pH vs. Alkalinity

Presented by: Stephanie Layfield

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- Active in TWQA as well as WQA

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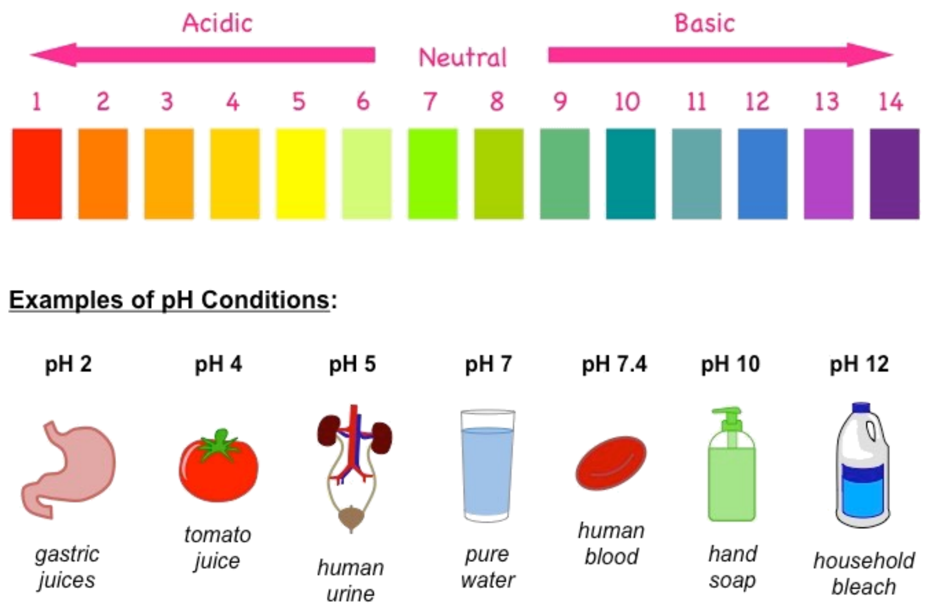
Ionico Technical Services

Objectives

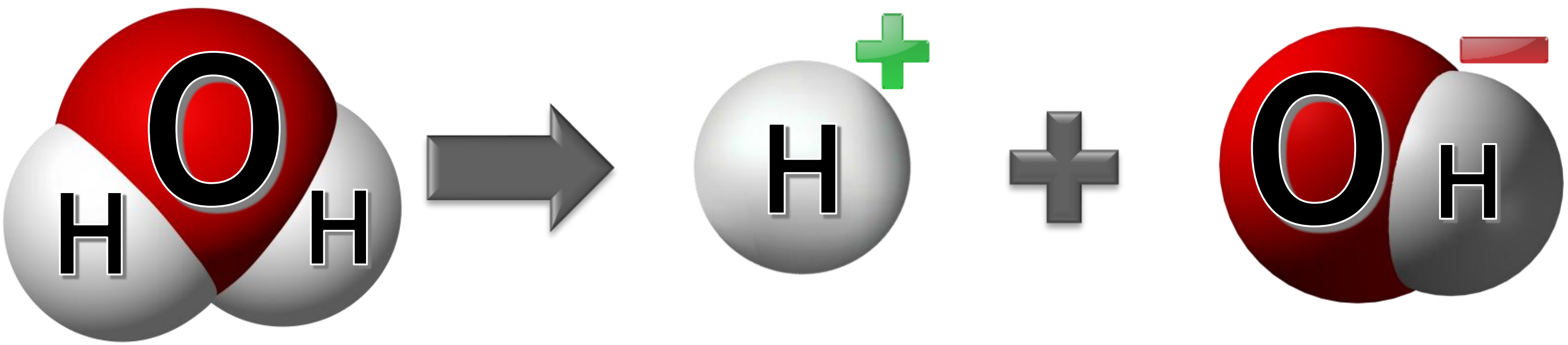
- Gain a greater understanding of the principal differences between pH and Alkalinity
- Define the measure of pH and what exactly it tells us about the chemical composition of water
- Visualize the effect that pH has on oxidation of Iron with air
- Explore the chemical composition of Alkalinity and how it can be tested
- Compare different forms of hardness based on Alkalinity
- Use water analysis to diagnose potential quality problems and how to correct them

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 neutral
  - “Pure Water”
- Below 7 indicates acidic
- Above 7 indicates basic



Can water dissolve itself?



Water Molecule *Hydrogen Ion* *Hydroxide Ion*

pH Meaning

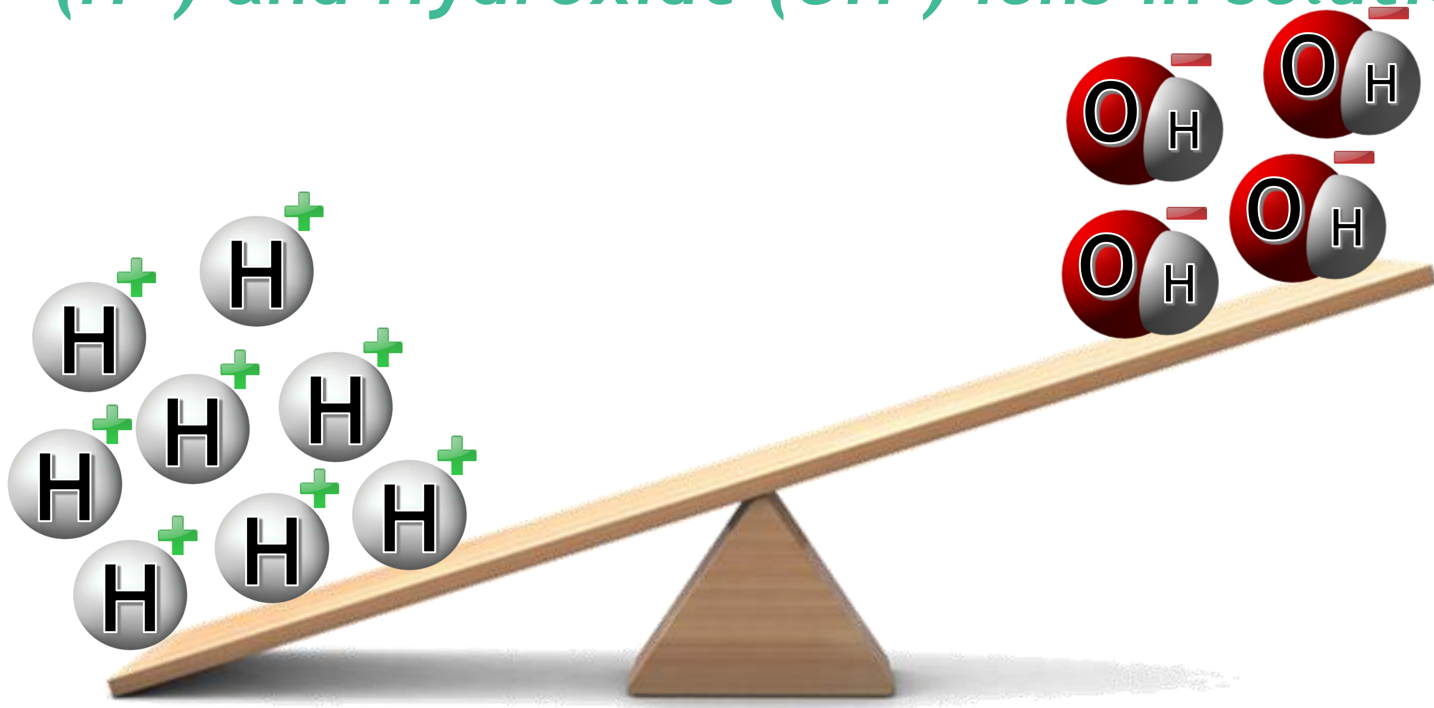
pH is the relative concentrations of Hydrogen (H+) and Hydroxide (OH-) ions in solution

