Chapter 1: Atoms and Periodic Trends

Learning Outcomes:

1) Analyze and interpret the experiments that led to the modern atomic model
2) Use the atomic number of an atom to determine the number of protons, neutrons and electrons in a neutral atom and ion
3) Analyze and interpret the periodic table to determine if an element is a metal, nonmetal or metalloid
4) Analyze and interpret the periodic table to determine periodic trends

Essential Vocabulary

Electron orbital, nucleons, ions, main group elements, transition elements, Lanthanides, Actinides, electronegativity, electron affinity, ionization energy

1.0 Introduction

Everyone you know and everything you can see is made up of atoms. The cars that you drive and the food that you eat are made up of atoms. The clothes that you wear and water that you drink are made up of atoms. However, these particles are so small that if not for the diligence of scientists over the last two centuries we would have no scientific proof that they exist.

1.1 History of the atom

The concept of atoms has its origins in ancient Greece. Democritus, a Greek philosopher, developed the original model of the atom. This proposed model, however, was disputed by other philosophers of his era. John Dalton (often referred to as the father of atomic theory), in 1804, proposed an atomic theory that sought to explain the inner works of chemical reactions. The following postulates made up what is referred to as Dalton's Law of Atomic Theory:

1. All particles are composed of atoms (very small particles) that are indivisible
2. In any element all atoms are the same
3. Different elements are composed of different atoms.
4. Atoms combine chemically in whole -number ratios when forming chemical compounds.
5. In chemical reactions atoms are only rearranged. They can neither be destroyed nor created.

1.2 Discovery of subatomic particles (electron, protons and neutrons)

Dalton's postulates were the beginning of the modern atomic theory, however some of his laws were eventually challenged and disproved. The first scientist to challenge Dalton's postulates was English scientist J.J. Thompson. In 1897, J.J. Thompson, using a cathode ray experiment, discovered the first subatomic particle. These subatomic particles were negatively charged which he named electrons. This led to Thompson's atomic theory (also referred to as the Plum Pudding model) which suggested that electrons were uniformly spread throughout a positively charged sphere.

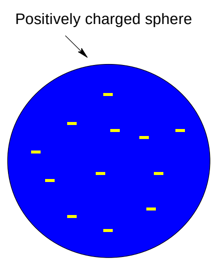


Figure 1: Illustration of J.J. Thompsons plum pudding model of the atom

In 1911 English scientist Earnest Rutherford published findings from his gold foil experiment. To test the plum pudding model, Rutherford directed a beam of positively charged alpha particles into a sheet of gold foil. Rutherford observed that most of the alpha particles went straight through the foil. However, some alpha particles were fully deflected and others partially deflected. This led him to the conclusion that there was mostly empty space in the atom and that there was a dense nucleus in the center that was positively charged. Electrons of the atoms revolved around the nucleus in a circular path.

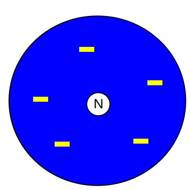


Figure 2: Illustration Earnest Rutherford's nuclear model of the atom

In 1913, Neils Bohr proposed his planetary model of the atom. The planetary model described the electrons of an atom moving in fixed, circular paths (orbits) around the nucleus of the atom.   These orbit shells represented the different energy levels that the electrons in the atom resided in. Shells are represented by the letter n followed by an equal sign, then the number. For example, the first energy shell is represented by n=1. The second energy shell is represented by n=2. The third energy shell is represented by n=3 and so on. Note that as the shell number increases so does the energy of the level.

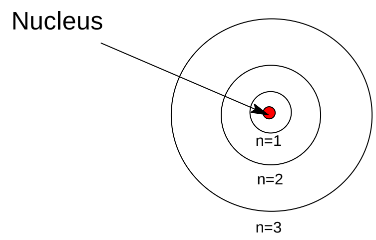


Figure 3: Illustration of Bohr's energy shells

Shell 1 can hold a maximum of 2 electrons. Shell 2 can hold a maximum of 8 electrons. Shell 3 can hold a maximum of 18 electrons. Notice the mathematical relationship between the shell number and the maximum number of electrons per shell. This mathematical relationship is $2(n)^2$; where n is equal to the shell number.

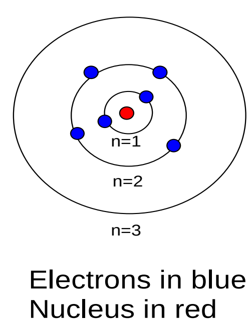


Figure 4: Illustration Earnest Rutherford's nuclear model of the atom

In 1926, Australian physicist Erwin Schrodinger proposed the quantum mechanical model of the atom. In the quantum mechanical model electrons do not move in fixed circular orbits they exist moving randomly in electron clouds surrounding the nucleus. These electron clouds were called orbitals. These **electron orbitals** are regions of high probability of finding an electron.

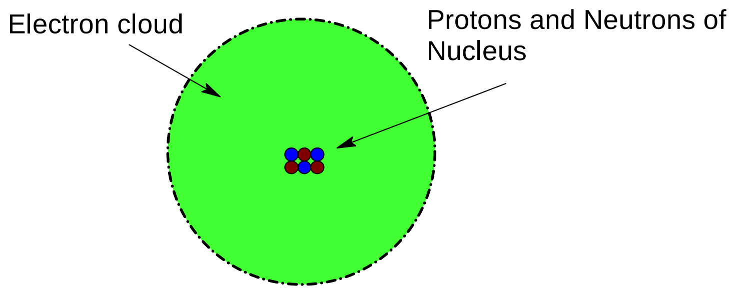


Figure 5: Illustration Schrödinger's quantum mechanical model of the atom

1.3 Atom composition (protons, neutrons and electrons)

Atoms are composed of three types of subatomic particles. They are protons, neutrons and electrons. Students often find it easy to remember this by using the Mnemonic device **PEN**. Protons were discovered by scientist Earnest Rutherford. Protons are positively charged subatomic particles that have an electric charge of 1.602×10^{-19} C (coulombs) and a mass of 1.6726 x 10-27 kg or **1 amu** (atomic mass unit). Neutrons were discovered by scientist James Chadwick in 1932. Neutrons are neutrally charged subatomic particles that have an electric charge of 0 and a mass of 1.6749 x 10-27 kg or **1 amu**. Protons and neutrons make up the nucleus of the atom and account for the atom's mass. Electrons were discovered by scientist J.J. Thompson. Electrons are negatively charged subatomic particles that have an electric charge of -1.602 x 10-19 C and a mass 9.109 x 10-31 kg or **0.0005 amu.** The mass of an electron is very small compared to the masses of protons and neutrons (approximately 1/1850) and is not used when determining an atom's mass. The electrons reside in orbitals outside of the nucleus of the atom.

