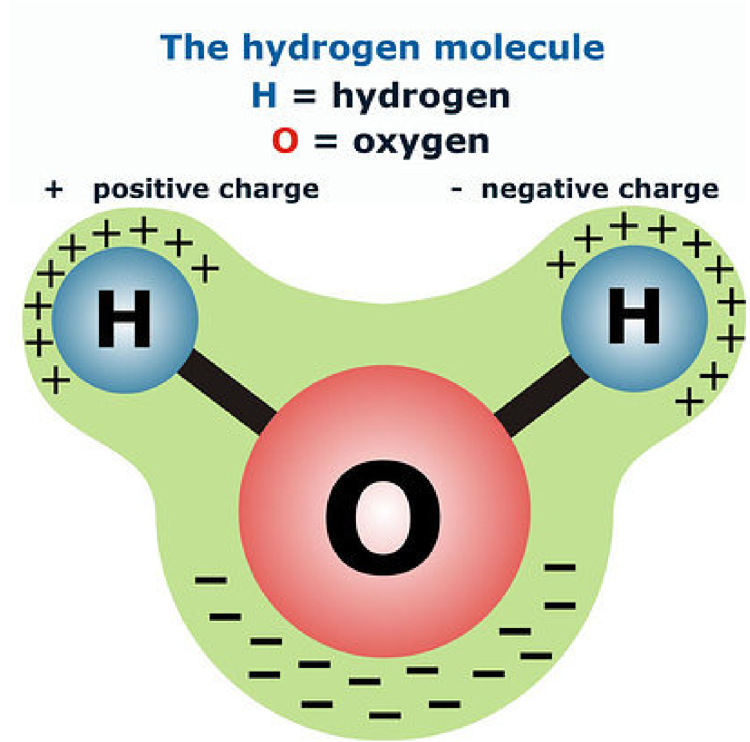
Water

Part One of Three

Water – It Makes Beer

The Universal Solvent

- Polar Covalent Bonds
  - Dissolves
    - Grain constituents in mash tun
    - Hop constituents in boil kettle
  - Disassociates salts
    - $NaCl \rightarrow Na^{+}(aq) + Cl^{-}(aq)$
    - Some salts are only partially soluble
    - $CaS0_4 \rightarrow Ca^{2+} + (aq) + S04^{2-} (aq)$



Hard versus Soft

- Hard Water contains calcium and magnesium salts in solution, in the form of bicarbonates when the water is drawn from a chalky or limestone source, or in the form of sulfates from sandstone sources. Hard waters have a fuller flavor and are thought to be most palatable and beneficial to consume.
- Soft water is frequently obtained from surface sources flowing through rocky terrain or can be abstracted from underground sources where the aquifer is gravel or laterite. The mineral content maybe very little and is usually sodium and potassium salts, such as bicarbonates, sulfates, chlorides, fluorides, or nitrates. The taste of soft water tends to be slightly soapy.

Total Hardness

- Total of all Ca and Mg salts and sum of all carbonate and non-cabronate hardness
- *Temporary* hardness (composed of $CaCO_3$, $Ca(HCO_3)_2$, $NaHCO_3$ and $MgHCO_3$) and *Permanent* hardness (MgSO4, CaSO4, CaCl, MgCl…)
- Analyzed as mmol/l liter by titration of ethylenediamine-tetra acetic acid(EDTA)
  - Hardness range 1—“soft” Up to 1.3 mmol/l
  - Hardness range 2—“average” 1.3 to 2.5 mmol/l
  - Hardness range 3—“hard” 2.5 to 3.8 mmol/l
  - Hardness range 4—“very hard” Over 3.8 mmol/l

Alkalinity, Temporary and Permanent Hardness

Temporary Hardness	Permanent Hardness
AKA Carbonate Hardness	AKA Non-Carbonate Hardness
Represents the Bicarbonate $HC0_3^{-1}$ and Carbonate $C0_3^{-2}$ content of water	Principally the Chloride and Sulfate salts of Calcium and Magnesium (MgSO4, CaSO4, CaCl, MgCl) content of water
pH increasing effect in solution through liberation of OH^{-1} $C0_3^{-2} + H_20 \leftarrow\rightarrow OH^{-1} + HC0_3^{-1}$ $HC0_3^{-1} + H_20 \leftarrow\rightarrow OH^{-1} + H_2C0_3^{-1}$	pH decreasing effect in solution through… ***insert formulae here***
It's role in brewing chemistry has been recognized for years as the major water treatment for most efficient beer production.	
These important reactions are, to a large extent, responsible for pH control throughout the brewing process	

