REVIEW: TOPIC 2
PERIODIC TABLE

NAME: _____

UNIT 2 – MAJOR UNDERSTANDINGS

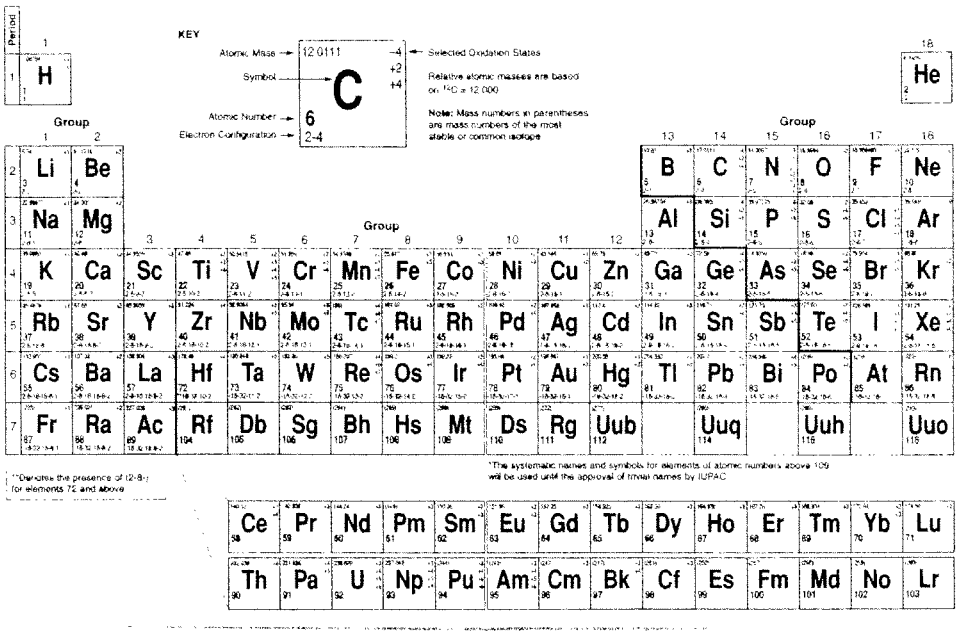
- ☆ 3.1y The placement or location of an element on the Periodic Table gives an indication of the physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number.
- ☆ 3.1g The number of protons in an atom (atomic number) identifies the element. The sum of the protons and neutrons in an atom (mass number) identifies an isotope. Common notations that represent isotopes include: ^{14}C, $^{14}_{6}C$, carbon-14, C-14.
- ☆ 3.1v Elements can be classified by their properties and located on the Periodic Table as metals, nonmetals, metalloids (B, Si, Ge, As, Sb, Te), and noble gases.
- ☆ 3.1w Elements can be differentiated by physical properties. Physical properties of substances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.
- ☆ 3.1x Elements can also be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction.
- ☆ 3.1z For Groups 1, 2, and 13-18 on the *Periodic Table*, elements within the same group have the same number of valence electrons (helium is an exception) and therefore similar chemical properties.
- ☆ 3.1aa The succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.
- ☆ 3.1bb The succession of elements across the same period demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.
- ☆ 5.2f Some elements exist in two or more forms in the same phase. These forms differ in their molecular or crystal structure, and hence in their properties.

INTRODUCTION

The ***Periodic Table of the Elements*** has passed through many stages of development, evolving into the present form. Observed regularity in the properties of elements led Dmitri Ivanovich Mendeleev and others to consider these regularities to be functions of the atomic mass. Henry Moseley established that properties of elements are periodic functions of the atomic number. This is known as the ***Periodic Law***.

The atomic number is the basis of the arrangement in the present form of the *Periodic Table*. The properties of the elements depend on the structure of the atom and vary with the atomic number in a systematic way.

