Brewing Water

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Nov 1, 2013

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Background:

- Homebrewer since 1994
- Penchant for big, hop-forward IPAs, well before they became a west coast phenomenon
- Now into curiously flavorful farmhouse ales!

Brewing Water

- Introduction: Why as a brewer, do you care about water?
- Treating Water for Chlorine and Chloramine
- Water pH, Alkalinity, and Hardness
- Managing water flavor profile
- Acidifying your sparge water

Introduction

Why as a brewer, you care about water?

Why do we care about Water?

- It is 90% of your beer
- Typical water sources contains chemicals that impact the beer process and beer flavor
- Knowing how to handle water *will improve your beer*

When you care about water (and when you don't)

- Most water sources are good to brew with and make good beer!

- Brewing GREAT beer requires management of your water, especially when:
  - Your water is nasty (too much iron, salt, or other off-flavors, or too much chloramine / chlorine)
  - Full mash brewing –alkalinity/pH or calcium deficiency impacts to mash effectiveness
  - When water mineralization doesn't meet the style

- When not to care about water
  - Extract brewing – just know what flavors your water may be adding
  - You brew what you brew, and it works
  - Talk about ions reminds you of the horrors of high school chemistry class

Three reasons to manage your brewing water

- *To remove unwanted chemicals or flavors in the water*
- *To Manage the chemistry of your mash*
- *To Tailor your desired flavor profile*

Treating Water for Chloramine and Chlorine

Water rule #1: Remove chlorine and chloramine from brewing water

- Chlorine (as hypochlorous acid)* and Chloramine are results of public water supply treatment
- Chlorine and chloramine react with phenols to make *chloro*phenols which have a very low flavor threshold and can give your beer that medicinal or "band-aid" flavor
- Filtering with activated carbon, boiling, or just letting the water sit overnight will remove chlorine
- Chloramine is stubborn and cannot be boiled off. Quality granulated activated carbon (GAC) filters can work if you manage flow rate
- **Recommendation: Use Metabisulfite (aka Campden Tablets) to remove chloramines (and chlorine) from water** because it is cheap and easy.

*Chlorine in this form (HClO) is "bleach" -- a disinfecting oxidizing agent -- and acts differently than the Cloride (Cl^-) ion contributed by salts, a topic covered later

METABISULFITE EASILY CLEARS CHLORINE AND CHLORAMINE FROM WATER

- Potassium metabisulfite or sodium metabisulfite effectively removes chloramine
  - Takes just a couple of minutes!
  - Campden tablets are a convenient form of metabisulfite
- Use 1/4 g, or 1/2 Campden tablet, per 10 gal
- Potassium Metabisulfite, sold in bulk powder ($4/lb), will last you forever
- (Metabisulfite comes in handy for wine must and cider making, but that is a different topic!)

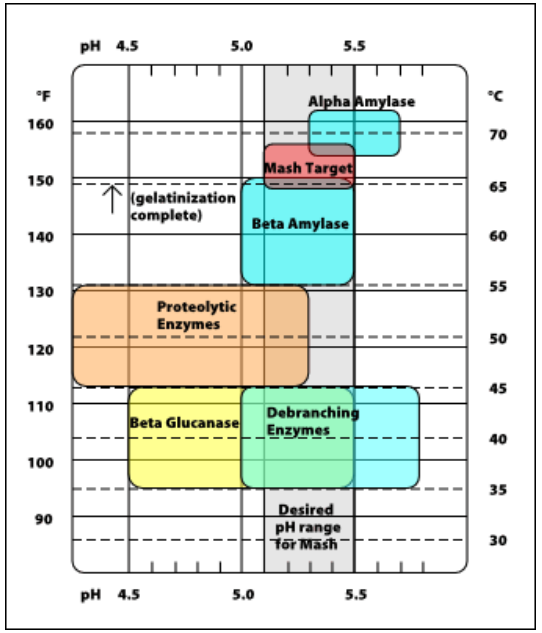
*Metabisulfite additions are a *small* amount of chemical and will not affect taste or mineral profile. Additions listed treat up to 3ppm chloramine*

