Chapter 18: The Representative Elements

- Hydrogen
- Group 1A
- Group 2A
- Group 3A
- Group 4A
- Group 5A
- Group 6A
- Group 7A
- Group 8A

Big Idea: The structure of atoms determines their properties; consequently, the behavior of elements is related to their location in the periodic table. In general nonmetallic character becomes more pronounced toward the right of the periodic table.

The Representative Elements

TABLE 18.1

Distribution (Mass Percent) of the 18 Most Abundant Elements in the Earth's Crust, Oceans, and Atmosphere

Element	Mass Percent	Element	Mass Percent
Oxygen	49.2	Chlorine	0.19
Silicon	25.7	Phosphorus	0.11
Aluminum	7.50	Manganese	0.09
Iron	4.71	Carbon	0.08
Calcium	3.39	Sulfur	0.06
Sodium	2.63	Barium	0.04
Potassium	2.40	Nitrogen	0.03
Magnesium	1.93	Fluorine	0.03
Hydrogen	0.87	All others	0.49
Titanium	0.58		

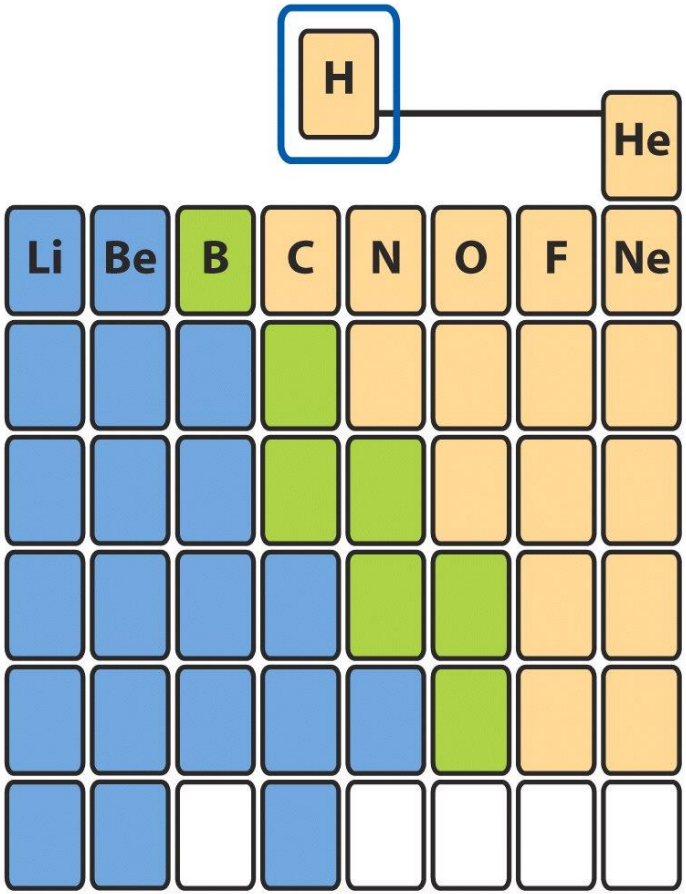
The Representative Elements

TABLE 18.2

Abundance of Elements in the Human Body

Major Elements	Mass Percent	Trace Elements (in alphabetical order)
Oxygen	65.0	Arsenic
Carbon	18.0	Chromium
Hydrogen	10.0	Cobalt
Nitrogen	3.0	Copper
Calcium	1.4	Fluorine
Phosphorus	1.0	Iodine
Magnesium	0.50	Manganese
Potassium	0.34	Molybdenum
Sulfur	0.26	Nickel
Sodium	0.14	Selenium
Chlorine	0.14	Silicon
Iron	0.004	Vanadium
Zinc	0.003	

Hydrogen



- Electron configuration is $1s^1$ (similar to the electron configurations of group 1A elements)
- Classified as a non metal
- Therefore it doesn't fit into any group

