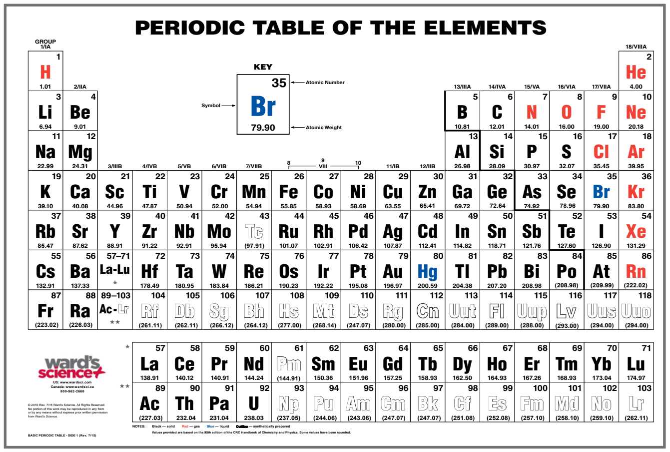
All About Elements:

Nitrogen

Boreal's All About Elements Series

Building Real-World Connections to the Building Blocks of Chemistry



The periodic table of elements is an essential part of any chemistry classroom or science lab, but have you ever stopped to wonder about all of the amazing ways each element is used to create the world around us? Each of the trillions of substances in our universe can be tied back to just these 118 simple, yet powerful elements.

In our ***All About Elements*** series, we've brought together the most fascinating facts and figures about your favorite elements so students can explore their properties and uses in the real world and you can create chemistry connections in your classroom and beyond.

Look for a new featured element each month, plus limited-time savings on select hands-on materials to incorporate these element in your lessons.

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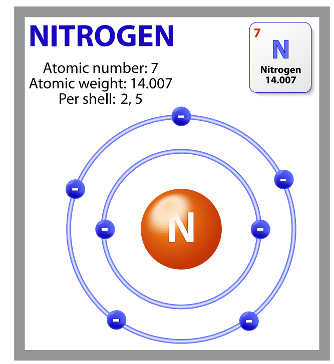
Fun Facts About... Nitrogen

1. Nitrogen is the fourth most abundant element in the universe and it makes up the majority of the earth's atmosphere, at a staggering 78 percent.[1,2]
2. Nitrogen is used in the food packaging industry to preserve food as well as create air pockets in packaging like potato chip bags to prevent food from being crushed.
3. To obtain pure nitrogen it must be distilled at cryogenic temperatures and transported in its liquid form to its destination.[21]
4. Upon stabilization of nitroglycerine, Alfred Nobel (founder of the Nobel Prize) discovered dynamite.
5. Dippin' Dots, a favorite frozen summer treat, get their characteristic "dot" shape from a process using liquid nitrogen.

All About Nitrogen:



Nitrogen is the seventh element on the periodic table. It is found in group 15 (5A) on the periodic table of elements with seven protons and a symbol of N. The name for nitrogen is derived from the Greek words "nitron" and "genes" which means nitre (or saltpeter) forming. It is the fourth most abundant element in the universe and it makes up the majority of the earth's atmosphere, at a staggering 78 percent.[1,2] Pure nitrogen was not "discovered" until the late 1700s, even though it is the main component of air. In order to find nitrogen in its pure inert form, it had to be distilled from the air around us. In its inert form, nitrogen is used for many things, ranging from creating a shield for welding and soldering in the semiconductor industry, to oil companies using high pressure nitrogen to help oil surface. Since the liquefaction process was developed in 1883, liquid nitrogen has been used for countlesspurposes[2] such as in cryogenics to help preserve biological samples, and for low temperature experiments. Liquid nitrogen is also used in the agriculture, medical, food, electronic, aircraft, refining, and missile industries. It's even used for a tasty new trend - liquid nitrogen ice cream![1, 2] You may recognize one frozen treat prepared with liquid nitrogen as Dippin' Dots.

