Chemistry 131

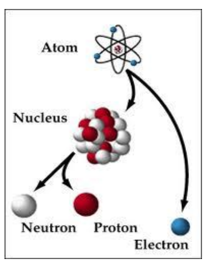
Chapter 2: Atoms

Suggested Chapter Problems

- 2.10 – 2.11
- 2.15 – 2.16
- 2.24 – 2.26
- 2.28 – 2.30
- 2.32
- 2.34 – 2.35
- 2.43
- 2.46 – 2.48
- 2.51 – 2.56
- 2.59
- 2.62
- 2.64 – 2.68
- 2.76
- 2.78
- 2.80
- 2.83 – 2.85
- 2.87
- 2.89

What's in an Atom?

- Nucleus:
- Subatomic Particles:
  - ___________ –
    - Charge: +1, 1 amu
  - ___________ –
    - Charge: neutral, 1 amu
- Electron Cloud:
  - ___________ –
    - charge: -1, 0.0005 amu



http://turnerjrarleeultimateweapon.webs.com/Atomic%20structure.jpg

Atomic Mass Unit

- amu – atomic mass units are used to describe mass since mass of atoms is very small.
- 1 amu = 1.6605×10^{-24}g
- Exactly 1/12th the mass of a __________ atom.
- The atomic mass of any atom is determined by comparing it with the mass of one C-12 atom, or 1 amu.
- Mass of subatomic particles:
  - Proton – 1.6726×10^{-24}g = 1.0073 amu
  - Neutron – 1.6749×10^{-24}g = 1.0087 amu
  - Electron – 9.1094×10^{-28}g = 5.4858×10^{-4} amu

Mass Number

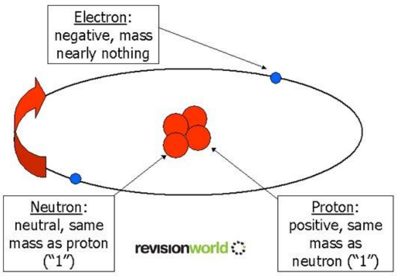
- Atoms have a fixed number of protons, neutrons, and electrons. Adding the masses of the protons and neutrons gives each atom a unique ________________(A).
  - The mass of an electron is so small compared to protons and neutrons they are not counted into the mass number.
- Example:
  - An atom containing 17 protons, 17 electrons, and 18 neutrons would have a mass number of _____ amu.

What is the mass number?

- What is the mass number if the nucleus contains 92 protons and 143 neutrons?
  - ________________
- What is the mass number of an atom containing 33 protons and 42 neutrons?
  - ________________

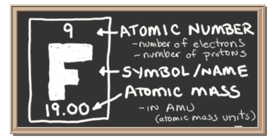
This will be important with isotopes

Another View…



Atomic Number (Z)

- The number of _____________ in an atoms nucleus.
- In a ______________the number of protons and neutrons are equal.

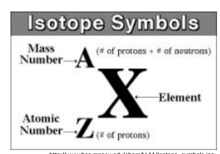


Using Mass & Atomic Numbers

- How many protons, electrons, and neutrons are there in an atom of chlorine – 37?

Isotopes

- Atoms that have the _____________________ but a _______________________________.
  - The only way to add mass without adding charge is to add neutrons!
- Isotopes have a different ________________.
- Differ by mass, but not in chemical behavior.



Atomic Weight

- Most elements occur as mixtures of isotopes.
  - The % of each isotope occurring in the element naturally is nearly always the same, no matter where the element is found.
- _______________– a weighted average of the masses of all the naturally occurring isotopes of an element.
- Atomic numbers are very close to the mass number…
- …the number of protons and neutrons in its nucleus.

How to Calculate a Weighted Average

- In a box that contains two different sizes of marbles, 25% have masses of 2.00g each. 75% have masses of 3.00g each. What is the weighted average of the marbles?

Solution

- Multiply the mass of each marble by the decimal fraction representing its percentage in the mixture. Then add the products.

Now, With an Element

- Naturally occurring copper consists of 69.15% copper – 63, which has an atomic of mass of 62.929601 amu, and 30.85% copper – 65, which has an atomic mass of 64.927794 amu.

Isotope Example

- Chlorine consists of two main isotopes where one isotope chlorine – 35 has a mass of 34.96885 amu and the average atomic mass is 35.453 amu. If chlorine – 35 occurs at 75% and the second isotope occurs at 25%, what is the mass of the second chlorine isotope?

