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Independent Study Mentorship

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"Sodium Chloride." *Chemical Compounds*, edited by Neil Schlager, et al., UXL, 2006. *Science in Context*, link.galegroup.com/apps/doc/EJGJOW727394318/SCIC?u=j043905010&xid=d77f78db. Accessed 22 Sept. 2017.

Hoyle, Brian D. "Food preservation." The Gale Encyclopedia of Science, edited by K. Lee Lerner and Brenda Wilmoth Lerner, 5th ed., Gale, 2014. Science in Context, link.galegroup.com/apps/doc/CV2644030924/SCIC?u=j043905010&xid=fa0f4df5. Accessed 22 Sept. 2017.

**Assessment:**

While exploring the topics under chemical engineering, I came upon the topic of food sciences. It involved food additives which I found out was a type of specialization during my career outlook research. That connection I made sparked my curiosity and made me want to focus on food additives so I can get an idea what kind of information and engineer in this field would need to know. From my last research, I noticed how my inexperience limited my full understanding of the DNA Fingerprinting process so I decided to go with a topic I understand fairly well. With this in mind, the articles I selected are specifically over Sodium Chloride and food preservatives.

According to the article “Sodium Chloride”, salt is the most widely known and used chemical compound. It has numerous uses in the food industry due to the history it has behind it. I discovered the main reason this compound helps preserve food it because it inhibits the growth of microorganisms. I was not completely aware of this fact but I was aware that sodium chloride absorbs moisture. This helped me understand the second article I read because of the insight of sodium chloride I obtained. The author then mentioned the possible health risks with salt. I noticed how professionals in the medical field work together with chemical engineers in the food industry. The health hazard sodium chloride creates is treated by medicals which also pushes engineers to find new alternatives to reduce the risk. It appears to me that this makes the job for chemical engineers more interesting because they are always looking for a better improvement to help consumers. The article also mentioned the chemical build-up of sodium chloride which I was able to interpret because of AP Chemistry, a class I took my junior year of high school. I was able to see how this information played a great role in this aspect of chemical engineering.

In the article “Food Preservatives”, I noticed how in depth the author explain numerous food preserving processes. I came to the realization that even when we have all these processes, chemical engineers are on the hunt looking for more. The passion chemical engineers must have is very apparent when seeing how much time and effort is put into their career. The determination is inspiring because without this career field, we would probably still be using primitive methods to preserve our food. To be well at their job, these engineers should know the chemical composition of different types of foods because of the diversity of chemical compounds. As well as this, there are so many other factors to consider which shows how much patience is required. I think this aspect fits in with my personality. I tend to have a lot of patience which is usually supported by my curiosity and interest. While reading about this topic, I feel that the direct information the author intends to give the reader is slowly sinking it but the main ideas I am carrying out with me is the small bits I can discover about the journey altogether.

The research I have conducted regarding this topic has enlightened me. I have gained valuable insight of the work food scientists may do in their career. While this research may have been surface level, the passion and determination of these professionals are apparent. I learned how broad and specific this topic can be and how this also fits into my previous research on DNA Fingerprinting. One of the main things I explored in that research was the inter-career relations chemical engineering has. In this research, I got to build upon that learn the general outlook as well as noticing how other careers play a role in this field. The challenge is clearly visible with only surface level exploring and I have been inspired to accept it and keep pushing forward on my journey.

## **Sodium Chloride**

*Chemical Compounds*, 2006

Key Facts

### **Other Names:**

[Salt](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te); table salt; common salt; rock salt

### **Formula:**

NaCl

### **Elements:**

[Sodium](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te), [chlorine](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te)

### **Compound Type:**

Binary salt (inorganic)

### **State:**

Solid

### **Molecular Weight:**

58.44 g/mol

### **Melting Point:**

800.7°C (1473°F)

### **Boiling Point:**

1465°C (2669°F)

## **Overview**

[Sodium chloride](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te) (SO-dee-um KLOR-ide) is a colorless to white powder or crystalline solid with no odor and a characteristic salty taste. It is slightly hygroscopic, meaning that it tends to absorb moisture from the air and become damp.

Salt is probably one of the best known and most widely used of all chemical compounds. Humans have been using salt as a preservative and to flavor foods since the beginning of recorded time. One of the earliest mentions of sodium chloride dates to 2,700 bce in the Chinese book *Peng Tzao Kan Mu*, probably the first book on pharmacology ever written. Access to salt resources has often been a contentious issue among peoples, leading to battles and wars over its ownership. It has been considered at times to be so valuable that it was used as a form of money. Today, sodium chloride has a host of applications beyond its use as a [food](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te) additive.