Before nitrogen was isolated in its inert form, a variety of nitrogen-containing compounds were known and used. Many are still in use today! In ancient Egyptian times, ammonium chloride (NH_4Cl) was manufactured by heating a mixture of dung, salt and urine.[10] Alchemists called this chemical sal ammonia.

Properties of Nitrogen

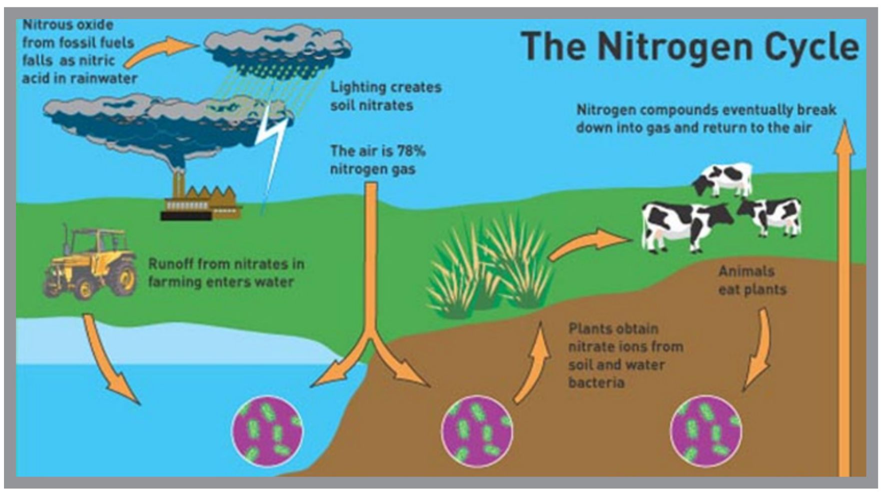
Even though nitrogen is the fourth most abundant element in the universe, it is found in only trace amounts in the earth's crust compared to other elements on the earth.[4] This being said, the human body is composed 3.3 percent nitrogen. Most nitrogen that is found in nature is found in the air as diatomic nitrogen (N_2). It is a non-metallic gas that is trivalent due to having five electrons in its outer shell.[5] This inert gas can be purified and used in a variety of different situations. In water and soil, nitrogen is found in nitrates and nitrites.[5] Within compounds, nitrogen's oxidation state can range from +5 in nitric acid, a strong acid many times used to clean glassware, to -3 in ammonia, which is a basic cleaning product found in Windex and other cleaners. Some other common examples of nitrogen-containing compounds are N_2O (laughing gas), nitrogen mustards (used in chemical warfare), and NaN_3 (decomposes to inflate airbags).

Although Nitrogen-14 is the most common isotope of nitrogen, with an abundance of 99.6%, Nitrogen-15 is also a stable isotope present at 0.37% in nature and has been used to research agricultural uptake.[6] In addition to these two stable isotopes, more than ten radioactive isotopes have been identified, but don't have widespread use at this time. The most stable of the radioactive isotopes is Nitrogen-13 with a half-life of 10 minutes.[7] The first nitrogen in the universe was created soon after the Big Bang in Red Giants when all of the hydrogen in the core was used up. The remaining helium fused into three different elements (including nitrogen.)[8] This isn't a surprising fact when you realize that all planets in our solar system except Mercury contain elemental nitrogen or compounds containing nitrogen.[9]

Where in the World is Nitrogen?