Hydrogen

TABLE 14.1 Physical Properties of Hydrogen

Valence configuration: $1s^1$
Normal form:* colorless, odorless gas

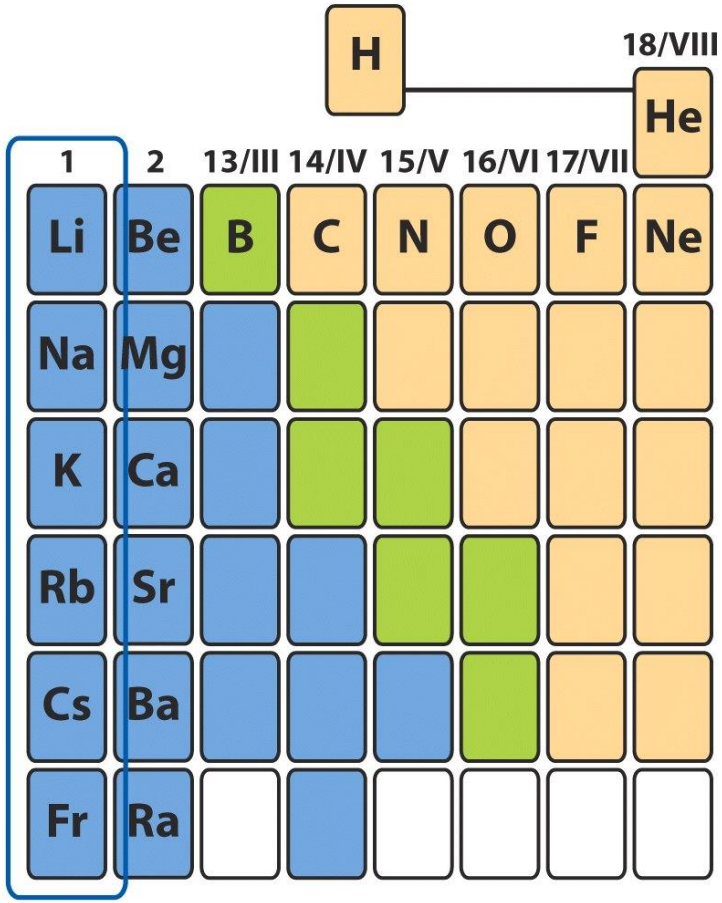
Z	Name	Symbol	Molar mass ($g \cdot mol^{-1}$)	Abundance (%)	Melting point (°C)	Boiling point (°C)	Density ($g \cdot L^{-1}$)†
1	hydrogen	H	1.008	99.98	−259 (14 K)	−253 (20 K)	0.089
1	deuterium	^{2}H or D	2.014	0.02	−254 (19 K)	−249 (24 K)	0.18
1	tritium	^{3}H or T	3.016	radioactive	−252 (21 K)	−248 (25 K)	0.27

**Normal form* means the state and appearance of the element at 25°C and 1 atm.
†The density refers to the same conditions.

- Most H is made up of only two particles (an electron and a proton)
- H is the most abundant element in the universe and accounts for 89% of all atoms
- Little free H on earth
- H_2 gas is so light that it moves very fast and can escape the Earth's gravitational pull
- Need heavier planets to confine H_2

Group 1A

The Alkali Metals

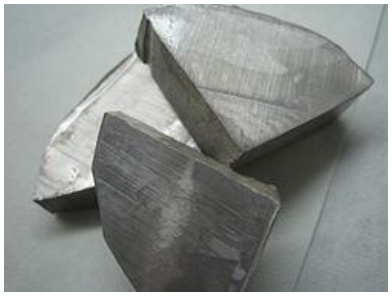


- Electron configuration is ns^1 (n = period number).
- Lose their valence e^- easily (great reducing agents).
- Most violently reactive of all the metals.
- React strongly with $H_2O(l)$; the vigor of the reaction increases down the group.
- The alkali metals are all too easily oxidized to be found in their free state in nature.

Group 1A

Lithium

- Strong polarizing power
- Forms bonds with highly covalent character
- Used in ceramics, Lubricants, Medicine (lithium carbonate (treatment for bipolar disorder))



Sodium

- Mined as rock salt which is a deposit of sodium chloride left as ancient oceans evaporated
- Extracted using electrolysis of molten NaCl (Downs process)

Group 1A

Important Group

- NaCl
- NaOH
- $NaHCO_3$ (Baking Soda)
  - $HCO_3^-(aq) + HA(aq) \rightarrow A^-(g) + H_2O(l) + CO_2(g)$
  - The weak acid (HA) must be present in the dough; Some weak acids are sour milk, buttermilk, lemon jucie, or vinegar.

Note: Baking powder contains a solid weak acid as well as the hydrogen carbonate therefore $CO_2(g)$ is released when water is added

