Sodium hydroxide

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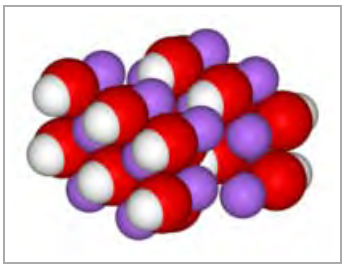
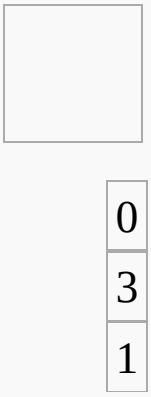
Jump to: navigation, search

Sodium hydroxide	
	
	
IUPAC name	Sodium hydroxide
Other names	Lye, Caustic Soda
Identifiers	
CAS number	1310-73-2
Properties	
Molecular formula	NaOH
Molar mass	39.9971 g/mol
Appearance	White solid

Density	2.1 g/cm³, solid
Melting point	318°C (591 K)
Boiling point	1390°C (1663 K)
Solubility in water	111 g/100 ml (20°C)
Basicity (pK_b)	-2.43
Hazards	
MSDS	External MSDS
NFPA 704	
Flash point	Non-flammable.
Related Compounds	
Related bases	Ammonia, lime.
Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa) Infobox disclaimer and references	

Sodium hydroxide (NaOH), also known as **lye**, **caustic soda** and **sodium hydrate**, is a caustic metallic base. Caustic soda forms a strong alkaline solution when dissolved in a solvent such as water. It is used in many industries, mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents and as a drain cleaner. Worldwide production in 1998 was around 45 million tonnes. Sodium hydroxide is the most used base in chemical laboratories.

Pure sodium hydroxide is a white solid; available in pellets, flakes, granules and as a 50% saturated solution. It is deliquescent and readily absorbs carbon dioxide from the air, so it should be stored in an airtight container. It is very soluble in water with liberation of heat. It also dissolves in ethanol and methanol, though it exhibits lower solubility in these

solvents than potassium hydroxide. It is insoluble in ether and other non-polar solvents. A sodium hydroxide solution will leave a yellow stain on fabric and paper.

Contents

[hide]

[edit] Chemical properties

Sodium hydroxide is completely ionic, containing sodium ions and hydroxide ions. The hydroxide ion makes sodium hydroxide a strong base which reacts with acids to form water and the corresponding salts, e.g., with hydrochloric acid, sodium chloride is formed:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

In general such neutralization reactions are represented by one simple net ionic equation:

$$OH^-(aq) + H^+(aq) \rightarrow H_2O$$

This type of reaction with a strong acid releases heat, and hence is referred to as exothermic. Such acid-base reactions can also be used for titrations, which is a common

method to determine the concentration of acids. Another type of reaction that sodium hydroxide is involved in is with acidic oxides. The reaction of carbon dioxide has already been mentioned, but other acidic oxides such as sulfur dioxide (SO_2) also react completely. Such reactions are often used to "scrub" harmful acidic gases (like SO_2 and H_2S) and prevent their release into the atmosphere.

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

Sodium hydroxide slowly reacts with glass to form sodium silicate, so glass joints and stopcocks exposed to NaOH have a tendency to "freeze". [*citation needed*] Flasks and glass-lined chemical reactors are damaged by long exposure to hot sodium hydroxide, and the glass becomes frosted. Sodium hydroxide does not attack iron or copper, but other metals such as aluminium, zinc and titanium are attacked rapidly. In 1986 an aluminium road tanker in the UK was mistakenly used to transport 25% sodium hydroxide solution, causing pressurisation of the contents and damage to the tanker. For this reason aluminium pans should never be cleaned with sodium hydroxide.

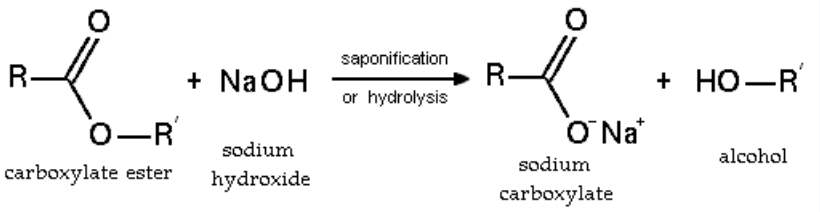
$$2Al(s) + 6NaOH(aq) \rightarrow 3H_2(g) + 2Na_3AlO_3(aq)$$

Many non-metals also react with sodium hydroxide, giving salts. For example phosphorus forms sodium hypophosphite, while silicon gives sodium silicate.