Neutral

pH 7

pH Meaning

pH is the relative concentrations of Hydrogen (H+) and Hydroxide (OH-) ions in solution

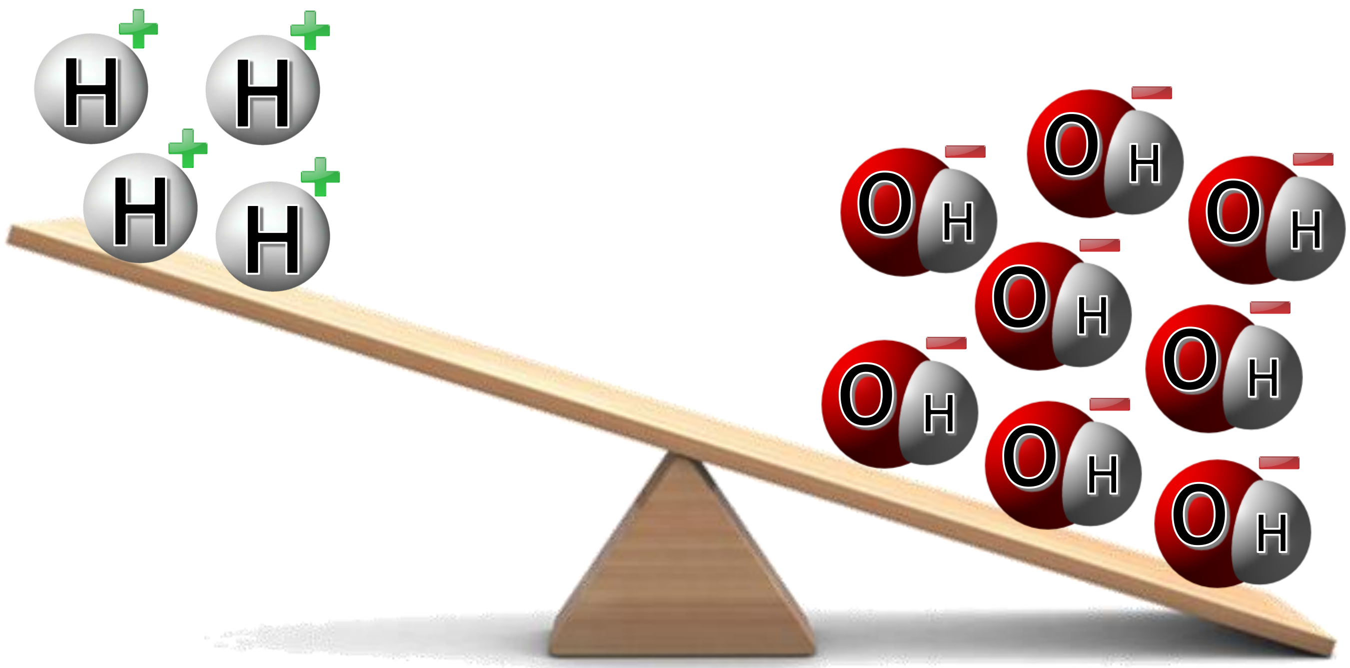


Acidic

pH <7

pH Meaning

pH is the relative concentrations of Hydrogen (H^+) and Hydroxide (OH^-) ions in solution