More details than you'll ever need: http://morebeer.com/articles/removing_chloramines_from_water

Water pH, Hardness, and Alkalinity

Why you care about pH

- pH measures a solution's acidic or basic nature (1 acidic – 14 basic)
  - Acids (Latin *acidus/acēre*, means *sour)*
  - RO/ Distilled water pH is 7.0
  - Municipal Water has a pH of 6.5 – 8
    - Water companies want it slightly basic



Source: http://www.howtobrew.com/section3/chapter14-1.html

- *You care about pH when mashing*
  - *Target pH between 5.2 and 5.6*
    - *~5.5 for dark beers*
    - *~5.2 for tart, crisp beers*

- *You care about pH when sparging*
  - *Sparge water should be < 6.0 pH to prevent tannin extraction*

- *pH in mash impacted by the grain bill and **water alkalinity***
- *pH is typically adjusted by adjusting grain bill, salt buffers, and/or acids*

http://braukaiser.com/wiki/index.php?title=An_Overview_of_pH

Water Hardness

Hardness

- is due to the concentration of calcium (and magnesium) in water

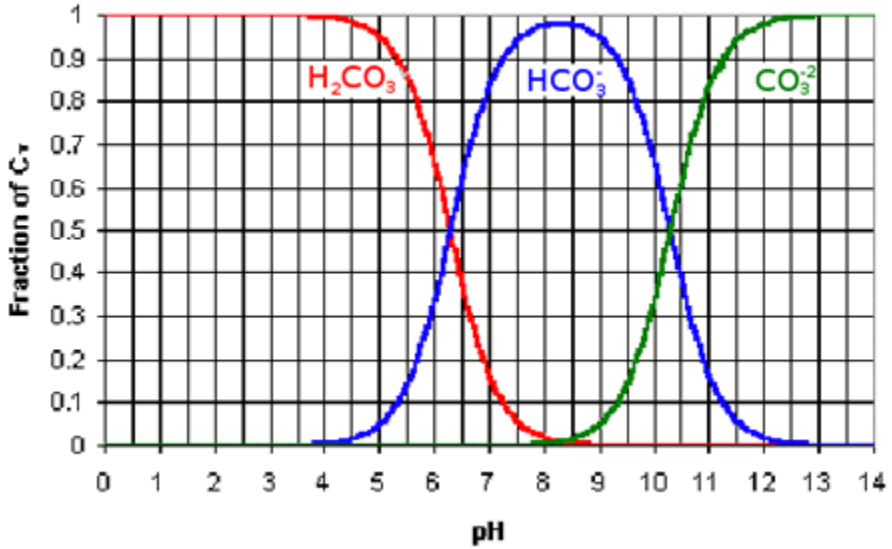
- Temporary Hardness:
  - Calcium or Magnesium paired with Carbonate/Bicarbonate
  - It can be boiled off (bi/carbonate leaves as CO2, calcium stays behind
- Permanent hardness
  - Calcium or Magnesium paired with Sulfates or Chlorides
  - Cannot be boiled off

Classification	hardness in mg/L	hardness in mmol/L	hardness in dGH/ °dH	hardness in gpg
Soft	0–60	0–0.60	0.3-3.00	0-3.50
Moderately hard	61–120	0.61–1.20	3.72-6.75	3.56-7.01
Hard	121–180	1.21–1.80	6.78–10.08	7.06-10.51
Very hard	≥ 181	≥ 1.81	≥ 10.14	≥ 10.57

Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-)

- These ions prevent decrease of pH (act as a buffer)
- They are twice as effective in raising wort pH as calcium is in lowering pH.
- Contribute to alkalinity
- Manage through pH adjustment

Carbonate and bicarbonate are in balance, based on the pH



Water Alkalinity

Alkalinity

- Is generally due to Carbonate / Bicarbonate in water*
- Acts as a buffer to pH changes (absorbs acids without changing pH much)
- ***Excessive alkalinity*** can make our mash pH too high, unless mashing with dark grains
  - We can lower by boiling, adding dark grains, adding acidulated malt, or adding acids

