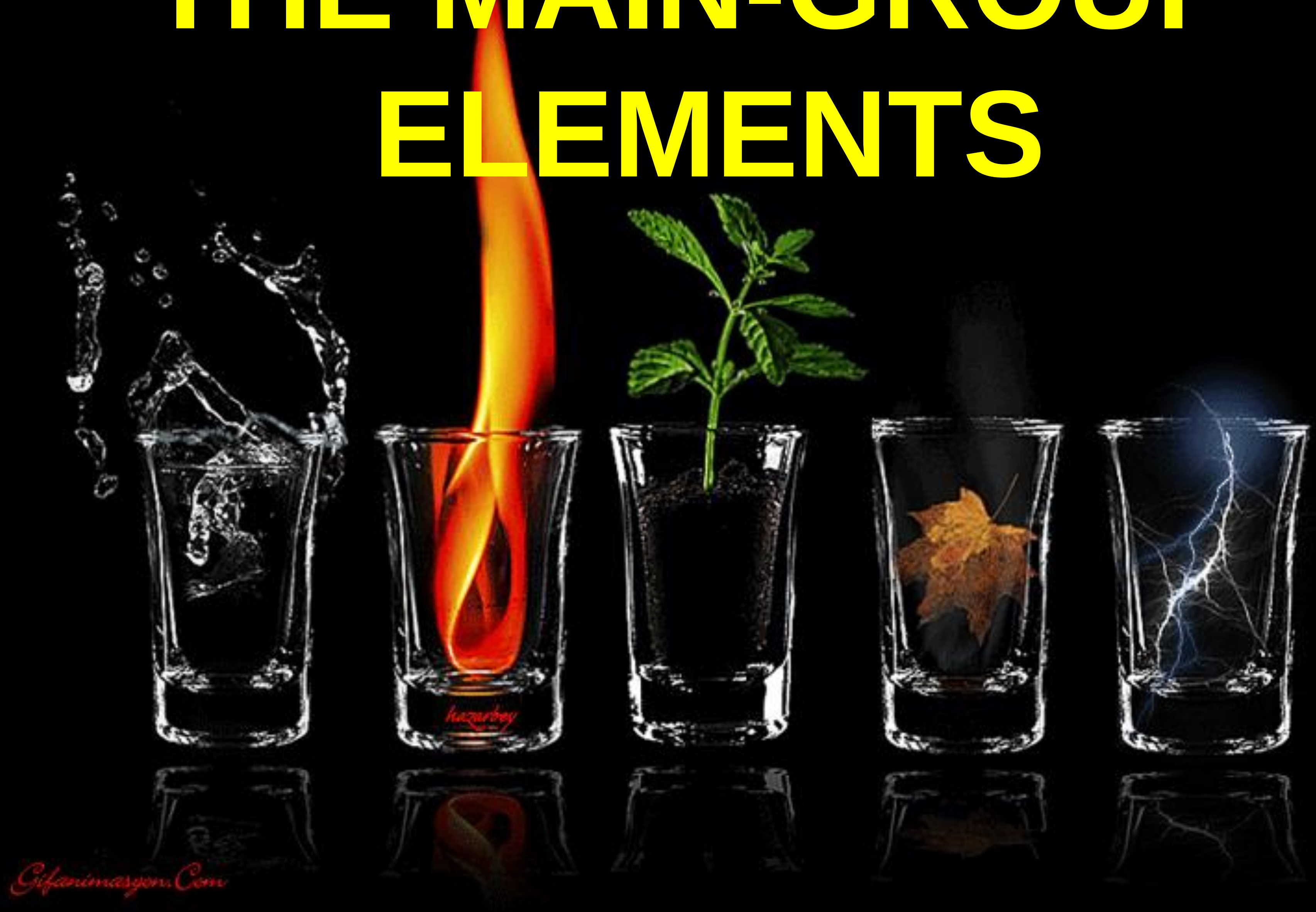
THE MAIN-GROUP ELEMENTS



Atomic Properties

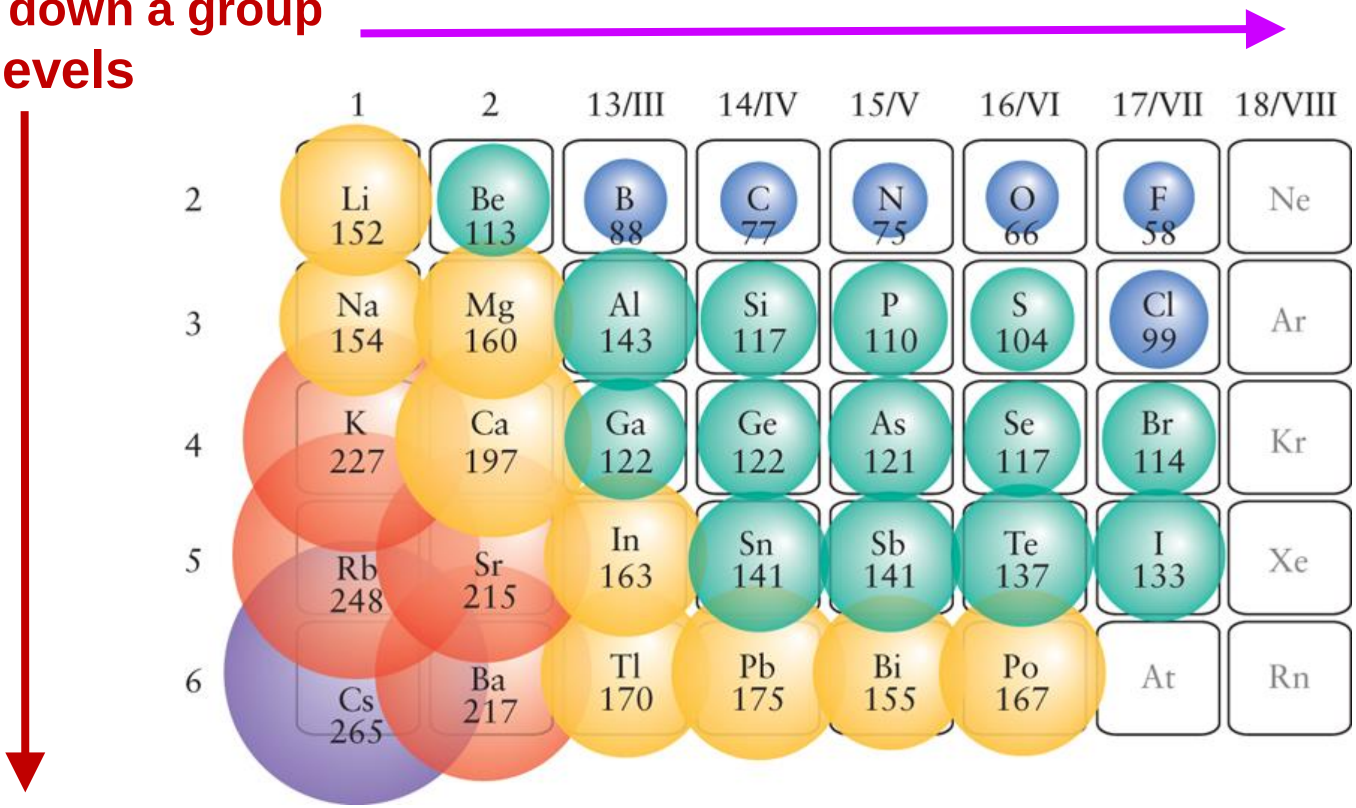
Properties of elements is based valence-shell electron configurations.

Five atomic properties:

1. atomic radius
2. ionization energy
3. electron affinity
4. electronegativity
5. polarizability

Atomic Size

Adding more **valence levels** **increases** the distance from the electrons to the nucleus, it also **decrease** the effect the nucleus has on the outer electrons.



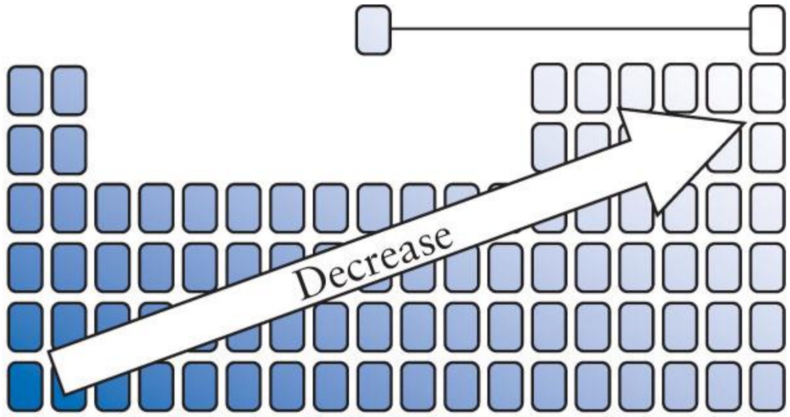
decreases across a period
Effective Nuclear Force

increases down a group
Valence levels

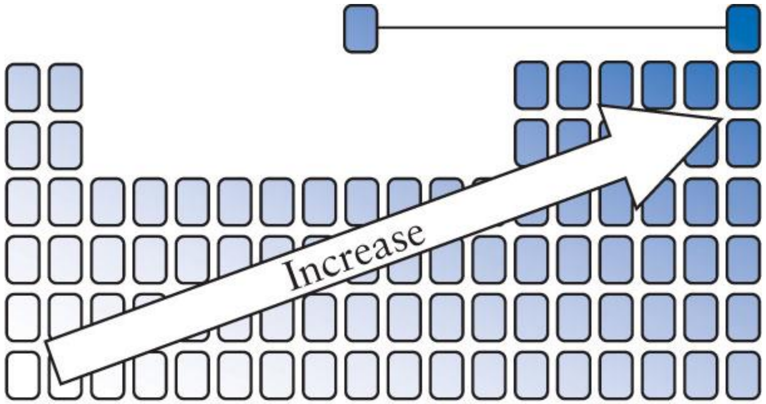
	1	2	13/III	14/IV	15/V	16/VI	17/VII	18/VIII
2	Li 152	Be 113	B 88	C 77	N 75	O 66	F 58	Ne
3	Na 154	Mg 160	Al 143	Si 117	P 110	S 104	Cl 99	Ar
4	K 227	Ca 197	Ga 122	Ge 122	As 121	Se 117	Br 114	Kr
5	Rb 248	Sr 215	In 163	Sn 141	Sb 141	Te 137	I 133	Xe
6	Cs 265	Ba 217	Tl 170	Pb 175	Bi 155	Po 167	At	Rn

Ionization Energy

Ionization energy: the energy required to remove the most loosely held electron from an atom in the gaseous state.