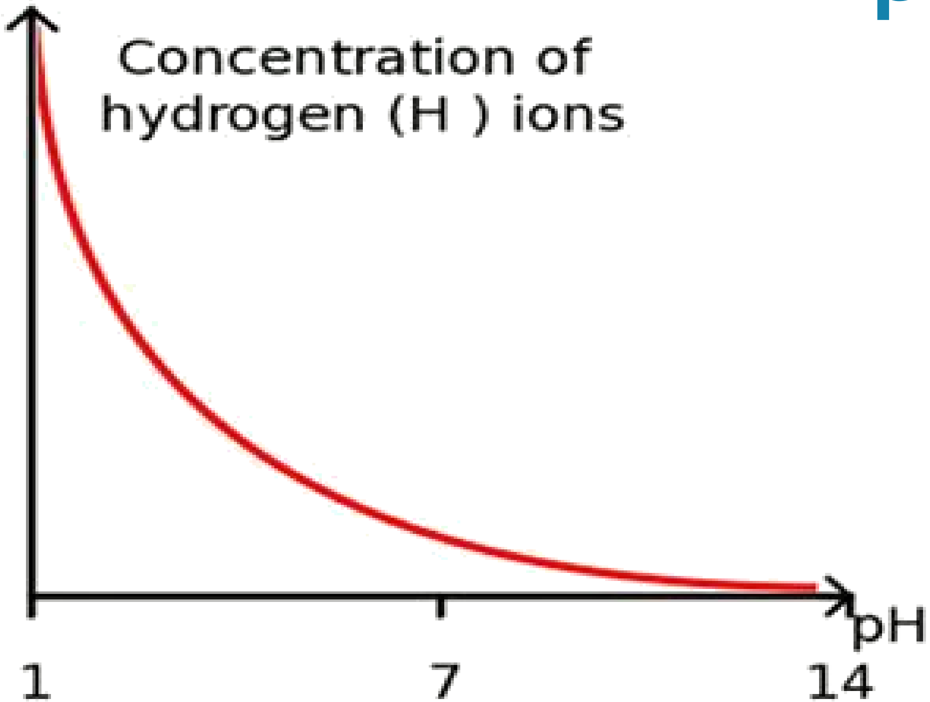
Basic

pH >7

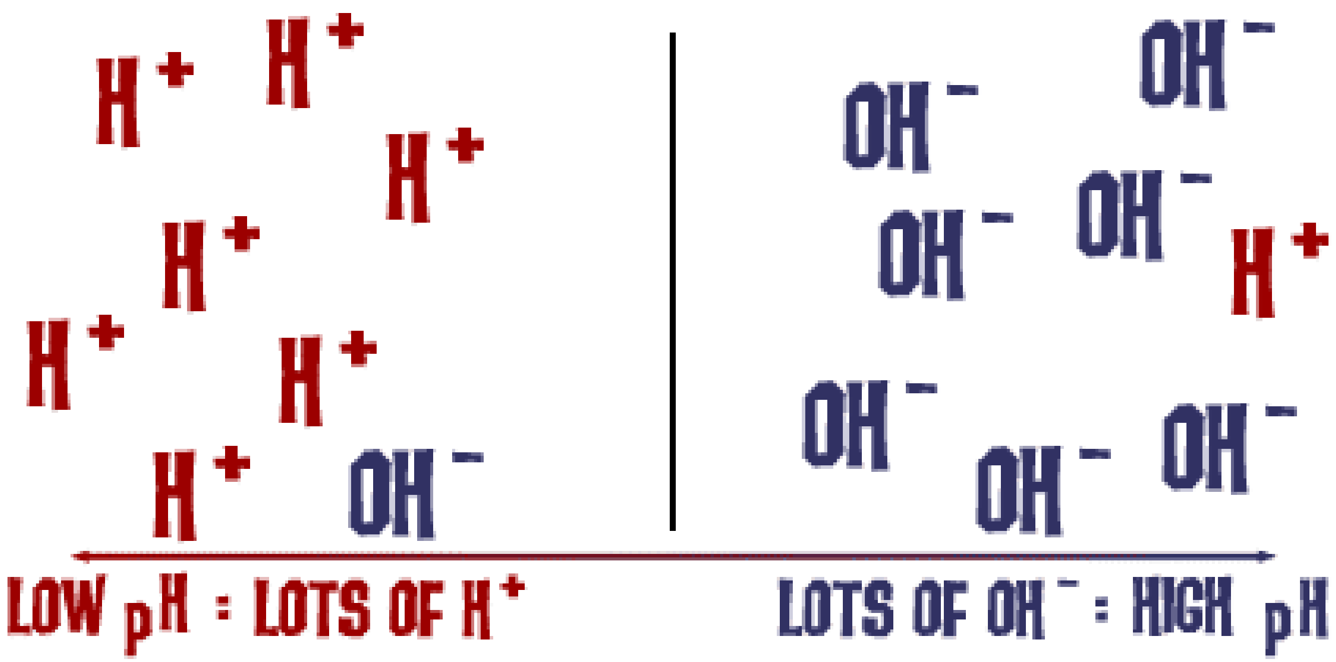
Not All Things Are Equal

- pH scale is logarithmic
  - Can be written in relation the H^+ concentration in solution

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



In Short……

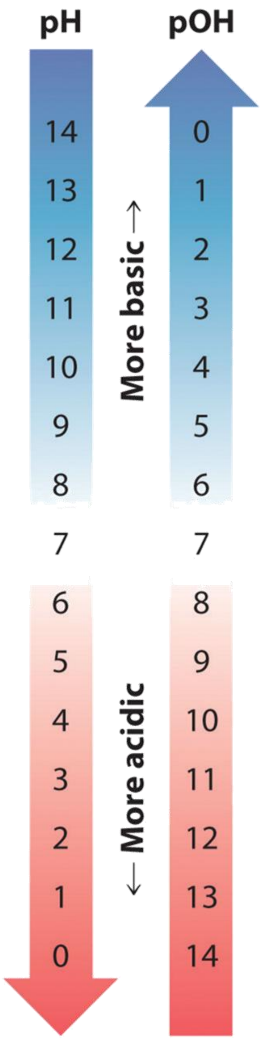

H +
H +
H +
H +
H +
H +
H +
OH −
OH −
OH −
OH −
OH −
H +
OH −
OH −
OH −
LOW pH : LOTS OF H +
LOTS OF OH − : HIGH pH

Measuring pH

- 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:

$$pH + pOH = 14$$

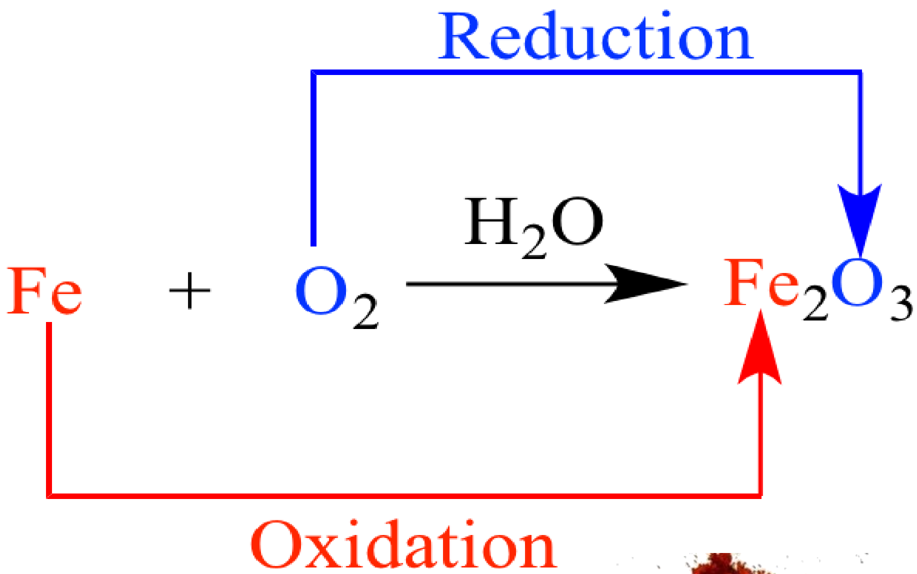
- There are pH meters and pH papers which can be used to measure pH values



Forms of Iron

- Iron can exist in two forms in water:
  - **Ferrous Iron** (Fe^{2+}) is dissolved or clear water iron
  - **Ferric Iron** (Fe^{3+}) is a suspended solid with a red color

