

## Ch. 6 Notes – THE PERIODIC TABLE AND PERIODIC LAW

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics*.

### 6.1 Notes

#### I. Development of the Periodic Table

##### A. Antoine Lavoisier (1743-1794)

-- compiled a list of the known elements (33 at the time)

##### B. Johann Dobereiner, German chemist (1780-1849) and his triads

- 1) In 1817, he formed *triads (groups of threes) of similar elements* such as Ca, Sr, Ba
- 2) the middle element of the triad was an average of the other two atomic masses

##### C. John Newlands, English chemist (1837-1898) and the Law of Octaves

- 1) In 1863, he arranged elements according to increasing atomic masses
- 2) *Law of Octaves—properties of elements seemed to change every eighth element* (noble gases were not known yet)

##### D. Dmitri Mendeleev—the father of the modern periodic table (1834-1907)

Lothar Meyer (1830-1895) also did this research but Mendeleev published first

- 1) *similar properties of elements were grouped in columns*
- 2) *he predicted properties of “missing” elements*
- 3) he arranged the elements by increasing atomic masses, not atomic numbers

##### E. Henry Moseley, British chemist (1887-1915)

- 1) In 1913, he found atomic numbers (“nuclear charges”) of the elements by measuring the wavelength of x-rays given off by specific metals
- 2) he *ordered the elements by increasing atomic numbers*
- 3) he was killed in World War I, which was a great loss to science

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#### II. The Modern Periodic Table

##### A. element arrangements

| <u>GROUP NUMBER</u>  | <u>SPECIAL NAME</u>          | <u>CHARGE OF IONS</u> |
|--|------------------------------|-----------------------|
| Group IA (1)   | <u>alkali metals</u>         | 1+                    |
| Group IIA (2)  | <u>alkaline earth metals</u> | 2+                    |
| Group IIIA (13)  | -----                        | some 3+               |
| Group IVA (14)   | -----                        | varies; metals 2+, 4+ |
| Group VA (15)  | -----                        | 3-                    |
| Group VIA (16)   | <u>chalcogens</u>            | 2-                    |
| Group VIIA (17)  | <u>halogens</u>              | 1-                    |
| Group VIIIA/0 (18)   | <u>Noble Gases (inert)</u>   | 0 (none)              |
| Group III B-XII B (3-12)   | <u>Transition Metals</u>     | varies                |
| <u>Inner Transition Metals; Lanthanide and Actinide Series ; Rare Earth Metals</u> |                              | varies                |

- 1) **representative elements**: A groups (IA – VIIIA), or Groups 1, 2, 13, 14, 15, 16, 17, 18
- 2) *transition elements*: B groups (IIIB-XIIB), or Groups 3-12
- 3) **groups** = vertical columns
- 4) **periods** = horizontal lines

##### B. **Periodic Law**— *there is a periodic (repeating) pattern in chemical and physical properties of the elements when they are arranged by increasing atomic numbers* This is **Periodicity**.

- 1) elements are arranged by increasing atomic numbers
- 2) *atomic masses are in amu (atomic mass units)*

C. electron “shell” capacities:

| <u>Shell #</u> | <u>maximum number of electrons</u> |
|----------------|------------------------------------|
| n = 1          | 2                                  |
| n = 2          | 8                                  |
| n = 3          | 18                                 |
| n = 4          | 32                                 |
| n = 5          | 32                                 |
| n = 6          | 18                                 |
| n = 7          | 8                                  |

III. A preview – valence electrons

- A. **valence electrons**—electrons in the outermost “shell” or level
- B. atomic structure of elements within a period: *as you move from left to right, the number of valence e- increases*
- C. atomic Structure of elements within a group: *valence number = group number*
  - 1) Electron dot structures (**Lewis dot diagrams**)—diagrams of valence electrons as *dots around the symbol of the element*
    - a) *only the valence electrons* are shown
    - b) used to see numbers of shared and unshared electron pairs around an atom
    - c) number of unpaired electrons can show how many bonds can form
    - d) procedure
      - i) write the symbol of the element
      - ii) imagine four rectangles framing the symbol
      - iii) place dots around symbol according to the number of valence electrons

*There are a few different methods of placing the dots, but we will use this way...*

