



Ionico Technical Services

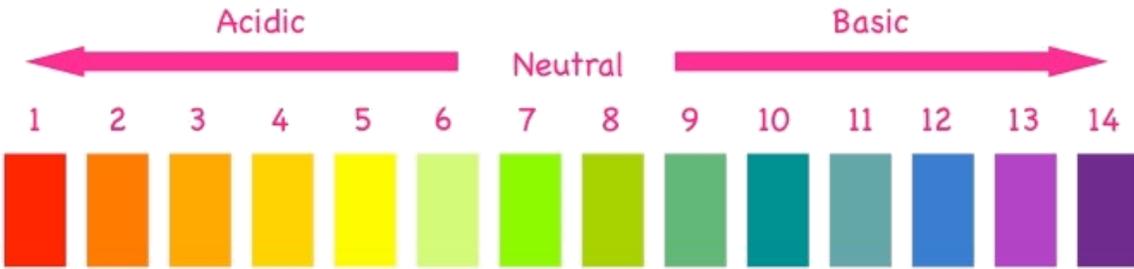
Alkalinity vs. pH

Ionico Technical Services

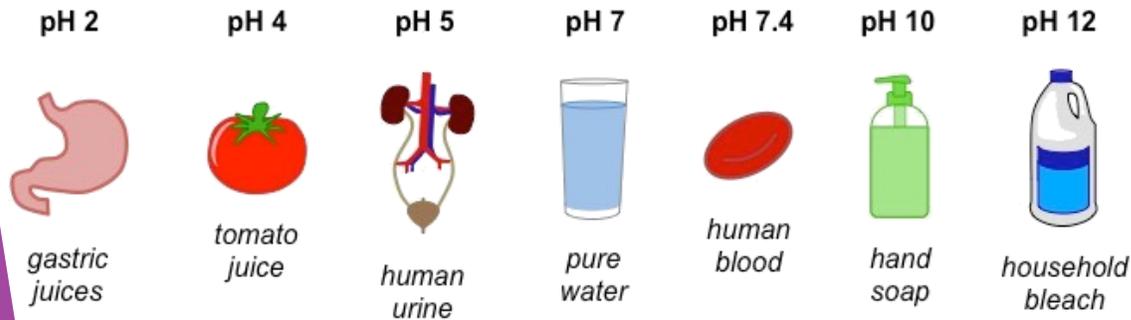
“Potential Hydrogen” Ion Concentration

pH

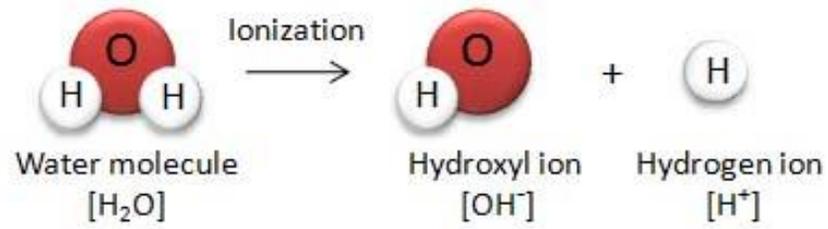
- ▶ pH is a scale, which can be used to indicate the acidity or basicity of a solution
- ▶ The scale has numbers from 1 to 14
- ▶ pH 7 is considered a neutral value
 - ▶ Pure water is said to have a pH 7
- ▶ Below 7 indicates acidic
- ▶ Above 7 indicates basic



Examples of pH Conditions:

