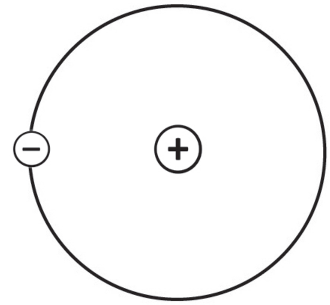
H

1 proton
1 electron

Atomic mass: 1.0



Hydrogen

From Greek words “hydro" (water) and “genes” (make)

Hydrogen is the smallest and lightest of all the elements. It is made of just one proton and one electron. Most of the time it doesn’t have any neutrons. On rare occasions when hydrogen does gain a neutron, we call it “heavy hydrogen.” Adding a neutron doesn’t change its identity; it will still be hydrogen because it has one proton.

Hydrogen is a gas. If you put hydrogen into balloons, they will float. But don’t try this because hydrogen is very flammable (catches fire easily). There was a terrible accident in 1937 in New Jersey, USA, when a hydrogen-filled blimp caught fire. That was the last time anyone put hydrogen into a blimp or balloon. The flammability of hydrogen can be put to good use, however, by using it as fuel in rocket engines. On a smaller scale, welders use tanks of hydrogen as a source of intense heat for joining steel parts.

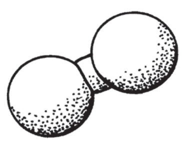
Stars, including our sun, are made primarily of burning hydrogen gas. The extreme heat causes the hydrogen atoms to bump into each other and sometimes they combine to form larger elements such as helium, lithium or sodium.

Hydrogen bonds to many other elements and is found in thousands of molecules. The reason it likes to bond to other atoms is because its one electron is “lonely” and would like to be part of a pair. There are many atoms who would be very happy to have hydrogen come over and share its electron with them. Atoms that frequently bond with hydrogen include oxygen, carbon, nitrogen, and chlorine. When carbon atoms join together to make very long chains, hydrogen atoms will attach themselves to any free place they can find along the chain. This type of molecule (a chain of carbon atoms with hydrogens attached) is called a “hydrocarbon.” Hydrocarbon molecules include methane (natural gas), octane (liquid gasoline), vegetable oils, animal fats, wax, and many types of plastics.

You can assign your own colors to the atoms, but here is what a professional scientific illustrator would be most likely to use:

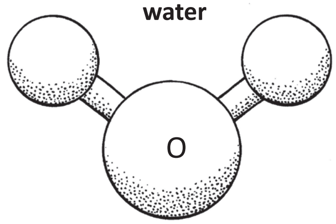
White: Hydrogen (blank)
Red: Oxygen (O)
Black: Carbon (C)
Green: Chlorine (Cl)
Blue: Nitrogen (N)

The hydrogens look pretty big in these models. They are actually much smaller than these other atoms, but it looks nicer if the balls are close to the same size.

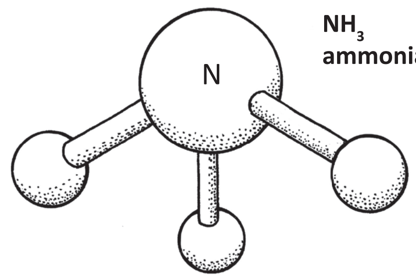


H_2 hydrogen gas

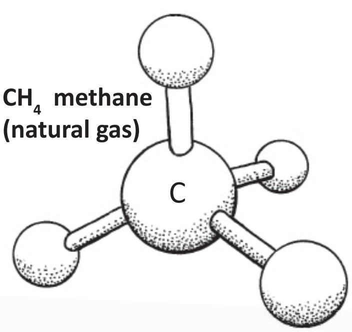
H_2O water

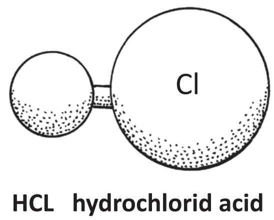


NH_3 ammonia



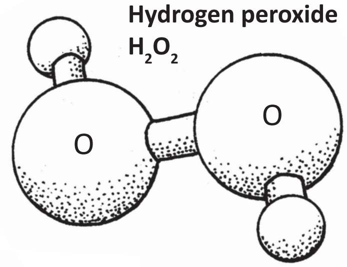
CH_4 methane (natural gas)

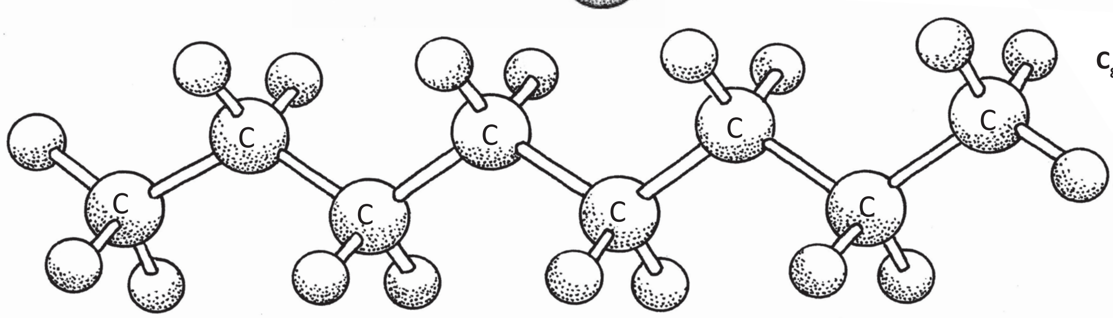




HCL hydrochlorid acid

Hydrogen peroxide H_2O_2





C_8H_{18} octane

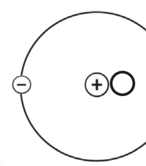
Octane is liquid gasoline (petrol). Hydrocarbon chains can grow to be very long. Plastics are made of chains that contain thousands of carbon atoms.

1 H

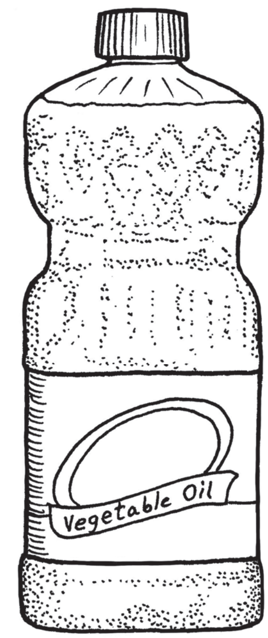
Hydrogen

Stars, including our sun, use hydrogen as fuel.

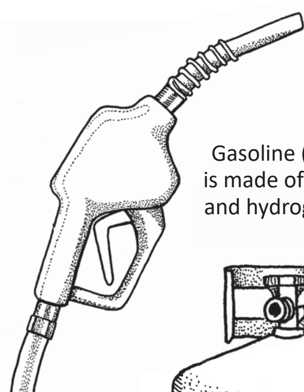
Water is H_2O.



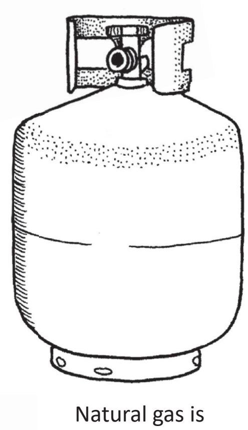
Deuterium, or "heavy hydrogen," has a neutron.



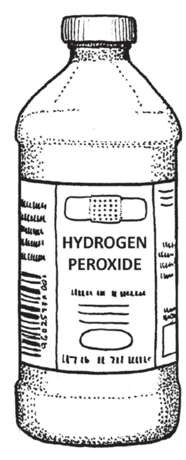
Hydrogenated oils are made of chains of carbon atoms with hydrogen atoms attached.



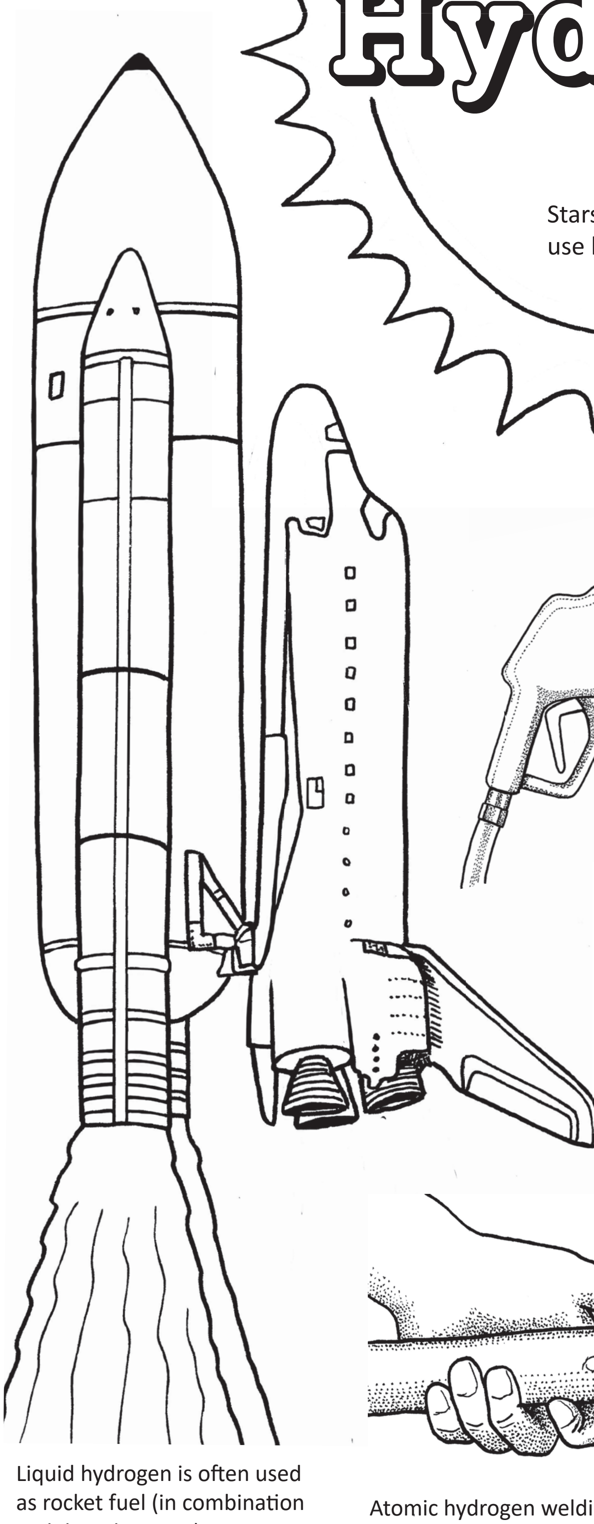
Gasoline (petrol) is made of carbon and hydrogen.



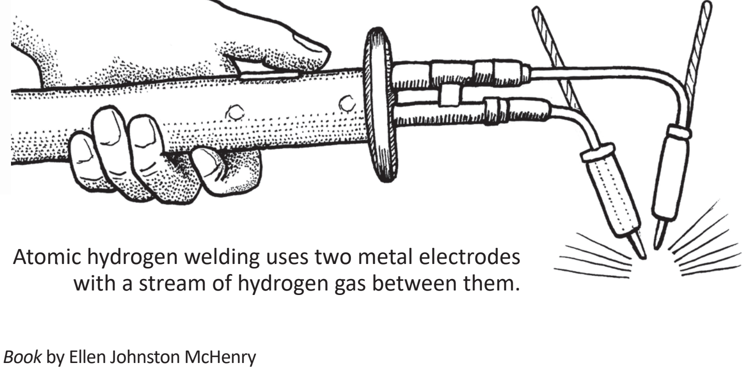
Natural gas is methane, CH_4.



Hydrogen peroxide, H_2O_2 is used to clean wounds.



Liquid hydrogen is often used as rocket fuel (in combination with liquid oxygen).



Atomic hydrogen welding uses two metal electrodes with a stream of hydrogen gas between them.

Some cleaning products contain ammonia, NH_3.

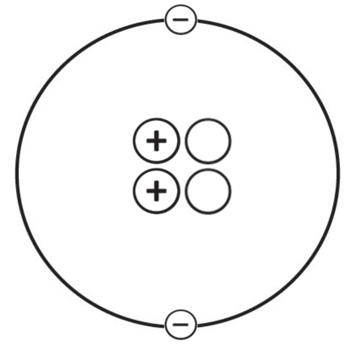
He

Helium

From the Greek word for sun: "helios"

2 protons
2 neutrons
2 electrons

Atomic mass: 4.0



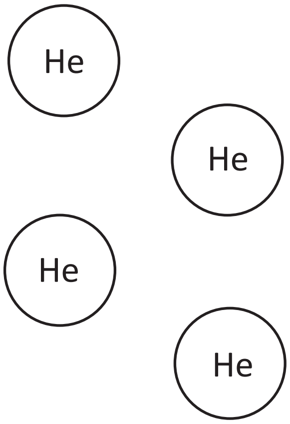
Helium was first discovered in the sun, which is why it was named after the Greek god of the sun, Helios. Scientists in the 1860s were beginning to use a new tool, called the spectrometer, to look at light produced by various things, including the elements as they were burned. They noticed that each burning element seemed to give off a unique light pattern, almost like a fingerprint, by which it could be identified. When they saw a new light pattern as they looked at the sun, they knew it must be a new element. In 1868, Norman Lockyer announced the discovery of a new element that he had named "helium." Then, in 1895, William Ramsay discovered helium in a sample of rock that contained the element uranium. Helium was not just in the sun, but on earth as well! It was later found that helium is produced as uranium atoms break apart, or "decay."

The element helium is a very light gas. Unlike hydrogen, helium is not flammable. Put a spark to helium and nothing happens. This makes it very safe to put in blimps, party balloons, and weather balloons.
Helium is so unreactive that it can be put into rocket engines that are filled with hydrogen. It is also used as a "shield gas" in arc welding, surrounding and insulating the dangerously hot arc of electricity.

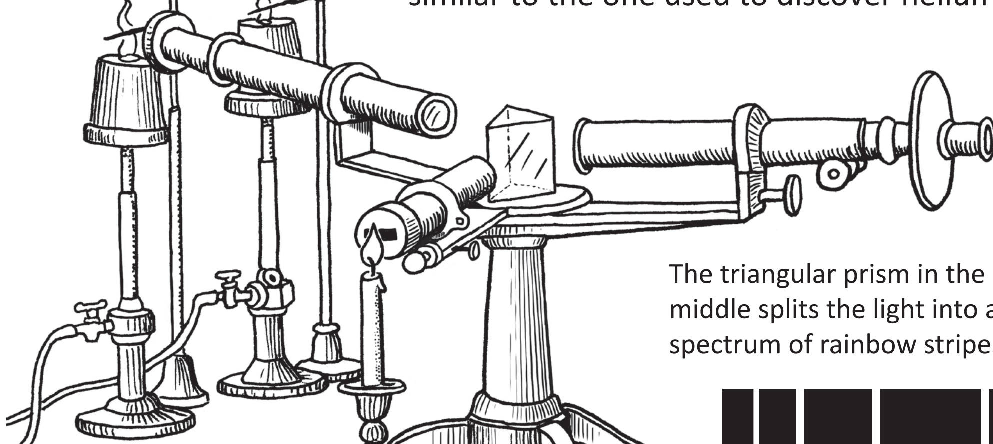
Another place the safety of helium comes in handy is in air tanks used by scuba divers. The air around us is mostly nitrogen, with some oxygen mixed in. If divers take normal air down with them, the nitrogen can do something harmful. If the divers come up too quickly, the nitrogen can bubble into their blood, much like bubbles appear when you open a carbonated beverage. Bubbles in your blood is not good! This dangerous condition is called "the bends." (Divers hurt so much they bend over with the pain.) However, if helium is used in place of nitrogen, divers can come back up without having to worry about getting "the bends."

Helium has other technological uses. A mixture of helium and neon is used in red lasers, the kind that are used to read bar codes at check outs in stores. Extremely cold liquid helium is used in machines and devices that need extremely powerful magnets, such as MRI machines in hospitals, and the particle accelerators used by physicists to do experiments with electrons, protons, and neutrons.

Helium atoms don't bond to other atoms. They float around by themselves.



This is a spectrometer from the 1800s, similar to the one used to discover helium.

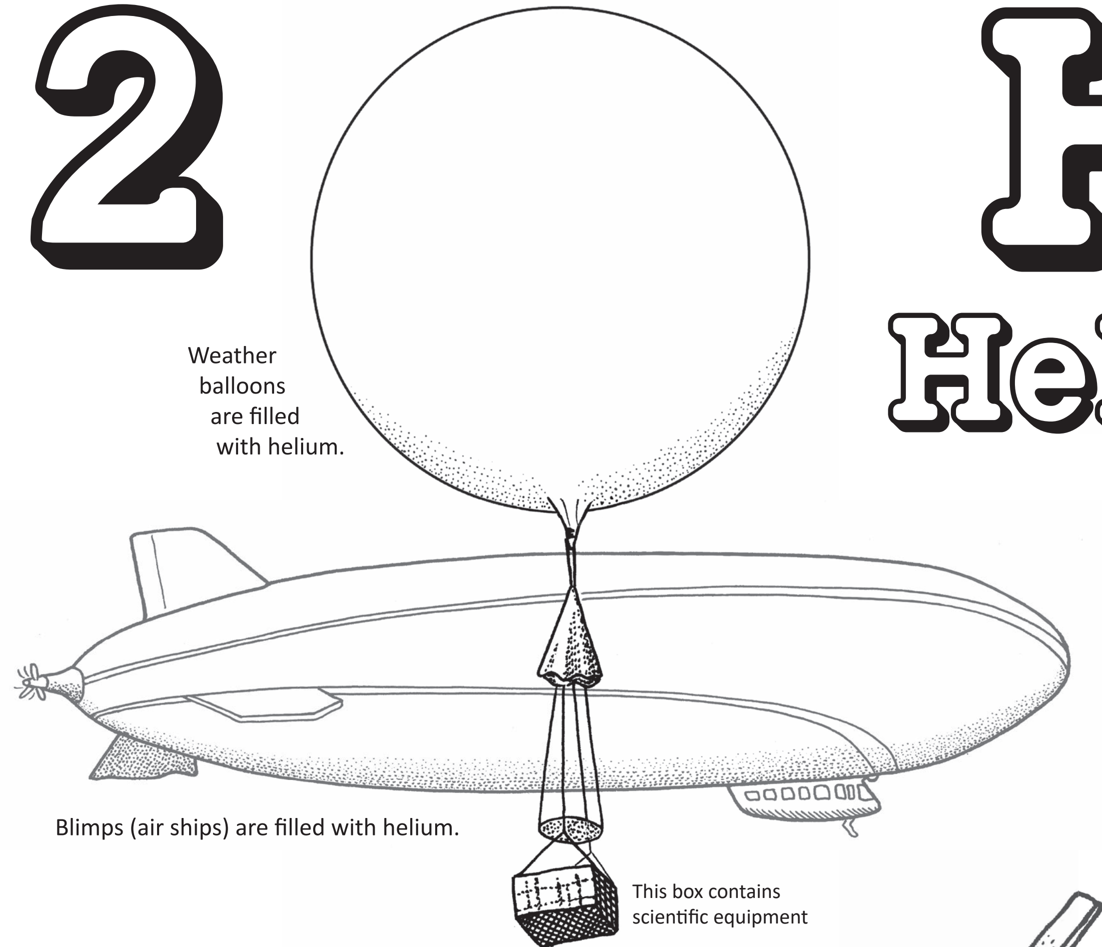


The triangular prism in the middle splits the light into a spectrum of rainbow stripes.

Helium's spectral lines

2 He

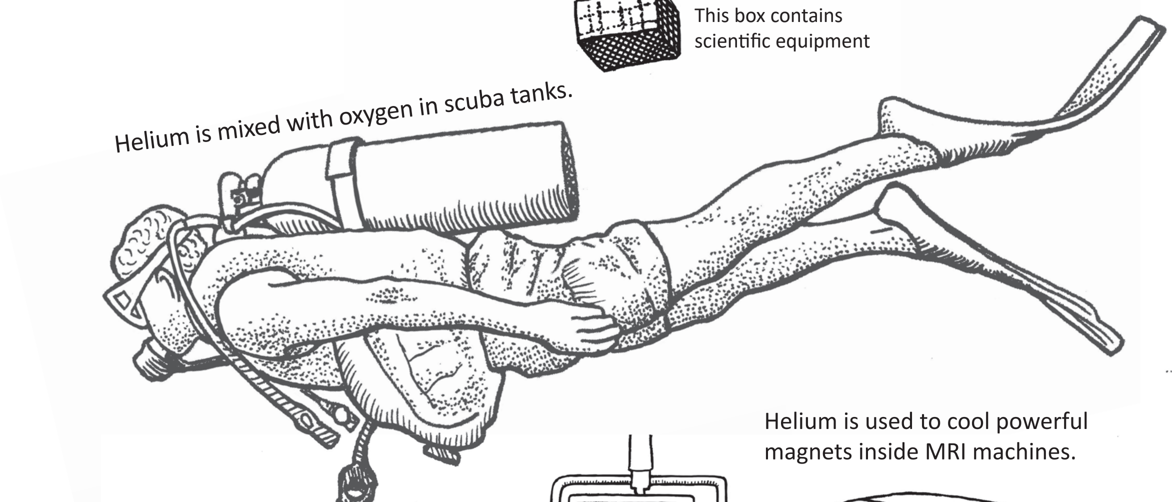
Helium



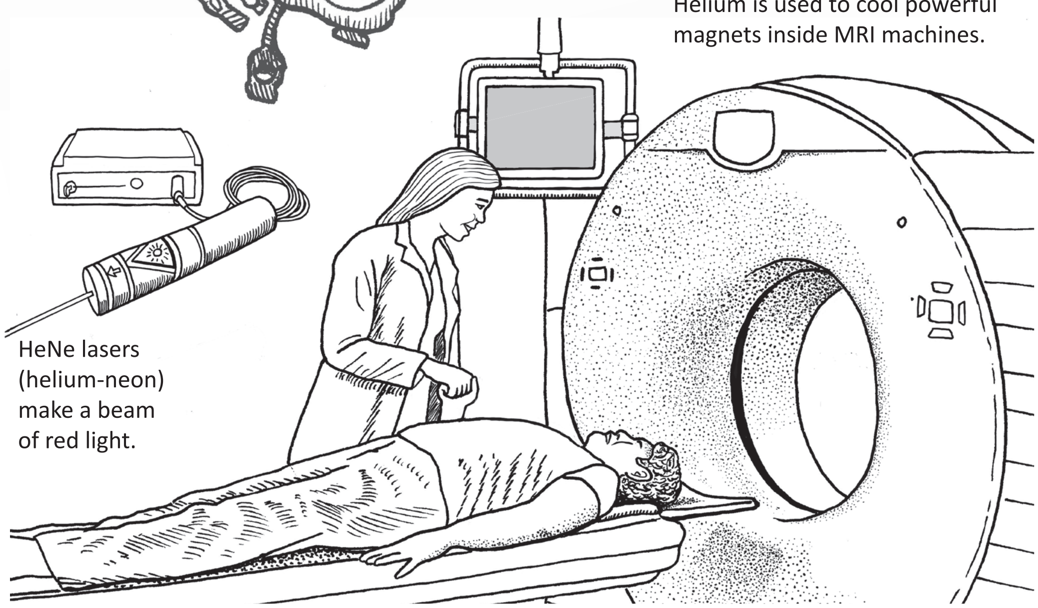
Weather balloons are filled with helium.