1.4 Atomic number of Elements

The atomic number of an element is determined by the number of protons in the nucleus in an atom. Each element has a different atomic number which is different from any other element. Let's look at the first five elements according to atomic numbers. Notice how hydrogen has a single proton therefore its atomic number must be one. Helium has two protons, and its atomic number is two. This relationship continues for all the elements with no exception.

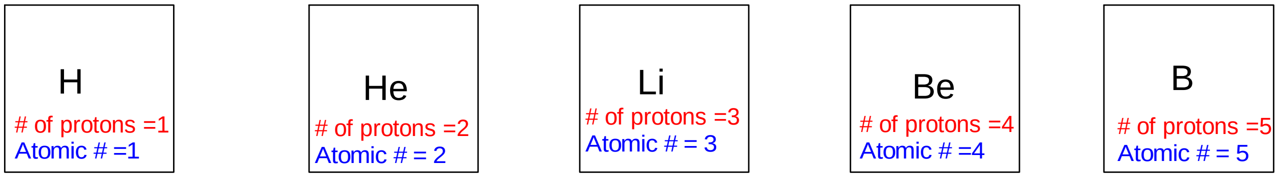


Figure 6: Illustration of elements and number of protons in the nucleus

All atoms in their ground state are electronically neutral. Consequently, an atom of any element has the same number of protons (+) as electrons (-). The reason for this is that the charges on both protons and electrons, if the same number cancel out to zero (neutral).

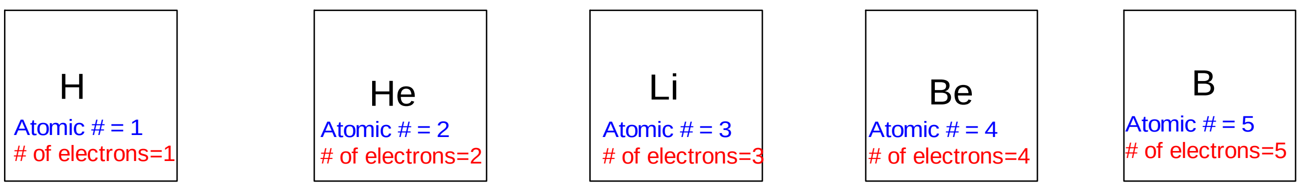


Figure 7: Illustration of elements with atomic number and number of electrons in a ground state atom

1.5 Mass number of Elements

The mass number of an atom is the sum of its ***nucleons*** (protons and neutrons in the nucleus of an atom). If you recall from Section 1.1, the masses of protons and neutrons are approximately 1850 times greater than the mass of an electron. Because of this the electrons mass is not used when determining an atom's mass. To calculate the mass number of an element the equation below is used:

(eq.1)   mass number of an element = mass of protons (atomic number) + mass of neutrons

The number of neutrons in an atom can be determined if the mass number and atomic number of the element is known. Rearranging the original mass number equation to calculate the number of neutrons gives the following equation.

(eq.2)   mass of neutrons = mass number of an element (atomic number) – number of protons

When describing a neutral atom of an element we can use a shorthand notation that represents the number of protons and neutrons in the nucleus of an atom. This shorthand representation is indicated below

$$^{\text{number of protons and neutrons}}_{\text{number of protons}}\text{Element Symbol}$$

The number of protons is written as a subscript to the lower left of the element symbol. The total number of protons and neutrons is written as a superscript at the upper left of the element symbol.

Problem: Carbon is an extremely important element in organic chemistry. Calculate the number of protons, neutrons and electrons of the following

$$^{12}_{6}C$$

Solution: The number of protons is indicated by the lower left subscript therefore there are 6 protons

The number of neutrons is calculated by subtracting the protons from the number of protons + neutrons. 12-6 = 6. Therefore, there are 6 neutrons

The atom has zero charge (neutral). To be a neutral atom the number of electrons must equal the number of protons. Therefore, there are 6 protons.

1.4 Ions

A neutral atom contains an equal number of protons (positive charge) and electrons (negative charge). For example, Hydrogen has one proton (+) and one electron (-) This balance of charges cancels out any charge on the atom. Ions however have a charge. The net charge on an ion is a result of the unequal balance in the number of protons (+) and electrons (-). Ions fall into two distinct categories ***cations*** and ***anions***. Cations are positively charged atoms that are formed when the atom loses electron(s). When loss of an electron(s) occurs the number of protons (positive charges) is greater than the number of electrons (negative charges). This imbalance results in the atom having a net positive charge. Anions are negatively charged atoms that are formed when the atom of an element gains electron(s). When gain of an electron(s) occurs the number of protons (positive charges) is less than the number of electrons (negative charges). This imbalance results in the atom having a net positive charge. Notice in both scenarios the number of protons does not change only the number of electrons.

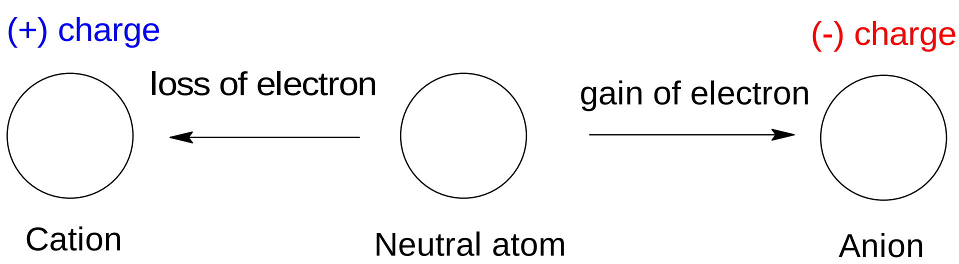


Figure 8: Illustration of cation and anion ion formation from a neutral atom.