- KNO_3
  - $2KNO_3(s) \xrightarrow{\Delta} 2KNO_2(s) + O_2(g)$

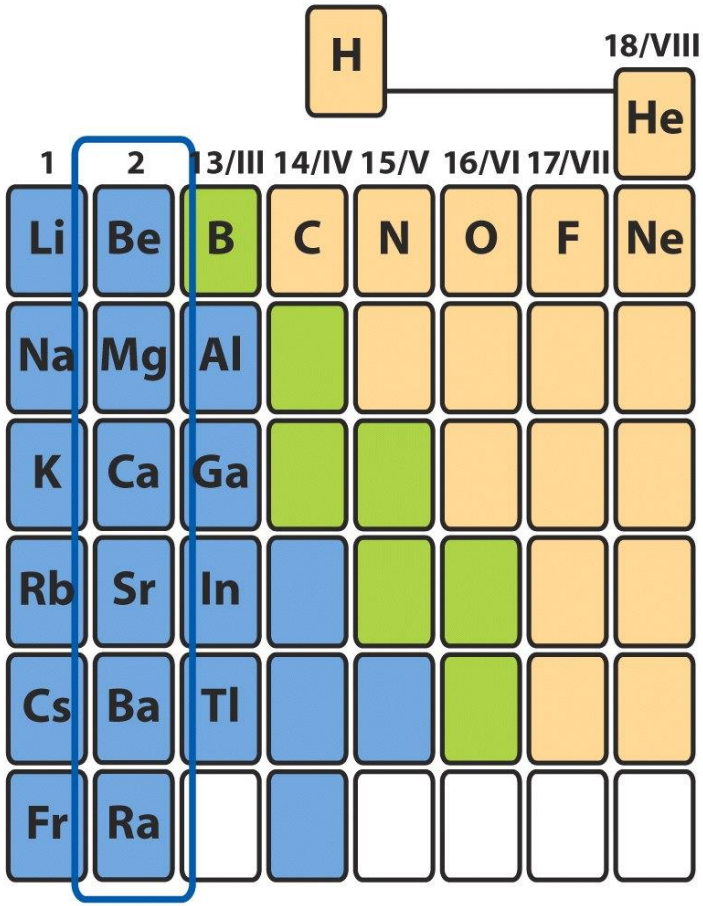
Group 1A

Common Reactions

- Reaction with **Halogens**
  - $2M + X_2 \rightarrow 2MX$
    X_2 is any halogen
- Reactions with **Oxygen**
  - $4Li + O_2 \rightarrow 2Li_2O$
    Need excess Oxygen
  - $2Na + O_2 \rightarrow Na_2O_2$
  - $M + O_2 \rightarrow MO_2$
    M = K, Rb, or Cs
- Reaction with **H**
  - $2M + H_2 \rightarrow 2MH$
- Reaction with **N**
  - $6Li + N_2 \rightarrow 2Li_3N$
    Li only
- Reaction with **Water**
  - $2M + 2H_2O \rightarrow 2MOH + H_2$
- Reaction with **Ions**
  - $2M + 2H^+ \rightarrow 2M+ + H_2$

Group 2A

The Alkaline Earth Metals



- Electron configuration is ns^2(n is the period number).
- All group 2 element are too reactive to occur in the uncombined state in nature.
- Usually found as doubly charged cations.
- All group 2 elements except for beryllium react with water and the vigor of the reaction increases going down the group.

Group 2A

Beryllium

- Has some non metal tendencies
- The gemstone emerald contains Be but its green color is caused by Cr^{3+} ions
- Obtained by the electrolytic reduction of molten beryllium chloride

Magnesium

- Found in sea water
- Mg is present in the chlorophyll molecule
- Forms protective oxide
- Obtained by either chemical or electrolytic reduction of its compounds

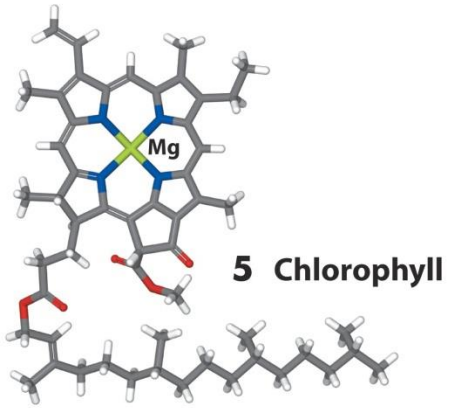
Calcium

- Found in sea water
- The element of rigidity and construction (bones, shells, concrete, mortar, limestone (buildings)…)

Group 2A

Important Compounds

- $Mg(OH)_2$ (milk of magnesia)
- $MgSO_4$ (epsom salt)
- Chlorophyll
- $CaCO_3$ (calcium carbonate)
  - $CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$
- CaO (quick lime)
  - $CaO(s) + H_2O(l) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$
- $Ca(OH)_2$ (slack lime)
- Concrete