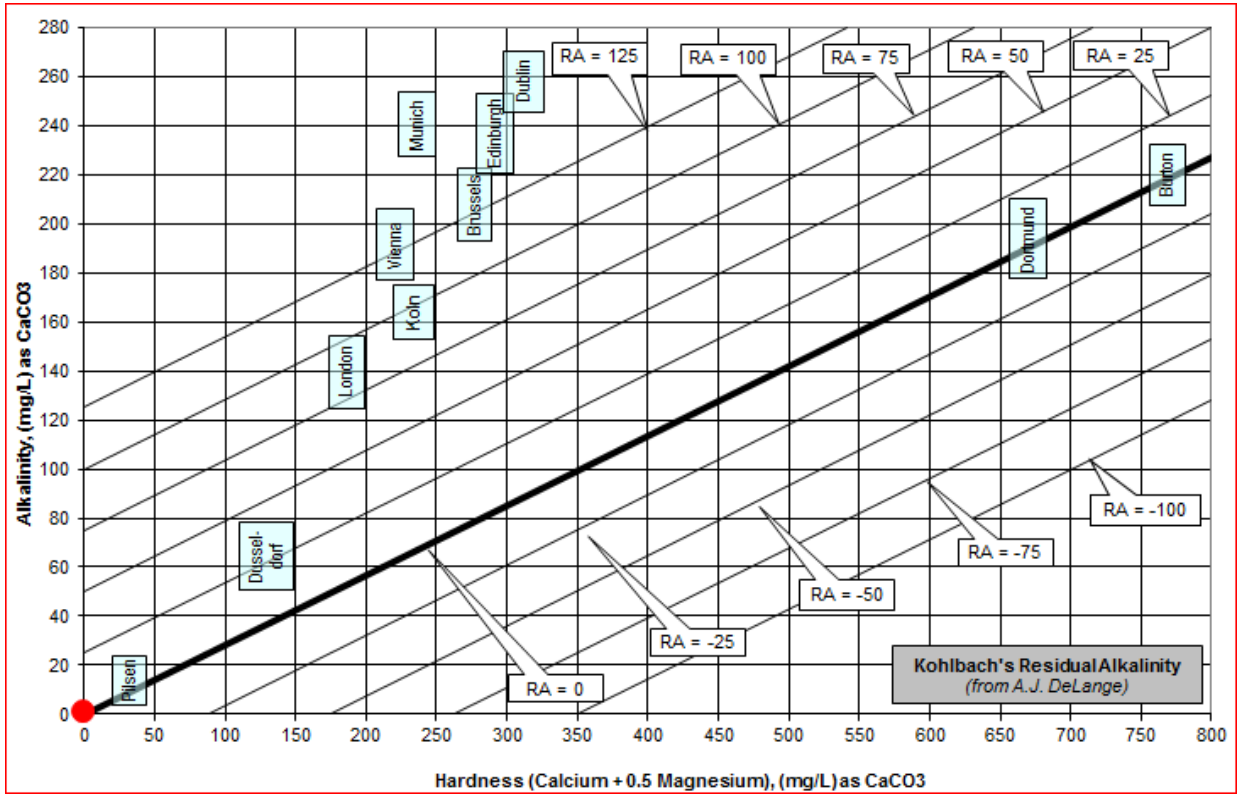
- ***Too little*** alkalinity:
  - will not work for dark beer mashes (Toasted malts make your pH lower, too low with low alkalinity water
  - Alkalinity can be raised with adding Pickling Lime, Potassium Hydroxide, or Sodium Bicarbonate (see table)

*Ground water Alkalinity is set equal to:

$$A_T = [HCO_3^-]_T + 2[CO_3^{-2}]_T + [B(OH)_4^-]_T + [OH^-]_T + 2[PO_4^{-3}]_T + [HPO_4^{-2}]_T + [SiO(OH)_3^-]_T - [H^+]_{sws} - [HSO_4^-]$$

Residual Alkalinity

- Residual alkalinity is the measure of alkalinity left after the acidity of the malt reacts with the water's hardness
- Helps predict mash pH based on water profile and beer color
- Not very accurate
- **Recommendation:** use the water calculator and buy a pH meter!



