

# BICEP #4

This session covers water, chlorophenol, metallic, mineral and salty off-flavors, as well as the English pale ale, American ale and India pale ale styles.

## Key to Abbreviations and Text

**Bolded Text (except for headers) is important information which you should know for the exam.**

*Italic Text is “just for fun” and won’t be covered on any of the exams.*

\* This material might appear on the Online Qualifier Exam.

† This material might appear on the Tasting Exam.

‡ This material will be (or might be) tested on the Written Proficiency Exam.

## Part 1: Water\*†‡

**Introduction:** Most beer is over 90% water, so not surprisingly it has an influence on flavor. Although its influence on beer flavor is subtle, more than any other ingredient, water characteristics helped define historical beer styles. For example, in order to get the proper mash pH when using the highly alkaline water of Dublin brewers had to use a higher percentage highly acidic highly kilned (dark) malts. As a result, Dublin is famous for its stouts. By contrast, the almost perfectly pure water of Plzen worked better for pale, sweet beers made using decoction mashing.

## A. Water Terminology

**Ions:** In reality, water itself has no influence on beer flavor. The real actors are ions in the water. Ions are positively and negatively charged molecules leached from the earth as the water flows over and through the ground. The fact that they are electrically charged helps them interact with chemicals in the malt and hops during the brewing process. Water which flows over limestone or chalk tends to have high levels of ions, while water which flows over granite, sandstone or lava tends to have lower levels. Ion levels are measured in terms of *parts per million* (ppm) which is the same as grams dissolved in 1 liter of water.

**Hard vs. Soft Water:** Hardness refers to level of minerals dissolved in water (usually calcium and magnesium ions). Water hardness is usually balanced by *water alkalinity*. Alkaline water is high in bicarbonates. Water with low levels of dissolved mineral salts (0-60 mg/l) is said to be “soft.” Water with higher levels (60-120 mg/l) is moderately hard, water with high levels (121-180 mg/l) is “hard” and water with higher levels (181+ mg/l) is very hard. Hard water causes scale on pipes, plumbing fixtures and brewing equipment, but is also desirable for brewing certain styles of beer. It is caused by water flowing over or through limestone, chalk, gypsum or dolomite.

About 85% of homes in the U.S. have moderately hard or harder water. Generally, areas with underlying sand, sandstone or granite rock formations have soft water, while areas with underlying shale or limestone rock formations have hard water. Areas with soft water include parts of New England, the Pacific Northwest and Hawaii. Large areas of the South, Midwest and Southwest (including Southern California) have very hard water. A very rough rule of thumb is that if there are a lot of caves in your part of the world, you probably have hard water. If there are mountains or volcanoes, you probably have soft water.

**Temporary vs. Permanent Hardness:** Temporary hardness refers to concentrations of mineral salts which can be precipitated out of solution by boiling or treatment with lime. These precipitated minerals are responsible for “lime scale” which occurs on plumbing fixtures in areas of hard water. Minerals responsible for permanent hardness can only be removed by ion-exchange systems, such as reverse osmosis or water softeners. **Carbonate and bicarbonate compounds are responsible for temporary hardness. Sulfate and chloride compounds are responsible for permanent hardness.**

Total water hardness is reported in ppm of Calcium Carbonate (CaCO<sub>3</sub>). Temporary hardness refers to the level dissolved ions after the water has been boiled or treated with lime (Calcium Hydroxide, CaOH-).

Permanent hardness refers to the dissolved ion levels after this treatment. Permanent hardness is caused by the presence of calcium and magnesium sulfates and/or chlorides in the water, which become more soluble as the temperature rises. Despite the name permanent hardness can be removed using a water softener or ion exchange filter.

**Water pH:** pH is a 0-14 logarithmic scale which measures the concentration of free hydrogen atoms in a solution. The more free hydrogen atoms, the more **Acidic** the solution. Solutions with low levels of free hydrogen are said to be **Basic** or **Alkaline**. **The pH scale goes from 1 (extremely caustic acids) to 14 (extremely caustic bases).** Bases generally taste bitter or soapy while acids generally taste sour.

**Pure water has pH 7.** Tap water has a pH of 6.5-8.5, typically 7.2-7.8. Unfermented wort has a pH of about 5.5 while fermented beer has a pH of 3-4.7. By comparison, wine has pH 2.7-3.5, apple juice has pH 3-3.5, Coffee has pH 5, a baking soda solution has pH 8-9, soapy water has pH ~10 and household bleach as pH ~12.

Water with high levels of carbonates and bicarbonates has a pH above 7 and is said to have a high level of Total Alkalinity. **Note that water hardness and water alkalinity are not always related. Water can be soft and alkaline, or hard and acidic!**

**Brewing Salts:** Chemically, a salt is formed when a positively charged atom and a negatively charged atom bind together to form an ionic bond. Typically, these compounds are water soluble solids. This means that salts dissolve in water, allowing the two charged atoms float about in solution separately from each other, but reassociate when the water evaporates. The most common salt is table salt - sodium chloride, but brewers use a number of similar salts, such as magnesium sulfate or potassium chloride.

### pH of Common Substances

Substance	pH
Battery acid	0.5
Gastric acid	1.5 – 2.0
Lemon juice	2.4
Cola	2.5
Vinegar	2.9
Orange or apple juice	3.5
Beer	4.5

Acid Rain	<5.0
Coffee	5.0
Tea or healthy skin	5.5
Ideal mash pH	5.3-5.8
Milk	6.5
Pure water	7.0
Rochester City Water	7.6
Healthy human saliva	6.5 – 7.4
Blood	7.34 – 7.45
Sea water	8.0
Hand soap	9.0 – 10.0
Household ammonia	11.5
Bleach	12.5
Household lye	13.5

(Adapted from Wikipedia entry on pH)

#### Relative Water Hardness

Relative Hardness	Ca++ ppm
Soft	0-20
Moderately soft	20-40
Slightly hard	40-60
Moderately hard	60-80
Hard	80-120
Very Hard	>120

(Adapted from Wikipedia entry on Hard Water)

## B. Brewing Water

Water constitutes ~85-90% of beer so, by volume, it is the most important component. Water is also necessary for hydrating the mash, cleaning, rinsing and sanitizing, so brewers use a lot of water which doesn't actually make it into the finished beer. In some parts of the world, where water is rare and expensive, brewers must practice careful water conservation and recycling measures.

**Suitability of Water for Brewing:** Water is unsuitable for brewing if it has:

- \* *Detectable (i.e., testable) levels of metallic ions.*
- \* *High levels pollutants:* nitrogen compounds or other contaminants (e.g., decayed plant material, algae, pollutants).
- \* *Smells and/or tastes bad* for any other reason.

**Sources of Brewing Water:** Brewers get their water from a number of sources, but different water sources are susceptible to different problems.

**1. Flowing Water:** Water from lakes or streams might have unacceptable levels of contaminants due to contact with pollutants or decaying organic matter (e.g., algae). It must at least be boiled before it can be used. Historically, many brewers used flowing water but none do so today.

**2. Municipal Water:** Due to national standards for drinking water, most city water supplies are suitable for brewing with minimal treatment. To control bacterial contamination, city water supplies are treated with chloramines (more rarely chlorine). **If not removed, these chlorine compounds can complex into unpleasant-tasting chlorophenols during the fermentation process. High levels of chlorine compounds are also toxic to yeast.**

**3. Well Water:** Well water suitable for brewing straight from the tap as long as it is otherwise fit for drinking. In many parts of the country, **well water might have very high levels of dissolved ions (e.g., calcium, sulfate) or unacceptable levels of metallic ions (e.g., iron) or contaminants (e.g., nitrates).**

In some cases, breweries can get both hard and soft water, by sinking wells into different rock strata. Water drawn from rocks which are mostly composed of silicon, like sandstone or granite, is generally soft. Water drawn from other types of rock, such as shale or limestone, is harder and is higher in levels of dissolved ions.

## C. Treatment Methods

Virtually all water must be treated in some way before it can be used for brewing. Most brewers use at least one of these methods. Beer judges should know them all.

**1. Boiling:** A rolling boil of at least 30 minutes, followed by cooling, drives off chlorine in the water. It also kills most microorganisms (but not heat-resistant bacteria spores) and precipitates calcium ions.

**2. Charcoal Filtration:** A charcoal filter, such as a countertop cartridge filter or a Brita™ filter, removes chlorines, chloramines and metallic ions from water filtered through it. The filters on these devices must be replaced at regular intervals for them to be fully effective, however.

**3. Distilled Water:** Removes virtually all foreign material from water. If you use 100% distilled water, though, you must put ions back into your water in order to get the proper levels for mash conversion and yeast development. Distilled water can be added to water treated in other means in order to dilute excessively high levels of ions.

**4. Potassium Metabisulfite (AKA Campden Tablets):** 1 tablet (~0.44 grams) added to 20 gallons of water converts chloramines to volatile chlorine and sulfites within 15 minutes. The water can then be boiled or left to stand to remove both the sulfites and the chlorine.

**5. Reverse Osmosis Filtration:** Removes almost all bacteria, chlorine, chloramines and ions from water. If you use 100% reverse osmosis water, though, you must put ions back into your water in order to get the proper levels for mash conversion and yeast development. Reverse osmosis water can be added to water treated in other means in order to dilute excessively high levels of ions.

**6. Standing:** Letting tap water stand in an open container for at least 24 hours will allow most chlorine to evaporate. Letting it stand in the sun accelerates the evaporation rate. **This technique doesn't work for water treated with chloramines.**

**7. Water Softening:** Typical ion-exchange water softeners remove calcium and magnesium ions, replacing them with sodium ions. They also remove some metallic ions, such as lead and copper. Softened water can reduce levels of calcium and magnesium below those needed for optimum mashing and yeast nutrition, while increasing the levels of sodium ions to unacceptable levels.