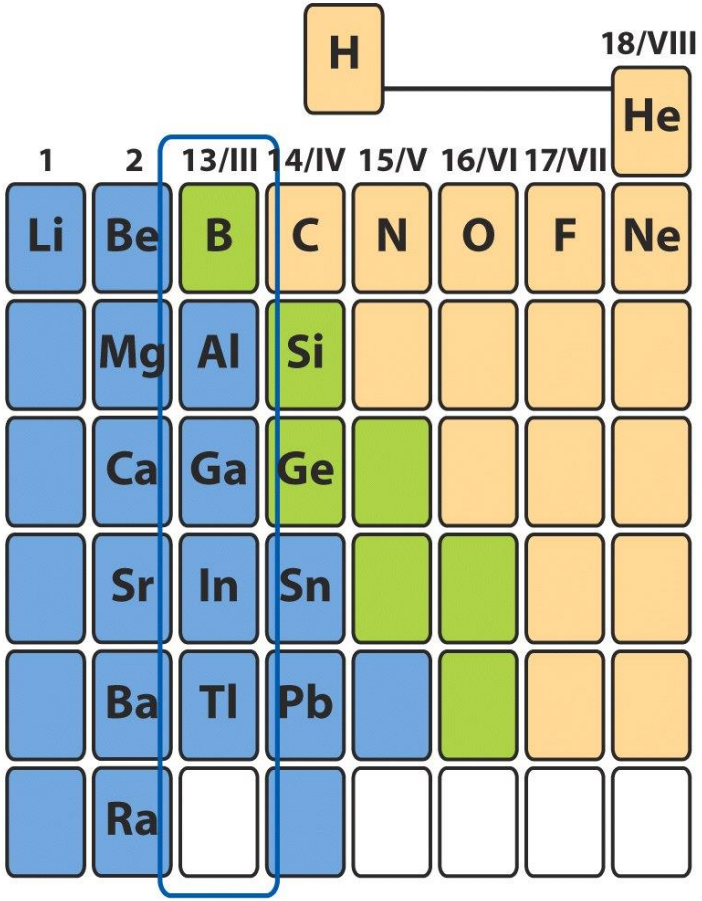
5 Chlorophyll

Group 2A

Common Reactions

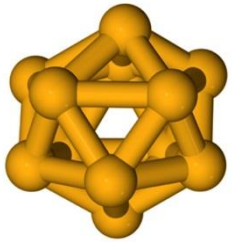
- Reaction with **Halogens**
  - $M + X_2 \rightarrow MX_2$
    X_2 is any halogen
- Reaction with **Oxygen**
  - $2M + O_2 \rightarrow 2MO$
- Reaction with **H**
  - $M + H_2 \rightarrow MH_2$
- Reaction with **N**
  - $3M + N_2 \rightarrow M_3N_2$
    High temperatures
- Reaction with **Water**
  - $M + 2H_2O \rightarrow M(OH)_2 + H_2$
- Reaction with **Ions**
  - $M + 2H^+ \rightarrow M^{2+} + H_2$

Group 3A



- Electron configuration is ns^2np^1 (n is the period number).
- Boron and aluminum almost always have an oxidation number of +3.
- The heavier elements of the group are more likely to keep their s electrons and can have oxidation numbers of +1 or +3.

Group 3A



$6\ B_{12}$

Boron

- High ionization energy
- Metalloid
- Forms covalent bonds
- Tends to form compounds that have incomplete octets or are electron deficient
- Mined as borax and kernite ($Na_2B_4O_7 \cdot xH_2O$ x = 10 or 4)

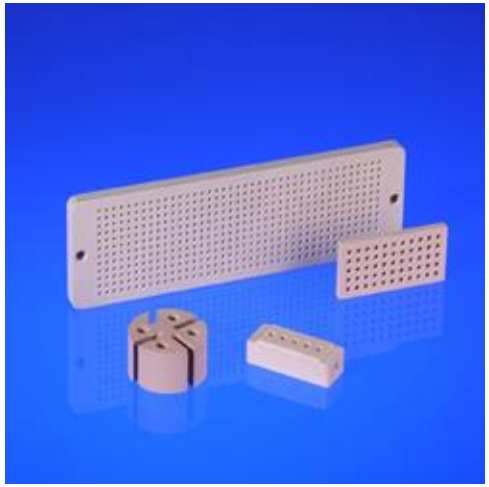
Aluminum

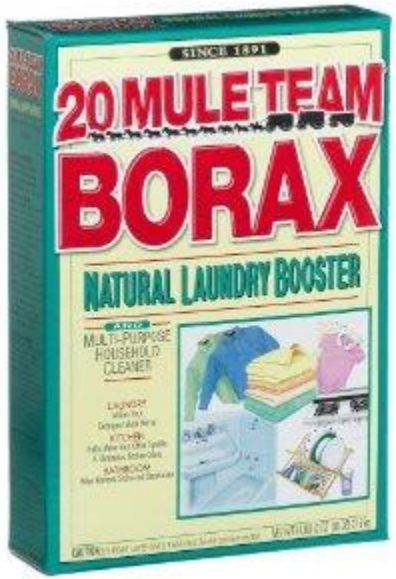
- Most abundant metallic element in the Earth's crust
- Low density
- Excellent electrical conductor
- Commercial source of aluminum is bauxite ($Al_2O_3 \cdot xH_2O$ where x ranges from 1 to 3)

Group 3A

Important Compounds

- $B(OH)_3$ (Boric Acid)
- $Na_2B_4O_7 \cdot 10H_2O$ (borax)
- Al_2O_3 (Aluminum oxide or alumina)