*“right, left, up, down, top all the way around.”*

|   |        |   |  |
|---|--------|---|--|
|   | 3      | 5 |  |
| 2 | SYMBOL | 1 |  |
| 6 |        | 8 |  |
|   | 4      | 7 |  |

e) exception to the procedure is helium **He:**



| GROUP NUMBER | # VALENCE (OUTER) ELECTRONS | # ELECTRON DOTS | STATUS                                    |
|--------------|-----------------------------|-----------------|---|
| Group IA     | 1                           | 1               | (has 1 out of 8, missing 7 to be full)    |
| Group IIA    | 2                           | 2               | (has 2 out of 8, missing 6 to be full)    |
| Group IIIA   | 3                           | 3               | (has 3 out of 8, missing 5 to be full)    |
| Group IVA    | 4                           | 4               | (has 4 out of 8, exactly half-full)       |
| Group VA     | 5                           | 5               | (has 5 out of 8, needs 3 more to be full) |
| Group VIA    | 6                           | 6               | (has 6 out of 8, needs 2 more to be full) |
| Group VIIA   | 7                           | 7               | (has 7 out of 8, needs 1 more to be full) |
| Group VIIIA  | 8                           | 8               | (has 8 out of 8, completely full)         |

#### IV. Physical States and Classes of the Elements

##### A. physical states of the elements

- 1) *most elements are solids at room temperature*
- 2) *bromine (Br) and mercury (Hg) are liquids at room temperature*
- 3) *gases at room temp.: H<sub>2</sub>, N<sub>2</sub>, O<sub>2</sub>, F<sub>2</sub>, Cl<sub>2</sub>, He, Ne, Ar, Kr, Xe, Rn*

##### B. occurrence

- 1) *most elements are naturally occurring*
- 2) *synthetic: Tc #43, Pm #61, all elements #93 and higher*

##### C. classification

- 1) **metals**—*ductile, malleable, shiny, lustrous, conductors*
- 2) **nonmetals**—*brittle solids, nonconductors*
  - *C, H, N, O, P, S, - important nonmetallic elements for living organisms*
- 3) **metalloids**—*semimetals or semiconductors; on the periodic table “staircase”*
  - *B, Si, Ge, As, Sb, Te, Po, and At are the 8 metalloids*

#### V. The Modern Periodic Table

##### A. **alkali metals**—Group IA; Group 1: **Li, Na, K, Rb, Cs, Fr**

- 1) *characteristics: good conductors, soft, silver-white, not found in elemental form naturally, react violently with water to form bases (alkali)*
- 2) *uses of sodium: Na in NaCl; NaOH used in paper-making and soap-making; NaOH in “lye” in oven and drain cleaners; Na<sup>+</sup> ion is important to our bodies*
- 3) *uses of potassium: K in KOH (hydroxide cleaners); in fertilizer; K<sup>+</sup> ion is important to our bodies*

##### B. **alkaline earth metals**—Group IIA; Group 2: **Be, Mg, Ca, Sr, Ba, Ra**

- 1) *obtained from mining mineral ores; not found in elemental form naturally*
- 2) *some react with water, but less violently than the alkali metals*
- 3) *uses of calcium ion and magnesium ion: important to our bodies*
- 4) *uses of strontium: pyrotechnics*

##### C. **Group IIIA; Group 13 (aluminum group): B, Al, Ga, In, Tl**

- 1) *Al is the most useful member of the group; does not react with water*
- 2) *uses of aluminum: water purification; fabric dyeing; aluminum cans, siding, and foil; paper manufacture; in deodorants; Al(OH)<sub>3</sub> in antacids*
- 3) *uses of boron: in Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub> · 10H<sub>2</sub>O borax (water softener and cleaner) and H<sub>3</sub>BO<sub>3</sub> boric acid (contact lens cleaner and roach insecticide)*
- 4) *uses of gallium: GaAs (gallium arsenide) used in some semiconductors*

- D. **Group IVA; Group 14 (carbon group): C, Si, Ge, Sn, Pb**
- 1) uses of carbon: graphite, diamond, organic compounds
  - 2) uses of silicon: (in many minerals); SiO<sub>2</sub> in sand; semiconductors; microchips; glass photocells
  - 3) uses of germanium: photocells
  - 4) uses of tin and lead: alloys (solder Pb + Sn; bronze = Cu + Sn)
  - 5) uses of tin: foil, metal can coating
- E. **Group VA; Group 15 (nitrogen group): N, P, As, Sb, Bi**
- 1) uses of nitrogen: needed by plants; nucleic acids (DNA and RNA); liquid N<sub>2</sub> for low temps; TNT; ammonia (NH<sub>3</sub>)
  - 2) uses of phosphorus: phosphate (PO<sub>4</sub>)<sup>3-</sup>; ATP; nucleic acids; fertilizer; red P used in matches
  - 3) uses of arsenic: GaAs (gallium arsenide) used in some semiconductors
  - 4) uses of antimony: alloys with Pb and other metals
- F. **chalcogens—Group VIA; Group 16 (oxygen group): O, S, Se, Te, Po**
- 1) uses of oxygen: atmospheric gas O<sub>2</sub>; in water (H<sub>2</sub>O); product of photosynthesis; ozone O<sub>3</sub>; hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>); in bleach – sodium hypochlorite (NaClO); in sulfuric acid (H<sub>2</sub>SO<sub>4</sub>)
  - 2) sulfur: S<sub>8</sub>, SO<sub>2</sub>, SO<sub>3</sub>; H<sub>2</sub>SO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>...
- G. **halogens—Group VIIA; Group 17 : F, Cl, Br, I, At**
- 1) F is the most reactive
  - 2) found as **diatomic molecules**: F<sub>2</sub>, Cl<sub>2</sub>, Br<sub>2</sub>, I<sub>2</sub>
  - 3) commonly found as ions in a salt
  - 4) hydrogen has characteristics of Group IA and VIIA
  - 5) uses of fluorine: NaF or SnF<sub>2</sub> “fluoride”
  - 6) uses of chlorine—CaCl<sub>2</sub> (“Damp Rid”), NaCl, Cl<sup>-</sup> (chloride) ion in the body; water purification
  - 7) uses of iodine: I<sup>-</sup> (iodide) ion in the body; ion put into table salt; antibacterial cleaner
- H. **Noble Gases—Group VIIIA / 0; Group 18: He, Ne, Ar, Kr, Xe, Rn**
- 1) inert; inactive; valence is full
  - 2) they do not form compounds unless chemically “forced” (XeO<sub>3</sub>)
  - 3) uses: Ne/Kr/Xe signs, He balloons, welding atmosphere Ar and He