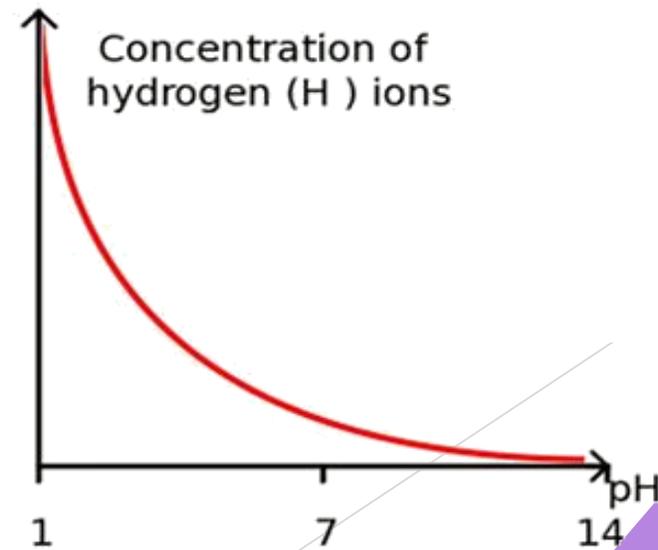
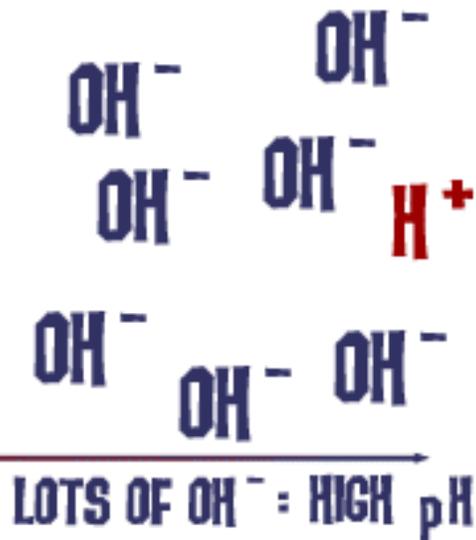
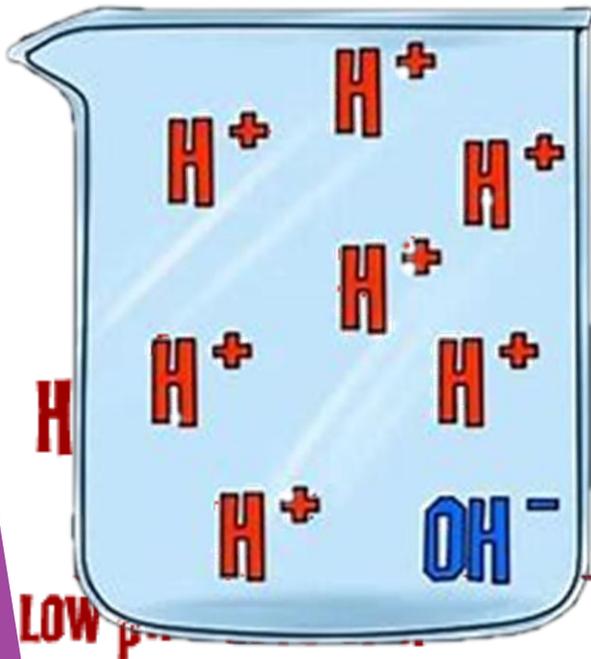


pH Scale



- ▶ pH is dependent on the relative concentrations of Hydrogen (H⁺) and Hydroxide (OH⁻) ions in solution
- ▶ pH scale is logarithmic. It can be written as below, in relation the H⁺ concentration in the solution

$$\text{pH} = -\log [\text{H}^+]$$

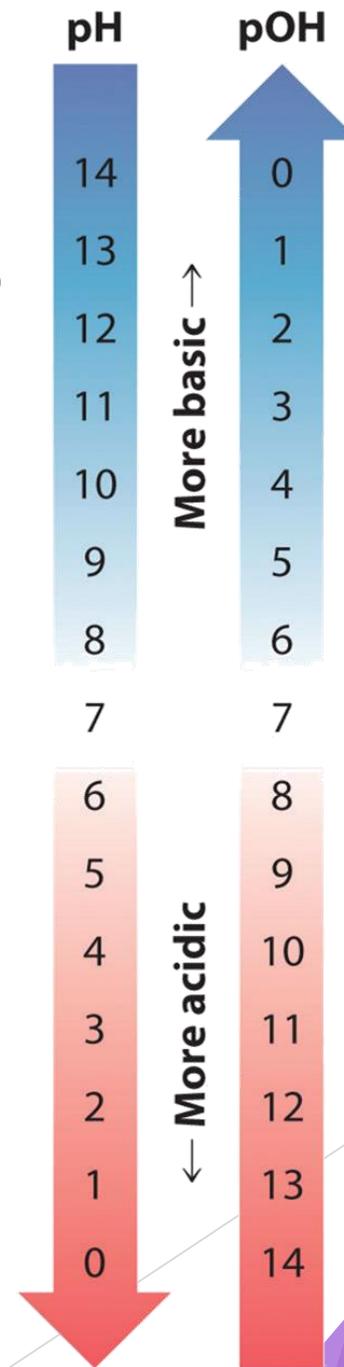


pH Scale Cont.

