Chapter 5: The Periodic Table

CHM 130
GCC Chemistry

5.1 Classification of the Elements

Dimitri Mendeleev (1869) arranged elements in a table in order of increasing ***mass***. He put elements with similar properties in the same column.

5.2 The Periodic Law

H. G. J. Moseley arranged elements in order of increasing ***atomic number***.

Periodic Law – elements in the same column have similar properties

The Periodic Law

Neils Bohr's introduction of electron energy levels altered the shape of the Periodic Table.

The modern Periodic Table shows s, p, d and f sublevels.

5.3 Organization of the Periodic Table

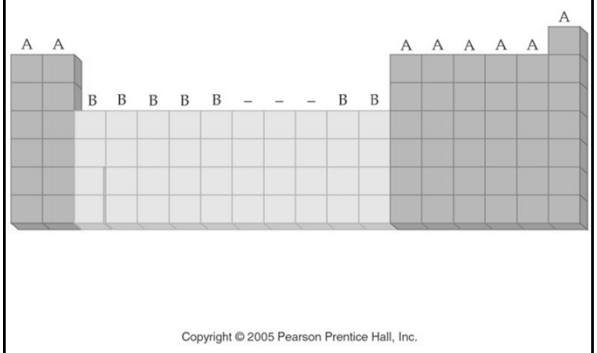
A ***horizontal row*** is called a period.

A ***vertical column*** is called a group.

Elements in the same ***group*** exhibit similar properties.

Main Group (Representative) Elements: A Group

Transition Metals: B Group



Group Names of Elements

Group IA: alkali metals

Group IIA: alkaline earth metals

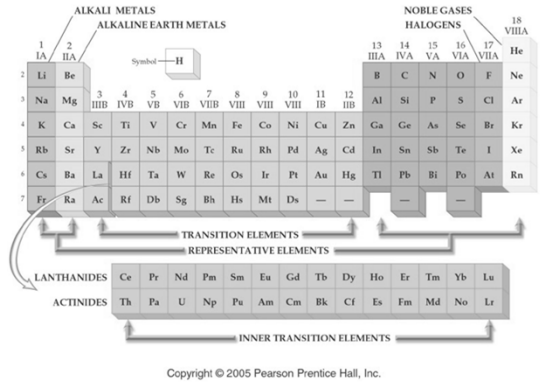
Group VIIA: halogens

Group VIIIA: noble gases

Group Names of Elements

- Transition Metals (B group)
- Inner Transition Metals (beneath the main body of Periodic Table)
  - lanthanide series: Ce-Lu, also called rare earth metals
  - actinide series: Th-Lr, all radioactive elements

Note: all elements $\geq$ 93 are man-made in particle accelerators.



Test Yourself

The Alkali metal in the third period is ____

The Halogen in the 2nd period is _____

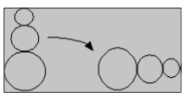
The Noble gas in the fourth period is ____

5.4 Atomic Size

- **Atomic Size**: average distance from nucleus to outermost electron
- **Increases down a group/column**
- As we go ↓, there are more energy levels and radium gets bigger
- **Increases from right to left (←) across a period/row**

Atomic Size

- As we go →, there are more protons and more positive nucleus. As positive charge increases, the electrons are pulled closer, so atoms get smaller. This is called the ***effective nuclear charge***.
- Trend is like a snowman that fell to the right
- **Trend increases ↓ and ←**



Atomic Size

Which is largest?

A) Cl, Se, or Te

B) Mg, Si, or S

Metallic Character

- **<u>Increases from right to left</u> →**
  - metals are on left-hand side
- **<u>Increases down a group</u> ↓**
  - For groups IVA and VA, we go from nonmetals (C & N) at the top to metals (Sn & Bi) at the bottom.
- ***Same snowman trend!***
- **Trend increases ↓ and →**

5.5 Properties of Elements

- Elements in the same group typically have similar chemical behavior and physical properties
- For example,
  - Na reacts with Cl_2 to form NaCl
  - K reacts with Cl_2 to form KCl

Properties of Elements

Ex. 1: Sodium reacts violently with water. Which other element(s) also will?

K Mg Al Li P

Ex. 2: Chlorine reacts with hydrogen to form HCl. Give the formula when fluorine reacts with hydrogen. _____

5.7 Valence Electrons

- <u>Core electrons</u>: inner e^- in *filled electron levels*
- <u>Valence electrons</u>: s and p e^- in the *outer unfilled level*
- Valence electrons form chemical bonds and dictate and element's properties and chemical behavior.