Isotopes, Review

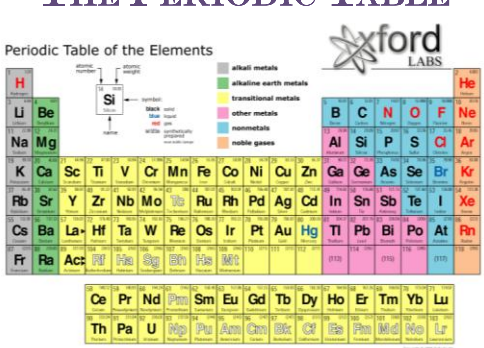
- Isotopes are:
  - Atoms with the same number of protons but a different number of neutrons.
- Most elements on earth are found as a mixture of isotopes.
  - For example: Carbon –
    - Carbon – 12: 98.93%

      $^{12}_{6}C$: ***Carbon with 6 protons and 6 neutrons***
    - Carbon – 13: 1.07%

      $^{13}_{6}C$: ***Carbon with 6 protons and 7 neutrons***
    - Carbon – 14: 0.0000000001% (1ppt) : Trace

      $^{14}_{6}C$: ***Carbon with 6 protons and 8 neutrons***

The Periodic Table



The Periodic Table

- Understanding how information is organized on the periodic table will help you find valuable information about each element.
- For example:
  - The chemical and physical __________ of each element can be ____________ reasonably well.
  - Predictions on the _____________ of specific elements can also be predicted with information obtained from the table

Periodic Table Does

- Organized to ______________________
- Can be used to __________________ of undiscovered or unfamiliar elements.
- Can ______________ between elements without actually doing the experiment.

Periodic Table History

- Dimitri Mendeleev –
  - Credited with creating the periodic table
  - Arranged elements according to their _______ __________ and looked for _________.
  - Noticed ______________________in chemical and physical properties of elements.
  - Some atoms didn't fit when they were arranged by __________________.
    - Ex: ____________________ ________________
  - Left empty spaces on the table where he thought undiscovered elements would fit.
    - Predicted the properties of these elements.

Two Questions

1. Why could most of the elements be arranged in order of increasing atomic mass but a few could not?
2. Why did chemical periodicity, or similar chemical properties recurring in intervals occur?

Answers

- Henry Mosely –
  - Worked with Ernest Rutherford.
  - Examined the spectra of 38 different metals 40 years after Mendeleev's first table.
  - Discovered a ____________with the number of ________________ in the nucleus.
  - This is known as the __________________.
  - This is the current organization of the periodic table.

Follows the Law

- The Periodic Law –
  - The periodic table is ________ _______________________ so that elements _____________ __________________ show a distinct pattern.

Today's Periodic Table

- Changed extensively since Mendeleev's time.
  - New elements have been discovered.
    - 60 elements in 1860, ~115 elements currently
  - Some new elements have been synthesized in the lab.
  - All fit into a _________ having similar properties.
- The periodic table is an arrangement of the elements in order of their _________________ so that elements with similar __________ fall into the same ___________, or ___________.

Similarities in the Table

- __________ : _________ rows on the periodic table.
  - ____ periods on the table
  - ________ have similar properties.
  - The length of the period is determined by the ______________________that can occupy the sublevels being filled in that period.
  - ____________in a period always an extremely ___________. The ___________in a period is always an _______________.

Similarities in the Table

- ______ (or _____): ______ columns on the periodic table have ___________ properties.
  - ____ families on the periodic table
  - For example: Li, Na, K, Rb, Cs, Fr are all soft, white, shiny metals.
  - All elements in a family have the ___________ of __________________ and react similarly in chemical reactions.

____________ Metal Family

s^1

Li
Na
K
Rb
Cs
Fr

- Group ___
- Alkali metals all end in s^1
- The _______________ metals.
- React ______________ with water.
  - Due to extreme reactivity with air & water usually stored in ______.
- Combine vigorously with _____________.
- Never found as ____________in nature. Always bonded with another element.
- In their pure state, they are soft, silvery metals.
- Soft enough to be cut with a knife.

____________________ Metal Family

s^2

Be
Mg
Ca
Sr
Ba
Ra

- Group ___
- Alkaline earth metals all end in s^2
- _______________ than alkali metals but reactive enough to never be found _______________ in nature.
- Harder, denser, and stronger than alkali metals.
- __________ melting points than alkali metals.