Unlike NaOH, the hydroxides of most metals are insoluble, and therefore sodium hydroxide can be used to precipitate metal hydroxides. One such hydroxide is aluminium hydroxide, used as a gelatinous floc to filter out particulate matter in water treatment. Aluminium hydroxide is prepared at the treatment plant from aluminium sulfate by reacting with NaOH:

$$6NaOH(aq) + Al_2(SO_4)_3(aq) \rightarrow 2Al(OH)_3(s) + 3Na_2SO_4(aq)$$

Sodium hydroxide reacts readily with carboxylic acids to form their salts and is even a strong enough base to form salts with phenols. NaOH can be used for the base-driven hydrolysis of esters (as in saponification), amides and alkyl halides. However, the limited solubility of NaOH in organic solvents means that the more soluble KOH is often preferred.



Basic hydrolysis of an ester

[edit] Manufacture

In 1998, total world production was around 45 million tonnes. North America and Asia collectively contributed around 14 million tonnes, while Europe produced around 10 million tonnes.

[edit] Methods of production

Sodium hydroxide is produced (along with chlorine and hydrogen) via the chloralkali process. This involves the electrolysis of an aqueous solution of sodium chloride. The sodium hydroxide builds up at the cathode, where water is reduced to hydrogen gas and hydroxide ion:

$$2Na^+ + 2H_2O + 2e^- \rightarrow H_2 + 2NaOH$$

To produce NaOH it is necessary to prevent reaction of the NaOH with the chlorine. This is typically done in one of three ways, of which the membrane cell process is economically the most viable.

- **Mercury cell process** (also called the Castner-Kellner process) – Sodium ions are reduced to sodium metal, which forms an amalgam with a mercury cathode; this is sodium(man liker) is then is reacted is with water to produce NaOH. There have been concerns about mercury releases, although modern plants claim to be safe in this regard.[1]
- **Diaphragm cell process** – uses a steel cathode, and the reaction of NaOH with Cl_2 is prevented using a porous diaphragm, often made of asbestos fibers. In the diaphragm cell process the anode area is separated from the cathode area by a permeable diaphragm. The brine is introduced into the anode compartment and flows through the diaphragm into the cathode compartment. A diluted caustic brine leaves the cell. The caustic soda must usually be concentrated to 50% and the salt removed. This is done using an evaporative process with about three tonnes of steam per tonne of caustic soda. The salt separated from the caustic brine can be used to saturate diluted brine. The chlorine contains oxygen and is purified by liquefaction and evaporation.[2][3]
- **Membrane cell process** – similar to the diaphragm cell process, with a Nafion membrane to separate the cathode and anode reactions. Only sodium ions and a little water pass through the membrane. It produces a higher quality of NaOH. Of the three processes, the membrane cell process requires the lowest consumption of electric energy and the amount of steam needed for concentration of the caustic is relatively small (less than one tonne per tonne of caustic soda).[4][5]

An older method for sodium hydroxide production was the LeBlanc process, which produced sodium carbonate, followed by roasting to create carbon dioxide and sodium oxide. This method is still occasionally used. It helped establish sodium hydroxide as an important commodity chemical.

[edit] Major producers

In the United States, the major producer of sodium hydroxide is the Dow Chemical Company, which has annual production around 3.7 million tonnes from sites at Freeport, Texas, and Plaquemine, Louisiana. Other major US producers include Oxychem, PPG, Olin, Pioneer Companies, Inc. (PIONA), and Formosa. All of these companies use the chloralkali process[6].

Reheis Inc. produces high purity sodium hydroxide pellets, NF/FCC and ACS grades [1].

[edit] Uses

[edit] General applications

Sodium hydroxide is the principal strong base used in the chemical industry. In bulk it is most often handled as an aqueous solution, since solutions are cheaper and easier to handle. It is used to drive chemical reactions and also for the neutralization of acidic materials. It can be used also as a neutralizing agent in petroleum refining

[edit] Gold pennies

Sodium hydroxide has also been used in conjunction with zinc for creation of the famous "Gold pennies" experiment. When a penny is boiled in a solution of NaOH together with some granular zinc metal (galvanised nails are one source), the colour of the penny will turn silver in about 45 seconds. The penny is then held in the flame of a burner for a few seconds and it turns golden. The reason this happens is that granular zinc dissolves in NaOH to form $Zn(OH)_4^{2-}$ (tetrahydroxozincate). This zincate ion becomes reduced to metallic zinc on the surface of a copper penny. Zinc and copper when heated in a flame form brass.

[edit] Use in chemical analysis

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 standardised by titration against a standard such as KHP. Burettes exposed to NaOH should be rinsed out immediately after use to prevent "freezing" of the stopcock. Sodium hydroxide was traditionally used to test for cations in Qualitative Inorganic Analysis, as well as to provide alkaline media for some reactions that need it, such as the Biuret test.

[edit] Soap production

Sodium hydroxide was traditionally used in soap making (cold process soap, saponification). The Arabs began producing soap in this way in the 7th century, and the same basic process is used today.

[edit] Biodiesel

For the manufacture of biodiesel, sodium hydroxide is used as a catalyst for the transesterification of methanol and triglycerides. This only works with anhydrous sodium hydroxide, because water and lye would turn the fat into soap which would be tainted with methanol. It is used more often than potassium hydroxide because it is cheaper and a smaller quantity is needed.