Blimps (air ships) are filled with helium.

This box contains scientific equipment

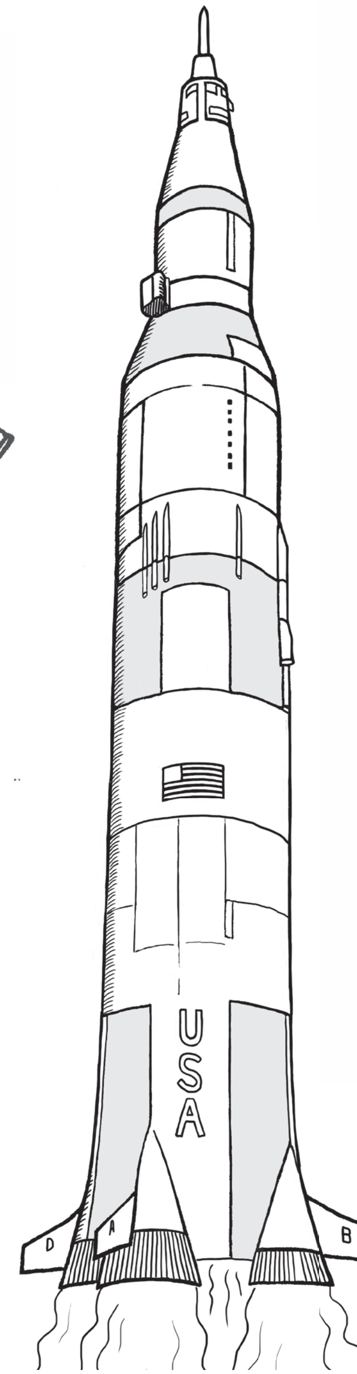


Helium is mixed with oxygen in scuba tanks.



HeNe lasers (helium-neon) make a beam of red light.

Helium is used to cool powerful magnets inside MRI machines.



Helium is used to pressurize the hydrogen in rocket engines.

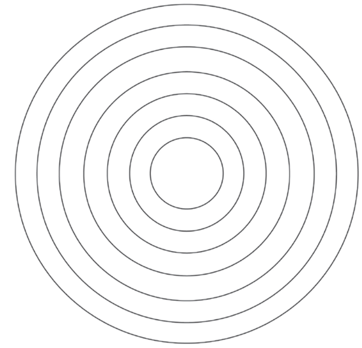
Li

Lithium

From the Greek word for stone: "lithos"

3 protons
4 neutrons
3 electrons

Atomic mass: 6.94

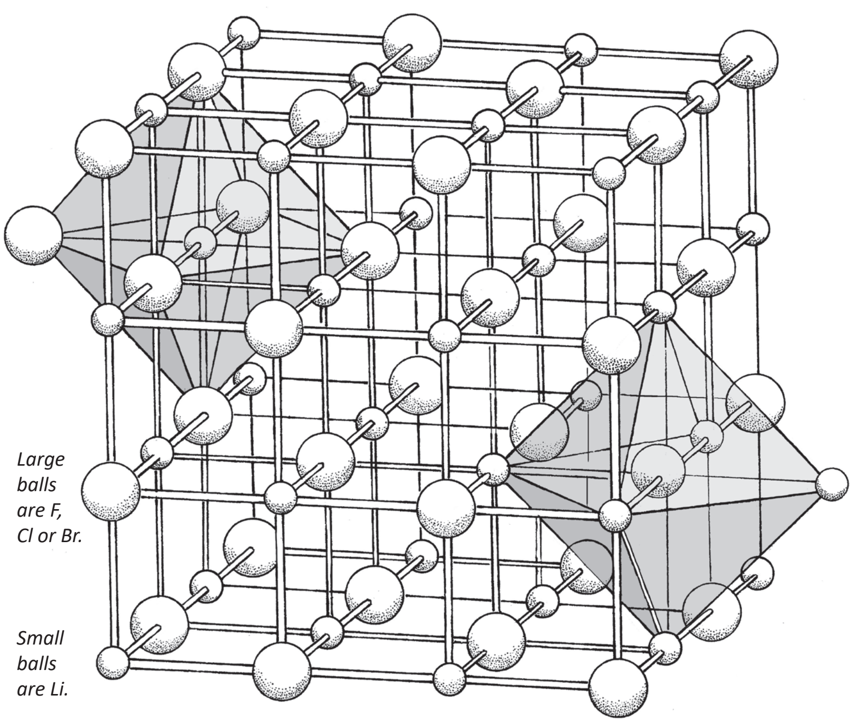


Lithium is most well-known for its use in long-life batteries, but it's also used in lubricants, fuels, metal alloys, glass making, and even medicines. Some of its useful qualities come from its electron configuration. Do you see that one lonely electron in the outer ring? It's very "unhappy" because it doesn't have a partner to pair up with. The two electrons in the inner ring are paired up, and are therefore very content. The unpaired electron in the outer ring is so "unhappy" that it would rather go off and be part of another atom than stay where it is. Some atoms, like fluorine, chlorine, and bromine (members of the halogen family) are desperate to grab an extra electron that doesn't belong to them, so if they run into a lithium atom, it's a perfect match. Molecules like LiF, LiCl and LiBr are relatively easy to make in a lab. LiF, lithium fluoride, takes the form of a clear crystal which can be used in optical lenses and in radiation detectors. LiCl, lithium chloride, is a white powder that is used in fireworks and emergency flares because it produces a bright reddish-pink flame. LiBr, lithium bromide, can be used to trap moisture in air conditioning systems.

Lithium atoms will bond to small groups of atoms, such as the carbonate ion, CO_3^{2-}. Lithium carbonate, Li_2CO_3, is used by the ceramics industry to make glazes and tile adhesives, by the metal industry to process aluminum, by the glass industry to make ovenware, by the pharmaceutical industry to make medicines, and by the battery industry to make long-life lithium ion batteries. Lithium bonds well to the hydroxide ion, OH^-, to form LiOH, a compound that can remove carbon dioxide from the air that circulates inside an airplane. Lithium will also bond to metals such as aluminum, copper and manganese, making lightweight alloys (metal mixtures) that are used to make airplanes.

Lithium atoms are never found alone in nature. To get a pure sample of lithium, a strong electrical current must be used. Pure lithium looks like a silvery metal and is so light it will float on water. It will also react with the water, trying to get rid of that lonely electron, and this will cause it to look like it is burning on top of the water.

When Li bonds to F, Cl, or Br, it forms a crystal shape:

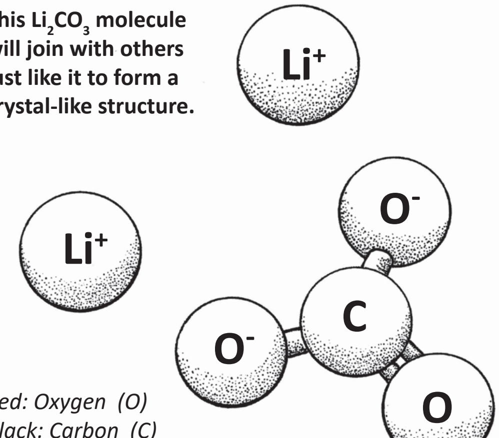


Large balls are F, Cl or Br.

Small balls are Li.

When two Li atoms connect to a CO_3, they don't bond in the way that C and O do. (The sticks represent bonds.) Instead, the Li atoms are held in place by electrical attraction. The positively charged Li atoms (ions) are attracted to the negatively charged oxygen atoms in the CO_3.

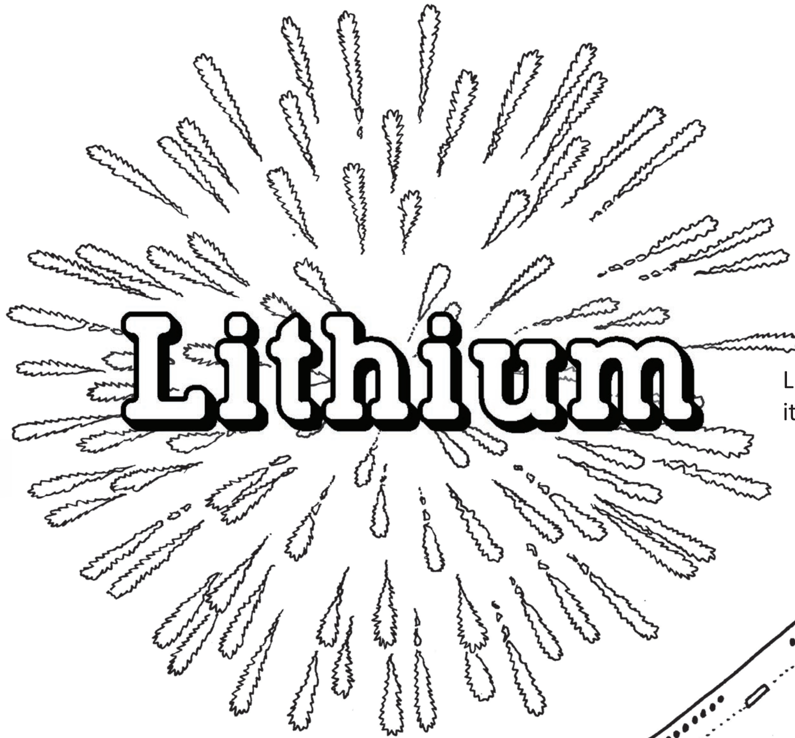
This Li_2CO_3 molecule will join with others just like it to form a crystal-like structure.



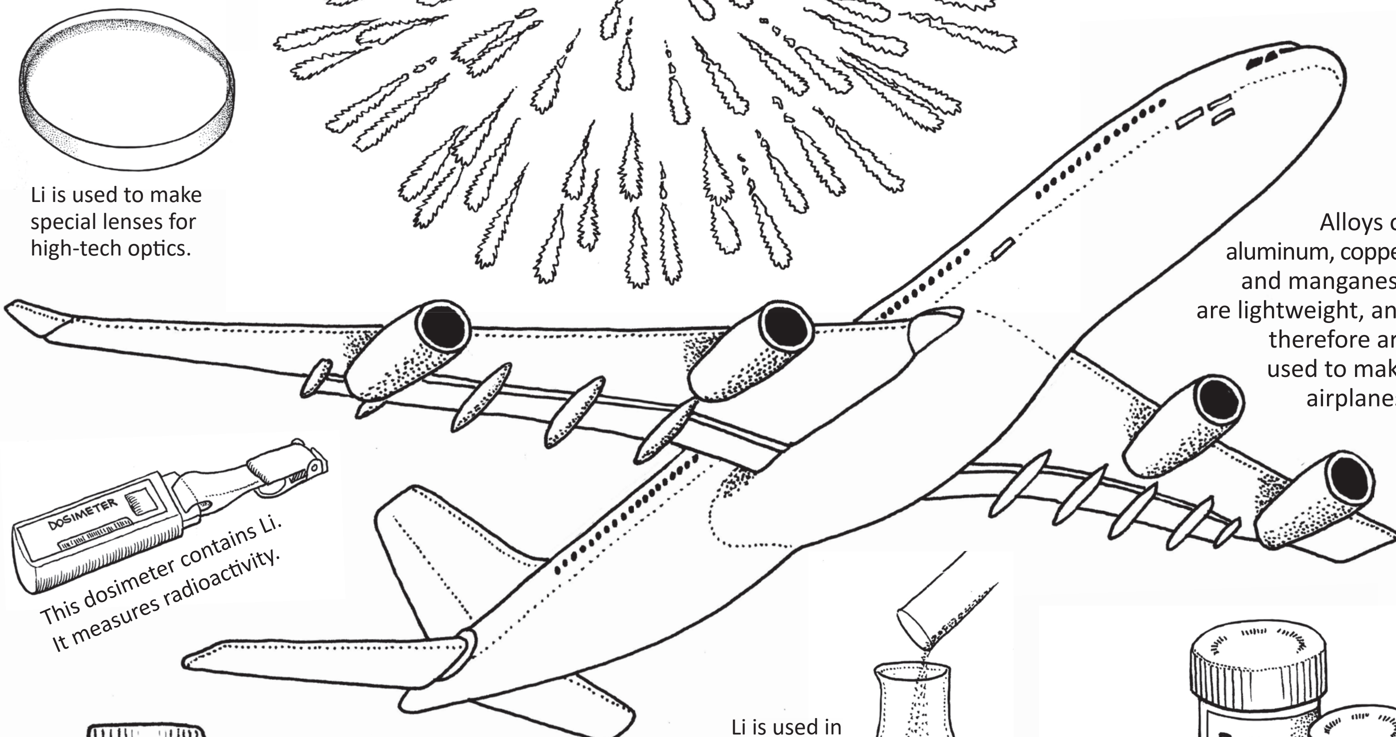
Red: Oxygen (O)
Black: Carbon (C)
You can decide what color to make lithium. A professional artist would probably use purple or pink.

3 Li

Lithium



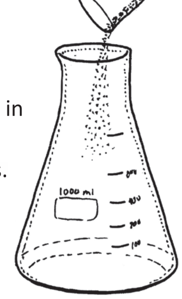
Lithium makes red sparks when it burns so it is used in fireworks.



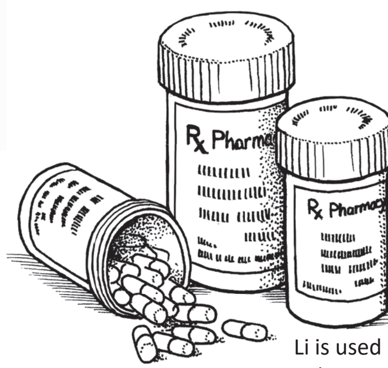
Li is used to make special lenses for high-tech optics.

Alloys of aluminum, copper and manganese are lightweight, and therefore are used to make airplanes.

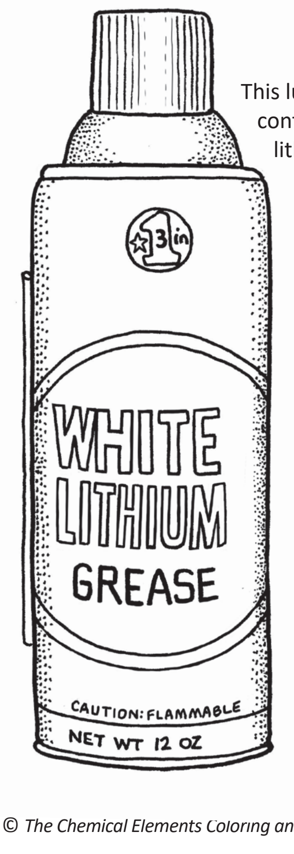
This dosimeter contains Li. It measures radioactivity.



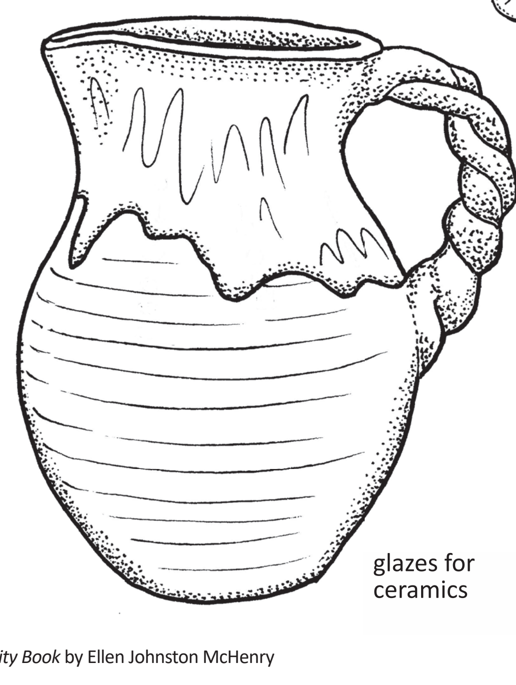
Li is used in chemical reactions.



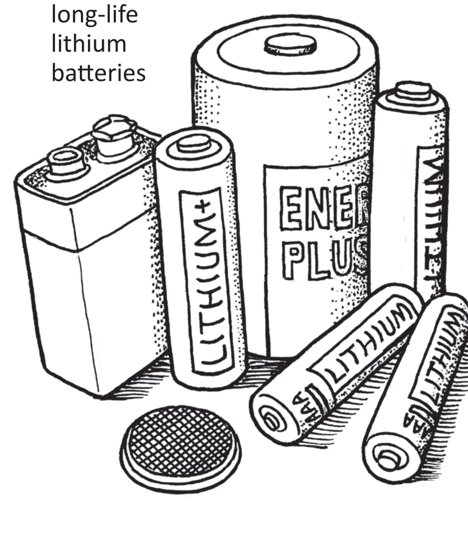
Li is used in medicines.



This lubricant contains lithium.



glazes for ceramics



long-life lithium batteries

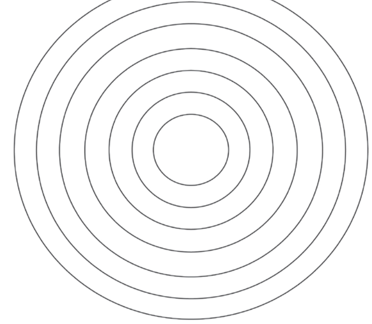
Be

Beryllium

From the mineral "beryl"

4 protons
5 neutrons
4 electrons

Atomic mass: 9.01



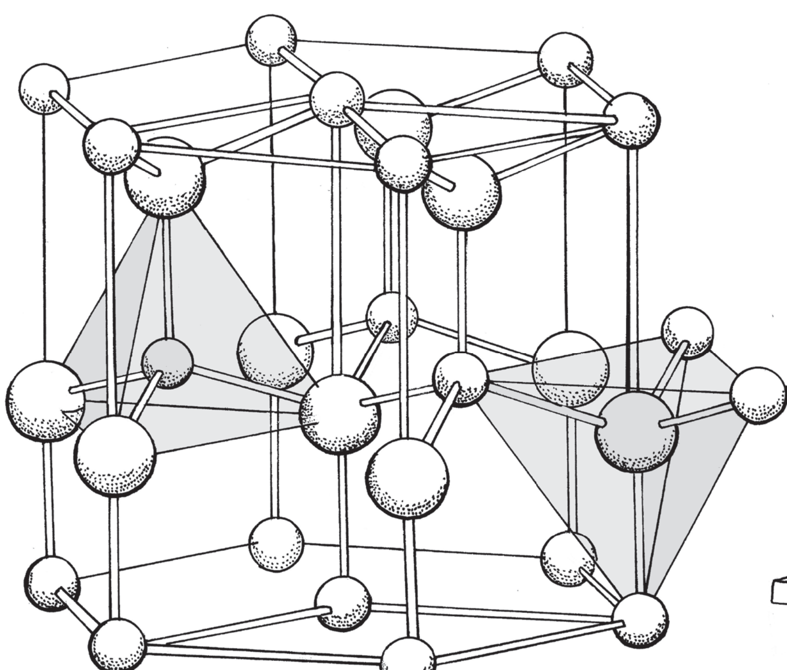
Beryllium's name comes from the mineral beryl. Beryl is made of beryllium, aluminum, silicon and oxygen, with this chemical formula: $Be_3Al_2(SiO_3)_6$. When beryl is made into a gemstone, we call it an emerald. Beryllium was first extracted from beryl in 1828 by two people working independently, one in France and one in Germany.

Beryllium is the smallest and lightest member of the alkali earth family (the second column from the left on the Periodic Table). This means that it has two electrons in its outer shell. This is better than just one, but beryllium would prefer to have 8 electrons in its outer shell, so it will easily give up its electrons to another atom or group of atoms. Oxygen makes a natural pairing, since it is looking for two electrons to complete its shell. BeO, beryllium oxide, is used to make parts for rocket engines, as a protective coating on telescope mirrors, as semiconductors in radios, and for ceramic parts in microwave devices, vacuum tubes, and lasers.

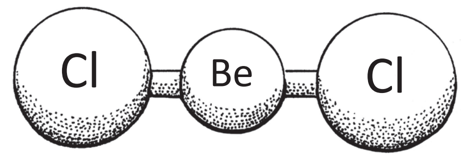
Pure beryllium can also be very useful, due to the fact that x-rays will go right through very small atoms. If you want to put a "window" in a vacuum tube, you need a substance that is both strong (won't cave in when the pressure drops inside the tube) and yet will let x-rays pass through. Beryllium is perfect for this.

When a little bit of beryllium is added to another metal, such as copper or aluminum, it makes it stronger. Beryllium bronze is made of 2% beryllium and 98% copper. The strength of beryllium bronze makes it an excellent choice for the manufacturing of parts such as heavy duty springs, which must maintain their shape even under a lot of stress. Beryllium bronze is special in another way, too. It won't create a spark if it strikes another metal, even steel. There are some places where sparks can be very dangerous, and you don't want to take the risk that your tool will start a fire or cause an explosion. Beryllium bronze tools are used on oil rigs, in coal mines, in satellite manufacturing, and by people who repair MRI machines.

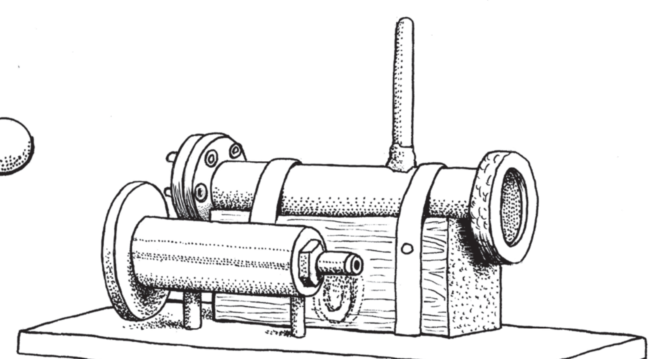
Beryllium's claim to fame is that it was used to discover neutrons. In 1932, James Chadwick shot alpha particles (nuclei of helium atoms) at a piece of beryllium, and unknown particles (neutrons) were produced. Beryllium can be used as a source of neutrons for lab experiments, particle accelerators, nuclear power plants, and in atomic bombs.



Beryllium oxide (BeO) will make a crystal lattice shape.

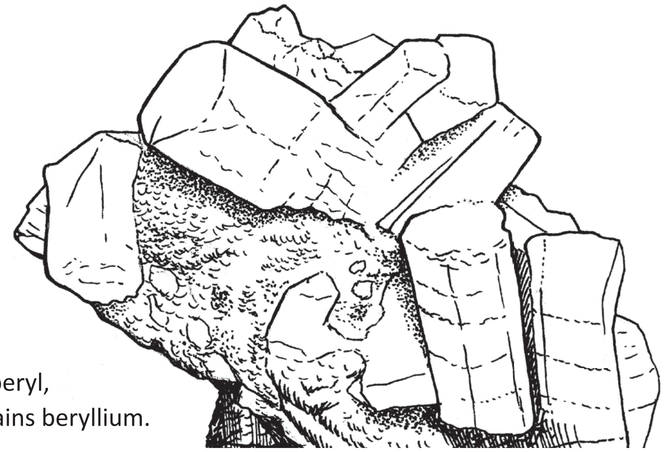


Beryllium chloride is a common Be compound.