## D. Adjusting Water pH

All-grain brewers must know how to adjust water pH in order to bring their mash pH into optimal ranges for enzyme activity. Since diastatic enzymes work best at pH 5.2-5.7, acid must be added to neutral or basic mash water, while a base must be added to neutralize acidic water. High hardness water is usually basic (pH 7.1-8.5 or more).

Historically, beer brewed using basic water was acidified by generous additions of highly-roasted, acidic malts. These days, mash water is generally acidified using food grade acid (usually Phosphoric Acid -  $H_3PO_4$  or Lactic Acid). This is especially important if calcium carbonate is also added to the mash water to promote enzyme activity.

**Adjusting pH: For optimal mashing, the mash and sparge water must have a pH of 5.2-5.8. Above pH 5.8 astringent tannin compounds can be extracted from grain husks.** This means water pH must be adjusted to suit the mash. The three main methods used in modern brewing are acid treatment, salt additions and buffering solutions, but all methods of adjusting mash pH are listed below:

**1. Acid Rest:** This is an obsolete, but traditional, method of lowering mash pH when working with undermodified light-colored malts. Pale malt is held at 95 °F for up to 2 hours, so that it converts phytins in the malt to phytic acid. This method was traditionally used to brew Bohemian Pilsners with very soft water. It isn't necessary when using modern ingredients and techniques.

**2. Acid Treatment:** This is the most common method of adjusting mash pH in the brewery. Mash and sparge water can be treated with food-grade acids (typically lactic acid or phosphoric acid, although some commercial breweries use sulfuric acid for economic reasons). Too much acid can impart unwanted sourness to the beer.

**3. Acidulated Malt (AKA Sauermalz or Sour Malt):** Brewers who wish to comply with the Reinheitsgebot use acidulated malt in order to acidify their mash. Acidulated malt is malt which has been allowed to sour mash and then dried. It contains 1-2% lactic acid. Up to 10% acidulated malt can be added to the grist.

**4. Buffering Solutions:** Five Star Chemical Company makes a food-grade pH buffer called 5<sup>TM</sup> that "locks" mash pH at 5.2. Added at 2 oz/31 gallons (~0.5 ml/l or ~0.33 oz/5 gallons, more for very alkaline water, less for soft water), it works by overriding the mash's natural buffering capacity. In most cases, it negates the need for pH testing and acid or salt additions. This is a new method which is gaining popularity with homebrewers and craft brewers.

The problem with buffering solutions, however, is that if the brewing water is already high in minerals they can give unwanted salty or mineral character to the beer. Buffering solutions can also interfere with other salts the brewer wishes to add to the beer.

**5. Dark Malt:** Dark malt is naturally slightly acidic. Beers made with dark malt reduce mash alkalinity by 0.1-0.2 pH or more, based on the amount of dark malt in the grist. This method was used traditionally in areas with alkaline water.

**6. Salt Additions:** Magnesium and calcium will reduce mash pH if added as salts which don't contain carbonate or bicarbonate. For this reason, salts such as calcium chloride,

## Water Treatment Reports

In the U.S., and most of the rest of the developed world, local water suppliers issue regular water quality reports, which list levels of all the important ions needed for brewing, in addition to other data, like levels of contaminants. Generally, these reports are free and many are available on the web.

In the United States, the Clean Water Act requires municipal water systems to produce annual water quality reports. In many cases these reports are online. If they are not available, you can call or write to the local water authority asking for an analysis of various ions in the water.

The ion levels (and contaminant levels) in other water sources (mostly well water) are determined by private, for-hire, water analysis companies. If using well water, the company that tests your water for safety should also be able to give a complete water quality analysis.

Some ion levels (e.g., Chlorine, Carbonates) can be detected using aquarium water testing kits, although these aren't particularly accurate.

If all else fails, you can use reverse osmosis water and treat it yourself to produce a particular water profile.

The ion levels of minerals necessary for brewing fall into a range, which is listed as an average level. **Depending on the exact time of year, and where the brewery is located, these values might change.**

**magnesium sulfate (AKA Epsom salts) or calcium sulfate (gypsum) are sometimes used to adjust mash pH.**

The problem is that excessive levels of ions can impart unwanted characteristics to beer, especially if the brewing water is already high in dissolved ions.

## E. Important Brewing Ions

Unless it has been distilled, water contains ions - positively or negatively charged atoms - from chemical compounds, usually salts, which have dissolved in the water.

For brewing purposes, these are the most important ions:

**1. Metallic Ions:** Iron (Fe+), Manganese (Mn+), Copper (Cu+), Zinc (Zn+). These are all necessary in trace amounts for yeast health. In excessive concentrations they can cause haze and produce metallic off-flavors. Metallic ions are generally present in sufficient levels in water that they don't need to be added.

**2. Salts:** These are simple water soluble chemical compounds consisting of a positively charged molecule or atom (a **Cation**) and a negatively charged molecule or atom (an **Anion**).

**I. Cations:** Positively charged ions:

**A. Calcium (Ca++):** The primary source of water hardness. Also described as temporary hardness. Reduces mash pH, 10-20 g/ml are needed for yeast nutrition. Calcium can be precipitated by boiling water and then letting it stand.

**B. Magnesium (Mg++):** The next biggest source of water hardness. Also described as permanent hardness because it can't be precipitated by boiling or lime treatments. It is an important enzyme cofactor and yeast nutrient. At 10-30 mg/l it accentuates beer flavor. At higher levels it imparts a harsh bitterness. At 125+ mg/l it is cathartic and diuretic.

**Sodium (Na+):** Imparts a sour, salty taste to beer. At 2-100 mg/l it accentuates beer sweetness. Higher levels are harsh-tasting and are poisonous to yeast.

**II. Anions:** Negatively charged ions.

**A. Carbonate/Bicarbonate ( $\text{HCO}_3^-$ ,  $\text{HCO}_3^-$ ):** Sometimes expressed as alkalinity or temporary hardness. These compounds are strong alkaline buffer which raise mash pH and neutralize acids. They can contribute a harsh, bitter flavor to beer. Their alkaline effects are traditionally countered by brewing beers made with dark malts. Carbonates also help extract color from malt, giving darker colored beers.

**B. Chloride ( $\text{Cl}^-$ ):** At 200-400 mg/l chloride accentuates sweetness, “mellowness” and perception of palate fullness. It also improves beer stability and improves clarity. Excessive levels can be bitter and salty.

**C. Sulfate ( $\text{SO}_4^{2-}$ ):** Also described as permanent hardness because it can't be precipitated by boiling or lime treatments. Sulfate ions impart dryness, fuller flavor and astringency to beer. They also aid alpha acid extraction from hops and increase the perception of hop bitterness. These effects become more concentrated at 200-400 mg/l. At levels above 500 mg/l sulfate becomes highly bitter.

## F. Famous Brewing Waters

Historically, before about 1850 when brewers learned to treat their water, variations in water characteristics led to the development of certain beer styles. For purposes of the exam, the “correct” answers are given below. [My personal research/opinions are given in brackets. Regardless of what I have to say, though, when taking the exam “print the legend.”]

**Burton-on-Trent:** High total alkalinity and moderately high permanent hardness, with very high levels of calcium carbonate and calcium sulfate. This gave Burton beers a drier, fuller finish and accentuated hop bitterness making it perfect for brewing pale, highly hopped beers.

[In the early 19<sup>th</sup> century, the superiority of Burton water led to them taking much of the pale ale trade away from the London brewers. By about 1850, however, London brewers had learned to “Burtonize” their water, by adding mineral salts.] *Beer Styles:* English Pale Ale, IPA, English Barleywine.

**Dortmund:** High total alkalinity and permanent hardness, with high sulfate and moderate carbonate levels. This accentuates hop bitterness and imparts “mineral” & sulfury hints. Historically, Dortmunder export was developed in the 1890s, after brewers had a keen understanding of water treatment, so local water character probably didn't play a big role in the emergence of the Dortmunder style. According to Jamil Zainasheff, Dortmunder brewers probably treated their water. *Beer Style:* Dortmunder Export.

**Dublin:** High total alkalinity, moderately high permanent hardness. Moderate levels of sulfates, very high levels of carbonates. Somewhat similar to London, so highly suited to brewing dark and amber beers. *Beer Styles:* Dry Stout, Porter, Irish Red Ale.

**Edinburgh:** Medium carbonate water with medium calcium levels and low sulfate levels, somewhat similar to London. Before Edinburgh brewers sunk wells in the 18<sup>th</sup> century, they might have used surface water which ran off from local peat bogs, which would have added “smoky” notes to their beer. Edinburgh has water similar to London's but it has more bicarbonate and sulfate, giving its beers a heavier malt body.

[By the late 18<sup>th</sup> century Edinburgh brewers had access to both hard and soft water, sometimes within the same brewery, and could brew any style of beer they wanted. They were also

## Treating Your Water

While there is a temptation to adjust mineral and pH levels to perfectly emulate the brewing process of some famous brewery, resist the urge to fiddle too much with your water. And, if you must adjust your water chemistry be careful.

You must know your water's pH and mineral profile in advance. From there calculate how much acid or salts you need to add, then measure carefully before you make any additions.

In most cases, it is better to have too few ions than too many. Bringing ion levels down to a desired level is much harder. While you can reduce carbonate levels by boiling, the only method of reducing other ion concentrations is to dilute your water with distilled water.

