

Better Living through Chemistry

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There are often quite a few jokes surrounding the statement: “Better Living through Chemistry”. Yet in the 21st century our very lives depend on chemicals used in the food industry, medical industry, and of course the water industry. Where would we be without the disinfectant properties of chlorine? Waterborne pathogens throughout history have and continue to have the potential to threaten entire cultures. The introduction of chlorine allowed us to maintain bacteriostatic controls in our drinking water. Chemicals allow us to coagulate, flocculate, and mitigate many issues associated with non-desirable characteristics of water. Corrosion control made it possible to reduce the levels of copper and lead in our drinking water. Soda ash, sodium bicarbonate, and caustic soda are 3 major chemicals used in water treatment. But this is not the story of all chemistry – NO! This is the story of one chemical that has not only historical significance but also lurks in the shadow of so many unknown uses. Stay tuned - you will be absolutely AMAZED!

What, you say, is this fantastic chemical? The answer is Sodium Hydroxide or Caustic Soda as it is commonly referred to. We as water operators know it as a helpful chemical to aid with raising the pH. That’s right, I said *raise* the pH – and that’s about all it does is *raise* the pH. Some have attempted to use it to mitigate corrosion issues only to find that they end up with a pH “roller coaster” effect. That is to say, without additional “buffering” capacity; once added - the pH goes up and then back down. With a steady influence of H⁺ (hydrogen ion activity or pH), the addition of OH⁻ (from the addition of sodium hydroxide – NaOH), merely makes the water increase in pH. Without the addition of buffering chemicals, i.e. carbonates, the pH will continue to decrease. If buffering agents are present, a stable neutralization process can occur - OH⁻ (aq) + H⁺ (aq) → H₂O. Notice how the hydroxide (OH⁻) is added to an acid (H⁺) and water is created? Cool huh? There is the H + OH and the result is H₂O!

Where does caustic soda come from? Sodium hydroxide is produced (along with chlorine and hydrogen via the chloralkali process. This involves

the electrolysis of an aqueous solution of sodium chloride (salt). The sodium hydroxide builds up at the cathode, where water is reduced to hydrogen gas and hydroxide ion: $2\text{Na}^+ + 2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{NaOH}$. Since you all know that our chlorine comes from salt – now you know that our caustic soda comes from the same process. ZAP a salt solution with electricity, and you have chlorine, sodium hydroxide, hydrogen, and a few other products.

Caustic: Where does the term caustic come from? Causticity is, in chemistry, the property of a substance that causes corrosion, the deterioration of a material. Caustic literally means **burning**. A caustic substance can be acidic or basic, and concentrated solutions of acids and bases are common corrosive substances. Have you ever heard of a “Caustic Personality”? There, there now, let’s not harp on the negative uses of caustic. I did say that you would be **amazed** with its uses...or would that be **amaized**?

In food: Hominy is dried **maize** (corn) kernels reconstituted by soaking in lye-water. These expand considerably in size. They may be further processed by cooking in hot oil and salting to form corn nuts (careful on the teeth!). Hominy is also known in some areas of the Southeastern United States, as the breakfast food grits, dried and ground into a coarse powder. They are prepared by boiling in water, with the addition of butter and other ingredient to suit the tastes of a hungry person.

Nixtamal is similar, but uses calcium hydroxide instead of sodium hydroxide. Nixtamal is more important than you may realize. In Mexico, they recognize it as a source of up to 50% of the daily protein intake. Where would that come from? Tortillas of course. The earliest tortillas were made sometime around 1200 – 1600 BC. The ancient Maya and Aztec Indians discovered that if they soaked the preserved corn kernels (maize) in a caustic solution, it would break down the outer layer (pericarp) and render the tender insides available to grind and mix with water. This would form the earliest form of the tortilla. The caustic solution came from mixing water with wood ashes to form the lye mixture. The Maya would burn mussel shells to make the needed ash. But why was

this so important? Others that did not soak the kernels and proceeded to eat moist corn suffered a terrible fate. They came down with the 3 – Ds known as diarrhea, dementia, and sometimes death. By not breaking down the pericarp, the necessary nutrients held captive inside the kernel were not released in the body and malnourishment was the result. Riboflavin, niacin, folic acid, iron, copper, zinc, and calcium could only be released by the use of a caustic reaction. The process usually involved mixing ashes (or today calcium hydroxide) with water and boiling and steeping for a period of time. Grinding the remaining substance was then mixed with water and formed into various products for consumption.

