as minerals. Soil may contain iron sulfide as pyrite or calcium sulfate as gypsum. Inorganic compounds are also found multitasking as biomolecules: as electrolytes (sodium chloride), in energy storage (ATP) or in construction (the polyphosphate backbone in DNA).

The first important man-made inorganic compound was ammonium nitrate for soil fertilization through the Haber process. Inorganic compounds are synthesized for use as catalysts such as vanadium(V) oxide and titanium(III) chloride, or as reagents in organic chemistry such as lithium aluminum hydride.

Subdivisions of inorganic chemistry are organometallic chemistry, cluster chemistry and bioinorganic chemistry. These fields are active areas of research in inorganic chemistry, aimed toward new catalysts, superconductors, and therapies.

## Industrial Inorganic Chemistry

Inorganic chemistry is a highly practical area of science. Traditionally, the scale of a nation's economy could be evaluated by their productivity of sulfuric acid. The top 20 inorganic chemicals manufactured in Canada, China, Europe, India, Japan, and the US (2005 data): aluminum sulfate, ammonia, ammonium nitrate, ammonium sulfate, carbon black, chlorine, hydrochloric acid, hydrogen, hydrogen peroxide, nitric acid, nitrogen, oxygen, phosphoric acid, sodium carbonate, sodium chlorate, sodium hydroxide, sodium silicate, sodium sulfate, sulfuric acid, and titanium dioxide. The manufacturing of fertilizers is another practical application of industrial inorganic chemistry.

## Descriptive Inorganic Chemistry

Descriptive inorganic chemistry focuses on the classification of compounds based on their properties. Partly the classification focuses on the position in the periodic table of the heaviest element (the element with the highest atomic weight) in the compound, partly by grouping compounds by their structural similarities. When studying inorganic compounds, one often encounters parts of the different classes of inorganic chemistry (an organometallic compound is characterized by its coordination chemistry, and may show interesting solid state properties).

Different classifications are:

## Coordination Compounds

Classical coordination compounds feature metals bound to "lone pairs" of electrons residing on the main group atoms of ligands such as  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{Cl}^-$ , and  $\text{CN}^-$ . In modern coordination compounds almost all organic and inorganic compounds can be used as ligands. The "metal" usually is a metal from the groups 3-13, as well as the *trans*-lanthanides and *trans*-actinides, but from a certain perspective, all chemical compounds can be described as coordination complexes.

The stereochemistry of coordination complexes can be quite rich, as hinted at by Werner's separation of two enantiomers of  $[\text{Co}((\text{OH})_2\text{Co}(\text{NH}_3)_4)_3]^{6+}$ , an early demonstration that chirality is not inherent to organic compounds. A topical theme within this specialization is supramolecular coordination chemistry.

- **Examples:**  $[\text{Co}(\text{EDTA})]^-$ ,  $[\text{Co}(\text{NH}_3)_6]^{3+}$ ,  $\text{TiCl}_4(\text{THF})_2$ .

## Main Group Compounds

These species feature elements from groups 1, 2 and 13-18 (excluding hydrogen) of the periodic table. Due to their often similar reactivity, the elements in group 3 (Sc, Y, and La) and group 12 (Zn, Cd, and Hg) are also generally included.

Main group compounds have been known since the beginnings of chemistry, e.g., elemental sulfur and the distillable white phosphorus. Experiments on oxygen,  $\text{O}_2$ , by Lavoisier and Priestley not only identified an important diatomic gas, but opened the way for describing compounds and reactions according to stoichiometric ratios.

The discovery of a practical synthesis of ammonia using iron catalysts by Carl Bosch and Fritz Haber in the early 1900s deeply impacted mankind, demonstrating the significance of inorganic chemical synthesis.

Typical main group compounds are  $\text{SiO}_2$ ,  $\text{SnCl}_4$ , and  $\text{N}_2\text{O}$ . Many main group compounds can also be classed as "organometallic", as they contain organic groups, e.g.,  $\text{B}(\text{CH}_3)_3$ . Main group compounds also occur in nature, e.g., phosphate in DNA, and therefore may be classed as bioinorganic. Conversely, organic compounds lacking (many) hydrogen ligands can be classed as "inorganic", such as the fullerenes, buckytubes and binary carbon oxides.

- **Examples:** tetrasulfur tetranitride  $\text{S}_4\text{N}_4$ , diborane  $\text{B}_2\text{H}_6$ , silicones, buckminsterfullerene  $\text{C}_{60}$ .

### Transition Metal Compounds

Compounds containing metals from group 4 to 11 are considered transition metal compounds. Compounds with a metal from group 3 or 12 are sometimes also incorporated into this group, but also often classified as main group compounds.

Transition metal compounds show a rich coordination chemistry, varying from tetrahedral for titanium (e.g.,  $\text{TiCl}_4$ ) to square planar for some nickel complexes to octahedral for coordination complexes of cobalt. A range of transition metals can be found in biologically important compounds, such as iron in hemoglobin.

- **Examples:** iron pentacarbonyl, titanium tetrachloride, cisplatin

### Organometallic Compounds

Usually, organometallic compounds are considered to contain the M-C-H group. The metal (M) in these species can either be a main group element or a transition metal. Operationally, the definition of an organometallic compound is more relaxed to include also highly lipophilic complexes such as metal carbonyls and even metal alkoxides.

Organometallic compounds are mainly considered a special category because organic ligands are often sensitive to hydrolysis or oxidation, necessitating that organometallic chemistry employs more specialized preparative methods than was traditional in Werner-type complexes.

Synthetic methodology, especially the ability to manipulate complexes in solvents of low coordinating power, enabled the exploration of very weakly coordinating ligands such as hydrocarbons,  $\text{H}_2$ , and  $\text{N}_2$ . Because the ligands are petrochemicals in some sense, the area of organometallic chemistry has greatly benefited from its relevance to industry.

- **Examples:** Cyclopentadienyliron dicarbonyl dimer  $(\text{C}_5\text{H}_5)_2\text{Fe}(\text{CO})_2$ , Ferrocene  $\text{Fe}(\text{C}_5\text{H}_5)_2$ , Molybdenum hexacarbonyl  $\text{Mo}(\text{CO})_6$ , Diborane  $\text{B}_2\text{H}_6$ , Tetrakis(triphenylphosphine)palladium(0)  $\text{Pd}[\text{P}(\text{C}_6\text{H}_5)_3]_4$

### Cluster Compounds

Clusters can be found in all classes of chemical compounds. According to the commonly accepted definition, a cluster consists minimally of a triangular set of atoms that are directly bonded to each other. But metal-metal bonded dimetallic complexes are highly relevant to the area. Clusters occur in "pure" inorganic systems, organometallic chemistry, main group chemistry, and bioinorganic chemistry. The distinction between very large clusters and bulk solids is increasingly blurred.

This interface is the chemical basis of nanoscience or nanotechnology and specifically arise from the study of quantum size effects in cadmium selenide clusters. Thus, large clusters can be described as an array of bound atoms intermediate in character between a molecule and a solid.

- **Examples:**  $\text{Fe}_3(\text{CO})_{12}$ ,  $\text{B}_{10}\text{H}_{14}$ ,  $[\text{Mo}_6\text{Cl}_{14}]^{2-}$ , 4Fe-4S

### **Bioinorganic Compounds**

By definition, these compounds occur in nature, but the subfield includes anthropogenic species, such as pollutants (e.g., methylmercury) and drugs (e.g., Cisplatin). The field, which incorporates many aspects of biochemistry, includes many kinds of compounds, e.g., the phosphates in DNA, and also metal complexes containing ligands that range from biological macromolecules, commonly peptides, to ill-defined species such as humic acid, and to water (e.g., coordinated to gadolinium complexes employed for MRI). Traditionally bioinorganic chemistry focuses on electron- and energy-transfer in proteins relevant to respiration. Medicinal inorganic chemistry includes the study of both non-essential and essential elements with applications to diagnosis and therapies.

- **Examples:** hemoglobin, methylmercury, carboxypeptidase

### **Solid State Compounds**

This important area focuses on structure, bonding, and the physical properties of materials. In practice, solid state inorganic chemistry uses techniques such as crystallography to gain an understanding of the properties that result from collective interactions between the subunits of the solid. Included in solid state chemistry are metals and their alloys or intermetallic derivatives. Related fields are condensed matter physics, mineralogy, and materials science.

- **Examples:** silicon chips, zeolites,  $\text{YBa}_2\text{Cu}_3\text{O}_7$

### **Theoretical Inorganic Chemistry**

An alternative perspective on the area of inorganic chemistry begins with the Bohr model of the atom and, using the tools and models of theoretical chemistry and computational chemistry, expands into bonding in simple and then more complex molecules. Precise quantum mechanical descriptions for multielectron species, the province of inorganic chemistry, is difficult. This challenge has spawned many semi-quantitative or semi-empirical approaches including molecular orbital theory and ligand field theory. In parallel with these theoretical descriptions, approximate methodologies are employed, including density functional theory.

Exceptions to theories, qualitative and quantitative, are extremely important in the development of the field. For example,  $\text{Cu}^{II}_2(\text{OAc})_4(\text{H}_2\text{O})_2$  is almost diamagnetic below room temperature whereas Crystal Field Theory predicts that the molecule would have two unpaired electrons.

The disagreement between qualitative theory (paramagnetic) and observation (diamagnetic) led to the development of models for "magnetic coupling." These improved models led to the development of new magnetic materials and new technologies.

## Main Group Elements and Lanthanides

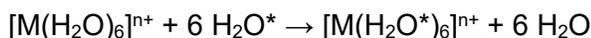
The mechanisms of main group compounds of groups 13-18 are usually discussed in the context of organic chemistry (organic compounds are main group compounds, after all). Elements heavier than C, N, O, and F often form compounds with more electrons than predicted by the octet rule, as explained in the article on hypervalent molecules. The mechanisms of their reactions differ from organic compounds for this reason.

Elements lighter than carbon (B, Be, Li) as well as Al and Mg often form electron-deficient structures that are electronically akin to carbocations. Such electron-deficient species tend to react via associative pathways. The chemistry of the lanthanides mirrors many aspects of chemistry seen for aluminum.

### Transition Metal Complexes

Mechanisms for the reactions of transition metals are discussed differently from main group compounds. The important role of d-orbitals in bonding strongly influences the pathways and rates of ligand substitution and dissociation. These themes are covered in articles on coordination chemistry and ligand. Both associative and dissociative pathways are observed.

An overarching aspect of mechanistic transition metal chemistry is the kinetic lability of the complex illustrated by the exchange of free and bound water in the prototypical complexes  $[M(H_2O)_6]^{n+}$ :

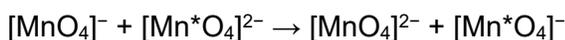


where  $H_2O^*$  denotes isotopically enriched water, e.g.,  $H_2^{17}O$

The rates of water exchange varies by 20 orders of magnitude across the periodic table, with lanthanide complexes at one extreme and Ir(III) species being the slowest.

### Redox Reactions

Redox reactions are prevalent for the transition elements. Two classes of redox reaction are considered: atom-transfer reactions, such as oxidative addition/reductive elimination, and electron-transfer. A fundamental redox reaction is "self-exchange", which involves the degenerate reaction between an oxidant and a reductant. For example, permanganate and its one-electron reduced relative manganate exchange one electron:



### Reactions at Ligands

Coordinated ligands display reactivity distinct from the free ligands. For example, the acidity of the ammonia ligands in  $[Co(NH_3)_6]^{3+}$  is elevated relative to  $NH_3$  itself. Alkenes bound to metal cations are reactive toward nucleophiles whereas alkenes normally are not. The large and industrially important area of catalysis hinges on the ability of metals to modify the reactivity of organic ligands.

Homogeneous catalysis occurs in solution and heterogeneous catalysis occurs when gaseous or dissolved substrates interact with surfaces of solids.

Traditionally homogeneous catalysis is considered part of organometallic chemistry and heterogeneous catalysis is discussed in the context of surface science, a subfield of solid state chemistry. But the basic inorganic chemical principles are the same.

Transition metals, almost uniquely, react with small molecules such as CO, H<sub>2</sub>, O<sub>2</sub>, and C<sub>2</sub>H<sub>4</sub>. The industrial significance of these feedstocks drives the active area of catalysis. Ligands can also undergo ligand transfer reactions such as transmetalation.

### **Inorganic Compound Characterization**

Because of the diverse range of elements and the correspondingly diverse properties of the resulting derivatives, inorganic chemistry is closely associated with many methods of analysis. Older methods tended to examine bulk properties such as the electrical conductivity of solutions, melting points, solubility, and acidity. With the advent of quantum theory and the corresponding expansion of electronic apparatus, new tools have been introduced to probe the electronic properties of inorganic molecules and solids. Often these measurements provide insights relevant to theoretical models.



For example, measurements on the photoelectron spectrum of methane demonstrated that describing the bonding by the two-center, two-electron bonds predicted between the carbon and hydrogen using Valence Bond Theory is not appropriate for describing ionization processes in a simple way. Such insights led to the popularization of molecular orbital theory as fully delocalized orbitals are a more appropriate simple description of electron removal and electron excitation.

**Commonly encountered techniques are:**

- X-ray crystallography: This technique allows for the 3D determination of molecular structures.
- Dual polarization interferometer: This technique measures the conformation and conformational change of molecules.
- Various forms of spectroscopy
  - Ultraviolet-visible spectroscopy: Historically, this has been an important tool, since many inorganic compounds are strongly colored
  - NMR spectroscopy: Besides  $^1\text{H}$  and  $^{13}\text{C}$  many other "good" NMR nuclei (e.g.,  $^{11}\text{B}$ ,  $^{19}\text{F}$ ,  $^{31}\text{P}$ , and  $^{195}\text{Pt}$ ) give important information on compound properties and structure. Also the NMR of paramagnetic species can result in important structural information. Proton NMR is also important because the light hydrogen nucleus is not easily detected by X-ray crystallography.
  - Infrared spectroscopy: Mostly for absorptions from carbonyl ligands
  - Electron nuclear double resonance (ENDOR) spectroscopy
  - Mössbauer spectroscopy
  - Electron-spin resonance: ESR (or EPR) allows for the measurement of the environment of paramagnetic metal centers.
- Electrochemistry: Cyclic voltammetry and related techniques probe the redox characteristics of compounds.

**Synthetic Inorganic Chemistry**

Although some inorganic species can be obtained in pure form from nature, most are synthesized in chemical plants and in the laboratory.

Inorganic synthetic methods can be classified roughly according the volatility or solubility of the component reactants. Soluble inorganic compounds are prepared using methods of organic synthesis. For metal-containing compounds that are reactive toward air, Schlenk line and glove box techniques are followed.

Volatile compounds and gases are manipulated in "vacuum manifolds" consisting of glass piping interconnected through valves, the entirety of which can be evacuated to 0.001 mm Hg or less.

Compounds are condensed using liquid nitrogen (b.p. 78K) or other cryogenes. Solids are typically prepared using tube furnaces, the reactants and products being sealed in containers, often made of fused silica (amorphous  $\text{SiO}_2$ ) but sometimes more specialized materials such as welded Ta tubes or Pt "boats". Products and reactants are transported between temperature zones to drive reactions.

## Qualitative Theories

Inorganic chemistry has greatly benefited from qualitative theories. Such theories are easier to learn as they require little background in quantum theory. Within main group compounds, VSEPR theory powerfully predicts, or at least rationalizes, the structures of main group compounds, such as an explanation for why  $\text{NH}_3$  is pyramidal whereas  $\text{ClF}_3$  is T-shaped.

For the transition metals, crystal field theory allows one to understand the magnetism of many simple complexes, such as why  $[\text{Fe}^{\text{III}}(\text{CN})_6]^{3-}$  has only one unpaired electron, whereas  $[\text{Fe}^{\text{III}}(\text{H}_2\text{O})_6]^{3+}$  has five. A particularly powerful qualitative approach to assessing the structure and reactivity begins with classifying molecules according to electron counting, focusing on the numbers of valence electrons, usually at the central atom in a molecule.

### Molecular Symmetry Group Theory

A central construct in inorganic chemistry is the theory of molecular symmetry. Mathematical group theory provides the language to describe the shapes of molecules according to their point group symmetry. Group theory also enables factoring and simplification of theoretical calculations.

Spectroscopic features are analyzed and described with respect to the symmetry properties of the, *inter alia*, vibrational or electronic states. Knowledge of the symmetry properties of the ground and excited states allows one to predict the numbers and intensities of absorptions in vibrational and electronic spectra. A classic application of group theory is the prediction of the number of C-O vibrations in substituted metal carbonyl complexes. The most common applications of symmetry to spectroscopy involve vibrational and electronic spectra.

As an instructional tool, group theory highlights commonalities and differences in the bonding of otherwise disparate species, such as  $\text{WF}_6$  and  $\text{Mo}(\text{CO})_6$  or  $\text{CO}_2$  and  $\text{NO}_2$ .