Neon Although 78 percent by volume of the atmosphere is nitrogen gas, this abundant reservoir exists in a form unusable by most organisms. Through a series of microbial transformations known as the nitrogen cycle, however, nitrogen is made available to plants, which in turn ultimately sustain all animal life.[28]

The Nitrogen Cycle



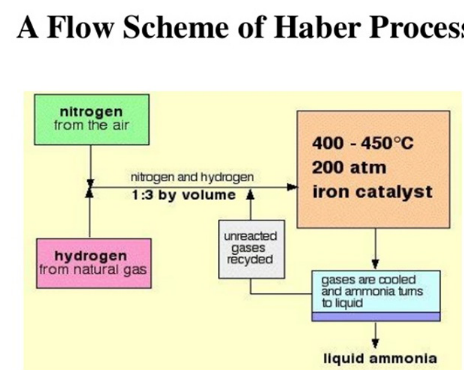
Similar to the carbon cycle, the nitrogen cycle acts to maintain consistent levels of nitrogen in the atmosphere while making usable nitrogen available to animals. The nitrogen cycle is an essential part of life on Earth, in that it helps to create DNA and all proteins necessary for life to occur.

While nitrogen is present in all living tissue and even in our genetic code, humans can't generate nitrogen nor can we distill the gas to create DNA for ourselves. So how do humans, or any living things obtain nitrogen? Through the nitrogen cycle, nitrates and nitrites found in fertilizer, soil and water are absorbed by green plants and algae. These are then used by the plants to build the foundations to construct DNA, RNA, and amino acids, which are the essential building blocks of proteins.[10] When animals consume the plants,the proteins and other nitrogen-containing nutrients are digested and reformed for their own use. The compounds sodium nitrate and potassium nitrate ($NaNO_3$ and KNO_3) are formed naturally by the decomposition of organic matter with sodium and potassium present in the compounds11 and are used as a fertilizer. The nitrogen cycle is completed when bacteria are able to convert nitrogen compounds back into nitrogen gas.

Although the nitrogen cycle helps to keep nitrogen levels relatively constant, it is important to note that not all nitrogen comes from natural or agricultural sources. Nitrates and nitrites are emitted extensively by industrial companies which lead to greater amounts of these compounds in the environment. This also leads to acid rain, erosion and concerns about water quality in communities with smog and large amounts of pollution.

When any fertilizer, particularly those manufactured from ammonia, is applied carelessly or in excess, this can cause problems within ecosystems. These problems are likely seen in your community with increased algae growth, which can then block light and prevent photosynthesis from occurring and decreases the amount of oxygen in the river or lake waters.

Discovery and History



The earliest form of nitrogen known to early alchemists was called sal ammonia (NH_4Cl), which is now known as ammonium chloride.[10] This was used and manufactured in Egypt before nitrogen was isolated. In the 1760s nitrogen gas was obtained by removing oxygen from air by both Henry Cavendish and Joseph Priestly. They noticed that it was different than air – it could extinguish a candle, and it also quickly killed mice when they inhaled the gas. Neither Cavendish or Priestly claimed it was an element, but Daniel Rutherford, in his doctoral thesis in 1772, did. It was Antoine Lavoisier who mistakenly named nitrogen "azote" which means without life. This is an incorrect name, as nitrogen is found in food, organic materials, fertilizers and all DNA.[11] The name was corrected and now comes from the Greek words "nitron" and "genes" which means saltpeter forming.[1]

The most important nitrogen-containing compound, some argue, is ammonia (NH_3). The aqueous solution was originally called the Spirit of Hartshorn and was made by distilling hooves and horns from deer and other large animals.[12] The name was later changed to volatile alkali or animal alkali, which helped to distinguish that ammonia was a base. Most farmers and animal handlers were familiar with the smell of animal urine. Many farmers realized that this might make it a good fertilizer, but it wasn't until the nineteenth century that Justus von Liebig from Germany discovered it was essential for plant health.[12] Once this was discovered, large amounts of saltpeter (sodium nitrate) were mined to create fertilizer. The problem was that there was too large a demand and a shortage was imminent until Fritz Haber found a way to use the nitrogen from the air to create ammonia.[12] This is an industrial process using hydrogen and nitrogen to create ammonia, one compound that is certainly characterized by a highly unpleasant odor. The process of creating ammonia is actually named after Fritiz Haber and is known today as the Haber Process. The Haber process is an essential starting point for many other nitrogen containing-compounds. These include urea (NH_2CONH_2) which is used in fertilizer and the plastic industry and in the livestock industry as a feed supplement.[11]