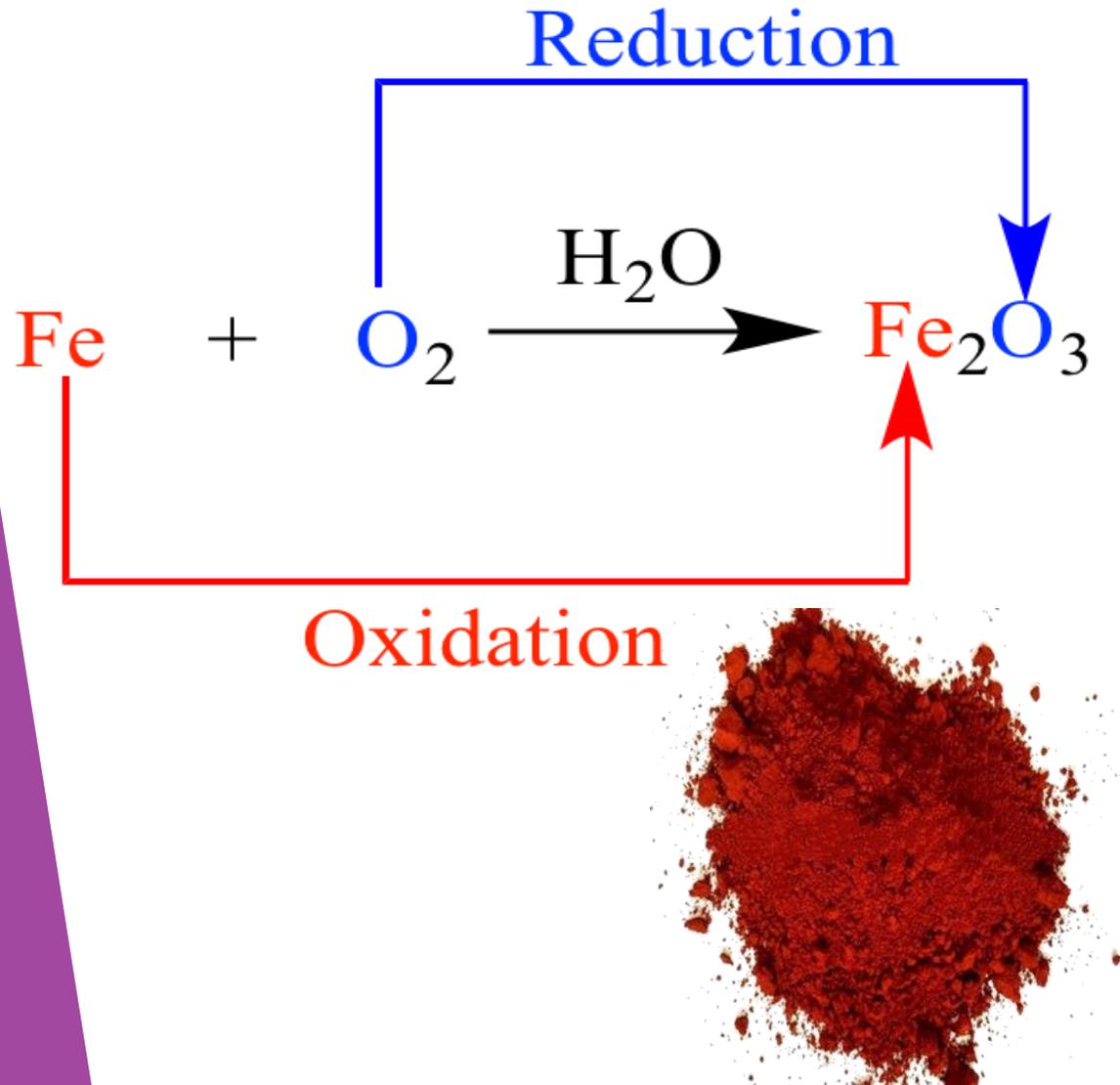
- ▶ In a basic solution, there aren't many H⁺s making it difficult to determine an accurate concentration
- ▶ In this case, the $-\log [\text{OH}^-]$ can be used to determine the pOH of the solution:

$$\text{pH} + \text{pOH} = 14$$

- ▶ Therefore, the pH value of a basic solution can also be calculated accurately
- ▶ There are pH meters and pH papers which can be used to measure pH values
 - ▶ pH papers will give approximate pH values, whereas pH meters give more accurate values



