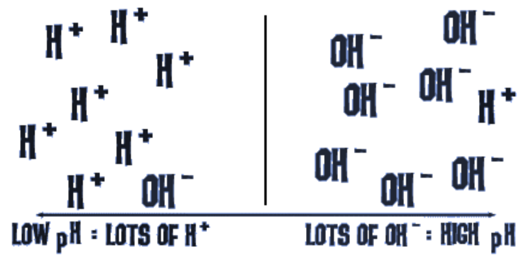
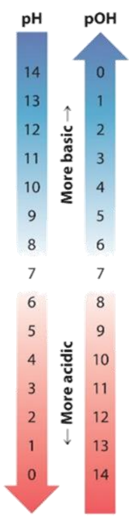
Alkalinity vs. pH

pH

“Potential Hydrogen” Ion Concentration

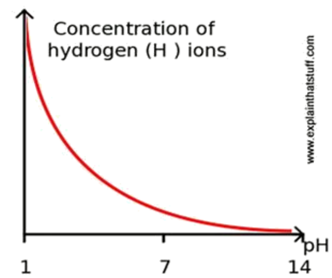
pH is a scale, which can be used to indicate the acidity or basicity of a solution. The scale has numbers from 1 to 14. A pH of 7 is considered a neutral value. Pure water is said to have a pH 7. Below 7 indicates acidic. Above 7 indicates basic.





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

$$pH = -\log [H^+]$$



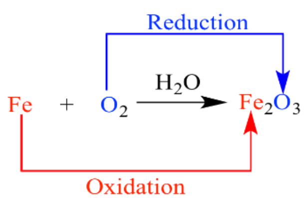
In a basic solution, there aren’t many H^+s making it difficult to determine an accurate concentration. In this case, the $-\log [OH^-]$ can be used to determine the pOH of the solution:

$$pH + pOH = 14$$

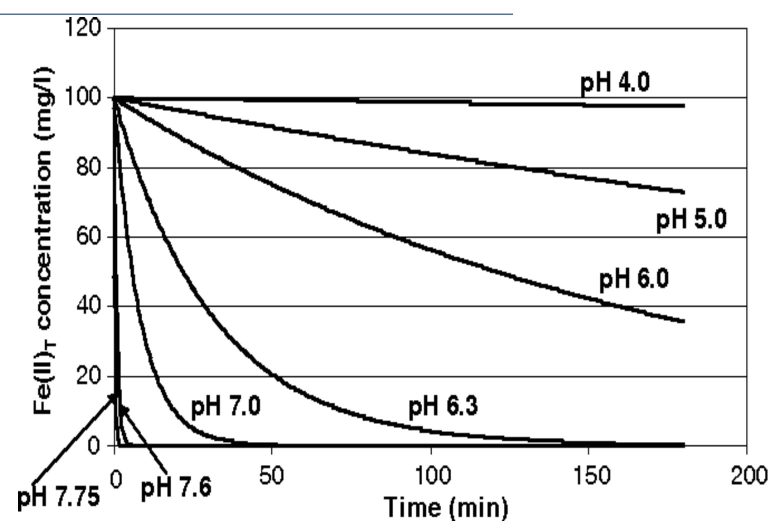
Therefore, the pH value of a basic solution can also be calculated accurately. There are pH meters and pH papers which can be used to measure pH values. pH papers will give approximate pH values, whereas pH meters give more accurate values.

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.

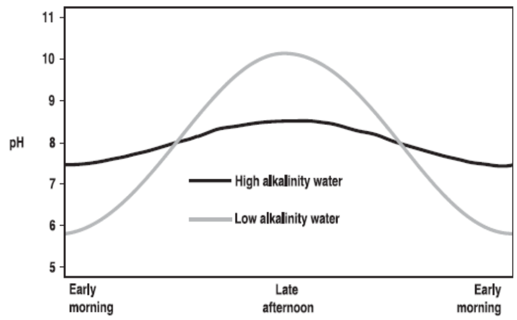


pH serves and vital role when evaluating the effectiveness of oxidation of Iron with air.



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.

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.