To calculate the number of electrons in a cation the equation below is used:

(eq 3) Number of electrons in cation = atomic number – electric charge number

If the ion is an anion we use the following equation:

(eq 4) Number of electrons in anion = atomic number + electric charge number

When describing an ion of an element we can use a shorthand notation that represents the number of protons and neutrons in the nucleus of an ion. The shorthand representation indicated below

number of protons and neutrons

Ion charge

number of protons

Element Symbol

As with a neutral atom the number of protons is written as a subscript to the lower left of the element symbol. The total number of protons and neutrons is written as a superscript at the upper right of the element symbol. Since this is an ion, we must indicate its charge. The ion charge is written as a superscript on the right of the element symbol.

Problem: Calculate the number of protons, neutrons and electrons. In addition, determine the atomic mass and atomic number of

$$^{32}_{16}S^{2-}$$

Solution The number of protons is indicated by the lower left subscript therefore there are 16 protons

The number of neutrons is calculated by subtracting the protons from the number of protons + neutrons. 32-16 = 16. Therefore, there are 16 neutrons

The atom has -2 charge (anion). There are 2 more electrons than protons =18 electrons

Atomic mass = number of protons + neutrons=32 Atomic number= number of protons = 16

1.6 Periodic Table

The modern periodic table has its roots in the groundbreaking research of Russian scientist Dmitri Mendeleev. In 1869, Mendeleev published his research on the development of the periodic table. During his research Mendeleev found that if the known elements at that time were arranged in increasing order of atomic weight a pattern occurred periodically. Mendeleev used this pattern to predict properties of elements that had not yet been discovered. However, there were still some properties of elements that Mendeleev periodic table could not explain. In 1913, English physicist approved on Mendeleev's periodic table by arranging the elements in order of atomic number instead of atomic weight.

The modern periodic table is a table that arranges all the elements in increasing atomic number starting from hydrogen (atomic number 1) to Oganesson (atomic number 118). The periodic table's vertical columns are arranged in order of valence (outer most) electron which affects the chemical properties of an element. Elements with the same chemical properties are placed in the same column. Below is a modern-day periodic table issued by the International Union of Pure and Applied chemistry.

IUPAC Periodic Table of the Elements

1									2
1 H hydrogen 1.0080 ± 0.0002	2	Key:	13	14	15	16	17		2 He helium 4.0026 ± 0.0001
3	4		5	6	7	8	9		10

Li lithium 6.94 ± 0.06	Be beryllium 9.0122 ± 0.0001		atomic number Symbol name abridged standard atomic weight									B boron 10.81 ± 0.02	C carbon 12.011 ± 0.002	N nitrogen 14.007 ± 0.001	O oxygen 15.999 ± 0.001	F fluorine 18.998 ± 0.001	Ne neon 20.180 ± 0.001
11 Na sodium 22.990 ± 0.001	12 Mg magnesium 24.305 ± 0.002	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 26.982 ± 0.001	14 Si silicon 28.085 ± 0.001	15 P phosphorus 30.974 ± 0.001	16 S sulfur 32.06 ± 0.02	17 Cl chlorine 35.45 ± 0.01	18 Ar argon 39.95 ± 0.16
19 K potassium 39.098 ± 0.001	20 Ca calcium 40.078 ± 0.004	21 Sc scandium 44.956 ± 0.001	22 Ti titanium 47.867 ± 0.001	23 V vanadium 50.942 ± 0.001	24 Cr chromium 51.996 ± 0.001	25 Mn manganese 54.938 ± 0.001	26 Fe iron 55.845 ± 0.002	27 Co cobalt 58.933 ± 0.001	28 Ni nickel 58.693 ± 0.001	29 Cu copper 63.546 ± 0.003	30 Zn zinc 65.38 ± 0.02	31 Ga gallium 69.723 ± 0.001	32 Ge germanium 72.630 ± 0.008	33 As arsenic 74.922 ± 0.001	34 Se selenium 78.971 ± 0.008	35 Br bromine 79.904 ± 0.003	36 Kr krypton 83.798 ± 0.002
37 Rb rubidium 85.468 ± 0.001	38 Sr strontium 87.62 ± 0.01	39 Y yttrium 88.906 ± 0.001	40 Zr zirconium 91.224 ± 0.002	41 Nb niobium 92.906 ± 0.001	42 Mo molybdenum 95.95 ± 0.01	43 Tc technetium [97]	44 Ru ruthenium 101.07 ± 0.02	45 Rh rhodium 102.91 ± 0.01	46 Pd palladium 106.42 ± 0.01	47 Ag silver 107.87 ± 0.01	48 Cd cadmium 112.41 ± 0.01	49 In indium 114.82 ± 0.01	50 Sn tin 118.71 ± 0.01	51 Sb antimony 121.76 ± 0.01	52 Te tellurium 127.60 ± 0.03	53 I iodine 126.90 ± 0.01	54 Xe xenon 131.29 ± 0.01
55 Cs caesium 132.91 ± 0.01	56 Ba barium 137.33 ± 0.01	57-71 lanthanoids	72 Hf hafnium 178.49 ± 0.01	73 Ta tantalum 180.95 ± 0.01	74 W tungsten 183.84 ± 0.01	75 Re rhenium 186.21 ± 0.01	76 Os osmium 190.23 ± 0.03	77 Ir iridium 192.22 ± 0.01	78 Pt platinum 195.08 ± 0.02	79 Au gold 196.97 ± 0.01	80 Hg mercury 200.59 ± 0.01	81 Tl thallium 204.38 ± 0.01	82 Pb lead 207.2 ± 1.1	83 Bi bismuth 208.98 ± 0.01	84 Po polonium [209]	85 At astatine [210]	86 Rn radon [222]
87 Fr francium [223]	88 Ra radium [226]	89-103 actinoids	104 Rf rutherfordium [267]	105 Db dubnium [268]	106 Sg seaborgium [269]	107 Bh bohrium [270]	108 Hs hassium [269]	109 Mt meitnerium [277]	110 Ds darmstadtium [281]	111 Rg roentgenium [282]	112 Cn copernicium [285]	113 Nh nihonium [286]	114 Fl flerovium [290]	115 Mc moscovium [290]	116 Lv livermorium [293]	117 Ts tennessine [294]	118 Og oganesson [294]