There are various notations by which **isotopes** of elements are identified. In the case of the element carbon, it should be written as $^{14}_{6}C$, ^{14}C, carbon-14, or C-14. The symbol C stands for carbon which has an atomic number of 6 because it has 6 protons in its nucleus. All that is needed is the mass number to identify which isotope of carbon is being studied. There are other isotopes of carbon such as $^{16}_{6}C$ or $^{15}_{6}C$. Note that the atomic number 6 is the same for all carbon isotopes.



A – Development of *Periodic Table*

Metals

Metal atoms possess relatively low ionization energy (allowing them to lose electrons easily) and low electronegativity (restricting the gain of electrons). More than two-thirds of the elements are metals; the rest are metalloids (semimetals), nonmetals, and inert gases.

Metal atoms tend to lose electrons and to form positive ions when combining with other elements. Metallic properties are most pronounced in those elements on the lower left side of the *Periodic Table*. Metals usually possess the properties of high thermal and electrical conductivity, metallic luster, malleability (drawn into sheets), and ductility (drawn into wire). The metal mercury is a liquid at room temperature, but the other metals are all solids.

Alloys are mixtures of metals combined by heat or other means. This gives them improved characteristics such as stainless steel.

Nonmetals

Nonmetal atoms possess high ionization energies and have high electronegativity. Nonmetallic properties are most pronounced in those elements in the upper right corner of the *Periodic Table* (not including Group 18). Nonmetal atoms tend to gain electrons when in combination with metals or to share electrons when in combination with other elements. Nonmetals tend to be gases, molecular solids, or network solids. The exception is bromine which is a volatile (ability to change from liquid to gas) liquid at room temperature. Nonmetals in the solid phase tend to be brittle, to have low thermal and electrical conductivity, and to lack metallic luster. A good example is the element sulfur.

Metalloids (Semimetals)

Metalloids (semimetals) are those elements that have some properties characteristic of metals and other properties characteristic of nonmetals. They are used in the manufacture of semiconductors. Examples of metalloids (semimetals) are boron, silicon, arsenic, tellurium, germanium, and antimony. They are solids.

- Elements in the *Periodic Table* are arranged according to their atomic number.
- For any element in a period, the number of principal energy levels equals the period number.
- The atomic number increases from left to right and from top to bottom.
- Elements to the left of the heavy line running step-wise from boron to astitine are generally classed as metals. Elements to the right of the line are generally classed as nonmetals.
- Elements that border the heavy line running step-wise from boron to astatine exhibit intermediate properties and are known as metalloids, or semimetals (aluminum *can* exhibit different properties).
- Metals greatly outnumber nonmetals.
- Metals conduct heat better than nonmetals.
- Metals are better conductors of electricity than nonmetals (carbon is an exception).
- Hydrogen exhibits both metallic and nonmetallic properties and is often an exception to any generalization about its location on the Table.
- The boiling points of metals are generally higher than those of nonmetals.

B – Properties of Elements

Physical Properties readily discernible by the senses without changing the identity of the substance such as odor, color, hardness, shape (crystalline or amorphous), density, malleability, solubility, melting, and boiling points.

Chemical Properties are characteristics of substances that change due to activities such as burning, reacting with air, water, acids, bases, or combining other solvents. Their reactions are classed as active (vigorously), inactive (sluggishly), or inert (under ordinary conditions these do not react).

The horizontal rows of the *Periodic Table* are called **periods**, **rows**, or **series**. The properties of elements change systematically through a period. Period 2 examples include: Li, Be, B, C, N, O, F, and Ne. The vertical columns of the *Periodic Table* are called **groups** (**families**). The elements of a group exhibit similar or related properties. Group 17 examples include: F, Cl, Br, I, and At.

Most elements are solids at room temperature, except for the liquids Mercury and Bromine. Gases include Hydrogen, Oxygen, Nitrogen, Fluorine, Chlorine, and all of Group 18.

Some elements exist as **allotropes**. Allotropes are two or more forms of the same element that differ in their molecular or crystalline structure, and therefore in their properties. The classical example of an allotropic element is carbon. **Fullerenes** (**buckyballs**) of carbon are geometrically different than diamonds or graphite. Oxygen gas (O_2) has an allotrope called ozone (O_3).