### Thermodynamics and Inorganic Chemistry

An alternative quantitative approach to inorganic chemistry focuses on energies of reactions. This approach is highly traditional and empirical, but it is also useful. Broad concepts that are couched in thermodynamic terms include redox potential, acidity, phase changes. A classic concept in inorganic thermodynamics is the Born-Haber cycle, which is used for assessing the energies of elementary processes such as electron affinity, some of which cannot be observed directly.

### Mechanistic Inorganic Chemistry

An important and increasingly popular aspect of inorganic chemistry focuses on reaction pathways. The mechanisms of reactions are discussed differently for different classes of compounds.

## Laboratory Safety Section

### OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450) addresses the unique features of laboratory work

- Laboratories use a greater variety of hazardous substances than the typical industrial workplace, but in smaller quantities. OSHA defines "laboratory scale" operations as those that use containers designed to be easily and safely manipulated by one person.
- Substances and procedures used tend to change frequently and unpredictably.
- Workers and supervisors are usually highly trained and educated about the substances.
  
- ✓ All laboratory personnel should be informed of the contents of "Occupational Exposure to Hazardous Chemicals in Laboratories," OSHA Standard 29 CFR 1910.1450, and the location and contents of your employer's Chemical Hygiene Plan.
- ✓ All laboratory personnel will be informed of the OSHA Permissible Exposure Limits (PELs) and ACGIH Threshold Limit Values (TLVs). A listing of OSHA PELs is located in Appendix B.

### Training

Your training should consist of methods and observations that may be used to detect the presence or release of a hazardous chemical, the physical and health hazards of chemicals in the work area, the measures employees can take to protect themselves from exposure, including engineering controls, personal protective equipment, work practices, and emergency procedures.

Your training should also cover your employer's Chemical Hygiene Plan, Hazard Communication and Hazardous Waste Management Procedures.



A normal day for a Lab Tech will include the washing of lab glassware. Sometimes the Tech will use acid to wash certain glass bottles. Notice the broken glass or Sharps container.



Clearly marked and different types of hazardous waste disposal containers need to be present in your lab.

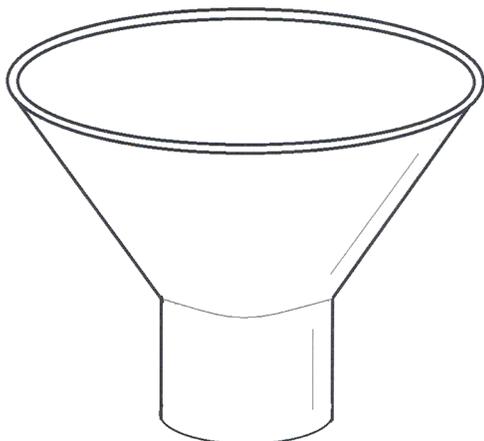
### **Common terms used in this course.**

**Hazardous chemical:** Is a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

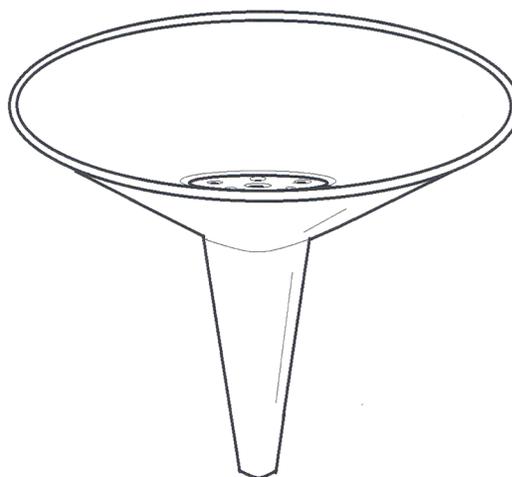
**Health Hazard:** The term "**health hazard**" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

**Employee:** Is an individual employed in a laboratory workplace who may be exposed to hazardous chemicals in the course of his or her assignments.

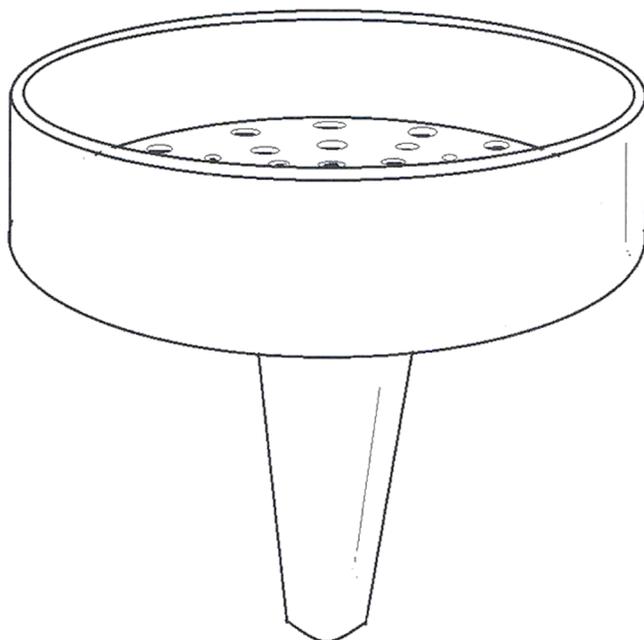
## Common Chemistry Glassware



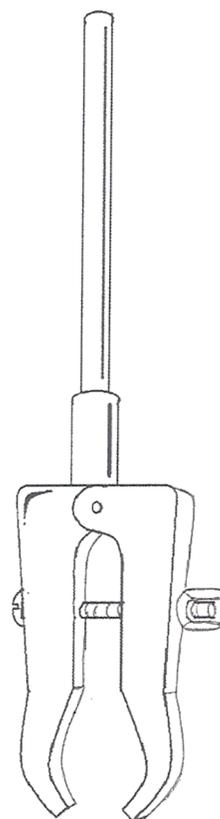
POWDER FUNNEL



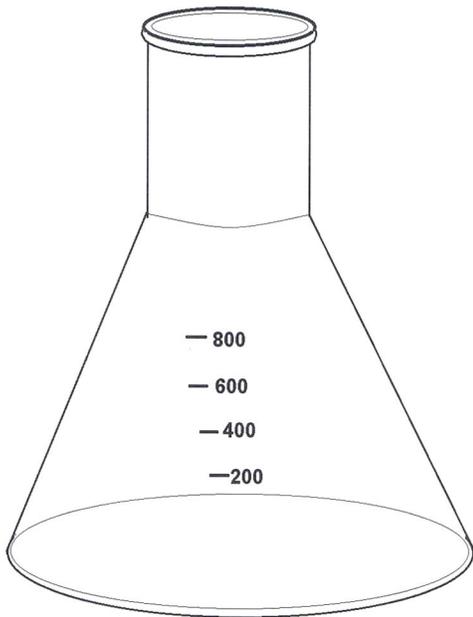
HIRSCH FUNNEL



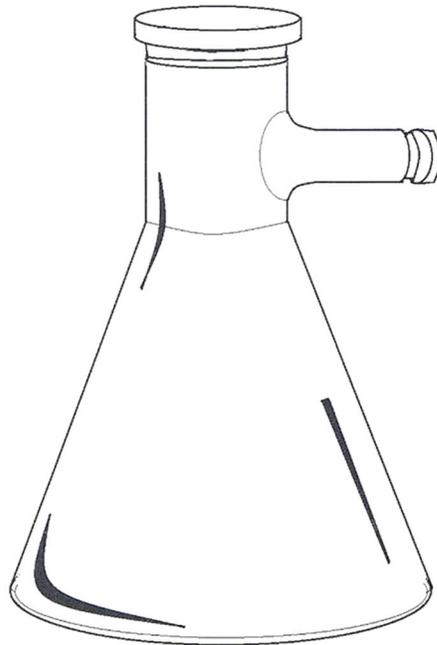
BÜCHNER FUNNEL



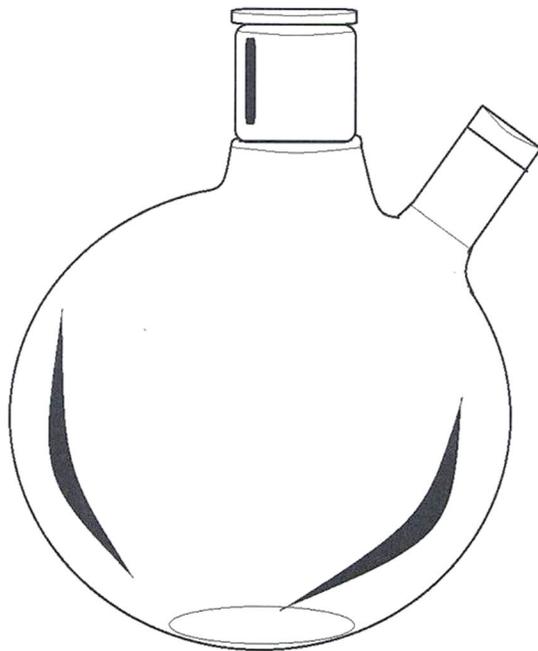
EXTENSION CLAMP



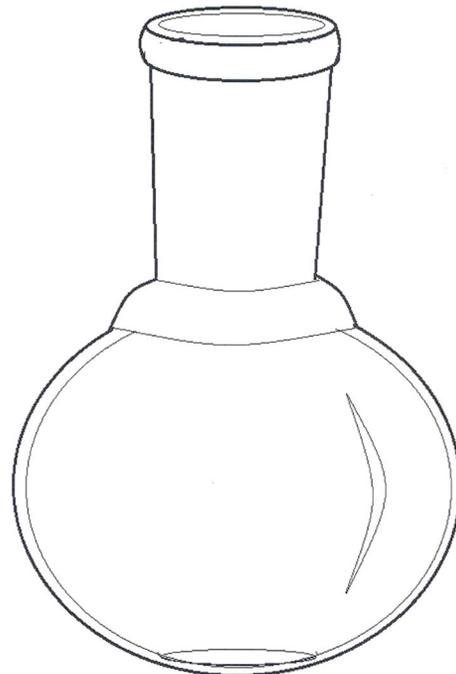
**ERLENMEYER FLASK**



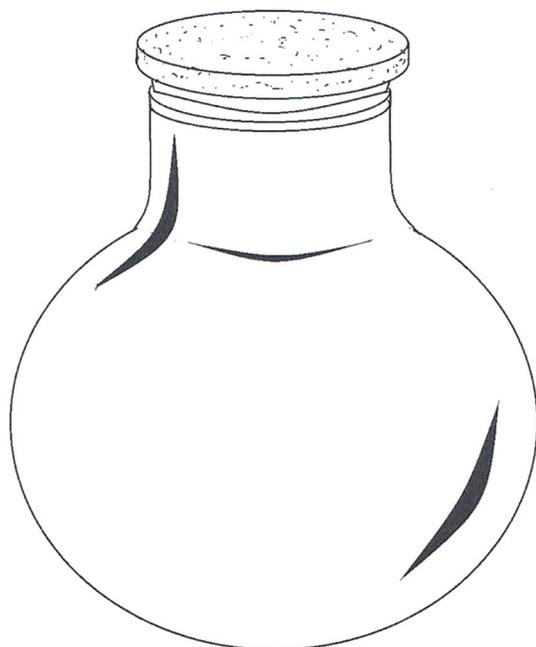
**500 ml FILTER FLASK**



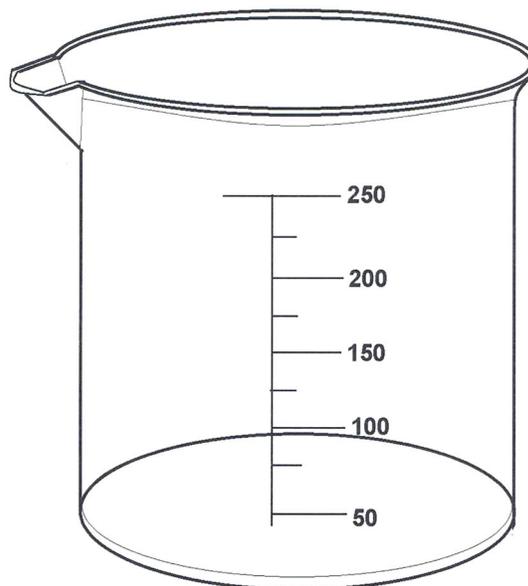
**TWO-NECK  
ROUND BOTTOM BOILING FLASK**



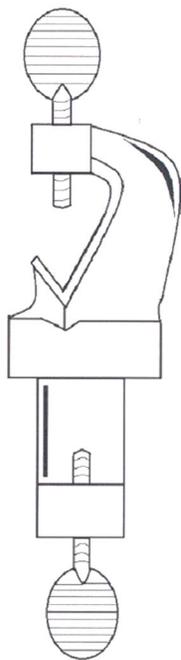
**ROUND-BOTTOM  
BOILING FLASK**



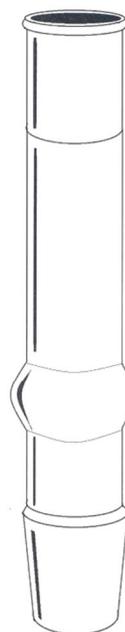
**ROUND-BOTTOM  
BOILING FLASK**



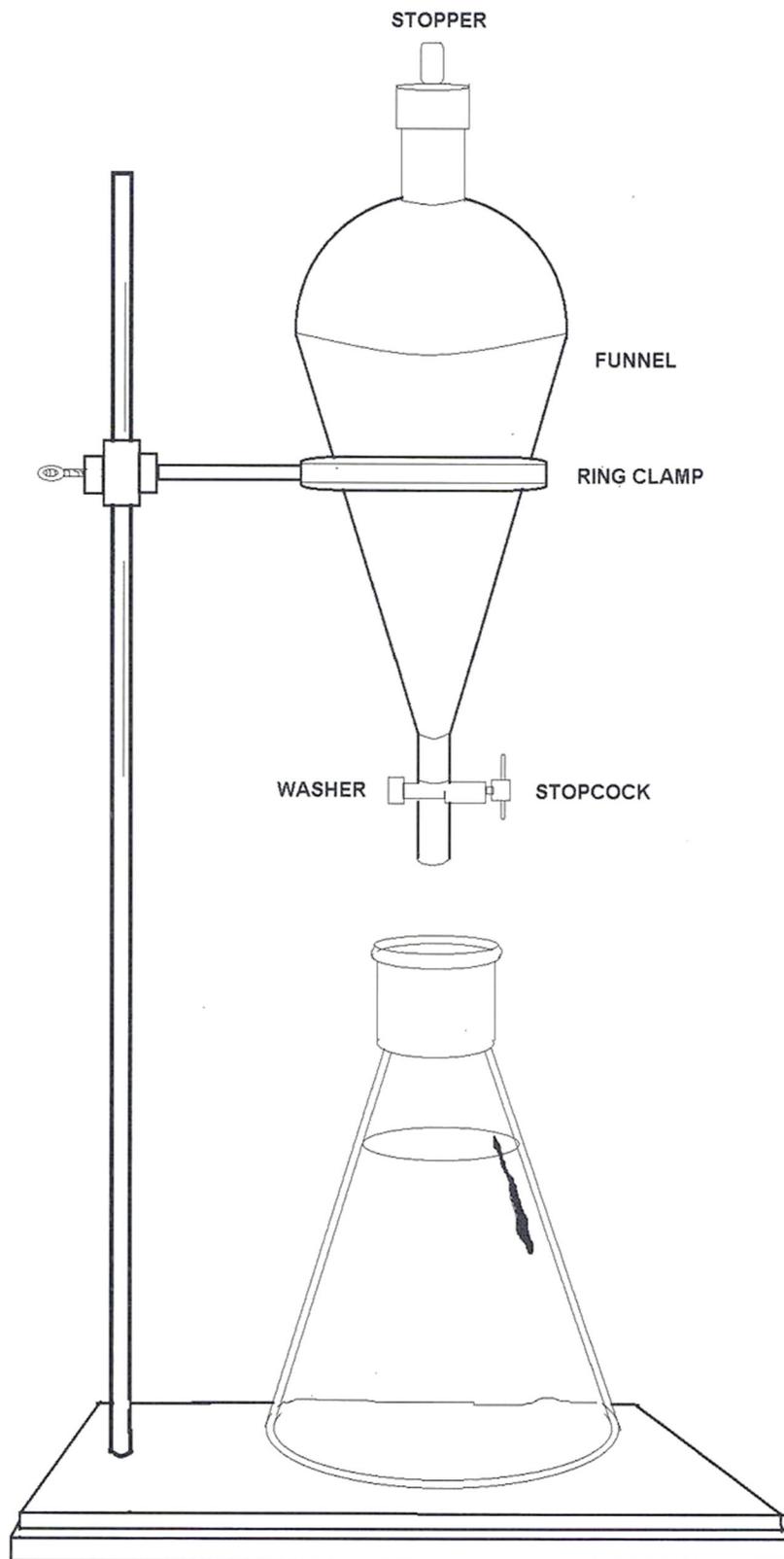
**BEAKER**



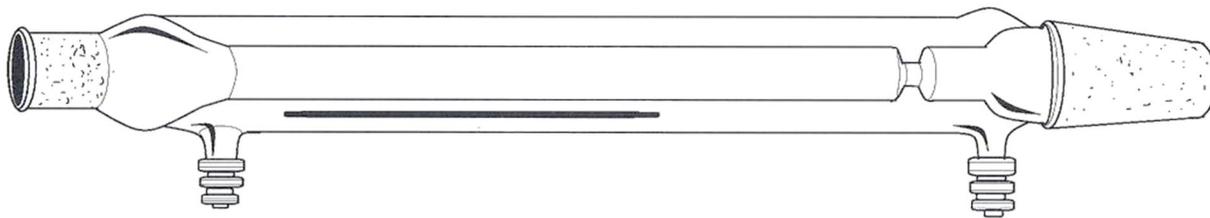
**EXTENSION CLAMP FASTENER**



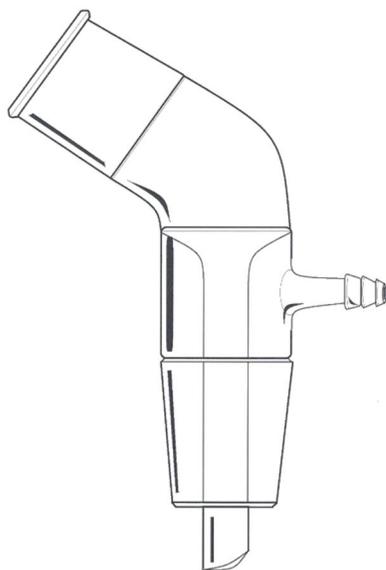
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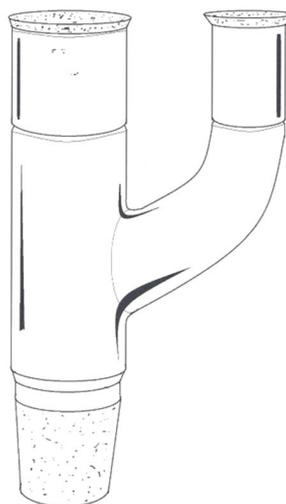
**SEPARATORY FUNNEL**