18

57 La lanthanum 138.91 ± 0.01	58 Ce cerium 140.12 ± 0.01	59 Pr praseodymium 140.91 ± 0.01	60 Nd neodymium 144.24 ± 0.01	61 Pm promethium [145]	62 Sm samarium 150.36 ± 0.02	63 Eu europium 151.96 ± 0.01	64 Gd gadolinium 157.25 ± 0.03	65 Tb terbium 158.93 ± 0.01	66 Dy dysprosium 162.50 ± 0.01	67 Ho holmium 164.93 ± 0.01	68 Er erbium 167.26 ± 0.01	69 Tm thulium 168.93 ± 0.01	70 Yb ytterbium 173.05 ± 0.02	71 Lu lutetium 174.97 ± 0.01
89 Ac actinium [227]	90 Th thorium 232.04 ± 0.01	91 Pa protactinium 231.04 ± 0.01	92 U uranium 238.03 ± 0.01	93 Np neptunium [237]	94 Pu plutonium [244]	95 Am americium [243]	96 Cm curium [247]	97 Bk berkelium [247]	98 Cf californium [251]	99 Es einsteinium [252]	100 Fm fermium [257]	101 Md mendelevium [258]	102 No nobelium [259]	103 Lr lawrencium [262]

PURE AND APPLIED CHEMISTRY

Each element is represented in a box on the periodic table with its name (abbreviation), its atomic number (number of protons) and its average atomic mass. Below is the element Lithium as it appears on the modern periodic table.

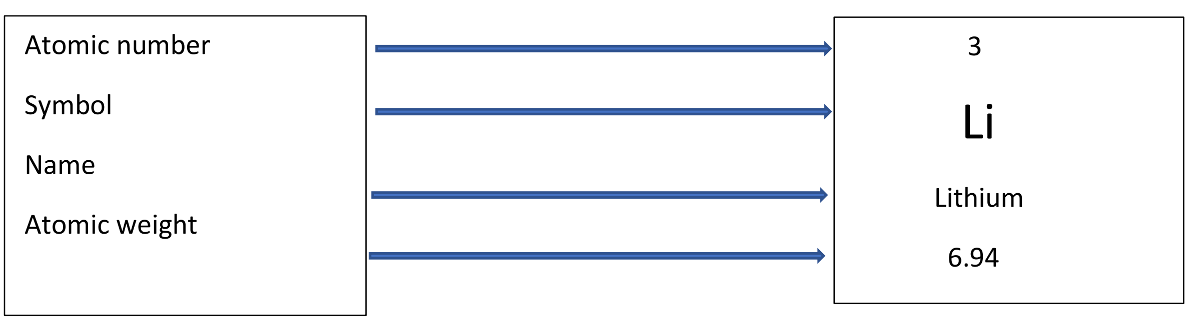


Figure 4: Illustration of element representation on the periodic table.

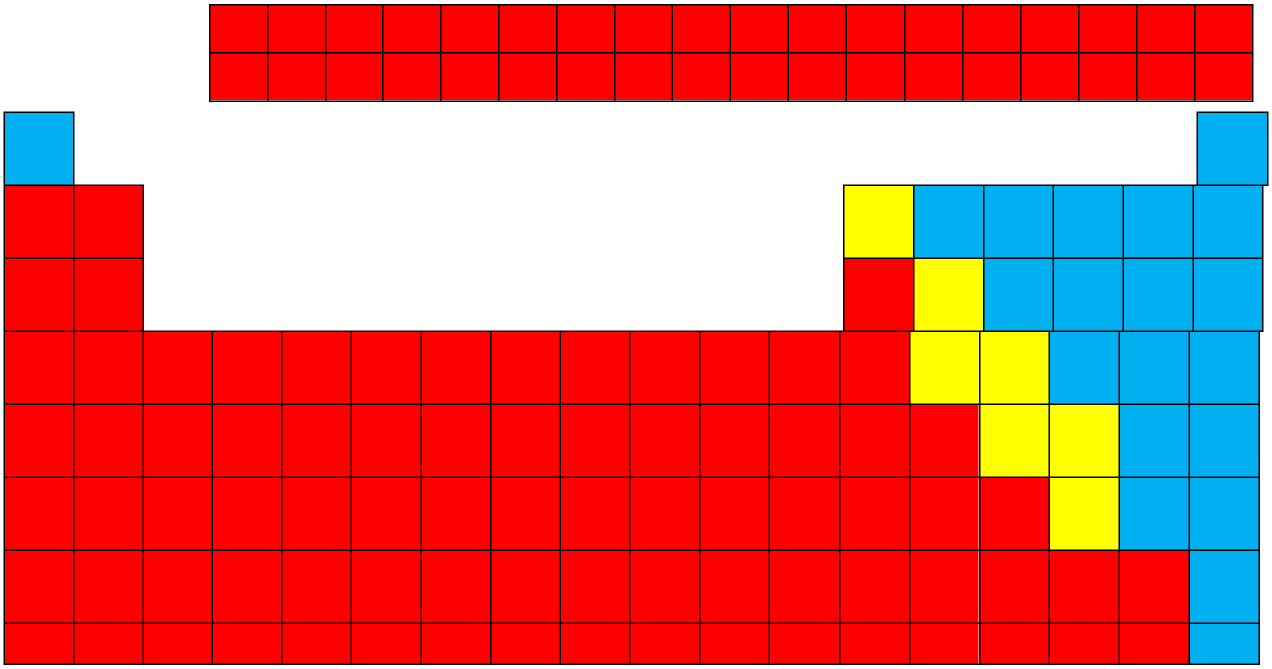
Notice that the atomic weight has a decimal. The reason for this is that the average atomic mass is not the sum of the protons and neutrons (atomic mass) rather it is the weighted % average of the naturally occurring isotope of Lithium.

The periodic table is divided into horizontal rows and vertical columns. Horizontal rows on the table are called periods. There are seven periods listed on the periodic table with atomic numbers increasing from left to right. Period 1 starts at the element Hydrogen (H) and ends at the element Helium (He). The vertical columns on the periodic table are called groups. There are 18 groups listed on the periodic table which are arranged according to their chemical properties. Elements that have the same chemical properties, which are determined based on their outer most (valence) electrons, are placed in the same groups. Many of the groups of the periodic table have special names assigned to them.