If you're trying “engineer” your water to perfectly hit some famous brewing water, it is probably better to start off with distilled water and add salts and acids rather than trying to guess at your water's mineral concentration.

Finally, remember that water measurements usually fall into a range of values. Be aware of seasonal variations in your water, and don't worry too much about hitting some exact magic number of dissolved ions.

*major exporters of IPA and pale ales. The idea of commercial brewers using peaty surface water is nonsense since brewers of the period tried to avoid smoke flavors and surface water was likely to be badly polluted. But, if asked for this information on the BJCP Written Proficiency exam “print the legend.”* *Beer Styles:* Scottish Ales, Scotch Ale. [And, actually, any style of ale. But, “print the legend.”]

**Köln:** Soft water, with low levels of calcium, magnesium, bicarbonates which favor the production of lighter, sweeter beers.

**London:** Medium to high total alkalinity and medium to high permanent hardness, with medium levels of sulfate and calcium. Well suited to producing dark, sweet beers. [Actually, there is no one profile for London water - it varies widely depending on the depth of the well, the location of the brewery, and in some cases, the flow of the tide up the Thames. Water drawn from the river itself is even more variable! Also, by about 1850, London brewers learned to treat their water by adding mineral salts. That said, the profile given above is fairly typical.] *Beer Style:* Brown Porter, Sweet Stout, Southern English Brown, Pale ales.

**Munich:** High total alkalinity and moderately high permanent hardness. It also has high levels of sulfates. It is suitable for beers with higher color and darker malt, such as Oktoberfest. [Historically, Munich brewers learned to adjust their water chemistry about the same time that everyone else did. Since most Munich beer styles emerged in their modern form after 1850, water character probably didn't have much to do with the development of modern Munich beers. It's also odd that despite the high sulfate water, most Munich styles are malty!] *Beer Styles:* Munich Dunkel, Dark and amber lagers, Bocks.

**Plzen:** Extremely soft water, with very low total alkalinity, and low overall ion levels. As close to pure water as ground water gets. Lack of ions decreases perception of hop bitterness, and historically made acid rests and decoction mashing necessary due to lack of minerals to aid

enzymatic reactions in the mash. *Beer Style:* Bohemian Pilsner.

*Vienna:* High total alkalinity and moderately high permanent hardness. High in calcium and medium high in carbonates. Somewhat similar to London or Dublin. Suited to

amber or dark, sweet beers. *Beer Style:* Vienna Lager [Amber Lager].

#### Brewing Ranges For Major Ions in Beer (PPM)

Name	Range	Sources	Effects	Notes
<b>Bicarbonate (HCO<sub>3</sub><sup>-</sup>)</b> <b>Carbonate (CO<sub>3</sub><sup>--</sup>)</b>	0-250	Baking Soda (NaHCO <sub>3</sub> ), Chalk (CaCO <sub>3</sub> ), MgCO <sub>3</sub>	<b>Mash:</b> Strongly alkaline. Resists acidification in mash. Hinders Alpha Amylase. Reddens pale beers. Impedes cold break. Brewing ranges: 0-50 ppm for pale malt beers, 50-150 ppm for amber or toasted malt beers, 150-250 ppm for dark, roasted malt beers. <b>Beer:</b> Emphasizes harsh bitterness. High levels best for lightly hopped dark beers.	<b>Carbonate: Main source of H2O permanent hardness &amp; alkalinity.</b> <b>Bicarbonate:</b> Main form of carbonates in H <sub>2</sub> O at =<pH 8.4. Similar properties to carbonates but half the pH buffering capacity. Can be removed from H <sub>2</sub> O by boiling in presence of Ca <sup>++</sup> , converting it to CaCO <sub>3</sub> (precipitates) & CO <sub>2</sub> .
<b>Sulfate (SO<sub>4</sub><sup>--</sup>)</b>	50-350	Epsom Salts (MgSO <sub>4</sub> ), Gypsum (CaSO <sub>4</sub> ), Na <sub>2</sub> SO <sub>4</sub>	<b>Mash:</b> Acidifies. Best for pale, dry beers (e.g., pale ales). <b>Beer:</b> Enhances clean, dry, crisp hop flavor. Decreases hop bitterness. Lightens color. Normal brewing range: 50-150 ppm or 150-350 ppm for very bitter beers.	>400 ppm gives astringent hop bitterness, >750 ppm causes diarrhea. <b>Contributes to permanent hardness</b> since doesn't precipitate when boiled.
<b>Chloride (Cl<sup>-</sup>)</b>	0-250	Nigari (MgCl <sub>2</sub> ), No-sodium salt (KCl), Pickling salt (CaCl <sub>2</sub> ), Table salt (NaCl)	<b>Mash:</b> None. <b>Beer:</b> Increases hop bitterness. Accentuates malt flavor and fullness of body.	>300 ppm inhibits yeast growth, interacts with mashing & fermentation byproducts to produce chlorophenols (medicinal off-flavors).
<b>Calcium (Ca<sup>++</sup>)</b>	50-150	Chalk (CaCO <sub>3</sub> ), Gypsum (CaSO <sub>4</sub> )	<b>Mash:</b> Acidifies. Precipitates phosphates. Aids enzyme action. Improves runoff. Speeds proteolysis. <b>Beer:</b> Enhances stability. Aids clarification.	Main measure of <i>hardness</i> .
<b>Magnesium (Mg<sup>++</sup>)</b>	10-30	Epsom Salts (MgSO <sub>4</sub> ), MgCO <sub>3</sub>	<b>Mash:</b> Acidifies. Precipitates phosphates. <b>Beer:</b> Yeast nutrient at 10-20 ppm, bitter/sour taste >50 ppm	Laxative & diuretic >125 ppm, minor effects on <i>hardness</i> .
<b>Sodium (Na<sup>+</sup>)</b>	0-150	Baking soda (NaHCO <sub>3</sub> ), Table salt (NaCl), Na <sub>2</sub> SO <sub>4</sub>	<b>Mash:</b> None. <b>Beer:</b> 70-150 ppm accentuates malt sweetness, gives "roundness" to body. >200 ppm gives taste salty taste, inhibits yeast growth.	High levels in H <sub>2</sub> O treated by commercial softening systems. High combined Na <sup>+</sup> & SO <sub>4</sub> <sup>+</sup> levels give very harsh hop bitterness

(Adapted from *Brewer's Companion*, Randy Mosher & *How to Brew*, Jim Palmer)

### Maximum Acceptable Limits of Trace Ions in Brewing Water (PPM)

Name (Symbol)	Max.	Notes
<b>Aluminum (Al)</b>		Causes haze. May leach from cooking or storage vessels.
<b>Ammonia (NH<sub>3</sub>)</b>	0.05	Symptom of organic contamination. High levels toxic to microorganism, humans. Can produce strong unpleasant odors.
<b>Arsenic (As), Beryllium (Be), Nickel (Ni)</b>	0.05-0.1	As for Cadmium, <i>et al</i> , but not as bad.
<b>Cadmium (Cd), Mercury (Hg), Silver (Ag)</b>	.0001-0.01	Very powerful yeast inhibitors. Can be toxic to humans. Produces metallic off-flavors. Contributes to haze formation.
<b>Chloramines</b>		Have largely replaced Chlorine as antiseptic in tap water. Have the same undesirable properties as Chloride, but can only be removed by carbon filtering.
<b>Chlorine, Free (Cl)</b>		Added to some tap water as antiseptic. Highly toxic to yeast. Carbon filtration removes. Reduced by boiling or standing uncovered for several days.
<b>Copper (Cu)</b>	0.05-0.1	Important yeast nutrient, but inhibits growth at high levels. Reduces sulfur components in fermentation. Can produce off-flavors, haze. Can be leached from brewing equipment.
<b>Fluorine (Fl)</b>	1.5	Fluorides added to tap water supplies to prevent dental cavities. Also naturally present in some H <sub>2</sub> O. No effect on yeast growth. Can produce off flavors at high levels.
<b>Iodine (I)</b>		Kills microorganisms above 25 ppm. At lower levels inhibits yeast growth. Can impart medicinal or bitter flavors to beer. Present in iodine-based sanitizers and in small amounts in iodized table salt. <i>To avoid, use non-iodinized salt in brewing and dry or rinse iodine cleanser from brewing equipment.</i>
<b>Iron (Fe)</b>	0.3	Causes yeast degeneration, haze, and unpleasant metallic flavors. Often in well water. Removed via sand filtration, oxygenation, chemical treatment.
<b>Lead (Pb)</b>	0.1	Toxic to yeast, humans, causes haze. May be leached from solder or brass fittings.
<b>Manganese (Mg)</b>	0.05	Similar to iron, often a problem in ground water.
<b>Nitrate (NO<sub>3</sub>)</b>	1	Contaminant from fertilizer runoff or sewage. Toxic to yeast.
<b>Nitrite (NO<sub>2</sub>)</b>	25	As per Nitrates. Over 10 ppm = polluted water. Very toxic to microorganisms. Used to preserve meat. Carcinogenic.
<b>Silica (SiO<sub>2</sub>)</b>	10	Relatively inert but can create colloidal haze. Found in ground water, also leached from malt husks.
<b>Tin (Sn)</b>	1.0	Powerful haze-former. May be leached out of solder joints or bronze/brass fittings.
<b>Zinc (Zn)</b>	1.0	Needed in small amounts for yeast nutrition, but harmful in larger amounts. Toxic to humans at high concentrations. Causes metallic off-flavors. Can leach from brass fittings.