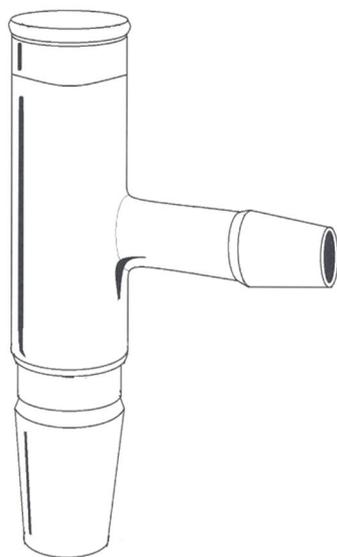
**DISTILLING COLUMN**



**VACUUM ADAPTER**



**CLAISEN ADAPTER**



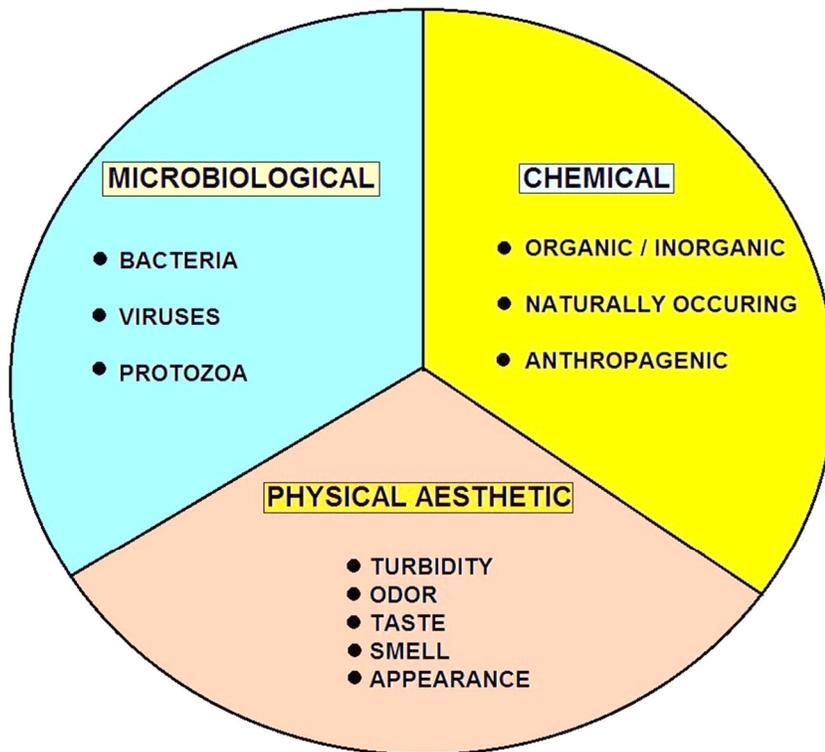
**DISTILLATION ADAPTER**



**WEST CONDENSER**

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



## WATER QUALITY BROKEN DOWN INTO 3 BROAD CATEGORIES

## Employees' Right to Know

### Employers must train workers about:

- Hazards in the lab, including criteria for too much chemical exposure.
- Protective clothing and equipment and how to use them.
- Emergency procedures.
- Detailed safety information about chemicals in safety data sheets (SDS) Formerly (MSDS).
- Free medical consultation/treatment in case of overexposure to hazardous chemicals.

### Permissible Exposure Limits and Exposure Determination

Employees of laboratories using OSHA-regulated substances cannot be exposed to these substances beyond the OSHA permissible exposure limits. Employers are required to measure employees' exposure to any regulated substances if that substance is required by a standard for monitoring. Employers must also inform employees of the monitoring results.

### Safety Precautions

Caution and common sense prevent safety problems:

- Assume that any unfamiliar chemical is hazardous.
- Read the label and SDS for important safety information before working with any chemical.
- Consider a mixture to be at least as hazardous as its most hazardous component.
- Never use anything that is not labeled.
- Never combine substances unless instructed to do so. They might react with one another, causing an explosion or release of harmful vapors. Don't add a chemical to a container that isn't clean and empty.
- Follow all safety procedures to the letter.
- In case of chemical overexposure, get medical attention, inform the supervisor, and check the SDS for first-aid information.
- Report any spill. Don't attempt to contain or clean up the spill **UNLESS** trained and equipped to do so.



Fish tanks are common where water or wastewater treatment is being used. Fish are a great detector/ indicator to chemical contention.

## Required Information

### Employees shall be informed of:

- (i) The contents of this standard and its appendices which shall be made available to employees;
- (ii) The location and availability of the employer's Chemical Hygiene Plan;
- (iii) The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard;
- (iv) Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory; and
- (v) The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, Material Safety Data Sheets received from the chemical supplier.



Notice the anti-slip mat and the several different types of gloves necessary to handle the different chemicals that could be present. Notice how each bottle and drawer is clearly marked.

## The Chemical Hygiene Plan (CHP)

Like the written hazard communication plan, the CHP covers procedures for protecting employees from hazards and keeping exposures below permissible limits. But it's more flexible so as to allow labs to adopt procedures for their individual needs. *Any CHP must include:*

- Standard operating procedures for lab work using hazardous substances.
- How the company will determine and reduce employee exposure to hazardous substances, examples, engineering controls, personal protective equipment, and hygiene practices.
- Measures to ensure that fume hoods and other protective equipment function properly.
- How the company will inform employees about potential health hazards and train them to protect themselves.
- Circumstances in which a particular operation, procedure, or activity will have to be pre-approved by the company.
- Provisions for medical consultation and medical examinations.
- Designation of personnel responsible for implementation of the CHP.
- Provisions for additional employee protection for work with particularly hazardous substances.

### Personal Protective Equipment

Always use assigned PPE and make sure it's in good condition. Types of PPE include goggles or side shield safety glasses; gloves; long sleeves; lab coats, aprons, coveralls; sturdy shoes; and respirators. Contact lenses could trap vapors-check with a safety director before wearing them.

### Lab Equipment

- Glassware can break, causing chemical contact or cuts:
- Use the right type of glass for the task.
- Discard chipped or cracked glassware.
- Don't use force on glassware.

### Autoclaves and other heating equipment:

- Use tongs or heat-resistant gloves.

### Electrical equipment creates electric shock hazard:

- Don't touch with wet hands or while standing on a wet floor.
- Report any incidents of shock.
- Don't attempt repairs unless you've been trained.

### Centrifuges and other equipment with moving parts can catch or open suddenly:

- Keep clothing and long hair away from equipment.
- Make sure the load is balanced, top is locked, and movement has stopped before opening. Compressed gas cylinders can explode or cause a fire; keep clean and chained in place.

## **Fire and Burn Hazards**

### ***Guidelines for safe work practices:***

- Be cautious and follow rules for open flames, reactive substances, and flammables.
- Wear gloves when handling hot glass or tools.
- Keep water and wet hands away from electrical equipment.
- Don't use electrical equipment with worn cords, damaged plugs, etc.

## **Emergency Preparedness**

- Don't work alone in the lab.
- Post emergency phone numbers.
- Keep SDSs on hand-and read them.
- Know what to do in an emergency.
- Know the location of showers, eyewash stations, fire extinguishers.

Know which type of fire extinguisher to use for the chemicals with which you are working. Consult organization procedures, SDSs, and your supervisor.

Work closely with your emergency services and practice annual drills with these agencies. It may be required by OSHA or EPA depending upon your chemical or biological storage at your facility. Don't risk a tragedy or a violation. It is bad press and a lot of red tape.

## **Summary**

- Remember that safety is the first priority in the lab!
- Read and understand the Chemical Hygiene Plan (CHP).
- Learn about the hazards of the chemicals you use.
- Take your time and concentrate on your work.
- Avoid contact with hazardous chemicals.
- Assume that unknown chemicals are hazardous.
- Follow all warning signs and instructions.
- Use the correct PPE.
- Follow all instructions for proper equipment operation.

## 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

°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<sup>-</sup> - Bromide ion

BrO<sup>2-</sup> - Bromite ion

BrO<sup>3-</sup> - Bromate ion

CI - Confidence interval

Cl<sup>2</sup> - Chlorine

ClO<sup>2</sup> - 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

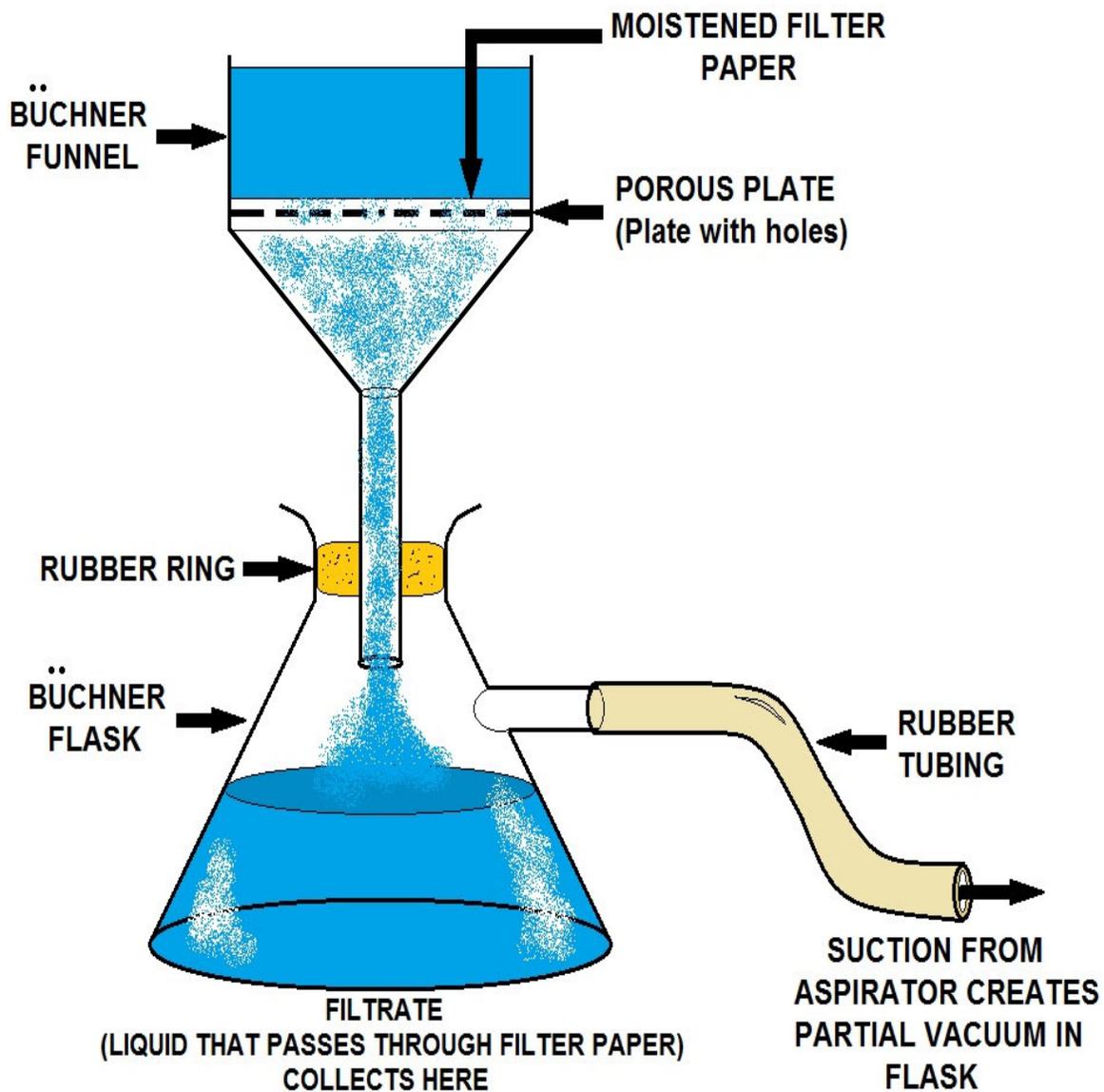
EMSL - EPA Environmental Monitoring and Support Laboratory (Cincinnati)

EPA - United States Environmental Protection Agency

ESWTR - Enhanced Surface Water Treatment Rule

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  
 H<sub>2</sub>O<sub>2</sub> - 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  
 KMnO<sub>4</sub> - 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<sub>2</sub>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<sup>2</sup> - Oxygen  
O<sup>3</sup> - Ozone  
OBr<sup>-</sup> - Hypobromite ion  
OCl<sup>-</sup> - 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<sub>r</sub> - 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



## USING A BÜCHNER FUNNEL AND FLASK TO FILTER SAMPLE

## Glossary

### A

**ABSENCE OF OXYGEN:** The complete absence of oxygen in water described as Anaerobic.

**ABSOLUTE ZERO:** A theoretical condition concerning a system at zero Kelvin where a system does not emit or absorb energy (all atoms are at rest).

**ACCURACY:** How close a value is to the actual or true value; also see precision. How closely an instrument measures the true or actual value.

**ACID AND BASE ARE MIXED:** When an acid and a base are mixed, an explosive reaction occurs and decomposition products are created under certain conditions.

**ACID ANHYDRIDE:** A compound with two acyl groups bound to a single oxygen atom.

**ACID DISSOCIATION CONSTANT:** An equilibrium constant for the dissociation of a weak acid.

**ACID RAIN:** A result of airborne pollutants.

**ACID:** Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.

**ACTINIDES:** The fifteen chemical elements that are between actinium (89) and lawrencium (103).

**ACTIVATED CARBON FILTRATION:** Can remove organic chemicals that produce off-taste and odor. These compounds are not dangerous to health but can make the water unpleasant to drink. Carbon filtration comes in several forms, from small filters that attach to sink faucets to large tanks that contain removable cartridges. Activated carbon filters require regular maintenance or they can become a health hazard.

**ACTIVATED CHARCOAL (GAC or PAC):** Granular Activated Charcoal or Powered Activated Charcoal. Used for taste and odor removal. A treatment technique that is not included in the grading of a water facility.

**ACTIVATED COMPLEX:** A structure that forms because of a collision between molecules while new bonds are formed.

**ACTIVATION ENERGY:** The minimum energy that must be input to a chemical system.

**ADDITION REACTION:** Within organic chemistry, when two or more molecules combine to make a larger one.

**ADSORPTION CLARIFIERS:** The concept of the adsorption clarifier package plant was developed in the early 1980s. This technology uses an up-flow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the adsorption media and onto the solids already adsorbed onto the media. Air scouring cleans adsorption clarifiers followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because the clarifier removes more solids. As with the tube-settler type of package plant, the sedimentation/clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.

**ADSORPTION:** Not to be confused with absorption. Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a film of molecules or atoms (the adsorbate). It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The term sorption encompasses both processes, while desorption is the reverse process. Adsorption is present in many natural physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, synthetic resins, and water purification.

**AERATION:** The mixing of air into a liquid or solid.

**AGGLOMERATION:** A jumbled cluster or mass of varied parts. The act or process of agglomerating.

**AIR ENTRAINMENT:** The dissolution or inclusion of air bubbles into water.

**AIR GAP SEPARATION:** A physical separation space that is present between the discharge vessel and the receiving vessel; for an example, a kitchen faucet.