1.7 Metals, Nonmetals and Metalloids

The modern periodic table of elements consists of elements that are metal, nonmetals and metalloids. Figure 8 illustrates how the table is divided into these three categories. The elements that are metals are depicted in the color red. The elements that are nonmetals are depicted in blue. Finally, the elements that separate metals and nonmetals are the metalloids, depicted in yellow. Notice when analyzing Figure 5 that the metalloids serve as a dividing line between metals and nonmetals

Figure 8: Metals, Nonmetals and Metalloids on the periodic table



Metals compose most of the elements on the periodic table. They are characterized by being solids, shiny hard and malleable. They are good conductors of heat and electricity and can be stretched. Nonmetals can be solids, liquids or gas. They are poor conductors of heat and electricity and can't be stretched. The elements that are classified as metalloids are Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium and Polonium.   Metalloids have physical properties of both metals and nonmetals. Metalloids conduct electricity however it is weaker than metals yet stronger than nonmetals and are often referred to as Semi-conductors. In addition, they conduct heat however it is weaker than metals yet stronger than nonmetals.

1.7 Main Group Elements, Transition Metals, Lanthanides and Actinides

The elements of the periodic table can also be classified into three main categories. The three main categories are the main group elements (also called the representative elements), transition metals, and inner transition metals (Lanthanides and Actinides). *Adapted from periodic table with permission from IUPAC*

The main group elements consist of elements in groups 1,2, 13, 14, 15, 16, 17 and 18. Group 1 is called the alkali metals. The alkali metals consist of the elements Lithium (Li), sodium (Na), potassium (K) Rubidium (Rb), Cesium (Cs) and Francium (Fr). *Note that the element Hydrogen, even though placed in group I on the periodic table is not included*. These elements are highly reactive and reactive vigorously with water. As you move down the group of alkali metals the reactivity tends to increase. Group 2 elements are called the alkaline earth metals. The alkaline earth metals consist of the elements Beryllium, Magnesium, Calcium, Strontium, Barium and Radium. The alkaline earth metals are reactive yet not as reactive as the alkali metals. Group 15 elements are called the Pnictogens. The Pnictogens consist of the elements Nitrogen, Phosphorous, Arsenic, Antimony, Bismuth and Moscovium. Group 16 elements are called chalcogens. Chalcogen consists of the elements Oxygen, Sulfur, Selenium, Tellurium, Polonium and Livermorium. Group 17 elements are called the halogens. The halogens consist of Fluorine, Chlorine, Bromine, Iodine, Astatine and Tennessine. Group 18 is called the noble gasses. The noble gasses consist of Helium, Neon, Argon, Krypton, Xenon, Radon and Oganesson. The noble gasses have filled orbitals and are inert (non-reactive).

The Transition Elements consist of the elements in groups 3-12. Transition metals have various oxidation states which make them idea elements for organometallic chemistry. Iron (Fe) is a transition metal that is commonly used in everyday life and has biological importance. Copper is used as wires due to its high conductivity.

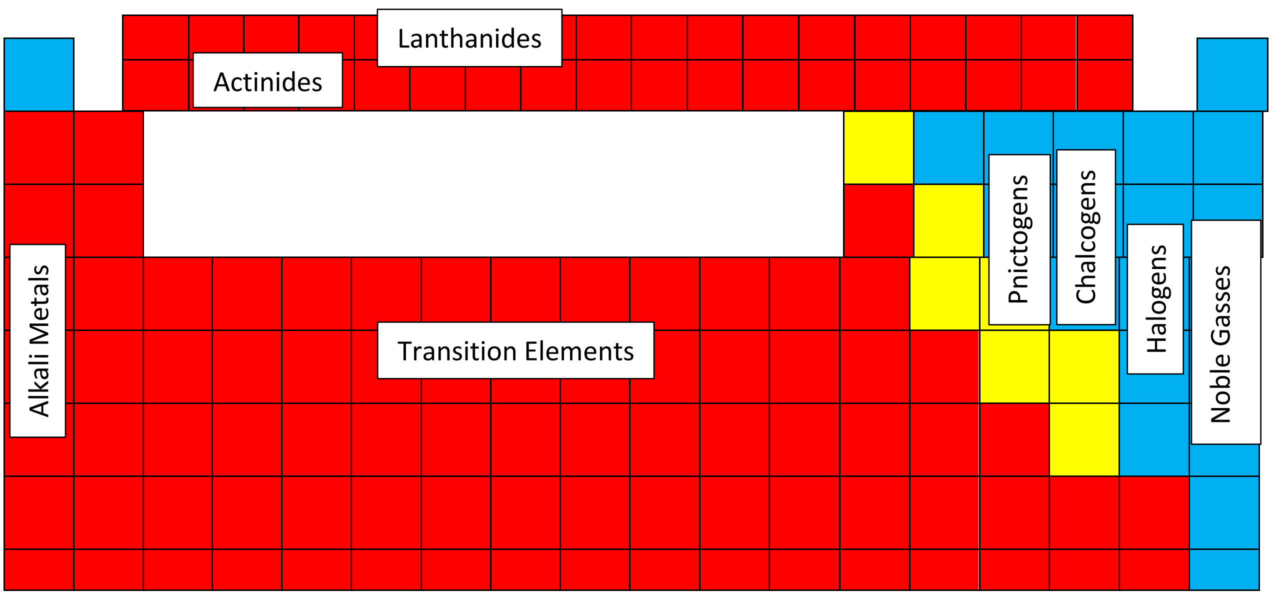
Inner transition metals-The Lanthanides consist of elements starting from element 57 (Lanthanum) and ending element 71 (Ytterbium). The Lanthanides consist of the elements Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium

(Gd), Terbium (Tb), Dysprosium (Dy), Holmium (HO), Erbium (Er), Thulium (Th), Ytterbium (Yb) and Lutetium.

Inner transition metals-The Actinides consist of elements starting from element 89 (Actinium) and ending at element 103 (Lawrencium). The actinides consist of the elements Actinium (Ac), Thorium (Th), Protactinium (Pa),

Uranium (U), Neptunium (Np), Plutonium (Pu), Americium (Am), Curium (Cm), Berkelium (Bk), Californium (Cf), Einsteinium (Es), Fermium (Fe), Mendelevium (Md), Nobelium (No) and Lawrencium (Lr).