pH and Iron Oxidation

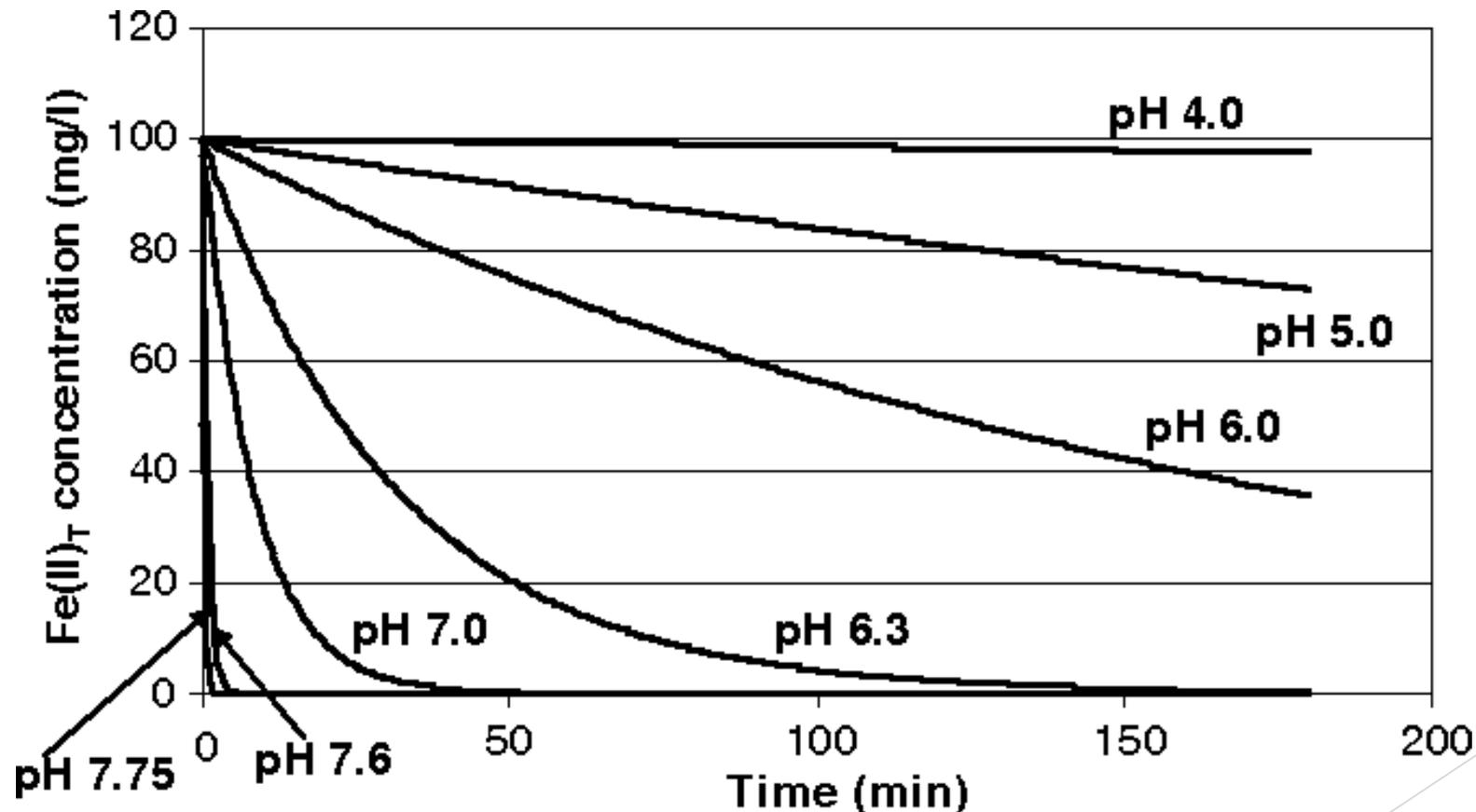


- ▶ The spontaneous chemical oxidation of Fe(II) to Fe(III) by O_2 is a complex process involving meta-stable partially oxidized intermediate species
- ▶ Dissolved iron (Fe^{2+}) is often oxidized into a precipitate (Fe^{3+}) so that it can be filtered from the water



pH and Iron Oxidation

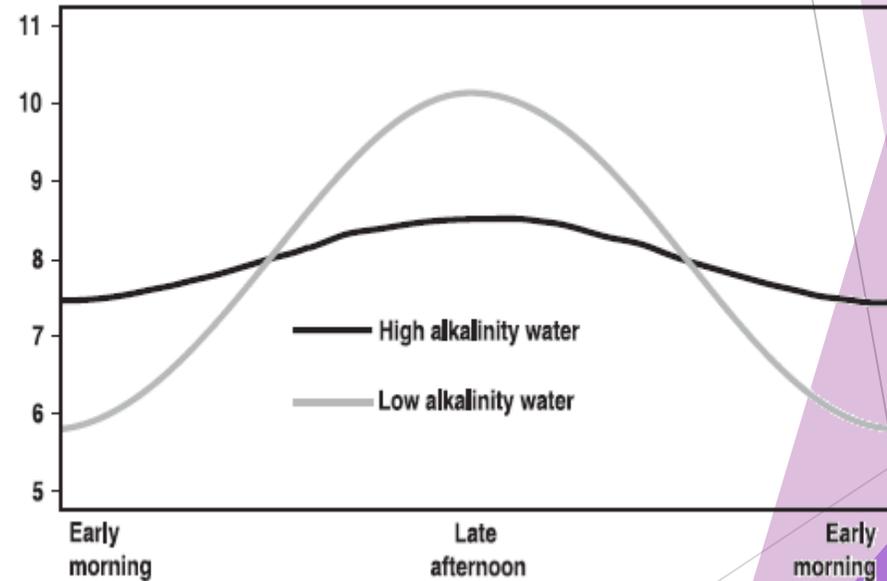
- ▶ pH serves and vital role when evaluating the effectiveness of oxidation of Iron with air:



Alkalinity

Alkalinity is a chemical measurement of a water's ability to neutralize acids

- ▶ Alkalinity and pH are often incorrectly believed to be the same property in water
- ▶ Alkalinity is actually a measure of a water's buffering capacity or its ability to resist changes in pH upon the addition of acids or bases
- ▶ Alkalinity of natural waters is due primarily to the presence of weak acid salts (CO_3^-) although strong bases may also contribute (i.e. OH^-) in extreme environments