Size of Atom

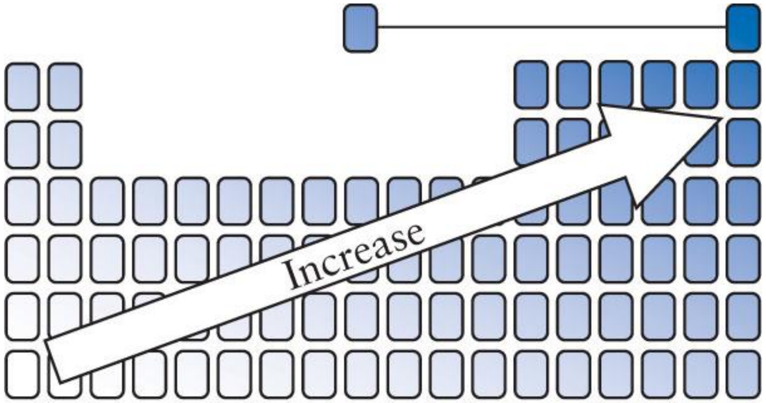


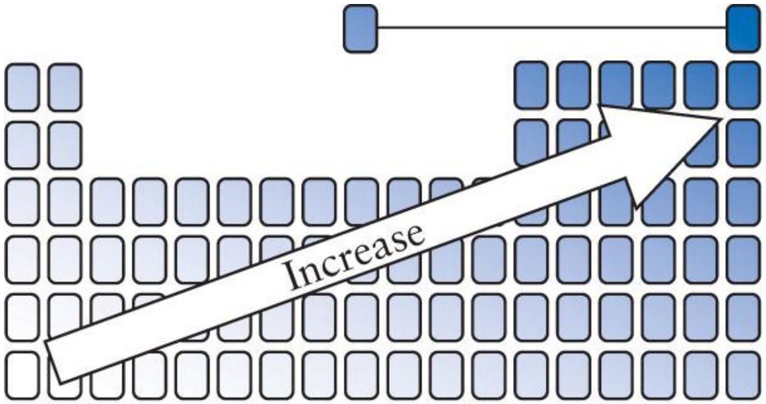
Ionization Energy

Smaller size → Higher ionization energy

Electron Affinity

The electron affinity is a **release of energy** to form an **anion**.





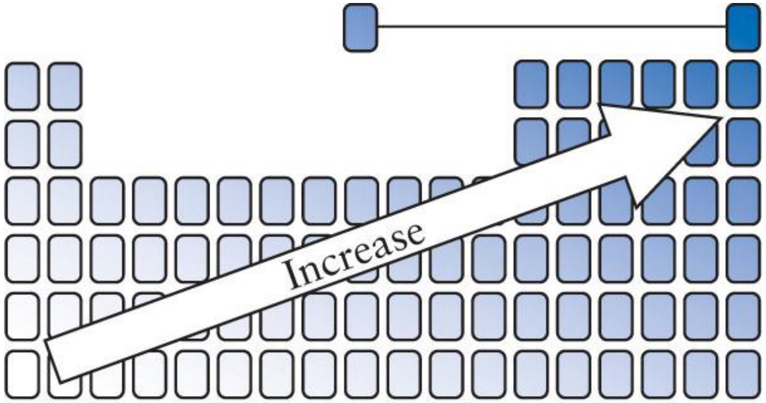
Ionization Energy

Electron Affinity

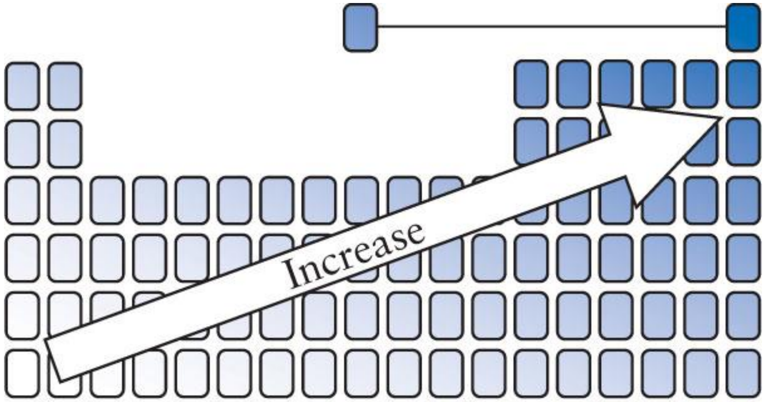
Atoms with **higher effective nuclear charges** release more energy.

Electronegativity

Electronegativity is the **tendency** of an atom to attract electrons to itself.



Ionization Energy



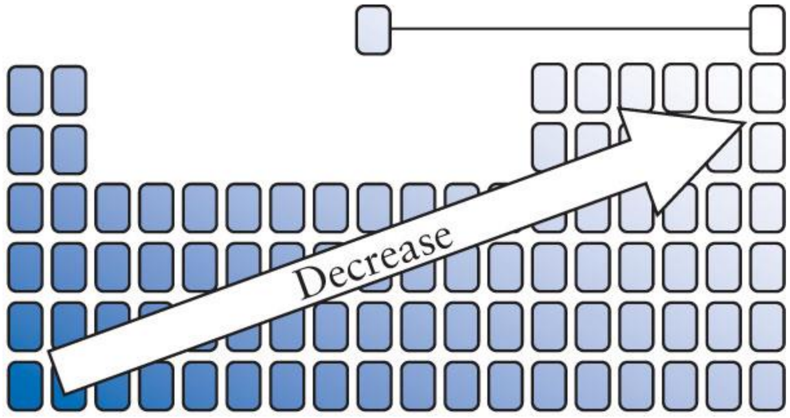
Electronegativity

Atoms with a **greater effective nuclear charge** have a **stronger pull on bonding electrons**.

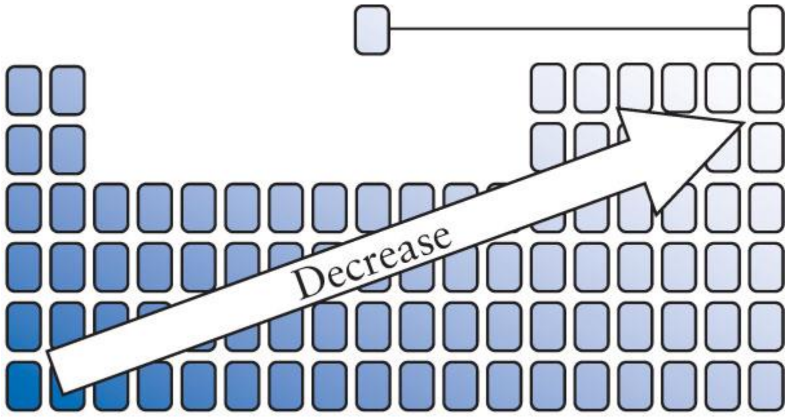
Large differences in electronegativity typically form ionic bonds and small differences from covalent bonds.

Polarizability

Polarizability is the ease an atoms electron cloud can be **distorted**.



Size of Atom

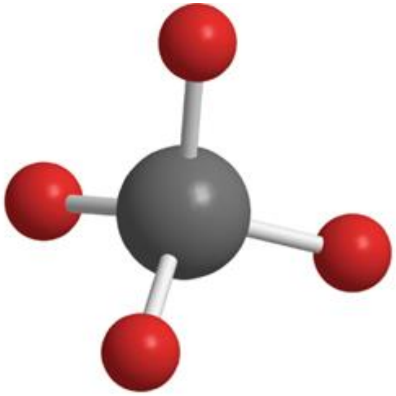


Polarizability

Electron-rich, heavier atoms are easily polarized.

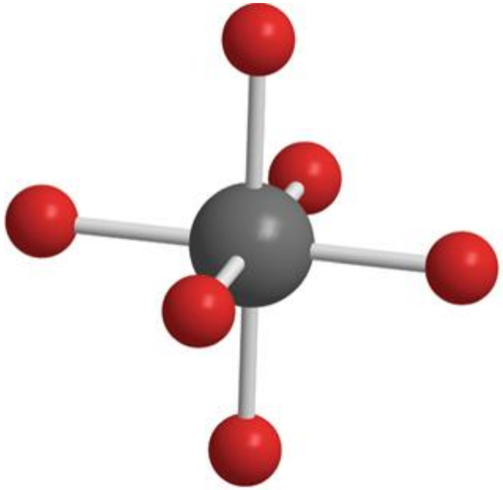
High polarizing power atom-are small sized, highly charged atoms.

Bonding Trends



Elements in period 2 strictly follow the octet rule; carbon forms four bonds.

Elements in Period 3 and higher periods exceed the octet. They reach higher oxidation states because they can access empty d-orbitals.