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6.2 Notes – covered in chapter 5, which we will cover next

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6.3 Notes

## VI. Periodic Trends in Atomic Size

- A. **atomic radius**—half the distance between two nuclei in a diatomic molecule
- 1) *diatomic = consisting of two identical atoms*
  - 2) **seven diatomic molecules (“Super Seven”): H<sub>2</sub>, N<sub>2</sub>, O<sub>2</sub>, F<sub>2</sub>, Cl<sub>2</sub>, Br<sub>2</sub>, I<sub>2</sub>**
- B. *group trends*
- 1) *atomic size increases from top to bottom*
  - 2) *reason: adding n #s = adding electrons = adding shells*
- C. *periodic trends*
- 1) *atomic size decreases from left to right*

- 2) reason: *adding electrons to the same shell pulls the electron clouds in more, as more protons are added to attract more electrons*)
  - 3) “shielding effect” of inner electrons
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#### VII. Periodic Trends in Ionic Size

- A. cations (positive ions)
    - 1) *cations are smaller than their neutral atoms*
    - 2) reason: *electrons have been removed*
  - B. anions (negative ions)
    - 1) *anions are larger than their neutral atoms*
    - 2) *electrons have been added*
  - C. group trends
    - 1) *ionic radius increases from top to bottom*
    - 2) reason: *adding n #s = adding electrons = adding shells*
  - D. periodic trends
    - 1) *ionic radius decreases from left to right*
    - 2) reason: *adding electrons to the same shell pulls the electron clouds in more, as more protons are added to attract more electrons*
    - 3) “shielding effect” of inner electrons
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#### VIII. Periodic Trends in Ionization Energy

- A. **ionization energy**—the *energy needed to remove an electron from an atom, in kJ/mol*
  - B. *first ionization energy*—the energy needed to remove the first electron
  - C. group trends
    - 1) *(first) ionization energy decreases from top to bottom*
    - 2) reason: *outermost electron is farther and farther from the nucleus in larger atoms, so it is more easily removed*
  - D. periodic trends
    - 1) *(first) ionization energy increases from left to right*
    - 2) reason: “nuclear charge” increases; more attraction between electrons and protons
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#### IX. Periodic Trends in Electronegativity

- A. **electronegativity**—the “greediness” of an atom for electrons when chemically reacting
  - B. noble gases do not have electronegativity values
  - C. electronegativity trends not completely regular
    - 1) *fluorine = most electronegative element with a value of 4.0 (smallest anion formed)*
    - 2) *cesium = least electronegative element (largest cation formed)*
  - D. group trends: *electronegativity decreases from top to bottom*
  - E. periodic trends: *electronegativity increases from left to right*
  - F. chemical bond character is determined by electronegativity differences between the bonding partners
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#### X. Periodic Trends in Electron Affinity

- A. *electron affinity (EA)*—energy required to add an electron to a gaseous atom
- B. EA hard to determine; trends less clear
- C. ...but usually increases from left to right and decreases from top to bottom

# SUMMARY OF TRENDS

(remember, trends are generalizations)

**INC = increases      DEC = decreases**

**TOP  
to  
BOTTOM**      **LEFT  
to  
RIGHT**

**ATOMIC SIZE                      INC                      DEC**

**IONIZATION  
ENERGY                      DEC                      INC**

**ELECTRO-  
NEGATIVITY                      DEC                      INC**

**ELECTRON  
AFFINITY                      DEC                      INC**

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**IONIC SIZE      cation (+) < neutral atom**  
**anion (-) > neutral atom**