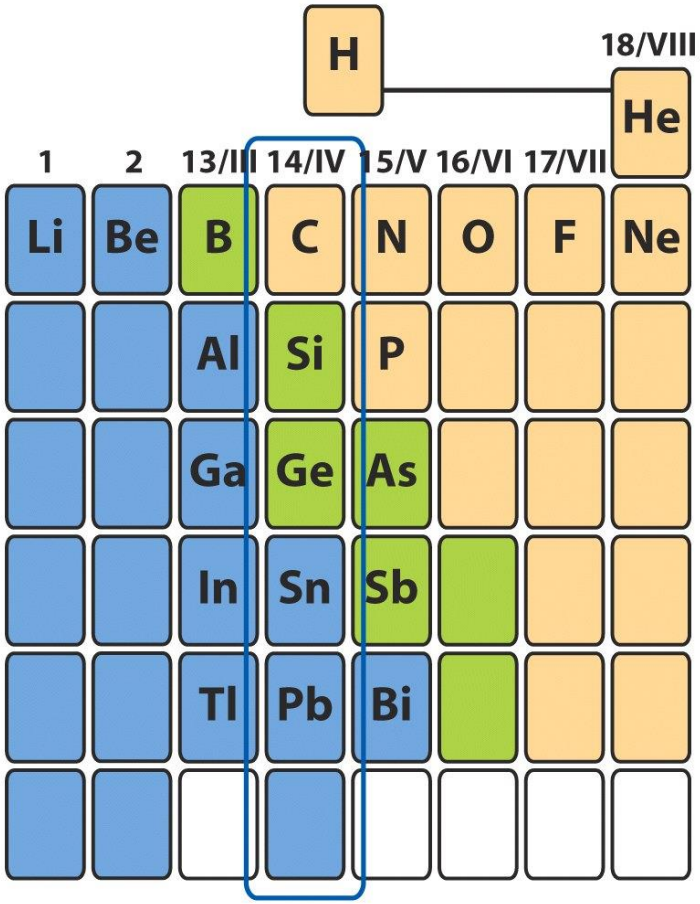


Group 3A

Common Reactions

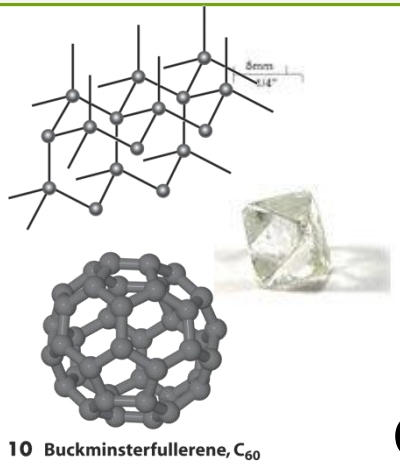
- Reaction with **Halogens**
  - $2M + 3X_2 \rightarrow 2MX_3$
    X_2 any halogen, TI gives as TIX well, but no TIl_3
- Reactions with **O**
  - $4M + 3O_2 \rightarrow 2M_2O_3$
- Reactions with **N**
  - $2M + N_2 \rightarrow 2MN$
- Reactions with **ions**
  - $2M + 6H^+ \rightarrow 2M^{3+} + 3H_2$
  - $2M + 2OH^- + 6H_2O \rightarrow 2M(OH)_4^- + 3H_2$

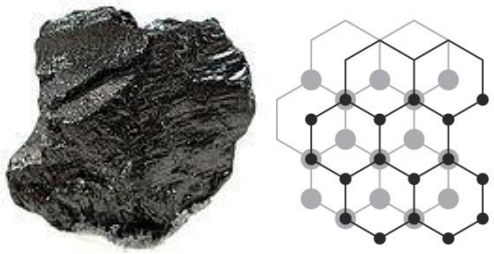
Group 4A

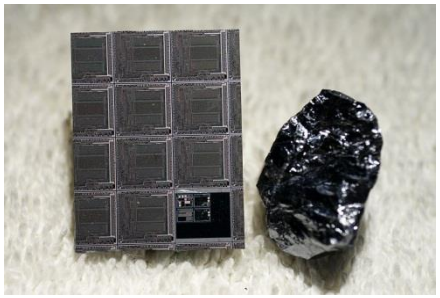


- Electron configuration is ns^2np^2 (n is the period number).
- The half filled orbital allows this group to straddle between metal and non metal.
- The heavier elements of the group are more likely to keep their s electrons and can have oxidation numbers of +2 or +4.

Group 4A







Carbon

- Central element to life
- Nonmetallic properties
- Forms Covalent bonds with nonmetals and ionic bonds with metals
- Small radius allows for the wide occurrence of C=C and C=O bonds in compounds

Silicon

- Central element to electronic technology and artificial intelligences.
- Larger atomic size than C which results in relatively few compounds that have Si=Si and Si=O bonds.

Group 4A

Germanium

- Germanium is recovered from the flue dust of industrial plants processing zinc ores.
- Germanium is mainly used in the semiconductor industry.

Tin

- Tin is easily obtained from it ore (cassiterite (SnO_2)) by reduction with carbon.
- Tin is expensive and not very strong but it is resistant to corrosion.

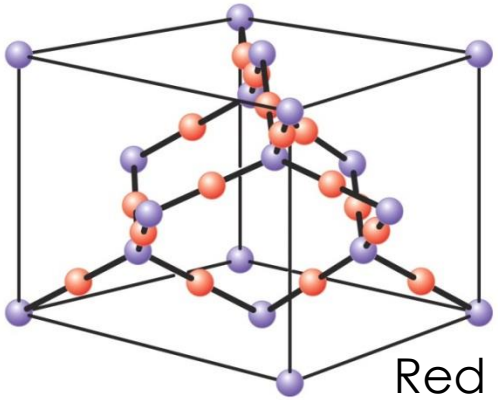
Lead

- Lead is durable and malleable which makes it useful in the construction industry
- It is very dense which makes it ideal as radiation shields from x rays

Group 4A

Important Compounds

- CO_2
- CO
- SiO_2 (Silica)
- ZnSiO4 (Zircon)
- $CaMg_5(Si_4O_{11})_2(OH)_2$
- Silicones