Uses of Nitrogen Today

Without nitrogen, none of us would be who we are today because it is a key component of both DNA and RNA which are essential for life. Why does nitrogen have so many uses? Nitrogen has a low boiling point and can form up to three covalent bonds, making it ideal for formation of compounds, as well as present in gaseous and liquid form. Diatomic nitrogen is most commonly used and distilled from air which contains about 78% nitrogen. This nitrogen can be used to sterilize environments, create inert atmospheres, for fuel injection systems, in the production of electronics, and in incandescent light bulbs. In addition to these uses, nitrogen helps in the production of stainless steel and in storing beer. Although liquid nitrogen is often used for scientific purposes, more recently it is becoming a culinary tool of showmanship in upscale restaurants, making "frozen" meals, as well as chilling drinks quickly and putting on shows at the table before dessert time.

Fertilizer

Saltpeter (sodium and potassium nitrate) when found in dry areas of the world is used as a fertilizer. In addition to natural compounds being used a plethora of other commercially created options are now available to help fertilize farmland and plants. These compounds include anhydrous ammonia, urea, aqua ammonia, ammonium sulfate, ammonium thiosulfate, calcium nitrate, sodium nitrate and ammonium nitrate.[14] Plants need nitrogen to grow as one of their essential nutrients; the other two are potassium and phosphorus. When crops from a farm are harvested, many times the nitrogen from the soil is harvested with it. Replenishing the nitrogen in the soil is part of the reason fertilizers must be used.

Air Bags

Hopefully you have not had the experience of air bags deploying in your car, but if you have, you know how quickly they are able to do so. Less than 30 milliseconds after the car's sensor detects a crash the airbag is fully inflated, so when the occupants of the car hit the airbag at a time of 50 milliseconds they are deployed and ready to protect.[15] The chemical that allows this reaction to occur so quickly is sodium azide (NaN_3). When the molecule is heated or triggered by an electrical signal that "detonates a small amount of igniter compound," the sodium azide breaks down into nitrogen gas and sodium metal.[15] Only 130 grams of sodium azide will produce 67 liters of the gas to inflate the airbag. What happens with the sodium? You may be wondering about the metal that is highly reactive with water and is also produced in this reaction that is designed to save your life with air. Manufacturers are able to mix the sodium azide with other chemicals to react with the sodium upon decomposition that make it less toxic.

2,4,6-Trinitrotoluene (TNT)

Most of us have heard of TNT at some point in our lives in reference to explosions, but most of us do not know how it was discovered. In 1863 a German chemist, Joseph Willbrand, was trying to make a dyestuff of which TNT has a yellow color. It was not until 20 years later that it was found to be a great high explosive.[16] That being said, it was used by Germans initially starting in 1902. It was found to be better than what had been used in the past due to its low boiling point of 80°C and could be poured in molten form and had a higher velocity shockwave.[16] Only two moles of solid TNT can change into 15 moles of hot gases and powdered carbon. The reason it works so well is that when TNT burns it produces stable gases (CO, CO_2, and N_2) that have very strong bonds. These bonds are then broken and release large amounts of energy. The molecule of TNT has nitro groups that are extremely packed and experience strain and hindrance to movement. This allows a small "initiating force" to break these bonds and start the explosion.[17]

$$\underset{\text{TNT}}{2C_7H_5N_3O_6}\ (s) \longrightarrow 3N_2(g) + 7CO(g) + 5H_2O(g) + \underset{\text{soot}}{7C(s)}$$