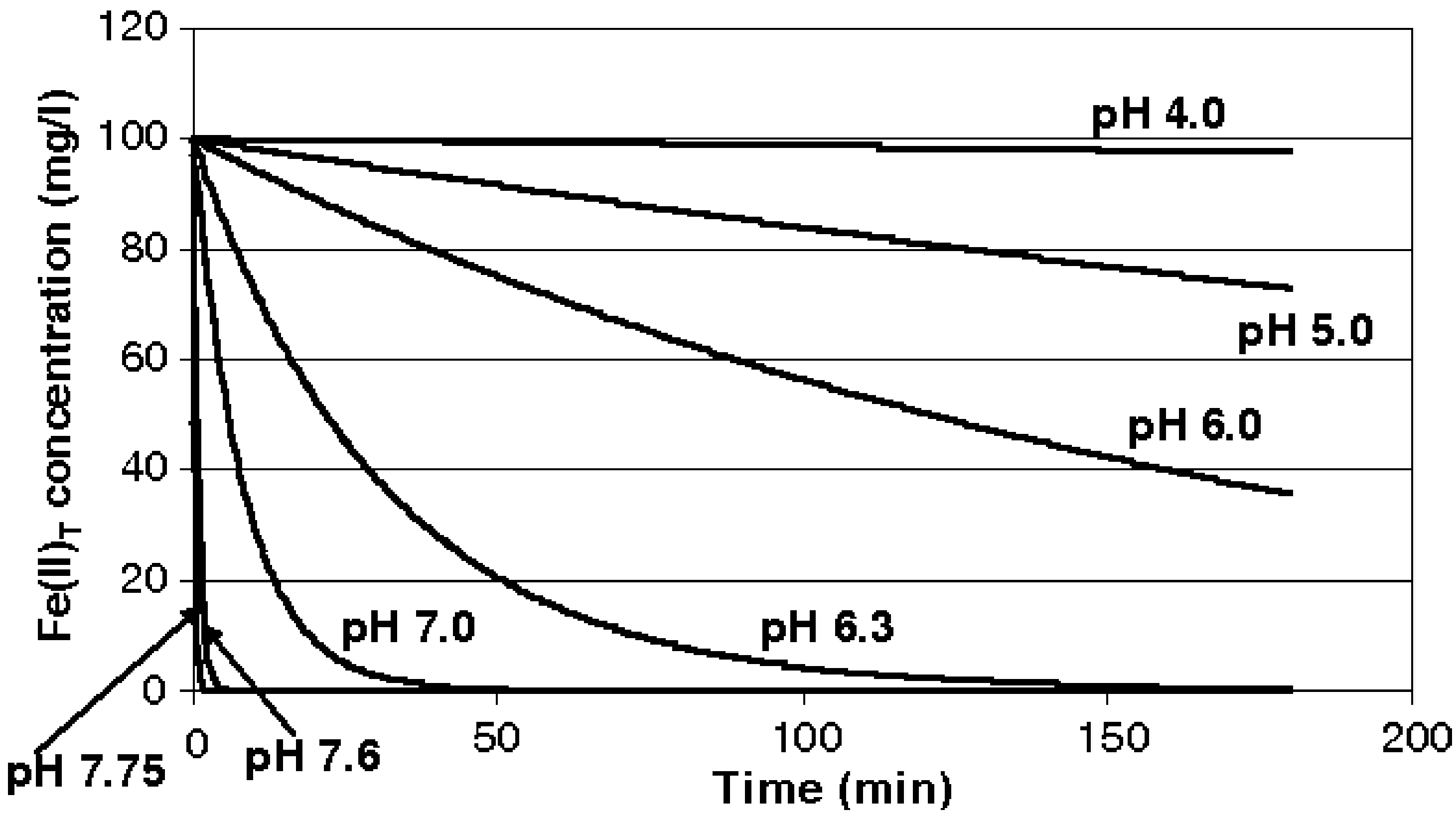
Iron Oxidation



- Iron can be changed from ferrous to ferric forms through oxidation
- 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

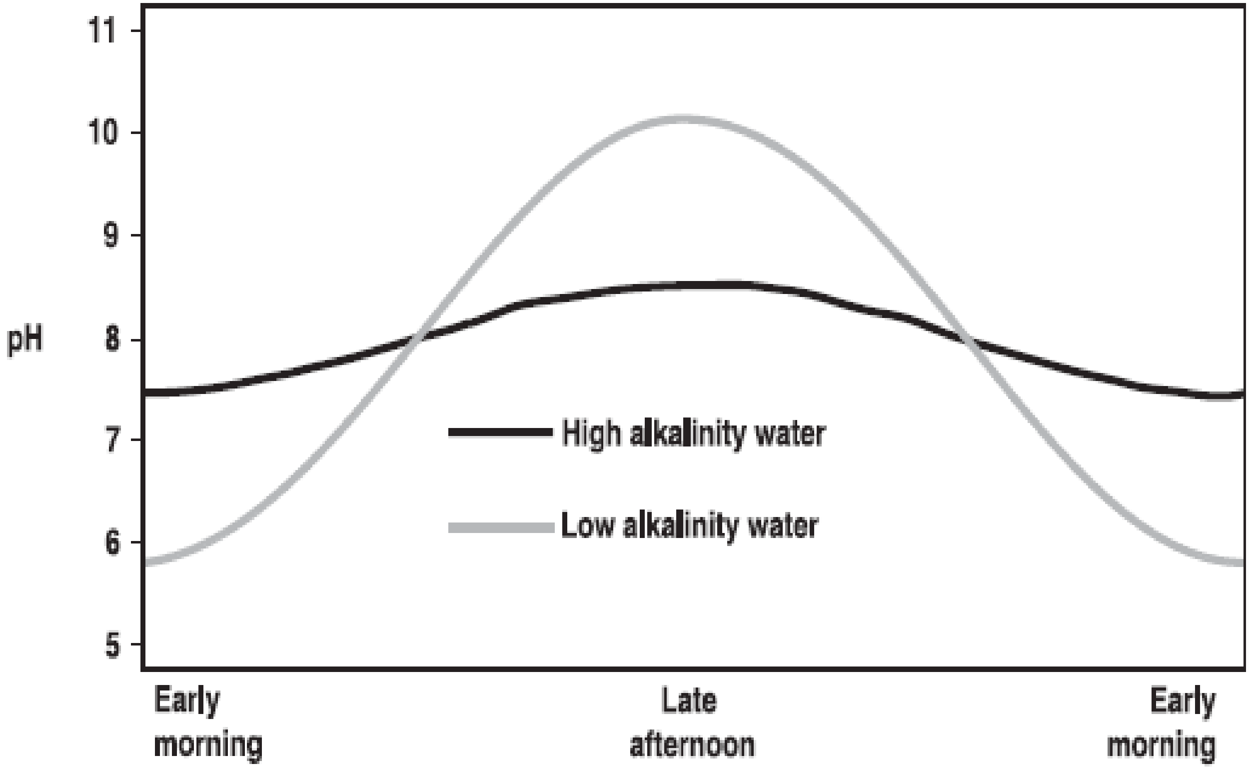


In short….

- Iron takes a **Ferrous form at Low pH (<7)**
  - Can be reduced through ion exchange
- Iron takes a **Ferric form at high pH (>7)**
  - Can be filtered out as a dissolved solid
  - Can be oxidized with air

Alkalinity

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

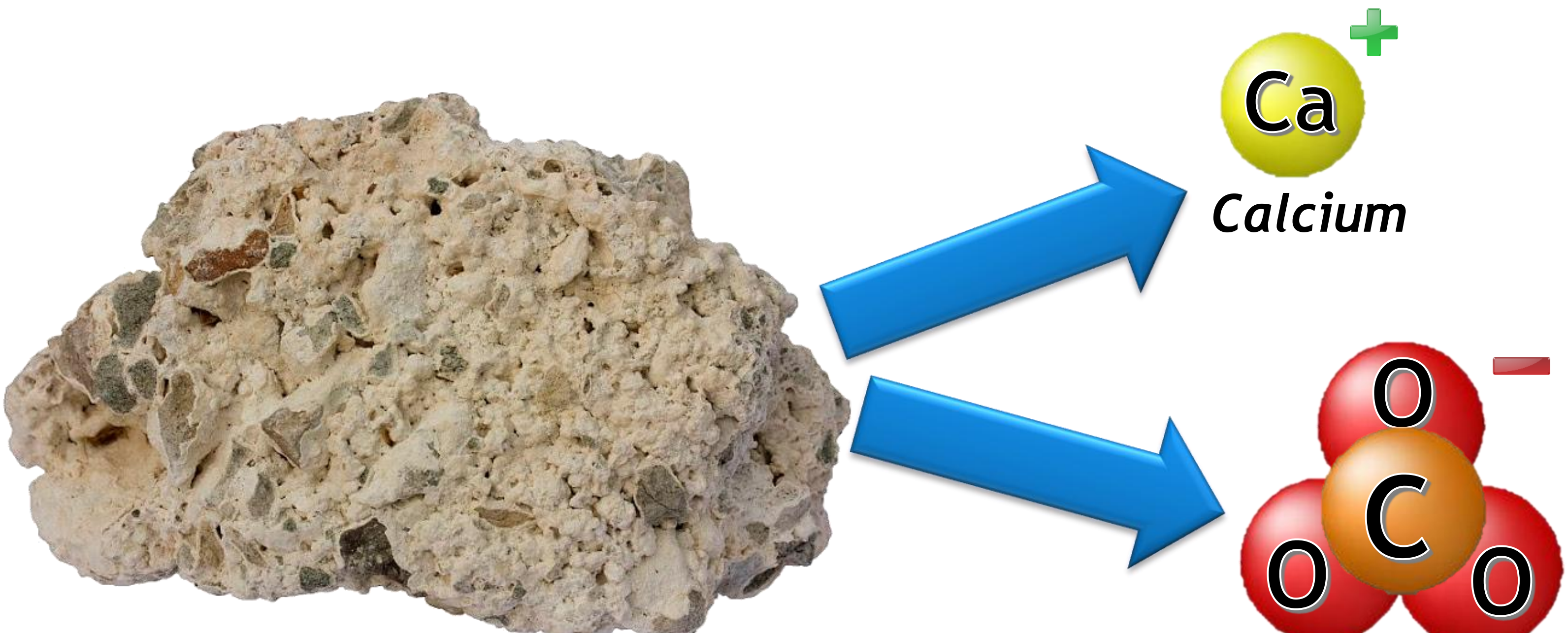


Measuring Alkalinity

- A strong acid is slowly added to a precise volume of water until the pH drops a specific amount
- The higher the alkalinity, the more acid will be required to drop the pH

What is alkalinity?