(Adapted from *Brewer's Companion*, Randy Mosher)

### Water Profiles for Various Beer Styles

Beer Style	Ca	Mg	Na	SO <sub>4</sub>	Cl	HCO <sub>3</sub>	Historical Origin
Alt	30-45	0	25-30	70-110	40-50	0	Düsseldorf, N. Germany
Bitter	60-120	10	15-40	180-300	25-50	0	London, Burton-on-Trent
Bock	55-65	0	40-60	35-55	60-90	60	Bamberg, Munich
Brown Ale	15-30	0	40-60	35-70	60-90	0	Burton-on-Trent, London, Newcastle-on-Tyne
Doppelbock	75-85	0	40-70	35-55	60-110	90	Bamberg, Munich
Dortmunder Export	60-90	0	45-60	140-210	70-90	0	Dortmund
Lager, Dark	75-90	0	40-60	35-70	60-90	90	Kulmbach, Munich
Lager, Light	35-55	0	20-35	85-130	35-55	0	Dortmund, Munich
Mild	25-50	10	30-40	95-170	50-60	0	Burton-on-Trent, London, Newcastle-on-Tyne
Munich Dunkel	50-75	0	5-15	20-35	5-20	60	Munich
Oktoberfest/Märzen	30-60	0	30-40	70-140	45-60	0	Munich
Pale Ale	100-150	20	20-30	300-425	30-50	0	Burton-on-Trent, London
Pilsener	7	2-8	2	5-6	5	15	Plzn, Munich
Porter	60-70	0	40	50-70	60	60	London
Scottish Ale	20-30	0	12-20	50-70	18-30	0	Edinburgh
Stout, Dry	60-120	10	10-20	35-110	18-30	20-80	Dublin
Stout, Sweet	55-75	0	10-20	35-55	18-30	20-80	Dublin, London
Weizen	15-30	0	5-15	35-70	10-20	0	Munich

(Adapted from *Zymurgy* Vol. 14, No. 5)

### Water Characteristics of Various European Cities & Regions

City/Region	pH	Ca	Mg	Na	SO4	Cl	CO3	Tot. Hard	Breweries
Achouffe, BE		29	4	12	12	35	72	87	d'Achouffe
Antwerp, BE	8.0	90	11	37	84	57	76		De Koninck
Anvers, BE		65	7	16	48	30	159	189	Westmalle, Duvel
Ardennes, BE		60	13	11	25	24	213	200	
Beerse, BE		41	8	16	62	26	91		Westmalle
Bamberg, DE 1	7.8	90	13	23				290	
Bamberg, DE 2	7.8	87	24	14				320	
Bamberg, DE 3	7.9	47	15	5				180	
Berlin, DE (Kladow)	7.5	104	8	30	103	45	10.5	16.4	
Berlin, DE (Spandau)	7.5	99	7.8	29	80	48	10.7	15.6	
Berlin, DE (Stolpe)	7.5	93	9.6	24	68	37	11	15.2	
Berlin, DE (Tegel)	7.5	102	9.8	38	121	52	10.3	16.5	
Berlin, DE (Tiefwerder)	7.4	130	10.2	59	135	89	12.9	20.5	
Berlin, DE (Beelitzhof)	7.5	95	8	39	84	50	11	15.1	
Berlin, DE (Kaulsdorf)	7.3	113	12.7	22	103	45	12	18.7	
Berlin, DE (Wuhlheide)	7.3	147	16.7	33	207	54	13.1	24.9	
Berlin (Friedrichshagen)	7.4	108	11.6	37	153	58	9.1	17.7	
Brabant, BE		111	12	14	74	40	315	328	Belle-Vue, Boon, Cantillon, Hoegaarden, Palm, Lefebvre, Drie Fonteyn, etc.
Brugge/Brugge, BE		132	13	20	99	38	326		
Brussels, BE		100	11	18	70	41	250		
Burton-on-Trent, UK 1		270	60	30	640	40	200	1200	
Burton-on-Trent, UK 2		268	62	54	638	36	275		
Burton-on-Trent, UK 3		270	60	30	640	40	197		
Burton-on-Trent, UK 4		295	45	55	725	25	300		
Charleroi, BE		113	17	15	65	41	355	351	Maes
Chimay, BE		70	7	7	21	21	216	203	Abbaye de Scourmont
Dortmund, DE 1		225	40	60	120	60	221		DAB
Dortmund, DE 2	8.0	250	25	70	280	100	550		DAB
Dublin, IR 1		119	4	12	53	19	156		Guinness
Dublin, IR 2		118	4	12	54	19	319		Guinness
Dublin, IR 3	8.0	115	4	12	55	19	200		Guinness
Düsseldorf, DE 1		40	80			25	45		
Düsseldorf, DE 2	7.5	86	12	50	56	92	203		
E. Flanders, BE		134	22	52	76	47	306	424	Bios, Bosteels, Crombe, De Ryck, Huyghe, Liefmans, Roman
Edinburgh, UK 1		140	60	80	96	34	140		
Edinburgh, UK 2	8.0	120	25	55	140	20	225		
Eeklo, BE		138	28	115	8	65	255		Bios
Ghent, BE		114	17	18	84	38	301		
Hainaut/Henegouwen, BE		116	25	101	106	45	598	389	de Pipaix, Dubuisson, Dupont, de Silly (Saisons)
Köln, DE 1		104	15	52	86	109	152		Uerige, Gaffel, Reisdorf
Köln, DE 2	7.2	109	38.4	14.9	86.6	69.8	269.7		Uerige, Gaffel, Reisdorf
Kulmbach, DE 1	7.4	71	16	11	27	8	210	244	
Kulmbach, DE 2	7.7	52	22	6	51	10			
Kulmbach, DE 3	7.7	51	3	5	29	5			
Liege, BE		60	15	11	28	24	231	213	Jupiler
Leipzig, DE 1	7.6	87	18.4	29.8	218			16.4	
Leipzig, DE 2	7.7	93.7	13.3	22.5	198			16.2	
Leipzig, DE 3	7.9	74.1	10.4	19.9	138			12.8	
London, UK 1	8.0	52	16	99	77	60	156		Courage, Tennant's, etc.
London, UK (City) 2		90	6	22	24	10	82		Courage, Tennant's, etc.
London, UK (Well) 3		52	32	86	32	34	104		Courage, Tennant's, etc.
Luik, BE		98	14	110	14	142	134		
Mechelen, BE		116	14	16	62	36	330		Het Anker (Gouden Carolus)
Munich, DE 1		75	18	2	10	2	150	275	Spaten, Paulaner, etc.

Munich, DE 2		75	18	2	10	2	148		Spaten, Paulaner, etc.
Munich, DE 3	8.0	75	20	10	10	2	200		Spaten, Paulaner, etc.
Orval, BE		96	4	5	25	13	287	257	Brasserie d'Orval
Pilsen, Czech 1		7	2	2	5	5	14		
Pilsen, Czech 2		10	3	4		4.3	3		
Pilsen, Czech 3	8.0	7	2	2	5	5	15	35	
Poperinge, BE		8	2	380	124	206	528		St. Sixtus, Van Eecke
Rochefort, BE		82	10	6	32	17	240	246	Abbaye Notre Dame
Vienna, Austria 1		200	60	8	125	12	118		
Vienna, Austria 2	8.0	200	60	8	125	12	120		
Vienna, Austria 3		200	60	8	120	12	125	850	
W. Flanders, BE		114	10	125	145	139	370	328	Westvleteren, Bavik, De Dolle Brouwers, De Gouden Boom, Riva, Rodenbach, Sint Bernardus, van Eecke, Van Honsebrouck
Willebroek/Rumst, BE		68	8	33	70	60	143		Moortgat

(Adapted from various web documents, *Complete Guide to Homebrewing*, Charlie Papazian, *Brewer's Companion*, Randy Mosher, *How to Brew*, Jim Palmer)