Figure 9: Main Group Elements, Transition Metals, Lanthanides and Actinides



1.8 Electronegativity

Electronegativity is the tendency of an atom to attract electron density towards itself when bonded to another atom. The higher the electronegativity on an atom the greater its ability to attract electrons. According to the Pauling scale of electronegativity the element Fluorine is the most electronegative element on the periodic table. Halogens generally tend to have high negativities since they have 7 valence electrons. If a halogen acquires one more electron it will then have a full octet and be

isoelectronic (same number of electrons) with a noble gas. According to the Pauling scale of negativity the element Francium is the least electronegative element.   This is very significant because knowing this information allows us to determine the general trend of electronegativity of elements in the periodic table. If we draw a straight line from the positions of Francium to Fluorine notice the following trend. Electronegativity increases as we go left to right in a period. Electronegativity also increases as we move up a group. Noble gasses are not included in this trend because they have zero electronegativity (due to eight electrons residing in their outer most shell).

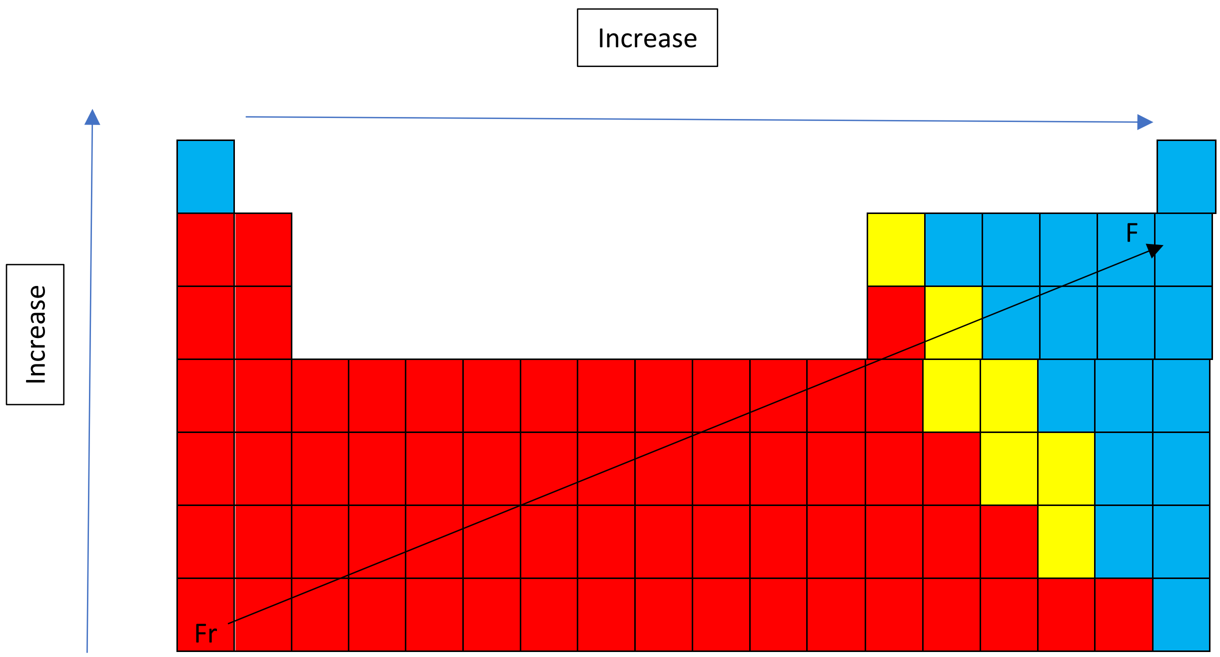


Figure 10: Electronegativity Trends of the periodic table

1.9 Atomic Radii

The atomic radius is the average distance from the center of an atom (nucleus) to the outer most electrons called ***valence electrons***. Elements that have more electrons occupying higher energy levels typically have a larger atomic radius. We can determine the number of energy levels occupied by the electrons atom by examining its period number. For example, Hydrogen is in period 1 and has an atomic number (number of protons) of 1. Since it has 1 proton it also has that electron resides in energy level one. Li is in period 2 and has 3 electrons (2 in the n=1 energy level and 1 in the n=2 level). Na is in period 3 and has 11 electrons (2 in n=1, 8 in n=2 energy level and 1 in the n=3 energy level). Therefore, we see that the atomic radius increases as we move down a group. The atomic radius also increases as we go from right to left in a period.

Figure 11: Atomic Radius Trends of the periodic table

1.10   Ion size

Remember from section (1.4) that ions are atoms with a charge. Metals form cations by losing electrons from their neutral atom forming cations. Cations of an element have a smaller size than its neutral counterpart. The larger the positive the charge on a cation the smaller the cation is. When analyzing the periodic table, cation size decreases as we go left to right. Cation size also increases as we go down a group. Nonmetals form anions by gaining electrons to their neutral atom. Anions of an element have a larger size than its neutral counterpart. For anions the larger the negative charge the larger the ion is. When analyzing the periodic table, anion size decreases as we go left to right. Anions also increase in size as we go down a group.