**AIR HOOD:** The most suitable protection when working with a chemical that produces dangerous fumes.

**ALGAE:** Microscopic plants that are free-living and usually live in water. They occur as single cells floating in water, or as multicellular plants like seaweed or strands of algae that attach to rocks.

**ALKALI METALS:** The metals of Group 1 on the periodic table.

**ALKALINITY:** Alkalinity or AT is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate. Alkalinity is closely related to the acid neutralizing capacity

(ANC) of a solution and ANC is often incorrectly used to refer to alkalinity. However, the acid neutralizing capacity refers to the combination of the solution and solids present (e.g., suspended matter, or aquifer solids), and the contribution of solids can dominate the ANC (see carbonate minerals below).

ALKALINE EARTH METALS: The metals of Group 2 on the periodic table.

ALLOMER: A substance that has different composition than another, but has the same crystalline structure.

ALLOTROPY: Elements that can have different structures (and therefore different forms), such as Carbon (diamonds, graphite, and fullerene).

ALPHA AND BETA RADIOACTIVITY: Represent two common forms of radioactive decay. Radioactive elements have atomic nuclei so heavy that the nucleus will break apart, or disintegrate spontaneously. When decay occurs, high-energy particles are released. These high-energy particles are called radioactivity. Although radioactivity from refined radioactive elements can be dangerous, it is rare to find dangerous levels of radioactivity in natural waters. An alpha particle is a doubly-charged helium nucleus comprised of two protons, two neutrons, and no electrons. A beta particle is a high-speed electron. Alpha particles do not penetrate matter easily, and are stopped by a piece of paper. Beta particles are much more penetrating and can pass through a millimeter of lead.

ALTERNATIVE DISINFECTANTS: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramine. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.

ALUMINUM SULFATE: The chemical name for Alum. The molecular formula of Alum is  $Al_2(SO_4)_3 \cdot 14H_2O$ . It is a cationic polymer.

AMMONIA:  $NH_3$  A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.

AMMONIATOR: AA control device which meters gaseous ammonia directly into water under positive pressure.

AMMONIATOR:

AMOEBA: Amoeba (sometimes amoeba or ameba, plural amoebae) is a genus of protozoa that moves by means of pseudopods, and is well-known as a representative unicellular organism. The word amoeba or ameba is variously used to refer to it and its close relatives, now grouped as the Amoebozoa, or to all protozoa that move using pseudopods, otherwise termed amoeboids.

ANAEROBIC CONDITIONS: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.

ANAEROBIC: An abnormal condition in which color and odor problems are most likely to occur.

ANEROID: Using no fluid, as in aneroid barometer.

ANION: Negatively charge ions.

ANODE: The positive side of a dry cell battery or a cell.

AQUIFER PARAMETERS: Referring to such attributes as specific capacity, aquifer storage, transmissivity, hydraulic conductivity, gradient, and water levels. Refers to all of the components of Darcy's Law and related parameters.

AROMATICITY: Chemical property of conjugated rings that results in unusual stability. See also benzene.

AS NITROGEN: An expression that tells how the concentration of a chemical is expressed mathematically. The chemical formula for the nitrate ion is  $NO_3$ , with a mass of 62. The concentration of nitrate can be expressed either in terms of the nitrate ion or in terms of the principal element, nitrogen.

The mass of the nitrogen atom is 14. The ratio of the nitrate ion mass to the nitrogen atom mass is 4.43. Thus a concentration of 10 mg/L nitrate expressed as nitrogen would be equivalent to a concentration of 44.3 mg/L nitrate expressed as nitrate ion. When dealing with nitrate numbers it is very important to know how numeric values are expressed.

As: The chemical symbol of Arsenic.

ASEPTIC: Free from the living germs of disease, fermentation, or putrefaction.

ASYNCHRONOUS: Not occurring at the same time.

ATOM: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.

ATOMIC NUMBER: The number representing an element which corresponds with the number of protons within the nucleus.

ATOMIC ORBITAL: The region where the electron of the atom may be found.  
AVOGADRO'S NUMBER: Is the number of particles in a mole of a substance (  $6.02 \times 10^{23}$  ).

## B

BACKFLOW PREVENTION: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

BACKFLOW: To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

BACKSIPHONAGE: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

BACTERIA: Small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Other bacteria can cause infections if they get into a cut or wound. Bacteria are the principal concern in evaluating the microbiological quality of drinking water, because some of the bacteria-caused diseases that can be transmitted by drinking water are potentially life-threatening.

BACTERIOPHAGE: Any of a group of viruses that infect specific bacteria, usually causing their disintegration or dissolution. A bacteriophage (from 'bacteria' and Greek phagein, 'to eat') is any one of a number of viruses that infect bacteria. The term is commonly used in its shortened form, phage. Typically, bacteriophages consist of an outer protein hull enclosing genetic material. The genetic material can be ssRNA (single stranded RNA), dsRNA, ssDNA, or dsDNA between 5 and 500 kilo base pairs long with either circular or linear arrangement. Bacteriophages are much smaller than the bacteria they destroy - usually between 20 and 200 nm in size.

BARITE: Processed barium sulfate often used to increase drilling fluid densities in mud rotary.

BAROMETER: A device used to measure the pressure in the atmosphere.

BASE: A substance that accepts a proton and has a high pH; a common example is sodium hydroxide (NaOH).

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE (BAT): A level of technology based on the best existing control and treatment measures that are economically achievable within the given industrial category or subcategory.

BEST MANAGEMENT PRACTICES (BMPs): Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S. BMPs also include treatment requirements, operating procedures and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPT): A level of technology represented by the average of the best existing wastewater treatment performance levels within an industrial category or subcategory.

BEST PROFESSIONAL JUDGMENT (BPJ): The method used by a permit writer to develop technology-based limitations on a case-by-case basis using all reasonably available and relevant data.

BEST PROFESSIONAL JUDGMENT (BPJ): The method used by a permit writer to develop technology-based limitations on a case-by-case basis using all reasonably available and relevant data.

BIOCHEMISTRY: The chemistry of organisms.

BOILING POINT: The temperature in which the substance starts to boil.

BOILING POINT ELEVATION: The process where the boiling point is elevated by adding a substance.

BOILING: The phase transition of liquid vaporizing.

BOND: The attraction and repulsion between atoms and molecules that is a cornerstone of chemistry.

BREAK POINT CHLORINATION: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.

BRIDGING: The tendency of sediment, filter, or seal media to create an obstruction if installed in too small an annulus or to rapidly. Also can occur within filter packs requiring development.

BROMINE: Chemical disinfectant (HALOGEN) that kills bacteria and algae. This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

BRONSTED-LOWREY ACID: A chemical species that donates a proton.

BRONSTED-LOWREY BASE: A chemical species that accepts a proton.

**BUFFER:** Chemical that resists pH change, e.g. sodium bicarbonate  
**BUFFERED SOLUTION:** An aqueous solution consisting of a weak acid and its conjugate base or a weak base and its conjugate acid that resists changes in pH when strong acids or bases are added.  
**BURETTE (also BURET):** Glassware used to dispense specific amounts of liquid when precision is necessary (e.g. titration and resource dependent reactions).

## C

**Ca:** The chemical symbol for calcium.  
**CADMIUM:** A contaminant that is usually not found naturally in water or in very small amounts.  
**CALCIUM HARDNESS:** A measure of the calcium salts dissolved in water.  
**CALCIUM ION:** Is divalent because it has a valence of +2.  
**CALCIUM, MAGNESIUM AND IRON:** The three elements that cause hardness in water.  
**CaOCl<sub>2</sub>·4H<sub>2</sub>O:** The molecular formula of Calcium hypochlorite.  
**CARBON DIOXIDE GAS:** The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.  
**CARBONATE HARDNESS:** Carbonate hardness is the measure of Calcium and Magnesium and other hard ions associated with carbonate (CO<sub>3</sub><sup>2-</sup>) and bicarbonate (HCO<sub>3</sub><sup>-</sup>) ions contained in a solution, usually water. It is usually expressed either as parts per million (ppm or mg/L), or in degrees (KH - from the German "Karbonathärte"). One German degree of carbonate hardness is equivalent to about 17.8575 mg/L. Both measurements (mg/L or KH) are usually expressed "as CaCO<sub>3</sub>" – meaning the amount of hardness expressed as if calcium carbonate was the sole source of hardness. Every bicarbonate ion only counts for half as much carbonate hardness as a carbonate ion does. If a solution contained 1 liter of water and 50 mg NaHCO<sub>3</sub> (baking soda), it would have a carbonate hardness of about 18 mg/L as CaCO<sub>3</sub>. If you had a liter of water containing 50 mg of Na<sub>2</sub>CO<sub>3</sub>, it would have a carbonate hardness of about 29 mg/L as CaCO<sub>3</sub>.  
**CARBONATE, BICARBONATE AND HYDROXIDE:** Chemicals that are responsible for the alkalinity of water.  
**CATALYST:** A chemical compound used to change the rate (either to speed up or slow down) of a reaction, but is regenerated at the end of the reaction.  
**CATHODIC PROTECTION:** An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode. Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism. Guards against stray current corrosion.  
**CATION:** Positively charged ion.  
**CAUSTIC SODA:** Also known as sodium hydroxide and is used to raise pH.  
**CAUSTIC:** NaOH (also called Sodium Hydroxide) is a strong chemical used in the treatment process to neutralize acidity, increase alkalinity or raise the pH value.  
**CEILING AREA:** The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling area. Cl<sub>2</sub> gas will settle on the floor.  
**CELL POTENTIAL:** The force in a galvanic cell that pulls electron through reducing agent to oxidizing agent.  
**CENTRIFUGE:** Equipment used to separate substances based on density by rotating the tubes around a centered axis  
**CESIUM (also Caesium):** Symbol Cs- A soft, silvery-white ductile metal, liquid at room temperature, the most electropositive and alkaline of the elements, used in photoelectric cells and to catalyze hydrogenation of some organic compounds.  
**CHAIN OF CUSTODY (COC):** A record of each person involved in the possession of a sample from the person who collects the sample to the person who analyzes the sample in the laboratory.  
**CHECK VALVE:** Allows water to flow in only one direction.  
**CHELATION:** A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.  
**CHEMICAL FEED RATE:** Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants. Coagulants are chemicals, such as alum, that neutralize positive or negative charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration. A variety of devices, such as baffles, static mixers, impellers and in-line sprays, can be used to mix the water and distribute the chemicals evenly.

**CHEMICAL LAW:** Certain rules that pertain to the laws of nature and chemistry.

**CHEMICAL OXIDIZER:**  $\text{KMnO}_4$  or Potassium Permanganate is used for taste and odor control

**CHEMICAL REACTION RATE:** In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.

**CHEMICAL REACTION:** The change of one or more substances into another or multiple substances.

**CHEMISORPTION:** (or chemical adsorption) Is adsorption in which the forces involved are valence forces of the same kind as those operating in the formation of chemical compounds.

**CHLORAMINATION:** Treating drinking water by applying chlorine before or after ammonia. This creates persistent disinfectant residual called chloramines.

**CHLORAMINES:** A group of chlorine ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors.

**CHLORINATION:** The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.

**CHLORINE DEMAND:** Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

**CHLORINE FEED:** Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

**CHLORINE, FREE:** Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.

**CHLORINE:** A chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water it kills them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats; protozoa are removed from drinking water by filtration.

**CHRONIC:** A stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of an organism. The measurement of chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

**Circulation:** The continual flow of drilling fluid from injection to recovery and recirculation at the surface.

**CLEAR WELL:** A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low. The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter and to provide detention time (or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.

**$\text{ClO}_2$ :** The molecular formula of Chlorine dioxide.

**COAGULATION:** The best pH range for coagulation is between 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible.

**COLIFORM TESTING:** The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.

**COLIFORM:** Bacteria normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria. Public water systems are required to deliver safe and reliable drinking water to their customers 24 hours a day, 365 days a year. If the water supply becomes contaminated, consumers can become seriously ill. Fortunately, public water systems take many steps to ensure that the public has safe, reliable drinking water. One of the most important steps is to regularly test the water for coliform bacteria. Coliform bacteria are organisms that are present in the environment and in the feces of all warm-blooded animals and humans. Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is relatively easy and inexpensive to test for

coliform bacteria. If coliform bacteria are found in a water sample, water system operators work to find the source of contamination and restore safe drinking water. There are three different groups of coliform bacteria; each has a different level of risk.

COLLOID: Mixture of evenly dispersed substances, such as many milks.

COLLOIDAL SUSPENSIONS: Because both iron and manganese react with dissolved oxygen to form insoluble compounds, they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.

COLORIMETRIC MEASUREMENT: A means of measuring an unknown chemical concentration in water by measuring a sample's color intensity.

COMBINED CHLORINE: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.

COMBUSTION: An exothermic reaction between an oxidant and fuel with heat and often light

COMMUNITY WATER SYSTEM: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

COMPLIANCE CYCLE: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

COMPLIANCE PERIOD: A 3-calendar year time-frame within a compliance cycle.

COMPOSITE SAMPLE: A water sample that is a combination of a group of samples collected at various intervals during the day.

COMPOUND: A substance that is made up of two or more chemically bonded elements.

CONDENSATION: The phase change from gas to liquid. The process that changes water vapor to tiny droplets or ice crystals.

CONDENSATION: The process that changes water vapor to tiny droplets or ice crystals.

CONDUCTOR: Material that allows electric flow more freely.

CONTACT TIME, pH and LOW TURBIDITY: Factors which are important in providing good disinfection using chlorine. If the water temperature decreases from 70°F (21°C) to 40°F (4°C). The operator needs to increase the detention time to maintain good disinfection of the water.

CONTAINS THE ELEMENT CARBON: A simple definition of an organic compound.

CONTAMINANT: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

CONTAMINATE: 1. To make impure or unclean by contact or mixture. 2. To expose to or permeate with radioactivity.

CONTAMINATION: A degradation in the quality of groundwater in result of the it's becoming polluted with unnatural or previously non-existent constituents.

CONTROL TASTE AND ODOR PROBLEMS:  $KMnO_4$  Potassium permanganate is a strong oxidizer commonly used to control taste and odor problems.

Conventional: A standard or common procedure to a group of more complex methods. (ex – Direct Rotary conventional vs. Reverse non-conventional)

COPPER: The chemical name for the symbol Cu.

CORROSION: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

CORROSIVITY: The Langelier Index measures corrosivity.

COUPON: A coupon placed to measure corrosion damage in the water mains.

COVALENT BOND: Chemical bond that involves sharing electrons.

CROSS-CONNECTION: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.

CROSS-CONTAMINATION: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical.

CRYPTOSPORIDIUM: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water. Cryptosporidium is a protozoan pathogen of the Phylum Apicomplexa and causes a diarrheal illness called cryptosporidiosis. Other apicomplexan pathogens include the malaria parasite Plasmodium, and Toxoplasma, the causative agent of toxoplasmosis. Unlike

Plasmodium, which transmits via a mosquito vector, Cryptosporidium does not utilize an insect vector and is capable of completing its life cycle within a single host, resulting in cyst stages which are excreted in feces and are capable of transmission to a new host.

CRYSTAL: A solid that is packed with ions, molecules or atoms in an orderly fashion.

CUVETTE: Glassware used in spectroscopic experiments. It is usually made of plastic, glass or quartz and should be as clean and clear as possible.

CYANOBACTERIA: Cyanobacteria, also known as blue-green algae, blue-green bacteria or Cyanophyta, is a phylum of bacteria that obtain their energy through photosynthesis. The name "cyanobacteria" comes from the color of the bacteria (Greek: kyanós = blue). They are a significant component of the marine nitrogen cycle and an important primary producer in many areas of the ocean, but are also found on land.

CYANURIC ACID: White, crystalline, water-soluble solid,  $C_3H_3O_3N_3 \cdot 2H_2O$ , used chiefly in organic synthesis. Chemical used to prevent the decomposition of chlorine by ultraviolet (UV) light.

## D

DAILY MAXIMUM LIMITATIONS: The maximum allowable discharge of pollutants during a 24 hour period. Where daily maximum limitations are expressed in units of mass, the daily discharge is the total mass discharged over the course of the day. Where daily maximum limitations are expressed in terms of a concentration, the daily discharge is the arithmetic average measurement of the pollutant concentration derived from all measurements taken that day.

DANGEROUS CHEMICALS: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood or fume hood.

DARCY'S LAW: ( $Q=KIA$ ) A fundamental equation used in the groundwater sciences to determine aquifer characteristics, where  $Q$ =Flux,  $K$ =Hydraulic Conductivity (Permeability),  $I$  = Hydraulic Gradient (change in head), and  $A$  = Cross Sectional Area of flow.

DECOMPOSE: To decay or rot.

DECOMPOSITION OF ORGANIC MATERIAL: The decomposition of organic material in water produces taste and odors.

DEIONIZATION: The removal of ions, and in water's case mineral ions such as sodium, iron and calcium.