______________ & ____________

s^1

H

- Hydrogen:
  - Is above Group 1 because of ____________, not _______________.
  - Is a class of its own
  - Has one ________ and one ____________.
  - Has one energy level.
  - Only needs ____________to fill its valence shell.

s^2

He

- Helium:
  - Only needs ____________to fill its valence shell.
  - Is part of the "_______________" Group.

______________ Family

p^1

B
Al
Ga
In
Tl

- Group ___ (or ___)
- Named after the first element in the family.
- Elements in this group have _ valence electrons.
- Includes _____ which is a __________, the rest of the elements are _________.
- Includes __________ which is the most abundant metal in the earth's crust.

________________ Group

p^2

Be
Mg
Ca
Sr
Ba

- Group ___ (or ____).
- Atoms of this family have ___ valence electrons.
- Includes a non-metal, ____________, metalloids, and metals.
- The element Carbon is called the "_____ _____________".
  - There is an entire branch of chemistry devoted to carbon containing compounds – ___________ Chemistry.

________________ Family

p^3

N
P
As
Sb
Bi

- Group ___ (or ___).
- Atoms in this family have ___ valence electrons.
- Named after the first member of the group, Nitrogen.
  - Nitrogen makes up ___ of our atmosphere and is another element that is very important for life.
- Includes non-metals, metalloids, and metals.
- Tend to ____________ when they bond.

_____________ Family

p^4

O
S
Se
Te
Po

- Group ___ (or ___)
- Atoms in this family have ___ valence electrons.
- Most elements in this family _________ ________ when forming compounds.
- ________ is the most abundant element in the earth's crust. It is _____________ ________ and combines with almost all elements.

________________ Family

p^5

F
Cl
Br
I
At

- The elements in this family have ___ valence electrons.
- They are the __________________. They are never found free in nature.
- They react vigorously with most ________ to form _________.
- Fluorine and chlorine are _________ at room temperature.
- Bromine is a reddish __________.
- Iodine is a dark purple _________.
- Astatine is a synthetic element that is solid at room temperature.

__________________Family

p^6

He
Ne
Ar
Kr
Xe
Rn

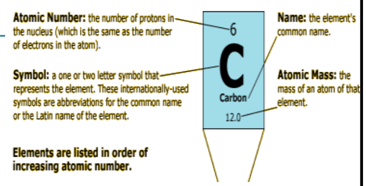
- Noble gases are _______________ that are extremely ______________.
- One important property of the noble gases is their inactivity. They are inactive because their ______________________ is _____.
- Because they do not readily combine with other elements to form compounds, the noble gases are called __________.
- All the noble gases are found in small amounts in the earth's _______________.

Key to the Periodic Table

- Elements are organized according to their ________ ___________.
  - The atomic number refers to how many _______ an atom of that element has.
  - For example, tungsten, W, has ____ protons so, its atomic number is ____.
  - REMEMBER! THE NUMBER OF ________ IN AN ELEMENT IS ______ TO THAT _______. IF THE NUMBER OF ____________________, IT IS A ______________________!

What's found in a square?

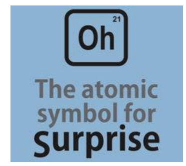
- Different Periodic Tables can include different amounts of information. The following are included most of the time:
  - – ____________
  - – ________
  - – ________



- The following are included some of the time:
  - Number of valence electrons
  - State of matter at room temperature.

Symbols

- As discussed previously:
  - All symbols have their own ________________.
  - It can consist of a single capital letter, or a capital letter and one or two lower case letters.

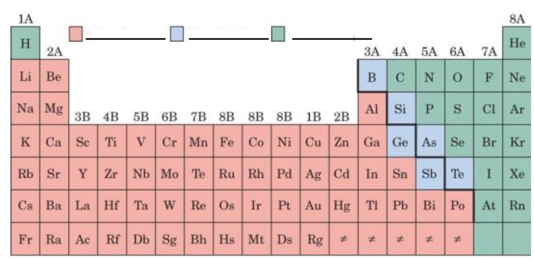


Be Careful!