Chadwick used this device to shoot alpha particles at beryllium. The alpha particles dislodged neutrons from the beryllium nuclei.

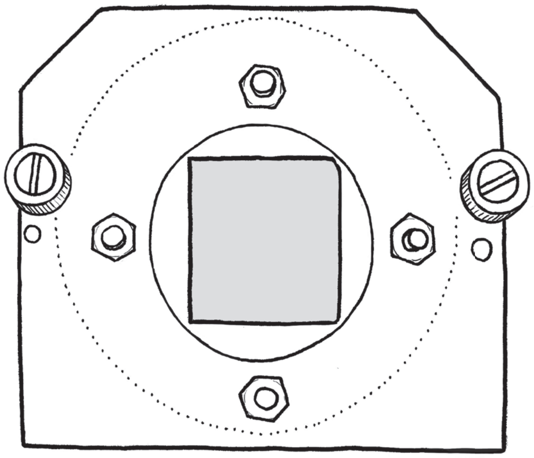
4 Be



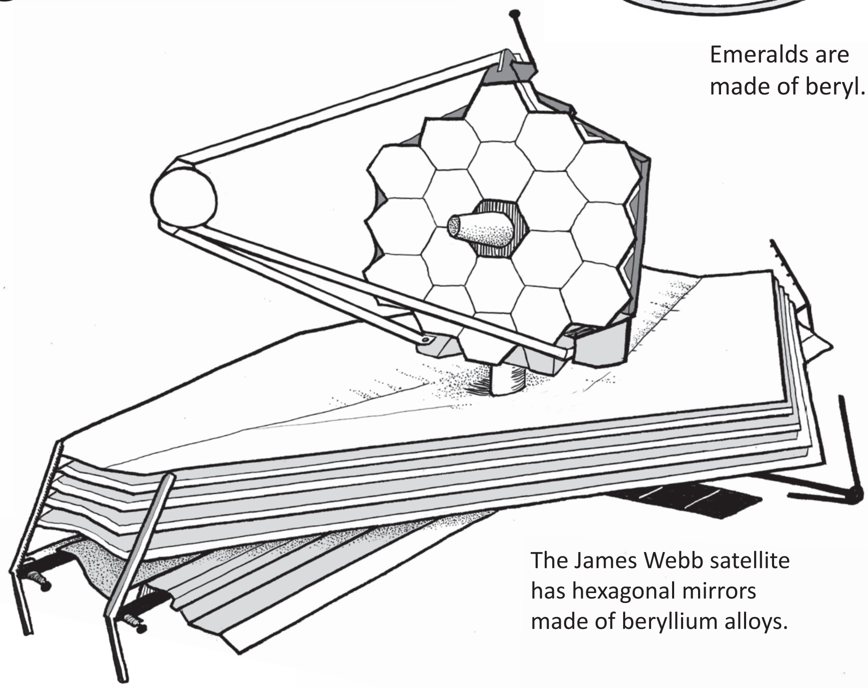
The green mineral beryl, $Be_3Al_2(SiO_3)_6$, contains beryllium.

Beryllium

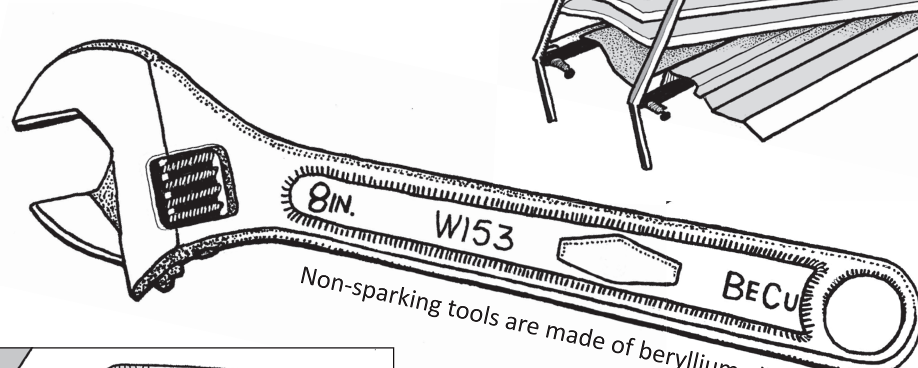
Emeralds are made of beryl.



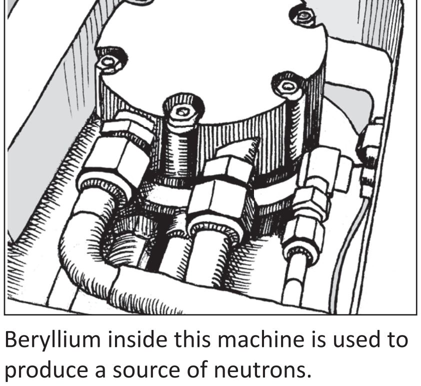
"Windows" for x-ray chambers



The James Webb satellite has hexagonal mirrors made of beryllium alloys.

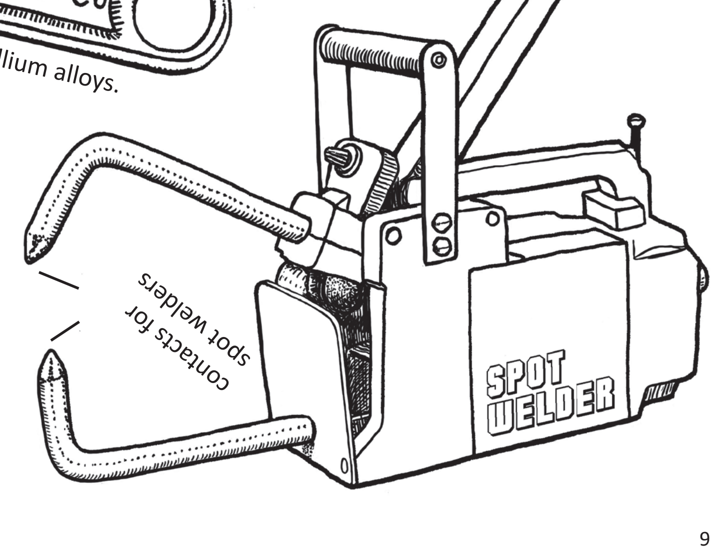


Non-sparking tools are made of beryllium alloys.



Beryllium inside this machine is used to produce a source of neutrons.

Heavy duty springs



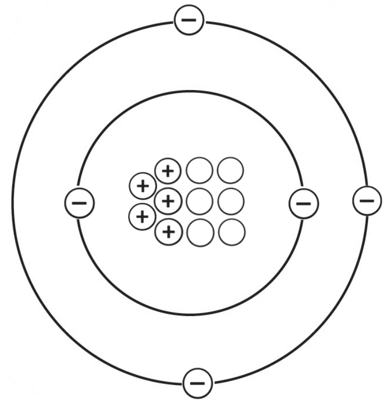
contacts for spot welders

B

5

protons
5 or 6 neutrons
5 electrons

Atomic mass: 10.81



Boron

From the mineral "borax"

Boron is happy with either 5 or 6 neutrons. It is shown here with 6 neutrons because 80% of all boron atoms have 6. However, if it loses a neutron, it's no big deal. In many atoms, losing a neutron IS a big deal, and this will make the nucleus unstable. (Unstable nuclei tend to fall apart and spit out dangerous particles that can cause damage to plants and animals.) Boron atoms with 5 neutrons can safely add one more. The atoms with 5 neutrons are useful in nuclear power plants that use radioactive (unstable) elements that emit neutrons when they fall apart. Rods containing boron atoms are placed in areas where dangerous free neutrons need to be safely absorbed.

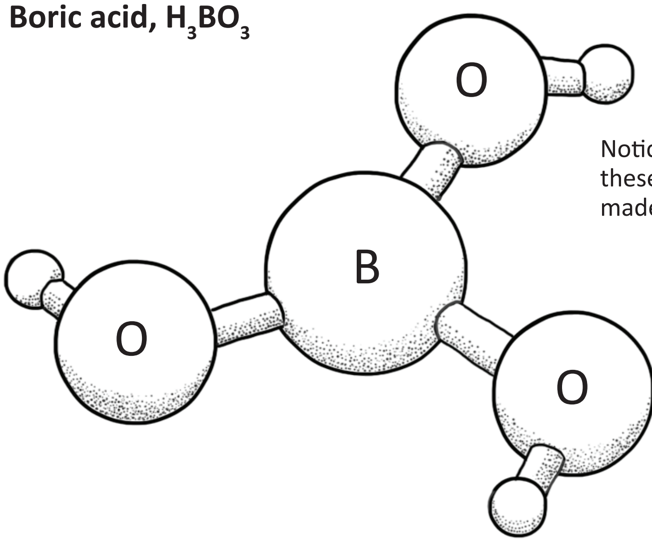
The fact that boron can have either 5 or 6 neutrons explains why its mass is listed as 10.81. The mass is the total number of protons and neutrons in the nucleus. Since boron can have either 5 or 6 neutrons, we must look at as many boron atoms as we can, and then calculate the average. The average turns out to be 10.81, so this is listed as the official atomic mass. But you'll never find a boron atom with 10.81 things in its nucleus! It will always be 10 or 11.

Boron is added to glass to make it less likely to shatter at high temperatures. This "borosilicate" glass is ideal for both kitchens and science labs. (The glassware called Pyrex® is borosilicate glass.) Tiny borosilicate glass beads can be added to paint that is used to put lines on roads. The glass beads in the paint will reflect shining headlights at night. Boron is added to glass that will be spun into the very thin fibers that make fiberglass insulation.

A very useful property of boron is that it won't burn (meaning combustion in the presence of oxygen). Boron compounds, such as zinc borate, can be sprayed onto fabric or wood to make them fire resistant. Boron's presence in fiberglass increases its resistance to fire as well as making the fibers stronger. When boron is used in fireworks, the atoms don't "burn" but they do heat up, showing a bright green color.

Boron is usually extracted from the mineral "borax" ($Na_2B_4O_7$ - $10H_2O$). Borax is used to make laundry washing powder. (Kids might know this powder as the stuff you combine with white glue to make an oozy substance known as "slime" or "goop.") The cleaning power of borax is useful in medicine, too. Borax can be turned into boric acid, H_3BO_3, and put into germ-fighting eye washes. Borax is poisonous to insects and is often used in ant and roach traps.

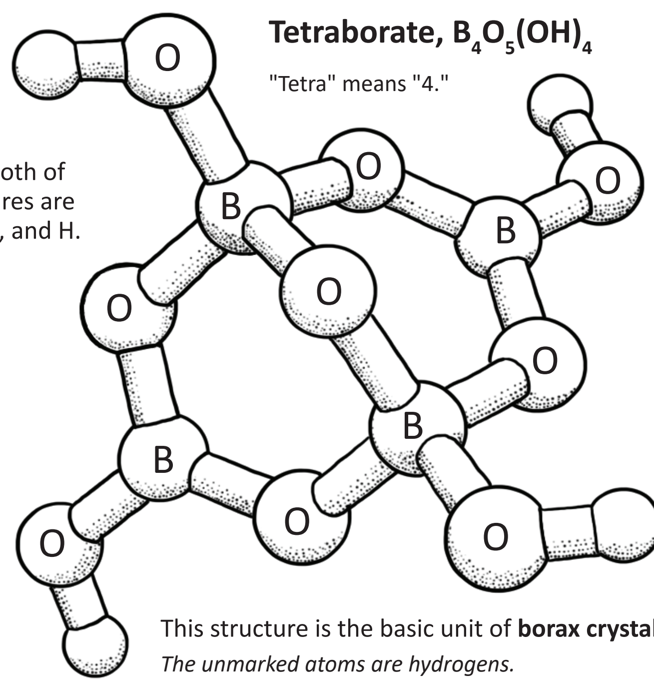
Boric acid, H_3BO_3



Notice that both of these structures are made of B, O, and H.

Tetraborate, $B_4O_5(OH)_4$

"Tetra" means "4."

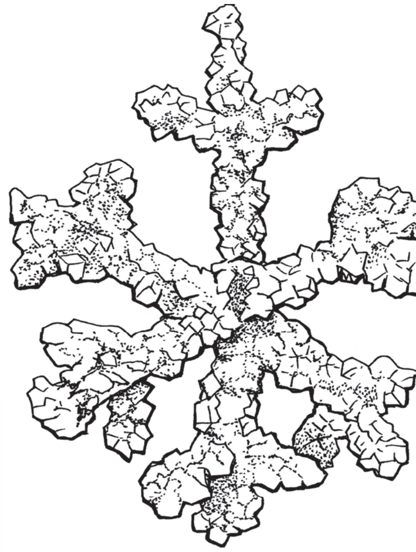


You can assign colors as you wish, but scientific illustrators usually make oxygen red and hydrogen white. (The unmarked atoms are H.)

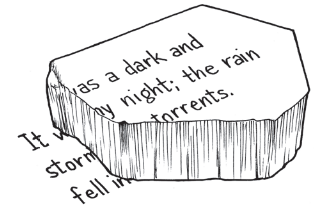
This structure is the basic unit of **borax crystals**.
The unmarked atoms are hydrogens.

5

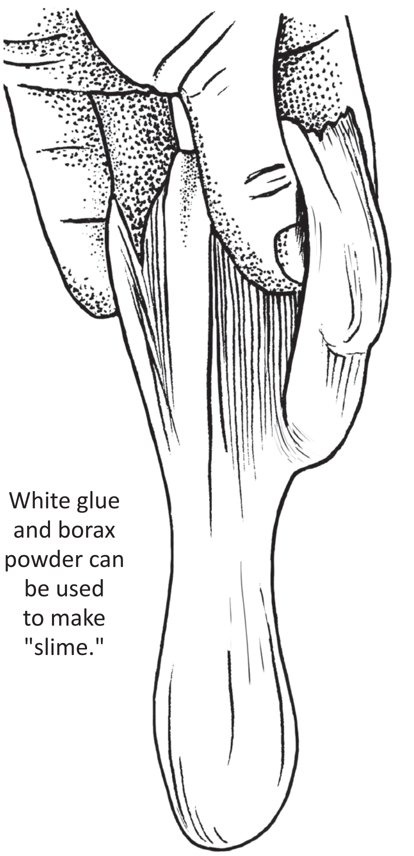
B



It's fun to watch borax crystals grow on top of shapes you make.



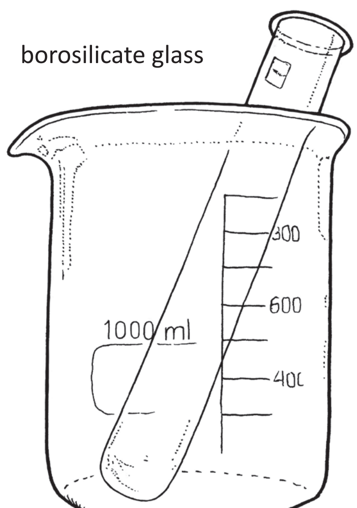
Ulexite is a boron mineral with interesting optical properties.

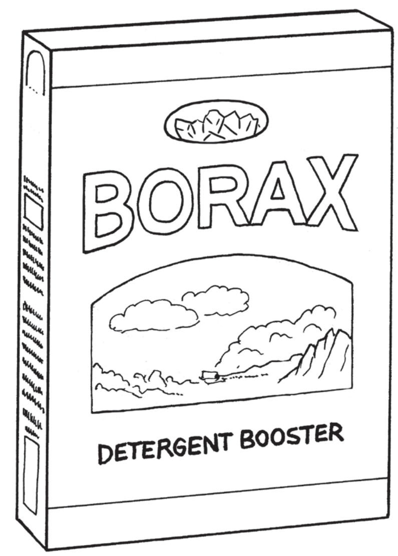


Boron

White glue and borax powder can be used to make "slime."

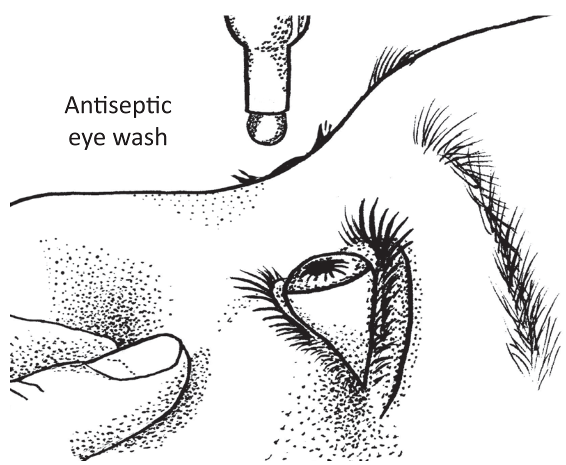
borosilicate glass



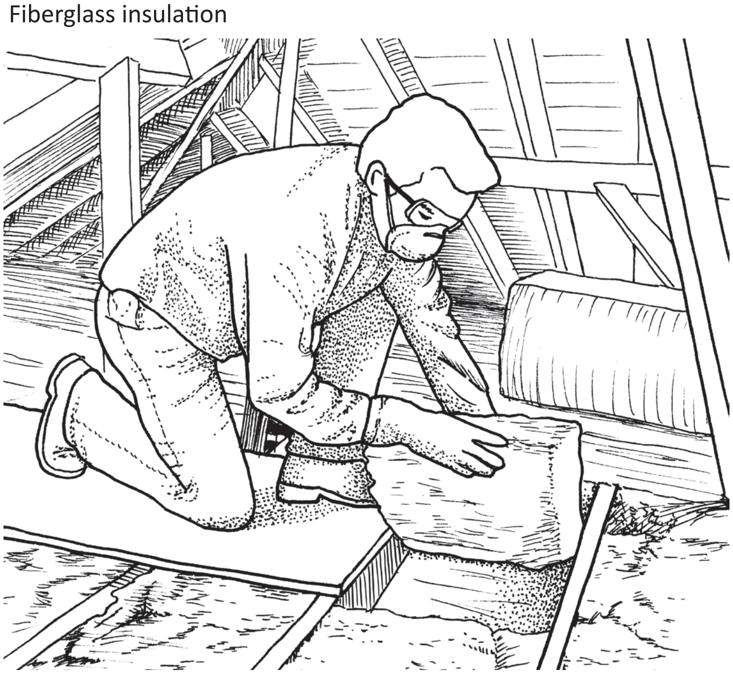


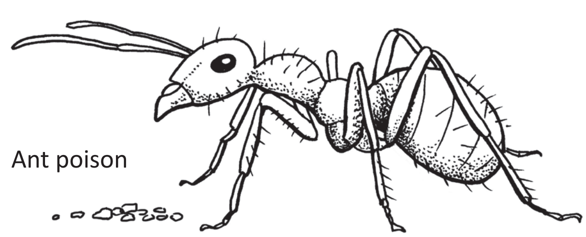
Borax washing powder

Antiseptic eye wash



Fiberglass insulation





Ant poison

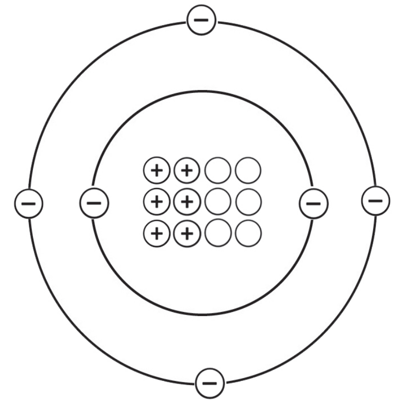
C 6

Carbon

From the Latin word for charcoal: "carbo"

6 protons
6 neutrons
6 electrons

Atomic mass: 12.01



Carbon is the most flexible and "friendly" atom on the Periodic Table. It will bond with many other elements, although its favorites are hydrogen and oxygen. If there are no other atoms around to bond with, carbon will bond to itself, forming pure-carbon substances such as diamonds, graphite and coal. That's right, coal and diamonds are made of the same stuff! The most fascinating pure-carbon structure is the buckyball, a hollow sphere of 60 carbon atoms arranged in the same pattern as a soccer ball (hexagons surrounded by pentagons).

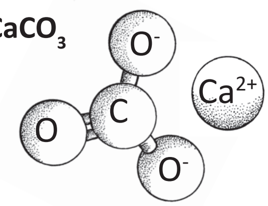
Carbon is found in the air around us as carbon dioxide, CO_2. Vehicles can put both CO_2 and CO (carbon monoxide) into the air as by-products of combustion. CO is very dangerous and many people have CO detectors in their homes if they have a furnace that burns natural gas, CH_4.

Carbon can bond to three oxygen atoms and make the carbonate ion, CO_3^{2-}. If a calcium atom sticks to carbonate, we get calcium carbonate, $CaCO_3$. Calcium carbonate is the main ingredient in the mineral calcite and in the rock known as limestone. Sea shells are a biological form of calcium carbonate.

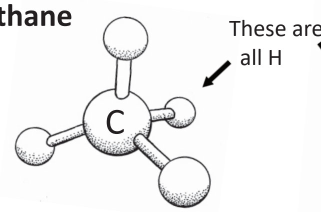
Hydrocarbon molecules are made of just carbon and hydrogen atoms and can be small (CH_4, natural gas), medium-sized (C_8H_{18}, octane, liquid gasoline) or so long we can't even count the carbon atoms (plastics and rubbers). Carbon and hydrogen atoms can also form a ring known as benzene. The benzene ring, or an adaptation of it, is at the heart of thousands of molecules, including polystyrene plastic, Styrofoam®, food preservatives, cholesterol, natural almond flavor, spot removers, moth balls, paints, and medicines.

Many biological molecules have carbon at their core. Proteins, fats and sugars are all carbon-based substances. DNA, the extremely long ladder-shaped molecule that is like a library of information for living cells, has carbon atoms at key points in its structure. Carbon is also at center of many other molecules essential to life, including enzymes.