DELIQUESCENCE: Substances that absorb water from the atmosphere to form liquid solutions.

DEMINERALIZATION PROCESS: Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.

DENTAL CAVES PREVENTION IN CHILDREN: The main reason that fluoride is added to a water supply.

DEPOLARIZATION: The removal of hydrogen from a cathode.

DEPOSITION: Settling of particles within a solution or mixture.

DESICCANT: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.

DESORPTION: Desorption is a phenomenon whereby a substance is released from or through a surface. The process is the opposite of sorption (that is, adsorption and absorption). This occurs in a system being in the state of sorption equilibrium between bulk phase (fluid, i.e. gas or liquid solution) and an adsorbing surface (solid or boundary separating two fluids). When the concentration (or pressure) of substance in the bulk phase is lowered, some of the sorbed substance changes to the bulk state. In chemistry, especially chromatography, desorption is the ability for a chemical to move with the mobile phase. The more a chemical desorbs, the less likely it will adsorb, thus instead of sticking to the stationary phase, the chemical moves up with the solvent front. In chemical separation processes, stripping is also referred to as desorption as one component of a liquid stream moves by mass transfer into a vapor phase through the liquid-vapor interface.

DETENTION LAG: Is the period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.

DEVELOPMENT: The cleaning of the well and bore once construction is complete.

DIATOMACEOUS EARTH: A fine silica material containing the skeletal remains of algae.

DIPOLE: Electric or magnetic separation of charge.

DIPOLE MOMENT: The polarity of a polar covalent bond.

DIRECT CURRENT: A source of direct current (DC) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

**DISINFECT:** The application of a chemical to kill most, but not all, microorganisms that may be present. Chlorine is added to public water drinking systems drinking water for disinfection. Depending on your state rule, drinking water must contain a minimum of 0.2 mg/L free chlorine. Disinfection makes drinking water safe to consume from the standpoint of killing pathogenic microorganisms including bacteria and viruses. Disinfection does not remove all bacteria from drinking water, but the bacteria that can survive disinfection with chlorine are not pathogenic bacteria that can cause disease in normal healthy humans.

**DISINFECTION BY-PRODUCTS (DBPs):** The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer. Chlorine is added to drinking water to kill or inactivate harmful organisms that cause various diseases. This process is called disinfection. However, chlorine is a very active substance and it reacts with naturally occurring substances to form compounds known as disinfection byproducts (DBPs). The most common DBPs formed when chlorine is used are trihalomethanes (THMs), and haloacetic acids (HAAs).

**DISINFECTION:** The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

**Dissolution:** The chemical and physical process of dissolving rock. Typically, limestone or carbonate rocks can be dissolved via the percolation or movement of groundwater that, in its infancy, is slightly acidic. As time goes on, the rock may also be physically worn away by the rapid movement of groundwater through the interconnected open spaces created by the initial chemical dissolving process.

**DISSOLUTION or SOLVATION:** The spread of ions in a monosaccharide.

**DISSOLVED OXYGEN:** Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.

**DISTILLATION, REVERSE OSMOSIS AND FREEZING:** Processes that can be used to remove minerals from the water.

**DOUBLE BOND:** Sharing of two pairs of electradsodes.

**DRY ACID:** A granular chemical used to lower pH and or total alkalinity.

## E

**E. COLI, Escherichia coli:** A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

**EARTH METAL:** See alkaline earth metal.

**EFFECTIVENESS OF CHLORINE:** The factors which influence the effectiveness of chlorination the most are pH, turbidity and temperature. Effectiveness of Chlorine decreases occurs during disinfection in source water with excessive turbidity.

**ELECTRIC CHARGE:** A measured property (coulombs) that determine electromagnetic interaction

**ELECTROCHEMICAL CELL:** Using a chemical reaction's current, electromotive force is made

**ELECTROLYTE:** A solution that conducts a certain amount of current and can be split categorically as weak and strong electrolytes.

**ELECTROMAGNETIC RADIATION:** A type of wave that can go through vacuums as well as material and classified as a self-propagating wave.

**ELECTROMAGNETISM:** Fields that have electric charge and electric properties that change the way that particles move and interact.

**ELECTROMOTIVE FORCE:** A device that gains energy as electric charges pass through it.

**ELECTRON:** A subatomic particle with a net charge that is negative.

**ELECTRON SHELLS:** An orbital around the atom's nucleus that has a fixed number electrons (usually two or eight).

**ELECTRON:** The name of a negatively charged atomic particle.

**ELEMENT:** An atom that is defined by its atomic number.

**ELEMENTARY BUSINESS PLAN:** Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by state environmental agency.

**EMERGENCY RESPONSE TEAM:** A local team that is thoroughly trained and equipped to deal with emergencies, e.g. chlorine gas leak. In case of a chlorine gas leak, get out of the area and notify your local emergency response team in case of a large uncontrolled chlorine leak.

**EMPOROCAL FORMULA:** Also called the simplest formula, gives the simplest whole :number ratio of atoms of each element present in a compound.

**ENERGY:** A system's ability to do work.

**ENHANCED COAGULATION:** The process of joining together particles in water to help remove organic matter.

**ENTAMOEBIA HISTOLYTICA:** Entamoeba histolytica, another water-borne pathogen, can cause diarrhea or a more serious invasive liver abscess. When in contact with human cells, these amoebae are cytotoxic. There is a rapid influx of calcium into the contacted cell, it quickly stops all membrane movement save for some surface blebbing. Internal organization is disrupted, organelles lyse, and the cell dies. The amoeba may eat the dead cell or just absorb nutrients released from the cell.

**ENTEROVIRUS:** A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

**ENTHALPY:** Measure of the total energy of a thermodynamic system (usually symbolized as H).

**ENTROPY:** The amount of energy not available for work in a closed thermodynamic system (usually symbolized as S).

**ENZYME:** A protein that speeds up (catalyzes) a reaction.

**EPPENDORF TUBE:** Generalized and trademarked term used for a type of tube; see microcentrifuge.

**EUGLENA:** Euglena are common protists, of the class Euglenoidea of the phylum Euglenophyta.

Currently, over 1000 species of Euglena have been described. Marin et al. (2003) revised the genus so and including several species without chloroplasts, formerly classified as Astasia and Khawkinea.

Euglena sometimes can be considered to have both plant and animal features. Euglena gracilis has a long hair-like thing that stretches from its body. You need a very powerful microscope to see it. This is called a flagellum, and the euglena uses it to swim. It also has a red eyespot. Euglena gracilis uses its eyespot to locate light. Without light, it cannot use its chloroplasts to make itself food.

**EVOLUTION:** Any process of formation or growth; development: the evolution of a language; the evolution of the airplane. A product of such development; something evolved: The exploration of space is the evolution of decades of research.

## F

**F:** The chemical symbol of Fluorine.

**FARADAY CONSTANT:** A unit of electrical charge widely used in electrochemistry and equal to ~ 96,500 coulombs. It represents 1 mol of electrons, or the Avogadro number of electrons:  $6.022 \times 10^{23}$  electrons.  $F = 96\,485.339\,9(24)$  C/mol.

**FARADAY'S LAW OF ELECTROLYSIS:** A two part law that Michael Faraday published about electrolysis. The mass of a substance altered at an electrode during electrolysis is directly proportional to the quantity of electricity transferred at that electrode. The mass of an elemental material altered at an electrode is directly proportional to the element's equivalent weight.

**FAUCET WITH AN AERATOR:** When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.

**FECAL COLIFORM:** A group of bacteria that may indicate the presence of human or animal fecal matter in water. Total coliform, fecal coliform, and E. coli are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. E. coli is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or E. coli, depending on the lab testing method.

**FILTER CLOGGING:** An inability to meet demand may occur when filters are clogging.

**FILTRATION METHODS:** The conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. Direct filtration method is similar to conventional except that the sedimentation step is omitted. Slow sand filtration process does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain. The Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and biological action treatment methods are filtration processes that involve a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

**FILTRATION:** The process of passing water through materials with very small holes to strain out particles. Most conventional water treatment plants used filters composed of gravel, sand, and anthracite. These materials settle into a compact mass that forms very small holes. Particles are filtered out as treated water passes through these holes. These holes are small enough to remove microorganisms including algae, bacteria, and protozoans, but not viruses. Viruses are eliminated from drinking water through the process of disinfection using chlorine. A series of processes that physically removes particles from water. A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

**FINISHED WATER:** Treated drinking water that meets minimum state and federal drinking water regulations.

**FLOC SHEARING:** Likely to happen to large floc particles when they reach the flocculation process.

**FLOC SHEARING:** Likely to happen to large floc particles when they reach the flocculation process.

**FLOCCULANTS:** Flocculants, or flocculating agents, are chemicals that promote flocculation by causing colloids and other suspended particles in liquids to aggregate, forming a floc. Flocculants are used in water treatment processes to improve the sedimentation or filterability of small particles. For example, a flocculant may be used in swimming pool or drinking water filtration to aid removal of microscopic particles which would otherwise cause the water to be cloudy and which would be difficult or impossible to remove by filtration alone. Many flocculants are multivalent cations such as aluminum, iron, calcium or magnesium. These positively charged molecules interact with negatively charged particles and molecules to reduce the barriers to aggregation. In addition, many of these chemicals, under appropriate pH and other conditions such as temperature and salinity, react with water to form insoluble hydroxides which, upon precipitating, link together to form long chains or meshes, physically trapping small particles into the larger floc.

**FLOCCULATION BASIN:** A compartmentalized basin with a reduction of speed in each compartment. This set-up or basin will give the best overall results.

**FLOCCULATION:** The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated. Conventional coagulation–flocculation–sedimentation practices are essential pretreatments for many water purification systems—especially filtration treatments. These processes agglomerate suspended solids together into larger bodies so that physical filtration processes can more easily remove them. Particulate removal by these methods makes later filtering processes far more effective. The process is often followed by gravity separation (sedimentation or flotation) and is always followed by filtration. A chemical coagulant, such as iron salts, aluminum salts, or polymers, is added to source water to facilitate bonding among particulates. Coagulants work by creating a chemical reaction and eliminating the negative charges that cause particles to repel each other. The coagulant-source water mixture is then slowly stirred in a process known as flocculation. This water churning induces particles to collide and clump together into larger and more easily removable clots, or “flocs.” The process requires chemical knowledge of source water characteristics to ensure that an effective coagulant mix is employed. Improper coagulants make these treatment methods ineffective. The ultimate effectiveness of coagulation/flocculation is also determined by the efficiency of the filtering process with which it is paired.

**FLOOD RIM:** The point of an object where the water would run over the edge of something and begin to cause a flood.

**FLOW MUST BE MEASURED:** A recorder that measures flow is most likely to be located in a central location.

**FLUORIDE FEEDING:** Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.

**FLUORIDE:** High levels of fluoride may stain the teeth of humans. This is called Mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals are that all fluoride chemicals are extremely corrosive. These are the substances most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.

**FLUX:** The term flux describes the rate of water flow through a semipermeable membrane. When the water flux decreases through a semipermeable membrane, it means that the mineral concentration of the water is increasing.

**FORMATION OF TUBERCLES:** This condition is of the most concern regarding corrosive water effects on a water system. It is the creation of mounds of rust inside the water lines.

**Formation:** A series of layers, deposits, or bodies of rock, which are geologically similar and related in depositional environment or origin. A formation can be clearly distinguished relative to bounding deposits or formations due to its particular characteristics and composition.

**Fracture:** A discrete break in a rock or formation.

**FREE CHLORINE RESIDUAL:** Regardless of whether pre-chlorination is practiced or not, a free chlorine residual of at least 10 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination. The reason for chlorinating past the breakpoint is to provide protection in case of backflow.

**FREE CHLORINE:** In disinfection, chlorine is used in the form of free chlorine or as hypochlorite ion.

**FREEZING:** Phase transition from liquid to solid.

**FREQUENCY:** Number of cycles per unit of time. Unit: 1 hertz = 1 cycle per 1 second.

## G

**GALVANIC CELL:** Battery made up of electrochemical with two different metals connected by salt bridge.

**GAS:** Particles that fill their container though have no definite shape or volume.

**GEOCHEMISTRY:** The chemistry of and chemical composition of the Earth.

**GIARDIA LAMBLIA:** *Giardia lamblia* (synonymous with *Lamblia intestinalis* and *Giardia duodenalis*) is a flagellated protozoan parasite that colonizes and reproduces in the small intestine, causing giardiasis.

The giardia parasite attaches to the epithelium by a ventral adhesive disc, and reproduces via binary fission. Giardiasis does not spread via the bloodstream, nor does it spread to other parts of the gastrointestinal tract, but remains confined to the lumen of the small intestine. *Giardia* trophozoites absorb their nutrients from the lumen of the small intestine, and are anaerobes.

**GIARDIASIS, HEPATITIS OR TYPHOID:** Diseases that may be transmitted through the contamination of a water supply but not AIDS.

**GIBBS ENERGY:** Value that indicates the spontaneity of a reaction (usually symbolized as G).

**GOOD CONTACT TIME, pH and LOW TURBIDITY:** These are factors that are important in providing good disinfection when using chlorine.

**GPM:** Gallons per minute.

**GRAB SAMPLE:** A sample which is taken from a water or wastestream on a one-time basis with no regard to the flow of the water or wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes.

**GT:** Represents (Detention time) x (mixing intensity) in flocculation.

## H

**H<sub>2</sub>SO<sub>4</sub>:** The molecular formula of Sulfuric acid.

**HALIDES:** A halide is a binary compound, of which one part is a halogen atom and the other part is an element or radical that is less electronegative than the halogen, to make a fluoride, chloride, bromide, iodide, or astatide compound. Many salts are halides. All Group 1 metals form halides with the halogens and they are white solids. A halide ion is a halogen atom bearing a negative charge. The halide anions are fluoride (F), chloride (Cl), bromide (Br), iodide (I) and astatide (At). Such ions are present in all ionic halide salts.

**HALL EFFECT:** Refers to the potential difference (Hall voltage) on the opposite sides of an electrical conductor through which an electric current is flowing, created by a magnetic field applied perpendicular to the current. Edwin Hall discovered this effect in 1879.

**HALOACETIC ACIDS:** Haloacetic acids are carboxylic acids in which a halogen atom takes the place of a hydrogen atom in acetic acid. Thus, in a monohaloacetic acid, a single halogen would replace a hydrogen atom. For example, chloroacetic acid would have the structural formula CH<sub>2</sub>ClCO<sub>2</sub>H. In the same manner, in dichloroacetic acid two chlorine atoms would take the place of two hydrogen atoms (CHCl<sub>2</sub>CO<sub>2</sub>H).

**HALOGENS:** Group 7 on the Periodic Table and are all non-metals.

**HARD WATER:** Hard water causes a buildup of scale in household hot water heaters. Hard water is a type of water that has high mineral content (in contrast with soft water). Hard water primarily consists of calcium (Ca<sup>2+</sup>), and magnesium (Mg<sup>2+</sup>) metal cations, and sometimes other dissolved compounds such as bicarbonates and sulfates. Calcium usually enters the water as either calcium carbonate (CaCO<sub>3</sub>), in the form of limestone and chalk, or calcium sulfate (CaSO<sub>4</sub>), in the form of other mineral deposits. The predominant source of magnesium is dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>). Hard water is generally not harmful. The

simplest way to determine the hardness of water is the lather/froth test: soap or toothpaste, when agitated, lathers easily in soft water but not in hard water. More exact measurements of hardness can be obtained through a wet titration. The total water 'hardness' (including both  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions) is read as parts per million or weight/volume (mg/L) of calcium carbonate ( $\text{CaCO}_3$ ) in the water. Although water hardness usually only measures the total concentrations of calcium and magnesium (the two most prevalent, divalent metal ions), iron, aluminum, and manganese may also be present at elevated levels in some geographical locations.

**HARDNESS:** A measure of the amount of calcium and magnesium salts in water. More calcium and magnesium lead to greater hardness. The term "hardness" comes from the fact that it is hard to get soap suds from soap or detergents in hard water. This happens because calcium and magnesium react strongly with negatively-charged chemicals like soap to form insoluble compounds.

**HARTSHORN:** The antler of a hart, formerly used as a source of ammonia. Ammonium carbonate.

**HAZARDS OF POLYMERS:** Slippery and difficult to clean-up are the most common hazards associated with the use of polymers in a water treatment plant.

**HEAD:** The measure of the pressure of water expressed in feet of height of water. 1 PSI = 2.31 feet of water or 1 foot of head equals about a half a pound of pressure or .433 PSI. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

**HEADWORKS:** The facility at the "head" of the water source where water is first treated and routed into the distribution system.

**HEALTH ADVISORY:** An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water, but which the EPA does not currently regulate in drinking water.

**HEAT:** Energy transferred from one system to another by thermal interaction.

**HERTZ:** The term used to describe the frequency of cycles in an alternating current (AC) circuit.

**HETEROTROPHIC PLATE COUNT:** A test performed on drinking water to determine the total number of all types of bacteria in the water.