Dynamite

Dynamite is a stabilized form of nitroglycerin which is a highly unstable and difficult to handle substance discovered by an Italian chemist in 1846.[22] It is formed by treating glycerol with a mixture of nitric and sulfuric acids.[23] Not only is the reaction highly exothermic, but the heat that is generated when it is created causes the compound to explode unless the mixture is cooled while being produced.[23] In 1862 Alfred Nobel, his father and younger brother started experimenting with nitroglycerin to study the problem of explosion. As nitroglycerine was highly unstable, an accidental explosion occurred at the plant where they were experimenting killing Alfred's younger brother, Emil, along with others in 1864. Even after this tragedy, Nobel continued working to stabilize nitroglycerin. He found kieselguhr, or in English diatomaceous earth, which reduced the volatility of the explosion and stabilized the explosive enough. Nobel continued to work on explosives earning a total of 355 patents, one of which was for dynamite-the stabilized form of nitroglycerine. He used the money from these patents to found the Nobel Prize which was designed to be awarded to the person who "conferred the greatest benefit on mankind".[22]

Food Packaging

Have you ever popped a potato chip bag during a meal to make a big "bang"? Ever wonder why all the chips in the bag aren't crushed when you get them? Or why all your food isn't stale when you buy it off the shelves? You have pressurized Nitrogen gas to thank. When chips and crackers are packaged the air containing oxygen is removed and replaced with nitrogen.[18] Oxygen not only introduces moisture to the atmosphere in the bag[18], but can cause oxidation, microbe and bacterial reproduction, which can lead to food spoilage and deterioration.[19] Not only does the nitrogen preserve freshness, but it prevents the chips or crackers from being crushed.

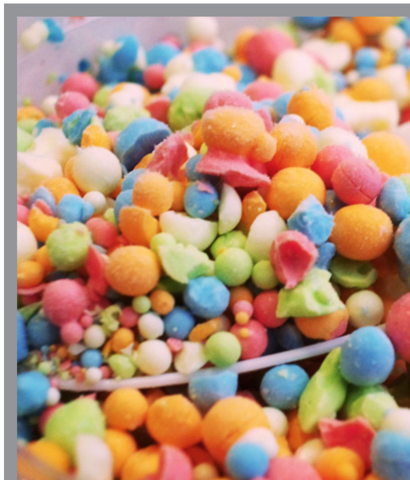
Laughing Gas

Wisdom teeth removal? Painful surgery not so painful? What is laughing gas and where did it come from? When nitrous oxide N_2O was first discovered by Joseph Priestly in 1772 it was thought to be useful for preserving food.[20] This turned out to be false, but Humphry Davy wanted to know more about the gas. He conducted experiments as well as performances looking at the physiological properties of the gas. Davy watched visitors and test subjects and he was amused by how they acted. He called the gas "laughing gas" and the name stuck. Davy also started to notice that there was an anesthetic effect that the gas had on people, but this potential wasn't realized for another forty years.[20] During that time medicine shows and carnivals used the gas to entertain people and earn money. In 1844 Dr. Horace Wells attended a demonstration of the gas noting that when a man who had inhaled the gas was injured he didn't seem to notice until the gas wore off and he set to making it useful in his dental practice. Sadly, when he demonstrated the effects at Harvard Medical School the patient claimed to feel pain, although it was significantly less pain that would have been without the gas. This demonstration ruined his reputation and lead to his suicide less than three years later. It wasn't until 150 years after his death that nitrous oxide was adopted by dental practices around the world and Wells being given the title "Discoverer of Anesthesia".[20]

Scuba Diving

Although pure nitrogen isn't used in scuba diving, the air that is in pressurized tanks does contain mostly nitrogen. This is important to know as a diver that careful timing is required when resurfacing, so that the diver does not end up with what is commonly known as "the bends". Nitrogen from the tank, at the high pressures on the body from being underwater, dissolves into the bloodstream. This is not a bad thing, as long as the diver doesn't resurface too quickly, as the nitrogen gas will slowly release out of the system. If a diver resurfaces too quickly the dissolved nitrogen forms bubbles in the bloodstream which can lead to a painful sickness, if not a fatal death.[11]