Atomic Radius

The radius of an atom is the closest distance to which one atom can approach another. Since each atom in a molecule or crystal is affected by the presence of other atoms, the radius of an atom will vary under certain specified circumstances.

The relationship between atomic radius and atomic number can be interpreted in terms of the arrangement of electrons in the orbitals of atoms and in terms of nuclear charge. Within a single period of the Periodic Table, the atomic radius generally decreases as the atomic number increases. Within any one period, the electrons in the outer orbitals are arranged around a **kernel** (core) containing the same number of filled levels.

As one proceeds from left to right in the period, the increase in nuclear charge – due to the increasing number of protons – pulls the electrons more tightly around the nucleus. This increased attraction more than balances the repulsion between the added electron and other electrons; therefore, the atomic radius is reduced.

The members of any group in the *Periodic Table* generally show an increase in atomic radius with an increase in the atomic number.

For a group of elements, the atoms of each successive member have a larger kernel containing more filled levels. Therefore, the electrons in the unfilled outer orbitals are farther from the nucleus. This results in an increase in atomic radius as the atomic number increases among the elements in a group.

Ionic Radius

A loss or gain of electrons by an atom causes a corresponding change in size.

- Metal atoms lose one or more electrons when they form ions. Ionic radii of metals are smaller than the corresponding atomic radii.
- Nonmetal atoms gain one or more electrons when they form ions. Ionic radii of nonmetals are larger than the corresponding atomic radii. Atomic and ionic radii are usually measured in Angstrom (Å) units (1Å= 1 x 10^{-10} meter).

Electronegativity

Electronegativity is a measure of the ability of an atom to attract the electrons that form a bond between it and another atom. The values designated are based on an arbitrary scale on which fluorine, the most electronegative element, is assigned a value of 4.0.

Keep in mind that this electronegativity value does *not* necessarily measure the reactivity of the element. However, the scale can be used to predict the type of intramolecular (attractive forces inside the molecule) bond formed.

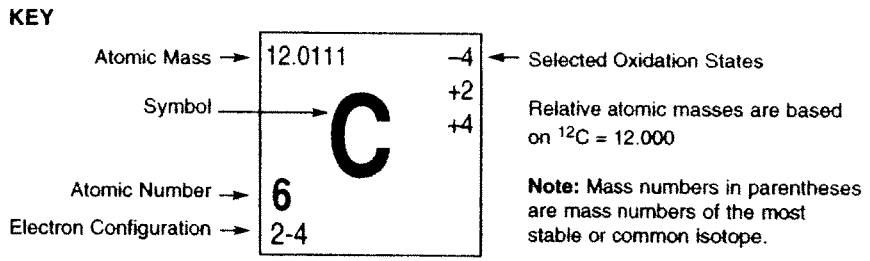
The **ionic** or **covalent** character of a bond can be approximated from the differences in electronegativity of the resulting species. Electronegativity differences of 1.7 or more indicate a bond that is predominately ionic in character. Differences of less than 1.7 indicate that the bond is predominately covalent. Some exceptions to this may be found. (For example, the metal hydrides, with an electronegativity difference of less than 1.7, are predominately ionic.)

Ionization Energy

Ionization energy is the amount of energy required to remove the most loosely bound electron from an atom in the gaseous phase. The *Reference Tables for Physical Setting: Chemistry* list the ionization energy in kilojoules./mole required for the removal of the first (outermost) electron. The second ionization energy refers to the removal of the second most loosely bound electron. Each successive ionization energy is greater than the previous one.

A Key to the *Periodic Table*

When referring to any reproduction of the *Periodic Table of Elements*, the first item the student should look at is the key. The key of the *Periodic Table* is illustrated below.



C - Chemistry of a Group

The chemical properties of the elements in each group are related. Similarities in chemical properties within a group are associated with the similarity in the number of valence electrons.