**HF:** The molecular formula of Hydrofluoric acid.

**HIGH TURBIDITY CAUSING INCREASED CHLORINE DEMAND:** May occur or be caused by the inadequate disinfection of water.

**hydraulic conductivity:** A primary factor in Darcy's Law, the measure of a soil or formations ability to transmit water, measured in gallons per day (gpd) See also Permeability and Darcy's Law.

**HYDRIDES:** Hydride is the name given to the negative ion of hydrogen, H. Although this ion does not exist except in extraordinary conditions, the term hydride is widely applied to describe compounds of hydrogen with other elements, particularly those of groups 1–16. The variety of compounds formed by hydrogen is vast, arguably greater than that of any other element. Various metal hydrides are currently being studied for use as a means of hydrogen storage in fuel cell-powered electric cars and batteries. They also have important uses in organic chemistry as powerful reducing agents, and many promising uses in hydrogen economy.

**HYDROCHLORIC AND HYPOCHLOROUS ACIDS:** HCL and HOCL The compounds that are formed in water when chlorine gas is introduced.

**HYDROFLUOSILICIC ACID:** ( $\text{H}_2\text{SiF}_6$ ) a clear, fuming corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water.

**HYDROGEN SULFIDE OR CHLORINE GAS:** These chemicals can cause olfactory fatigue.

**Hydrologic Cycle: (Water Cycle)** The continual process of precipitation (rain and snowfall), evaporation (primarily from the oceans), percolation (recharge to groundwater), runoff (surface water), and transpiration (plants) constituting the renew ability and recycling of each component.

**HYDROPHOBIC:** Does not mix readily with water.

**HYGROSCOPIC:** Absorbing or attracting moisture from the air.

**HYPOCHLORITE ( $\text{OCl}^-$ ) AND ORGANIC MATERIALS:** Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

**HYPOLIMNION:** The layer of water in a thermally stratified lake that lies below the thermocline, is noncirculating, and remains perpetually cold.

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**IMPELLERS:** The semi-open or closed props or blades of a turbine pump that when rotated generate the pumping force.

**IMPERVIOUS:** Not allowing, or allowing only with great difficulty, the movement of water.

**In Series:** Several components being connected one to the other without a bypass, requiring each component to work dependent on the one before it.

**INDICATOR:** A special compound added to solution that changes color depending on the acidity of the solution; different indicators have different colors and effective pH ranges.

**INFECTIOUS PATHOGENS/MICROBES/GERMS:** Are considered disease-producing bacteria, viruses and other microorganisms.

**Infiltration:** The percolation of fluid into soil or formation. See also percolation.

**INFORMATION COLLECTION RULE:** ICR EPA collected data required by the Information Collection Rule (May 14, 1996) to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule was intended to provide EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (DBPs)); disease-causing microorganisms (pathogens), including Cryptosporidium; and engineering data to control these contaminants.

**INITIAL MONITORING YEAR:** An initial monitoring year is the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a point of entry.

**INORGANIC CHEMISTRY:** A part of chemistry concerned with inorganic compounds.

**INORGANIC COMPOUND:** Compounds that do not contain carbon, though there are exceptions.

**INORGANIC CONTAMINANTS:** Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. EPA has set legal limits on 15 inorganic contaminants.

**INORGANIC IONS:** Present in all waters. Inorganic ions are essential for human health in small quantities, but in larger quantities they can cause unpleasant taste and odor or even illness. Most community water systems will commonly test for the concentrations of seven inorganic ions: nitrate, nitrite, fluoride, phosphate, sulfate, chloride, and bromide. Nitrate and nitrite can cause an illness in infants called methemoglobinemia. Fluoride is actually added to the drinking water in some public water systems to promote dental health. Phosphate, sulfate, chloride, and bromide have little direct effect on health, but high concentrations of inorganic ions can give water a salty or briny taste.

**INSOLUBLE COMPOUNDS:** Are types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (DO) insoluble compound are formed.

**INSULATOR:** Material that resists the flow of electric current.

**INTAKE FACILITIES:** One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for cathodic protection.

**ION:** A molecule that has gained or lost one or more electrons.

**ION EXCHANGE:** An effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

**IONIC BOND:** Electrostatic attraction between oppositely charged ions.

**IONIZATION:** The breaking up of a compound into separate ions.

**IRON AND MANGANESE:** Fe and Mn In water they can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

**IRON BACTERIA:** Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.

IRON FOULING: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling

IRON: Fe The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

IUPAC: International Union of Pure and Applied Chemistry

## J

JODIUM: Latin name of the halogen element iodine.

JOULE: The SI unit of energy, defined as a newton-meter.

## K

KILL = C X T: Where other factors are constant, the disinfecting action may be represented by:

Kill=C x T. C= Chlorine T= Contact time.

KINETIC ENERGY: The energy of an object due to its motion. The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

KINETICS: A sub-field of chemistry specializing in reaction rates.

## L

L.O.T.O.: Lock Out, Tag Out. If a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.

LACRIMATION: The secretion of tears, esp. in abnormal abundance Also, lachrymation, lachrimation.

LANGELIER INDEX: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling). The Langelier Saturation Index (sometimes Langelier Stability Index) is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Langelier developed a method for predicting the pH at which water is saturated in calcium carbonate (called pHs). The LSI is expressed as the difference between the actual system pH and the saturation pH.

LANTHANIDES: Elements 57 through 71.

LATTICE: Unique arrangement of atoms or molecules in a crystalline liquid or solid.

LAW OF MOTION: An object in motion stay in motion an object in rest stays in rest unless an unbalanced force acts on it.

LEACHING: A chemical reaction between water and metals that allows for removal of soluble materials.

LEAD AND COPPER: Initial tap water monitoring for lead and copper must be conducted during 2 consecutive 6-month periods.

LIGHT: Portion of the electromagnetic spectrum which is visible to the naked eye. Also called "visible light."

LIME SODA SOFTENING: In a lime soda softening process, to the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove Calcium and Magnesium Bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.

LIME SOFTENING: Lime softening is primarily used to "soften" water—that is to remove calcium and magnesium mineral salts. But it also removes harmful toxins like radon and arsenic. Though there is no consensus, some studies have even suggested that lime softening is effective at removal of Giardia. Hard water is a common condition responsible for numerous problems. Users often recognize hard water because it prevents their soap from lathering properly. However, it can also cause buildup ("scale") in hot water heaters, boilers, and hot water pipes. Because of these inconveniences, many treatment facilities use lime softening to soften hard water for consumer use. Before lime softening can be used, managers must determine the softening chemistry required. This is a relatively easy task for groundwater sources, which remain more constant in their composition. Surface waters, however, fluctuate widely in quality and may require frequent changes to the softening chemical mix. In lime softening, lime and sometimes sodium carbonate are added to the water as it enters a combination solids contact clarifier. This raises

the pH (i.e., increases alkalinity) and leads to the precipitation of calcium carbonate. Later, the pH of the effluent from the clarifier is reduced again, and the water is then filtered through a granular media filter. The water chemistry requirements of these systems require knowledgeable operators, which may make lime softening an economic challenge for some very small systems.

**LIME:** Is a chemical that may be added to water to reduce the corrosivity. When an operator adds lime to water, Calcium and magnesium become less soluble.

**LIQUID:** A state of matter which takes the shape of its container.

**LONDON DISPERSION FORCES:** A weak intermolecular force.

$LSI = pH - pHs$

## M

**M.S.D.S.:** Material Safety Data Sheet, now S.D.S. (Safety Data Sheet). A safety document must an employer provide to an operator upon request.

**MAGNESIUM HARDNESS:** Measure of the magnesium salts dissolved in water – it is not a factor in water balance.

**MARBLE AND LANGELIER TESTS:** Are used to measure or determine the corrosiveness of a water source.

**MAXIMUM CONTAMINANT LEVEL (MCLs):** The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.

**MAXIMUM CONTAMINANT LEVEL GOAL (MCLG):** The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.

**MCL for TURBIDITY:** Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.

**MEASURE CORROSION DAMAGE:** A coupon such as a strip of metal and is placed to measure corrosion damage in the distribution system in a water main.

**MEDIUM WATER SYSTEM:** More than 3,300 persons and 50,000 or fewer persons.

**MELTING:** The phase change from a solid to a liquid.

**M-ENDO BROTH:** The coliform group is used as indicators of fecal pollution in water, for assessing the effectiveness of water treatment and disinfection, and for monitoring water quality. m-Endo Broth is used for selectively isolating coliform bacteria from water and other specimens using the membrane filtration technique. m-Endo Broth is prepared according to the formula of Fifield and Schaufus.<sup>1</sup> It is recommended by the American Public Health Association in standard total coliform membrane filtration procedure for testing water, wastewater, and foods.<sup>2,3</sup> The US EPA specifies using m-Endo Broth in the total coliform methods for testing water using single-step, two-step, and delayed incubation membrane filtration methods.: The media shall be brought to the boiling point when preparing M-Endo broth to be used in the membrane filter test for total coliform.

**METAL:** Chemical element that is a good conductor of both electricity and heat and forms cations and ionic bonds with non-metals.

**METALIMNION:** Thermocline, middle layer of a thermally stratified lake which is characterized by a rapid decrease in temperature in proportion to depth.

**METALLOID:** Metalloid is a term used in chemistry when classifying the chemical elements. On the basis of their general physical and chemical properties, nearly every element in the periodic table can be termed either a metal or a nonmetal. A few elements with intermediate properties are, however, referred to as metalloids. (In Greek metallon = metal and eidos = sort)

**METHANE:** Methane is a chemical compound with the molecular formula CH<sub>4</sub>. It is the simplest alkane, and the principal component of natural gas. Methane's bond angles are 109.5 degrees. Burning methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of methane and its clean burning process makes it a very attractive fuel. However, because it is a gas at normal temperature and pressure, methane is difficult to transport from its source. In its natural gas form, it is generally transported in bulk by pipeline or LNG carriers; few countries still transport it by truck.

**METHYLENE BLUE:** A heterocyclic aromatic chemical compound with the molecular formula C<sub>16</sub>H<sub>18</sub>N<sub>3</sub>SCl.

Mg/L: Stands for "milligrams per liter." A common unit of chemical concentration. It expresses the mass of a chemical that is present in a given volume of water. A milligram (one one-thousandth of a gram) is equivalent to about 18 grains of table salt. A liter is equivalent to about one quart.

MICROBE OR MICROBIAL: Any minute, simple, single-celled form of life, especially one that causes disease.

MICROBIAL CONTAMINANTS: Microscopic organisms present in untreated water that can cause waterborne diseases.

MICROBIOLOGICAL: Is a type of analysis in which a composite sample unacceptable.

MICROCENTRIFUGE: A small plastic container that is used to store small amounts of liquid.

MICROORGANISMS: Very small animals and plants that are too small to be seen by the naked eye and must be observed using a microscope. Microorganisms in water include algae, bacteria, viruses, and protozoa. Algae growing in surface waters can cause off-taste and odor by producing the chemicals MIB and geosmin. Certain types of bacteria, viruses, and protozoa can cause disease in humans. Bacteria are the most common microorganisms found in treated drinking water. The great majority of bacteria are not harmful. In fact, humans would not be able to live without the bacteria that inhabit the intestines. However, certain types of bacteria called coliform bacteria can signal the presence of possible drinking water contamination.

MILLILITER: One one-thousandth of a liter. A liter is a little more than a quart. A milliliter is about two drops from an eye dropper.

MOISTURE AND POTASSIUM PERMANGANATE: The combination of moisture and potassium permanganate produces heat.

MOISTURE: If a material is hygroscopic, it must be protected from water.

MOLE: Abbreviated mol : a measurement of an amount of substance; a single mole contains approximately  $6.022 \times 10^{23}$  units or entities .A mole of water contains  $6.022 \times 10^{23}$  H<sub>2</sub>O molecules.

MOLECULAR ORBITAL: Region where an electron can be found in a molecule (as opposed to an atom).

MOLECULAR WEIGHT: The molecular mass (abbreviated Mr) of a substance, formerly also called molecular weight and abbreviated as MW, is the mass of one molecule of that substance, relative to the unified atomic mass unit u (equal to 1/12 the mass of one atom of carbon-12). This is distinct from the relative molecular mass of a molecule, which is the ratio of the mass of that molecule to 1/12 of the mass of carbon 12 and is a dimensionless number. Relative molecular mass is abbreviated to Mr.

MOLECULE: A chemically bonded number of atoms that are electrically neutral.

MOTTILING: High levels of fluoride may stain the teeth of humans.

MUD BALLS IN FILTER MEDIA: Is a possible result of an ineffective or inadequate filter backwash.

Mud Cake: A film of mud drilling fluid that builds up on borehole walls adding to borehole stability and limits the groundwater's ability to enter the borehole while drilling.

Mud Caking: The process of building up the mud cake.

Mud Engineer: A specially trained individual who's responsible for maintaining proper drilling fluid densities and viscosity.

Mud Pit: Single or multiple subsurface or surface containment system used for settling cuttings out of drilling fluid and for recirculation of drilling fluid.

MURIATIC ACID: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.

MYCOTOXIN: A toxin produced by a fungus.

## N

NaOCl: Is the molecular formula of Sodium hypochlorite.

NaOH: Is the molecular formula of Sodium hydroxide.

NASCENT: Coming into existence; emerging.

NASCENT: Coming into existence; emerging.

NATURAL GRAVEL PACK (Naturally packed): Refers to a well that has no gravel pack installed but is simply allowed to develop a filter pack composed of the aquifer particles itself. Usually coarse grained and hard rock aquifers are naturally packed.

NEAT: Conditions with a liquid reagent or gas performed with no added solvent or co-solvent.

NEUTRINO: A particle that can travel at speeds close to the speed of light and are created as a result of radioactive decay.

NEUTRON: A neutral unit or subatomic particle that has no net charge.

NH<sub>3</sub>: The molecular formula of Ammonia.

NH<sub>4</sub><sup>+</sup>: The molecular formula of the Ammonium ion.

NITRATES: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.

NITROGEN AND PHOSPHORUS: Pairs of elements and major plant nutrients that cause algae to grow.

NITROGEN: Nitrogen is a nonmetal, with an electronegativity of 3.0. It has five electrons in its outer shell and is therefore trivalent in most compounds. The triple bond in molecular nitrogen (N<sub>2</sub>) is one of the strongest in nature. The resulting difficulty of converting (N<sub>2</sub>) into other compounds, and the ease (and associated high energy release) of converting nitrogen compounds into elemental N<sub>2</sub>, have dominated the role of nitrogen in both nature and human economic activities.

NO<sub>3</sub><sup>-</sup>: The molecular formula of the Nitrate ion.

NO<sub>3</sub><sup>-</sup>: The molecular formula of the Nitrate ion.

NOBLE GASES: Group 18 elements, those whose outer electron shell is filled.

NON-CARBONATE HARDNESS: The portion of the total hardness in excess of the alkalinity.

NON-CARBONATE IONS: Water contains non-carbonate ions if it cannot be softened to a desired level through the use of lime only.

NON-METAL: An element which is not metallic.

NON-POINT SOURCE POLLUTION: Air pollution may leave contaminants on highway surfaces. This non-point source pollution adversely impacts reservoir water and groundwater quality.

NON-TRANSIENT, NON-COMMUNITY WATER SYSTEM: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

NORMALITY: It is the number of equivalent weights of solute per liter of solution. Normality highlights the chemical nature of salts: in solution, salts dissociate into distinct reactive species (ions such as H<sup>+</sup>, Fe<sup>3+</sup>, or Cl<sup>-</sup>). Normality accounts for any discrepancy between the concentrations of the various ionic species in a solution. For example, in a salt such as MgCl<sub>2</sub>, there are two moles of Cl<sup>-</sup> for every mole of Mg<sup>2+</sup>, so the concentration of Cl<sup>-</sup> as well as of Mg<sup>2+</sup> is said to be 2 N (read: "two normal"). Further examples are given below. A normal is one gram equivalent of a solute per liter of solution. The definition of a gram equivalent varies depending on the type of chemical reaction that is discussed - it can refer to acids, bases, redox species, and ions that will precipitate. It is critical to note that normality measures a single ion which takes part in an overall solute. For example, one could determine the normality of hydroxide or sodium in an aqueous solution of sodium hydroxide, but the normality of sodium hydroxide itself has no meaning. Nevertheless it is often used to describe solutions of acids or bases, in those cases it is implied that the normality refers to the H<sup>+</sup> or OH<sup>-</sup> ion. For example, 2 Normal sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), means that the normality of H<sup>+</sup> ions is 2, or that the molarity of the sulfuric acid is 1. Similarly for 1 Molar H<sub>3</sub>PO<sub>4</sub> the normality is 3 as it contains three H<sup>+</sup> ions.

NTNCWS: Non-transient non-community water system.

NTU (Nephelometric turbidity unit): A measure of the clarity or cloudiness of water.

NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY: Technique that exploits the magnetic properties of certain nuclei, useful for identifying unknown compounds.

NUCLEAR: Of or pertaining to the atomic nucleus.