Water Rule #2: Buy a pH Meter

- Chemistry calculations, including Residual Alkalinity is great for understanding and predicting mash pH
- In practice, measuring and adjusting ACTUAL mash pH takes the guess work out of what often happens on brew day!
- Test strips aren't accurate enough!

Brewing Water Ions

(at least the ones you care about)

Important Ions For Brewing: Calcium (Ca^{++})

- Protects enzymes from thermal degradation, extends activity in mash
- Improves trub formation during wort boil
- Decreases pH during mashing and wort boil
  - 100 ppm calcium addition decreases pH by 0.4 pH units
  - However adding calcium is not an effective method for lowering pH (there are easier ways!)
- General rule:
  - 40-60 ppm is needed in packaged all malt beer.
  - 80-120 ppm calcium is required from brewing water AND calcium addition in mashing all-malt beer.

Important Ions For Brewing: Magnesium (Mg^{++})

- Magnesium salts are much more soluble than those of calcium.
- Less effect on wort pH
- Can provide slightly bitter or sour flavor to beer.
- General rule:
  - < 50 ppm

Important Ions For Brewing: Sodium (Na^+)

- At low concentrations (<100ppm), sodium gives a slightly sweet flavor to beer.
- But > 100 ppm, sodium gives a salty flavor.
- General rule:
  - < 100ppm
  - < 50 ppm for dry, crisp beers

Important Ions For Brewing: Sulfate (SO_4^{2-}) / Chloride (Cl^-)

- Chloride increases palate fullness and gives a mellow flavor to beer.
- Sulfate results in drier, more bitter flavors in beer.
- Sulfate can be a source of SO_2 and H_2S formed during fermentation that may give the beer a sulfury note (especially in "Burton" beers).
- **Sulfate to Cloride ratio** is generally used to target beer flavor profiles. A high ratio accentuates bitterness; a low ratio, sweetness
  - 2:1 Sulfate to Cloride => great for Pale Ales, IPAs
  - 1:1 Sulfate to Cloride => Balanced beers
  - 1:2 Sulfate to Cloride => Malty beers
- General Guideline:
  - Chloride below 100ppm
  - Sulfate below 100ppm generally, higher can work (up to 400ppm) for distinct Pale Ale beer character

Understanding your Water Ions

Sources of water information

Source	Accuracy	Cost
City Water Report	Low to medium	Free
Ward Labs	Very high	$30 / test
Testing Kits	Medium to high	$100 + / kit

Ward Labs: Brewers' Test "W-5A" $27.25

Ward Labs Test Results – Aptos, CA

		Hard Water Tap August '13	Water Softener August '13
	pH	7.7	7.7
	Total Dissolve Solids	484	500
	Electrical Conductivity, mmho/cm	0.81	0.83
	Cations/Anions, me/L	8.9 / 8.7	8.5 / 8.5
Ppm (mg/L)	Sodium, Na	67	188
	Potassium, K	8	8
	Calcium, Ca	82	2
	Magnesium, Mg	21	< 1
	Total Hardness, $CaCO_3$	293	5
	Nitrate, NO_3-N	< 0.1	< 0.1
	Sulfate, SO_4-S	33	32
	Chloride, Cl	61	59
	Carbonate, CO_3	< 1	< 1
	Bicarbonate, HCO_3	299	293
	Total Alkalinity, $CaCO_3$	245	240
	Total Phosphorus, P	0.02	0.03
	Total Iron, Fe	0.28	0.01

Water softener adds too much Sodium (> 100 ppm)