[edit] Aluminium etching

Strong bases attack aluminium. This can be useful in etching through a resist or in converting a polished surface to a satin-like finish, but without further passivation such as anodizing or allodizing the surface may become corroded, either under normal use or in severe atmospheric conditions.

[edit] Food preparation

Food uses of lye 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, while pretzels and German lye rolls are glazed with a lye solution before baking to make them crisp.

Specific foods processed with lye include:

- The Scandinavian delicacy known as lutefisk (from *lutfisk*, "lye fish").
- Hominy is dried maize (corn) kernels reconstituted by soaking in lye-water. These expand considerably in size and may be further processed by cooking in hot oil and salting to form corn nuts. Nixtamal is similar, but uses calcium hydroxide instead of sodium hydroxide.
- 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 the preparer.
- Sodium hydroxide is also the chemical that causes gelling of egg whites in the production of Century eggs.
- German pretzels are poached in a boiling sodium hydroxide solution before baking, which contributes to their unique crust.

[edit] Delignification of Cellulosic Materials

Sodium Hydroxide, in addition to Sodium Sulfide, is a key component of the white liquor solution used to separate lignin from cellulose fibers in the Kraft process. It also plays a key role in several following stages of the process of bleaching the brown pulp resulting from the pulping process. These stages include oxygen delignification, oxidative extraction, and simple extraction, all of which require a strong alkaline environment with a pH > 10.5 at the end of the stages.

[edit] Domestic uses

Sodium hydroxide is used in the home as an agent for unblocking drains, provided as a dry crystal (e.g. "Drāno") or as a thick liquid gel. The chemical mechanism employed is the conversion of grease to a form of soap, and so forming a water soluble form to be dissolved by flushing; also decomposing complex molecules such as the protein of hair. Such **drain cleaners** (and their acidic versions) are highly caustic and should be handled with care.

Beginning in the early 1900s, lye has been used to relax or straighten the hair of persons of African ethnicity. Among men, this treatment was often called a process. However, because of the high incidence and intensity of chemical burns, chemical relaxer manufacturers began switching to other alkaline chemicals (most commonly guanidine hydroxide) during the latter quarter of the 20th Century, although lye relaxers are still available, usually under use by professionals.

[edit] 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 chemical bonds 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 roadkill dumped in landfills by animal disposal contractors[*citation needed*].

Sodium hydroxide has also been used by criminals and serial killers to dispose of their victim's bodies.

[edit] Illegal drugs

Sodium hydroxide is a key reagent in the process of making Methamphetamine and other illegal drugs. Contrary to popular media reports, it is not actually an "ingredient" in these drugs, but simply a strong base used to manipulate the pH at various points in a chemical synthesis.

[edit] Safety

Solid sodium hydroxide or solutions containing high concentrations of sodium hydroxide may cause chemical burns, permanent injury or scarring, and blindness.

Dissolution of sodium hydroxide is highly exothermic, and the resulting heat may cause heat burns or ignite flammables.

The combination of aluminium and sodium hydroxide results in a large production of hydrogen gas:
$2Al(s) + 6NaOH(aq) \rightarrow 3H_2(g) + 2Na_3AlO_3(aq)$.
Mixing these two in a closed container is therefore dangerous.

[edit] See also

- Common chemicals
- Soda lime

[edit] External links

- International Chemical Safety Card 0360
- NIOSH Pocket Guide to Chemical Hazards
- European Chemicals Bureau
- Chlorine Online - Facts about Chlorine, Sodium Hydroxide (Caustic Soda) is an important co-product of Chlorine
- The Chlorine Institute, Inc. website
- Sodium hydroxide products of Bayer MaterialScience in North America
- Titration of acids with sodium hydroxide – freeware for data analysis, simulation of curves and pH calculation

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[edit] References

1. ^ Chlorine Online Diagram of mercury cell process. Euro Chlor. Retrieved on 2006-09-15.
2. ^ Euro Chlor - How is chlorine made?. Euro Chlor. Retrieved on 2006-09-15.
3. ^ Chlorine Online Diagram of diaphragm cell process. Euro Chlor. Retrieved on 2006-09-15.
4. ^ Chlorine Online Diagram of membrane cell process. Euro Chlor. Retrieved on 2006-09-15.
5. ^ Euro Chlor - How is chlorine made?. Euro Chlor. Retrieved on 2006-09-15.

6. ^ See *Kirk-Othmer* in general references

[edit] General references

1. N. N. Greenwood, A. Earnshaw, *Chemistry of the Elements*, 2nd ed., Butterworth-Heinemann, Oxford, UK, 1997.
2. Heaton, A. (1996) *An Introduction to Industrial Chemistry*, 3rd edition, New York:Blackie. ISBN 0-7514-0272-9.
3. Kirk-Othmer Encyclopedia of Chemical Technology 5th edition (online, account needed), John Wiley & Sons. Accessed November 21, 2005.
4. Euro Chlor - How is chlorine made? Chlorine Online