Source of Alkalinity

- ▶ **Bicarbonates** represent the major form of alkalinity in natural waters; its source being the partitioning of CO_2 from the atmosphere and the weathering of carbonate minerals in rocks and soil
- ▶ Other salts of weak acids, such as borate, silicates, ammonia, phosphates, and organic bases from natural organic matter, may be present in small amounts
- ▶ Alkalinity, by convention, is reported as mg/L CaCO_3 since most alkalinity is derived from the weathering of carbonate minerals



Importance of Alkalinity

- ▶ Neither alkalinity nor acidity, have any known adverse health effects. Nonetheless, highly acidic and alkaline waters are considered unpalatable. Knowledge of these parameters may be important because:
 - ▶ The alkalinity of a body of water provides information about how sensitive that water body will be to acid inputs such as acid rain
 - ▶ Turbidity is frequently removed from drinking water by coagulation and flocculation
 - ▶ This process releases H^+ into the water, alkalinity must be present in excess for effective and complete coagulation to occur
 - ▶ Hard waters may be partially softened by precipitation methods
 - ▶ The alkalinity of the water must be known in order to calculate the lime ($Ca(OH)_2$) and soda ash (Na_2CO_3) requirements for precipitation
 - ▶ Alkalinity is important to control corrosion in piping systems

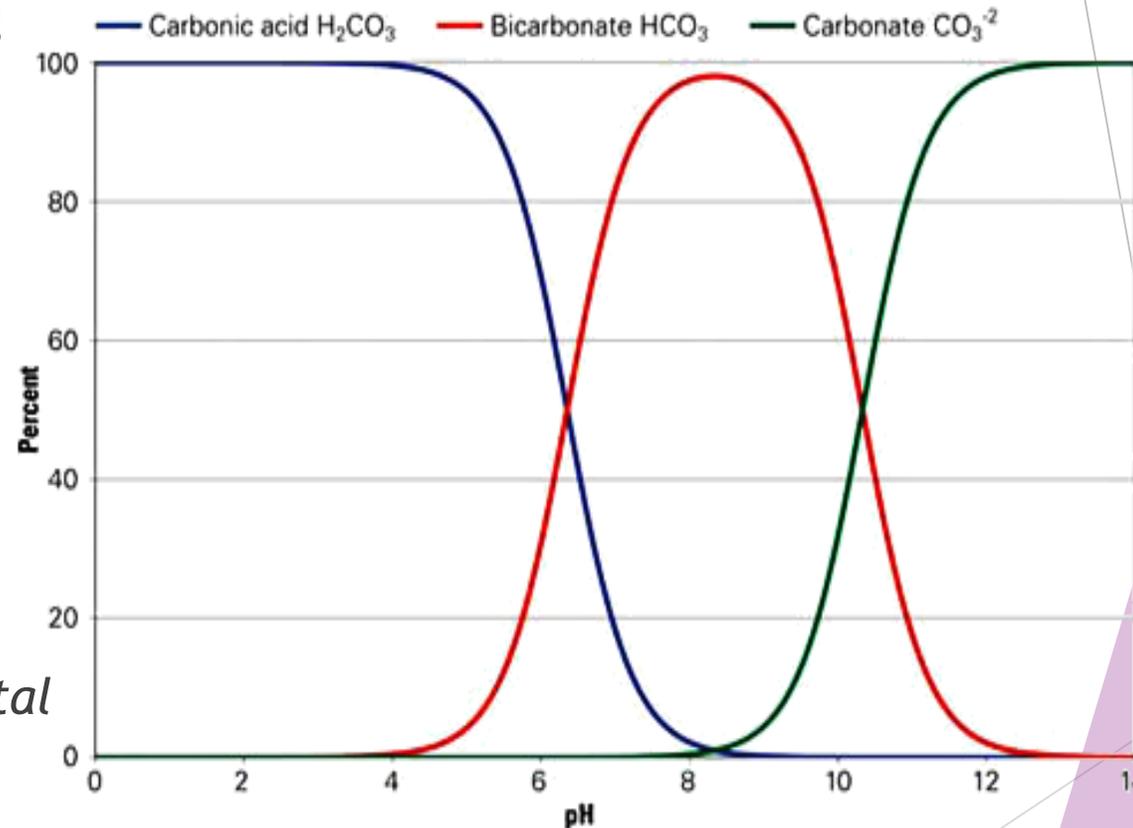


What is Alkalinity made of?