- Always start a new element with a ______ ___________
- The second (third, etc.) letter in an element symbol is always ___________.
- For example:
  - C – __________
  - O – __________
  - CO – __________________
  - Co – __________
  - Ca - __________

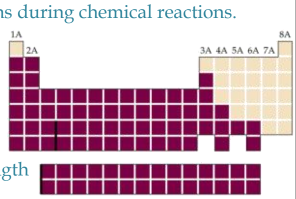
Categories of Elements

The elements on the periodic table can be divided into ________ main categories:



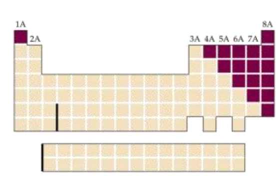
Metals

- On the _______ side of the periodic table.
- _____________ at room temperature
  - One exception is ______________, Hg (liquid).
- Form __________ (solutions of one metal dissolved in another); brass, for example, is an alloy of copper and zinc.
- Tend to _________ electrons during chemical reactions.
- Properties of metals:
  - – ________________
  - Conduct electricity & heat
  - – ________________
  - – ________________
  - High ___________ strength



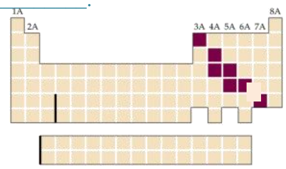
Non-Metals

- Lie on the ____ side of the table, except __.
- Do not conduct ______ or ___________.
  - Except graphite.
- Tend to _______ electrons during chemical reactions.
- _______

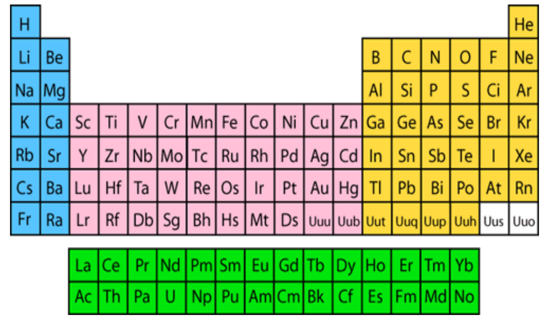


Metalloids

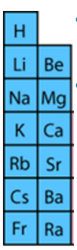
- A.K.A – Semi-metals
- Have characteristics of metals and non-metals.
  - Shiny or dull.
  - ___________
  - Conduct heat and electricity _______ than non-metals but not as good as _________.
  - ________ and _____________.
- Six Metalloids:
  - Boron, Silicon, Germanium, Arsenic, Antimony, and Tellurium.



I'm still Jenny from the block



The s-Block



- Contains only Hydrogen, Alkali, and Alkaline Earth metal groups.
- Maximum number of valence electrons is ____
  - Should include _______. Doesn't because helium and hydrogen are special because only have ___ s-shell to fill, ___ electrons.

The p-Block

Unwittingly, and against his mother's advice, Vince the first-row Transition Metal had been lured far away from home, and now found himself surrounded by heavier elements of the P-Block.

The p-Block

- Contains the Boron, Carbon, Nitrogen, Oxygen, Halogen, and Noble gas groups.
  - Except _________! It has no ____________.
- Are non-metals, metals, and semi-metals.
- Have valence electrons in ___, and _________
- Have between ______ valence electrons.
- _________ Number (or how many ________ they _____ or _____) very predictable.

The d-Block

- The "_____________ Metals"
- Have valence electrons in the ___ and ___ orbitals.
- Oxidations states more ______________
- They are all metals – ________________
- Some deviations occur in the _________ of these _________ by ____________.

The f-Block

- Or the "________ transition metals"
- Contains the ____________ and _________ series.
- _____________ are shiny metals, similar in reactivity to group ____ elements.
- ____________ are all ______________.
- Only the first ______ actinides have been found naturally, the rest are synthetic.

Trendy

- Trends we will study:
  - Atomic Mass
  - Atomic Number
  - State of Matter
  - Metallic Character
  - Atomic Radius
  - Ionization Energy
  - Reactivity / Bonding
  - Electronegativity

Atomic Size

- _______ are very small.
- We cannot see atoms or how they work.
- We know most of the ______ of the atom is centered in the ___________ – formed by ____________ and _____________.
- The size of an atom is measured from the _________ of its nucleus to the _____ of it's ___________________.