Valence Electrons

- For Group A elements: **Group # = # of valence electrons**

IA = 1 v.e. IIA = 2 v.e. IIIA = 3 v.e.
IVA = 4 v.e. VA = 5 v.e. VIA = 6 v.e.
VIIA = 7 v.e. VIIIA = 8 v.e.

- How many valence electrons do the following elements have?

Si? Kr? P? Na? Ca? S?

5.8 Writing Electron Dot Formulas

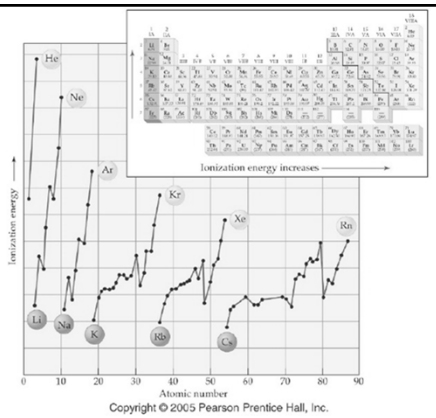
1. Write down the element symbol.
2. How many valence electrons?
3. Assume the atom has four sides, and put electrons *with one electron per side before pairing. There are a maximum of 2 e^- on each side!*

Let's try some on the board!

5.9 Ionization Energy

- **Ionization energy**: energy required to *remove* an electron from a neutral atom.
- IE increases up a group ↑
  - easier to remove electrons from a larger atom (e^-'s are further from the nucleus)
- IE increases left to right →
- Metals have low IE's because they **want** to lose electrons to be like a noble gas
  - Nonmetal elements have high IE's because they would rather gain electrons.

These trends are the opposite of the snowman



Ionization Energy

Which element in each group has the largest ionization energy?

A) Cl, P, or Ca?

B) Li, Rb, or Be?

5.10 Ion Formation

- Atoms gain or lose electrons to have same number of valence electrons as a noble gas.
- Noble gas: charge = 0; very stable, chemically inert, happy with 8 valence electrons (full s and p)
- Except He has full 1s only = 2 e- (He does not have 8 valence electrons!)

Ion Formation

- Metals lose electrons and become positively charged ions called **cations**

Group	Group IA metals	Group IIA metals	Group IIIA metals
Charge	+1	+2	+3
Example	Li^{+}	Mg^{2+}	Al^{3+}

• magnesium ion can be shown as Mg^{+2} or Mg^{2+}.
• The 1 is omitted for +1 or –1

Ion Formation

- Nonmetals gain electrons and become negatively charged ions called **anions**

Group	Group VA nonmetals	Group VIA nonmetals	Group VIIA nonmetals
Charge	–3	–2	–1
Example	N^{3-}	O^{2-}	F^{-}

What charge will ions of these elements have?

lithium
magnesium
sulfur
bromine
nitrogen
aluminum

Isoelectronic

Iso- = same

-electronic = electrons

Isoelectronic = 2 elements that have the same number of electrons and therefore the same electron configurations!

Electron Configuration of Ions

- + charge means less e^- than the atom (cations lose electrons)
- – charge means more e^- than the atom (anions gain electrons)
- Write the electron configuration of the neutral atom first, then remove the correct number of electrons for cations, or add electrons for anions.

Electron Configuration of Ions

1) Na^+ is like Ne
Na atom $1s^2 2s^2 2p^6 3s^1$
Na^+ (isoelectronic w/?)

2) Mg^{2+} is like ?
Mg atom $1s^2 2s^2 2p^6 3s^2$
Mg^{+2} (isoelectronic w/?)

3) F^- is like ?
F atom $1s^2 2s^2 2p^5$
F^- (isoelectronic w/?)

Ion	Isoelectronic with which Noble gas?	Electron Configuration
K^+		
P^{3-}		
Cl^-		
Ca^{2+}		

Answers

- **They are all the same**
- **$1s^2 2s^2 2p^6 3s^2 3p^6$**
- **All isoelectronic with Argon**

Isoelectronic Ions

Example 2: Circle all the ions below that are isoelectronic with neon:

Al^{3+}	Ti^{4+}	P^{3-}	K^+
Cl^-	Ca^{2+}	S^{2-}	Na^+

Coulomb's Law

- Law of physics published in 1783
- Basically describes how opposites attract.
- This is VERY important in chemistry as ions of opposite charge attract
- The electrostatic attraction between two charges is proportional to the charge magnitude (q) and inversely proportional to the distance (r) squared.
- $F = k_e(q_1 q_2 / r^2)$

Ch. 5 Self Test, p. 159

- Try numbers 2-4, 7-13, 15-17
- Answers in Appendix J