"<" – Not Detected / Below Detection Limit

Ward Labs Test Results
Los Altos, CA 2011, Winter vs. Summer

		Winter March '11	Summer August '11	RO Water (Pure Water)
	pH	7.9	7.9	6.6
	Total Dissolve Solids	249	395	12
	Electrical Conductivity, mmho/cm	0.41	0.66	0.02
	Cations/Anions, me/L	3.8 / 3.6	7.1 / 8.0	< 0.1 / <0.1
Ppm (mg/L)	Sodium, Na	41	28	< 1
	Potassium, K	2	1	< 1
	Calcium, Ca	22	78	< 1
	Magnesium, Mg	11	23	< 1
	Total Hardness, $CaCO_3$	101	291	< 1
	Nitrate, NO_3-N	0.3	4.7	0.1
	Sulfate, SO_4-S	20	11	< 1
	Chloride, Cl	33	49	< 1
	Carbonate, CO_3	< 1	< 1	< 1
	Bicarbonate, HCO_3	89	338	3
	Total Alkalinity, $CaCO_3$	73	277	3
	Total Phosphorus, P			
	Total Iron, Fe			

"<

Moderately hard in winter to VERY hard water in summer! (3X)

Adjusting Water

Water Profiles for Lager Styles

Type	Color	Bitterness	CA	Alkalinity	Sulfate	Chloride	Acidify	Styles
Light Lager	Pale	Soft	50	0-40	0-50	50-100	Yes	American Lager, Munich Helles
Medium lager	pale	Moderate	50-75	0-40	50-150	50-100	Yes	American premium lager, Germin Pils
Medium lager	amber	Soft, moderate	50-75	40-120	0-100	50-150	Maybe	Vienna, Oktoberfest
Medium lager	Brown/ black	Soft, moderate	50-75	80-120	0-50	50-150	No	American Dark, Munich Dunkel, Schwarzbier
Strong lager	Amber	Soft, moderate	50-75	40-80	0-100	50-150	Maybe	Helles, Traditional Bock, Doppelbock
Strong lager	Brown/ black	Soft, moderate	50-100	80-150	0-100	50-100	No	Traditional Bock, Doppelbock, Eisbock, Baltic Porter

Source: Water: A Comprehensive Guide, Palmer , pp 156-7

Water Profiles for Ale Styles

Type	Color	Bitterness	CA	Alkalinity	Sulfate	Chloride	Acidify	Styles
Light Ale	Pale	Moderate	50-100	0-80	100-200	50-100	Yes	Blonde Ale, American Wheat,, Best Bitter
Light Ale	Amber	Soft, moderate	50-150	40-120	100-200	50-100	Maybe	English Mild, Scottish 60/70/80
Light Ale	Brown / black	moderate	50-75	80-150	50-150	50-100	Maybe	English Brown, Dry Stout
Medium Ale	Pale	Soft, moderate	50-100	0-80	0-50	0-100	Yes	Weizen, Witbier, Koelsch
Medium Ale	Pale	Moderate, assertive	50-150	40-120	100-400	0-100	Maybe	American Pale Ale, IPA, Saison
Medium Ale	amber	Moderate, assertive	50-150	40-120	100-300	50-100	No	Altbier, Cal Common, Amber
Medium Ale	Brown/ black	Moderate, assertive	50-75	80-160	50-150	50-150	No	Brown, Dry Stout, Dunkelweizen
Strong Ale	pale	Moderate	50-100	0-40	50-100	50-100	Maybe	Belgian blonde, Golden strong, Tripel
Strong Ale	amber	Moderate, assertive	50-100	50-100	40-120	50-100	No	Strong Scotch Ale, Dubbel, Barleywine
Strong Ale	Brown / black	Moderate, assertive	50-75	120-200	50-150	50-150	No	Baltic Porter, RIS, Old Ale