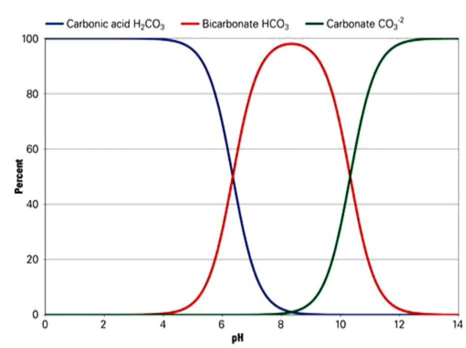
Importance of Alkalinity

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:

1. The alkalinity of a body of water provides information about how sensitive that water body will be to acid inputs such as acid rain.
2. 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.
3. 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.
4. 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:



$$CO_2 + H_2O \Leftrightarrow H_2CO_3^*$$

$$H_2CO_3 \Leftrightarrow HCO_3^- + H^+$$

$$HCO_3^- \Leftrightarrow CO3^{2-} + H^+$$

where H2CO3 represents the total concentration of dissolved CO2 and H2CO3 (Carbonic Acid). The first chemical equation represents the equilibrium of CO2 in the atmosphere with dissolved CO2 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

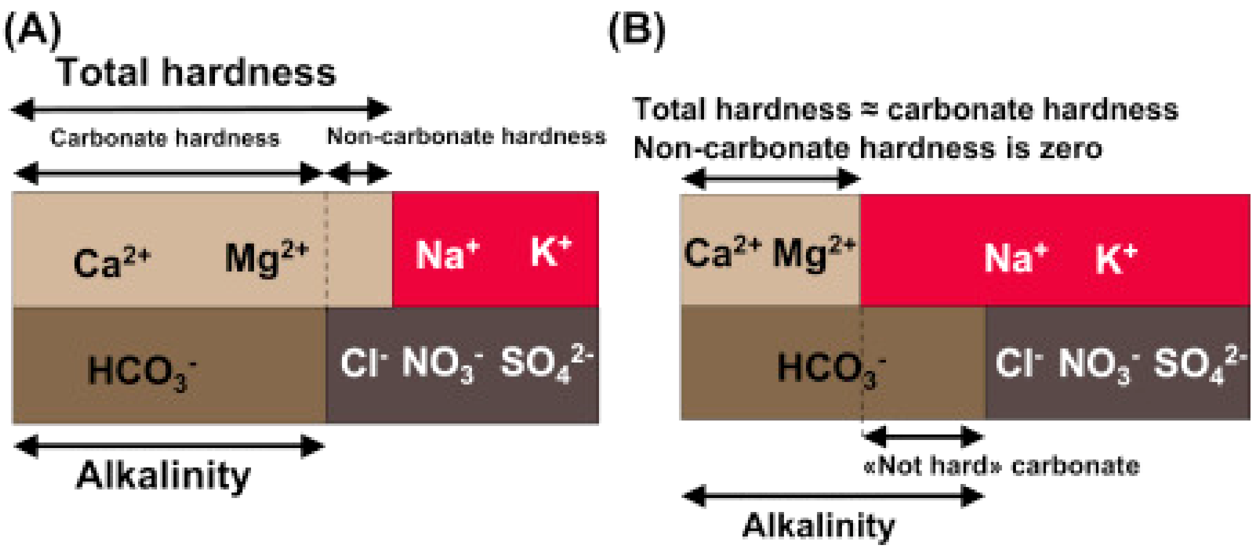
Alkalinity determines the type of hardness that is present in the water:

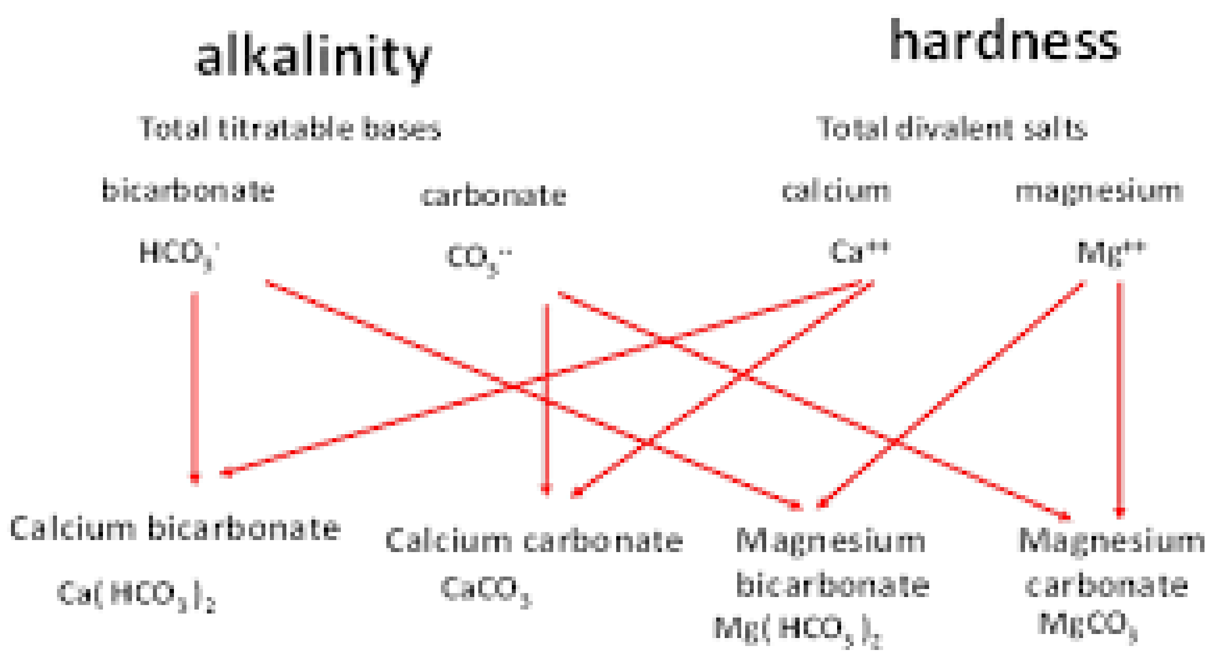
If Alkalinity > Total hardness

- *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 (HCO_3^-)

= ___________ mg/l

Total Hardness:

Primary components are Calcium (Ca+) and Magnesium (Mg+)

= __________mg/l + __________mg/l = ___________mg/l

Convert to GPG:

= ___________ mg/l ÷ 7.48 = ___________ gpg

Carbonate Hardness:

Hardness covered by alkalinity

Alkalinity > Total Hardness

= __________ mg/l

Non-Carbonate Hardness:

Hardness not covered by alkalinity

Total Hardness – Carbonate Hardness

= __________ mg/l

Using a Water Analysis #2

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
Na^+	14	Cl^-	15
K^+	<1	F^-	0.03
TDS	183	pH	6.7

Alkalinity:

Primary components are Bicarbonate (HCO_3^-) and Carbonate (CO_3^-)

= ___________ mg/l **+** ___________ mg/l **=** ___________ mg/l

Total Hardness:

Primary components are Calcium (Ca+) and Magnesium (Mg+)

= __________mg/l **+** __________mg/l **=** ___________mg/l

Convert to GPG:

= ___________ mg/l ÷ 7.48 = ___________ gpg

Carbonate Hardness:

Hardness covered by alkalinity

Alkalinity < Total Hardness

= __________ mg/l

Non-Carbonate Hardness:

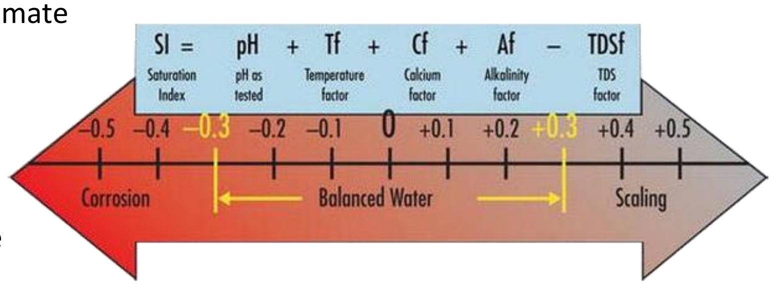
Hardness not covered by alkalinity

Total Hardness – Carbonate Hardness

= ___________ mg/l **-** ___________ mg/l **=** ___________ mg/l

Langelier Index

The Langelier Index is an approximate indicator of the degree of saturation of Calcium Carbonate in water. It is 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

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

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:

1. **Will air oxidation followed by filtration be a beneficial treatment technology? Why?**

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2. **If the homeowner were to boil their water, would hardness increase or decrease? Why?**

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3. **Over time, is the homeowner more likely to have scale or corrosion issues inside their pipes? Why?**

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Putting it all together! #2

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

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 throughs 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.

1. **He obtained this simple water analysis. What is the problem with John's treatment system?**

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2. **Option for a treatment solution:**

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