

# FLUORINE

Atomic Number **9**

Chemical Symbol **F**

Group **VIIA**—  
**The Halogens**

IA												VIII A									
H											He										
IIA												VIII A									
Li	Be											B	C	N	O	F	Ne				
III B		IV B		V B		VI B		VII B		VIII B		I B		II B		VIII A					
Na	Mg	Al	Si	P	S	Cl	Ar														
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn				
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub										
* Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu																					
† Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr																					



Fluorine heads the column of elements in the periodic table known as the halogens, or “salt formers.” The other members of this family are chlorine, bromine, iodine, and astatine. Astatine, at the bottom of the group, is highly radioactive.

All halogen atoms react chemically by accepting electrons from other atoms and readily combine with metals to form compounds known as salts. The smaller the halogen atom, the closer to the nucleus the incoming electron will be and the greater the force that attracts it and makes the reaction occur. Fluorine is the smallest, lightest, and most reactive member of the halogen group.

Fluorine is a pale yellow gas whose molecules contain two atoms. It is, however, far too reactive to be found in nature in its diatomic form. Fairly large quantities of fluorine occur in the minerals fluorite or calcium fluoride (sometimes called fluorspar) and cryolite, which contains fluorine, aluminum, and sodium. Fluorine is also found in small quantities in seawater, teeth, bones, and blood.

The French chemist Henri Moissan won the Nobel Prize in 1906 for first producing fluorine in its pure elemental form. Its name is taken from the Latin word *fluere*, which means “to flow.” The origin of the name is probably due to the use of fluorite as a flux. A flux is added to many compounds and minerals to lower their melting point and make them more available for further chemical treatment. It was long known that fluorine compounds existed, but because of its extreme reactivity, pure fluorine had never been isolated. It took 75 years of continuous effort on the part of many chemists before it was finally isolated by Moissan in 1886.

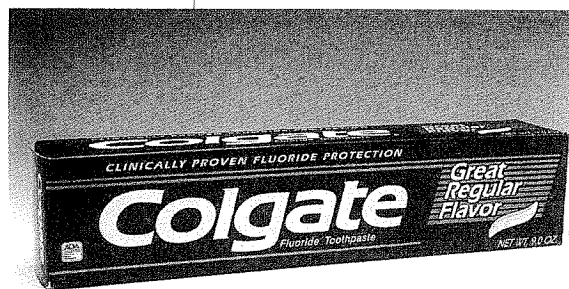
Fluorine is usually prepared by passing an electric current through molten fluoride salts. In 1986, however, Karl O. Christie, working at the Air Force laboratory at Edwards Air Force Base in California, astounded many chemists by successfully isolating pure fluorine from a fluorine compound using only chemical means. Because of the large amounts of energy required for such a procedure, it had long been believed that such a chemical separation was impossible.

Today fluorine is commercially prepared from fluorspar at the rate of thousands of tons a year. It is shipped as a liquid in special containers, cooled by liquid air.

Fluorine gas is used to produce a rather exotic gaseous compound of uranium called uranium hexafluoride ( $\text{UF}_6$ ). It is in the form of this compound that uranium is usually shipped to huge gas diffusion plants, where the important uranium-235 isotope is then separated from the more common uranium-238 isotope. It is the U-235 isotope that is easily fissionable and plays such a major role in nuclear reactors and nuclear weapons.

Another important role for fluorine in nuclear research is in producing a gas for detecting the presence of neutrons. This sensitive gas is a compound of fluorine and boron called boron trifluoride ( $\text{BF}_3$ ). As we have seen in the section on boron, this element readily absorbs neutrons and then emits highly charged alpha particles that are easily detected. However, there are technical obstacles to the use of pure, solid boron for such detectors, and it is far easier to construct a neutron detector that uses the gaseous, boron-containing molecules of  $\text{BF}_3$ .  $\text{BF}_3$  detectors, as they are called, are among the most important tools for this purpose.

Many communities in the United States now add fluorine, in the form of sodium fluoride, to their public water supplies. Research has shown that small quantities of fluorine can retard the occurrence of cavities in teeth. Teeth are protected by a hard enamel that is composed of a mineral called hydroxyapatite. This mineral is not very soluble, but in the presence of the weak acids that bacteria in the mouth produce from food that has a high sugar content, some breakdown of hydroxyapatite occurs. The resulting loss of enamel promotes the onset of tooth decay. One of the body's defenses against the loss of tooth enamel is to make new enamel constantly, a process called remineralization. In the presence of sodium fluoride, the remineralization process makes a modified form of enamel, called fluorapatite, that is more resistant to attack



*Toothpastes containing fluorine, in the form of sodium fluoride, can help prevent cavities. In the presence of sodium fluoride, a process called remineralization makes a modified form of tooth enamel that is resistant to attack by acids.*

*Fluorocarbons in aerosol cans have been banned in the United States because these gases diffuse into the upper atmosphere and the resulting loss of ozone permits dangerous ultraviolet radiation to reach the surface of the Earth.*

by acid than hydroxyapatite is. Manufacturers of toothpaste now routinely add sodium fluoride to their products.

Considering the extreme reactivity of fluorine gas, it is somewhat surprising that a plastic called Teflon, consisting of long, chainlike molecules of carbon linked chemically to fluorine, should be as inert as it is. Teflon is used for nonstick surfaces on frying pans and on a variety of other products that require smooth, nonreactive surfaces. It is also used to make artificial valves for the heart.

Other fluorinated compounds of carbon include aerosol propellants for spray cans and Freon, an inert gas used as a refrigerant. The use of fluorinated carbon gases, known as fluorocarbons, in aerosol cans has been banned in the United States since 1978 because it is known that these gases diffuse into the upper atmosphere and react with the ozone layer. The resulting loss of ozone permits dangerous ultraviolet radiation to reach the surface of the Earth.

In the presence of hydrogen, fluorine burns with explosive force. The reaction is spontaneous, and not even a match or spark is needed. The reaction forms hydrogen fluoride, which when dissolved in water is an acid. Hydrofluoric acid is extremely dangerous and must be carefully handled. A small amount on the skin can cause extreme pain. However, this acid has the ability to dissolve glass and is used to etch designs on glass objects.

An artificially made, radioactive isotope of fluorine, fluorine-18, is one of several isotopes used in the medical procedure called positron emission tomography (PET). Fluorine-18 spontaneously emits positrons, which are the antiparticles of electrons and resemble the latter in every respect but their electric charge. When a positron collides with an electron, the two particles “annihilate” each other, yielding a burst of energy that takes the form of X-ray-like radiation. If fluorine-18 is introduced into the body, this “annihilation” radiation is emitted within the body and can be scanned by special detecting instruments to produce cross-sectional pictures of portions of the body. Fluorine-18 is ideal for this technique because it has a half-life of only 109.8 minutes, which is important for minimizing radiation injury to the patient’s body tissues.