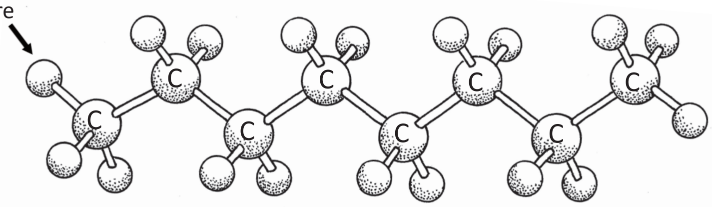
Limestone $CaCO_3$



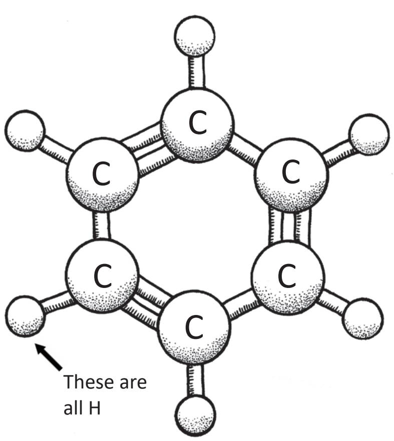
Methane CH_4



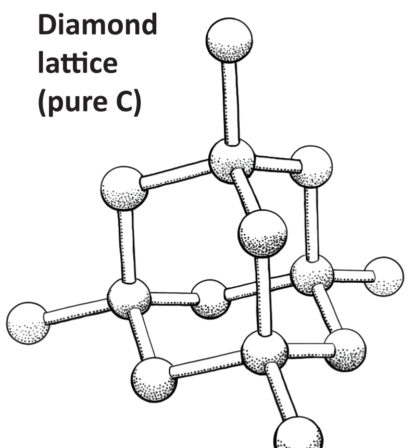
Octane C_8H_{18}

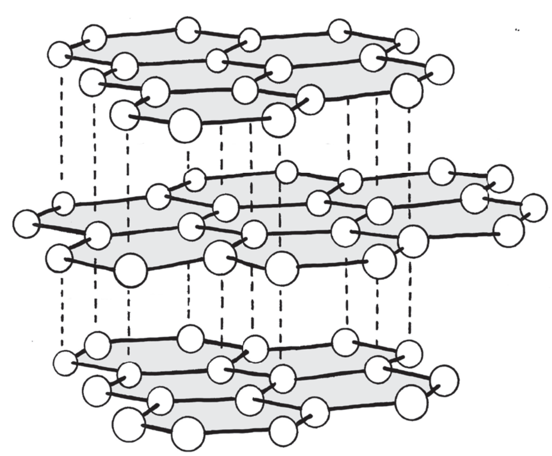


Benzene C_6H_6



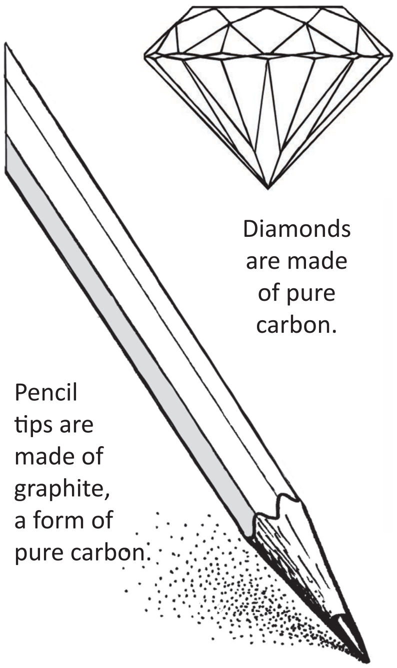
Diamond lattice (pure C)





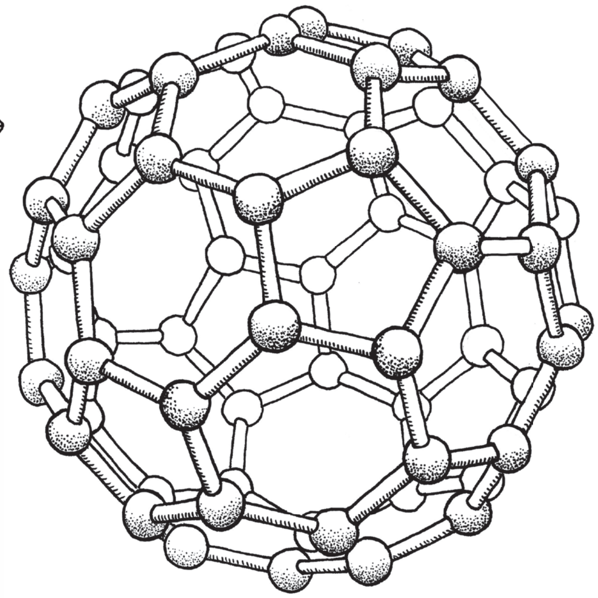
Graphite lattice (pure C)

6 Carbon C

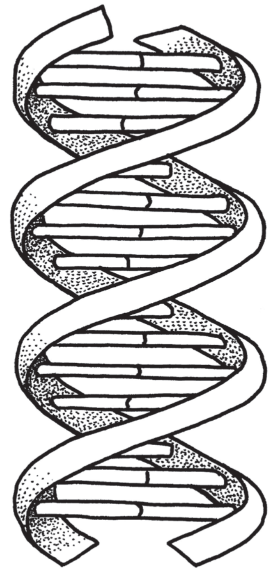


Pencil tips are made of graphite, a form of pure carbon.

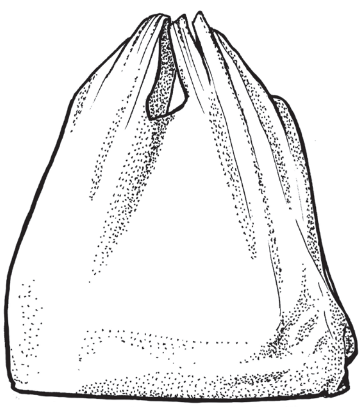
Diamonds are made of pure carbon.



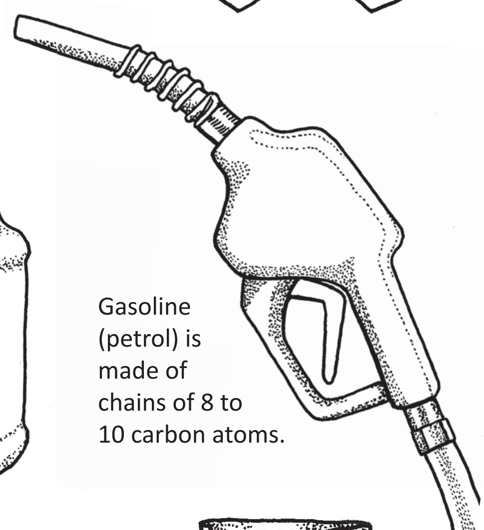
"Buckyballs" are made of 60 carbon atoms.



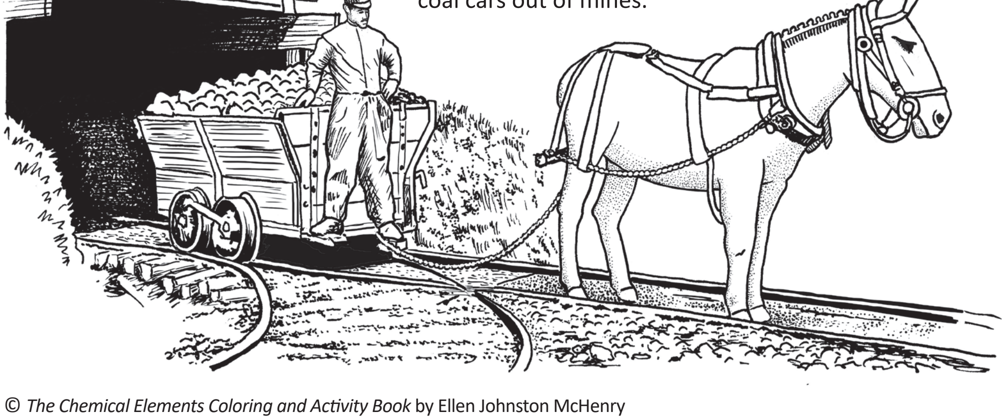
Carbon atoms determine the structure of DNA.



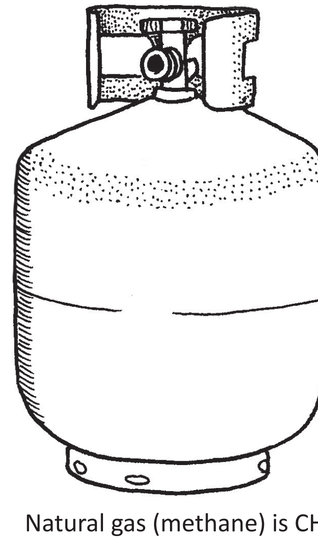
All forms of plastic are made of long chains of carbon atoms (with hydrogens attached).



Gasoline (petrol) is made of chains of 8 to 10 carbon atoms.



Coal is also a form of carbon. Miners in the 19th century used mules to pull heavy coal cars out of mines.



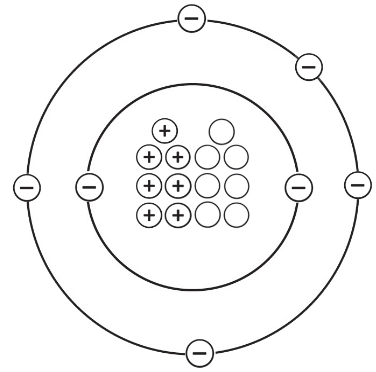
Natural gas (methane) is CH_4.

N

7

protons
7 neutrons
7 electrons

Atomic mass: 14.0



Nitrogen

From Greek words "nitron" (saltpeter) and "genes" (make)

Nitrogen is named after one of the compounds in which it is found, potassium nitrate (KNO_3), which was known in the ancient world as "nitron" and was named "saltpeter" by the Europeans. ("Peter" means "rock.") Since ancient times, this mineral has been used to preserve meats, and nitrates are still used today to keep packaged meats from turning brown. Eventually, it was discovered that saltpeter could be made into gunpowder if charcoal and sulfur were added it to. Gunpowder isn't just for guns; large amounts of gunpowder are also used to make fireworks. Nitrogen is found in other explosive chemicals, such as TNT (trinitrotoluene), nitroglycerin (dynamite), and sodium azide (NaN_3) which is found in air bags in cars. The explosive nature of all these chemicals is due to the fact that they allow nitrogen gas, N_2, to form very quickly.

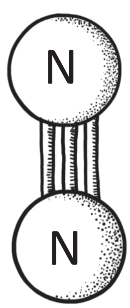
The air around us is mostly nitrogen in its stable form, N_2. When two nitrogen atoms are bound to each other, they form one of the most stable molecules in nature, unwilling to react with anything around it. N_2 is so stable that it can be used as a fireproof shield in high temperature welding. Pure nitrogen gas can also protect and preserve fruits such as apples, keeping them fresh (in cold storage) for up to two years.

N_2O is nitrous oxide, often called "laughing gas." It has a slightly sweet smell and is used by doctors and dentists as a mild anesthetic for minor surgery or dental procedures. It's easy to confuse N_2O with NO_2, but NO_2 is nitrogen dioxide, a reddish-brown gas that is a common form of air pollution.

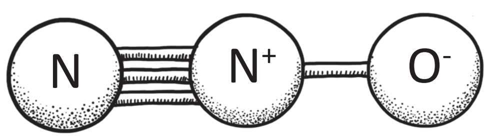
NH_3 is ammonia, a gas with a pungent odor that can sting your nose. It's that strong smell that comes from wet diapers or cat litter boxes that have been sitting for a while. NH_3 is used in many industrial processes, including the manufacturing of fertilizers that can put nitrogen into the soil. Plants need nitrogen but can't get it from the air.

In biology, we find nitrogen in more complex molecules, such as amino acids, which are strung together to form proteins. Proteins are the building blocks from which cells and tissues are made.

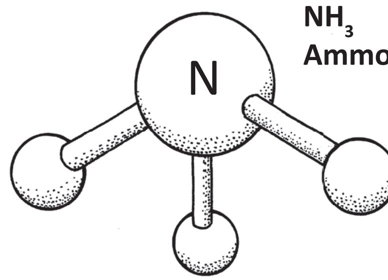
N_2 Nitrogen gas

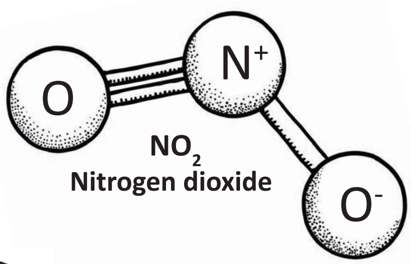


N_2O Nitrous oxide



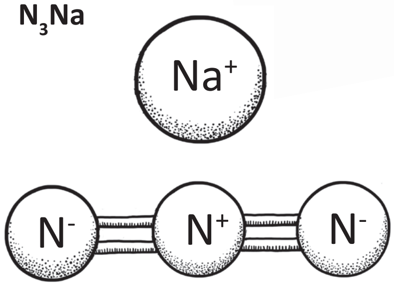
NH_3 Ammonia



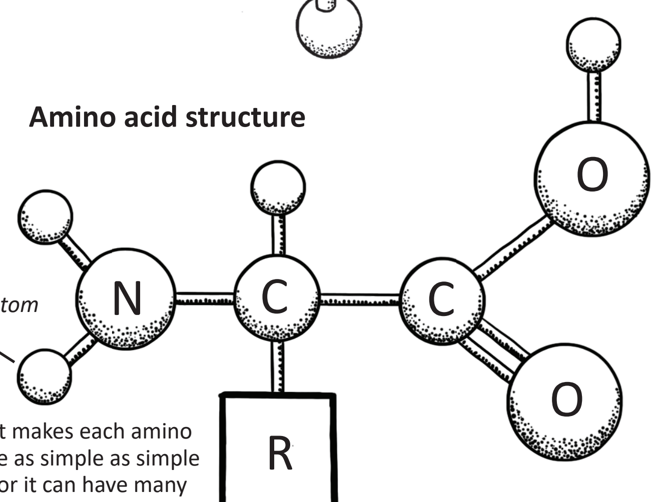


NO_2 Nitrogen dioxide

Sodium azide N_3Na



Amino acid structure



Remember, if a small atom is not labeled, it's H.

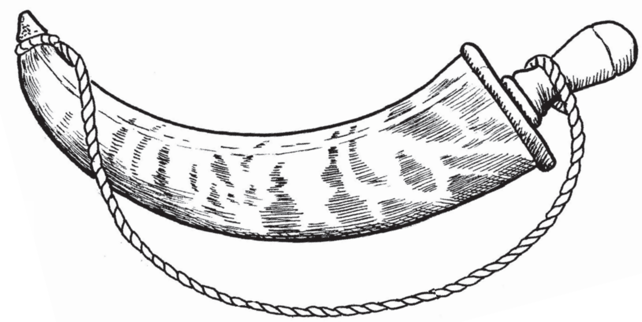
The "R group" is what makes each amino acid unique. It can be as simple as simple one hydrogen atom, or it can have many atoms, like this: $C_6H_{14}N_4O_2$.

7 N

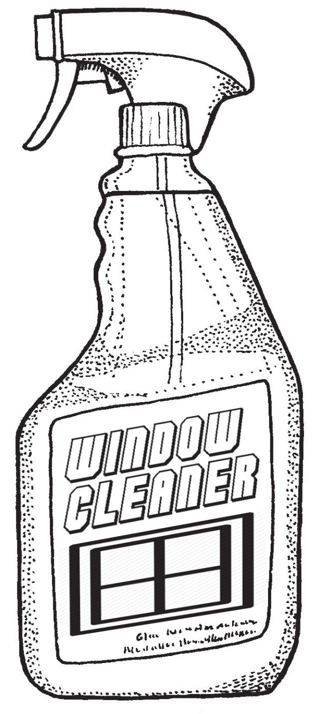
Nitrogen

If leaves don't get enough nitrogen they lose their green color.

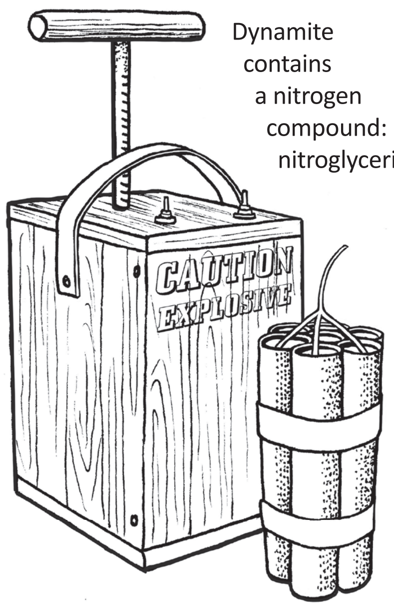
Nitrates and nitrites are used to preserve meats.



Throughout history, horns have often been used to store gunpowder (a nitrogen compound).



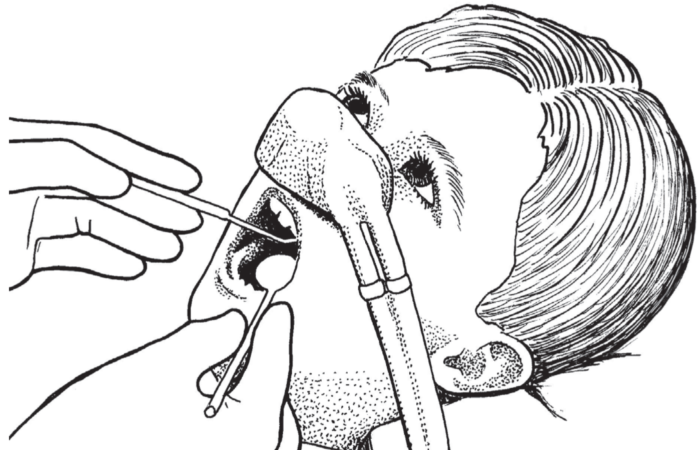
Some cleaning products contain ammonia, NH_3.



Dynamite contains a nitrogen compound: nitroglycerin.

Plant fertilizers often contain nitrogen.

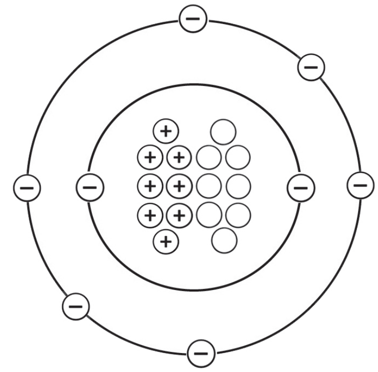
Air bags in vehicles are inflated with nitrogen.



N_2O, nitrous oxide, is used by dentists as a mild anesthetic..

O 8

protons
8 neutrons
8 electrons
Atomic mass: 15.9



Oxygen

From Greek words "oxy" (sour) and "genes" (make)

Oxygen's name comes from the fact that when it was discovered in the late 1700s, it was mistakenly believed to be the key factor in the formation of acids, which taste sour (lemon juice, for example). This idea was eventually proven wrong, but by that time the name "oxygen" was being used by everyone and it was too late to change it.

Oxygen is the third most abundant element in the universe, after hydrogen and helium. Oxygen is in the air all around us as O_2. Nitrogen, N_2, makes up about 78% of our atmosphere and oxygen comes in second at about 20%. In the upper atmosphere we find three oxygen atoms stuck together to form ozone, O_3. Ozone layers help to protect earth from dangerous ultra-violet radiation produced by the sun.

Oxygen is a very reactive element and will bond to most of the other elements to form compounds whose names usually end in "ate," "ide," or "ite." The most well known oxide compound is water, H_2O. A similar molecule is H_2O_2, hydrogen peroxide, whose usefulness as a disinfectant is due to the fact that the second oxygen atom falls off easily, reverting back to H_2O. A single oxygen atom is very dangerous and will try to steal electrons from any atom or molecule it comes into contact with. We have body cells that use single oxygens as "bullets" to fire at germs.

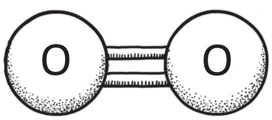
All forms of animal life need oxygen for cellular respiration, the process by which cells extract energy from sugars and fats. Fish and other sealife use oxygen that is dissolved into the water around them. Plants produce oxygen as a waste product of photosynthesis, so there is a balance between oxygen produced and oxygen used.

Plants use carbon dioxide, CO_2, from the air to make sugar molecules (glucose, $C_6H_{12}O_6$).

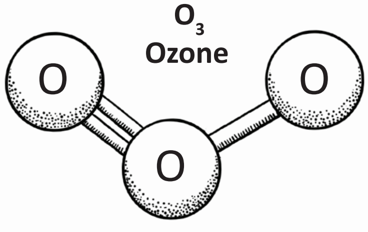
Oxygen is found in the crust of the earth bound to the element silicon to form minerals such as quartz, feldspar, mica, and olivine. All these minerals are based on the silicon tetrahedron, SiO_4, which forms crystal lattices.

When oxygen is cooled down to -183° C it becomes a liquid. Oxygen is often transported in its liquid state because it takes up less space. One liter of liquid oxygen expands to become 840 liters of oxygen gas. Oxygen gas is used in medical devices, in steel production, in plastic manufacturing and as fuel in welding. Liquid oxygen is used (along with liquid hydrogen) as rocket fuel.

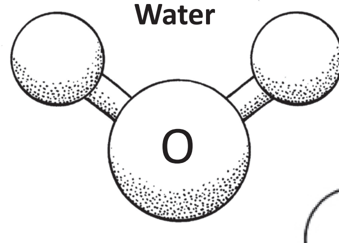
O_2 Oxygen gas



O_3 Ozone

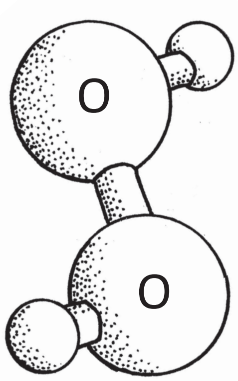


H_2O Water

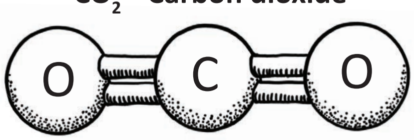


Standard colors:
White: Hydrogen
Red: Oxygen (O)
Black: Carbon (C)

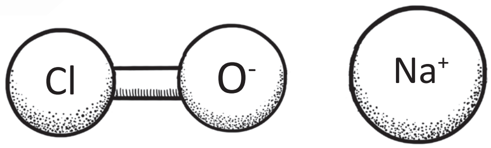
H_2O_2 Hydrogen peroxide



CO_2 Carbon dioxide

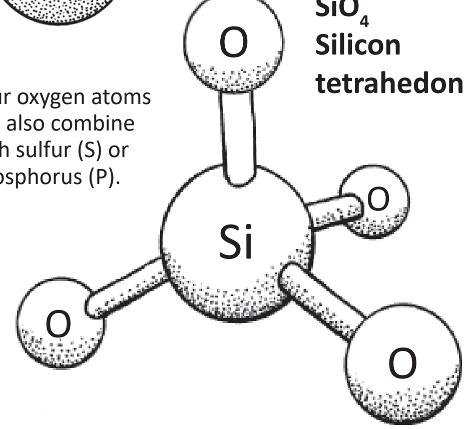


NaClO Sodium hypochlorate (bleach)



SiO_4 Silicon tetrahedon

Four oxygen atoms will also combine with sulfur (S) or phosphorus (P).