Other uses for lye with foods include washing or chemical peeling of fruits and vegetables, chocolate and cocoa processing, caramel color production, poultry scalding, soft drink processing, and thickening ice cream. Olives are often soaked in lye to soften them. Pretzels are glazed with a lye solution before baking to make them crisp. Oh yea – ever hear of lutfisk (lye fish)?

Soap making: Soap is made by using a caustic base to break down animal fats and vegetable oils. These are commonly in the form of triglycerides. Saturated salt is then used in the process to precipitate the soap from the solution. Lye is a form of sodium hydroxide (NaOH) which is a caustic base made from ashes. If NaOH is used, a hard soap is formed, whereas a soft soap is formed when potassium hydroxide (KOH) is used.

In the lab: In analytical chemistry, sodium hydroxide solutions are often used to measure the concentration of acids by titration. Since NaOH is not a primary standard, solutions must first be standardized by titration against a standard.

Biodiesel: For the manufacture of biodiesel, sodium hydroxide is used as a catalyst for the transesterification (changing one type of alcohol for another more desired alcohol) of methanol and triglycerides. This only works with anhydrous (dry) sodium hydroxide.

Aluminum: Strong caustic bases attack aluminum. This can be useful in etching to form a polished surface to a satin-like finish on the outer aluminum.

Anodizing (protective coating to prevent corrosion), completes the process.

Paper: Sodium hydroxide is used in the pulp mills to break down the protein fibers of wood in the manufacture of paper. Boy, without that, you wouldn't have this great magazine to read...no paper to take notes on! Hmmm.

Illegal drugs: Because it is a key ingredient in the process of making Methamphetamine, it is now impossible to purchase pure Sodium hydroxide as a consumer product in much of the United States. Products containing pure Sodium hydroxide, such as Red Devil, are no longer available for sale. As a result, many amateur soap makers must now purchase Sodium hydroxide in bulk.

Tissue digestion: This is a process that was used with farm animals at one time. This process involves the placing of a carcass into a sealed chamber, which then puts the carcass in a mixture of lye and water, which breaks down the proteins keeping the body intact. This eventually turns the body into a coffee-like liquid, and the only solid remains are bone hulls, which could be crushed between one's fingertips. It is also of note that sodium hydroxide is frequently used in the process of decomposing road kill dumped in landfills by animal disposal contractors. Sodium hydroxide has also been used by criminals and serial killers to dispose of their victim's bodies...mmm yummy mummy.

In the home: Finally we must discuss some place that hits closer to home. We have plungers and plumbers. Which one is more effective and which one is more expensive? Ahh, but what of the liquid plumber? Most of us, at some time or another, have gone to the kitchen sink or master bath only to find that the gray water and muck are gaining on us. The drains are plugged and you have to get to work...what DO you do? In the kitchen, greases and food products tend to block the P-trap drain. Over in the bathtub hides a lump of greasy hair down in the drain. So you grab for a liquid friend under the sink. Most of us have heard of Drano. By carefully examining the ingredients on the label, you will notice that the active ingredient is sodium hydroxide. After pouring the caustic solution into the stopped drain, the strong base immediately begins to break down the grease similarly to the

process in soap making. In the tub, the proteins, similar to the proteins in the pulp industry, are beginning to break down as well. As time passes, you hear from the next room a comforting suction sound as the drains release their caustic mixture. A hot water rinse as a final flush and you're ready for another wonderful day at the office. Thanks to your liquid friend, you can now have a sigh of relief and realize that there truly is "Better living through Chemistry"!

Safety hint: Since I can speak with experience, I must emphasize the importance of safety when dealing with sodium hydroxide (both hydrous and anhydrous). *If it spills on your clothes – it will continue to burn into your skin throughout the day as you perspire. If it comes in direct contact with your skin (or even worse – eyes), rinsing with water will not help much.* The best thing I have found is to have a cheap bottle of white vinegar handy. The mild acid of the vinegar tends to neutralize the caustic sting quite well. I would rather smell like a salad than suffer from chemical burns. Please wear the proper safety gear when handling this wonderful chemical. Be safe!