- **Limestone** substrate dissolved in groundwater increases hardness (Ca^{+})
  - Also increases **Carbonates** (CO_3^{-})

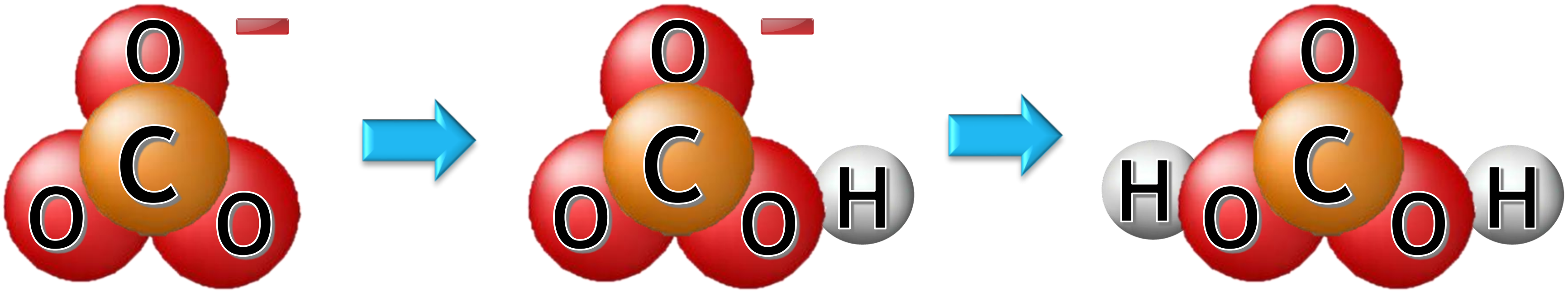


***Limestone** (Calcium Carbonate)*

Carbonate

Forms of Alkalinity

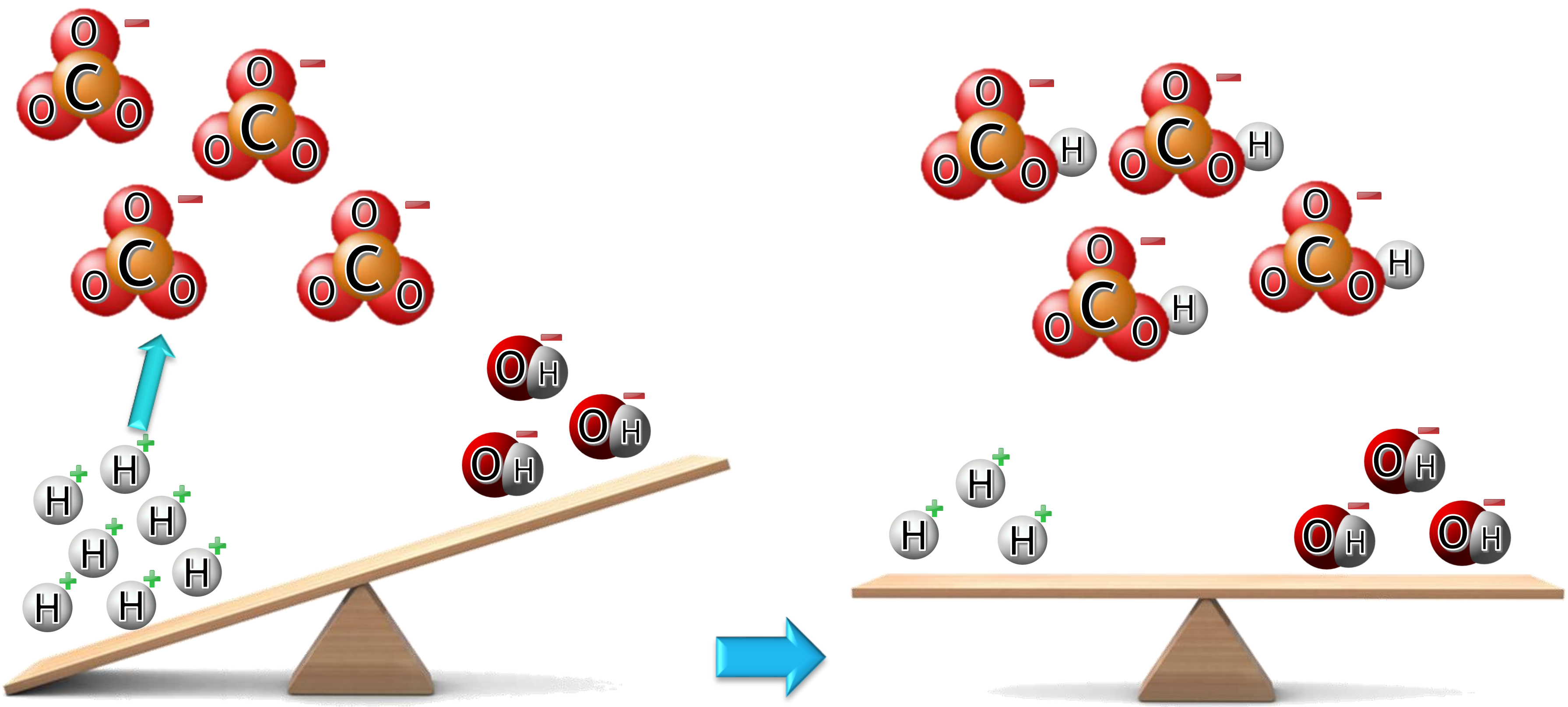
- Carbonate can bond to or release Hydrogen ions (H^+) to create different forms



Carbonate (CO_3^-) *Bicarbonate* (HCO_3^-) *Carbonic Acid* (H_2CO_3)