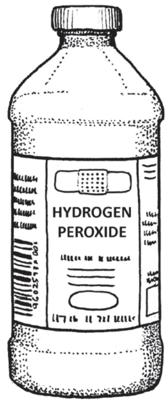


8

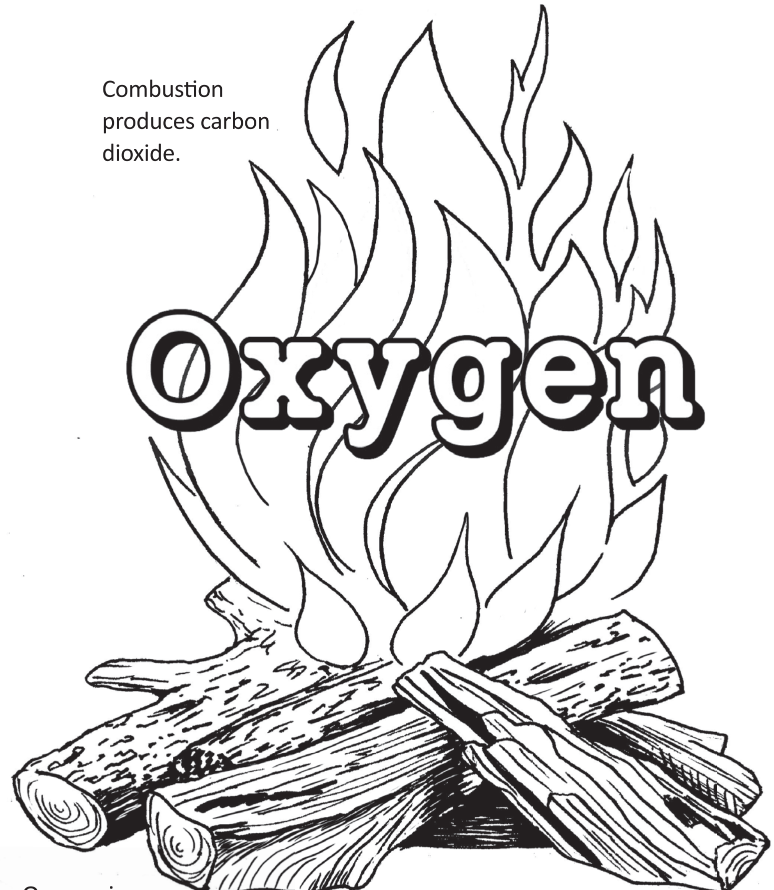
O

Oxygen

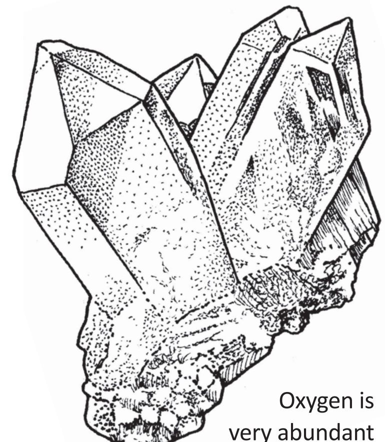
Combustion produces carbon dioxide.



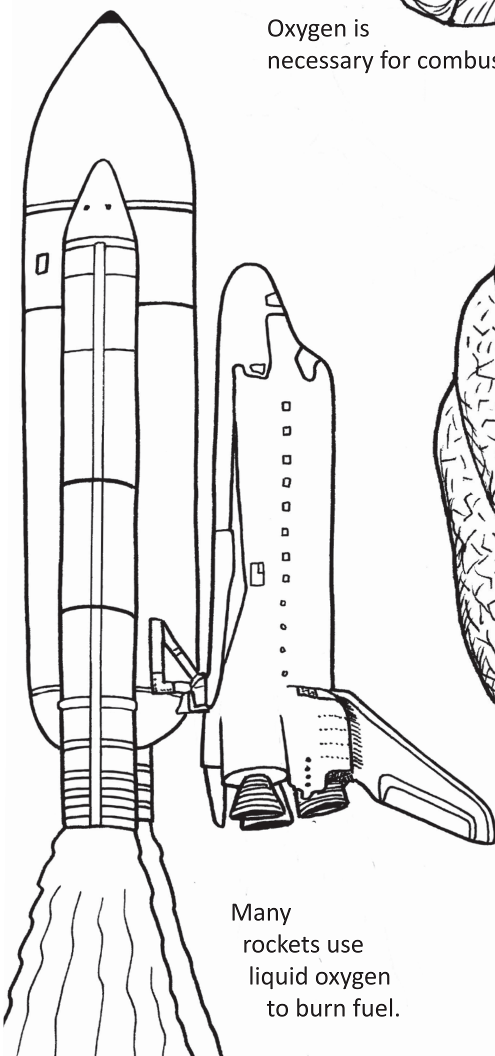
Hydrogen peroxide is used in first aid.



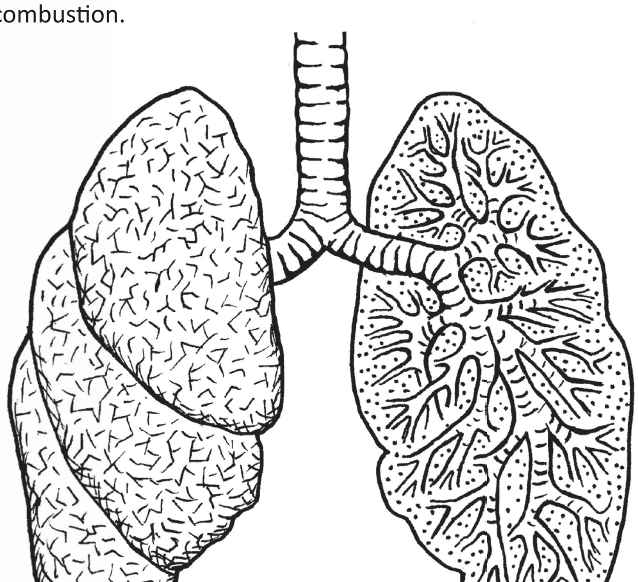
Oxygen is necessary for combustion.



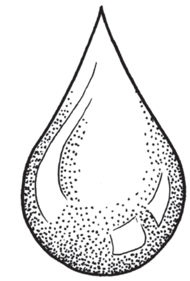
Oxygen is very abundant in the crust of the earth, often as quartz.



Many rockets use liquid oxygen to burn fuel.

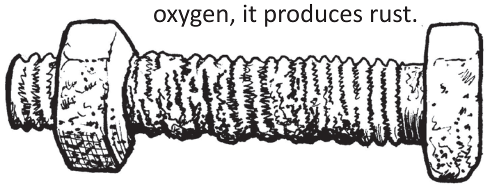


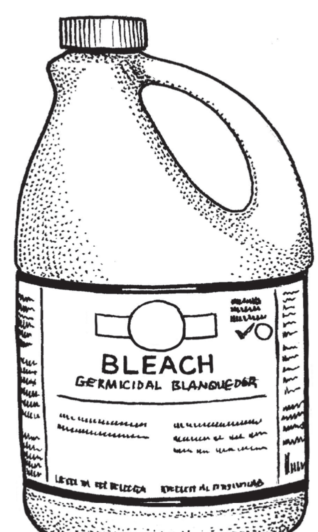
The oxygen we take in with our lungs is used in the process of cellular respiration.



Oxygen and hydrogen make water.

When iron combines with oxygen, it produces rust.



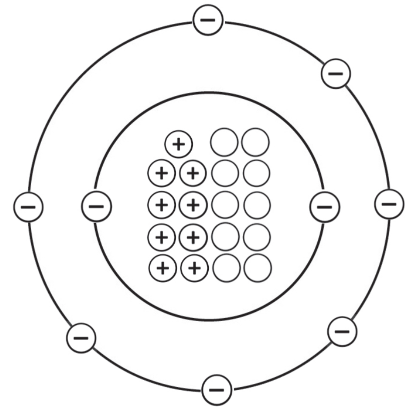


Bleach, NaClO, has an oxygen atom that falls off easily.

F

9 protons
10 neutrons
9 electrons

Atomic mass: 18.9



Fluorine

From Latin word "fluere" meaning "to flow"

Fluorine is famous for being the most "electronegative" element on the Periodic Table. This means that it can hold on to other atoms more tightly than any other element can. This is due to its size and its number of electrons. Because fluorine is a fairly small atom, its electrons are very close to the positively charged protons in the nucleus. Opposite charges attract, and fluorine's protons are able to hold the electrons very tightly. (Larger atoms can lose some of their outer electrons.) Because fluorine's outer shell has only 7 electrons, it falls one short of the perfect number: 8. Atoms with one empty place in their outer shell desperately want to steal or borrow an electron to fill that slot. Fluorine is so desperate that it will grab the first available electron it finds, usually an electron belonging to another atom. Thus, fluorine is never found alone in nature. (A single F atom is very dangerous!)

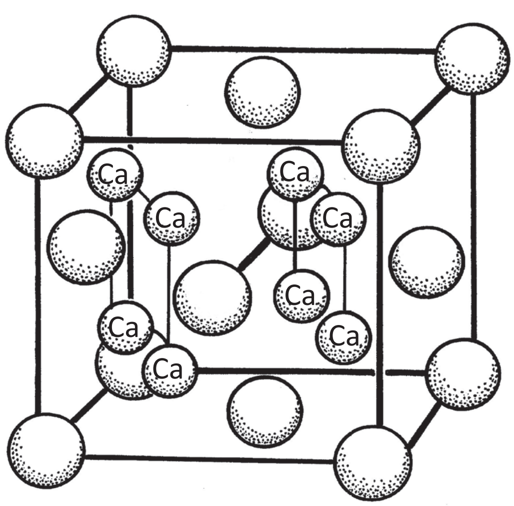
Fluorine is often found in the company of the element calcium, forming calcium fluoride, CaF_2. When found in rocks, CaF_2 is a mineral called fluorite (or fluorospar). Very pure fluorite crystals can be made into camera and telescope lenses. Crystals of lesser value can be crushed into a powder and used as "flux" in metal smelting. The fluorine atoms will grab impurities that metallurgists don't want in the hot, liquid metal. Getting rid of these contaminants makes the hot metal flow more easily. Fluorine's name comes from this ability to make liquid metals flow.

When fluorine grabs a hydrogen atom, hydrofluoric acid, HF, is formed. This acid is very dangerous to work with. It burns flesh and it steals calcium from bones. It is used to etch designs into glass because it is one of the few substances that can dissolve glass. Despite the fact that it is so dangerous, fluorine does play an important role in the body, being one of the minerals that help to make our teeth very strong.

Sulfur atoms can bond to six fluorines, making SF_6, sulfur hexafluoride. Unlike HF, this substance is very safe. SF_6 is a gas that won't react with anything and can be used as insulation. A similar molecule is uranium hexafluoride, UF_6. This molecule is used to "enrich" uranium by collecting U atoms that have an atomic mass of 235.

When fluorine bonds with carbon, it forms C_2F_4, tetra-fluoro-ethylene, better known as Teflon®. Teflon® is very slippery so when pans are coated with it, they become "non-stick." A similar substance is poly-tetra-fluoro-ethylene, better known by the brand name Gore-Tex®. Gore-Tex® fabric is rainproof while still allowing body moisture to escape.

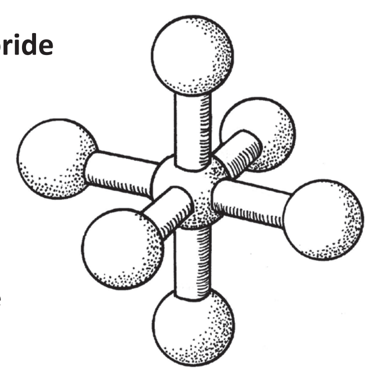
CaF_2 Calcium fluorite (crystal lattice)



This cube is called a unit cell. We see only part of the crystal, so it seems like the math is wrong. If you looked at the entire crystal, there would be 2 Fs for every Ca.

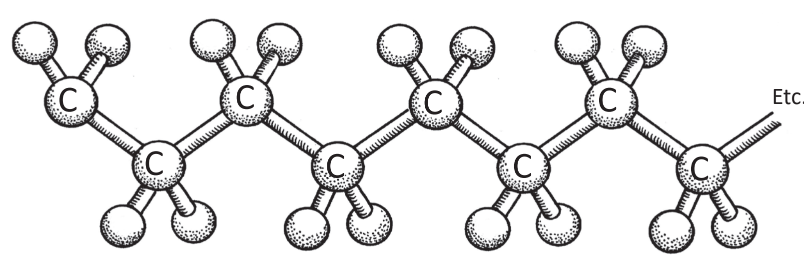
SF_6 Sulfur hexafluoride

The central atom is sulfur. Artists usually make sulfur yellow. All the other atoms are fluorine.



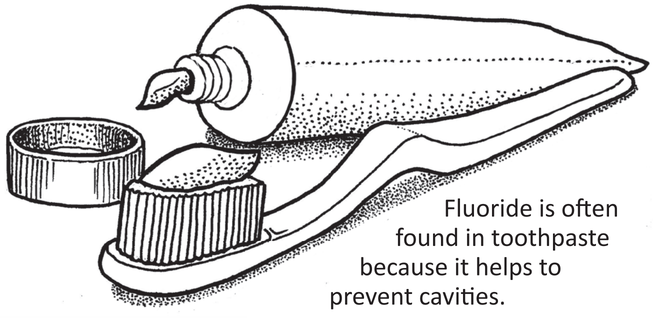
C_2F_4 Teflon®

This molecule is a very long polymer made of thousands of carbon atoms bonded to fluorine atoms.

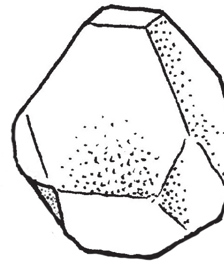


9 F

Fluorine



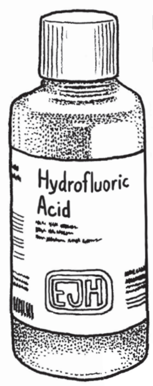
Fluoride is often found in toothpaste because it helps to prevent cavities.

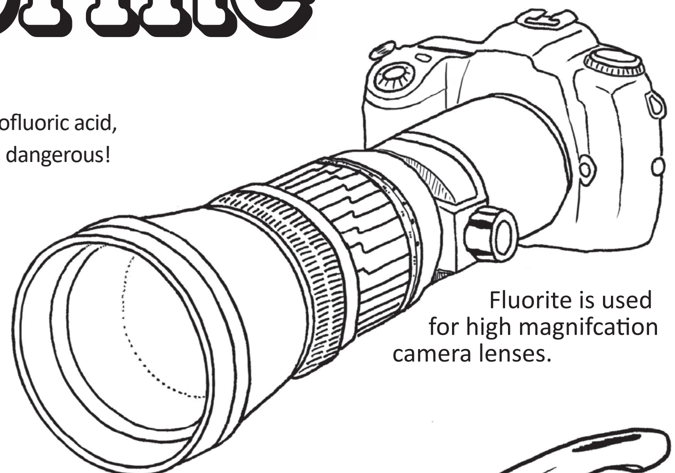


Fluorite crystals are often green or purple.

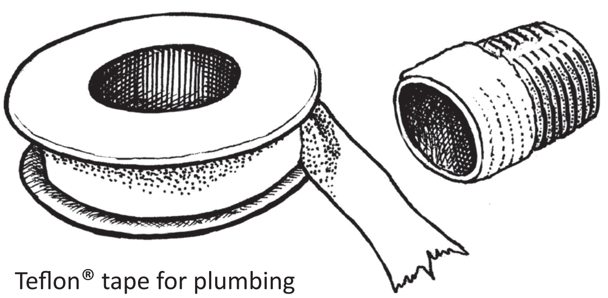
Gore-Tex® clothes use a modified form of Teflon®.

Hydrofluoric acid, HF, is dangerous!





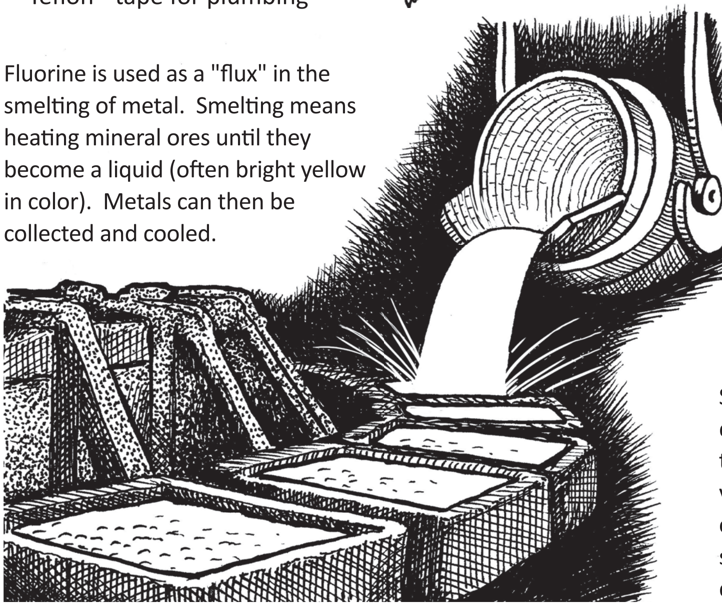
Fluorite is used for high magnifcation camera lenses.

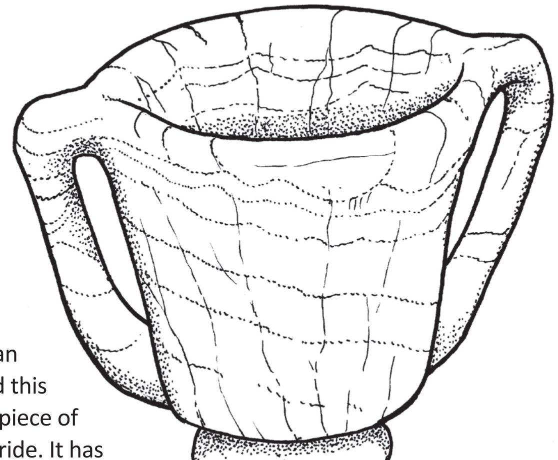


Teflon® tape for plumbing

Teflon® makes cooking pans "non-stick."

Fluorine is used as a "flux" in the smelting of metal. Smelting means heating mineral ores until they become a liquid (often bright yellow in color). Metals can then be collected and cooled.



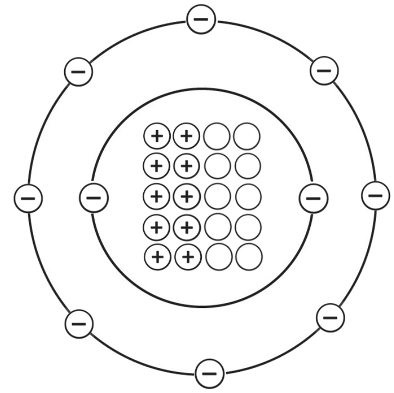


Someone during Roman times carved this vase from a piece of calcium fluoride. It has stripes of dark green, dark red, and yellow-tan.

Ne 10

protons
10 neutrons
10 electrons

Atomic mass: 20.2



Neon

From the Greek word for "new"

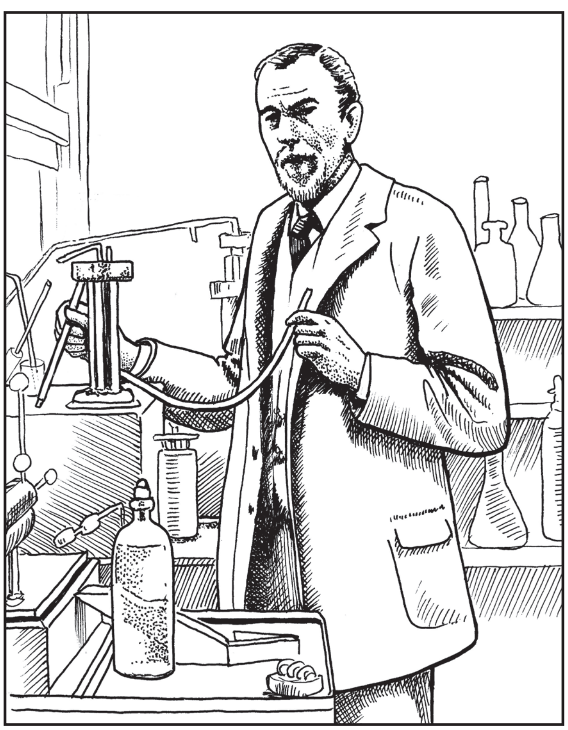
Neon belongs to the family of elements called the noble gases. They are found in the last column on the right side of the Periodic Table. The noble gases are very lucky because their outer electron shells are completely filled. They do not have any empty slots, nor do they have any extra electrons to give away. This is why they will not interact with other atoms. The noble gases are called "inert" because they are so unreactive. Neon is sometimes called the most inert element on the Periodic Table.

Like most of the noble gases, neon can be safely used in places where there is electricity, such as inside fluorescent light tubes. Neon lights (the ones that actually have neon in them) glow with an orange-red color. Most of the lights that are called "neon" lights are actually filled with other gases and with powdered minerals that produce colors like green, yellow, or blue.

Neon is used in cold-cathode voltage regulator tubes, which look a lot like old-fashioned vacuum tubes. A similar product, called "nixie tubes," are used to make an unusual type of digital clock. Neon can also be used in high-voltage indicator devices, and in structures that absorb lightning strikes. Helium, another noble gas, is used with neon to make helium-neon (HeNe) lasers, which produce a bright red line of light.

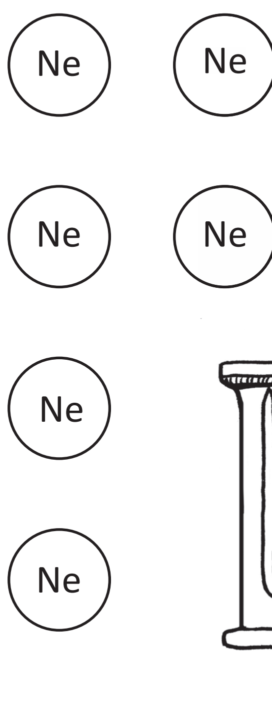
Neon is found in the air all around us, but in very small quantities. The way you collect it out of the air is to chill the air to hundreds of degrees below zero, until all the gases turn to liquid. Then the temperature is turned up very slowly, one degree at a time. At -246^{o} C, liquid neon turns back into a gas and is captured.

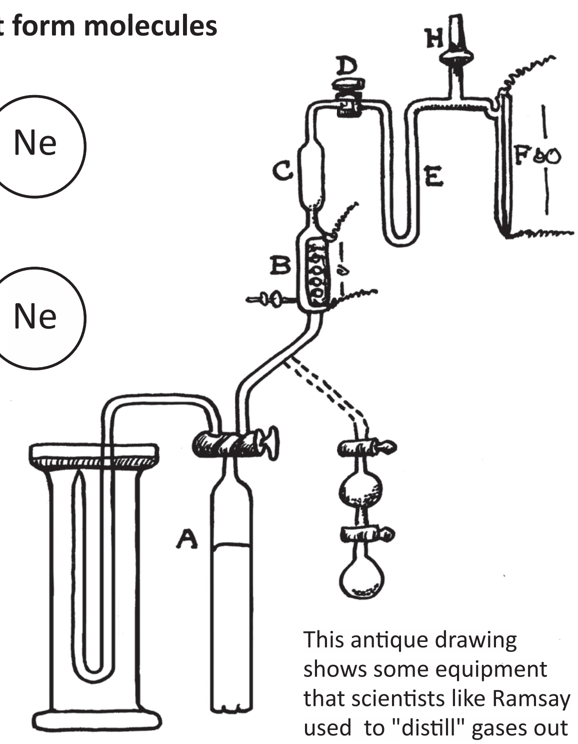
Neon was discovered at about the same time as the elements krypton and xenon, in 1898, by Sir William Ramsay and his assistant Morris Travers, using this chilling technique. As they watched the gases appear, some of them were familiar, such as oxygen, nitrogen, helium, and carbon dioxide. Then they found a "new" one, so they named it neon, after the Greek word for new.



