AP Chemistry
A. Allan

Chapter 19 - The Representative Elements: Groups 1A through 4A

19.1 A Survey of the Representative Elements

A. Basic Trends
1. Metals tend to lose electrons and form cations
2. Nonmetals tend to gain electrons and form anions
3. Metalloids (semi-metals) have properties of both metals and nonmetals
    a. B, Si, Ge, As, Sb, Te, Po, At
4. Metallic character tends to increase as atomic number increases within a group

B. Atomic Size and Group Anomalies (Anomaly = oddity)
1. Hydrogen vs. Other Group I Elements
    a. Very small, relatively high electronegativity (2.1)
    b. Forms covalent bonds with nonmetals - other Group I elements form ionic bonds with nonmetals
2. Beryllium vs. Other Group II Elements
    a. Small, electronegativity of 1.5 produces covalent bonds with many nonmetals (other group II's form ionic bonds)
    b. BeO is amphoteric, other group II oxides are basic (form hydroxides) in solution
3. Boron vs. Other Group III Elements
    a. Boron is a nonmetal/semimetal, all others are active metals
4. Carbon vs. Silicon (Group IV Elements)
    a. Carbon readily achieves the octet by forming π bonds with oxygen in CO_2
    b. Silicon does not form π bonds with oxygen in discrete SiO_2 molecules
        (1) Si 3p orbitals do not easily overlap with oxygen 2p orbitals
        (2) Si forms interlocking SiO4 tetrahedra which make up the crystalline structure of quartz
5. Nitrogen and Phosphorus (Group V)
    a. Nitrogen forms a diatomic molecule with π bonds (N_2)
    b. Phosphorus forms aggregates based on the tetrahedral P_4 molecule
        (1) Single bonds
        (2) Large atoms = weak π bonds
6. Oxygen and Sulfur (Group VI)
    a. Oxygen forms a diatomic molecule with π bonds (O_2)
    b. Sulfur forms aggregates such as the cyclic S_8 molecule, with all single bonds
7. Halogens (Group VII)
    a. Chlorine has an unexpectedly higher electron affinity than fluorine
        (1) Small size of fluorine atoms bring unshared (lone) pairs close together, where they repel each other

C. Abundance and Preparation

1. Earth's Crust, Ocean, Atmosphere

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

2. Major Elements in the Human Body

Oxygen	65.0%	Potassium	0.34%
Carbon	18.0%	Sulfur	0.26%
Hydrogen	10.0%	Sodium	0.14%
Nitrogen	3.0%	Chlorine	0.14%
Calcium	1.4%	Iron	0.004%
Phosphorus	1.0%	Zinc	0.003%
Magnesium	0.50%		

3. Metallurgy - Obtaining a Metal from its Ore
    a. Reduction of metal ions to atoms, usually using carbon as the reducing agent

        $2SnO(s) + C(s) + heat \rightarrow 2Sn(s) + CO_2(g)$

        $2PbO(s) + C(s) + heat \rightarrow 2Pb(s) + CO_2(g)$

        Hydrogen as reducing agent

        $SnO(s) + H_2(g) + heat \rightarrow Sn(s) + H_2O(g)$

    b. Electrolysis
        (1) purification of highly active metals
4. Purification of Nonmetals
    a. Liquefaction
        (1) sequential expansion (cooling) followed by compression of a gas
    b. Electrolysis
        (1) Hydrogen from water
    c. Decomposition
        (1) Hydrogen from methane (more common)

19.2 The Group 1A Elements - The Alkali Metals

A. Reactivities
   1. With water
      a. $2M(s) + 2H_2O(l) \rightarrow 2M^+(aq) + 2OH^-(aq) + H_2(g)$
   2. Sodium forms oxides or peroxides
      a. $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$ (limited oxygen)
      b. $2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$ (excess oxygen)
   3. K, Rb, Ce react with oxygen to form superoxides, containing the O_2^-
      a. $K(s) + O_2(g) \rightarrow KO_2(s)$
      b. Superoxides react with water or carbon dioxide to release oxygen
   4. Lithium reacts with nitrogen to form a nitride salt
      a. $6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$

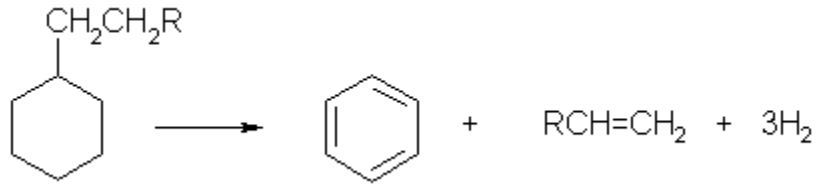
B. Biological Importance of Alkali Metals
   1. Na^+ and K^+ are important in nerve conduction and muscle contraction
   2. Li^+ affects levels of neurotransmitters and is used to treat bipolar disorder

19.3 Hydrogen

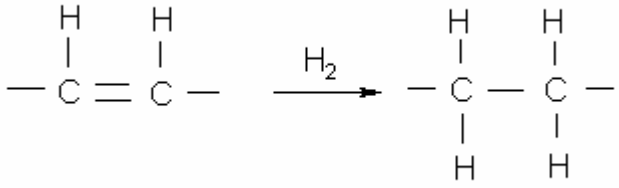
A. Properties
   1. Colorless
   2. Odorless
   3. Low boiling (-253°C) and melting (-260°C)points
   4. Highly flammable