## **How It Is Made**

Sodium chloride occurs naturally as the mineral halite and abundantly in the oceans, where it is found in [seawater](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te) at an average concentration of about 2.6 percent. There are several methods for harvesting salt, some of which date to ancient times. The earliest known method of production is also the simplest: evaporation of seawater by the Sun. In this method, seawater is collected in large, shallow ponds and allowed to evaporate. The [salts](https://docs.google.com/document/d/1MgtCsjy5Z-GjAdFfAZXhO53eNmj89WlNYsDPsP6oqxE/edit#bookmark=id.1fob9te) dissolved in the water crystallize on the bottom of the ponds and can be scraped off and the individual compounds present—including sodium chloride—separated from each other.

This method works best in hot, arid parts of the world. In cooler, moister regions, seawater must be collected in large containers that can be heated artificially. In many cases, the seawater is heated under reduced pressure to allow it to boil at a lower temperature and save heating costs. Again, crystals of sodium chloride (and other dissolved salts) form as the water boils away.

Perhaps the most important source of sodium chloride is salt mines, large underground reserves of sodium chloride left behind when ancient seas dried up and were buried by the accumulation of rocks and soil. Salt mines are found in many parts of the world, especially Russia, Germany, the United Kingdom, India, France, Mexico, Canada, and the United States. These mines often span many kilometers and extend hundreds of meters deep. One of the most famous salt mines in the United States is located under the city of Detroit. It contains more than 80 kilometers (50 miles) of underground roads built to remove blocks of sodium chloride, some as wide as four-lane highways. The Detroit mine ceased production in 1983 when lower salt prices and resulting lower profits were no longer able to sustain the costs of extraction. The Detroit mine was reopened in 1988, but only for the mining of road salt.

Two methods of mining are used to remove sodium chloride from underground sources. In the room-and-pillar method, shafts are dug into the deposit. Drilling and blasting are then used to break off pieces of sodium chloride, which are removed for processing. As mining progresses, large pillars of salt are left standing to support the empty chambers. Thus the name: room-and-pillar. A second method of salt removal is solution mining. A well is drilled into the ground and flooded to create a saturated solution of sodium chloride, a *brine* solution. The brine is then pumped to the surface and processed.

## **Common Uses and Potential Hazards**

Probably the best known use of sodium chloride is as a food additive. The Salt Institute estimates that humans consume an average of 16 tons of salt during their lifetimes. Salt has long been used on foods to improve flavor and also as a preservative. Salted foods last longer than unsalted foods because salt inhibits the growth of microorganisms that cause decay.

Still, the most important use of sodium chloride by far is as a raw material in the production of other compounds. In 2004, 65 percent of all the sodium chloride consumed in the United States was used in the production of sodium hydroxide, sodium carbonate, hydrogen chloride, sodium metal, chlorine gas, and other chemical products. The next most important use of sodium chloride is in water conditioners. The compound is used in such devices because the sodium in sodium chloride will replace the calcium and magnesium in “hard” water (water in which it is hard to make suds). By softening water with sodium chloride, clothing and other materials can be cleaned more efficiently at lower cost. The Salt Institute claims that sodium chloride has more than 14,000 distinct uses. Some of the most important of those uses include:

* As a feed additive for livestock, poultry, and other domestic animals, to ensure that they receive the sodium and chlorine they need to remain healthy and grow normally;
* As a deicing product on roads and highways;
* In the manufacture of glazes used on ceramic products;
* For the curing of animal hides;
* In the dyeing and printing of fabrics;
* In the manufacture of soaps;
* As a herbicide, a chemical used to kill weeds; and
* As a fire extinguisher for certain types of fires (such as grease fires).

Given its widespread use, sodium chloride is obviously safe for consumption by most humans under normal conditions. As with any chemical compound, consumption of a large excess of sodium chloride can be harmful. The one health issue of greatest concern has to do with high blood pressure. Scientists have learned that the ingestion of large amounts of sodium can contribute to hypertension (high blood pressure), which in turn is associated with increased risk for heart attacks and stroke. The American Heart Association recommends that healthy American adults consume no more than 2,300 milligrams of sodium a day. That amount is equivalent to about a teaspoon of salt. For those considered at higher risk, people with high blood pressure, blacks, and middle-aged and older adults, the 2005 U.S. Department of Agriculture guidelines recommend no more than 1,500 milligrams of sodium per day. The problem with sodium chloride consumption is that most people have no idea how much salt they eat every day. Of course, they can keep track of the salt they add to the foods they prepare in their own homes. But most commercially prepared foods also have sodium chloride added to them. In some cases, the total amount of salt ingested from processed foods by the average American can be significant, easily exceeding the recommended daily average recommended by the American Heart Association. People can, therefore, be consuming dangerously high levels of sodium without being aware of that fact.