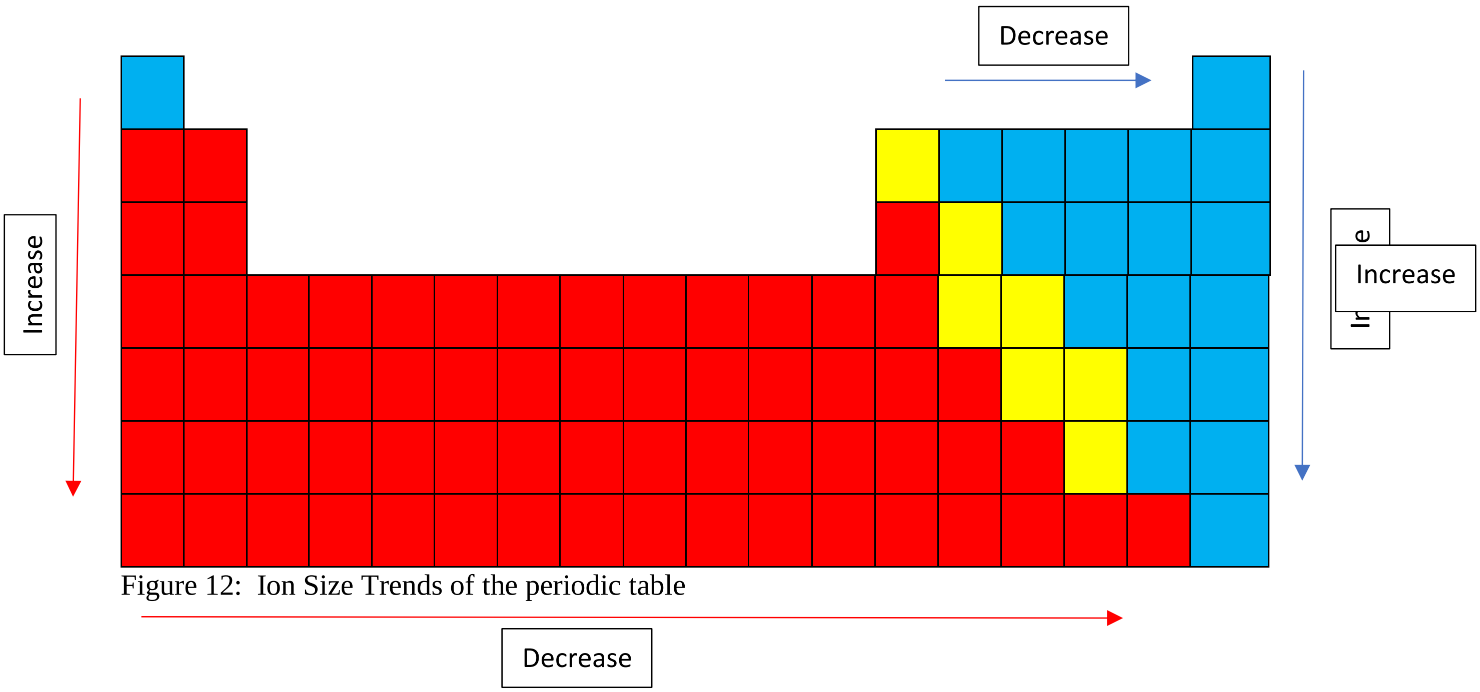
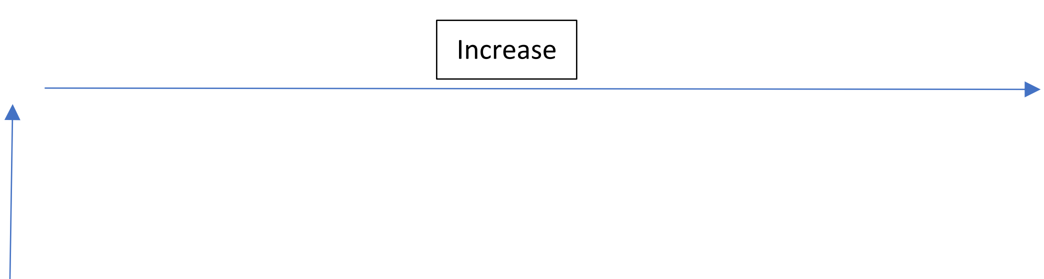


Figure 12: Ion Size Trends of the periodic table

1.11 Ionization Energy

Ionization energy is the amount of energy required to remove an electron from a neutral atom. Removal of an electron results in the formation of a positively charged atom (cation). The noble gases are chemically inert and very stable due to the filled outer electron shell. Because of the noble gasses do not want to lose (form cations) or gain (form anions) electrons. All elements prefer this noble gas configuration if possible. Halogens, in group 7, have 7 valence electrons in their outer shell and a -1 charge. It is extremely difficult to remove an electron from a halogen (it would rather gain an electron to have a noble gas configuration) therefore it requires more ionization energy to do so. When looking at the nonmetals, ionization energy increases as you go up a column on the periodic table and right on a period. For metals the trend is the opposite. For example, Alkali metals, in group 1, have 1 valence electron in their outer shell and a +1 charge. It is much easier to remove an electron from an alkali metal (it would like to lose an electron to have a noble gas configuration) therefore it requires less ionization to do so. When looking at the metal's ionization energy increases as you go up a column.



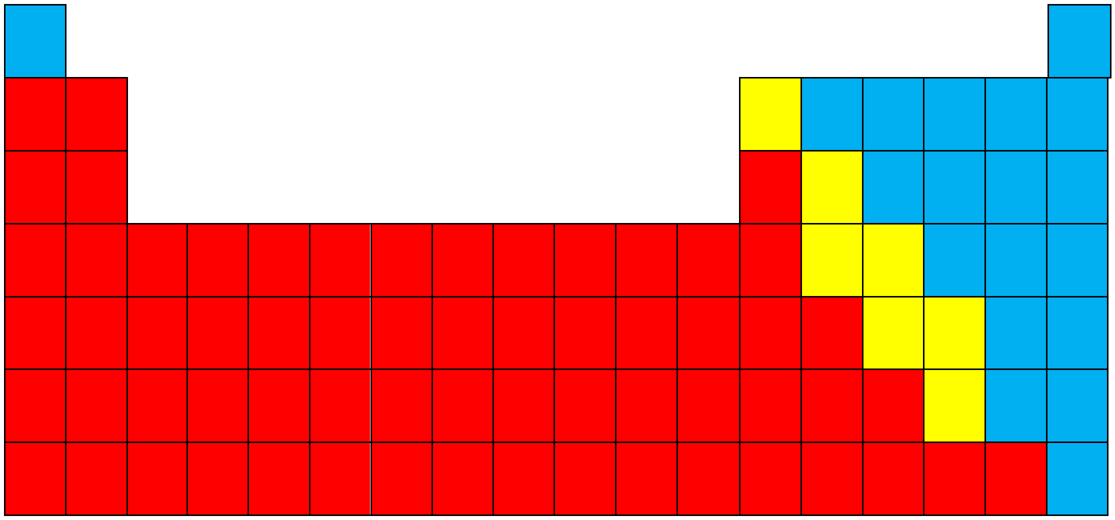
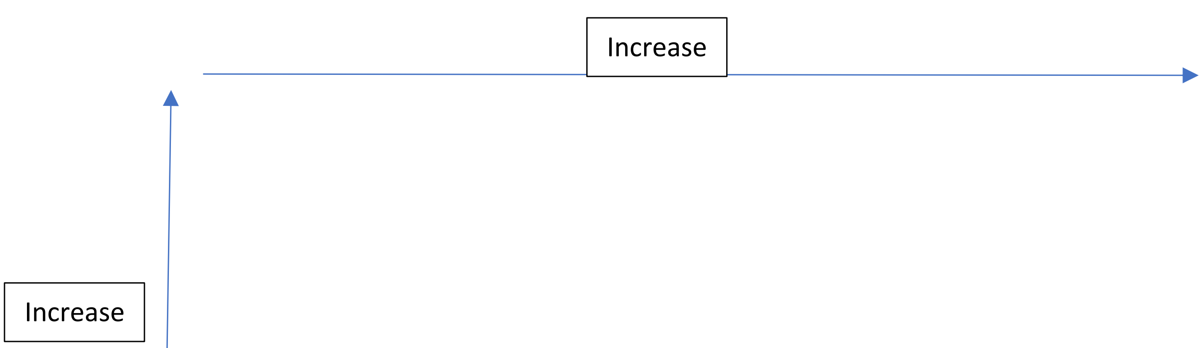