- ▶ As mentioned previously, alkalinity in natural waters is primarily due to carbonate species and the following set of chemical equilibria is established in waters:

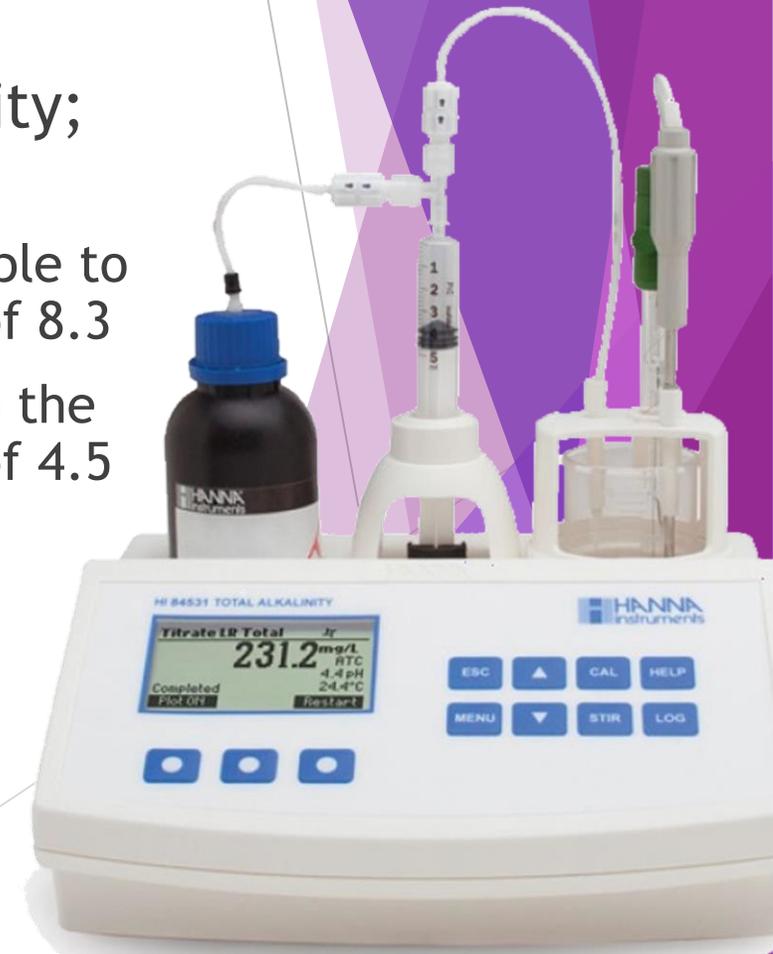


- ▶ where H_2CO_3^* represents the total concentration of dissolved CO_2 and H_2CO_3 (Carbonic Acid). The first chemical equation represents the equilibrium of CO_2 in the atmosphere with dissolved CO_2 in the water.



How is Alkalinity Determined?

- ▶ To determine the alkalinity, a known volume of water sample is titrated with a standard solution of strong acid to an approximate pH value
- ▶ Titrations can distinguish between three types of alkalinity; carbonate, bicarbonate, and total alkalinity:
 - ▶ Carbonate alkalinity is determined by titration of the water sample to the phenolphthalein indicator endpoint, or approximately a pH of 8.3
 - ▶ Total alkalinity is determined by titration of the water sample to the endpoint of the methyl orange indicator, or an approximate pH of 4.5
 - ▶ The difference between the two is the bicarbonate alkalinity
- ▶ Note that only approximate pH endpoints can be given
- ▶ The higher the total alkalinity, the more acid will be required to lower the pH value



Hard Water

- ▶ Hardness is a common problem in Texas water sources caused by elevated levels of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ions in solution that can cause scale build up on different surfaces
- ▶ The primary source of hardness ions is the dissolution of limestone rock in Texas
 - ▶ The same rock as the source of alkalinity
- ▶ Hardness can be measured as milligrams per liter (mg/l) or as grains per gallon (gpg)
 - ▶ *1 gpg = 17.12 mg/l*