## **Words to Know**

**pharmacology**

The study of compounds used as drugs.

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## **Food preservation**

*The Gale Encyclopedia of Science*, 2014

The term [food preservation](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) refers to any one of a number of techniques used to prevent food from spoiling. It includes methods such as [canning](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs), pickling, drying and freeze-drying, irradiation, [pasteurization](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs), smoking, and the addition of chemical additives. Food preservation has become an increasingly important component of the [food industry](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) as fewer people eat foods produced on their own lands, and as consumers expect to be able to purchase and consume foods that are out of season.

The vast majority of instances of [food spoilage](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) can be attributed to one of two major causes: (1) the attack by pathogens (disease-causing [microorganisms](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs)) such as [bacteria](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) and molds, or (2) oxidation that causes the destruction of essential biochemical compounds and/or the destruction of plant and animal cells. The various methods that have been devised for preserving foods are all designed to reduce or eliminate one or the other (or both) of these causative agents.

For example, a simple and common method of preserving food is by [heating](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) it to some minimum [temperature](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs). This process prevents or retards spoilage because high temperatures kill or inactivate most kinds of pathogens. The addition of compounds known as BHA and BHT to foods also prevents spoilage in another different way. These compounds are known to act as antioxidants, preventing [chemical reactions](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) that cause the oxidation of food that results in its spoilage. Almost all techniques of preservation are designed to extend the life of food by acting in one of these two ways.

The search for methods of food preservation probably can be traced to the dawn of human civilization. People who lived through harsh winters found it necessary to find some means of insuring a food supply during seasons when no fresh fruits and vegetables were available. Evidence for the use of [dehydration](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) (drying) as a method of food preservation, for example, goes back at least 5,000 years. Among the most primitive forms of food preservation that are still in use today are such methods as smoking, drying, [salting](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs), [freezing](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs), and fermenting.

Early humans probably discovered by accident that certain foods exposed to smoke seem to last longer than those that are not. Meats, fish, fowl, and cheese were among such foods. It appears that compounds present in wood smoke have anti-microbial actions that prevent the growth of organisms that cause spoilage. today, the process of smoking has become a sophisticated method of food preservation with both hot and cold forms in use. Hot smoking is used primarily with fresh or frozen foods, while cold smoking is used most often with salted products. The most advantageous conditions for each kind of smoking—air velocity, relative [humidity](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs), length of exposure, and salt content, for example—are now generally understood and applied during the smoking process. For example, electrostatic precipitators can be employed to attract smoke particles and improve the penetration of the particles into meat or fish. So many alternative forms of preservation are now available that smoking no longer holds the position of importance it once did with ancient peoples. More frequently, the process is used to add interesting and distinctive flavors to foods.

Because most disease-causing organisms require a moist environment in which to survive and multiply, drying is a natural technique for preventing spoilage. Indeed, the act of simply leaving foods out in the sun and wind to dry out is probably one of the earliest forms of food preservation. Evidence for the drying of meats, fish, fruits, and vegetables go back to the earliest recorded human history. At some point, humans also learned that the drying process could be hastened and improved by various mechanical techniques. For example, the Arabs learned early on that apricots could be preserved almost indefinitely by macerating them, [boiling](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) them, and then leaving them to dry on broad sheets. The product of this technique, quamaradeen, is still made by the same process in modern Muslim countries.

Today, a host of dehydrating techniques are known and used. The specific technique adopted depends on the properties of the food being preserved. For example, a traditional method for preserving rice is to allow it to dry naturally in the fields or on drying racks in barns for about two weeks. After this period of time, the native rice is threshed and then dried again by allowing it to sit on straw mats in the sun for about three days. Modern drying techniques make use of fans and heaters in controlled environments. Such methods avoid the uncertainties that arise from leaving crops in the field to dry under natural conditions. Controlled temperature air drying is especially popular for the preservation of grains such as maize, barley, and bulgur.

Vacuum drying is a form of preservation in which a food is placed in a large container from which air is removed. Water vapor pressure within the food is greater than that outside of it, and water evaporates more quickly from the food than in a normal atmosphere. Vacuum drying is biologically desirable since some [enzymes](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) that cause oxidation of foods become active during normal air drying. These enzymes do not appear to be as active under vacuum drying conditions, however. Two of the special advantages of vacuum drying are that the process is more efficient at removing water from a food product, and it takes place more quickly than air drying. In one study, for example, the drying time of a fish fillet was reduced from about 16 hours by air drying to six hours as a result of vacuum drying.