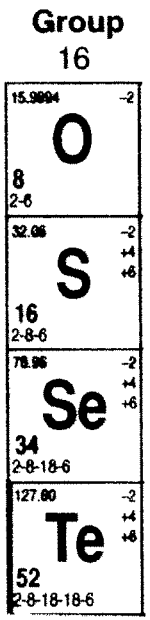
Related chemical properties are illustrated by the similarity in the type of compound formed by the members of a group. For example, the elements in **Group 1** form chlorides having the general formula **MCl**, where **M** represents any member of the group. Elements in **Group 2** form chlorides having the general formula MCl_2. In general, the properties of elements in a group change progressively as the atomic number increases.

a) As one moves down a group, a new, fully occupied shell is added, giving the atom a larger atomic radius.

b) These newly occupied shells allow the "kernel" (all the occupied shells except the valence shell) to enlarge. The positive nuclear charge which holds the valence electrons must penetrate a "**screening**" or "**shielding effect**" caused by the electrons in the inner shells. This, coupled with the increased distance of the valence electron(s) from the nucleus, causes the nuclear attraction to diminish. Generally, it can be stated that the ionization energy of the valence electrons decreases as one proceeds down a group.

c) Going down a group, the electronegativity of the element generally decreases.

d) Going down a group, the elements tend to have more metallic properties.



D - Chemistry of a Period

In each period, as the atomic number increases:

a) The radius of the atom generally decreases.

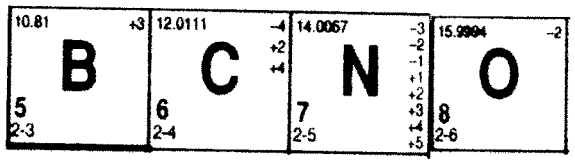
b) The ionization energy of the element generally increases.

c) The electronegativity of the element generally increases.

d) The elements generally change from very active metals, to less active nonmetals, and, finally, to an "inert" monatomic gas molecule.

e) There is a transition from positive to negative oxidation states. Elements near the center of the period may exhibit both positive and negative oxidation states.

f) The metallic characteristics of the elements decrease.



Unit Two - Periodic Table

Key Concepts

- Atomic Number
- Mass Number
- Isotopic Notation
- Metals
- Nonmetals
- Metalloids (Semi-metals)
- Noble Gases
- Physical Properties
- Chemical Properties
- Placement of Elements
- Trends of Periodic Elements

I. Elements

The placement or location of an element on the Periodic Table gives an indication of physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number. The number of protons in an atom (**Atomic Number**) identifies the element. The sum of the protons and neutrons in an atom (**Mass Number**) identifies an isotope. Common notations that represent isotopes includes: ^{14}C, $^{14}{}_{6}C$, carbon - 14, C-14. This is known as **isotopic notation**.

II. Properties of Elements

Elements can be classified by their properties, and located on the Periodic Table, as **metals**, **nonmetals**, **metalloids** (B, Si, Ge, As, Sb, Te) and **noble gases**. Elements can be differentiated by their physical properties. **Physical properties** of substances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.

Property	Metals	Nonmetals
Conductivity as a solid	Yes	No
Hardness	Malleable	Brittle
Reflection of light	Have metallic Luster	Dull in appearance

Chemical properties describe how an element behaves during a chemical reaction. Elements in the same column are called **groups**. For groups 1, 2, and 13-18 on the Periodic Table, elements within the same group have the same number of valence electrons (helium is an exception) and therefore similar properties. Elements in the same row are called **periods**. Elements in the same period have the same number of occupied principal energy levels but <u>do not</u> have similar properties.