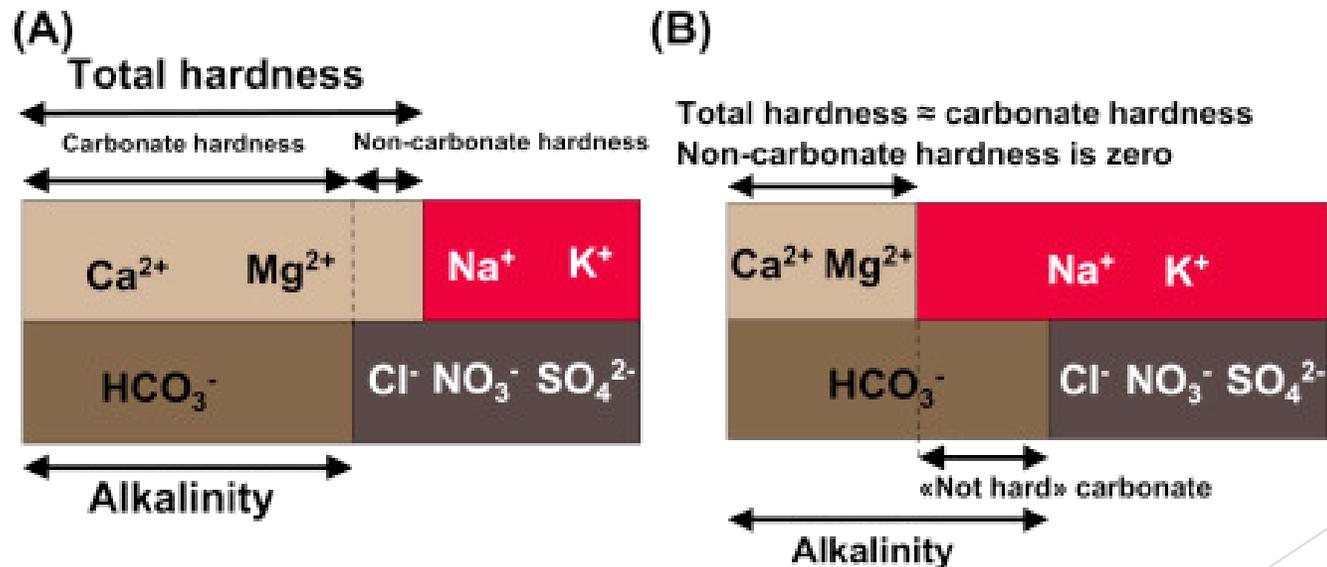
Types of Hardness

- ▶ Hardness can be divided into two categories:
 - ▶ **Carbonate Hardness** is also called temporary because it will precipitate when exposed to heat
 - ▶ Boiling will soften as hardness precipitates
 - ▶ **Non-carbonate Hardness** is also called permanent hardness because it will not precipitate when exposed to heat
 - ▶ Boiling will not soften



Alkalinity and Hardness

- ▶ Alkalinity determines the type of hardness that is present in the water:
- ▶ If Alkalinity > Total hardness
 - ▶ All hardness is Temporary
- ▶ If Alkalinity < Total Hardness
 - ▶ Temporary Hardness = Amount of Alkalinity
 - ▶ Permanent Hardness = Total Hardness - Temporary Hardness



Using a Water Analysis #1

Calculate the alkalinity, total hardness, carbonate hardness, and non-carbonate hardness from the following water analysis:

Cations	mg/l	Anions	mg/l
Ca ²⁺	94	HCO ₃ ⁻	135
Mg ²⁺	28	SO ₄ ²⁻	134
Na ⁺	14	Cl ⁻	92
K ⁺	31	pH	7.8

- ▶ **Alkalinity:**
 - ▶ Primary component is Bicarbonate (HCO₃⁻)
 - ▶ = 135 mg/l
- ▶ **Total Hardness:**
 - ▶ Primary components are Calcium (Ca⁺) and Magnesium (Mg⁺)
 - ▶ = 94 + 28 = 122 mg/l
 - ▶ 122 ÷ 17.12 = 7.1 gpg
- ▶ **Carbonate Hardness:**
 - ▶ Hardness covered by alkalinity
 - ▶ Alkalinity > Total Hardness
 - ▶ = 122 mg/l
- ▶ **Non-Carbonate Hardness:**
 - ▶ Hardness not covered by alkalinity
 - ▶ Total Hardness - Carbonate Hardness
 - ▶ = 0 mg/l



Using a Water Analysis #2

▶ Alkalinity:

- ▶ Primary components are Bicarbonate (HCO_3^-) and Carbonate (CO_3^{2-})
- ▶ = $37 + 2 = \underline{39 \text{ mg/l}}$

▶ Total Hardness:

- ▶ Primary components are Calcium (Ca^{2+}) and Magnesium (Mg^{2+})
- ▶ = $48 + 11 = \underline{59 \text{ mg/l}}$
- ▶ $59 \div 17.12 = 3.4 \text{ gpg}$

▶ Carbonate Hardness:

- ▶ Hardness covered by alkalinity
- ▶ Alkalinity < Total Hardness
- ▶ = 39 mg/l

▶ Non-Carbonate Hardness:

- ▶ Hardness not covered by alkalinity
- ▶ Total Hardness - Carbonate Hardness
- ▶ = $59 - 39 = \underline{20 \text{ mg/l}}$