Source: Water: A Comprehensive Guide, Palmer , pp 158-9

Brewing Water Adjuncts to adjust your Ions

Use your favorite water calculator to find right combination

Common Name	Molecular Formula	ppm impact at 1 gram/gal	pH impact	Use
Water Adjuncts				
Gypsum	**$CaSO_4 \cdot 2H_2O$**	**61.5 ppm Ca^{+2} 147.4 ppm SO_4^{-2}**	**down**	**Adds calcium to lower RA and sulfate to add crispness to hop bitterness**
Epsom Salt	$MgSO_4 \cdot 7H_2O$	26 ppm Mg^{+2} 103 ppm SO_4^{-2}	down	Can be used *sparingly* to lower pH, add Mg for yeast nutrition (5-30ppm) and add sulfate crispness. Too much Mg (>50ppm) adds sour/bitter flavor
Canning Salt	NaCl	104 ppm Na^{+1} 160.2 ppm Cl^{-1}		generally sodium should stay low for bitter beers, higher range of Na+ increases malt sweetness. NEVER add iodized salt.
Baking Soda	$NaHCO_3$	75 ppm Na^{+1} 191 ppm HCO_3^{-1}	up	use to add alkalinity but watch the Na+ levels
Calcium Chloride	$CaCl_2$	72 ppm Ca^{+2} 127 ppm Cl^{-1}	down	good for adding calcium without the sulfates, i.e., good source of calcium for light lagers
Chalk	$CaCO_3$	105 ppm Ca^{+2} 158 ppm CO_3^{-2}	up	Adds hardness, but not very soluable. Adding directly to the slightly acidic mash will dissolve ~50% of the chalk, so add 2x the perscribed amount. Alternatively for better control, can pre-mix brew water with pressurized CO_2 to re-create "hard" water (carbonic acid interacts dissolving chalk and making bicarbonate (HCO_3^{-1}) as principle anion). Keep in mind that boiling will reverse the effect (i.e. decarbonation) so don't go boiling your newly concocted HLT water!
Pickling Lime (Calcium Hydroxide)	$Ca(OH)_2$	142.9 ppm Ca^{+2} 121.3 ppm OH^{-1}	UP	Very effective at adding alkalinity to water. Use sparingly!
Magnesium Chloride	$MgCl_2 \cdot 6H_2O$	31.6 ppm Mg^{+2} 92 ppm Cl^{-1}		generally not used; alternative to Epsom salt for Mg addition
Potassium Bicarbonate	$KHCO_3$	103 ppm K^{+1} 161 ppm HCO_3^{-2}	Up	can be used to buffer pH/decrease acidity; more often seen in wine production since Ca is a more useful Cation in beer than K
Potassium Carbonate	K_2CO_3	149.5 ppm K^{+1} 114.7 ppm CO_3^{-2}	UP	Can be used as a pH buffer & increase alkalinity; unlike $CaCO_3$ it is soluable in water (1.1Kg/L at 20°C). Good for mead production since K is short & needed for yeast

Adjusting Ions with Salts in Brewing Water

- Use a mix of RO water to *lower* ions
- If desire is to impact mash, add salts to strike water or at start of mash
- Add salts *sparingly*. Gram scales are useful
- Spreadsheet and web calculators are very useful
- You can experiment with impact to flavor *after* brewing, if desired

Adjusting Water with Acids

- Acids can be used to adjust mash pH and acidify the sparge water
- Phosphoric Acid – Easy to use, will not impact flavor profile with its ion (Phosphate)
- Other options:
  - Lactic Acid (traditional, due to Reinheitsgebot, adds a smooth sourness)
  - Sulphuric Acid (adds sulfate)
  - Hydrochloric Acid (adds chloride)
  - Citric Acid (adds some sour fruitiness in larger concentrations)

Water Rule #3: Use a Water Calculator

- Uses water report ion concentrations, target beer style, and grain bill as input
- Provides recommendation for adjusting water with dilution (RO water), salt additions, and acid additions for the mash and sparge
- Several exist (see references at end for links):
  - Bru'n Water
  - EZ Water Calculator
  - Brewer's Friend Brewing Water Chemistry Calculator
  - Howtobrew.com water calculator

Bru'n Water Calculator (example)

Uses your source water and target profile as input, accounting for water dilution