#### Water Characteristics of Some U.S. & Canadian Cities & Regions (NY locations bolded)

City/Region	pH	Ca	Mg	Na	SO4	Cl	CO3	Tot. Hard
Atlanta, GA	7.2	6	1	3	7	0	19	
<b>Auburn, NY (Owasco Lake)</b>	<b>6.9-8.3</b>	<b>1.3</b>		<b>14</b>	<b>13</b>	<b>27</b>	<b>1.3</b>	
<b>Batavia, NY (MCWA Well)</b>	<b>9.3</b>	<b>13</b>		<b>60</b>	<b>46</b>	<b>120</b>		
Boston, MA	7.9	4	1	10	8	14	10	
<b>Buffalo, NY</b>	<b>8.1</b>	<b>90.8</b>		<b>10</b>	<b>22</b>			
Chicago, IL	8.1	34	11	6	25	11	106	
<b>Corfu, NY (MCWA Well)</b>	<b>7.4</b>	<b>70</b>	<b>14</b>	<b>130</b>	<b>62</b>	<b>47</b>	<b>80</b>	
Dallas, TX	9.0	24	3	17	440	34	45	
Denver, CO	7.6	31.5	8.5	21.4	50.8	23.5	104	
<b>Eagle Bridge (Adirondacks), NY (Spring)</b>	<b>7.8</b>	<b>45</b>	<b>7</b>	<b>5</b>	<b>5</b>	<b>1</b>	<b>130</b>	<b>142</b>
<b>Eagle Bridge (Adirondacks), NY (Well)</b>	<b>7.6</b>	<b>114</b>	<b>17</b>	<b>124</b>	<b>12</b>	<b>196</b>	<b>272</b>	<b>356</b>
<b>Erie County, NY (ECWA, Lake Erie)</b>	<b>8.0</b>	<b>34</b>	<b>23</b>	<b>8</b>	<b>22</b>	<b>30</b>	<b>115</b>	
Fort Worth, TX	7.8-8.7	34-55	3-10	13-37	36-47	16-48	98-154	119-163
Kalamazoo, MI	7.9	2	<1	112	10	8	208	9
Kentucky, US	7.0	24.6	<1	10.62	21.7	23.1	41	79
Las Vegas, NV (Colorado R./Lake Powell)	7.9	74	28.6	84	224	71.5	302	302
Los Angeles, CA	8.0	68	27.5	96		91		283
Milwaukee, WI	7.5	96	47	7	26	16	107	
<b>New York, NY</b>	<b>7.2</b>	<b>13</b>	<b>4</b>	<b>11</b>	<b>12</b>	<b>21</b>	<b>29</b>	
<b>Ontario, NY (Lake Ontario)</b>	<b>7.6</b>							
Pittsburgh, PA		32	6	20	72	31	45	179
Portland, OR 1	6.7	2	1	2	0	2	9	
Portland, OR 2		1.8	<1	1.6	<1	10	7.5	
<b>Rochester, NY (MCWA, Hemlock Lake)</b>	<b>7.6</b>	<b>25</b>	<b>6.1</b>	<b>17</b>	<b>16</b>	<b>32</b>	<b>64</b>	<b>86</b>
Rockwood, ONT (Well)	7.2	90.27	34.31	204	21.20	400	394	366.62
Salt Lake City, UT	7.9	30	17	5	12	7	252	
Sacramento (Shingle Springs), CA	7.3	4.7	<1	11	2.4	5.4	15	15
San Francisco, CA 1	8.9	16	6.6	15	19	9		56
San Francisco, CA 2	8.8	14	5.4	12	23	10	62	62
Seattle, WA	7.8	17	1	4	2	4	18	
<b>Shoremont, NY (Lake Ontario)</b>	<b>7.4</b>	<b>35</b>	<b>8.7</b>	<b>12</b>	<b>28</b>	<b>23</b>	<b>125</b>	
St. Louis, MO (Missouri R.)		21.9	10.7	19.6	66.9	20.6	39	104
<b>Syracuse, NY (Lake Ontario)</b>		<b>35</b>		<b>17</b>	<b>27</b>	<b>36</b>		
<b>Syracuse, NY (Skaneateles Lake)</b>				<b>8.5</b>	<b>11.75</b>	<b>18</b>		
Washington, DC	7.5	38	9.4	19.4	32.7	35.6	10	
Burlington (Winooski), VT		45		7.5	15	17		

(Compiled for various online sources, including *Monroe County Water Authority*)



## Rochester, NY Water Compared to Great Brewing Cities

City	Calcium	Magnesium	Sodium	Chloride	Sulfates	Carbonates (Alkalinity)	Hardness	pH
Rochester - Lake Ontario	35	8.7	12	23	28	88	125	7.4
Corfu - Well water	30	14	130	47	62	250	80	7.4
Rochester - Hemlock Lake	25	6.1	17	32	16	64	86	7.6
Batavia	37	23	60	120	46	42	n/a	9.3
<b>Burton-on-Trent (IPA, etc.)</b>	295	45	55	25	725	300	850	8
<b>Dortmund (Export)</b>	250	25	70	100	280	550	750	8
<b>Dublin (Dry Stout)</b>	115	4	12	19	55	200	300	8
<b>Edinburgh (Scotch Ales)</b>	120	25	55	20	140	225	350	8
<b>London (Porter, Stout)</b>	50	20	100	60	80	160	400	8
<b>Munich (Bock, etc.)</b>	75	20	10	2	10	200	250	8
<b>Pilzen (Czech Pilsener)</b>	7	2	2	5	5	15	30	8
<b>Vienna (Vienna Lager)</b>	200	60	8	12	125	120	750	8
<b>Antwerp (Belgian Ales, etc.)</b>	90	11	37	57	84	76		8

Source: (<http://www.mcwa.com/watqlsum.htm>)

## G. Treatment of Rochester, NY Water For Brewing

With the exception Pilsen, the mineral content of Rochester-area water is less than of other great brewing cities. This is fortunate since it is much easier to add minerals to brewing water than to remove them.

In the table below, levels of common ions found in Rochester-area water are compared to ion levels for water from famous brewing cities.

**How Rochester-Area Water Compares:** Here's how Rochester-area water compares in terms of five important brewing ions.

**Carbonates:** Rochester-area water has a very low level of carbonates (alkalinity), which makes it fantastic for brewing. Highly alkaline water is undesirable when brewing most beers because it promotes the extraction of tannins from grain during mashing, contributes to harsh, bitter hop flavor during the wort boil, impedes trub flocculation during hot break and increases the risk of bacterial contamination in the fermenter. Dark beers brewed in the Rochester area need no further reduction in carbonate level.

**Sulfates:** Sulfates give beer a drier, fuller flavor and sharpens hop bitterness. As you can see, Rochester-area water has very low sulfate levels, making it necessary to add a small amount of gypsum or Epsom salts if you are brewing Burton-style IPA or Pale Ales.

**Sodium:** Sodium contributes to the perceived malt flavor of beer by enhancing sweetness. Levels from 75 to 150 ppm give a round smoothness and accentuate sweetness, which is most pleasant when paired with chloride ions. In the presence of sulfate ions, however, sodium creates an unpleasant harshness. To increase sodium levels of Rochester-area water, add a bit of kosher salt, especially if you are brewing a Dortmunder export. Do not add kosher salt if you have already added gypsum or Epsom salts!

**Chloride:** Imparted by additions of table salt or calcium chloride, chloride ions enhance beer flavor and palate fullness,

by increasing perception of sweetness or mellowness. Chloride also increases beer stability and improves beer clarity.

**Chlorine:** Chlorine, as opposed to Chlorides, is used to help sanitize public water supplies. It can combine with organic substances to produce plastic-like or medicinal chlorine-phenol complexes. It is undesirable in your beer and should be removed, either by boiling or by filtration before you begin brewing.

**Rochester Area Brewing Water Treatment:** The following information is a simplification, designed to adjust Rochester Lake Ontario water to imitate the water of a famous brewing city when brewing a 5-gallon all-grain batch of beer. (No water treatment, other than chlorine removal, is necessary for extract brewing.) This information comes from Gregory Noonan's "Water Witch Spreadsheet" ([http://byo.com/brewwater/VPB\\_Water\\_Witch.xls](http://byo.com/brewwater/VPB_Water_Witch.xls)).

City (Styles)	Gypsum	Epsom Salts	Calcium Chloride	Notes
<b>Burton-On-Trent</b> (English IPA & Pale Ales)	20 g (5 level tsp.)	5 g (1 level tsp.)		
<b>Dortmund</b> (Dortmunder Export)	15 g (4 level tsp.)		2.3 g (1/2 level tsp.)	Do not mix kosher salt and gypsum or Epsom salts!
<b>Dublin</b> (Dry Stout, Foreign Extra Stout)	5.7 g (1 1/2 level tsp.)			
<b>Munich</b> (Bock, Oktoberfest, Helles, Munich Dunkel)	3 g (3/4 level tsp.)	1.5 g (1/4 level tsp.)		

<b>Pilzen</b> (Czech Pilsner)	No additions needed	Boil brewing water uncovered and allow to cool overnight to precipitate carbonates and to drive off chlorine.
<b>Antwerp</b> (Belgian Ales)	No additions needed	

## Part 2: Off-Flavors

### Chlorophenol\*†‡

**Detected in:** Aroma, flavor, mouthfeel.

**Described As:** Adhesive tape, antiseptic, Band-Aid™, Chloraseptic™, disinfectant, “hospital,” medicinal, mouthwash, trichlorophenol (TCP). In high levels they might have an astringent, drying, numbing, prickly or puckering mouthfeel.

**Typical Origins:** Process/equipment faults, contamination.

**Typical Concentrations in Beer:** 0 mg/l.

**Perception Threshold:** 1-5 µg/l in water, 3-40 µg/l in beer.

**Beer Flavor Wheel Number:** 0504.

**Discussion:** Chlorophenols (e.g., 2, 6-dichlorophenol) are a class of phenols (see Phenols); a large family of aromatic alcohols consisting of a benzene ring plus a hydroxyl group and side chains.

Chlorophenols are phenols with a chlorine side chain. They are formed from chemical reactions between alcohol and chlorine-based sanitizers, chlorine or chloramines used to treat water supplies, or water polluted with chlorine compounds.

Unlike esters or fusel alcohols, phenols are largely non-volatile and don't get converted into other compounds. This means that once they're in a beer, they tend to remain in it.

There is genetic variation in the ability to detect certain phenolic compounds and some people are completely insensitive to them. Also see Bromophenols, Iodoform, Phenol, Smoky, Spicy and Vanilla.

**To Avoid:** \* Use chlorine-based cleaners and sanitizers in the proper concentrations; more isn't necessarily better \* Thoroughly rinse brewing equipment and packaging to remove chlorine sanitizer. \* Treat treated water to remove chlorine or chloramines. Filter through a carbon filter to remove chloramines and chlorine. Let tap water sit overnight to remove chlorine (won't work for chloramines). Add 1 Campden tablet (40 mg potassium metabisulfite) per 20 gallons of water to remove chloramines; let stand 15 minutes or boil. \* Don't use polluted water (e.g., exposed to industrial pollutants).

**When Are Chlorophenols Appropriate?:** Never. Off-flavors and aromas from chlorophenols are always a fault in beer.

### Metallic†

**Detected in:** Appearance, aroma, flavor, mouthfeel.

**Described As:** Aluminum foil, Bitter, blood-like, bloody, coin-like, coppery, ferrous sulfate, inky, iron, iron-like, rusty, rusty water, tin-like or tinny. Metallic ions can cause haze in beer and can affect foam quality.