Residual Alkalinity

Data Available	Formula
Alkalinity, Ca, Mg Hardness in ppm	= Alkalinity - Ca / 3.5 - Mg / 7
Alkalinity as $CaCO_3$, Ca and Mg in ppm	= Alkalinity (ppm as $CaCO_3$) - 0.714 x Ca (ppm) - 0.585 x Mg (ppm)
Alkalinity and Hardness both in Hardness as $CaCO_3$ ppm. Assume Hardness is 80% Ca and 20% Mg.	= Alkalinity - 0.80 x TH / 3.5 - 0.20 x TH / 7

- Result of the competition between the pH raising (carbonate hardness) and pH lowering (permanent hardness (all Ca and Mg ions except those which effects are neutralized by pH increasing ions)
- The higher the residual alkalinity, the more effective the carbonate hardness, the higher the pH to be expect.

Historical Data

- Certain brewing centers became renowned for particular beer types as a consequence of prevailing water composition.

Chemical Compositions (mg/l) of Various Brewing Waters

	Burton	Munich	London	Pilsen
Ca^{2+}	268	80	90	7
Mg^{2+}	62	19	4	1
Na^{+}	30	1	24	3
HCO_3^-	141	164	123	9
SO_4^{2-}	638	5	58	6
Cl^-	36	1	18	5
NO_3^-	31	3	3	0

•Burton on Trent – Strong Bitter Ales
•London and Munich – (Milds and Browns, lightly hopped dark lagers.)
•Pilsen – Higly hopped pale lagers

50 ppm <= $[Ca^{2+}]$ <= 150 ppm

- Arguably the most important mineral in brewing
  - Important to many enzymes, yeast, protein reactions in mash and boil
  - Promotes clarity, flavor and stability in finished beer
- Calcium rich water naturally acidifies the mash
  - Reacts with phosphates in malt, K_2HPO_4 and KH_2P0_4 to liberate H^+ lowering pH. $3\ Ca^{2+} + 2\ HP04^{2-} \leftrightarrow 2H^+ + Ca_3(PO4)_2$
- Sources include:
  - Calcium Sulfate ($CaSO_4$) , Calcium Chloride ($CaCL_2$) and Calcium Hydroxide ($Ca(OH)_2$)

10 ppm <= [Mg^{2+}] <= 30ppm [J1]

- Enzymatic cofactor [J2] during fermentation
- >50 ppm can give a sour-bitter taste to beer
- >150 ppm can be a diuretic and laxative effectsm
- Also “sours” the mash:
  - Half the pH lowering power of Calcium
- Sources Include:
- Epsom Salts $MgS0_4$

Slide 9

J1 Palmer - How To Brew
Jesse, 1/8/2012

J2 A cofactor is a non-protein chemical compound that is bound to a protein and is required for the protein's biological activity
Jesse, 1/8/2012

“Tasty Ions” – Sulfate, Chloride and Sodium

- Do not affect mash pH like the others
- Do affect perception of hops and malt
- Chloride to sulfate ratio an important factor
  - Can make a beer seem more malty, more bitter or sublimely balanced

0 <= Chloride (Cl^{-1}) <= 250

- The chloride ion also accentuates the flavor and fullness of beer Chloride does not have the same effect as chlorine. However, concentrations above 300 ppm (from heavily chlorinated water or residual bleach sanitizer) can lead to mediciney flavors due to chlorophenol compounds.

50 ppm <= Sulfate($SO4^{-2}$) <= 350 ppm[1]

- 50-150 ppm for normal beers
- 150-350 ppm for hop bombs
- It accentuates hop bitterness, making the bitterness seem drier and crisper.

[1] Palmer, John J. (2006). How to Brew: Brewers Publications

0 ppm <= $[Na^+]$ <= 150 ppm

- At 70 ppm to 150 ppm “rounds out” beers or provides “palate fullness” accentuates malty sweetness
- Concentrations above 150 ppm can impart salty/sour flavors
- Avoid combining lots of Na^+ with lots of SO_4, this can lead to a harsh unpleasant bitterness
- Some disagreement in literature about how much is too much, I play it safe and stay below 100ppm

Chlorine and Chloramine

- Recent problems at MBC, I suspect Chloramine as being the culprit.
- Could have been prevented by:
  - Carbon Filtering (cheap and effective)
  - Campden (Metabisulfate tablets)
- Would boiling have worked?
  - Prehaps if chlorine was being

References

- Palmer, John J. (2006). How to Brew: Brewers Publications
- Noonan, Greg (1996) New Brewing Lager Beer Water Chapter