Bru'n Water

Water Profile Adjustment Calculator

Check for Bru'n Water Updates

Desired Water Profile		Calcium (ppm)	Magnesium (ppm)	Sodium (ppm)	Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)	Cations (meq/L)	Anions (meq/L)	Total Hardness	Alkalinity (ppm)	RA (ppm)	SO_4/Cl Ratio	SRM Needed
Pale Ale Profile		165.0	18.0	25.0	300.0	55.0	180.0	10.8	10.8	487	149	20	5.5	4.6
Existing Water Profile		39.0	17.0	51.0	62.0	52.0	176.0	5.1	5.6	167	146	108	1.2	23.9
Dilution Water Profile														
RO Water		1.0	0.0	8.0	1.0	4.0	16.0	0.4	0.4	3	13	13		
Dilution Percentage	50	64.0	oz/gal	4.0	pt/gal	< These conversions are provided for your convenience								
Diluted Water Profile		20.0	8.5	29.5	31.5	28.0	96.0	3.0	3.0	85	79	60	1.1	13.4
Target Water Adjustment (ppm)		145.0	9.5	-4.5	268.5	27.0	84.0	7.8	7.7	402				
Actual Water Adjustment (ppm)		135.1	10.4	0.0	262.4	25.5	87.0	7.6	7.6	381				
Finished Water Profile		155.1	18.9	29.5	293.9	53.5	183.0	10.6	10.6	466	151	29	5.8	6.5

Water Additions

Water Amount to Treat (gallons) ---> 5.00

Mineral	Addition (gram/gal)	Calcium (ppm)	Magnesium (ppm)	Sodium (ppm)	Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)	
Gypsum ($CaSO_4$)	1.50	92.2			221.2			
Epsom Salt ($MgSO_4$)	0.40		10.4		41.2			
Canning Salt (NaCl)	0.00			0.0		0.0		
Baking Soda ($NaHCO_3$)	0.00			0.0			0.0	
Calcium Chloride ($CaCl_2$)	0.20	14.4				25.5		
Chalk ($CaCO_3$)	0.00	0.0					0.0	< This is the equivalent bicarbonate concentration
Pickling Lime ($Ca(OH)_2$)	0.20	28.6					87.0	< This is the equivalent bicarbonate concentration
Magnesium Chloride ($MgCl_2$)	0.00		0.0			0.0		

Acid	Addition (mL/gal)				Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)
Lactic	0.00	Strength	88.0	%	0.0	0.0	0.0

Approximate Color Descriptors for Water Profiles
Yellow: less than 6 SRM
Amber: 7 to 17 SRM
Brown: 18 to 30 SRM
Black: greater than 31 SRM

Total Mineral Additions (grams)	
$CaSO_4$	7.5
$MgSO_4$	2.0
NaCl	0.0
$NaHCO_3$	0.0
$CaCl_2$	1.0
$CaCO_3$	0.0
$Ca(OH)_2$	1.0
$MgCl_2$	0.0
Total Acid Addition (mL)	
Acid	0.0

Calculates salt and acid addtions based on source and target water profile

Water Adjustment for the Mash

1. Identify your water profile to match your beer style
   - Bru'n Water Calculator is my favorite
2. Adjust water to match style. Adjustment options:
   - Dilute source water with RO water to lower alkalinity and/or mineralization
   - Option: Boil to lower alkalinity via *decarbonation*
   - Add Salts to raise ions to profile
   - Add Acid (or, rarely, add alkalinity) to adjust pH
3. Ensure the mash pH is in target Range (5.2-5.6)
   - Mash pH is important, not the strike water
   - Use acid to lower pH

Water Rule #4: Acidify your Sparge Water

- Sparge water pH should be < 6.0 (I target 5.5)
- Higher pH can cause extraction of tannins (polyphenols) from the husks of your grain, imparting a harsh astringent flavor
- Many brewers acidify *all* of the brewing water because it is easier for them to do so
- If you acidify all the water, be sure to account for acid additions to your mash calculations

RESOURCES

- Bru'n Water calculator and Water knowledge https://sites.google.com/site/brunwater/
- EZ Water Calculator http://www.ezwatercalculator.com/
- Brewing Water Chemistry Calculator http://www.brewersfriend.com/water-chemistry/
- Howtobrew water calculator spreadsheet http://howtobrew.com/section3/Palmers_Mash_RA_ver3ptO.xls
- Water: A Comprehensive Guide for Brewers by John Palmer and Colin Kaminski http://www.amazon.com/Water-Comprehensive-Brewers-Brewing-Elements/dp/0937381993

Thank You!