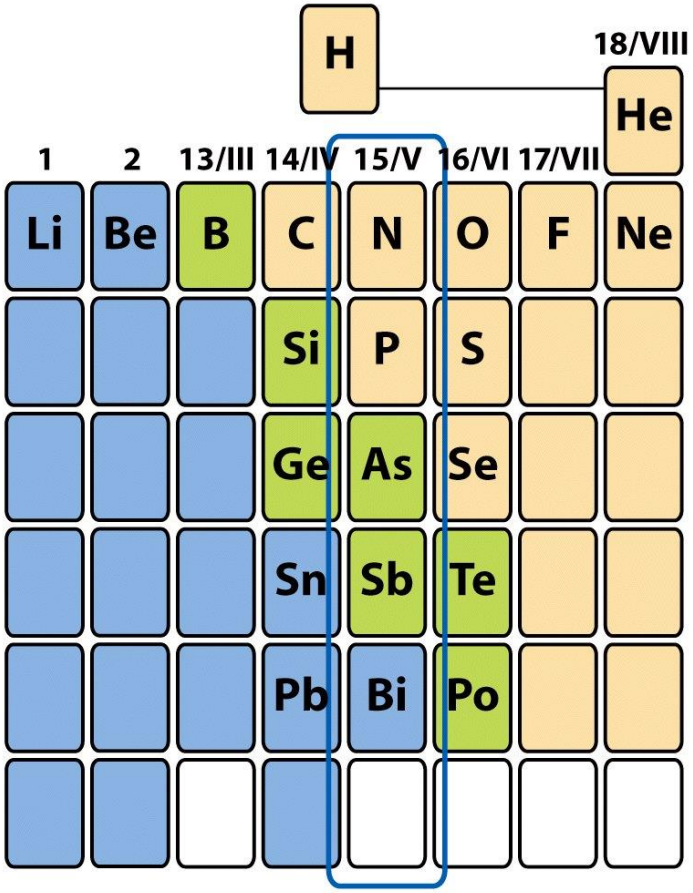
Red = Silicon
Purple = Oxygen

Group 4A

Common Reactions

- Reaction with **Halogens**
  - $M + 2X_2 \rightarrow MX_4$
    X_2 = any halogen molecule,
    M = Ge or Sn; Pb gives PbX_2
- Reactions with **O**
  - $M + O_2 \rightarrow MO_2$
- Reactions with **ions**
  - $M + 2H^+ \rightarrow M^{2+} + H_2$
    M = Sn or Pb

Group 5A



- Electron configurations ns^2np^3 (n is the period number)
- Oxidation states that range from -3 to +5
- The metallic character of the group increases down the group

Group 5A

Nitrogen

- Rare in the Earth's crust but elemental nitrogen (N_2) is the principal component of our atmosphere (76% by mass)
- N ≡ N triple bond strength is 944 $\frac{kJ}{mol}$ making it almost as inert as the noble gases.

Phosphorus

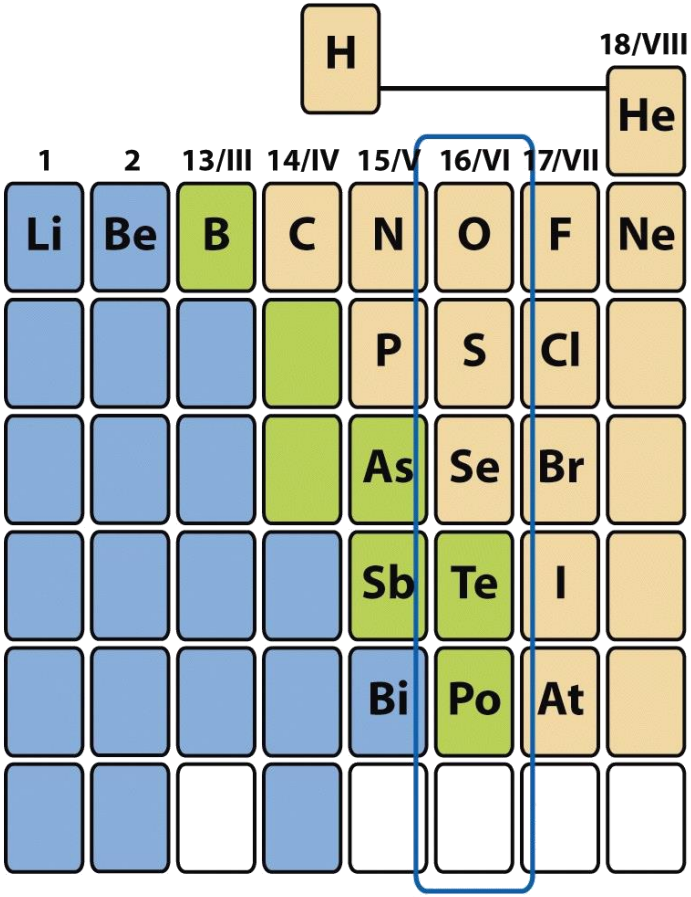
- White phosphorus is a soft, white, poisonous, highly reactive molecular solid consisting of tetrahedral P_4 molecules. White phosphorus burst into flames when exposed to air.
- Red phosphorus is used in the striking surfaces of matches because the phosphorus ignites with friction.