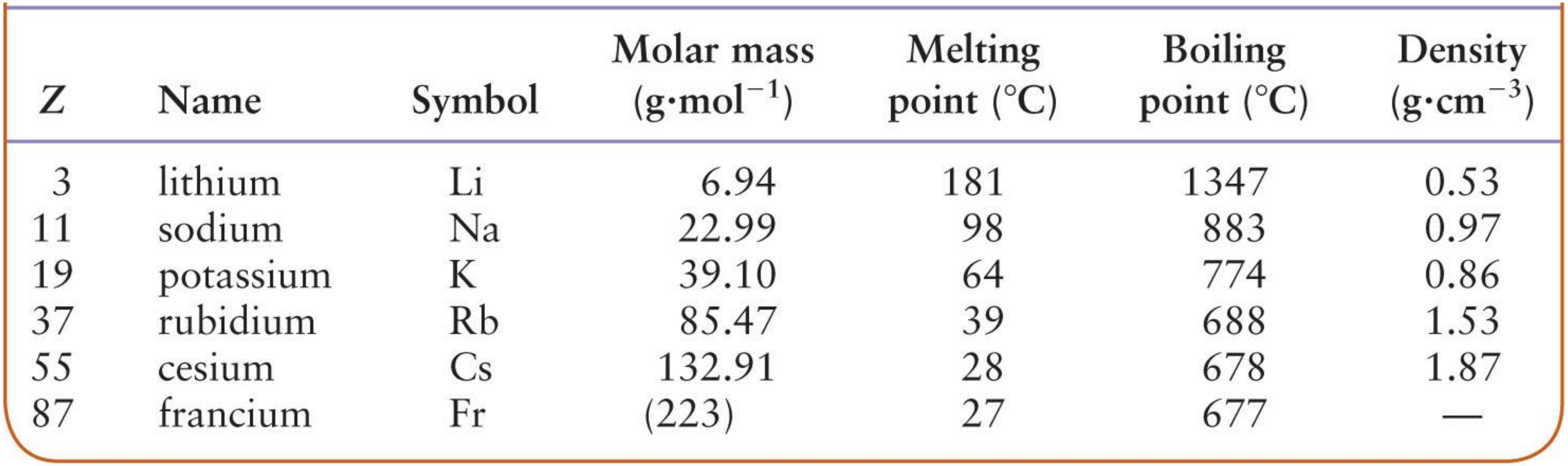
Also, larger atoms can simply make more bonds to more neighbors .

Group 1A: Alkali Metals

The chemical properties of alkali metals are striking similar.

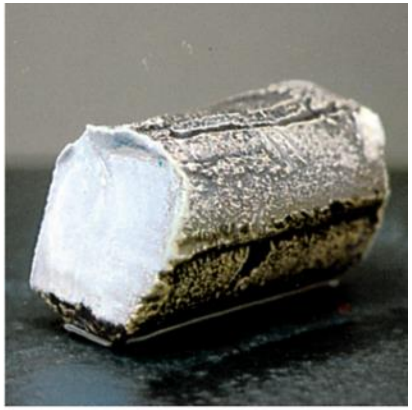
Sodium and potassium are used to transmit electrical signals throughout our brain and nervous system.

One valance electron dominates their chemical and physical properties.

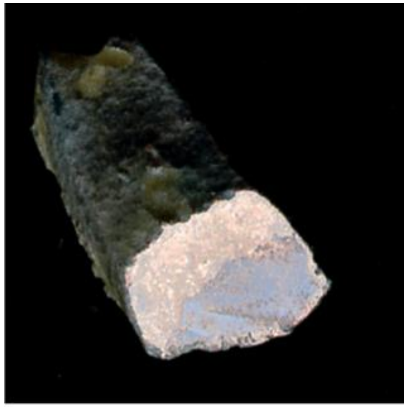


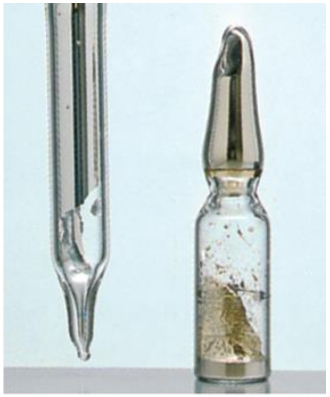
Z	Name	Symbol	Molar mass (g·mol^{-1})	Melting point (°C)	Boiling point (°C)	Density (g·cm^{-3})
3	lithium	Li	6.94	181	1347	0.53
11	sodium	Na	22.99	98	883	0.97
19	potassium	K	39.10	64	774	0.86
37	rubidium	Rb	85.47	39	688	1.53
55	cesium	Cs	132.91	28	678	1.87
87	francium	Fr	(223)	27	677	—

Group 1A: Alkali Metals


(a) **Lithium**


(b) **Sodium**


(c) **Potassium**


(d) **Rubidium**

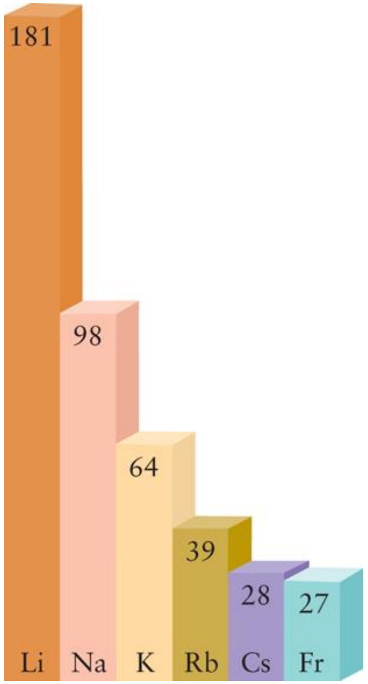
The alkali metals **react most violently** of all metals.

Rubidium and Cesium *must be stored* in sealed, *airless containers*. Francium has *never been isolated* in visible quantities. These *rapidly corrode* in moist air.

Francium is intensely radioactive, and very difficult to study.

Group 1A: Alkali Metals

Forming single valences their bonding is weak, leading to *low* melting points, boiling points, and densities.



Melting
Points (°C)

All alkali metals react directly with most nonmetals except noble gases.

$6\ Li(s) + N_2(g) \rightarrow 2\ Li_3N(s)$

$K(s) + O_2(g) \rightarrow KO_2(s)$

Li, Na, and K

Lithium is used in *ceramics, lubricants, and medicine*. Small daily doses of lithium carbonate are an *effective treatment for bipolar* (manic depressive) disorder. Lithium is found in *soaps, as thickener* in lubricating greases for *high-temperature applications*.

lithium-7 the primary isotope for devices like rechargeable batteries.

NaCl is obtained from the evaporation of brine (salt water). The blue is a dye to help it evaporate faster.

Li, Na, and K

NaOH is an inexpensive starting material for the production of other sodium salts.

NaOH is used to produce solid soaps.

$NaHCO_3$ (sodium bicarbonate), or bicarbonate of soda or baking soda.

HCO_3^- (aq) + HA(aq) → A^- (aq) + H_2O(l) + CO_2 (g)

Baking powder, $Na_2CO_3 \cdot 10\ H_2O$, is added to water to precipitate Mg^{2+} and Ca^{2+} ions.

Ca^{2+} (aq) + CO_3^{-2} (aq) → $CaCO_3$(s)

Li, Na, and K

The principal mineral sources of potassium are Carnallite, $KCl \cdot MgCl_2 \cdot 6H_2O$, and Sylvite, KCl.

Potassium compounds have many similarities to sodium compounds. However, potassium compounds are more expensive than the corresponding sodium compounds. But they have some advantages:

KOH is used to produce liquid soaps.

Potassium nitrate, KNO_3, releases oxygen when heated, in the reaction. It is used to facilitate the ignition of matches.

$$2\,KNO_3(s) \rightarrow 2\,KNO_3(s) + O_2(g)$$

Group 2A: Alkaline Earth Metals

beryllium

magnesium

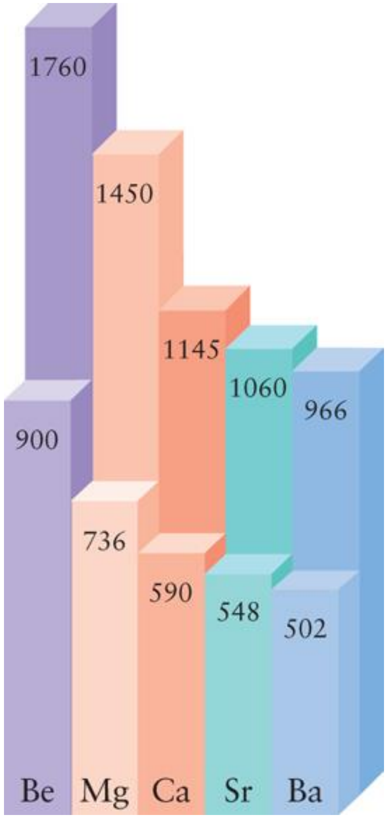
calcium

strontium

barium

The ns^2 valence electron configuration means the second ionization energy is low with a typical +2 oxidation number.

These are very reactive elements, never found in an uncombined state.



1st and 2nd ionization energies

Group 2A: Where to find them

Beryllium is found mainly as beryl, $3BeO \cdot Al_2O_3 \cdot 6SiO_2$, crystals can weigh several tons. Green beryl, Cr^{3+} impurities, are emeralds.

Magnesium occurs in seawater and as the mineral dolomite, $CaCO_3 \cdot MgCO_3$.

Calcium also occurs as $CaCO_3$ in compressed deposits of the sea shells including limestone, calcite, and chalk.

Reactions of Group 2A

Calcium, strontium, and barium are obtained either by electrolysis or by reduction with aluminum in a version of the Thermite process,

$3\ BaO(s) + 2\ Al(s) \xrightarrow{\Delta} Al_2O_3(s) + 3\ Ba(s)$

Except beryllium all group 2 metals react with water to make a basic solution.

$Ca(s) + 2\ H_2O(l) \rightarrow Ca^{2+}(aq) + 2\ OH^-(aq) + H_2(g)$

They react with an acid to produce hydrogen gas in a redox reaction.

$Mg(s) + 2\ H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

Group 2A: Applications

Beryllium atoms have so few electrons, thin sheets of the metal are transparent to x-rays and allow the rays to escape.

Beryllium is added as an **interstitial alloy** to copper giving rigidity to copper. It is also used as a nonsparking tools for use in oil refineries and grain elevators.