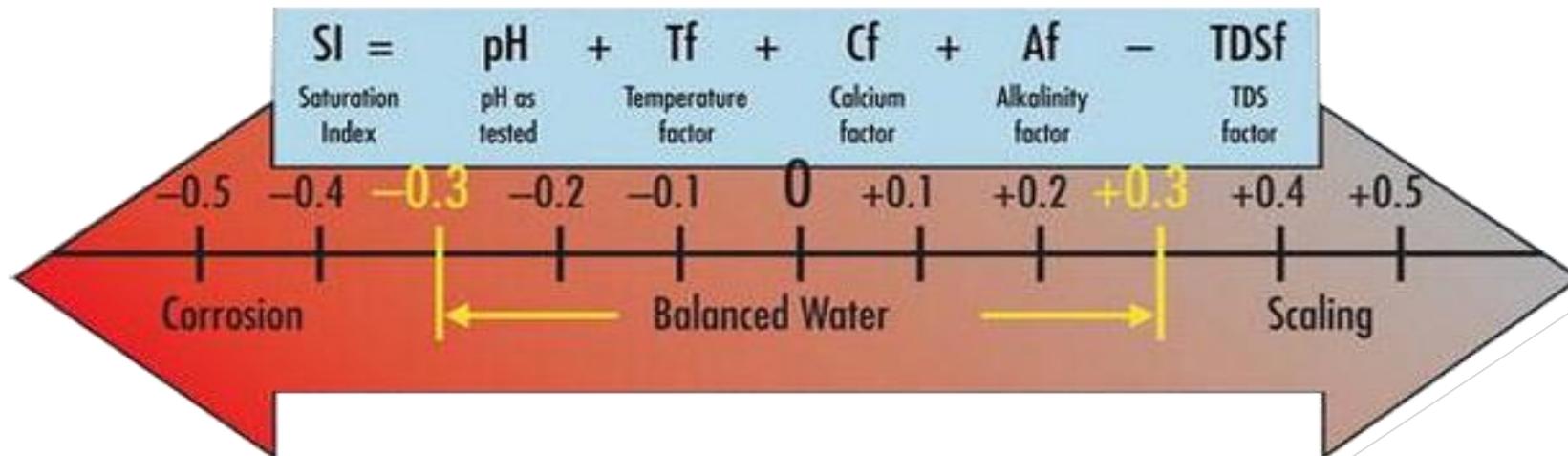
Calculate the alkalinity, total hardness, carbonate hardness, and non-carbonate hardness from the following water analysis:

Cations	mg/l	Anions	mg/l
Ca^{2+}	48	HCO_3^-	37
Mg^{2+}	11	SO_4^{2-}	4
Fe^+	<0.01	CO_3^{2-}	2
Na^+	14	Cl^-	15
K^+	<1	F^-	0.03
TDS	183	pH	6.7



Langelier Index

- ▶ The Langelier Index is an approximate indicator of the degree of saturation of Calcium Carbonate in water
- ▶ Calculated using the pH, alkalinity, Calcium concentration, total dissolved solids, and water temperature of a water sample collected at the tap
 - ▶ If the Langelier Index is negative, then the water is under saturated with Calcium Carbonate and will tend to be corrosive in the distribution system
 - ▶ If the Langelier Index is positive, then the water is over saturated with Calcium Carbonate and will tend to deposit Calcium Carbonate forming scales in the distribution system
 - ▶ If the Langelier Index is close to zero, then the water is just saturated with Calcium Carbonate and will neither be strongly corrosive or scale forming



Putting it all together! #1

- ▶ A homeowner has installed a new well and is having some quality problems in their home. Based on the simple analysis, answer the following questions about water treatment on this system:
- ▶ **Will air oxidation followed by filtration be a beneficial treatment technology? Why?**
 - ▶ Yes. The pH is high enough to effectively oxidize the iron and remove it through filtration.
- ▶ **If the homeowner were to boil their water, would hardness increase or decrease? Why?**
 - ▶ Decrease. The alkalinity is higher than total hardness making all the hardness temporary (carbonate). Temporary hardness will precipitate when boiled and the resulting water will be softer.
- ▶ **Over time, is the homeowner more likely to have scale or corrosion issues inside their pipes? Why?**
 - ▶ Scale issues. The Langelier Index is a positive value indicating the tendency for the water to deposit Calcium Carbonate in pipes.

Material	ppm
Calcium	127
Magnesium	78
Sodium	49
Ferrous	2.7
Alkalinity	493
TDS	1,050
pH	7.6
Langelier	+1.5



Putting it all together! #2

- ▶ John just moved to a ranch that mixes water from both a rainwater collection system and a well to supply water to his horse barn. He is complaining of red stains in his horse troughs and pinhole leaks in his metal piping. He bought an air oxidation/filtration system and a large ion exchange water softener, but they don't seem to be helping.
- ▶ **He obtained this simple water analysis. What is the problem with John's treatment system?**
 - ▶ Iron: pH is too low for air oxidation to be effective on dissolved iron
 - ▶ Corrosion: acidic pH and negative Langelier Index indicate corrosiveness that is dissolving the metal piping and causing leaks
 - ▶ Hardness: very low (< 1 gpg) Langelier Index is negative, there is no reason to have a large water softener on this system, also the high iron is most likely fouling the cation resin within the softener

Option for a treatment solution:

- ▶ First, increase both the pH and alkalinity with a sacrificial media, Calcite, before the oxidation/filtration unit
- ▶ Remove the large softener
- ▶ Replace the leaking pipe segments (avoid dissimilar metals)

Material	mg/l
Calcium	13
Magnesium	<1.0
Sodium	5
Ferrous	2.1
Alkalinity	3
TDS	154
pH	5.8
Langelier	-0.7