Group 5A

Important Compounds

- NH_3 (ammonia)
- NH_4NO_3 (ammonium nitrate)
- NH_2NH_2 (hydrazine)
- NaN_3 (sodium azide)
- PH_3
- N_2O (nitrous oxide or laughing gas)
- NO (nitrogen oxide, nitrogen monoxide, or nitric oxide)
- NO_2
- HNO_3 (nitric acid)
- H_3PO_4 (phosphoric acid)

Group 6A

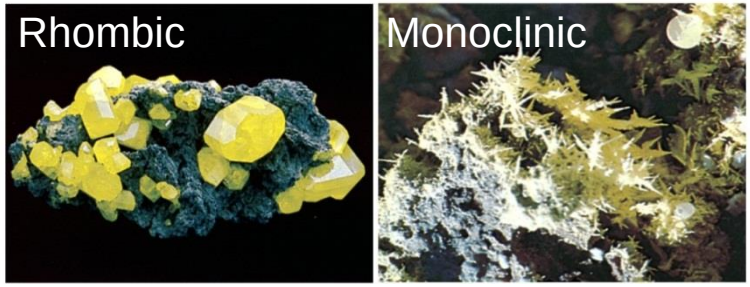


- Electron configurations ns^2np^4 (n is the period number)
- Elements become increasingly more nonmetallic toward the right-hand side of the periodic table

Group 6A

Oxygen

- Oxygen is the most abundant element in the Earth's crust.
- The free element accounts for 23% of the mass of the atmosphere.
- The combustion of all living organisms in oxygen is thermodynamically spontaneous.
- Two allotopes of oxygen are O_2 and O_3.



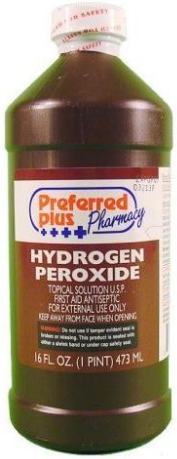
Sulfur

- Sulfur behaves differently than oxygen due to its increased size and decreased electronegativity.
- Sulfur also has weaker tendencies to form multiple bonds to one atom.
- Sulfur can extend its octet.
- Sulfur has a striking ability to catenate, or forms chains of atoms.

Group 6A

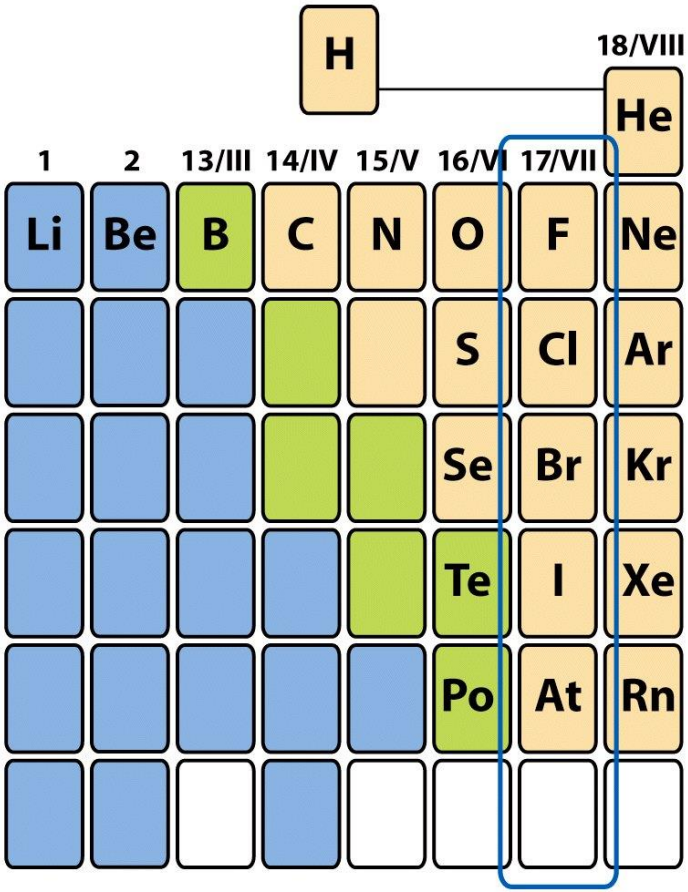
Important Compounds

- H_2O
- H_2O_2 (hydrogen peroxide)
- SO_2
- H_2SO_4
- SF_6 (sulfur hexaflouride)
- S_2Cl_2



Group 7A

The Halogens



- Electron configurations ns^2np^5 (n is the period number).
- In its elemental state, all halogens atoms combine to form diatomic molecules (ex. F_2,I_2,…).
- With the exception of F, the halogens can also lose valence electrons and their oxidation states can range from -1 to +7.