Figure 13: Ionization Energy Trends of the periodic table

1.12 Electron Affinity

Electron Affinity is defined as the energy change that occurs when a gaseous neutral atom gains an electron. The change that is being measured is the release of energy. Electron affinity is a quantitative measurement (involves numbers). The gaining of an electron results in the formation of a negatively charged atom (anion). Remember nonmetals form anions therefore typically their electron affinities are high.   For example, Halogens, in group 7, have 7 valence electrons in their outer shell. If a halogen gains an electron, it will have eight electrons in its outer shell (a stable Noble gas configuration). This noble gas configuration is much lower in energy than the gaseous neutral atom and a release of energy has occurred. Alternatively, nonmetals form cations, and their electron affinity is low. Electron affinity increases as we go up a column on the periodic table. Electron affinity increases as we go left to right across a period on the periodic table. There are exceptions to this general trend for example, when comparing elements in group 1 and 2, group 2 elements have lower electron affinities. Also, when comparing elements in group 14 to 15, group 15 elements have lower electron affinities



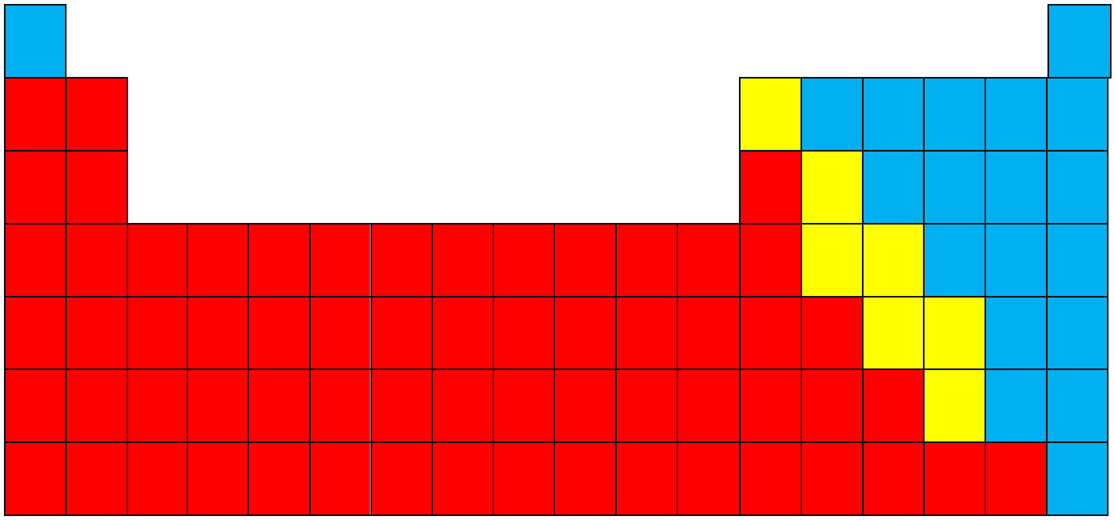


Figure 14: Electron Affinity Trends of the periodic table

1.13 Metallic character

The metallic character of an element is determined by how well an atom loses an electron. Loss of an electron results in the atom becoming a cation. We have already discussed that nonmetals tend to lose electrons. Metallic character decreases across a period on the periodic table. Metallic character increases as we move down a column.

Figure 15: Electron Affinity Trends of the periodic table

Review

Essential equations:

(eq.1) mass number of an element = mass of protons (atomic number) + mass of neutrons

(eq.2) mass of neutrons = mass number of an element (atomic number) – number of protons

(eq 3) Number of electrons in cation = atomic number – electric charge number

(eq 4) Number of electrons in anion = atomic number + electric charge number

Problem: Carbon is an extremely important element in organic chemistry. Calculate the number of protons, neutrons and electrons of the following

$$^{12}_{6}C$$

Solution: The number of protons is indicated by the lower left subscript therefore there are 6 protons

The number of neutrons is calculated by subtracting the protons from the number of protons + neutrons. 12-6 = 6. Therefore, there are 6 neutrons

The atom has zero charge (neutral). To be a neutral atom the number of electrons must equal the number of protons. Therefore, there are 6 protons.

Problem: Calculate the number of protons, neutrons and electrons. In addition, determine the atomic mass and atomic number of

$$^{32}_{16}S^{2-}$$

Solution The number of protons is indicated by the lower left subscript therefore there are 16 protons

The number of neutrons is calculated by subtracting the protons from the number of protons + neutrons. 32-16 = 16. Therefore, there are 16 neutrons

The atom has -2 charge (anion). There are 2 more electrons than protons =18 electrons

Atomic mass = number of protons + neutrons=32 Atomic number= number of protons = 16

Essential vocabulary: Electron orbital, nucleons, ions, main group elements, transition elements, Lanthanides, Actinides, electronegativity, electron affinity, ionization energy

Problems:

1. Fill in the table below.

Element	Atomic #	Protons	Electrons	Group #	Forms Cation or anion
N					
F					
K					
B					
S					
Be					

2. Which atom is larger?

S or S^{2-} Na or Na^{+} Li^{+} or F^{-}

3. Who discovered the proton?

4. Who discovered the electron?

5. Who discovered the neutron?

6. How many protons, neutrons and electrons are in $Al3^{+}$

7. Which atom is more electronegative?

N or S

Summary: The atom is a building block for everything. Understanding how it works gives us insight into the universe which is composed of atoms. The rich scientific history of the atom continues to be a cornerstone in science. Analyzing the atom, with the assistance of the Periodic table allows us to predict and decipher the true nature of the atom