**Typical Origins:** Contamination.

**Typical Concentrations in Beer:** <0.5 mg/l.

**Perception Threshold:** 1-1.5 mg/l.

**Beer Flavor Wheel Number:** 1330.

**Discussion:** While trace amounts of copper, manganese, iron and zinc are necessary for yeast health, detectable levels of metallic ions are rare in beer. When they arise, they are usually due to high levels of metallic ions in brewing liquor or due to ions leached from metallic brewing equipment. Metallic notes might also arise due to products of lipid oxidation, through processes which aren't fully understood. Metallic ions can also promote the formation of other staling compounds. High levels of some metallic ions can also be toxic to yeast.

There is some scientific controversy over whether metallic tastes are properly part of mouthfeel or flavor, and the exact neurological pathways involved in perceiving metallic sensations.

**To Avoid:** \* Properly treat water to remove excess metallic ions. \* Don't use fittings, containers or sealants which are likely to corrode (e.g., iron, mild steel, lead, solder, non-food-grade brazing compounds). \* Properly passivate brass fittings used in the brewing process. \* To avoid corrosion, don't leave caustic cleansers or sanitizers in prolonged contact with metal fittings, rinse thoroughly and allow equipment to air dry. \* Only use stainless steel, food-grade plastic or glass containers to store fermenting wort or finished beer.

**When are Metallic Notes Appropriate?:** Never.

### Mineral

**Detected in:** Aroma (sulfate only), Flavor, mouthfeel.

**Described As:** Alkaline, bitter, chalky, dusty, drywall, eggs, plaster, sulfate, salty. High sulfate levels can impart a “clean” or “eggy” hydrogen sulfate aroma to beer. Some mineral ions, such as calcium or sulfate, can impart a harsh mouthfeel, by accentuating hop or alkaline bitterness.

**Typical Origins:** Water.

**Typical Concentrations in Beer:** Variable, depending on style. Typically no more than 200 ppm for calcium, carbonate/bicarbonate, and sulfate, no more than 50 ppm for magnesium, sodium and chloride.

**Perception Threshold:** Variable.

**Beer Flavor Wheel Number:** n/a.

**Discussion:** Mineral character can be imparted to beer by using brewing water which is high in certain non-metallic mineral salts, or by adding excess levels of brewing salts to beer. Sulfate aids isomerization of alpha acids, and increases perception of hop bitterness. In excessive levels it can produce a harsh, lingering hop bitterness. On its own, it can produce a detectable aroma. Chloride enhances perception of sweetness at low levels, but can seem bitter at higher levels. Calcium, carbonates and bicarbonates can seem chalky or plaster-like at high levels. Magnesium can seem bitter at high levels. At low levels, sodium, rather than seeming salty, can seem slightly powdery or minerally.

**To Avoid:** \* Properly treat brewing water. \* Don't use excessive amounts of brewing salts.

**When are Mineral Notes Appropriate?:** Very low levels of mineral notes might sometimes appear in pale ales and Dortmunder export. Excessive, harsh or unpleasant mineral notes are always a fault.

### Salty

**Detected in:** Flavor.

**Described As:** Salty. Can be described as bitter, harsh, mineral-like or sour at low levels.

**Typical Origins:** Water, process faults.

**Typical Concentrations in Beer:** <100 mg/l (typically 10-50 mg/l).

**Perception Threshold:** 200 - 500 mg/l.

**Beer Flavor Wheel Number:** 0150.

**Discussion:** The ability to detect saltiness is one of the basic tastes in humans. Saltiness in beer is due to excess sodium ions, usually due to excessive sodium chloride (table salt) additions rather than brewing with naturally salty water. Potassium chloride (a form of potash, also added to "lite" or dietetic salts) can also have a salty character. Salt is also found in trace amounts in malt, but this isn't a significant source of salt in beer.

At sub-threshold, sodium enhances the perception of sweetness in beer. Saltiness is detectable at 100-1,000 mg/l in water, although most people detect it at 100-500 mg/l. IN beer, it can be detected at 200 mg/l.

**To Reduce or Avoid:** Limit brewing salt additions, particularly sodium chloride. Don't use water treated by ion-substitution water softening systems.

**When is Saltiness Appropriate?:** Never for the styles listed in the BJCP style guidelines. Dortmund export comes the closest to having detectable levels of salt since the profile for Dortmund water has 60 ppm. Scottish beer styles come next, since Edinburgh has 55 ppm of sodium. Specialty beers, such as German gose, might have detectable levels of salt, but only at low to medium-low levels.

## Part 3: BJCP Category 8 - English Pale Ales

*English pale ales are the modern descendents of 18<sup>th</sup> and 19<sup>th</sup> strong pale stock ales which were once popular with the English gentry. Due to tax regulations, social movements and changing public tastes, ABV levels for all British beers dropped dramatically over the course of the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, following the worldwide trend towards light-colored, low-alcohol "present use" beers.*

*Despite their low gravity, however, English Pale Ales should always have enough malt and hop flavor to satisfy the palate. Most importantly, English Pale Ales are intended to be "session beers" – inexpensive, thirst-quenching beverages with a low enough ABV that you can drink two or more over the course of an hour without (serious) impairment.*

*English pale ales are originally descended from strong, hoppy "pale ales" or "harvest ales" which were popular with the English gentry in the 18<sup>th</sup> and early 19<sup>th</sup> centuries. By contrast, working class folk preferred (or could afford) sweeter, darker, weaker beers such as porter.*

*By the middle of the 19<sup>th</sup> century, however, improvements in technology, and the ready availability of cheap coke (coal heated in an anaerobic environment to drive off volatile gasses) led to relatively inexpensive pale malt, making pale ales affordable to the masses - especially the rapidly growing middle class eager to emulate their social betters.*

*By the middle of the 19<sup>th</sup> century, table-strength (3-6% ABV) moderately hopped "pale milds" accounted for up to 50% of some breweries' production. In their cask form, these beers were designated by the abbreviation "AK" (possibly from the Dutch "ankel koyt" or "single hoppy beer") or some number of*

*Ks on the barrel. The greater the number, the greater the strength. The weakest products were just described as "K," while stronger products were labeled "KK", "KKK," or even, "KKKK." Pub-goers referred to such beers as "mild" or "pale mild" in comparison to aged ("stale" or "keeping") beers. In their bottled form, these beers were marketed variously as "pale ales," "sparkling ales," "luncheon ales" or "dinner ales."*

*Related to the pale milds were weak (1-2% ABV) "temperance beers," "boys beers" or "small beers," which were intended as low-alcohol refreshers in an age when the water supplies were still uncertain and other soft drinks were relatively rare and expensive.*

*On the other end of the strength scale, most breweries produced strong "Burton ales," which were similar to pale ales (sometimes identical) but were stronger, fuller bodied, darker in color and sweeter in malt character, often with a distinct minerally aftertaste due to the high sulfate Burton-on-Trent water. Many were very similar to modern English barleywine, old ales or winter warmers.*

*Pale ale began to assume its modern form in the 1890s, when the British government repealed the tax on malt, allowing (in some cases, encouraging) brewers to add adjunct sugars and grains to their beers. This led some brewers to add up to 10% sugar to their beers.*

*English beers began the downward slide to their current levels of strength as a result of two calamitous world wars and the Great Depression. The first blow came in 1916, when the combination of grain shortages, a temperance-minded prime minister and a noisy temperance movement forced brewers to cap the average ABV of their products. In order to keep the prices on their most popular products low, and the profits on their strongest products high, brewers responded by dropping the alcoholic strengths of their least expensive beers.*

*The next strike came in 1917, when the government placed further restrictions on the sort of beers brewers could brew, and also forced them to start brewing so-called "government ale." Government ale was an extremely low alcohol (2% ABV) beer which had to be sold at a subsidized price (two pence). It was intended as a beverage which armaments workers could safely consume without getting drunk. Surprisingly, however, "two penny ale" (later "four penny ale") survived the war, lasting until World War II as a cheap refreshment for the masses.*

*Another blow occurred in 1932, when the British government raised the tax on beer in order to cover the budget shortfall caused by the Great Depression. In order to keep their prices low, brewers further reduced the strength of their products.*

*The final blow occurred during World War II, when another round of taxation, as well as ingredient shortages, forced brewers to reduce the strength of their products yet again. In 1940, British brewers largely stopped production of their strong "Burton" ales, leading RAF pilots to adopt the slang expression "Gone for a Burton" (i.e., slipped out for a beer no longer made) when referring to fallen or missing comrades. Other types of beer dropped in strength, leading brewers to drop or consolidate various products. This period saw the demise of most historical brands of porter (by then reduced to a piddling 2-3% ABV), as well as the death of "four penny ale." Stronger beers were reduced in strength by about 20%, to their current levels.*

*After 1945, British ales had assumed their modern forms. Weak "temperance" beers had vanished, strong Burton ales*

were largely extinct, while ordinary bitters ranged from 3.2-3.8% ABV, best bitters ranged from 3.8 - 4.8% ABV, and “extra special” or “premium” bitters (known as pale ales in their bottled form) ranged from 4.8-6.2% ABV.

In the 1950s and 60s, brewers capitalized on bitter’s “posh” reputation, at the expense of porter and mild, making various forms of pale ale the dominant style in the British brewing trade. By the 1970s, however, pale ale was rapidly losing ground to various forms of light lager, such as Carling Black Label (originally a Canadian import) and by 1975, it was in second place.