Sir William Ramsay in his lab

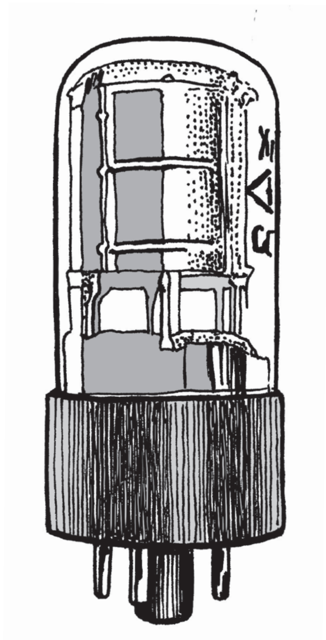
Neon does not form molecules



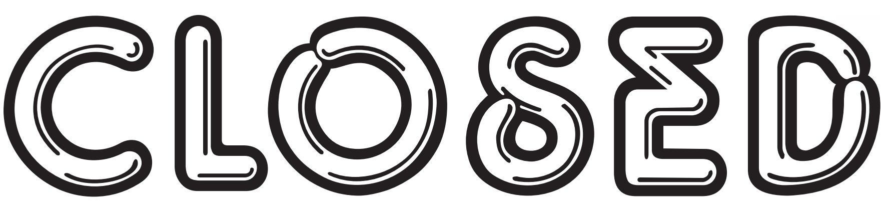


This antique drawing shows some equipment that scientists like Ramsay used to "distill" gases out of the air by chilling them.

10 Neon Ne

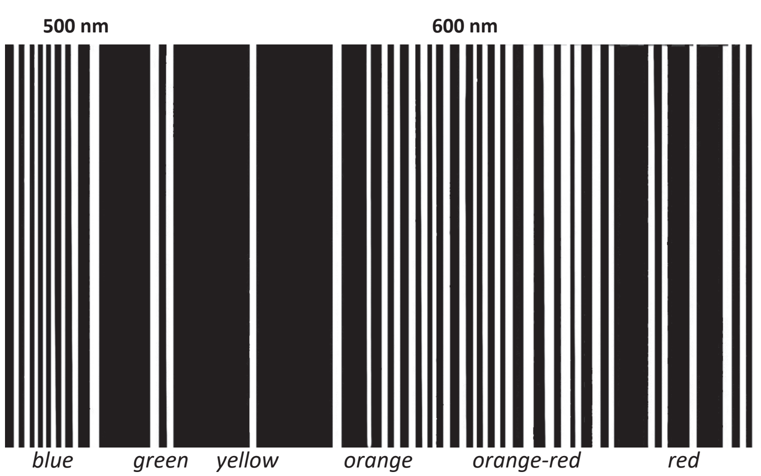


This is a cold-cathode voltage regulator tube. They are used only rarely now, as solid state regulators have mostly replaced them.

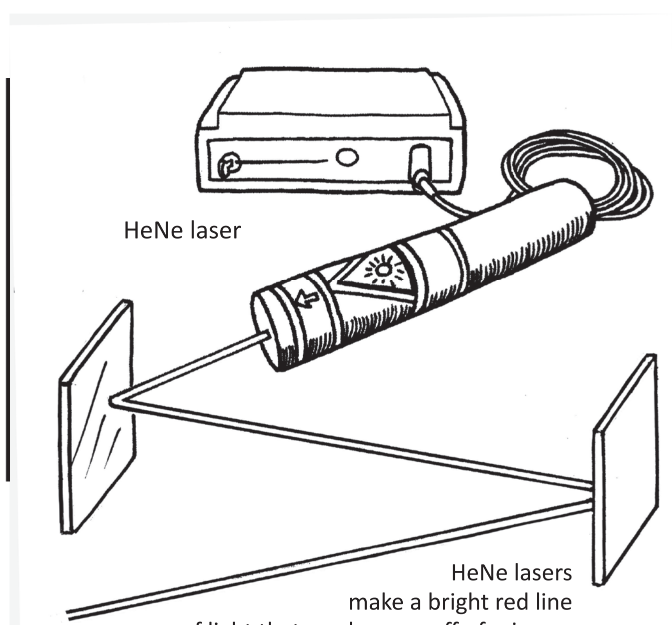


Neon signs (that actually have neon in them) glow bright orange-red.

This is a "nixie" tube. It contains tiny neon tubes shaped like numbers. The tubes can be used to make clocks that are purchased by collectors as novelties.



If you look at glowing neon gas through a spectrometer, this is what you will see. The small amount of blue and green light that comes from glowing neon atoms is drowned out by all the orange and red.

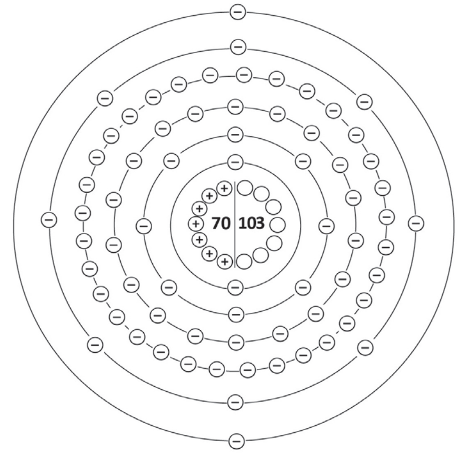


HeNe lasers make a bright red line of light that can bounce off of mirrors.

Yb 70

protons
103 neutrons
70 electrons

Atomic mass: 173



Ytterbium

Named after Ytterby, Sweden

Ytterbium *(i-TER-bee-um)* was discovered several times. The first time was by Swiss chemist Jean Charles Galissard de Marignac in 1878. He was working with a sample of erbia, Er_2O_3. He suspected that there was something else in the sample, and managed to isolate its oxide form, naming it ytterbia. In 1907, French chemist Georges Urbain decided to take a second look at ytterbia and to his surprise, his chemical tests revealed that ytterbia wasn't a single compound, but a combination of two, which he called neoytterbia and lutecia. (Lutetia is the old Roman name for Paris.) What Urbain didn't know was that two other chemists were working on the same experiments at that same time. One of these chemists, Carl von Welsbach (who discovered neodymium and praseodymium) wanted to name the new elements aldebaranium and cassiopeium. An international committee finally decided to give Urbain the credit for discovery, but also to honor Marignac's work, and they officially named the elements ytterbium and lutetium. (Urbain was one of the three people on the committee. Was that cheating?)

The largest use of ytterbium is in solid state lasers. Yb is "doped" into a crystal (often YAG, yttrium aluminum garnet) to make the crystal better for producing a certain wavelength of light. These lasers are able to do extremely precise cutting, and can make "cuts" that are so shallow that only microscopic amounts of material are removed. This is ideal for cleaning very old paintings, stone monuments, or even the surface of airplanes. These lasers can also be used in dentistry, for medical surgery, and for engraving letters or patterns on rings and jewelry.

Ytterbium atoms are being used to make new and improved atomic clocks that are even more accurate than cesium clocks. The Yb atoms must be cooled down to almost absolute zero (-273.15º C). About 10,000 Yb atoms are trapped by a laser beam while another beam is passed through them.

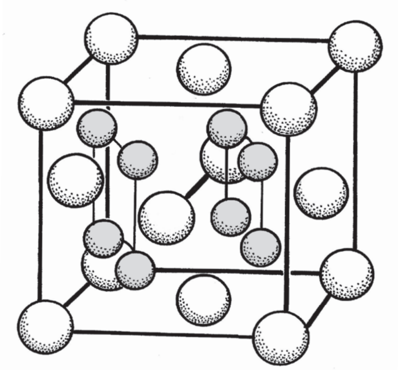
Radioactive Yb atoms can be used as a source of gamma rays in portable radiography testing units.

Military researchers are experimenting with using ytterbium as a substitute for magnesium compounds in decoy flares. Military airplanes can shoot decoys to confuse heat-seeking missiles that are trying to track the plane by using infrared sensors. Ytterbium is able to produce even more infrared radiation so it might be a better decoy.

Ytterbium's electrical properties change when subjected to high levels of mechanical stress, so can be used in machines that monitor earthquakes and large explosions.

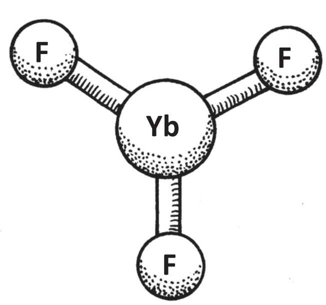
YbF_3 can be used for dental fillings. It has the added benefit of slowing releasing fluorine atoms which can be absorbed by teeth, making them stronger and healthier.

Yb_2O_3 Ytterbium (III) oxide

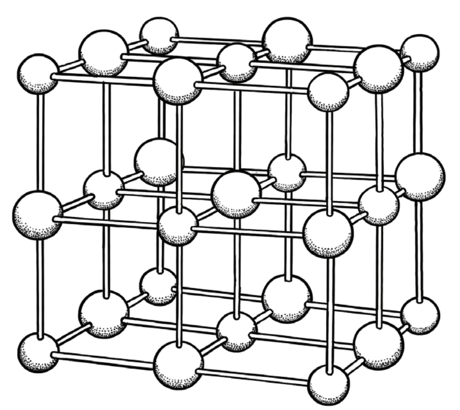


The darker balls are Dy. The lighter balls are O.

YbF_3 Ytterbium fluoride

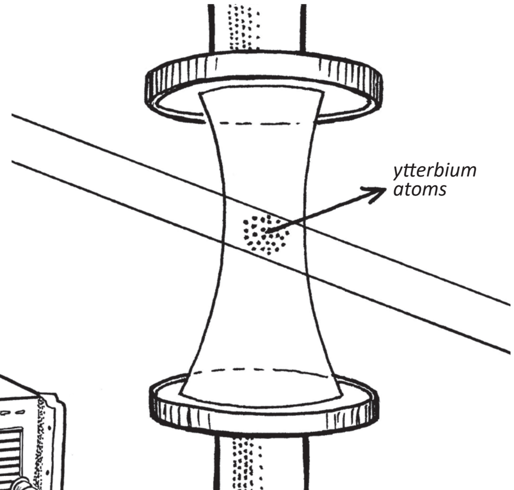


YbO Ytterbium (II) oxide

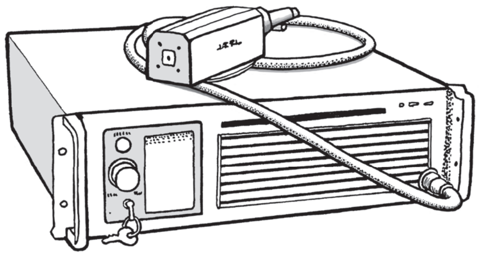


The larger balls are Yb. The smaller balls are O.

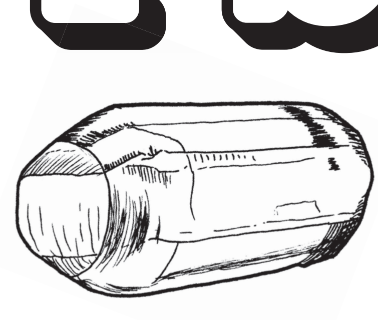
70 Yb



The newest atomic clock uses atoms of ytterbium suspended (trapped) in a laser beam.



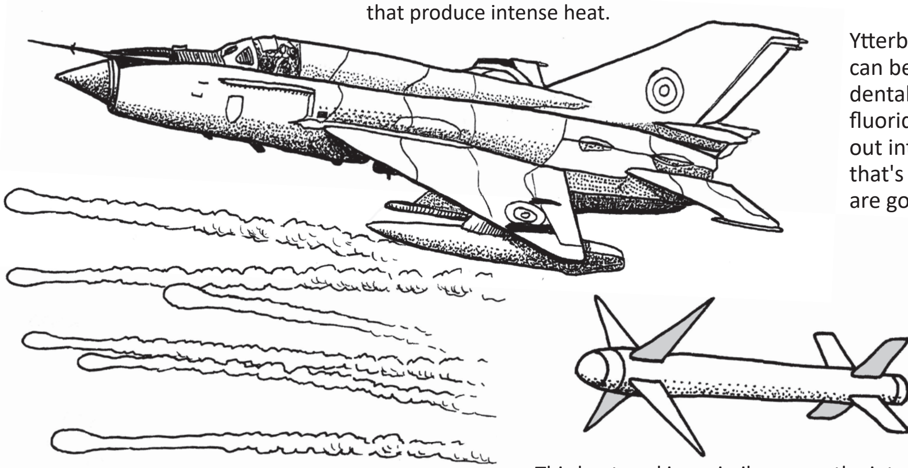
Yb-doped YAG lasers are used in industries for engraving, cutting, welding, or surface cleaning (ablation).



Yb: CALGO Ytterbium-doped Calcium Aluminum Gadolinium Oxide crystal

Ytterbium

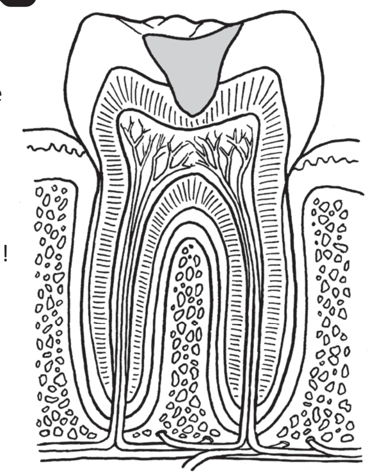
Ytterbium might replace magnesium to make burning decoys that produce intense heat.



The decoys burn yellow, with orange tails.

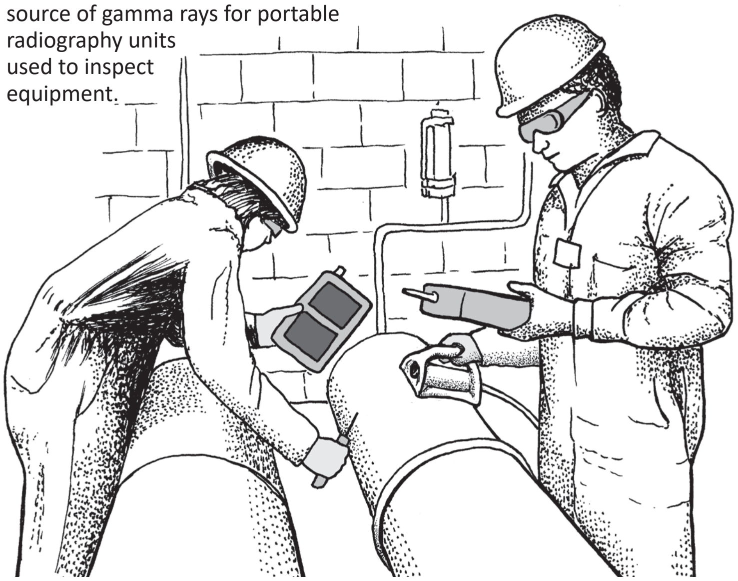
This heat-seeking missile senses the intense infrared radiation of the decoys and is drawn off course, away from the airplane.

Ytterbium fluoride can be used for dental fillings. If fluoride ions leak out into the tooth that's okay, they are good for teeth!



Yb-doped YAG (yttrium aluminum garnet) lasers can be used to clean old paintings because their precision allows for the removal of just dirt, not paint.

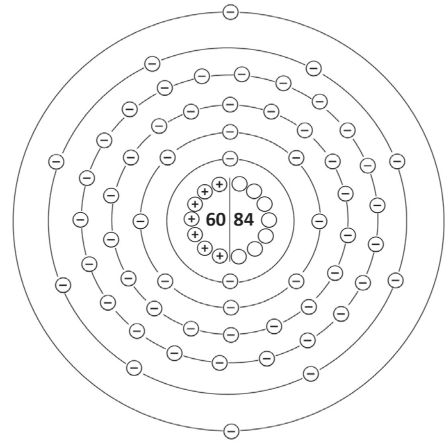
Radioactive ytterbium is useful as a source of gamma rays for portable radiography units used to inspect equipment.



Nd 60

protons
84 neutrons
60 electrons

Atomic mass: 144.2



Neodymium

From Greek words "neo" (new) and "didymos" (twin)

Neodymium was discovered at the same time as praseodymium. The year was 1885. Carl von Welsbach, one of the world's first experts on rare earth minerals, thought he had discovered a new element: didymium. However, upon further investigation he found that his mineral sample contained not one new element, but two, and he named them praseodymium and neodymium.

Neodymium can be found in two mineral ores: monazite and bastnasite. Monazite is found mainly as sand, though larger crystals show up once in a while. Bastnasite is a type of rock named after the town in Sweden where it was first identified. Extracting rare earth elements from mineral ores is a long and complicated process, no matter which ore you use. These ores always contain many of the rare earth elements so extraction of neodymium always produces many other elements as well.

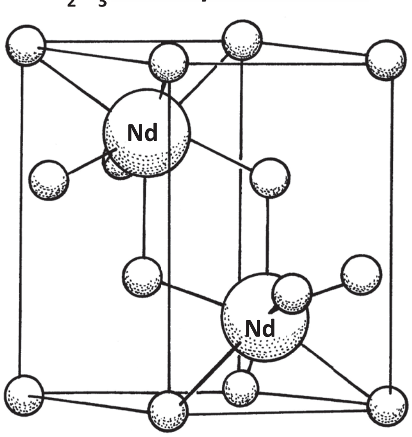
Like all of the rare earth elements (numbers 57- 71), neodymium limits the number of electrons in its outer shell. This arrangement enhances its magnetic properties and makes it ideal for alloys (such as $Nd_2Fe_{14}B$) that are used to make small, but extremely strong, magnets. Tiny-but-strong magnets are necessary for making electronic devices such as computers, phones, microphones, headphones, pickups on electric guitars, and many machines used in technical industries. Neodymium magnets are strong enough to lift an object 1,000 times their own weight.

Neodymium-yttrium-aluminum-garnet lasers (Nd-YAGs) are used to create laser beams for "optical tweezers." Microscopic things like bacteria, DNA, or even single atoms, can be trapped and held at the focal point of the laser light beams. Optical tweezers are essential for many branches of research in biology, chemistry and physics.

Neodymium can be used with, or instead of, praseodymium in many applications. For example, neodymium is an ingredient in mischmetal, the material used to make "flints" for lighters and other fire-starting devices. Neodymium is combined with praseodymium to make "didymium glass" which is used to make filters for telescopes and protective glasses for glass blowers and welders because it is able to absorb yellow and orange light.

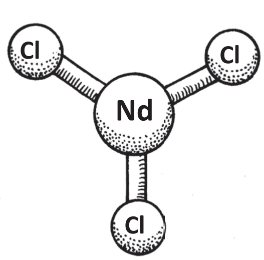
When neodymium oxide (Nd_2O_3) is added to glass, it makes a most unusual effect: the glass will change color depending on what type of light it is under. The glass might look reddish-purple in daylight, but blue under fluorescent lights.

Nd_2O_3 Neodymium oxide



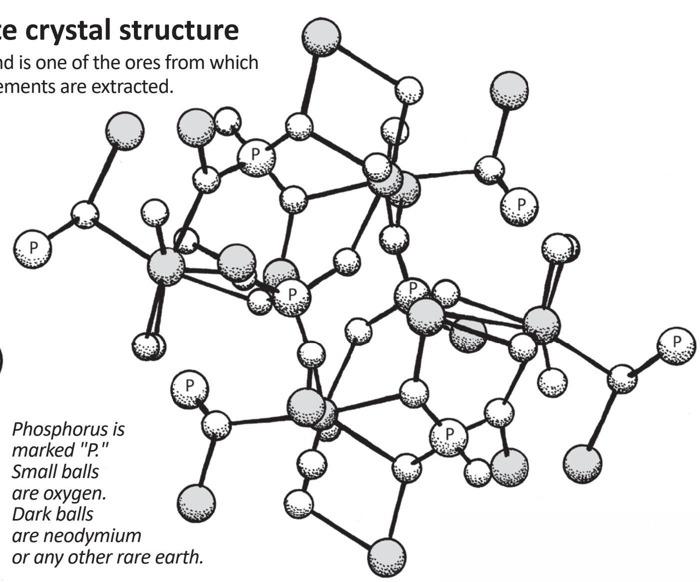
The darker balls are Nd. The lighter balls are O.

$NdCl_3$ Neodymium chloride



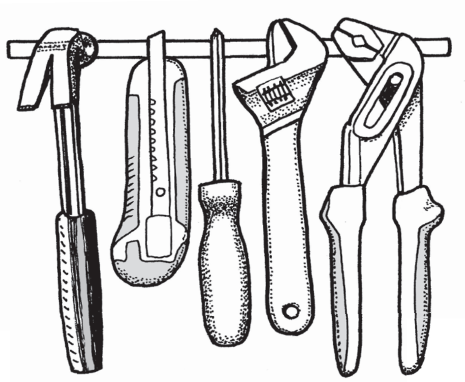
Monazite crystal structure

Monazite sand is one of the ores from which rare earth elements are extracted.

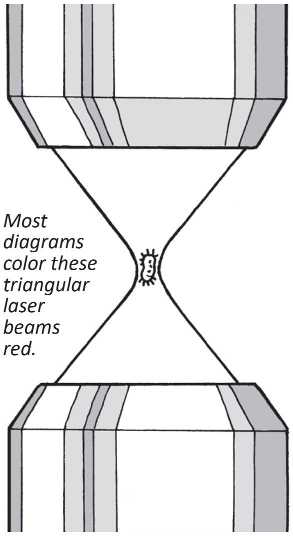


Phosphorus is marked "P." Small balls are oxygen. Dark balls are neodymium or any other rare earth.

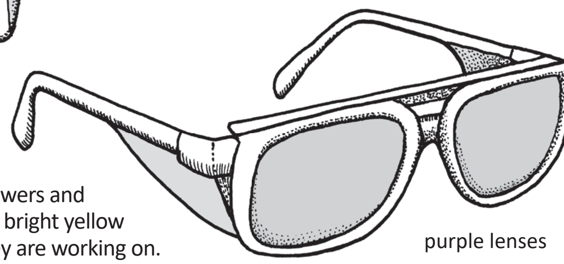
60 Nd



Neodymium magnets can hold 1,000 times their weight! Here, a long bar magnet holds heavy tools.



Nd-YAG lasers are used in "optical tweezers" that can trap and hold microscopic things from bacteria and DNA down to single atoms.

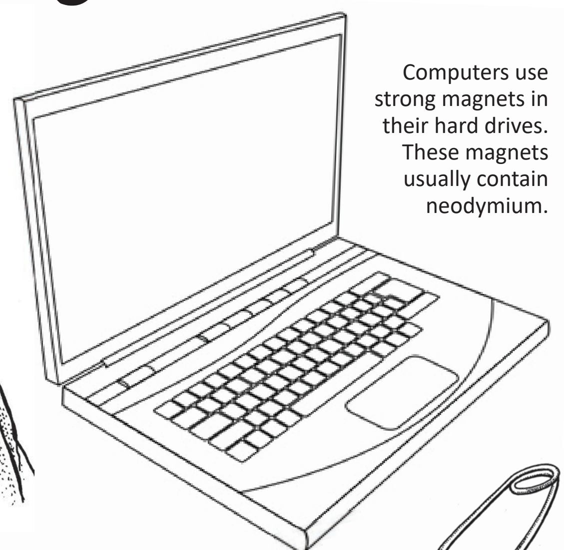


Didymium glasses are used by glass blowers and welders because they absorb annoying bright yellow light that makes it hard to see what they are working on.