Alkalinity and pH

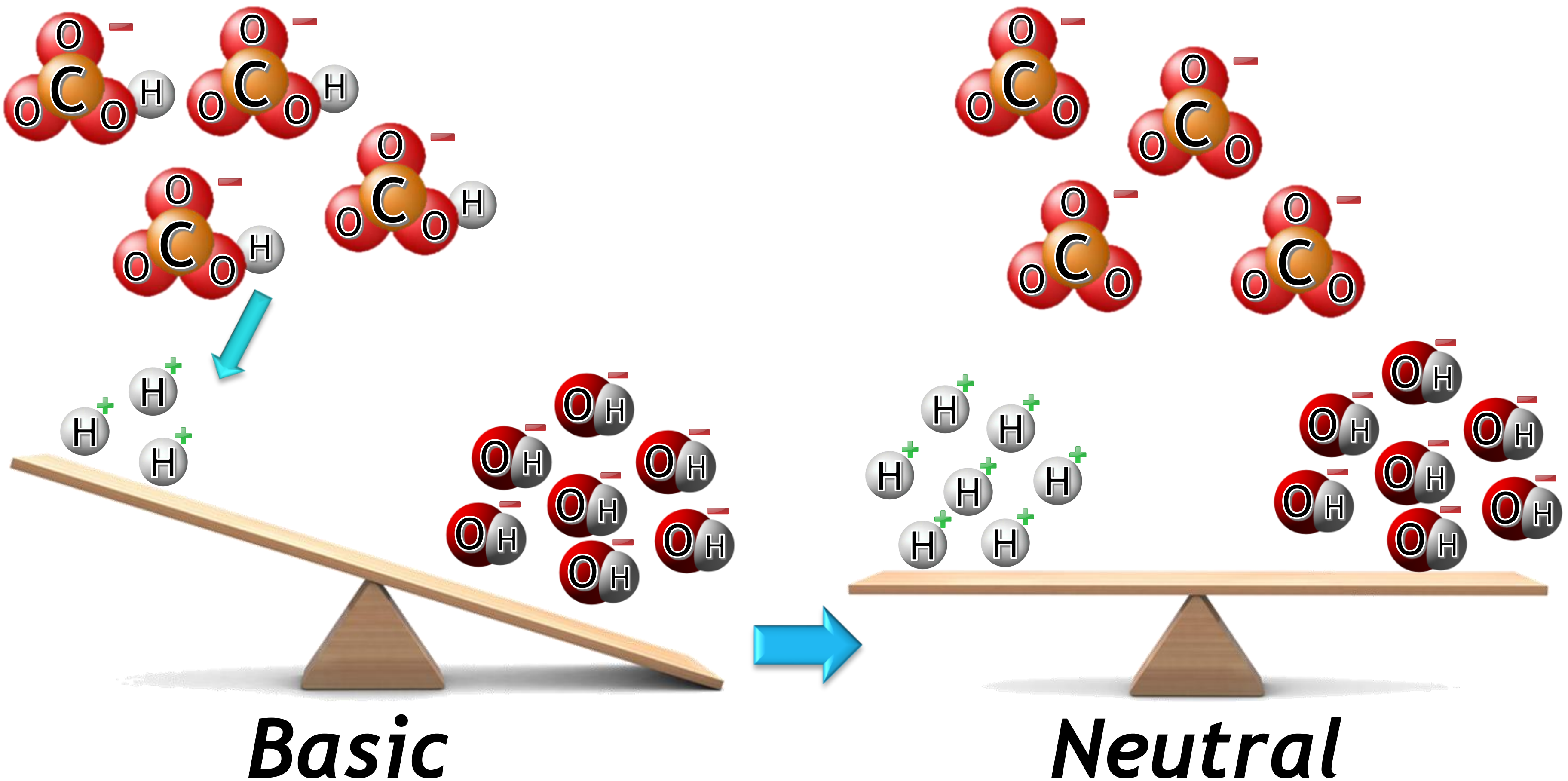
Alkalinity works to stabilize pH



Acidic *Neutral*

Alkalinity and pH

Alkalinity works to stabilize pH



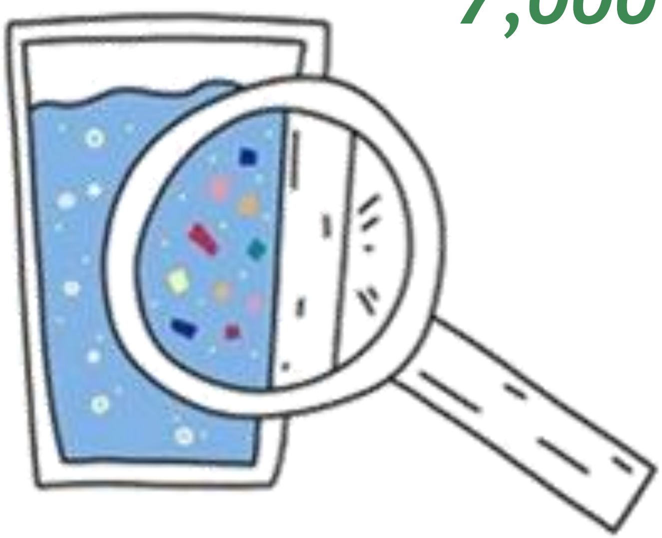
Hardness

- The same rock as the source of alkalinity
- Can be measured as milligrams per liter (mg/l) or as grains per gallon (gpg)

1 gpg = 17.12 mg/l

1 ppm = 1 mg/l

7,000 Gr. = 1 Lb.



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

Types of Hardness

Cation	Anion
Hardness	**Temporary**
Calcium	Carbonate
Magnesium	Bicarbonate
Not-Hardness	**Permanent**
Sodium	Sulfate
Potassium	Chloride

Types of Hardness

Identify if the following compounds are Temporary Hardness, Permanent Hardness, or Neither

Sodium Bicarbonate	*Neither*
Calcium Sulfate	*Permanent*
Magnesium Carbonate	*Temporary*
Manganese Chloride	*Neither*
Calcium Bicarbonate	*Temporary*

Hardness Analysis

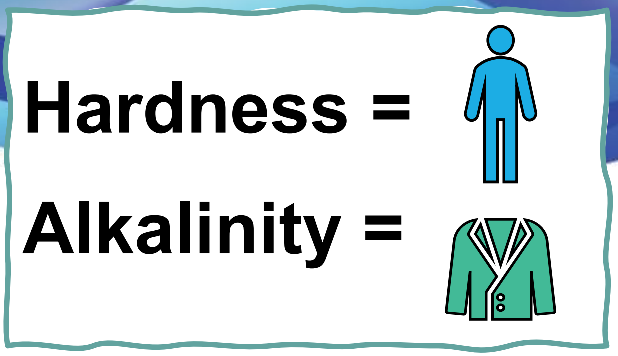
In a water analysis that gives you total alkalinity and total hardness, you can calculate how much is temporary hardness and how much is permanent.