NUCLEUS: The center of an atom made up of neutrons and protons, with a net positive charge.

NUMBER DENSITY: A measure of concentration of countable objects (atoms, molecules, etc.) in space; number per volume.

O

O<sub>3</sub>: The molecular formula of ozone.

OLIGOTROPHIC: A reservoir that is nutrient-poor and contains little plant or animal life. An oligotrophic ecosystem or environment is one that offers little to sustain life. The term is commonly utilized to describe bodies of water or soils with very low nutrient levels. It derives etymologically from the Greek oligo (small, little, few) and trophe (nutrients, food). Oligotrophic environments are of special interest for the alternative energy sources and survival strategies upon which life could rely.

ORBITAL: May refer to either an atomic orbital or a molecular orbital.

ORGANIC CHEMISTRY: A part of chemistry concerned with organic compounds.

ORGANIC COMPOUND: Compounds that contain carbon.

**ORGANIC PRECURSORS:** Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.

**OSMOSIS:** Osmosis is the process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.

**OXIDE:** An oxide is a chemical compound containing at least one oxygen atom as well as at least one other element. Most of the Earth's crust consists of oxides. Oxides result when elements are oxidized by oxygen in air. Combustion of hydrocarbons affords the two principal oxides of carbon, carbon monoxide and carbon dioxide. Even materials that are considered to be pure elements often contain a coating of oxides. For example, aluminum foil has a thin skin of  $Al_2O_3$  that protects the foil from further corrosion.

**OXIDIZING:** The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.

**OXYGEN DEFICIENT ENVIRONMENT:** One of the most dangerous threats to an operator upon entering a manhole.

**OZONE DOES NOT PROVIDE A RESIDUAL:** One of the major drawbacks to using ozone as a disinfectant.

**OZONE, CHLORINE DIOXIDE, UV, CHLORAMINES:** These chemicals may be used as alternative disinfectants.

**OZONE:** Ozone or trioxygen ( $O_3$ ) is a triatomic molecule, consisting of three oxygen atoms. It is an allotrope of oxygen that is much less stable than the diatomic  $O_2$ . Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals. Ozone in the upper atmosphere filters potentially damaging ultraviolet light from reaching the Earth's surface. It is present in low concentrations throughout the Earth's atmosphere. It has many industrial and consumer applications. Ozone, the first allotrope of a chemical element to be recognized by science, was proposed as a distinct chemical compound by Christian Friedrich Schönbein in 1840, who named it after the Greek word for smell (ozein), from the peculiar odor in lightning storms. The formula for ozone,  $O_3$ , was not determined until 1865 by Jacques-Louis Soret and confirmed by Schönbein in 1867. Ozone is a powerful oxidizing agent, far better than dioxygen. It is also unstable at high concentrations, decaying to ordinary diatomic oxygen (in about half an hour in atmospheric conditions): $2 O_3 = 3 O_2$ .

## P

**PAC:** A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment. One precaution that should be taken in storing PAC is that bags of carbon should not be stored near bags of HTH. Removes tastes and odors by adsorption only. Powered activated carbon frequently used for taste and odor control because PAC is non-specific and removes a broad range of compounds. Jar tests and threshold odor number testing determines the application rate for powdered activated carbon.

Powdered activated carbon, or PAC, commonly used for in a water treatment plant for taste and odor control. Powdered activated carbon may be used with some success in removing the precursors of THMs.

**PACKING:** Material, usually of woven fiber, placed in rings around the shaft of a pump and used to control the leakage from the stuffing box.

**PARAMECIUM:** Paramecia are a group of unicellular ciliate protozoa formerly known as slipper animalcules from their slipper shape. They are commonly studied as a representative of the ciliate group. Simple cilia cover the body which allows the cell to move with a synchronous motion (like a caterpillar).

There is also a deep oral groove containing inconspicuous compound oral cilia (as found in other peniculids) that is used to draw food inside. They generally feed upon bacteria and other small cells.

Osmoregulation is carried out by a pair of contractile vacuoles, which actively expel water absorbed by osmosis from their surroundings. Paramecia are widespread in freshwater environments, and are especially common in scums. Paramecia are attracted by acidic conditions. Certain single-celled eukaryotes, such as Paramecium, are examples for exceptions to the universality of the genetic code (translation systems where a few codons differ from the standard ones).

**PATHOGENS:** Disease-causing pathogens; waterborne pathogens A pathogen may contaminate water and cause waterborne disease.

**Pb:** The chemical symbol of Lead.

**PCE:** Perchloroethylene. Known also as perc or tetrachloroethylene, perchloroethylene is a clear, colorless liquid with a distinctive, somewhat ether-like odor. It is non-flammable, having no measurable

flashpoint or flammable limits in air. Effective over a wide range of applications, perchloroethylene is supported by closed loop transfer systems, stabilizers and employee exposure monitoring.

pCi/L: Picocuries per liter A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

PERKINESIS: The aggregation resulting from random thermal motion of fluid molecules.

PEAK DEMAND: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.

PEPTIDOGLYCAN: A polymer found in the cell walls of prokaryotes that consists of polysaccharide and peptide chains in a strong molecular network. Also called mucopeptide, murein.

PERMEATE: The term for water which has passed through the membrane of a reverse osmosis unit.

pH OF SATURATION: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.

pH: A unit of measure which describes the degree of acidity or alkalinity of a solution. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. The term pH is derived from "p", the mathematical symbol of the negative logarithm, and "H", the chemical symbol of Hydrogen. The definition of pH is the negative logarithm of the Hydrogen ion activity.  $pH = -\log[H^+]$ .

PHENOL RED: Chemical reagent used for testing pH in the range of 6.8 - 8.4.

PHENOLPHTHALEIN/TOTAL ALKALINITY: The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.

PHOSPHATE, NITRATE AND ORGANIC NITROGEN: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.

PHOTON: A carrier of electromagnetic radiation of all wavelength (such as gamma rays and radio waves).

PHYSISORPTION: (Or physical adsorption) Is adsorption in which the forces involved are intermolecular forces (van der Waals forces) of the same kind as those responsible for the imperfection of real gases and the condensation of vapors, and which do not involve a significant change in the electronic orbital patterns of the species involved. The term van der Waals adsorption is synonymous with physical adsorption, but its use is not recommended.

PICOCURIE: A unit of radioactivity. "Pico" is a metric prefix that means one one-millionth of one one-millionth. A picocurie is one one-millionth of one one-millionth of a Curie. A Curie is that quantity of any radioactive substance that undergoes 37 billion nuclear disintegrations per second. Thus a picocurie is that quantity of any radioactive substance that undergoes 0.037 nuclear disintegrations per second.

PLANKTON: The aggregate of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising microscopic algae and protozoa.

PLASMA: State of matter similar to gas in which a certain portion of the particles are ionized.

PLATFORM: The portion of the drilling rig where a driller and crew operate the drill rig.

Plug: A removable cap installed behind the pilot and cutter bits on hollow stem auger flighting.

PLUNGER: See Surge-block.

POINT OF ENTRY: POE.

POLLUTION: To make something unclean or impure. See Contaminated.

POLYMER: A type of chemical when combined with other types of coagulants aid in binding small suspended particles to larger particles to help in the settling and filtering processes.

POLYPHOSPHATES: Chemicals that may be added to remove low levels of iron and manganese.

POLYPHOSPHATES: Chemicals that may be added to remove low levels of iron and manganese.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

POTABLE: Good water which is safe for drinking or cooking purposes. Non-Potable: A liquid or water that is not approved for drinking.

POTENTIAL ENERGY: Energy stored in a body or in a system due to its position in a force field or due to its configuration.

PPM: Abbreviation for parts per million.

PRE-CHLORINATION: The addition of chlorine before the filtration process will help:

PRE-CHLORINE: Where the raw water is dosed with a large concentration of chlorine.

**PRESIPATATE:** Formation of a solid in a solution or inside another solid during a chemical reaction or by diffusion in a solid.

**PRESSURE MEASUREMENT:** Bourdon tube, Bellows gauge and Diaphragm are commonly used to measure pressure in waterworks systems. A Bellows-type sensor reacts to a change in pressure.

**PRESSURE:** Pressure is defined as force per unit area. It is usually more convenient to use pressure rather than force to describe the influences upon fluid behavior. The standard unit for pressure is the Pascal, which is a Newton per square meter. For an object sitting on a surface, the force pressing on the surface is the weight of the object, but in different orientations it might have a different area in contact with the surface and therefore exert a different pressure.

**PREVENTION:** To take action; stop something before it happens.

**PROTIST:** Any of a group of eukaryotic organisms belonging to the kingdom Protista according to some widely used modern taxonomic systems. The protists include a variety of unicellular, coenocytic, colonial, and multicellular organisms, such as the protozoans, slime molds, brown algae, and red algae. A unicellular protocyst in taxonomic systems in which the protocysts are considered to form a kingdom.

**PROTOCTIST:** Any of various unicellular eukaryotic organisms and their multicellular, coenocytic, or colonial descendants that belong to the kingdom Protocista according to some taxonomic systems. The protocysts include the protozoans, slime molds, various algae, and other groups. In many new classification systems, all protocysts are considered to be protists.

**PROTON:** A positive unit or subatomic particle that has a positive charge.

**PROTON, NEUTRON AND ELECTRON:** Are the 3 fundamental particles of an atom.

**PROTONATION:** The addition of a proton (H<sup>+</sup>) to an atom, molecule, or ion.

**PROTOZOA:** Microscopic animals that occur as single cells. Some protozoa can cause disease in humans. Protozoa form cysts, which are specialized cells like eggs that are very resistant to chlorine.

Cysts can survive the disinfection process, then "hatch" into normal cells that can cause disease.

Protozoa must be removed from drinking water by filtration, because they cannot be effectively killed by chlorine.

**PUBLIC NOTIFICATION:** An advisory that EPA requires a water system to distribute to affected consumers when the system has violated MCLs or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.

**PUBLIC WATER SYSTEM (PWS):** Any water system which provides water to at least 25 people for at least 60 days annually. There are more than 170,000 PWSs providing water from wells, rivers and other sources to about 250 million Americans. The others drink water from private wells. There are differing standards for PWSs of different sizes and types.

**PWS:** 3 types of public water systems. Community water system, non-transient non-community water system, transient non-community water system.

## Q

**QUANTA:** It is the minimum amount of bundle of energy.

**QUANTUM MECHANICS:** The study of how atoms, molecules, subatomic particles, etc. behave and are structured.

**QUARKS:** Elementary particle and a fundamental constituent of matter.

## R

**RADIATION:** Energy in the form of waves or subatomic particles when there is a change from high energy to low energy states.

**RADIOACTIVE DECAY:** The process of an unstable atomic nucleus losing energy by emitting radiation.

**RADIOCHEMICALS:** (Or radioactive chemicals) Occur in natural waters. Naturally radioactive ores are particularly common in the Southwestern United States, and some streams and wells can have dangerously high levels of radioactivity. Total alpha and beta radioactivity and isotopes of radium and strontium are the major tests performed for radiochemicals. The federal drinking water standard for gross alpha radioactivity is set at 5 picocuries per liter.

**RAW TURBIDITY:** The turbidity of the water coming to the treatment plant from the raw water source.

**RAW WATER:** Water that has not been treated in any way; it is generally considered to be unsafe to drink.

**REAGENT:** A substance used in a chemical reaction to measure, detect, examine, or produce other substances.

**RECHARGE:** The infiltration component of the hydrologic cycle. Often used in the context of referring to: The infiltration of water back into an aquifer, resulting in the restoration of lost storage and water levels which had been decreased due to pumping and/or natural discharges from the aquifer.

**RECORDER, FLOW:** A flow recorder that measures flow is most likely to be located anywhere in the plant where a flow must be measured and in a central location.

**RED WATER AND SLIME:** Iron bacteria are undesirable in a water distribution system because of red water and slime complaints.

**REDOX POTENTIAL:** Reduction potential (also known as redox potential, oxidation / reduction potential or ORP) is the tendency of a chemical species to acquire electrons and thereby be reduced. Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species' affinity for electrons and tendency to be reduced. In aqueous solutions, the reduction potential is the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species. A solution with a higher (more positive) reduction potential than the new species will have a tendency to gain electrons from the new species (i.e. to be reduced by oxidizing the new species) and a solution with a lower (more negative) reduction potential will have a tendency to lose electrons to the new species (i.e. to be oxidized by reducing the new species).

**RELAY LOGIC:** The name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices.

**RESERVOIR:** An impoundment used to store water.

**RESIDUAL DISINFECTION PROTECTION:** A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

**REVERSE OSMOSIS:** Forces water through membranes that contain holes so small that even salts cannot pass through. Reverse osmosis removes microorganisms, organic chemicals, and inorganic chemicals, producing very pure water. For some people, drinking highly purified water exclusively can upset the natural balance of salts in the body. Reverse osmosis units require regular maintenance or they can become a health hazard.

**ROTAMETER:** The name of transparent tube with a tapered bore containing a ball is often used to measure the rate of flow of a gas or liquid.

**ROTIFER:** Rotifers get their name (derived from Greek and meaning "wheel-bearer"; they have also been called wheel animalcules) from the corona, which is composed of several ciliated tufts around the mouth that in motion resemble a wheel. These create a current that sweeps food into the mouth, where it is chewed up by a characteristic pharynx (called the mastax) containing a tiny, calcified, jaw-like structure called the trophi. The cilia also pull the animal, when unattached, through the water. Most free-living forms have pairs of posterior toes to anchor themselves while feeding. Rotifers have bilateral symmetry and a variety of different shapes. There is a well-developed cuticle which may be thick and rigid, giving the animal a box-like shape, or flexible, giving the animal a worm-like shape; such rotifers are respectively called loricate and illoricate.

## S

**S- BLOCK ELEMENTS:** Group 1 and 2 elements (alkali and alkaline metals), which includes Hydrogen and Helium.

**S.T.P.:** Standard temperature and pressure standard temperature and pressure the temperature of 0°C and pressure of 1 atmosphere, usually taken as the conditions when stating properties of gases.

**SAFE YIELD:** A possible consequence when the "safe yield" of a well is exceeded and water continues to be pumped from a well, is land subsidence around the well will occur. Safe yield refers to a long-term balance between the water that is naturally and artificially recharged to an aquifer and the groundwater that is pumped out. When more water is removed than is recharged, the aquifer is described as being out of safe yield. When the water level in the aquifer then drops, we are said to be mining groundwater.

**SALINE SOLUTION:** General term for NaCl in water.

**SALT BRIDGE:** Devices used to connection reduction with oxidation half-cells in an electrochemical cell.

**SALTS:** Ionic compounds composed of anions and cations.

**SALTS ARE ABSENT:** Is a strange characteristic that is unique to water vapor in the atmosphere.

**SAMPLE:** The water that is analyzed for the presence of EPA-regulated drinking water contaminants.

Depending on the regulation, EPA requires water systems and states to take samples from source water,

from water leaving the treatment facility, or from the taps of selected consumers. Sampling Location: A location where soil or cuttings samples may be readily and accurately collected.

**SANITARY SURVEY:** Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source cannot be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.

**SANITIZER:** A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.

**SATURATION INDEX:** See Langelier's Index.

**SATURATOR:** A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.

**SCADA:** A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to withstand. If the level controller may be set with too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.

**SCALE:** Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.

**SCHMUTZDECKE:** German, "grime or filth cover", sometimes spelt schmutzedecke) is a complex biological layer formed on the surface of a slow sand filter. The schmutzdecke is the layer that provides the effective purification in potable water treatment, the underlying sand providing the support medium for this biological treatment layer. The composition of any particular schmutzdecke varies, but will typically consist of a gelatinous biofilm matrix of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larvae. As a schmutzdecke ages, more algae tend to develop, and larger aquatic organisms may be present including some bryozoan, snails and annelid worms.

**SCHRODINGER EQUATION:** Quantum state equation which represents the behavior of an electron around an atom.

**SCROLL AND BASKET:** The two basic types of centrifuges used in water treatment.

**SEAL:** For wells: to abandon a well by filling up the well with approved seal material including cementing with grout from a required depth to the land surface.

**SECONDARY DRINKING WATER STANDARDS:** Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

**SECTIONAL MAP:** The name of a map that provides detailed drawings of the distribution system's zones. Sometimes we call these quarter-sections.

**Sediment:** Grains of soil, sand, gravel, or rock deposited by and generated by water movement.

**SEDIMENTATION BASIN:** Where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.

**SEDIMENTATION:** The process of suspended solid particles settling out (going to the bottom of the vessel) in water.

**SEMICONDUCTOR:** An electrically conductive solid that is between a conductor and an insulator.

**SENSOR:** A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.

**SESSILE:** Botany. attached by the base, or without any distinct projecting support, as a leaf issuing directly from the stem. Zoology. permanently attached; not freely moving.

**SETTLED SOLIDS:** Solids that have been removed from the raw water by the coagulation and settling processes.

**SHOCK:** Also known as superchlorination or break point chlorination. Ridding a water of organic waste through oxidization by the addition of significant quantities of a halogen.