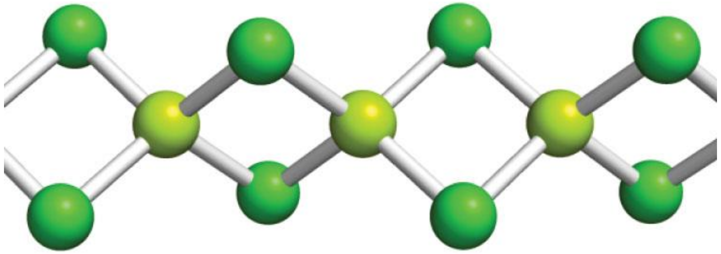
Magnesium has 1/3 the density of aluminum and is very soft. It is used as an alloy for building soda pop cans and aircraft.

Group 2A: Application

Beryllium compounds are **very toxic**.

Be^{2+} ion *highly polarizing* and *small size* limits it to only forming tetrahedral compounds.

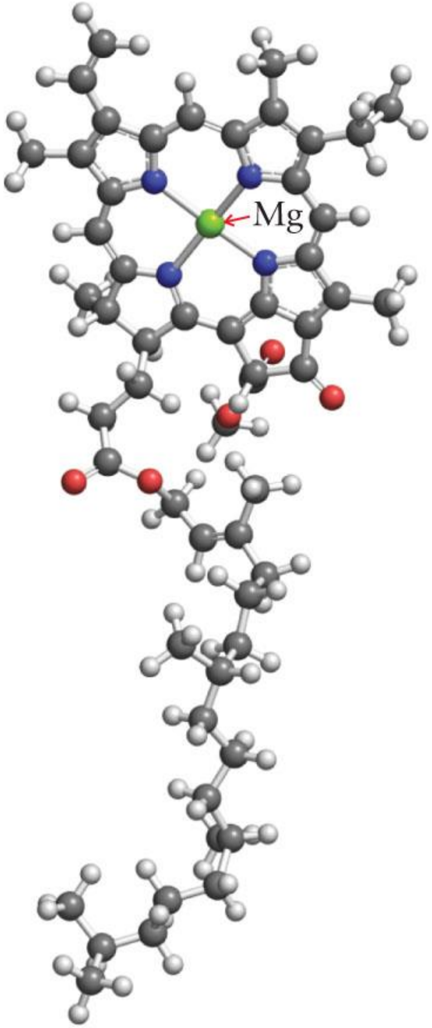
The Be acts as a Lewis acid accepting electron pairs from neighboring atoms forming long chains.



Beryllium chloride, $BeCl_2$

Group 2A: Application

Magnesium's primary role is in **chlorophyll**. This green organic compound captures light from the Sun for photosynthesis.



Chlorophyll

$Mg(OH)_2$, is a base. It is not very soluble in water. Milk of magnesia (a white colloidal suspension of $Mg(OH)_2$) is used as a stomach antacid.

Magnesium is, in effect, the **doorway to life**:

Mg plays a role in *muscle contraction*.

Mg also plays an important role in energy generation in living cells.

$MgSO_4.7H_2O$ (Epsom salts) inhibits the absorption of water from the intestine (because of the doubly charge ion Mg^{2+})

Group 2A: Application

Calcium carbonate decomposes to make **quicklime** when heated:

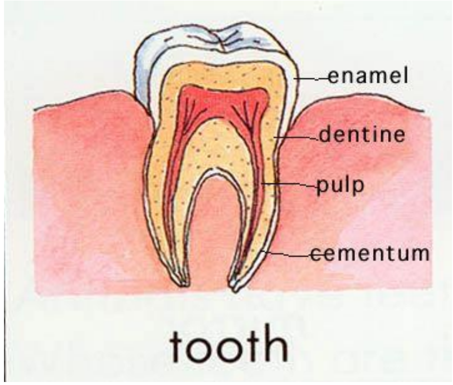
$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

Calcium compounds are often used in ridged structural materials, because of the small, high charged Ca^{2+}.

Concrete filler is a low density material. Concrete binder is cement.

Group 2A: Application

Tooth enamel is a hydroxyapatite, $Ca_5(PO_4)_3OH$.



Tooth decay begins when acids attack the enamel:

$Ca_5(PO_4)_3OH(s) + 4\ H_3O^+\ (aq) \rightarrow 5\ Ca^{2+}\ (aq) + 3\ HPO_4^-\ (aq) + 5\ H_2O(l)$

F^- ions produce a more resistant coating with apatite producing the mineral called fluorapatite:

$Ca_5(PO_4)_3OH(s) + F^-\ (aq) \rightarrow Ca_5(PO_4)_3F(s) + OH^-\ (aq)$

Adding fluoride ions to water supplies (as NaF) is widespread, dramatically decrease tooth cavities.

Fluoridated toothpastes is either tin(II) fluoride or sodium monofluorophosphate (MFP, Na_2FPO_3).

Group 3A: Boron Family

Group 3A elements are not extremely electropositive or electronegative.

B and Al are typically +3, the heavier elements tend to keep their s-electrons (inert pairing effect) so are typically +1.

Physical properties of Group 3A elements.

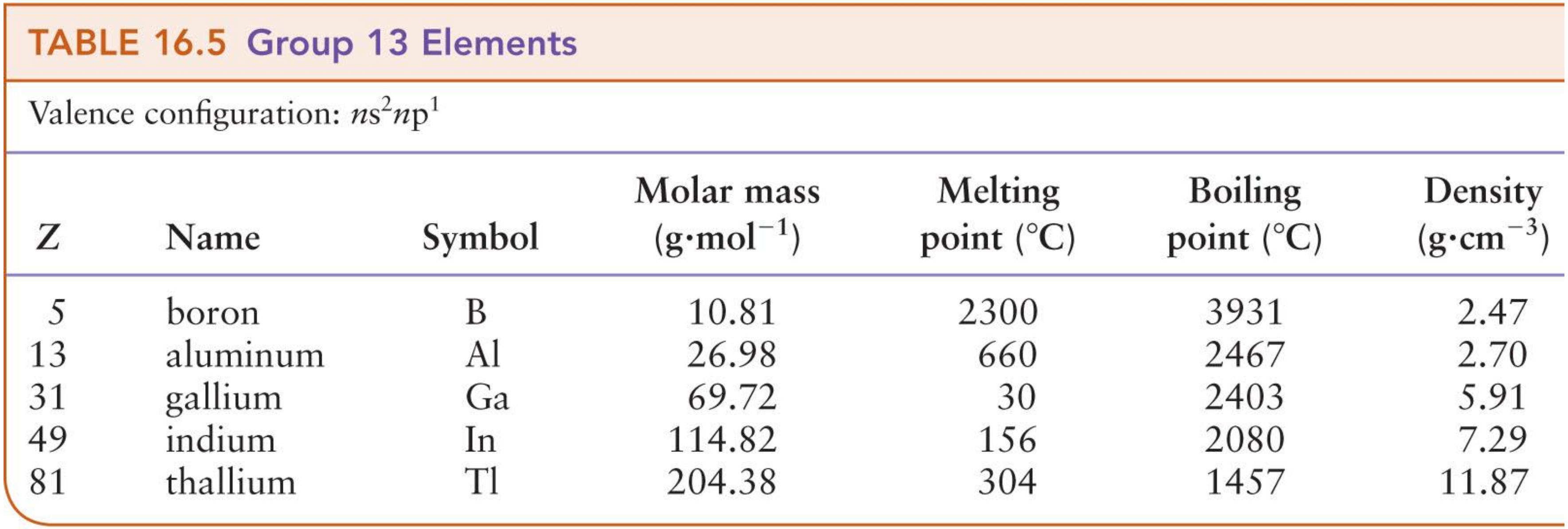


TABLE 16.5 Group 13 Elements

Valence configuration: ns^2np^1

Z	Name	Symbol	Molar mass ($g{\cdot}mol^{-1}$)	Melting point (°C)	Boiling point (°C)	Density ($g{\cdot}cm^{-3}$)
5	boron	B	10.81	2300	3931	2.47
13	aluminum	Al	26.98	660	2467	2.70
31	gallium	Ga	69.72	30	2403	5.91
49	indium	In	114.82	156	2080	7.29
81	thallium	Tl	204.38	304	1457	11.87

Group 3A: Boron Family

Boron forms perhaps the most extraordinary structures of all the elements.

With only 3 valence electrons and a small atomic radii it tends to form only three covalent bonds with an incomplete octet.

Boron is mined in Mojave Desert region of California as borax and kernite,

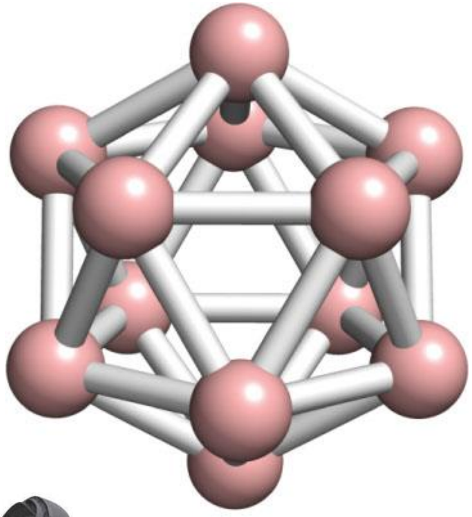
$Na_2B_4O_7 \cdot xH_2O$, with $x = 10$ and 4.

It is converted to an amorphous boron using magnesium.

$$B_2O_3(s) + 3\,Mg(s) \xrightarrow{\Delta} 2\,B(s) + 3\,MgO(s)$$

Group 3A: Boron Family

Boron has many allotropes. The most common an icosahedral (20-faced) clusters of 12 atoms.

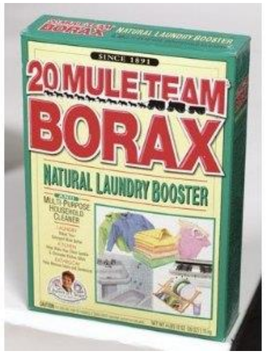


B_{12}

Boron is very hard and is chemically unreactive.

Boron fibers are tough so incorporated into plastics, are stiffer than steel yet lighter than aluminum so found in aircrafts, missiles, and body armor.

Other applications:



Group 3A: Boron Family

Aluminum is the **most abundant metal** in the Earth's crust after oxygen and silicon.

