1 Periodicity

How often do I like jokes about chemistry? Periodically.

1.1 Introduction to Periodic Table & Activity

Dmitri Mendeleev

- Many people had arranged the known elements of their day, and Dmitri Mendeleev arranged them by increasing atomic mass.

In 1869 when created, he left gaps and predicted some elements that had yet to be discovered. Later, they were and they fit into his table perfectly.

Henry Moseley

- Moseley's periodic table was similar, but he arranged them in order of increasing atomic number, not mass
- Remember that atomic number is the same as number of protons.
- This is the periodic table we use today.

Mass vs. Number

- Increasing atomic mass and atomic number are not exactly the same
- On our modern periodic table (Moseley's) there are a few atomic masses out of order. That's okay because we organize it by atomic number.

Modern Periodic Law

- States that the physical and chemical properties of elements repeat when they are arranged by increasing atomic number.

Classification of Elements

- The zig-zag line divides periodic table into two parts.
- Left of zig-zag line are metals.
- Right of zig-zag line are nonmetals.
- The elements touching the line are metalloids.

Properties of Metals

- Usually silver-gray in color, except gold & copper
- Solid at room temperature, except mercury
- Lustrous or shiny appearance
- Malleable
- Ductile
- Good conductors
- Usually react with acids
- High melting points

Properties of Nonmetals

- Dull

- Brittle (nonmalleable)
- Poor conductors of heat and electricity
- Usually no reaction with acids
- Gases, liquids, or low-melting-point solids

Properties of Metalloids

- All elements touching zig-zag line, except aluminum which is a metal
- Exhibit properties of both metals and nonmetals
- Not good conductors alone

The metals can be divided up into smaller groups.

Alkali Metals

- Group 1 of the periodic table
- Have one valence electron
- Very reactive
- Form +1 ions
- The exception in group 1 is hydrogen, which is not an alkali metal

Alkaline Earth Metals

- Group 2
- Two valence electrons
- Form +2 ions
- Less reactive than group 1

Blocks:

- The periodic table is divide up into four blocks, the s block, the p block, the d block, and the f block, based on electron arrangement.
- The s-block is all elements in groups 1 and 2.
- Groups 3-12 have transition metals and are called the d-block. They do not follow patterns as well as groups 1, 2, and 13-18. The number of valence electrons are harder to predict and they can have a variety of charges.
- Al, Ga, In, Sn, Tl, Pb, Bi are sometimes called "poor metals" because they don't have perfectly metallic properties
- Metalloids are the elements touching the zig-zag line, except aluminum which is a metal. These are commonly used in electronics as a semiconductor

Rare Earth Elements:

- The Lanthanide and Actinide series
- The Lanthanide series is part of Period 6
- The Actinide series is part of Period 7
- These are found in the f-block and are also called rare earth elements

There are also a few groups of elements that are nonmetals.

Halogens

- Group 17 of the table
- Have 7 valence electrons
- Form -1 ions

- Very reactive, especially with the alkali metals.

Noble Gases (Inert Gases)

- Group 18 of the PT.
- Octet of valence electrons (full valence shell)
- Tend not to form ions
- Inert (do not react)

p-block

- Groups 13-18 are called the p block
- The p-block has a few metals: Al, Ga, In, Sn, Tl, Pb, Bi, Po
- The p-block also contains metalloids and nonmetals

Once you know which group an element is in, the number of valence electrons that element has is predictable.

Once you know which group an element is in, the charge of the ion that element forms is likewise predictable.

Exercise Calcium is in which block?

Exercise Uranium is in which block?

Exercise Silicon is in which block?

1.2 Periodic Trends

Periodic Trends are patterns that appear on the periodic table.

4 factors that cause the trends

- Nuclear Pull (Z) - the number of protons
  - The protons pull on the outer electrons. The more protons, the more pull exerted by the nucleus on the outer electrons.

  Exercise Which of the following elements has the most nuclear pull? Carbon or Fluorine?
- Electron repulsion - size of the e^- cloud.
  - The more electrons in an atom's electron cloud, the more they are pushed away from each other, making a bigger cloud.
- Shielding electrons - all inner e^- shield the valence electrons from nuclear pull
  - Electrons on the inner shells feel the nuclear pull stronger than the valence electrons, which are farther from the nucleus
- Z_{eff} - the "effective" nuclear pull on outer electrons. This takes into account the shielding electrons which are taking most of the force.

Atomic Radius Trend

Atomic radius increases down a column because the valence electrons are in a farther energy level and decrease across a period because the nuclear pull is increasing and pulling the energy levels in.

Ionic Size

Metals ions are smaller than their atoms because metal ions lose electrons causing electron repulsion and smaller size.

Nonmetal ions are larger than their atoms because they are gaining electrons, causing more electron repulsion, and larger size.

Ionization Energy

The energy needed to pull an electron from an atom.

The greater the ionization energy, the more difficult it is to remove an electron.

This decreases down a group because there are more shielding electrons, so it takes less energy to "steal" and electron. This increases across a period because the nuclear pull on those electrons is increased with no extra shielding, so its takes more energy to get the electrons away.

Electronegativity

The ability of an atom to take an electron from another atom.

This decreases down a group because there are more electrons to shield the nucleus. This increases across a period because of increased Z.

Electron Affinity

The energy change that occurs when an atom acquires an electron.

Most atoms give off energy when gaining an electron, the more attracted an atom is to the new electron, the more energy released.

Therefore, the trend correlates with electronegativity.

Z_{eff}

The effective nuclear charge - the nuclear pull as felt by the valence electrons.

Equal to the number of protons in the nucleus minus the number of electrons that are between the nucleus and the valence electrons.

No change down a group, because even though nuclear pull has increased, you have more shielding e^-'s.

Increases across a period because nuclear pull is increasing and no additional shielding.

Reactivity

Most reactive corners of the PT are lower left and upper right.

This is because metals tend to donate electrons to obtain their octet. The most reactive metals are therefore the ones with the lowest ionization energy.

Nonmetals tend to gain electrons to obtain their octet. The most reactive nonmetals are on the upper right because they have the highest electronegativity.

Exercise Which is the smallest atom? Na, Li, or Be?

Exercise Which has the highest electronegativity? As, Sn, or S?

Exercise In the following pairs, which have the larger atomic radius? Mg or Ba, Cu or Cu^{2+}, S or S^{2-}.

Exercise In the following pairs, which has the higher ionization energy? Li or Cs, Ca or Br.

Chapter Problems

1. Explain why it takes more energy to remove the second electron from a lithium atom than it does to remove the first electron from a lithium atom.
2. How does the ionic radius of a nonmetal compare with its atomic radius? Explain why the change in radius occurs.
3. Experiments show that the electronegativity of phosphorus is 2.5, and the electronegativity of chlorine 3.5. Explain the difference in electronegativity using principles of atomic structure.
4. Explain how ionization energy changes as you move left to right across a period using principles of atomic structure.