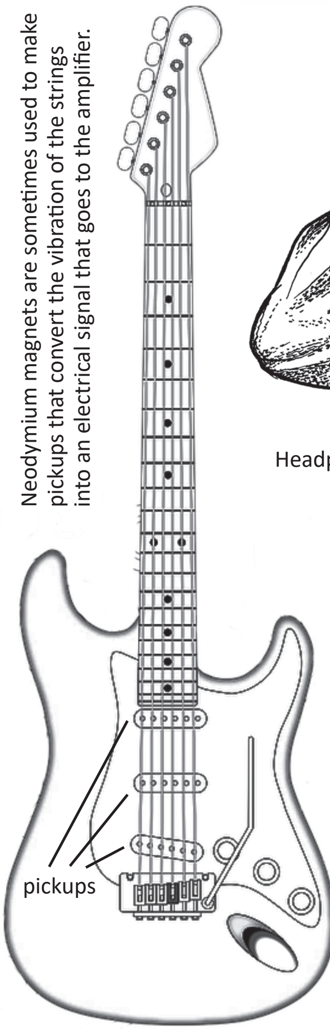
purple lenses

Neodymium

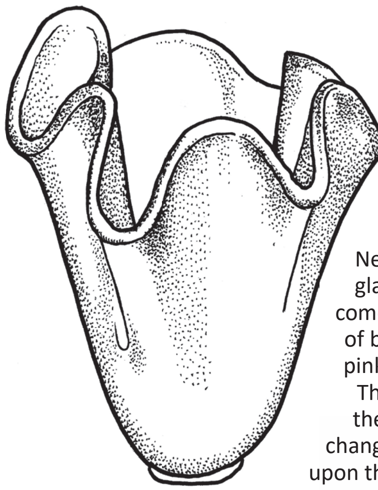
Headphones and microphones often use neodymium magnets.

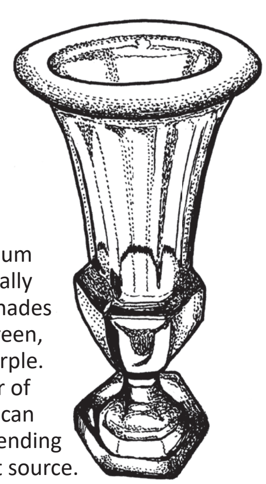


Computers use strong magnets in their hard drives. These magnets usually contain neodymium.

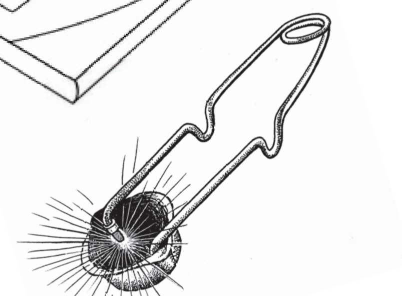


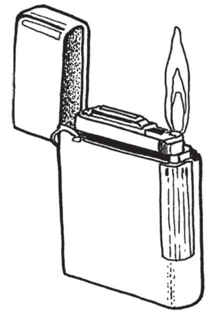
Neodymium magnets are sometimes used to make pickups that convert the vibration of the strings into an electrical signal that goes to the amplifier.





Neodymium glass usually comes in shades of blue, green, pink or purple. The color of the glass can change depending upon the light source.



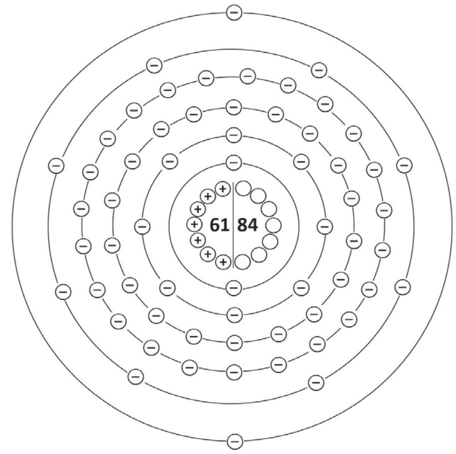


Fire-starting devices such as welding sparkers and lighters have "flints" made of rare earth alloys that often include Nd.

Pm 61

protons
84 neutrons
61 electrons

Atomic mass: 145



Promethium

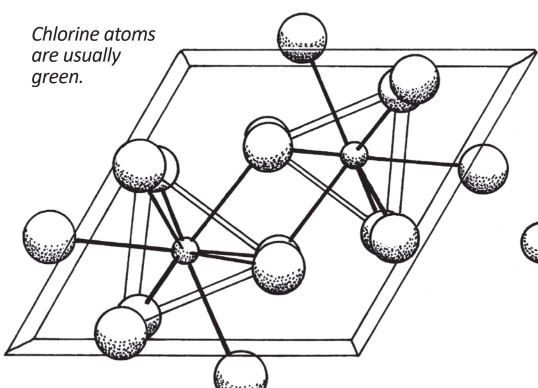
Named after Prometheus, the Greek god who gave fire

Like technetium, promethium is a man-made element, produced in labs that work with radioactive elements. The existence of element 61 was recognized as early as 1902, but no one was able to produce an actual sample until 1944. Three scientists working at what is now called Oak Ridge National Lab (in Tennessee) were examining the smaller radioactive atoms produced by the splitting of uranium atoms. This was right at the end of World War 2, so the reason they were researching uranium was to help create atomic weapons. They were not able to announce their discovery until 1947. They were going to name the new element "clintonium" after the name of the lab at that time (Clinton Lab) but the wife of one of the scientists suggested naming it after the Greek god Prometheus who was said to have brought the technology of fire to early humans. This was right after two atomic bombs had been dropped on Japan to end the war, so the naming of this element was to suggest "the benefits and the possible misuse of mankind's intellect."

In 1963, promethium flouride was created, and was allowed to react with lithium ions so that the fluoride atoms left the promethium and joined with the lithium to form molecules of lithium fluoride. This left the scientists with enough pure promethium metal that they were able to do experiments to determine its properties. There are several isotopes of promethium (atoms with more or less than 84 neutrons) but most decay quickly and turn into either neodymium or samarium. The most stable isotope, Pm-145, has a half-life of about 17 years, which means that after 17 years half your original sample will be gone and in another 17 years half of that remaining half will be gone. After 68 years you will only have 1/16 of your original sample left.

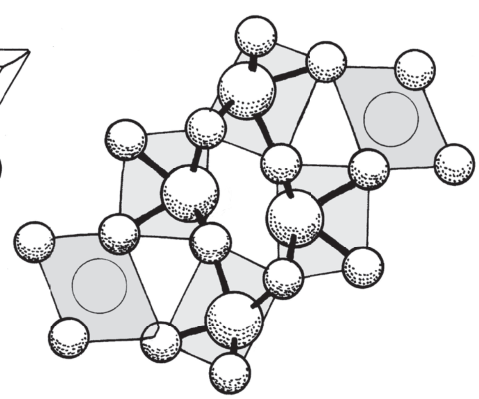
The only useful isotope of promethium is Pm-147, which does not emit deadly gamma rays like many radioactive atoms do. The "beta" radiation it emits (essentially electrons) has an extremely short range and is easily absorbed by other elements. It can be used to make glow-in-the-dark paint that glows by using the energy coming out of the promethium atoms. The Pm-147 has a half-life of only 2.6 years, so it has to be used in places that only need a good strong glow for a few years. The Apollo lunar rover, used in 1971 and 1972 on missions 15, 16 and 17, had control panels painted with luminous promethium paint (promethium chloride mixed with zinc sulfide). During the mid 1900s, Pm-147 was used as a safer replacement for radium paint, which they had used for decades to make the faces of watches glow in the dark, not realizing how dangerous the radium was.

$PmCl_3$ Promethium (III) chloride



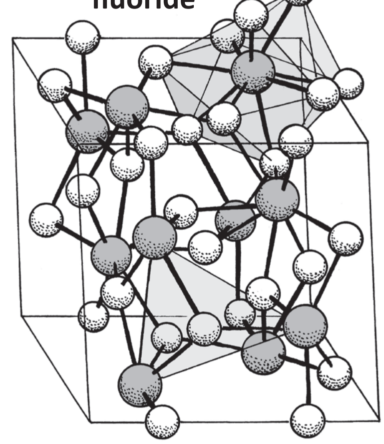
The larger balls are Cl. The smaller balls are Pm.

Pm_2O_3 Promethium (III) oxide



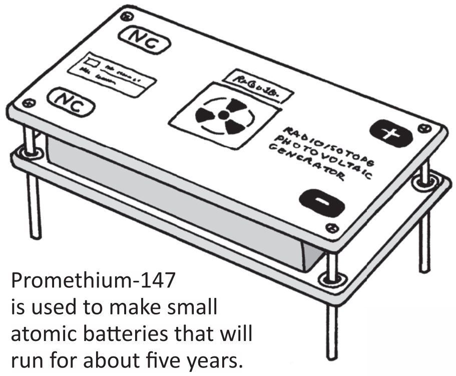
The larger balls are Pm. The smaller balls are O.

PmF_3 Promethium fluoride



The dark balls are Pm. The light balls are F.

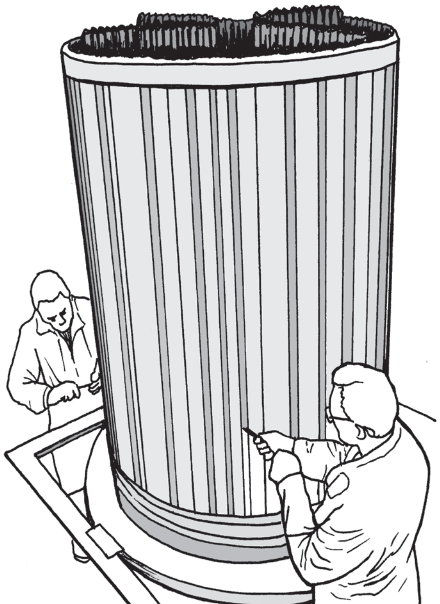
61 Pm



Promethium-147 is used to make small atomic batteries that will run for about five years.

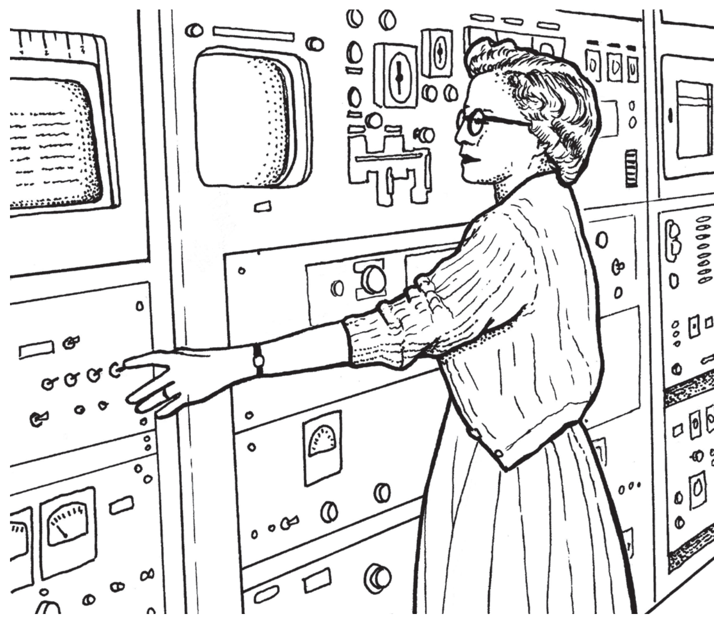
Promethium was discovered in 1944 as a waste product produced during experiments with uranium atoms.

Promethium



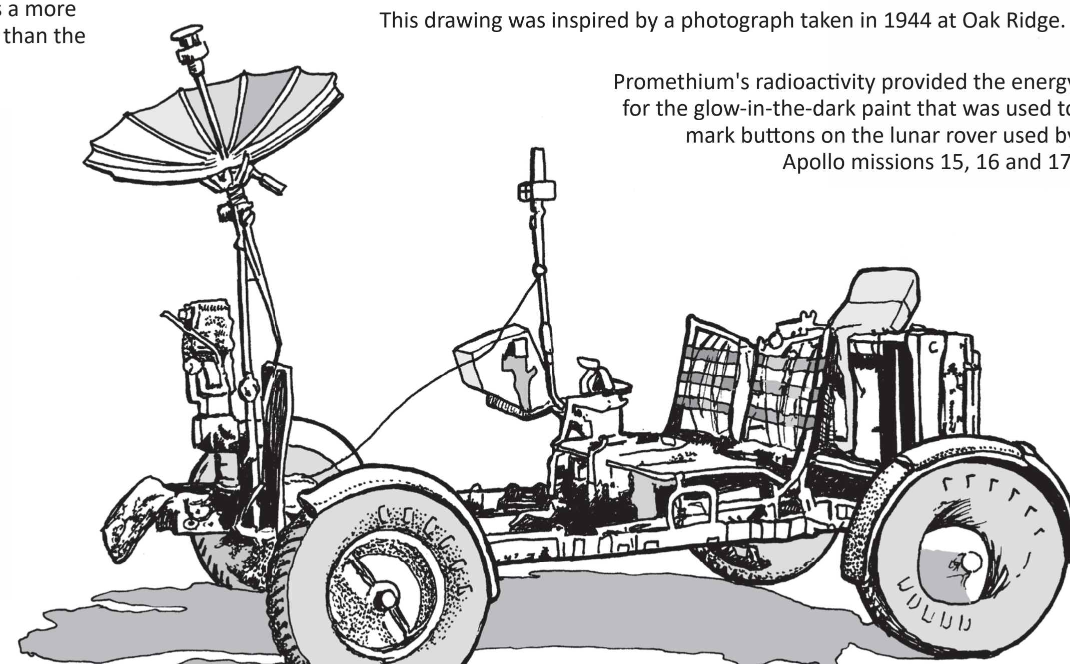
The nuclear reactor at the lab that discovered promethium (now Oak Ridge National Lab) used a core of graphite to slow down the free neutrons that were hitting uranium atoms. (This is a more modern graphite core, smaller than the one used at Oak Ridge.)

In a way, many people helped to discover promethium, though they did not know it at the time. Many non-scientists were employed at the top-secret facility in Oak Ridge, Tennessee, where scientists were enriching uranium in order to develop the atomic bomb. This woman was taught to push buttons in a certain order. She did not know that the lab was making a nuclear weapon.



This drawing was inspired by a photograph taken in 1944 at Oak Ridge.

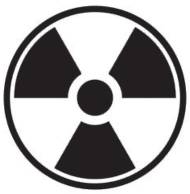
Promethium's radioactivity provided the energy for the glow-in-the-dark paint that was used to mark buttons on the lunar rover used by Apollo missions 15, 16 and 17.



Promethium replaced radium in luminescent paint after they discovered how dangerously radioactive radium is.

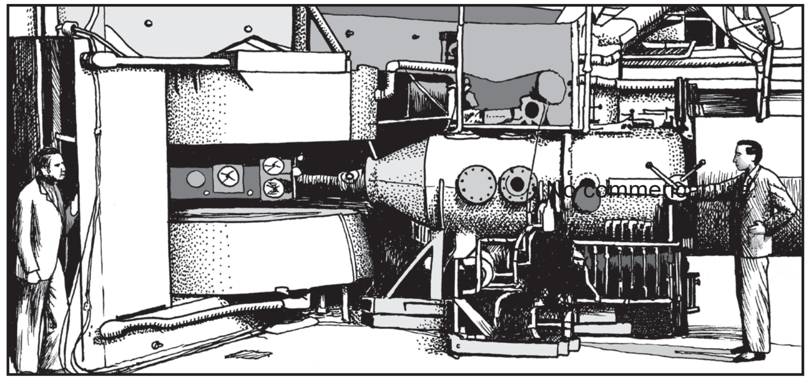
103 Lawrencium Lr

103 protons
151-163 neut.
103 electrons



Ernest O. Lawrence (1901-1958)

The 60-inch cyclotron at Berkeley looked metallic grayish blue.



Lawrencium was named in honor of Ernest Lawrence, inventor of the cyclotron. The 60-inch cyclotron at the Berkeley Lab was used to discover many super heavy elements. The claim of first discovery of element 103 was made by both the Berkeley lab and by the Joint Institute for Nuclear Research in Dubna, Russia. Albert Ghiorso and his team at Berkeley announced they had made element 103 in February, 1961, using a californium target and bombarding it with boron atoms. The scientists in Dubna looked at their research results and raised some questions as to whether these isotopes with a half-life of only 8 seconds were, in fact, element 103, but the research was convincing enough for the International Union of Pure and Applied Chemistry (IUPAC) to accept the discovery and approve the name. Later, as the years went on and more experiments were done by both the U.S. and Russian labs, the measurements and facts about this element were refined. In 1992, the IUPAC looked at all the research done by these labs and decided that they should share the credit and be listed as co-discoverers.

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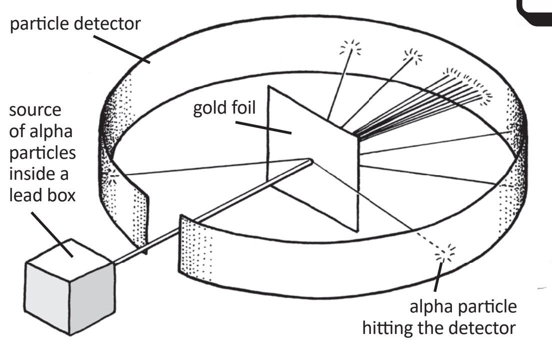
104 Rutherfordium Rf

104 protons
157-163 neut.
104 electrons

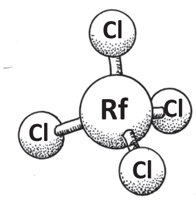
This stamp is light purple.

Rutherford is the "father of nuclear physics."



This shows the concept behind Rutherford's famous gold foil experiment. Most of the alpha particles went right through the gold foil, demonstrating that atoms were mostly empty space.

Even with their short half-lives of less than an hour, researchers have still been able to make Rf atoms form some molecules.



Rutherfordium was named to honor Ernest Rutherford who worked with J. J. Thompson to discover the electron. Rutherford went on to investigate radioactivity and gave us the names of the alpha and beta particles. He also worked with Hans Geiger (for whom the "geiger counter" is named) to develop new ways of sensing and counting alpha and beta particles. His most famous experiment came in 1908 when he and Geiger and Ernest Marsden shot alpha particles through gold foil. Most of the particles went right through, with only a few bouncing back. This led to the conclusion that atoms were mostly empty space. Rutherford suggested that atoms had a small "nucleus" made of positive protons and uncharged neutrons. Rutherford received many awards during his life, and spent 5 years as president of the Royal Society.

The fact that rutherfordium will form molecules with atoms like chlorine and bromine is due to the fact that it is right under titanium, zirconium and hafnium. Chemists expect that elements in the same column will have similar chemical properties. The half-lives of isotopes of Rf range from about an hour to a few millionths of a second.

Rutherfordium was first reported by the JINR lab in Dubna, Russia, in 1964, and then by Berkeley in 1969.

105 Dubnium Db

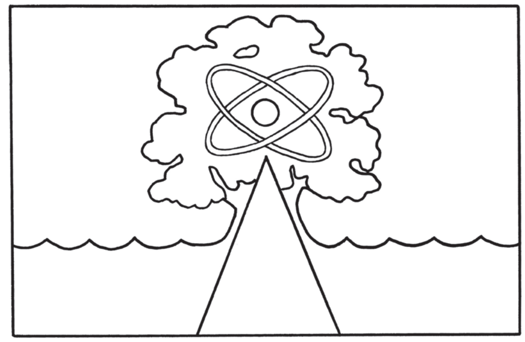
105 protons
157-165 neutrons
105 electrons

Joint Institute of Nuclear Research.

Walls: yellow
Columns: white
Flags: mostly red, white, and blue.

The flag of Dubna, Russia

The atom and triangle: yellow
Tree top: green
Water: blue



The existence of element 105 was first reported in 1968 by the Joint Institute for Nuclear Research (JINR) in Dubna, Russia (just a little north of Moscow). The researchers bombarded a target of americium atoms (95 protons) with neon atoms (10 protons). In 1970, the team at Berkeley lab used californium and nitrogen to create atoms with 105 protons. Both teams heavily relied on the observation of alpha decay producing element 103. This implied that something had started with 105 protons, and lost 2 to become element 103.

The Russian team proposed the name "nielsbohrium," after Danish physicist Niels Bohr, and the American team proposed the name hahnium, after Otto Hahn, who had worked with Lise Meitner to discover the fission process. After two decades of arguments between Berkeley lab, JINR, and the IUPAC, and suggestions of renaming many of these new elements, it was finally decided that both labs should share credit for discovery, but the name would be dubnium.

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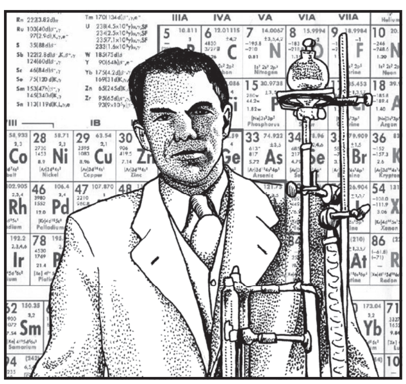
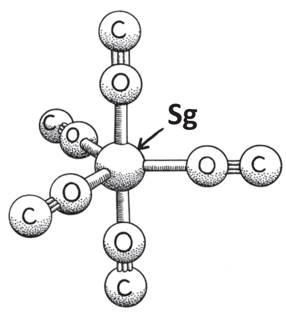
106 Seaborgium Sg

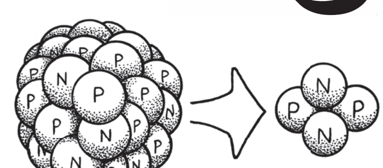
106 protons
152-165 neut.
106 electrons



Glenn Seaborg standing in front of the ion exchange equipment that isolated actinides.



Seaborgium hexacarbonyl was created in a lab in 2014. The Sg soon decayed, however.