The commercial source of aluminum is **bauxite**, a hydrated oxide, $Al_2O_3 \cdot xH_2O$, where x can range from 1 to 3.

Bauxite ore is processed into alumina, $\mathbf{Al_2O_3}$, by the **Bayer process**. Ore is dissolved in NaOH forming aluminate, $Al(OH)_4^-(aq)$. $CO_2(g)$ is bubbled in to remove OH^- as HCO_3^- forming insoluble $Al(OH)_3(s)$. When heated to 1200°C to dehydrate it, it forms the aluminum oxide.

Group 3A: Boron Family

Aluminum’s low density makes it ideal in airplanes. It is also an excellent electrical conductor so it is mixed with copper and silicon.

It resists corrosion by forming a self-protecting oxide layer that passivated the pure aluminum below.

Boron reacts as a nonmetal, aluminum is more metallic and can react with either an acid or base so is **amphoteric**.

$$2\,Al(s) + 6\,H^{+}(aq) \rightarrow 2\,Al^{3+}(aq) + 3\,H_2(g)$$

$$2\,Al(s) + 2\,OH^{-}(aq) + 6\,H_2O(l) \rightarrow 2\,Al(OH)_4^{-}(aq) + 3\,H_2(g)$$

Group 3A: Boron Family

Alumina is aluminum oxide, Al_2O_3.

α-alumina is very hard, stable and used as an abrasive known as emery.

γ-alumina is less dense found in chromatography.

Ruby, alumina with Cr^{3+}.

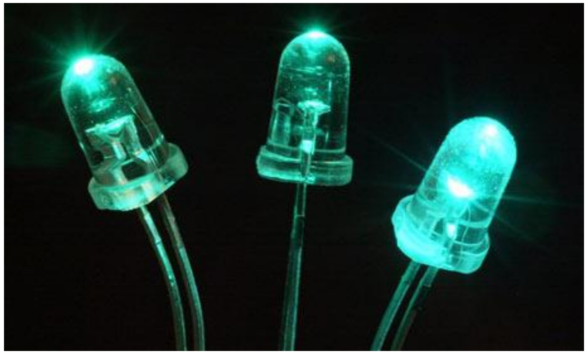
Sapphire, alumina with Fe^{3+} and Ti^{4+}.

Topaz, alumina with Fe^{3+}.

Group 3A: Boron Family

Gallium, is a by-product of the **Bayer process**.

It is a common doping agent for semiconductors as GaAs to make light-emitting diodes.

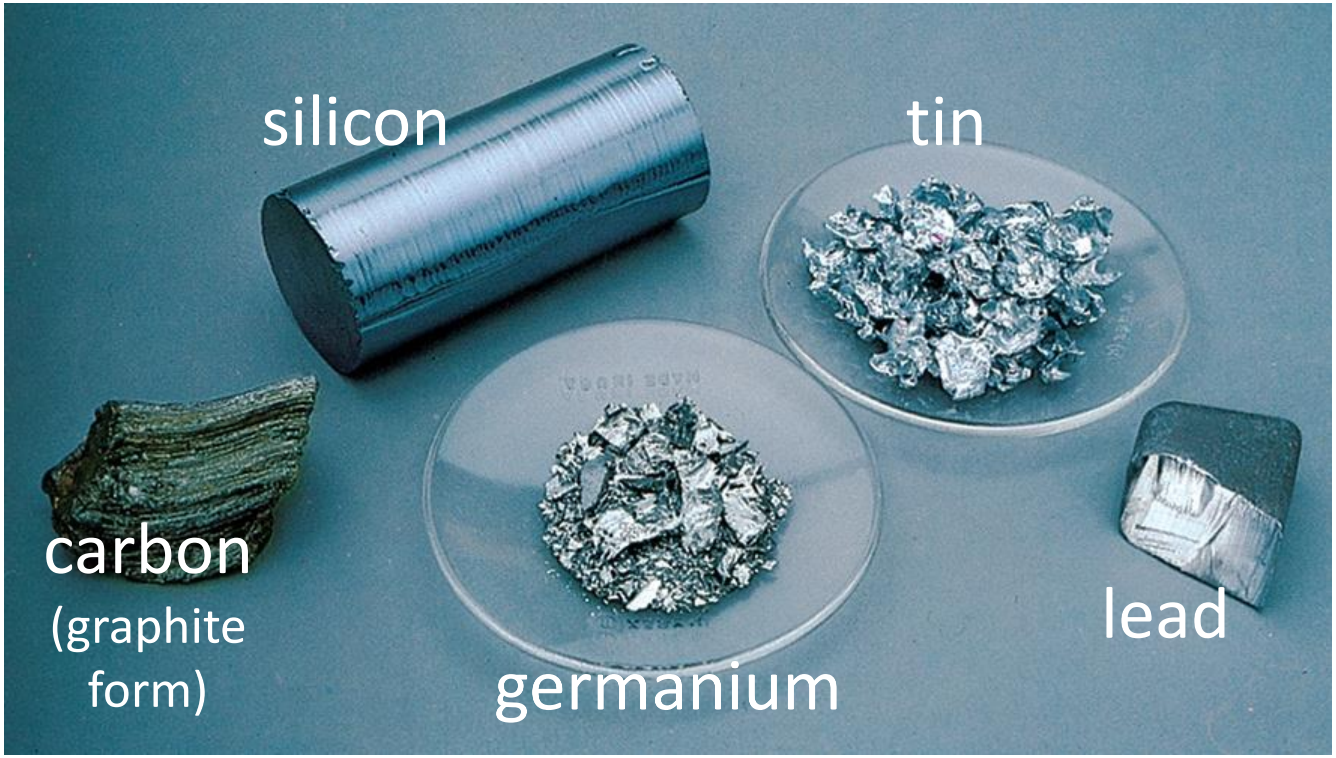


Thallium, at the bottom of Group 3A, is a dangerously poisonous heavy metal used as a rat poison.

Group 4A: Carbon Family

The ns^2np^2 valence electron configuration are why carbon and silicon typically make four-bonds.

Inert-pair effect is common for the heavier elements and why lead is commonly +2 oxidation state.



Group 4A: Carbon Family

Carbon is nonmetallic, forming covalent compounds.

Carbon and silicon oxides are acidic.

The **metallic character** increases down the group.

Germanium is a typical **metalloid**.

Tin and lead have definite metallic properties.

Tin has some **amphoteric properties**.

$Sn(s) + 2\,H_3O^+(aq) \rightarrow Sn^{2+}(aq) + H_2(g) + 2\,H_2O(l)$

$Sn(s) + 2\,OH^-(aq) + 2\,H_2O(l) \rightarrow Sn(OH)_2^{2-}(aq) + H_2(g)$

Group 4A: Carbon Family

Carbon is smaller than silicon so carbon’s p-orbitals get closer together forming π-bonds, C=C and C=O double whereas silicon double bonds are rare.

Carbon forms discrete molecules, O=C=O. Silicon dioxide (silica), forms networks of -O-Si-O- groups.

Silicon is bigger so it expands its valence shells using d-orbitals, and acts as a Lewis acid.

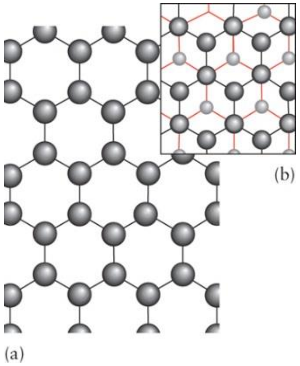
A carbon atom is smaller with no available d-orbitals so it cannot act as Lewis acid.

Group 4A: Carbon Family

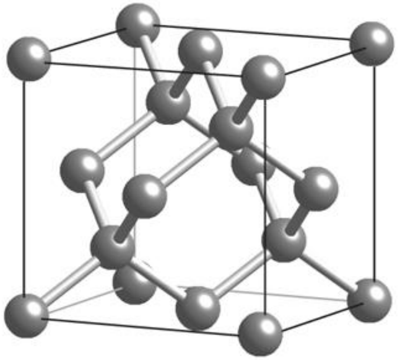
Carbon black, produced by heating *hydrocarbons* 1000°C in the absence of air, is used for reinforcing rubber, for pigments, and for printing inks, such as the ink.

Activated carbon, is produced by heating waste *organic matter* in the absence of air. The very high specific surface area (2000 $m^2 \cdot g^{-1}$) enables it to remove organic impurities from liquids and gases in air purifiers, gas masks, and aquarium water filters as well as water purification plants.

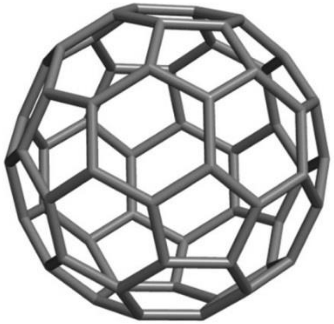
Graphite is the most stable solid allotropes.



graphite



diamond



10 Buckminsterfullerene, C_{60}

fullerenes

Group 4A: Carbon Family

Germanium is mainly used as a semiconductor.

Tin and **lead** are obtained very easily from their ores and have been known since antiquity by the reduction of the mineral cassiterite, SnO_2 and carbon at 1200°C.

$$SnO_2(s) + C(s) \overset{\Delta}{\rightarrow} Sn(l) + CO_2(g)$$

Lead ore is called galena, PbS, and converted to the oxide first then metal.

$$2\ PbS(s) + 3\ O_2(g) \overset{\Delta}{\rightarrow} 2\ PbO(s) + 2\ SO_2(g)$$

$$PbO(s) + C(s) \rightarrow Pb(s) + CO(g)$$

Group 5A: Nitrogen Family

The chemical and physical properties *vary sharply* in this group. N_2 is inert in air, phosphorus ignites in air, and arsenic, antimony and bismuth are used in semiconductors.

Oxidation states range from -3 to +5.