Since then, there has been a bit of a revival of the style, in large part due to the efforts of CAMRA and a resurgent British craft beer scene. Sadly, the last quarter of the 20<sup>th</sup> century saw many historic brands of British pale ale, including the iconic Bass Pale Ale, go by the wayside, as various British breweries were either bought out by competitors or abandoned the brewing business in order to go into the more lucrative pub-management trade.

**Brewing English Pale Ales:** Modern English pale ales and bitters are brewed using mostly English pale malt, with a bit of English light crystal (60 - 120 °L) malt and possibly light amber or toasted malt (e.g., Biscuit™, mild malt) for malt character and color. Many versions are brewed using up to 10% sugar (e.g., Demerara sugar) or light caramel syrup (e.g., Lyle’s Golden Syrup) to slightly lighten body and to further improve malt character. Some versions incorporate flaked maize or flaked rice in similar percentages to achieve a similar effect. Still other versions might incorporate a tiny amount of wheat or oat flakes, or wheat or oat malt to improve body, head and head retention.

Both in modern times, and historically, British brewers will incorporate malts from outside the UK into their grist, although English malt character should dominate. From the late 19<sup>th</sup> century until World War II, English maltsters regularly used barley from California, Turkey, North Africa, India and elsewhere.

Likewise, English brewers would import malt as needed, although they were careful to make sure that high quality English malt dominated the grist. For much of the 20<sup>th</sup> century, commercial English brewers supplemented their low nitrogen English malts with a bit of higher protein, more diastatically powerful U.S. 6-row malt, especially when mashing using adjunct grains. Before and after World War II, higher protein continental malts were sometimes used to achieve similar effects.

English brewers would import foreign hops as necessary, although they were usually used for bittering. Historically, the freshest, finest English hops (e.g., Fuggles, Goldings) were used for late hop additions, while older, coarser and imported varieties were used as kettle hops. If recreating a historical recipe, using of a high percentage of older hops might give “grassy” or “hay-like” notes to the beer, but also possibly unpleasant “cheesy” notes (reminiscent of blue cheese). Traditional English hop varieties are generally described as floral, earthy, herbal or woody.

Water is moderately hard to very hard. Exact water profile can vary widely depending on the brewery and the season. The water profile of some London wells depends on the flow of the tide up the Thames! London water tends to be moderate in carbonates and sodium (about 80 - 100 ppm), medium low in sulfate and calcium (about 30 - 50 ppm) and low in other

minerals (~ 30 ppm). In some cases, brewers might adjust calcium, carbonate and sulfate levels upwards.

The famous water of Burton-on-Trent is very high in carbonates and calcium (350+ ppm), ridiculously high in sulfates (~800 ppm) and somewhat low in other minerals (15 - 45 ppm).

Brewing water for other cities falls someplace between these extremes. Of course, English brewers have been adjusting their water profiles since the late 19<sup>th</sup> century, so there’s no reason you can’t either.

Extremely high levels of sulfate will increase extraction of hop bitterness and increase perception of hop flavor, as well as giving the beer a mineral, dry aftertaste. High sulfates, combined with high hop levels, give a beer a distinctive lingering, resinous hop bitterness, the famous “Burton snatch.”

Yeast varieties are top-cropping moderately to extremely flocculent English ale yeasts, pitched at about 3 quarts per 5 gallons. Historically, British brewers used open fermentors or elaborate yeast collection systems (e.g., the Burton Union system) to harvest yeast for reculturing, and to eliminate suspended trub, to produce a cleaner-tasting beer.

Some English ale strains, especially those used in traditional open “Yorkshire square” fermentors are indifferent flocculators and might need to be filtered out. Many modern English pale ales are cold-conditioned. Usually, however, English ale yeasts drop very quickly. In some cases, they might need to be roused back into solution in order to finish reducing

## Styles That Time Forgot

*If you could time-travel to London at the turn of the 20<sup>th</sup> century, many beer styles would be familiar, but there would be some you’ve never heard of. Here are a few of them:*

**Boy’s Bitter (AKA Boy’s Ale, Temperance Ale, Servant’s Ale):** Thin-bodied, very low alcohol (1-2% ABV), lightly hopped pale ales, usually bottled but sometimes served from casks. These were the Victorian equivalent of soft drinks, intended as relatively non-intoxicating refreshers in an age when the water could still potentially kill you and lack of refrigeration and sanitation made it difficult to produce or store fruit juices or sugary soft drinks.

**Burton Ale:** Darker, sweeter, fuller bodied and usually stronger than pale ale, with lower hop flavor and aroma, similar hop bitterness. Most examples had a distinctive hop aftertaste due to high levels of sulfates in the water found in their place of origin, Burton-on-Trent.

After World War II, most British breweries stopped brewing Burton ales. The few survivors were given new names: Fuller’s Burton ale became Fuller’s ESB, while Young’s brand of Burton ale eventually became Young’s Winter Warmer. Modern revivals of Burton ale include Theakson’s Old Peculier.

The BJCP treats weaker forms of Burton ale as English Pale Ales and stronger versions as Old Ales (if aged) or English Barleywines.

**Pale Mild (AKA AK, Dinner Ale, Luncheon Ale):** Lighter in color and body than modern English pale ales and perhaps lower in hop bitterness and flavor, with alcoholic strengths corresponding to ordinary bitter to ESB. Some were made using a fair percentage of refined sugar adjuncts. These beers eventually became darker and weaker and morphed into modern English bitter. An American descendent is Cream Ale.

diacetyl.

English ale yeasts generally produce medium to high levels of fruity esters - especially aromas reminiscent of tree fruit such as apples, pears and occasionally cherries. Many strains also produce fairly high levels of diacetyl, which can be a problem if the yeast is taken out of the beer too soon (e.g., bottled or pasteurized products, as opposed to cask-conditioned ales).

Single infusion mash is traditional when producing English ales, although many modern breweries will use a limited step mash (usually just saccharification to mash out, or a two-step saccharification regime to improve extract efficiency). Some brewers run the hot wort through a hopback, both to strain the trub which formed in the kettle and to extract further hop flavor and aroma. Similarly, many brewers dry hop their products. Traditionally, cellarman might also dry hop casks of beer before serving.

Primary fermentation takes 3-5 days and is usually conducted at 65-68 °F. Many brewers then cold-condition their beer for a few days and then filter it, although some do not, especially when producing cask-conditioned beer. Historically, cask conditioned beer was shipped from the brewery very young (perhaps just a week or so old). It was up to the cellarman to condition it to the peak of perfection. Typical cellar temperatures (50-60 °F) both served as a form of cold-conditioning, as well as a form of refrigeration.

**Serving English Ales:** *Historically, most British ale was not filtered or carbonated before it was kegged for shipment to the consumer, allowing the beer to condition and carbonate in the cask.*

*In the pub trade, a "cellarman" was responsible for the storage and final conditioning of the beer before it was dispensed. A cellarman could control the beer's temperature, and might add finings or dry hops to the cask, or control the cask's level of carbonation by inserting or removing "hollow" (actually gas-permeable) "spiles" (thin cylinders of wood inserted into a hole in the middle of the bung). Casks of beer which were identical when shipped from the brewery might taste very different at different pubs, based on storage conditions and the cellarman's skills.*

*At the bar, before forced carbonation dispensing systems were introduced, beer was hand-pumped from barrels in the cellar to taps at the bar, using a "cask engine." The resulting glass of "draught" beer had a temperature of 50-55° F and low levels of carbonation: "warm" and "flat" by German or American standards.*

**CAMRA:** *After World War II, following standard industry practice the large English brewers began to filter and force carbonate their beer and brewery-owned pubs (so-called "tied houses") began to adopt forced carbonation dispensing systems. As a result cellar-conditioned, cask-engine drawn beer nearly went extinct. In the 1960s, however, a group of British beer-drinkers created a craft-brew consumers movement called the Campaign for Real Ale (CAMRA), to preserve and promote authentic British cellared, hand-drawn ales. While the movement has had mixed success, it has been vital in promoting British craft brewers. If you travel in Britain, the yearly CAMRA "Guide to Real Ale" is an excellent guide to traditional independent pubs and brewpubs.*

## Part 4: BJCP Category 10 - American Ales

This category is a catch-all, like several other BJCP styles. It covers light ales too hoppy and alcoholic to be Cream Ales (BJCP Substyle 6A) or Blonde Ales (BJCP Substyle 6B) to brown ales too light in body and flavor to be Robust Porters (BJCP Substyle 12B).

While there were historical American Ales before Prohibition, modern American Ales are products of the home-brewing and craft-brewing revival. As with most "American" style beers, they tend to be "bigger" than their European counterparts, with higher ABV and IBU levels. In many examples, American hops (the "4 Cs" –Cascade, Chinook, Centennial, and Cluster) are quite assertive, but don't quite dominate in the way they do with American IPA or American Robust Porters.

All American ales have a relatively clean, neutral yeast character. American pale ale is dominated by hop character with supporting bready, grainy and possibly slightly caramel pale and light crystal malt notes. American amber ale is more malt-focused with bready, caramel and biscuity notes and more of a balance between hops and malt. American brown ale is also somewhat malt-focused with caramel, nutty, toasty and very light roast notes. Typically, all three styles feature American hops in aroma and flavor, but this isn't always the case.

In the absence of typical American hop character, yeast and malt character define these styles as compared to related styles like Amber Hybrids or English Brown Ales.