**SHORT-CIRCUITING:** Short Circuiting is a condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction or settling times in comparison with the presumed detention times.

**SINGLE BOND:** Sharing of one pair of electrons.

**SINGLE PHASE POWER:** The type of power used for lighting systems, small motors, appliances, portable power tools and in homes.

**SINUSOID:** A curve described by the equation  $y = a \sin x$ , the ordinate being proportional to the sine of the abscissa.

**SINUSOIDAL:** Mathematics. Of or pertaining to a sinusoid. Having a magnitude that varies as the sine of an independent variable: a sinusoidal current.

**SLUDGE BASINS:** After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

**SLUDGE REDUCTION:** Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.

**SMALL WATER SYSTEM:** 3,300 or fewer persons.

**SOC:** Synthetic organic chemical. A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

**SODA ASH:** Chemical used to raise pH and total alkalinity (sodium carbonate).

**SODIUM BICARBONATE:** Commonly used to increase alkalinity of water and stabilize pH.

**SODIUM BISULFATE:** Chemical used to lower pH and total alkalinity (dry acid).

**SODIUM HYDROXIDE:** Also known as caustic soda, a by-product chlorine generation and often used to raise pH.

**SOFTENING WATER:** When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.

**SOFTENING:** The process that removes the ions which cause hardness in water.

**SOL:** A suspension of solid particles in liquid. Artificial examples include sol-gels.

**SOLAR DRYING BEDS OR LAGOONS:** Are shallow, small-volume storage pond where sludge is concentrated and stored for an extended periods.

**SOLAR DRYING BEDS, CENTRIFUGES AND FILTER PRESSES:** Are procedures used in the dewatering of sludge.

**SOLDER:** A fusible alloy used to join metallic parts.

**SOLID:** One of the states of matter, where the molecules are packed close together, there is a resistance of movement/deformation and volume change; see Young's modulus.

**SOLID, LIQUID AND VAPOR:** 3 forms of matter.

**SOLUTE:** The part of the solution that is mixed into the solvent (NaCl in saline water).

**SOLUTION:** Homogeneous mixture made up of multiple substances. It is made up of solutes and solvents.

**SOLVENT:** The part of the solution that dissolves the solute (H<sub>2</sub>O in saline water).

**SPADNS:** The lab reagent called SPADNS solution is used in performing the Fluoride test.

**SPECTROSCOPY:** Study of radiation and matter, such as X:ray absorption and emission spectroscopy.

**SPEED OF LIGHT:** The speed of anything that has zero rest mass (Energyrest =  $mc^2$  where m is the mass and c is the speed of light).

**SPIRIT OF HARTSHORN:** A colorless, pungent, suffocating, aqueous solution of about 28.5 percent ammonia gas: used chiefly as a detergent, for removing stains and extracting certain vegetable coloring agents, and in the manufacture of ammonium salts.

**SPLIT FLOW CONTROL SYSTEM:** This type of control system is to control the flow to each filter influent which is divided by a weir.

**SPRAY BOTTLE OF AMMONIA:** An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.

**STANDARD CONDITIONS FOR TEMPERATURE AND PRESSURE or SATP :** A standardization used in order compare experimental results (25 °C and 100.000 kPa).

**STANDPIPE:** A water tank that is taller than it is wide. Should not be found in low point.

**STATE OF MATTER:** Matter having a homogeneous, macroscopic phase; gas, plasma, liquid, and solid are the most well-known (in increasing concentration).

**STERILIZED GLASSWARE:** The only type of glassware that should be used in testing for coliform bacteria.

**STORAGE TANKS:** Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protects the interior about 3-5 years.

**SUBATOMIC PARTICLES:** Particles that are smaller than an atom; examples are protons, neutrons and electrons.

**SUBLIMATION:** A phase transition from solid to limewater fuel or gas.

**SUBSTANCE:** Material with definite chemical composition.

**SULFATE:** Will readily dissolve in water to form an anion. Sulfate is a substance that occurs naturally in drinking water. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.

**SULFIDE:** The term sulfide refers to several types of chemical compounds containing sulfur in its lowest oxidation number of -2. Formally, "sulfide" is the dianion,  $S^{2-}$ , which exists in strongly alkaline aqueous solutions formed from  $H_2S$  or alkali metal salts such as  $Li_2S$ ,  $Na_2S$ , and  $K_2S$ . Sulfide is exceptionally basic and, with a  $pK_a > 14$ , it does not exist in appreciable concentrations even in highly alkaline water, being undetectable at  $pH < \sim 15$  (8 M NaOH). Instead, sulfide combines with electrons in hydrogen to form  $HS^-$ , which is variously called hydrogen sulfide ion, hydrosulfide ion, sulfhydryl ion, or bisulfide ion. At still lower pH's ( $< 7$ ),  $HS^-$  converts to  $H_2S$ , hydrogen sulfide. Thus, the exact sulfur species obtained upon dissolving sulfide salts depends on the pH of the final solution. Aqueous solutions of transition metals cations react with sulfide sources ( $H_2S$ ,  $NaSH$ ,  $Na_2S$ ) to precipitate solid sulfides. Such inorganic sulfides typically have very low solubility in water and many are related to minerals. One famous example is the bright yellow species  $CdS$  or "cadmium yellow". The black tarnish formed on sterling silver is  $Ag_2S$ . Such species are sometimes referred to as salts. In fact, the bonding in transition metal sulfides is highly covalent, which gives rise to their semiconductor properties, which in turn is related to the practical applications of many sulfide materials.

**SUPERNATANT:** The liquid layer which forms above the sludge in a settling basin.

**SURFACE WATER SOURCES:** Surface water sources such as a river or lake are primarily the result of Runoff.

**SURFACE WATER:** Water that is open to the atmosphere and subject to surface runoff; generally, lakes, streams, rivers.

**SURFACTANT:** Surfactants reduce the surface tension of water by adsorbing at the liquid-gas interface. They also reduce the interfacial tension between oil and water by adsorbing at the liquid-liquid interface. Many surfactants can also assemble in the bulk solution into aggregates. Examples of such aggregates are vesicles and micelles. The concentration at which surfactants begin to form micelles is known as the critical micelle concentration or CMC. When micelles form in water, their tails form a core that can encapsulate an oil droplet, and their (ionic/polar) heads form an outer shell that maintains favorable contact with water. When surfactants assemble in oil, the aggregate is referred to as a reverse micelle. In a reverse micelle, the heads are in the core and the tails maintain favorable contact with oil. Surfactants are also often classified into four primary groups; anionic, cationic, non-ionic, and zwitterionic (dual charge).

**SUSCEPTIBILITY WAIVER:** A waiver that is granted based upon the results of a vulnerability assessment.

**SYNCHRONY:** Simultaneous occurrence; synchronism.

## T

**TALC:** A mineral representing the one on the Mohs Scale and composed of hydrated magnesium silicate with the chemical formula  $H_2Mg_3(SiO_3)_4$  or  $Mg_3Si_4O_{10}(OH)_2$ .

**TASTE AND ODORS:** The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions. Taste and odor problems in the water may happen if sludge and other debris are allowed to accumulate in a water treatment plant.

**TCE, trichloroethylene:** A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant. Trichloroethylene is a colorless liquid which is used as a solvent for

cleaning metal parts. Drinking or breathing high levels of trichloroethylene may cause nervous system effects, liver and lung damage, abnormal heartbeat, coma, and possibly death. Trichloroethylene has been found in at least 852 of the 1,430 National Priorities List sites identified by the Environmental Protection Agency (EPA).

**TDS-TOTAL DISSOLVED SOLIDS:** An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally, the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants. Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.

**TEMPERATURE:** The average energy of microscopic motions of particles.

**TEMPERATURE SAMPLE:** This test should be performed immediately in the field, this is a grab sample.

**THE RATE DECREASES:** In general, when the temperature decreases, the chemical reaction rate decreases also.

**THEORY:** A model describing the nature of a phenomenon.

**THERMAL CONDUCTIVITY:** A property of a material to conduct heat (often noted as  $k$ ).

**THERMOCHEMISTRY:** The study of absorption/release of heat within a chemical reaction.

**THERMODYNAMIC STABILITY:** When a system is in its lowest energy state with its environment (equilibrium).

**THERMODYNAMICS:** The study of the effects of changing temperature, volume or pressure (or work, heat, and energy) on a macroscopic scale.

**THERMOMETER:** Device that measures the average energy of a system.

**THICKENING, CONDITIONING AND DEWATERING:** Common processes that are utilized to reduce the volume of sludge.

**TIME FOR TURBIDITY BREAKTHROUGH AND MAXIMUM HEADLOSS:** Are the two factors which determine whether or not a change in filter media size should be made.

**TITRATION:** The process of titrating one solution with another, also called volumetric analysis. A method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

**TITRIMETRIC:** Chemistry. Using or obtained by titration. Titrimetrically, adverb.

**TOROID:** A surface generated by the revolution of any closed plane curve or contour about an axis lying in its plane. The solid enclosed by such a surface.

**TORR:** A unit to measure pressure (1 Torr is equivalent to 133.322 Pa or  $1.3158 \times 10^{-3}$  atm).

**TOTAL ALKALINITY:** A measure of the acid-neutralizing capacity of water which indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.

**TOTAL COLIFORM:** Total coliform, fecal coliform, and E. coli are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. E. coli is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or E. coli, depending on the lab testing method.

**TOTAL DISSOLVED SOLIDS (TDS):** The accumulated total of all solids that might be dissolved in water.

**TRANSIENT, NON-COMMUNITY WATER SYSTEM: TNCWS** A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals. A Transient Non-community Water System: Is not required to sample for VOC's.

**TRANSITION METAL:** Elements that have incomplete d sub-shells, but also may be referred to as the d-block elements.

**TRANSURANIC ELEMENT:** Element with atomic number greater than 92; none of the transuranic elements are stable.

**TREATED WATER:** Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.

**TRIHALOMETHANES (THM):** Four separate compounds including chloroform, dichlorobromomethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. See Disinfectant Byproducts.

**TRIPLE BOND:** The sharing of three pairs of electrons within a covalent bond (example N<sub>2</sub>).

**TRIPLE POINT:** The place where temperature and pressure of three phases are the same (Water has a special phase diagram).

**TUBE SETTLERS:** This modification of the conventional process contains many metal tubes that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1 inch deep and 36 inches long, split-hexagonal shape and installed at an angle of 60 degrees or less. These tubes provide for a very large surface area upon which particles may settle as the water flows upward. The slope of the tubes facilitates gravity settling of the solids to the bottom of the basin, where they can be collected and removed. The large surface settling area also means that adequate clarification can be obtained with detention times of 15 minutes or less. As with conventional treatment, this sedimentation step is followed by filtration through mixed media.

**TUBERCLES:** The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

**TUNDALL EFFECT:** The effect of light scattering by colloidal (mixture where one substance is dispersed evenly through another) or suspended particles.

**TURBIDIMETER:** Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.

**TURBIDITY:** A measure of the cloudiness of water caused by suspended particles.

## U

**U.S. ENVIRONMENTAL PROTECTION AGENCY:** In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.

**UN NUMBER:** A four digit code used to note hazardous and flammable substances.

**UNCERTAINTY:** A characteristic that any measurement that involves estimation of any amount cannot be exactly reproducible.

**UNCERTAINTY PRINCIPLE:** Knowing the location of a particle makes the momentum uncertain, while knowing the momentum of a particle makes the location uncertain.

**UNDER PRESSURE IN STEEL CONTAINERS:** After chlorine gas is manufactured, it is primarily transported in steel containers.

**UNIT CELL:** The smallest repeating unit of a lattice.

**UNIT FACTOR:** Statements used in converting between units.

**UNIT FILTER RUN VOLUME (UFRV):** One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.

**UNIVERSAL OR IDEAL GAS CONSTANT:** Proportionality constant in the ideal gas law (0.08206 L·atm/(K·mol)).

## V

**VALENCE BOND THEORY:** A theory explaining the chemical bonding within molecules by discussing valencies, the number of chemical bonds formed by an atom.

**VALENCE ELECTRON:** The outermost electrons of an atom, which are located in electron shells.

**VAN DER WAALS FORCE:** One of the forces (attraction/repulsion) between molecules.

**VAN'T HOFF FACTOR:** Ratio of moles of particles in solution to moles of solute dissolved.

**VANE:** That portion of an impeller that throws the water toward the volute.

**VAPOR PRESSURE:** Pressure of vapor over a liquid at equilibrium.

VAPOR: When a substance is below the critical temperature while in the gas phase.

VAPORIZATION: Phase change from liquid to gas.

VARIABLE DISPLACEMENT PUMP: A pump that will produce different volumes of water dependent on the pressure head against it.

VELOCITY HEAD: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

VENTURI: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

VIRION: A complete viral particle, consisting of RNA or DNA surrounded by a protein shell and constituting the infective form of a virus.

VIRUSES: Are very small disease-causing microorganisms that are too small to be seen even with microscopes. Viruses cannot multiply or produce disease outside of a living cell.

VISCOSITY: The resistance of a liquid to flow (oil).

VITRIFICATION: Vitrification is a process of converting a material into a glass-like amorphous solid that is free from any crystalline structure, either by the quick removal or addition of heat, or by mixing with an additive. Solidification of a vitreous solid occurs at the glass transition temperature (which is lower than melting temperature,  $T_m$ , due to supercooling). When the starting material is solid, vitrification usually involves heating the substances to very high temperatures. Many ceramics are produced in such a manner. Vitrification may also occur naturally when lightning strikes sand, where the extreme and immediate heat can create hollow, branching rootlike structures of glass, called fulgurite. When applied to whiteware ceramics, vitreous means the material has an extremely low permeability to liquids, often but not always water, when determined by a specified test regime. The microstructure of whiteware ceramics frequently contain both amorphous and crystalline phases.

VOC WAIVER: The longest term VOC waiver that a public water system using groundwater could receive is 9 years.

Void: An opening, gap, or space within rock or sedimentary formations formed at the time of origin or deposition.

VOLATILE ORGANIC COMPOUNDS: (VOCs) Solvents used as degreasers or cleaning agents. Improper disposal of VOCs can lead to contamination of natural waters. VOCs tend to evaporate very easily. This characteristic gives VOCs very distinct chemical odors like gasoline, kerosene, lighter fluid, or dry cleaning fluid. Some VOCs are suspected cancer-causing agents. Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOCs. The term often is used in a legal or regulatory context and in such cases the precise definition is a matter of law. These definitions can be contradictory and may contain "loopholes"; e.g. exceptions, exemptions, and exclusions. The United States Environmental Protection Agency defines a VOC as any organic compound that participates in a photoreaction; others believe this definition is very broad and vague as organics that are not volatile in the sense that they vaporize under normal conditions can be considered volatile by this EPA definition. The term may refer both to well characterized organic compounds and to mixtures of variable composition.

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VOLT: One joule of work per coulomb - the unit of electrical potential transferred.

**VOLTAGE:** Voltage (sometimes also called electric or electrical tension) is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts. It measures the potential energy of an electric field to cause an electric current in an electrical conductor. Depending on the difference of electrical potential it is called extra low voltage, low voltage, high voltage or extra high voltage. Specifically Voltage is equal to energy per unit charge.

**VOLTIMETER:** Instrument that measures the cell potential.

**VOLUMETRIC ANALYSIS:** See titration.

**VULNERABILITY ASSESSMENT:** An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.

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## W

**WAIVERS:** Monitoring waivers for nitrate and nitrite are prohibited.

**WATER H<sub>2</sub>O:** A chemical substance, a major part of cells and Earth, and covalently bonded.

**WATER PURVEYOR:** The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

**WATER QUALITY CRITERIA:** Comprised of both numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

**WATER QUALITY STANDARD:** A statute or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

**WATER QUALITY:** The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be performed when a public water system exceeds an action level for lead or copper.

**WATER VAPOR:** A characteristic that is unique to water vapor in the atmosphere is that water does not contain any salts.

**WATERBORNE DISEASE:** A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

**WATERSHED:** An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river, or reservoir.

**WAVE FUNCTION:** A function describing the electron's position in a three-dimensional space.

**Weathered:** The existence of rock or formation in a chemically or physically broken down or decomposed state. Weathered material is in an unstable state.

**WHOLE EFFLUENT TOXICITY:** The total toxic effect of an effluent measured directly with a toxicity test.

**WORK:** The amount of force over distance and is in terms of joules (energy).

## X

**X-RAY:** Form of ionizing, electromagnetic radiation, between gamma and UV rays.

**X-RAY DIFFRACTION:** A method for establishing structures of crystalline solids using single wavelength X-rays and looking at diffraction pattern.

**X-RAY PHOTOELECTRON SPECTROSCOPY:** A spectroscopic technique to measure composition of a material.

## Y

**YIELD:** The amount of product produced during a chemical reaction.

## Z

**ZONE MELTING:** A way to remove impurities from an element by melting it and slowly travel down an ingot (cast).

ZWITTERION: Is a chemical compound whose net charge is zero and hence is electrically neutral. But there are some positive and negative charges in it, due to the formal charge, owing to the partial charges of its constituent atoms.

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