Dippin' Dots Ice Cream



This summertime treat at baseball games and amusement parks are a practical and tasty application of liquid nitrogen. The Dippin' Dots story began in 1987 when microbiologist Curt Jones began research on how to cryogenically freeze ice cream into small beads.[26]The use of liquid nitrogen requires that the "dots" be kept at extremely cold temperatures (-40 degrees Celsius) to retain their shape. According to the company website, and Jones' knowledge as a microbiologist, the liquid nitrogen helps to lock in the flavor and freshness into the ice cream. There is science behind ice cream that shows the smaller the crystals in the ice cream the better it tastes. One of the ways to get smaller crystals is to cool the ingredient faster which creates smaller crystals for smoother ice cream.[27]

Health Concerns Related to Nitrogen

Although nitrogen constitutes 78 percent of our air in elemental form, there are some major issues that are created when excess nitrogen containing compounds are used. When fertilizer that is high in nitrogen is used in large quantities, usually on farmland, the excess seeps into the ground and can contaminate the topsoil as well as the water in the ground.[24] The nitrates, nitrites and ammonia in the fertilizer can be toxic to the surrounding environment. The nitrogen containing compounds also seep into the air we breathe.[24] For humans, nitrates can cause problems such as decreased function of the thyroid gland, vitamin A shortages, as well as creation of nitro amines which are known as one of the most common causes of cancer.[5] Nitrites also are known to create nitro amines as well as reacting with hemoglobin in blood decreasing the amount of oxygen carried in the blood.[5]

In addition to compounds containing nitrogen, nitrogen in both liquid and gaseous phases can become potentially fatal. As previously discussed, if a scuba diver resurfaces too quickly nitrogen bubbles in their bloodstream can make them either very sick or can be fatal. Liquid nitrogen, used in a variety of places including food, industrial and laboratory setting can be fatal if spilled. This would occur if there is no ventilation and result in asphyxiation as nitrogen is colorless, odorless and tasteless.[25] Nitrogen has a boiling point of -196° C .This absolutely frigid temperature can cause frostbite or cryogenic burns if it isn't used or handled correctly.[25]

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Determination of the Ammonia Nitrogen Concentration in Water

Determine the Amount of Nitrogen in Water Samples.

This kit has been designed to allow the analyst to perform a very simple colorimetric analysis to determine the ammonia nitrogen concentration of their fresh water sample. The analysis yields an easily identifiable color transition that can be compared with the included color key to determine the concentration in your sample. The kit contains everything an analyst would need to perform a water analysis either in the laboratory setting or out in the field. Kit contains enough materials to perform 40 tests. Concentration Reader Range: 0, 0.25, 0.5, 0.75 1.0, 1.5 and 2.0 mg NH. Higher concentrations can be tested using a dilution of the water sample with DI water (not supplied).

Item Number: 470146-434

Ammonia (Household)

Approximately 10% by mass, (~2.3 M).

(NH_3) aqueous

CAS#: 7664-41-7

Hazard: Irritant, Corrosive
Shelf Life (months): 36
Storage: Green
Soluble: Water
bp (°C): 36
Density (g/mL): 1.023

General Storage

Solution, Household
Item Number: 470045-568

Ammonium Nitrate

NH_4NO_3

F.W.: 80.04 CAS#: 6484-52-2

Hazard: Irritant, Reactive, Toxic
Shelf Life (months): 36
Storage: Yellow
Soluble: Water, Alcohol, and Alkalies
mp (°C): 169
Density (g/mL): 1.72

Grade: Laboratory, Solution
Item Number: 470300-226

Ecology Symbiosis Lab Activity

Demonstrate How Varying Levels of Nitrogen-Fixing Bacteria Affect Plants

Students will explore the benefits of mutualistic symbiosis by growing rye seeds in three different media, including complete nutrient media and nitrogen deficient media, inoculated with clover. They will plot average heights and weights, calculate the percent differences in growth rates, and observe the changes in general appearance over the course of one month. They will then use their data to determine the effects that nitrogen-fixing bacteria have on the growth of these plants. The kit contains enough materials for 24 students, a teacher's guide, and student data sheet copymaster.

Item Number: 360889