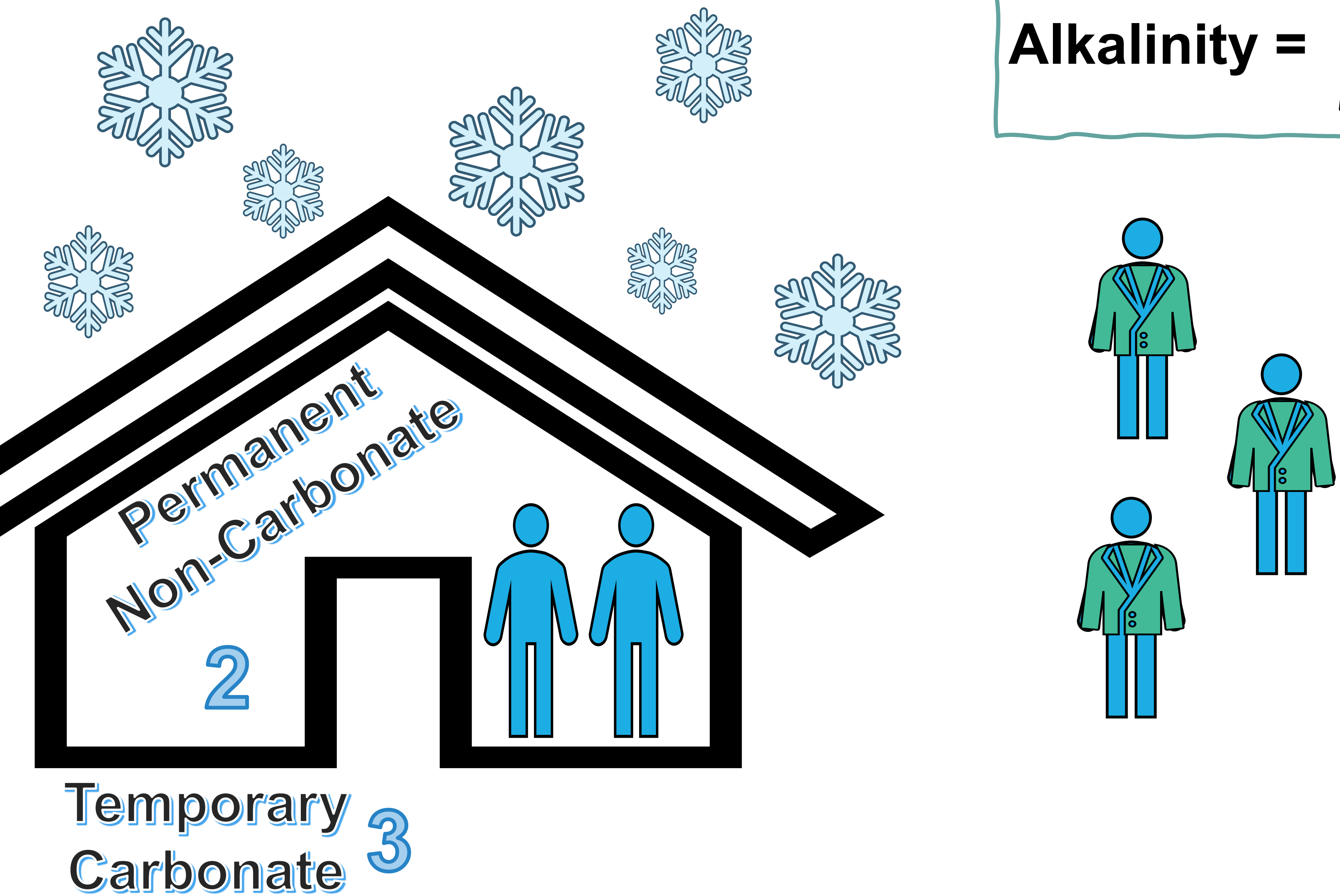
Temporary = Carbonate Hardness

- Hardness covered by alkalinity

- **Permanent = Non-Carbonate Hardness**
  - Total hardness – Temporary hardness

Hardness Analysis

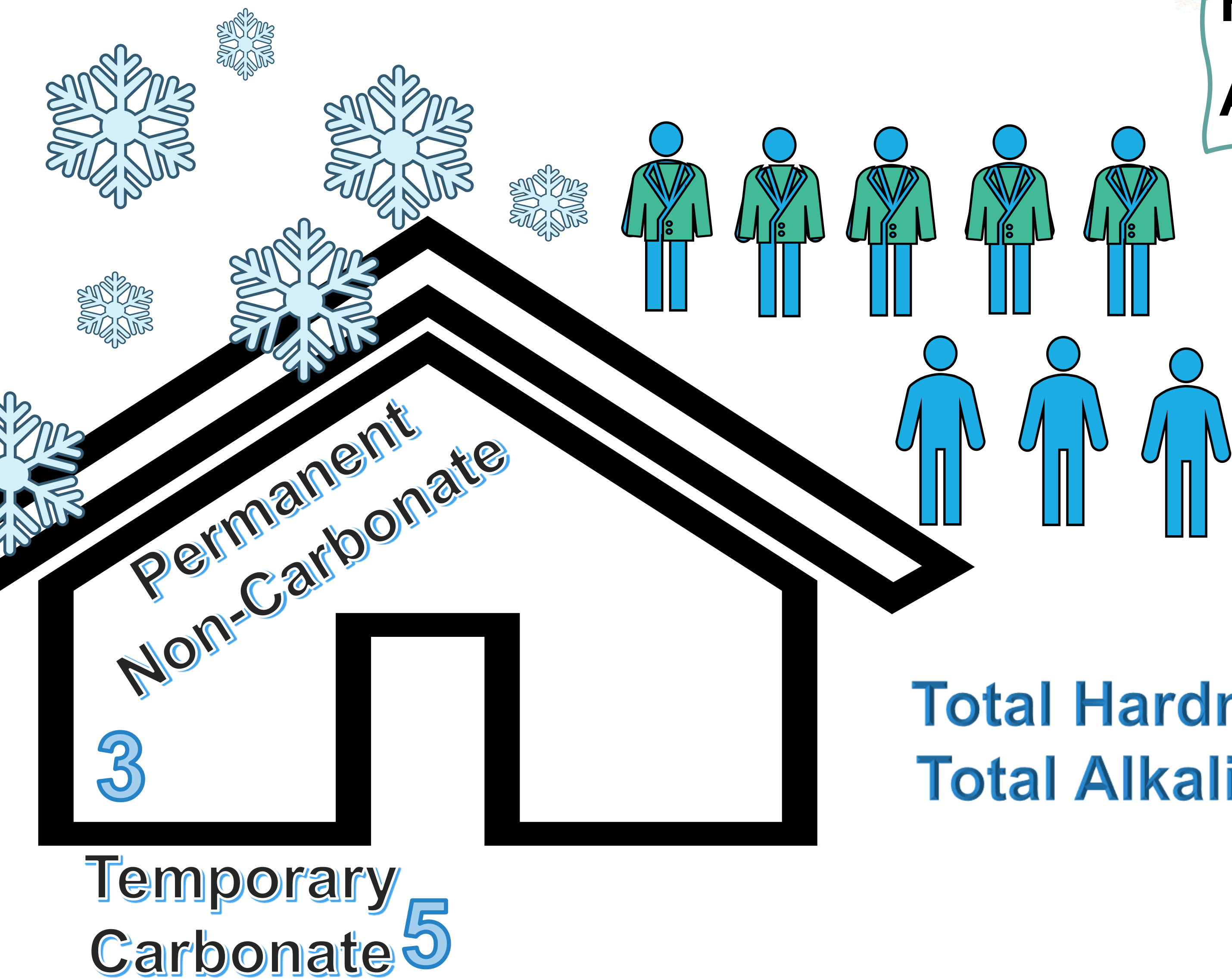




Hardness Analysis

Hardness =

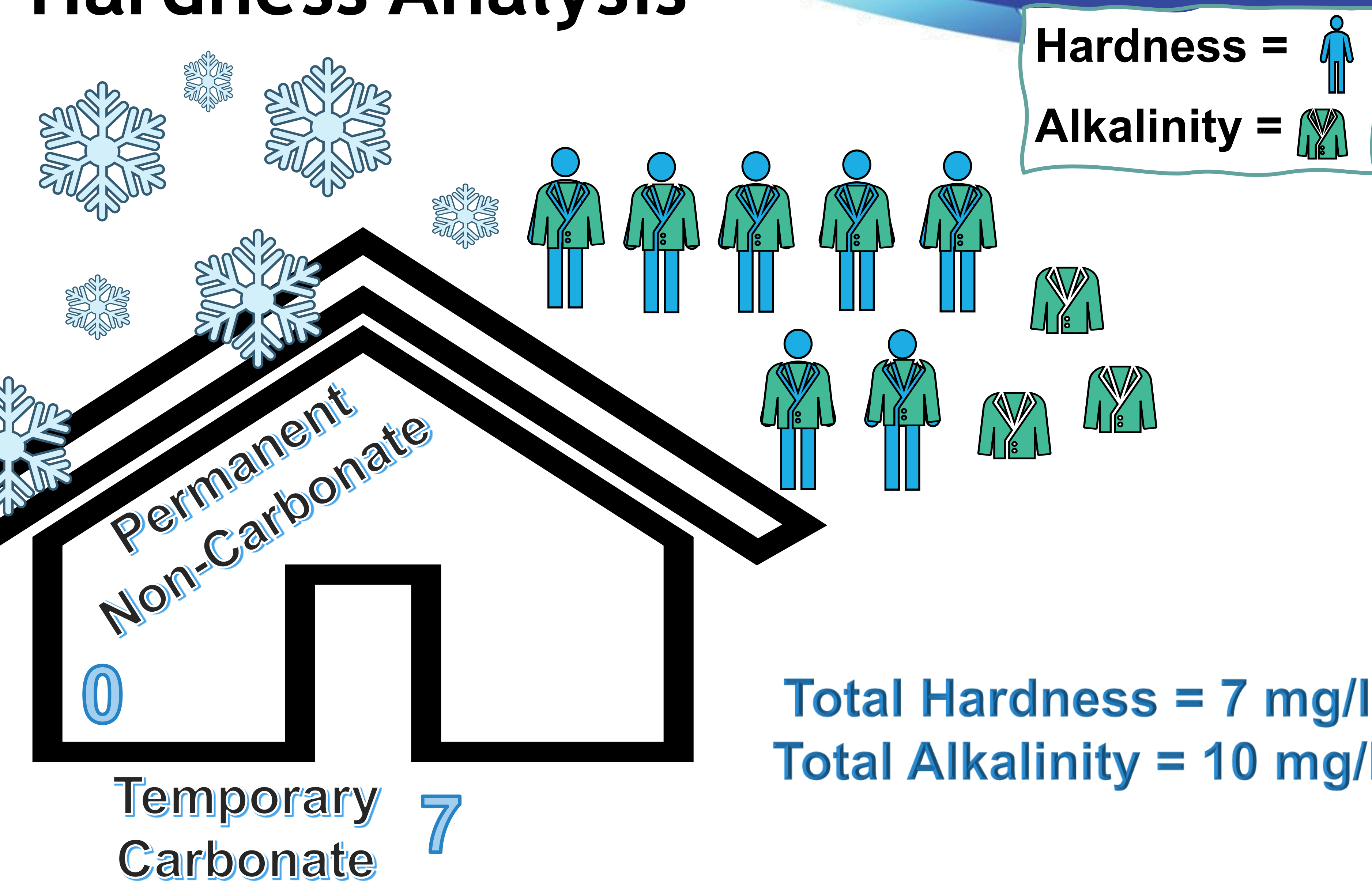
Alkalinity =



Total Hardness = 8 mg/l

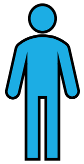
Total Alkalinity = 5 mg/l

Hardness Analysis



Hardness Calculations

From the following water analysis, determine the type and amount of hardness.

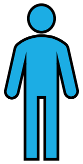
- Total alkalinity = 300 mg/l 
- Total Hardness = 200 mg/l 

Temporary (Carbonate) Hardness = 200 mg/l

Permanent (Non-Carbonate) Hardness = 0 mg/l

Hardness Calculations

From the following water analysis, determine the type and amount of hardness.

- Total alkalinity = 150 mg/l 
- Total Hardness = 350 mg/l 

Temporary (Carbonate) Hardness = 150 mg/l

Permanent (Non-Carbonate) Hardness = 200 mg/l

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: 135 mg/l

- Primary component is Bicarbonate (HCO_3^-)

Total Hardness: 7.1 gpg

- Primary components are Calcium (Ca^+) and Magnesium (Mg^+)
- = 94 + 28 = 122 mg/l
  - 122 ÷ 17.12 = 7.1 gpg

Carbonate Hardness: 122 mg/l