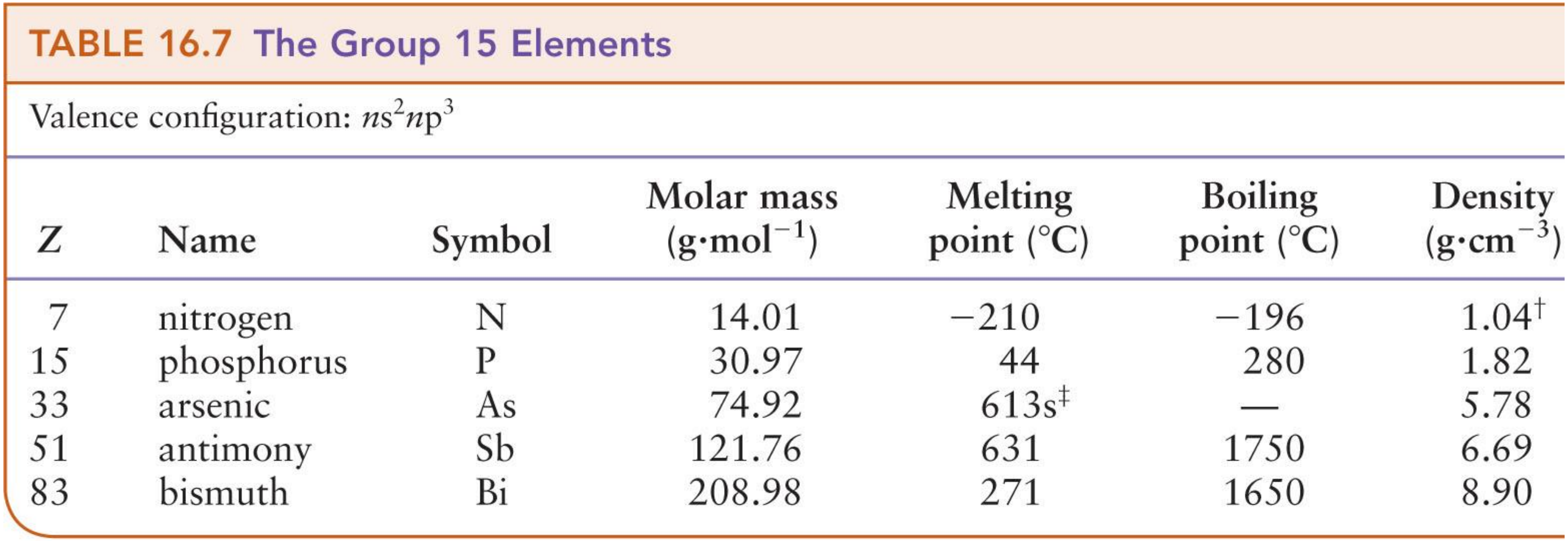


TABLE 16.7 The Group 15 Elements

Valence configuration: ns^2np^3

Z	Name	Symbol	Molar mass ($g \cdot mol^{-1}$)	Melting point (°C)	Boiling point (°C)	Density ($g \cdot cm^{-3}$)
7	nitrogen	N	14.01	−210	−196	1.04[†]
15	phosphorus	P	30.97	44	280	1.82
33	arsenic	As	74.92	613s[‡]	—	5.78
51	antimony	Sb	121.76	631	1750	6.69
83	bismuth	Bi	208.98	271	1650	8.90

Group 5A: Nitrogen Family

Nitrogen is rare in the Earth's crust, but elemental nitrogen is 76% by mass in our atmosphere.

Pure nitrogen gas (N_2) is obtained by the fractional distillation of liquid air. Air is cooled to below -196°C by repeated expansion and compression in a refrigerator.

The liquid is then warmed, and the nitrogen (b.p. -196°C) boils off while most of the argon (b.p. -186°C) and oxygen (b.p. -183°C) remain liquid.

Nitrogen gas's primary use is as a raw material for the synthesis of ammonia in the Haber process.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Group 5A: Nitrogen Family

Nitrogen, is **highly electronegative**, χ = 3.0, the same as chlorine, but smaller so capable of hydrogen-bonding.

Nitrogen's **small size** and lack of any available d-orbitals means the p-orbitals can overlap, *making π-bonds possible*.

Phosphorus, is significantly different from nitrogen. It is nearly **50% larger** than nitrogen, too big for π-bonding.

However it's large size and **availability of d-orbitals** means it can form as many as six bonds (PCl_6^-), nitrogen only four.

Phosphorus is obtained from apatite, a mineral of calcium phosphate, $Ca_3(PO_4)_2$:

$$2\ Ca_3(PO_4)_2(s) + 6\ SiO_2(s) + 10\ C(s) \xrightarrow{\Delta} P_4(g) + 6\ Ca_3(PO_4)_2(l) + 10\ CO(g)$$

Group 5A: Nitrogen Family

Sodium azide, NaN_3, like most azide salts, is shock sensitive. It is used in **automobile air bags**:

$$2\ NaN_3(s) \rightarrow 2\ Na(s) + 3\ N_2(g)$$

Hydrazine, NH_2NH_2, is prepared by the gentle oxidation of ammonia with alkaline hypochlorite solution:

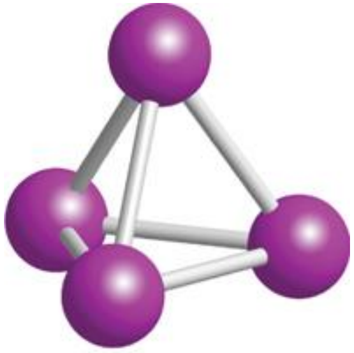
$$2\ NH_3(aq) + ClO^-(aq) \rightarrow NH_2NH_2(aq) + Cl^-(aq) + H_2O(l)$$

It is dangerously explosive and is stored and used in aqueous solution. Hydrazine is used as a rocket fuel.

Group 5A: Nitrogen Family

White phosphorus, a soft, white, poisonous molecular solid.

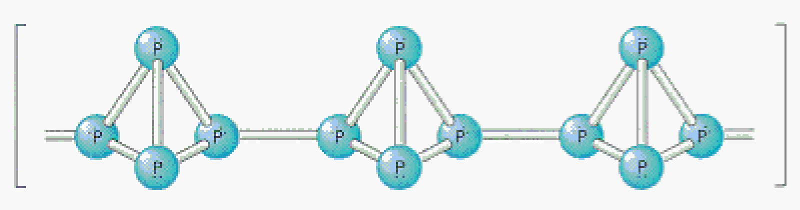
tetrahedral



Phosphorus, P_4

This allotrope is highly reactive with strained 60° bond angles. It is very dangerous, it bursts into flame on contact with air and normally stored under water.

Red phosphorus is less reactive allotrope, and is only *ignited by friction*, so used on the *surfaces* of matchbooks, thought to consist of linked-P_4-chains.



Red Phosphorous

Group 5A: Nitrogen Family

H_3PO_4, phosphoric acid primary use is for fertilizers, food additives, and in detergents.

Many soft drinks owe their tart taste to low concentrations of phosphoric acid.

Arsenic and **antimony** are metalloids; known since antiquity. Their main use is in the semiconductor industry.

Group 6A: Oxygen Family

Oxygen is the most abundant element in the Earth's crust, and oxygen we breathe, O_2, for 23% of atmospheres mass.

The combustion of all living organisms in oxygen is thermodynamically spontaneous; however the high activation energy is why we don’t spontaneously combust and we do not burst into flame at normal temperature.

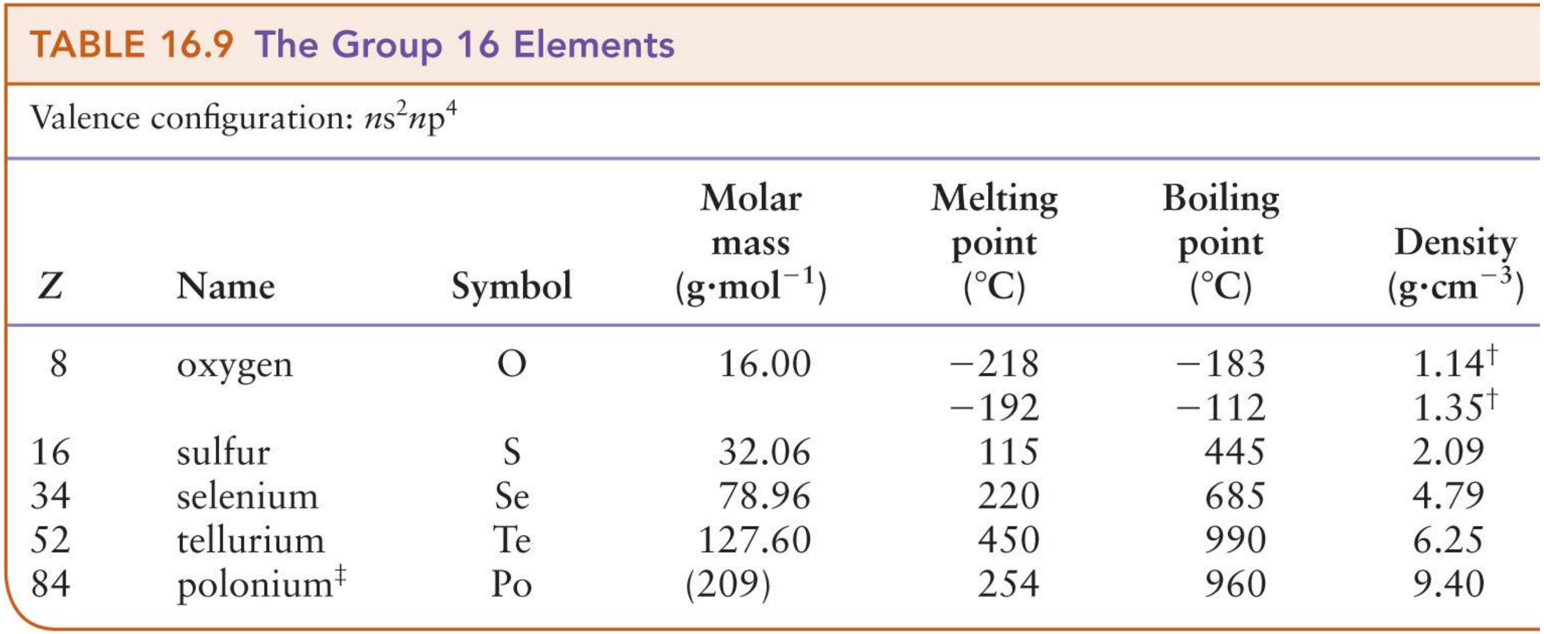


TABLE 16.9 The Group 16 Elements

Valence configuration: ns^2np^4

Z	Name	Symbol	Molar mass ($g \cdot mol^{-1}$)	Melting point (°C)	Boiling point (°C)	Density ($g \cdot cm^{-3}$)
8	oxygen	O	16.00	−218 −192	−183 −112	1.14† 1.35†
16	sulfur	S	32.06	115	445	2.09
34	selenium	Se	78.96	220	685	4.79
52	tellurium	Te	127.60	450	990	6.25
84	polonium‡	Po	(209)	254	960	9.40

Group 6A: Oxygen Family

Oxygen, O_2, is a colorless, tasteless, odorless gas; condenses as a pale-blue liquid at -183°C.