Group 7A

Fluorine

- Fluorine is the halogen with greatest abundance in the Earth's crust
- It occurs widely in many minerals
- Fluorine is the most strongly oxidizing element.
- Most of the F produced by industry is used to make the volatile solid UF_6 used for processing nuclear fuel

Chlorine

- Chlorine is more soluble in water than fluorine.
- As a result even though there is more F present in the Earth's crust the oceans are salty with chlorides rather than fluorides.
- Cl is one of the most heavily manufactured chemicals.
- It is a strong oxidizing agent.

Group 7A

Bromine

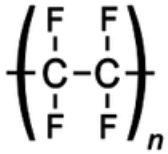
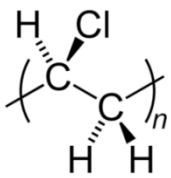
- One of two elements that are liquid at SATP.
- Br is used widely in synthetic organic chemistry because of the ease at which it can be added to and removed from organic chemicals that are being used to carry out complicated syntheses.

Iodine

- When iodine dissolves in organic solvents it produces solutions having a variety of colors.
- Iodine is an essential trace element for living systems; a deficiency in humans leads to a swelling of the thyroid gland in the neck.
- Iodides are added to table salt (iodized salt) to prevent this deficiency.

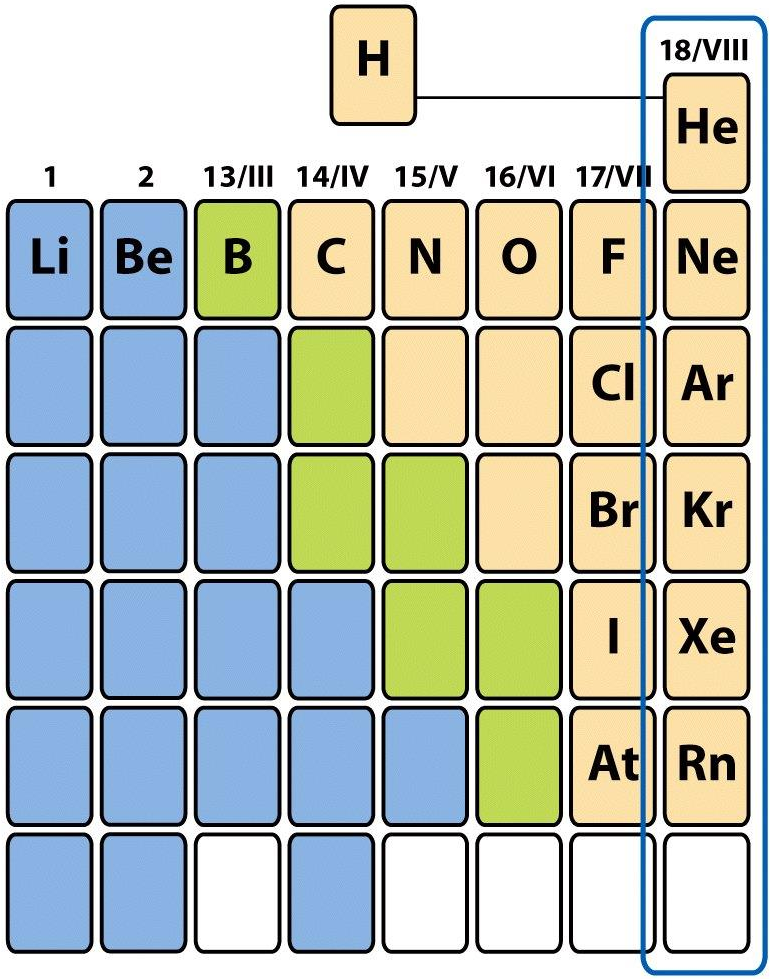
Group 6A

Important Compounds

- HF
- HCl
-  (polytetrafluoroethylene (PTFE), or Teflon)
-  (Polyvinyl chloride, or PVC)

Group 8A

The Halogens



- Electron configurations ns^2np^6 (n is the period number).
- Their closed shell electron configuration makes them have a very low reactivity.

Group 8A

Helium

- Helium is the second most abundant element in the universe after hydrogen.
- Low density and nonflammable therefore it is used to provide buoyancy in blimps.

Neon

- Neon glows orange-red when an electrical current is passed through it and is used for advertising sings and displays.

Argon

- Argon is used to provide an inert atmosphere for welding to prevent oxidation.
- Argon is also used to fill some types of light bulbs, where it conducts heat away from the filament.

Group 8A

Krypton

- Used in airports for there runway lights.
- Krypton is produced by nuclear fission, its atmospheric abundance is one measure of worldwide nuclear activity.

Xeon

- Xeon is used in halogen lamps, for automobile headlights, and in high speed photographic flash tubes.

Radon

- Radon is a radioactive gas that seeps out of the ground and its presence can lead to dangerously high levels of radiation.

Take Away From Chapter 18

- **Big Idea:** The structure of atoms determines their properties; consequently, the behavior of elements is related to their location in the periodic table. In general nonmetallic character becomes more pronounced toward the right of the periodic table.

- **Group 1A**
- **Group 2A**
- **Group 3A**
- **Group 4A**
- **Group 5A**
- **Group 6A**
- **Group 7A**