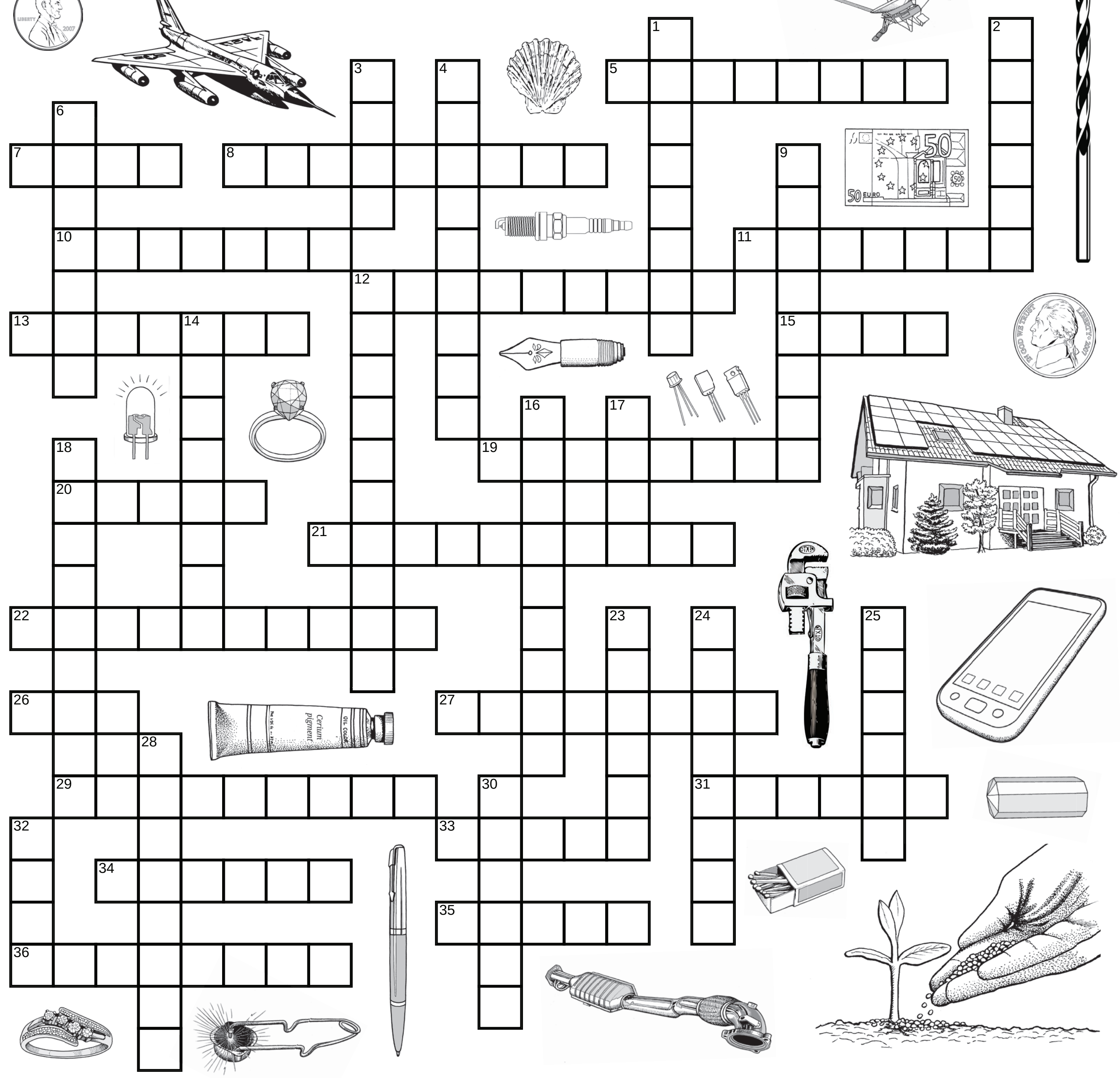


Observing alpha decays was the primary method used to determine whether element 106 had been made. They were able to accurately predict how each isotope of 106 would decay, so if they observed a certain decay pattern, they asssumed it had come from element 106.

In 1974, a few atoms of element 106 were observed at both Berkeley lab and the JINR in Dubna, Russia. The Russians used lead and chromium (82+24) in their experiments, and the Americans used californium and oxygen (98+8). The naming of this element was disputed for years, until the issue was resolved in 1997 when the IUPAC decided that this element could be named after Glenn T. Seaborg who was the leader of the Berkeley lab in the late 1950s and helped to discover americium, berkelium, californium and lawrencium. Seaborg was still alive when the name was proposed, and this became controversial because no previous element had been named after a living person. In 1997, the IUPAC evaluated many naming controversies and renamed several elements, but kept seaborgium for 106.

Research on seaborgium is difficult because it must be produced one atom at a time, and the longest lived isotope has a half-life of only 14 minutes. The least stable isotope only exists for a few millionths of a second. However, in 2014 scientists were able to make a molecule called seaborgium hexacarbonyl, $Sg(CO)_6$. They expected Sg to be able to form this compound because the elements right above it on the Periodic Table are able to do so.

SYMBOL PRACTICE



ACROSS

5) Tl
7) Pb
8) Te
10) Ca
11) Cd
12) K
13) As
15) Fe
19) Se
20) Ar
21) Mo
22) Tc
26) Sn
27) F
29) Mn
31) Na
33) B
34) Ni
35) Rn
36) Cl

DOWN

1) Cr
2) Ra
3) Au
4) Sr
6) Hg
9) Pt
12) P
14) N
16) Nd
17) Ne
18) Mg
23) C
24) W
25) S
28) Sb
30) Co
32) Zn

1) Which two letters do not appear in any symbol? ____, ____

2) Which element's name has only three letters? ___ ___ ___

3) Which 4 letters appear only once as the first (or only) letter of a symbol? ____, ____, ____, ____

4) Which letter appears most frequently as the first letter of a symbol? ____

TRADITIONAL BINGO

The goal of this activity is to review and reinforce the learning they have been doing about individual elements, and to use critical thinking skills to make good guesses in cases where they are not sure.

NOTE: For this game, you will use only a few dozen of the element picture cards, not the entire set. Choose which elements you want to include in the game, and use the clues for those elements. Also, if you are working with advanced players and don't want them to have any pictures as clues, you can use the symbol (letter) cards instead.

Before you start preparing, decide how large you want to make the Bingo boards. You can use 16 cards to make a 4 by 4 square, or you can use 25 cards to make a 5 by 5 square. In the 5 by 5 arrangement, if you want to make the center square a "free" square, you can simply leave it open and not put a card there, or you can use the FREE squares shown after element 118.
(Note that each page of picture cards has 12 elements. If you want to limit the number of pages that need to be copied, you can choose just 2 pages to print, giving you 24 elements, and simply leave the central spot open as a "free" square.)

<u>You will need</u>:
- a set of cards for each player (You may want to put an identifying mark on each set so you can sort them out easily if they get mixed up.)
- tokens for each player to set on top of their cards (ex: pennies, paper squares, candies, nuts, uncooked macaroni, dry beans...)
- appropriate clues

<u>How to prepare</u>:
1) Make a card set for each player.
2) Make sure each player has access to a supply of tokens (enough to almost cover their board)
3) Decide which clues you want to use and how you want to use them. You can cut the page into strips and have one clue per strip, then put the clue strips into a bag or box so you can pull them out randomly. You might want to consider having more than one bag of clues, so that after one or two rounds you can switch to a set of new clues. If you will be having the players take turns reading clues, you will want to have clue strips. However, if you will have an adult reading all the clues, you can leave the pages intact and have the adult reading through the clues (on the spot) and choose them randomly, keeping track of which ones they have used by writing numbers next to the clues as they are used.

<u>How to play</u>:
1) The players should set their element cards out to form a square, either 4x4 or 5x5 (as you have decided ahead of time).
Each player's arrangement will be unique, reducing the possibilty of a tie. If there are more elements than squares (which will happen if you use a 4x4 square) the players will choose which elements to use and which to set aside. Between rounds, they can change their arrangements and use some of the cards they had set aside.
2) Read out clues one at a time. Players place tokens on squares that fit the clues.
3) When someond gets 4 in row (or 5 in a row) they call out "Bingo!" then read their answers, which are checked by the clue giver. If this player is successful, you can either keep this game going until a few more players get a Bingo, or you can have the players clear their boards and everyone starts a new round. (The advantage to keeping the game going and allowing more than one winner is that you can keep going on your current list of clues, upping the chance that most of the clues will be used.)

"ELEMENT CONNECTIONS"

The goal of this activity is to review facts about various elements. It can be played with any number of participants. Instructors should choose questions from the question bank (or create their own) that target the knowledge base of the players. The question bank has easy, medium and hard clues, and all of the clues are based on the information given in the coloring section of this book.

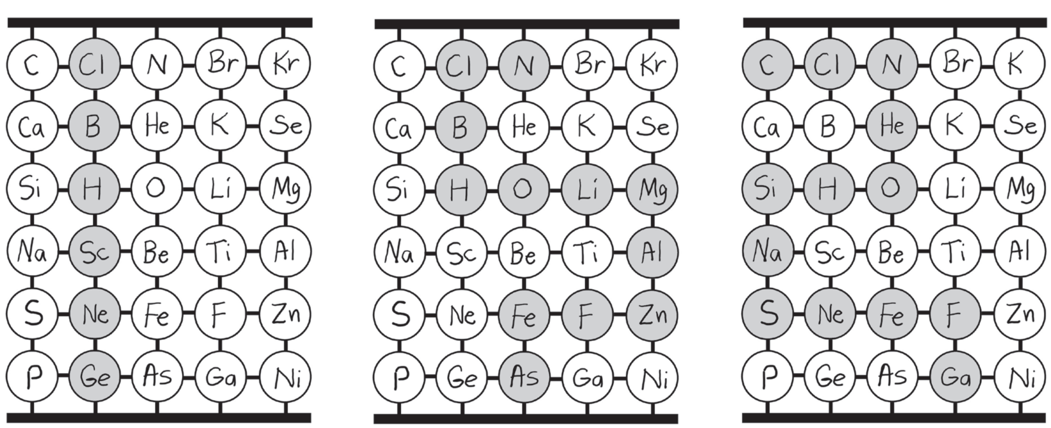
<u>You will need</u>:
- one copy of the following pattern page for each player
- pencils or markers so the players can write a symbol on each circle
- tokens for each player (pennies work well)
- appropriate clues

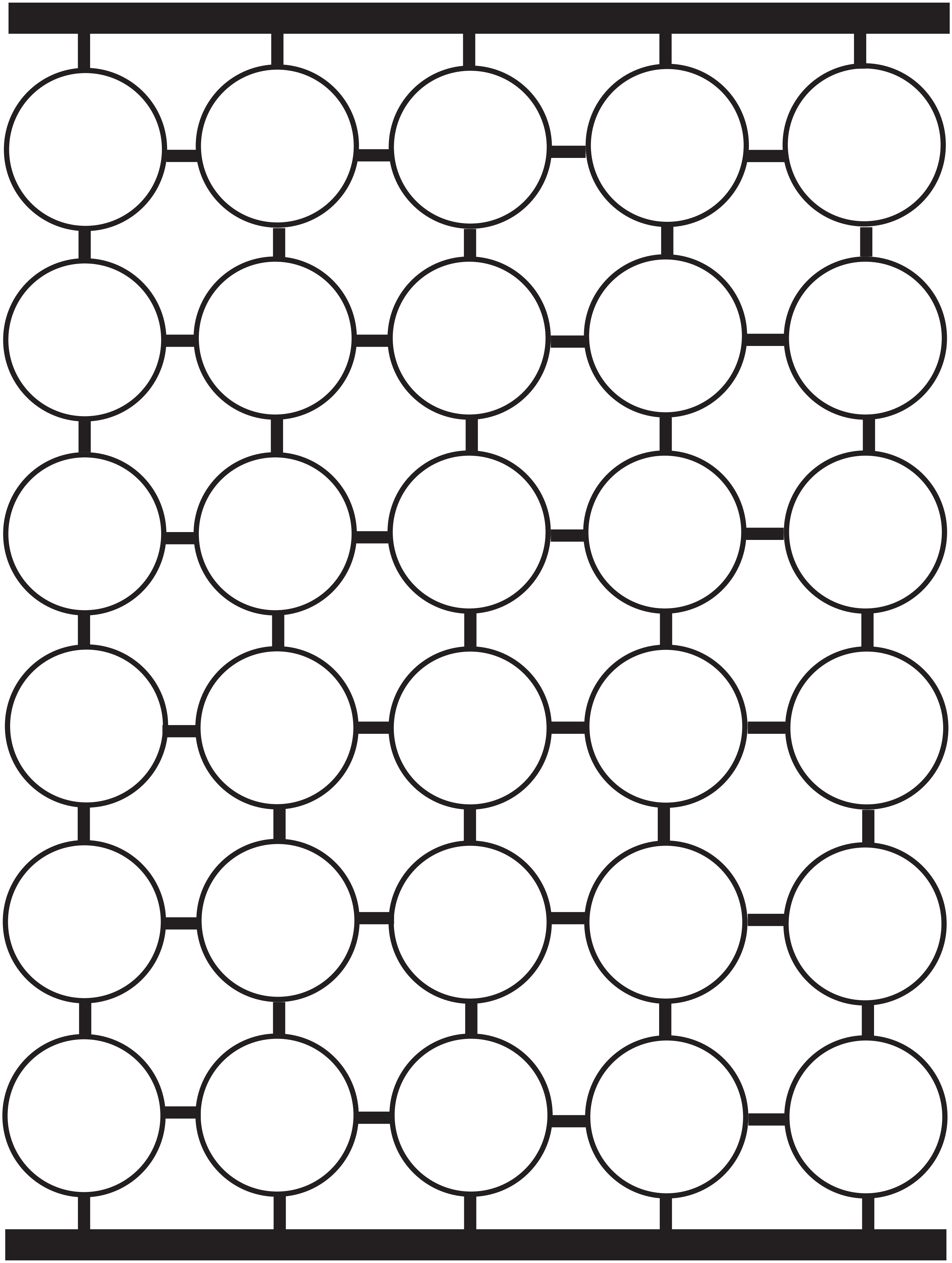
<u>How to prepare</u>:
1) Make a copy of the pattern page for each player.
2) Choose at least 30 elements to use in this game. You can select more than 30, giving the players some choice about which ones they would like to use on their board. Bear in mind that the larger the number of possible elements, the more turns each player will have to "pass" because they don't have that element on their board. However, it is okay if they have to pass once in a while. If you have been going through the elements sequentially, consider starting with the first 36 (up to krypton). You could also choose a theme such as "transition metals." If you want to cover additional elements, just make more copies of the pattern page and have the players make a second board with new elements.
3) Get clues ready for each of the elements you have chosen. Select several clues for each element so you can play more than one round. If you decide to use the QUESTION BANK provided, select the clues that are best suited to the knowledge base of your players. (If you have students with very different levels of knowledge, you might want to create two groups and use separate clues for each.) You can make copies of the question pages and cut them into strips with one question per strip, or you can keep the pages intact and simply check off the clues you use as you go along.

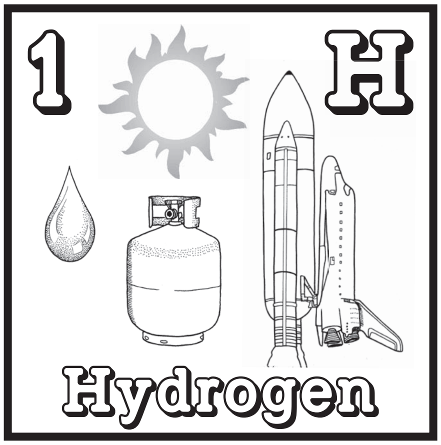
<u>What to do</u>:
1) Tell the players which elements will be included in this game. Give them pencils or markers and have them fill in the circles on their game board with element symbols. Use each element only once. If the players work on their own, each board should be unique. This will reduce the chances of a tie.
2) Make sure each player has at least two dozen tokens.
3) Tell the players that the goal is to connect the top bar and the bottom bar with a continuous line of tokens. Notice how the circles are connected by small black lines. Imagine that the top bar is carrying electricity and you want to run a wire to the bottom bar. The wire would be a path of filled circles all connected by small lines. This means that your wire does not have to be straight. As long as there is a line between the circles, you can make a path. You can't do diagonals because there are no diagonal lines. The path can go left, right, up, down, as long as it is continuous from the top bar to the bottom bar.
4) Begin reading clues. If a player thinks the clue matches one of the elements on their board, they put a token on it.
5) When a player has completed a continuous path of tokens, they yell "Connection!" They will then read off the elements in that pathway and the person calling clues will check the answers. If they do not get them all correct, the game continues until someone succeeds.
6) When someone wins, players take the tokens off their board and then a new round starts. (Or, if you are working with younger students, you may want to continue the same game and let a few more players get their connection made.)

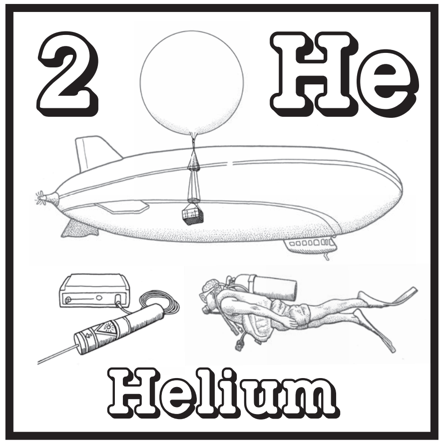
Here are some samples of "connections." You want a continuous pathway. It can be straight, but it doesn't have to be.

Of course, actual game boards will have more tokens on them than the paths shown here. As in Bingo, there will be tokens on the board that won't end up being part of the winning pathway.





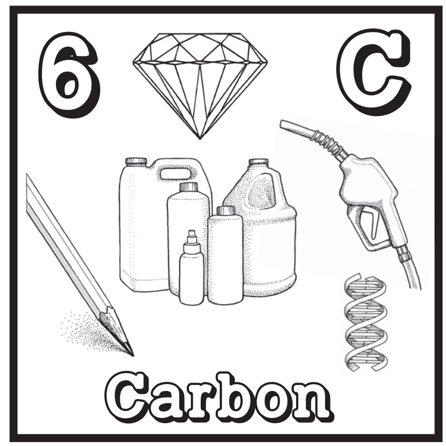

1
H
Hydrogen

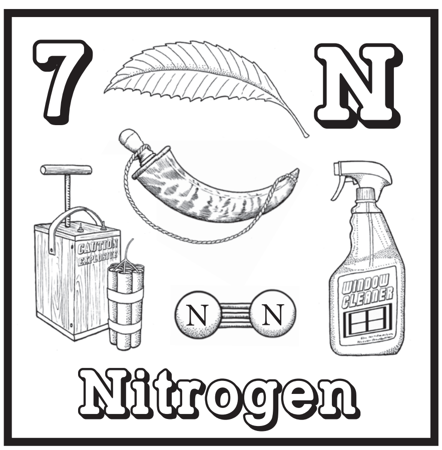

2
He
Helium

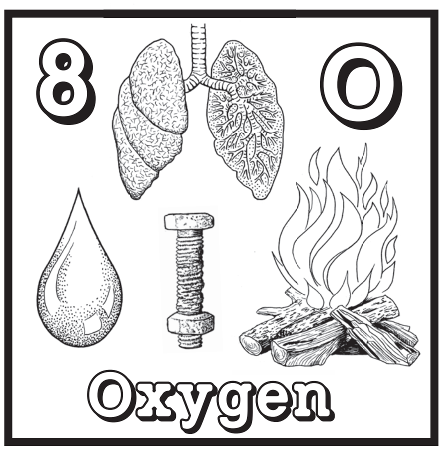

3
Li
WHITE LITHIUM GREASE
LITHIUM
Lithium

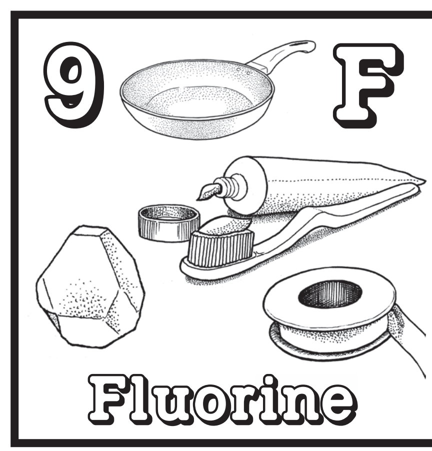

4
Be
8IN.
W153
Beryllium

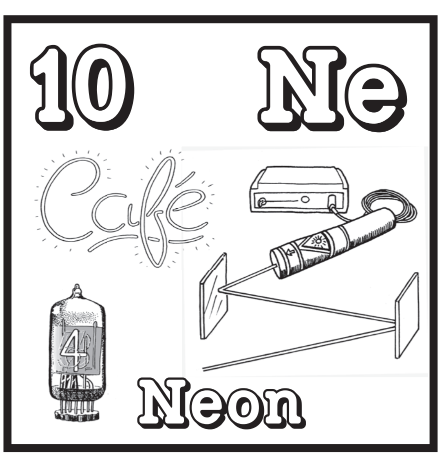

5
B
BORAX
DETERGENT BOOSTER
Boron

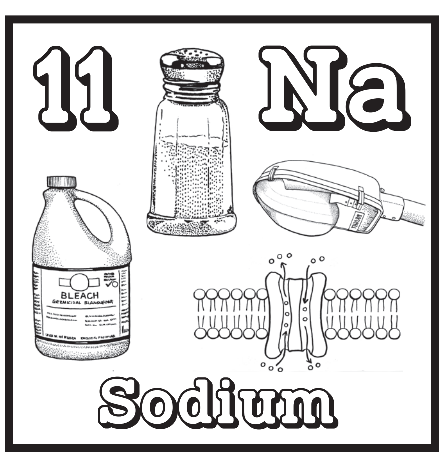

6
C
Carbon


7
N
CAUTION EXPLOSIVE
N
N
WINDOW CLEANER
Nitrogen


8
O
Oxygen


9
F
Fluorine


10
Ne
Café
Neon


11
Na
BLEACH
Sodium


12
Mg
EPSOM SALT
Magnesium

E	This element is very abundant in our sun and is part of the fusion reaction that makes heat.	hydrogen 1
E	Two atoms of this element are found in every water molecule.	hydrogen 1
E	This element is often used as rocket fuel. It combines with liquid oxygen to create combustion.	hydrogen 1
E	This is the smallest and lightest of all elements.	hydrogen 1
M	Three atoms of this element are connected to a nitrogen atom to make an ammonia molecule.	hydrogen 1
M	Four atoms of this element are connected to a carbon atom to make a molecule of methane.	hydrogen 1
M	Hydrogenated oils are made of strings of carbons with atoms of this element attached.	hydrogen 1
H	When combined with chlorine atoms, this element make a strong acid (found in our stomachs).	hydrogen 1
H	Two atoms of this element combined with two atoms of oxygen make a common first aid product.	hydrogen 1
H	Atomic welding uses this gaseous element between two metal electrodes.	hydrogen 1

E	This element was first discovered in the sun, using a spectrometer.	helium 2
E	This element is used to fill balloons and blimps because it is light and non-flammable.	helium 2
E	This element has 2 protons and 2 neutrons.	helium 2
E	This element is used as a shielding gas in arc welding.	helilum 2
M	This element is mixed with oxygen and put into scuba tanks (to replace nitrogen).	helium 2
M	This elemental gas is used to pressurize liquid hydrogen in rocket fuel tanks.	helium 2
M	This elemental gas is produced as the result of the decay of uranium atoms.	helium 2
H	In 1895, William Ramsay discovered this gaseous element in rocks.	helium 2
H	This element is mixed with neon and used in lasers.	helium 2
H	This gas can be liquefied and used to cool magnets in MRI machines and particle accelerators.	helium 2

E	This element is best known for its use in long-life batteries.	lithium 3
E	This element makes bright red spark in fireworks and flares.	lithium 3
E	This element has 3 protons and usually 4 neutrons, though sometimes it can have 3 neutrons.	lithium 3
E	If a pure sample of this element is put into water, it will burn while floating on the surface.	lithium 3
M	Compounds containing this element are used to make medicines, mostly for neurological problems.	lithium 3
M	This lightest of all metals is used to make industrial lubricants.	lithium 3
M	Because this element is so light, it is added to metal alloys that will be used to build airplanes.	lithium 3
H	When combined with fluorine, it makes a clear crystal that is used in optical lenses.	lithium 3
H	When combined with carbonate, CO_3, this element can be used in ceramic glazes and tile adhesives.	lithium 3
H	When combined with hydroxide (OH) it makes a compound that can remove CO_2 from the air inside airplanes.	lithium 3i