2 × 10^{10} kg of liquid oxygen is produced each year in the US (80 kg per person) by fractional distillation of liquid air.

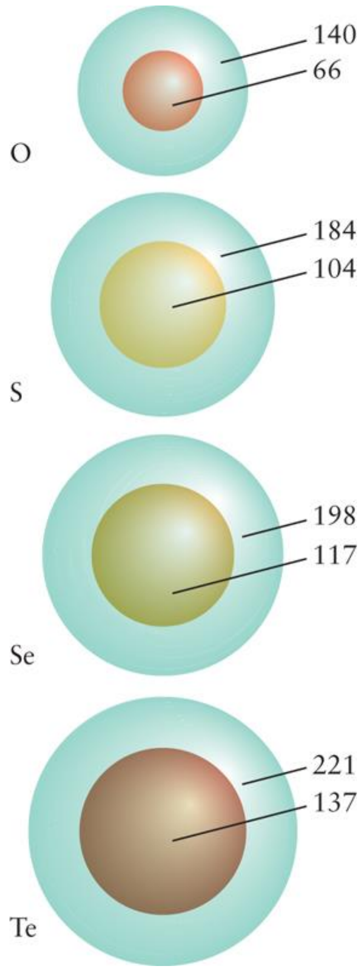
The biggest consumer is the steel industry, where 1t of oxygen (1t = 10^3 kg) produces 1t of steel.

An allotrope of oxygen, ozone, O_3. Formed in the stratosphere by the solar bombardment on O_2 molecules. Its total atmospheric abundance is equivalent to a layer 3 mm (at 25ºC and 1 atm), yet vital to life on Earth.

$$O + O_2 \rightarrow O_3$$

Its pungent smell can often be detected near electrical equipment and after lightning.

Group 6A: Oxygen Family

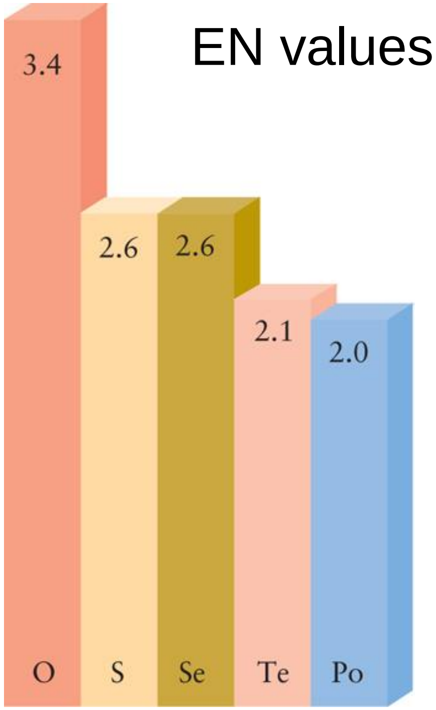


Electronegativities (EN) decrease and atomic and ionic radii increase down the group.

Sulfur is to larger to form π-bonds, and large enough to extend the octet with it's empty d-orbitals.

Sulfur is not very polar (EN=2.6) so will not hydrogen bond; so H_2S is a gas, and H_2O is a liquid at room temperature.

EN values



Group 6A: Oxygen Family

Sulfur is commonly found in petroleum.

One method for **removing H_2S** from petroleum and natural gas is the **Claus process**, H_2S is first oxidized to sulfur dioxide:

$$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ SO_2(g) + 2\ H_2O(l)$$

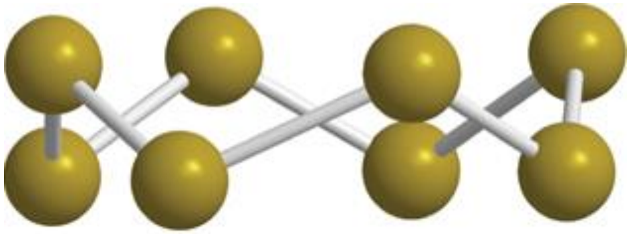
Then SO_2 oxidizes the remainder of hydrogen sulfide:

$$2\ H_2S\ (g) + SO_2\ (g) \xrightarrow{300℃,\ Al_2O_3} 3\ S(s) + 2\ H_2O\ (l)$$

Group 6A: Oxygen Family

Sulfur has a striking ability to catenate, or form chains of atoms. Whereas, oxygen's is limited to H_2O_2, O_3, and the anions O_2^-, O_3^{2-}, and O_3^{-2}.

Sulfur's S_8 rings form long strands of "plastic sulfur" when sulfur is heated to about 200°C and suddenly cooled.



The -S-S- link found in amino acids of proteins, the keratin of our hair, and helps keep us alive and is responsible for curly hair.

Group 6A: Oxygen Family

The **contact process** burns sulfur in oxygen, then using a vanadium (V) oxide catalyst to a make SO_3:

$S(s) + O_2(g) \xrightarrow{1000℃} SO_2(g)$

$SO_2(g) + 2\ H_2O(g) \rightarrow H_2SO_3(aq)$ Sulfurous acid

$2\ SO_2(g) + O_2(g) \xrightarrow{500℃, V_2O_5} 2\ SO_3(g)$

SO_3 transforms into **oleum**, a dense oily liquid; an easier form to transport (sulfuric acid is so corrosive);

$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(g)$ (**98% oleum**)

When need, it is added to water to make sulfuric acid

$H_2S_2O_7(g) + H_2O(l) \rightarrow H_2SO_4(l)$

Group 6A: Oxygen Family

Sulfuric acid, H_2SO_4, is the ***most heavily produced*** inorganic chemical worldwide, the annual production in the United States alone being more than 4 × 10^{10} kg.

The low cost of sulfuric acid production leads to its widespread use for the production of fertilizers, petrochemicals, dyestuffs, and detergents.

About two thirds is used to manufacture phosphate and ammonium sulfate fertilizers.

H_2SO_4, is a very strong acid, and even it's conjugate base HSO_4^- has a pK_a of 1.92, which is a strong acid.

Group 7A: Halogens

All halogens are diatomic from F_2 through I_2. Fluorine always gains one electron, yet the others have oxidation numbers between -1 to +7.

The chemical and physical trends are consistent (unlike Groups 5A and 6A). London forces dominate these elements.

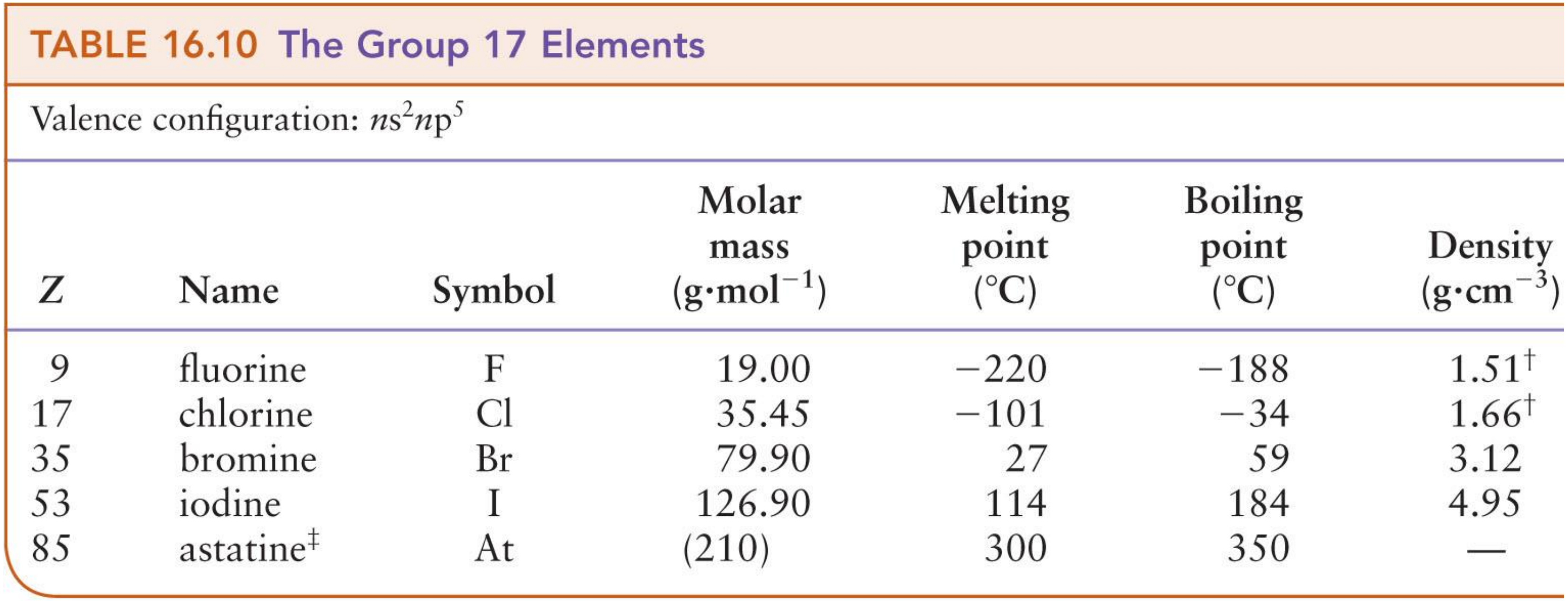
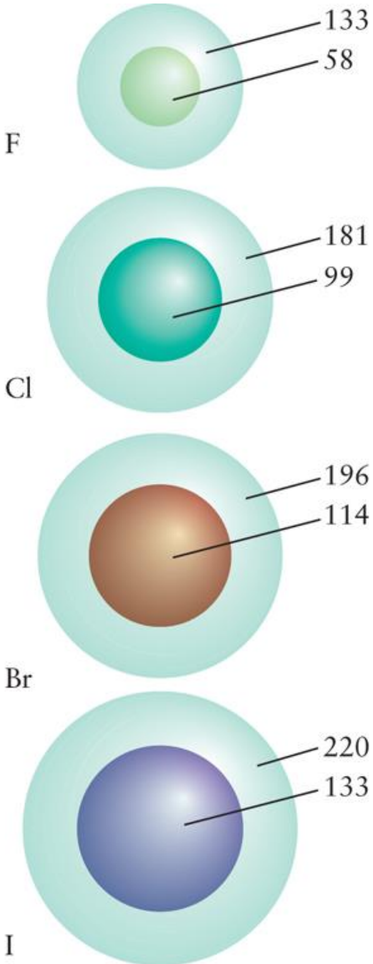