Coffee drinkers are familiar with the process of dehydration known as spray drying. In this process, a concentrated solution of coffee in water is sprayed though a disk with many small holes in it. The surface area of the original coffee grounds is increased many times, making dehydration of the dry product much more efficient. Freeze-drying is a method of preservation that makes use of the physical principle known as sublimation. Sublimation is the process by which a solid passes directly to the gaseous phase without first [melting](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs). Freeze-drying is a desirable way of preserving food because at low temperatures (commonly around 14°F to −13°F [−10°C to −25°C]) chemical reactions take place very slowly and pathogens have difficulty surviving. The food to be preserved by this method is first frozen and then placed into a vacuum chamber. Water in the food first freezes and then sublimes, leaving a moisture content in the final product of as low as 0.5%.

The precise mechanism by which salting preserves food is not entirely understood. It is known that salt binds with water molecules and thus acts as a dehydrating agent in foods. A high level of salinity may also impair the conditions under which pathogens can survive. In any case, the value of adding salt to foods for preservation has been well known for centuries. Sugar appears to have effects similar to those of salt in preventing spoilage of food. The use of either compound (and of certain other natural materials) is known as curing. A desirable side effect of using salt or sugar as a food preservative is, of course, the pleasant flavor each compound adds to the final product.

Freezing is an effective form of food preservation because the pathogens that cause food spoilage are killed or do not grow very rapidly at reduced temperatures. The process is less effective in food preservation than are thermal techniques such as boiling because pathogens are more likely to be able to survive cold temperatures than hot temperatures. In fact, one of the problems surrounding the use of freezing as a method of food preservation is the danger that pathogens deactivated (but not killed) by the process will once again become active when the frozen food thaws.

Fermentation is a naturally occurring chemical reaction by which a natural food is converted into another form by pathogens. It is a process in which food spoils, but results in the formation of an edible product. Perhaps the best example of such a food is cheese. Fresh milk does not remain in edible condition for a very long period of time. Its pH is such that harmful pathogens begin to grow in it very rapidly. Early humans discovered, however, that the spoilage of milk can be controlled in such a way as to produce a new product, cheese.

The majority of food preservation operations used today also employ some kind of chemical additive to reduce spoilage. Of the many dozens of chemical additives available, all are designed either to kill or retard the growth of pathogens or to prevent or retard chemical reactions that result in the oxidation of foods. Some familiar examples of the former class of [food additives](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) are sodium benzoate and benzoic acid; calcium, sodium propionate, and propionic acid; calcium, potassium, sodium sorbate, and sorbic acid; and sodium and potassium sulfite. Examples of the latter class of additives include calcium, sodium ascorbate, and ascorbic acid (vitamin C); butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT); lecithin; and sodium and potassium sulfite and sulfur dioxide.

## **KEY TERMS**

**Additive**

A chemical compound that is added to foods to give them some desirable quality, such as preventing them from spoiling.

#### **Antioxidant**

A chemical compound that has the ability to prevent the oxidation of substances with which it is associated.

#### **Curing**

A term used for various methods of preserving foods, most commonly by treating them with salt or sugar.

#### **Dehydration**

The removal of water from a material.

#### **Fermentation**

A chemical reaction in which sugars are converted to organic acids.

#### **Irradiation**

The process by which some substance, such as a food, is exposed to some form of radiation, such as gamma rays or x rays.

#### **Oxidation**

A chemical reaction in which [oxygen](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) reacts with some other substance.

#### **Pasteurization**

A method for treating milk and other liquids by heating them to a high enough temperature for a long enough period of time to kill or inactivate any pathogens present in the liquid.

#### **Pathogen**

A disease causing microorganism such as a mold or a bacterium.

A special class of additives that reduce oxidation is known as the sequestrants. Sequestrants are compounds that “capture” metallic ions, such as those of copper, iron, and nickel, and remove them from contact with foods. The removal of these ions helps preserve foods because in their free state they increase the rate at which oxidation of foods takes place. Some examples of sequestrants used as [food preservatives](https://docs.google.com/document/d/1JkNNkQ9x1YLcWQjquDyRiILczWO_BmhFXcW-Q2CNadk/edit#bookmark=id.gjdgxs) are ethylenediamine-tetraacetic acid (EDTA), citric acid, sorbitol, and tartaric acid.

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