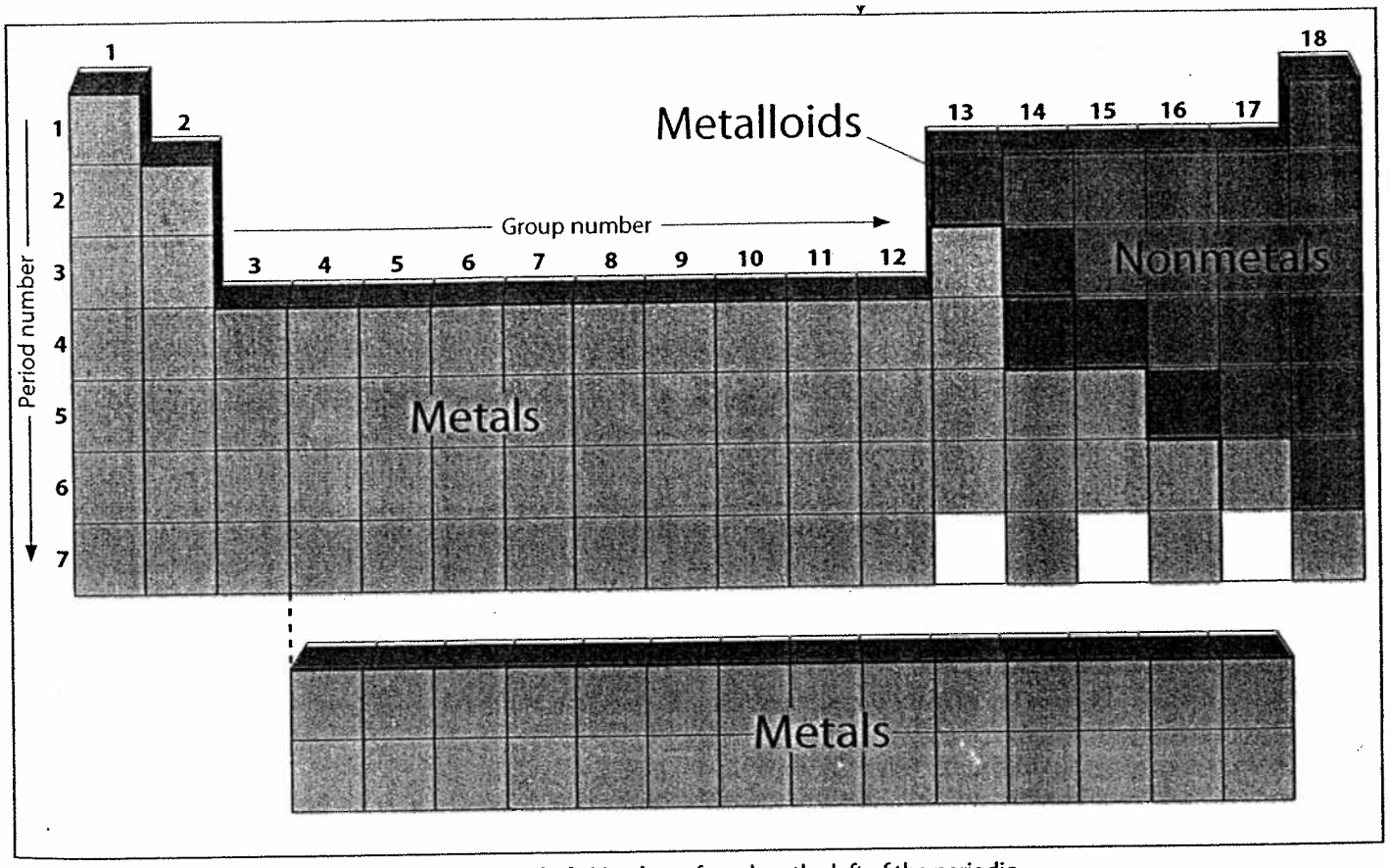


Figure 5-3. A trend from left to right across a period: Metals are found on the left of the periodic table; metalloids, on the staircase; and nonmetals, including noble gases, on the right side.

IV Trends of the Periodic Table

The succession of elements within the same group demonstrates characteristic trends. As you move down a group . . .

Atomic Radius Increases
Electronegativity Decreases
First Ionization Energy Decreases
Metallic Character Increases

The succession of elements across the same period demonstrates characteristic trends. As you move from Left-to-Right in the same period...

Atomic Radius (tends to) Decrease
Electronegativity Increases
First Ionization Energy Increases
Metallic Character Decreases

As metals lose electrons the ionic radius decreases as non-metals gain electrons the ionic radius increases.