## Part 5: BJCP Category 14 - India Pale Ales

*India Pale Ale was possibly invented circa 1790 By George Hodgson, owner of the Bow Street Brewery of London, as a "keeping beer" which could be shipped to British soldiers, sailors and colonists overseas.*

*At the time, the British East India Company was a massive multi-national corporation which had conquered much of India and basically ran it as a corporate colony. To supervise and subdue the native workers, the East India Company had legions of soldiers, merchants and bureaucrats, all of whom enjoyed English beer.*

*The problem with shipping beer to India was that due to the time spent in storage, the severe temperature fluctuations as the ship traveled from the cool waters of the North Atlantic to the warm waters of the Indian Ocean, and the constant motion of the ship at sea, ordinary beers were often sour, flat and oxidized by the time they reached their destination.*

*While other brewers had shipped pale ales and porters to India, Hodgson's bright idea was to brew a strong pale ale of the sort favored by gentlemen at the time, add more hops as a preservative, and to make sure the barrels were tightly sealed to keep the carbonation in.*

*Hodgson's India Ale not only survived the journey but tasted better when it arrived, since aging mellowed the ferocious hop bitterness present in the fresh brew. The first IPA was copper- or brown-colored, highly carbonated, relatively highly attenuated, very bitter and highly alcoholic. Although intended to be diluted, many drinkers preferred Hodgson's India Ale in its original state.*

Not surprisingly, Hodgson's India Ale was very popular. Hodgson's brewery kept a monopoly on the Indian beer trade for nearly 30 years, driving out competitors and fixing prices in the Indian market.

Despite the legend, Hodgson's success is probably less due to his business acumen than the fact that his brewery was right next to the British East India Company's docks. Since company ship captains were allowed some space aboard the ship to carry their own cargo and since East Indiamen tended to be lightly loaded during their voyage to India, English beer made for good trade goods and good ballast.

Since there were few other brewers making a similar product in the London market, and demand for the beer was very high in India, the captains of the East India Company could put up with a local monopoly.

Hodgson's hold was broken in 1822, when the Alsopp Brewery of Burton successfully entered the market.

The legend is that Hodgson's sons finally abused their monopoly too badly, leading the East India Company to look elsewhere for a similar product. By coincidence, one of the Company managers happened to be dining with Mr. Alsopp - a major brewery owner based out of Burton-on-Trent - and mentioned the problem.

Alerted to the lucrative possibilities of the India trade, Mr. Alsopp had his brewer, Job Goodhead, design a beer based on Hodgson's India Ale. Due to the higher sulfate content of the Burton water Alsopp's India Ale was clearer, had higher hopping rates and cleaner-tasting hop bitterness than Hodgson's IPA.

Despite the difficulties of transporting beer from Burton to London for shipment overseas, Alsopp's ale quickly became a favorite on the Indian market. By the 1830s, the Burton brewers Alsopp, Bass and Salt had firmly established themselves as the main producers of IPA.

Again, the legend probably is more interesting than fact. By 1822 there were many canals which crisscrossed England and early railroads were starting to be developed, allowing products from the countryside to be more easily shipped to London and other major ports. This fact, as much as the improved Burton product, probably helped to break Hodgson's monopoly.

Allegedly, IPA made its debut as a beverage for domestic consumption in 1827 when a ship bound for India wrecked on the West coast of England. Salvaged barrels of IPA were sold at auction in Liverpool and customers there were soon clamoring for the product. Soon thereafter, Londoners discovered the joys of IPA as well. Compared to the strong, sweet dark ales of the time, the pale, effervescent, highly-attenuated and highly-hopped IPAs were revolutionary.

Again, the reality is quite different. Strong pale (that is, amber or lighter-colored) ales had been popular among the English upper classes since the 17<sup>th</sup> century. While it wasn't called by that name, "India Ale" was available for purchase in England, under the name of "Keeping Beer." In any case, by the 19<sup>th</sup> century, brewers across the UK (including Scotland) were brewing India Ales for export. Brewers in Europe and North America also began to brew IPA-style beers. For example, at one time Ballantine's Ale was a high-gravity IPA!

In 1880, changes to British tax laws penalized high-alcohol beers. That, plus changing consumer tastes forced the British brewers to produce lower-gravity beers with proportionately reduced hopping rates. The trend towards weaker, less hoppy

## IPA Legends

**1. IPA was brewed stronger to survive the voyage to India.** *False.* While 18<sup>th</sup> century IPA was strong, it was no stronger than similar "keeping beers" of the time.

**2. IPA was invented by George Hodgson.** *Probably False.* Other brewers were producing similar products. Hodgson might have produced a hoppier product, however.

**3. IPA was the only style of beer exported to India.** *False.* English brewers were sending all sorts of beer to India, but Pale India Ale was a premium product, preferred by officers and gentlemen of the East India Company. Regular soldiers, sailors and laborers preferred porter and stout.

**4. IPA is a strong beer.** *False.* It's perfectly legitimate to have a low-alcohol IPA. It's the hops (or more specifically, the BU:GU ratio) that make the style, not the alcohol. Late 19<sup>th</sup> and early 20<sup>th</sup> century "London IPA" could be as low as 2-3% ABV!

**5. IPA is a light-colored beer.** *False.* India Pale Ale is only called pale ale because it was paler than the majority of the beers at the time, which were brown to dark brown colored. IPA can range from golden to dark amber in color.

IPAs continued throughout the 20<sup>th</sup> century until English IPAs were little more than hoppy Extra Special Bitters. The style was nearly extinct until homebrewers in the U.S. and the U.K., revived English IPA in its current form.

The American homebrewers went even further, creating (or reviving) two new variations of IPA: American IPA and Imperial IPA. While 18<sup>th</sup> and 19<sup>th</sup> century American brewers produced highly-hopped, highly-alcohol "stock ales" and sometimes described them as IPAs, modern American IPAs are very different with their predecessors with paler color and extremely aggressive hop taste and aroma. Partially inspired by historical recipes, but mostly driven by the desire to produce "bigger" beers, craft brewers have recently started to brew so-called "Imperial" or "Double" IPAs which are much more similar to the original 18<sup>th</sup> and 19<sup>th</sup> century IPAs in alcohol content and hop bitterness.

**Differences Between the Styles:** The BJCP recognizes three styles of IPA, English IPA, American IPA and Imperial IPA.

**English IPA:** English IPA is generally drier, less fruity, has less caramel taste, higher carbonation and higher attenuation than English Pale Ale.

It is typically made using English pale, biscuit, crystal and chocolate malt and English hop varieties such as Challenger, Northern Brewer, Goldings, Fuggles or Bramblings. Some versions have limited additions of refined sugar.

Yeast can be any of a number of top-fermenting English Ale strains, although Burton and London strains are traditional. Typically, such strains produce fruity, flowery or perfume-like ester compounds, although these shouldn't be excessive in an IPA.

High sulfate and low carbonate ("Burtonized") water is essential for Burton-on-Trent examples. Due to lower sulfate levels, London-produced IPAs tend to have more malt sweetness with a less "crisp" or "bitter" hop flavor. (Limestone or chalk bedrock predominates around London and Burton-on-Trent. Similar water can be found in much of the Midwestern and Central Plains in the U.S.).

English aroma hops provide a fruity, flowery or citrusy flavor and aroma, while the moderately hard water can further accentuate hop bitterness. IPAs are typically made using a single temperature infusion mash; historically most were fermented using a Burton Union system.

Note that some English IPA can feature citrusy American hop, but these complement the English malt and yeast character.

**American IPA:** A modern American craft brew inspired by American homebrewed interpretations of English IPA.

American IPA is made using English or American pale, crystal and chocolate malt, possibly with minor additions of other malts such as Belgian biscuit, Cara-Munich or Carapils.

It is bittered using some combination of English and American hops; although even with purely English hops hopping levels are higher than for English IPAs.

Exuberant use of modern American hops such as Centennial, Cascade, Chinook, Amarillo, Simcoe and Warrior are extremely common for this style, especially as dry-hopped additions, but some versions will feature different hop varieties. It's the level of hop character, not type, which defines the style.

Yeast can be any of a number of English or American ale strains, all of which should produce a "cleaner" flavor than yeast strains used for English IPA. Yeasts such as Sierra Nevada "Chico" strain or Sam Adams are classic.

Water can vary depending on local conditions and treatment regimens and can vary from soft to moderate sulfate and carbonate levels. Typically brewed using a single temperature infusion mash, but at lower conversion temperatures to produce better attenuation.

**Imperial IPA:** Also called Double IPA, Extra IPA or I2PA, Imperial IPA is an even "bigger" American IPA developed by enthusiastic homebrewers looking for an ever more massive load of hops and alcohol in their beer.

To a lesser extent, it also represents attempts to recreate the extremely strong IPAs or Stock Ales of the 18<sup>th</sup> and 19<sup>th</sup> centuries. The latter style is slightly lower in hops and alcohol than the most extreme Imperial IPA. This is a very new style, since the first commercial examples only appeared in the 1990s.

The basic recipe is similar to that for an American or English IPA, but the grain bill is 50-100% larger and hopping is increased accordingly. Enormous quantities of English, American or Noble hops characterize the style; in some examples IBU levels approach or exceed the upper limit of human perception. Dry hopping is almost a requirement, since massive hop taste and aroma helps set Imperial IPA apart from barleywine.

Malt character should be mild and fermentation should yield a relatively neutral flavor to better show off the hops. Water can vary depending on local conditions and treatment regimens and can vary from soft to moderate sulfate and carbonate levels. It is typically brewed using a single temperature infusion mash, but at lower conversion temperatures to produce better attenuation.

**IPA Faults:** Insufficient hop bitterness, flavor and/or aroma. Harsh hop bitterness. Excessive or unbalanced malt sweetness. Excessive haziness. Body inappropriately thick or thin. Too light or dark color. Poor carbonation and/or no head. DMS, diacetyl, phenolic or higher ("hot") alcohol aromas or flavors. Oak or wood flavors.