- **Hardness covered by alkalinity**
- **Alkalinity > Total Hardness**

Non-Carbonate Hardness: 0 mg/l

- Hardness not covered by alkalinity
- Total Hardness – Carbonate Hardness

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: 39 mg/l

- Primary components are Bicarbonate (HCO_3^-) and Carbonate (CO_3^-)
- = 37 + 2 = 39 mg/l

Total Hardness: 3.4 gpg

- Primary components are Calcium (Ca^+) and Magnesium (Mg^+)
- = 48 + 11 = 59 mg/l
  - 59 ÷ 17.12 = 3.4 gpg

Carbonate Hardness: 39 mg/l

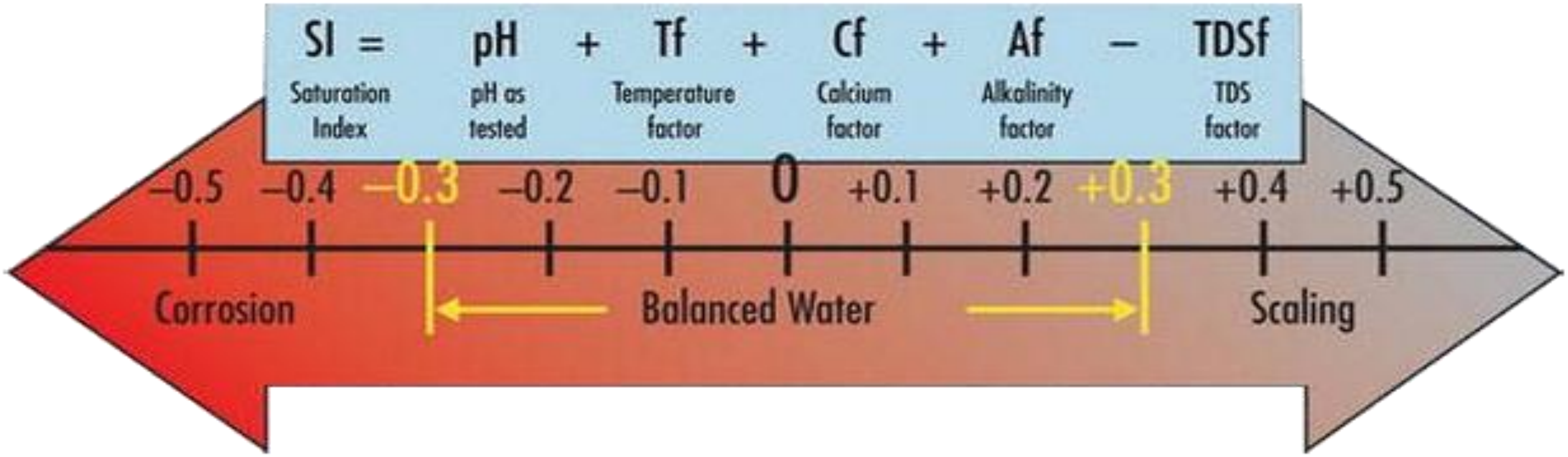
- Hardness covered by alkalinity
- Alkalinity < Total Hardness
- = 39 mg/l

Non-Carbonate Hardness: 20 mg/l

- Hardness not covered by alkalinity
- Total Hardness – Carbonate Hardness
- = 59 – 39 = 20 mg/l

Langelier Index

- The Langelier Index is an approximate indicator of the degree of saturation of Calcium Carbonate in water
  - 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:

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

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

- **Yes.** The pH is high enough to effectively oxidize iron with air before removal with 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.

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

Thank you!

Stephanie Layfield

Contact Info *Presentation*