B. Purification of Hydrogen
   1. Decomposition of methane in water, using heat, pressure and a catalyst

      $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$
   2. Cracking of hydrocarbons in gasoline production



C. Industrial Uses
   1. Production of Ammonia by the Haber Process
   2. Hydrogenating unsaturated vegetable oils



D. Hydrogen Halides
    1. Ionic hydrides
        a. Hydrogen and a Group I or II metal
        b. Hydride ion is H^-
        c. Hydrides are powerful reducing agents, explosive in water
        d. Examples include LiH and CaH_2
    2. Nonmetals + hydrogen (covalent hydrides)
        a. Examples include H_2O, NH_3, CH_4, HCl
    3. Metallic (Interstitial) Hydrides
        a. Hydrogen and a transition metal
        b. Hydrogen is absorbed by transition metals
            (1) Amount of hydrogen depends on length of exposure
            (2) Potential method of storing Hydrogen fuel

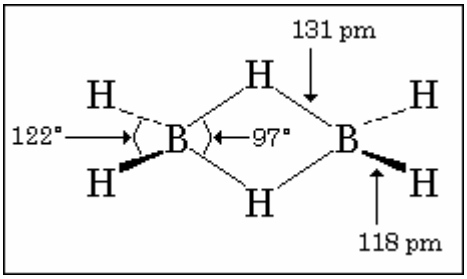
19.4 The Group 2A Elements - The Alkaline Earth Metals

A. Basicity of Oxides
    1. $MO(s) + H_2O(l) \rightarrow M^{2+}(aq) + 2OH^-(aq)$
    2. BeO has amphoteric properties
B. Reaction with Water
    1. $M(s) + H_2O(l) \rightarrow M^{2+}(aq) + 2OH^-(aq) + H_2(g)$
    2. Ca, Sr, Ba react at room temperature, Mg in boiling water
C. Uses
    1. Calcium phosphate in bone structure
    2. Mg in metabolism and muscle function
    3. Mg metal in flash bulbs and metal alloys
D. Removal from "hard" water
    1. Cation exchange resin replaces each Mg^{+2} and Ca^{+2} in water with 2 sodium ions

    Note: Detergents are less soluble in hard water. There is noticeable difficulty, for instance, washing detergent out of one's hair when the concentration of Group II ions is high

19.5 The Group 3A Elements

A. Boranes
    1. B_2H_6 (diborane) and others (B_5H_9) are electron deficient and highly reactive

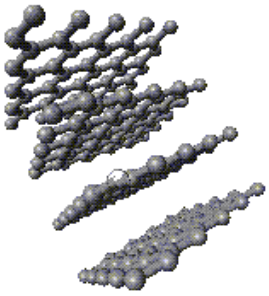


B. Aluminum
    1. Most abundant metal on earth
    2. Oxide (Al2O3) is amphoteric
    3. Metallic properties, but covalent bonds to nonmetals

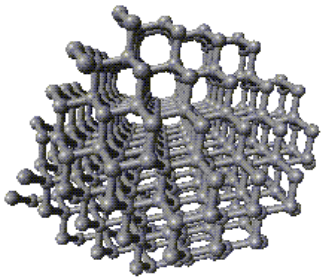
C. Gallium
    1. Largest liquid range of any metal
        a. melts at 29.8°C
        b. boils at 2400°C
D. Indium and Thallium
    1. The Inert Pair Effect
        a. Lose one electron to form +1 ion (full s orbital)
        b. Lose three electrons to form +3 ion (octet)

19.6 The Group 4A Elements

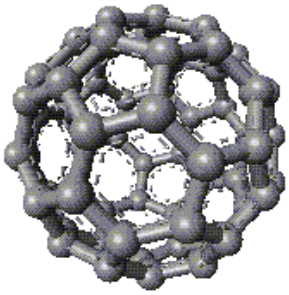
A. Variation within the Group
    1. C is a nonmetal
    2. Si and Ge are semimetals
    3. Sn and Pb are metals
    4. All tend to form 4 covalent bonds to nonmetals (tetravalence)
B. Carbon
    1. Three allotropic forms (allotropic = two or more distinct forms)



Graphite

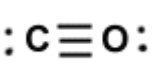


Diamond

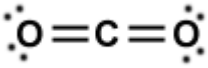


Buckminster Fullerene

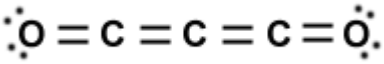
    2. Carbon oxides



carbon monoxide



carbon dioxide



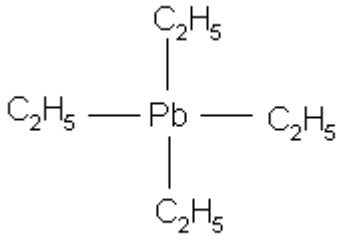
carbon suboxide

C. Silicon
    1. Found in earth's crust in silica and silicates
    2. Semimetal used in semiconductors
D. Germanium
    1. Rare semimetal used as a semiconductor in electric devices
E. Tin
    1. Widely used in alloys

Bronze	20% Sn, 80% Cu
Solder	33% Sn, 67% Pb
Pewter	85% Sn, 7% Cu, 6% Bi, 2% Sn

F. Lead

1. Obtained from the galena ore (PbS)
2. Widely used in the anti-knock agent tetraethyl lead, $(C_2H_5)_4Pb$



3. Produced in greatest quantity for lead storage batteries