TABLE 16.10 The Group 17 Elements

Valence configuration: ns^2np^5

Z	Name	Symbol	Molar mass $(g \cdot mol^{-1})$	Melting point (°C)	Boiling point (°C)	Density $(g \cdot cm^{-3})$
9	fluorine	F	19.00	−220	−188	1.51†
17	chlorine	Cl	35.45	−101	−34	1.66†
35	bromine	Br	79.90	27	59	3.12
53	iodine	I	126.90	114	184	4.95
85	astatine‡	At	(210)	300	350	—

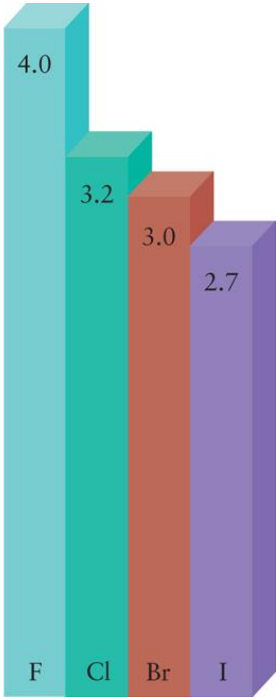
Group 7A: Halogens



Fluorine, is the most abundant halogen in Earth's crust.

Because fluorine is the most strongly oxidizing element (E°= +2.87 V), it cannot be obtained by oxidation of another element.

EN values



Fluorine is produced by electrolyzing molten KF and HF at about 75°C with a carbon anode.

Group 7A: Halogens

Fluorine is a reactive, almost colorless gas of F_2 molecules.

Most of the fluorine is used to make volatile **solid UF_6** for processing nuclear fuel. The rest is used for producing **SF_6** for electrical equipment.

Fluorine is **small** and has a **high effective nuclear charge**. Therefore, it’s ***lattice energies*** are **high**, therefore, it’ ***solubility’s*** are **low**. Low **solubility's** is why the *oceans are primarily chloride*.

An exception being AgF, it is soluble because the molecule is completely ionic, whereas AgI is polarizable and not soluble.

Group 7A: Halogens

Chlorine is one of the most heavily manufactured chemicals.

It is obtained from sodium chloride by electrolysis of molten rock salt or brine.

It is a pale yellow-green gas.

It reacts directly with nearly all the elements (except for carbon, nitrogen, oxygen, and the noble gases).

Chlorine is used to manufacture of plastics, solvents, and pesticides.

Bleach (NaClO) is added to paper, textiles and a disinfectant in water treatment.

Group 7A: Halogens

Bromine is a corrosive, red-brown fuming liquid of Br_2 molecules that has a penetrating odor.

Bromine is used widely in synthetic organic chemistry.

Organic bromides are incorporated into textiles as fire retardants and are used as pesticides; inorganic bromides, particularly silver bromide, are used in photographic emulsions.

Group 7A: Halogens

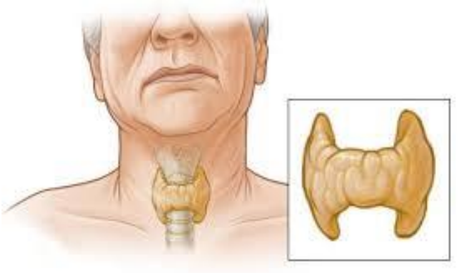
Iodine occurs as iodide ions in brines and as an impurity in Chile saltpeter ($NaNO_3$). It was once obtained from seaweed, 2000 kg of seaweed produce about 1 kg of iodine.

The best modern source is the brine from oil wells.

Elemental iodine is produced by oxidation with chlorine:

$$2\,I^-(aq) + Cl_2(g) \rightarrow I_2(l) + 2\,Cl^-(aq) \qquad \Delta G^\circ = -54.54\ \text{kJ}$$

I_2 is slightly soluble in water, more so in ethanol. It is used as an antiseptic, living organisms need trace amounts for the thyroid gland, the reason for buying “iodized salt.”



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Astatine is radioactive, occurs with heavy elements like uranium.

Group 8A: Noble Gases

Noble gases get their group name from their very low reactivity. It is believed their closed-shell electron configurations (ns^2np^6) is the reason for their chemical inertness.

All the Group 8A elements occur in the atmosphere as a gas; together they make up about 1% of its mass.

Argon is the third most abundant gas in the atmosphere after nitrogen and oxygen.

Helium, the second most abundant element in the universe after hydrogen. It is rare on Earth because it is so light that they easily reach high speeds and escape from the atmosphere.

Group 8A: Noble Gases

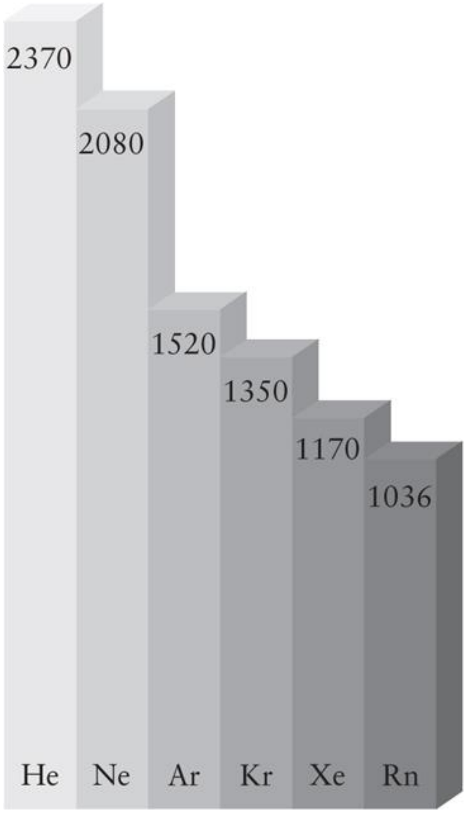
The ionization energies of the noble gases are very high.

Xenon's ionization energy is low enough to very electronegative elements.

Xenon difluoride, XeF_2, and xenon tetrafluoride, XeF_4, are made by heating the elements to 400°C at 6 atm.

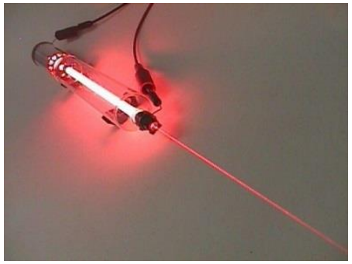
No compounds of helium, neon, and argon exist, except under very special conditions, for below -50°C for Kr-N.

ionization energy



Group 8A: Noble Gases

Helium has a low density, and is nonflammable so it used to dilute oxygen for use in hospitals and in deep-sea diving, to pressurize rocket fuels, as a coolant, and in helium-neon lasers.



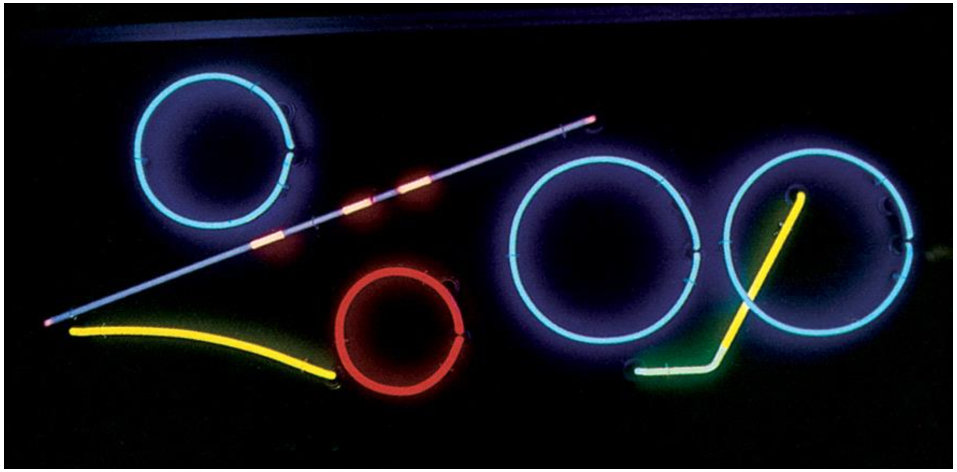
Neon, emits an orange-red glow when an electric current flows through it, so used in advertising signs and displays.

Argon is used to provide an inert atmosphere for welding (to prevent oxidation) and to fill some types of light bulbs.

Group 8A: Noble Gases

Krypton gives an intense white light when electrically excited. Krypton is a nuclear fission by-product; a way measure worldwide nuclear activity.

Xenon is used in halogen lamps, high-speed photographic flash tubes and being investigated as an anesthetic.



Red = neon
Blue = argon

Yellow is a phosphors material.