Atomic Radii

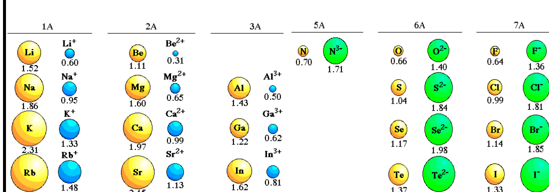
- An atoms size is ideally defined by the edge of its ________.
  - ____________ are not clearly defined, they are a ______________.
  - Vary under different conditions.
- Atomic _______ – ___________between the ______ of identical atoms bonded together
  - Estimation:
    - Dividing this distance by two gives the radius.

Ions

- _____ are formed when an atom ________or ________electrons
  - | Protons (positive charges) – Electrons (negative charges) | = Charge on Ion
    - _________: has _____ electrons - charge is positive
    - _______: has _______ electrons – charge is negative
- Some examples:
  - Sodium: ______________ electron – Na^{+}
    - ______________________________________
  - Magnesium: _______________electrons – Mg^{2+}
    - ______________________________________
  - Oxygen: _______________electrons – O^{2-}
    - ______________________________________
  - Nitrogen: ______________electrons – N^{3-}
    - ______________________________________

Ionic Radii

- ______________
  - Always leads to a decrease in atomic radii
- ______________
  - Always leads to an increase in atomic radii



Atomic Energy

- ________state: ______ energy of atom. All electrons are in the lowest possible energy levels.
- ________state: A state in which an atom has a _____ PE then it does in the ground state.

Bohr Model of the Atom

- The Bohr Model of the Hydrogen Atom –
  - Neils Bohr (1911) put together Rutherford's and Planck's ideas.
  - An electron is allowed to have only _________________ corresponding to different amounts of ___________.
- Bohr labeled each energy level/orbit by quantum number, n.
  - Lowest energy level is the _________________________
    - It is the orbital ____________ to the nucleus
    - When an electron ___________ the correct amount of _________, it jumps to a higher level called the excited state having quantum numbers n=__, n=__, n=__, etc.
      - This is called ________________.
    - When an electron _______ from an excited state back to ground state, _______________.
      - This is called ________________.

Bohr Model of the Atom

- The Schrödinger Wave Equation – Laid the foundation for ____________________________ which describes mathematically the wave properties of electron and other very small particles.
- A New Approach to the Atom
  - Quantum – Mechanical Model:
    - electron is a ______ that has _____________ its energy.
    - describes the _________ that electrons will be found in ____.
- Probability and _____________
  - Density of an electron cloud – _________________ an electron likely to be _______ areas of ________________ have ______ electron density.

Orbitals

- Regions around the nucleus of an atom where an electron with a given energy is likely to be found.
  - orbitals have characteristic _______, _______ and _________
  - orbitals do NOT describe the path of an electron.
  - Four different kinds of orbitals determined by fundamental shape.
    - ___ – spherical
    - ___ – dumb-bell
    - ___ - more complex
    - ___ - more complex

Orbitals

- **Orbitals and Energy**
  - Principle energy levels are designated by ____________ __________, __, called the ___________________________.
  - Each principal energy level is divided into ____________
    - number of sublevels in each principal energy level = the quantum number, n, for that energy level for n=1 to n=4.

___ = 1 orbital, $2e^-$ a. n=___ has ___ sublevel ___

___ = 3 orbitals, $6e^-$ b. n=___ has ___ sublevels ___, ___

___ = 5 orbitals, $10e^-$ c. n=___ has ___ sublevels ___, ___, ___

___ = 7 orbitals, $14e^-$ d. n=___ has ___ sublevels __, __, __, __

e. n=___, ___, or ___ also has ___ sublevels

Orbitals

- Each principal energy level consists of one or more sublevels and each sublevel consist of one or more orbitals.
  - n=__ has __ sublevel, __, and its orbital is the __ orbital
  - n=__ has __ sublevels, __ and __, and its orbitals are ____, ____, ____ and ____
    - ____ is spherical but larger than ___
    - 2p sublevel has _____ p orbitals at right angles to each other, _____, _____ and _____ (3-D space)

Orbitals

- n=__ has __ sublevels, __, __ and __
- Orbitals
  - ____ - spherical and larger than ____
  - 3px, 3py and 3pz
  - 5 d orbitals: 3dxy, 3dxz, 3dyz, $3d_{x^2-y^2}$, $3d_{z^2}$
  - n=__ has __ sublevels, __, __, __ and __
- Orbitals
  - _______ 4s orbital
  - _________ 4p orbitals
  - ________ 4d orbitals
  - _________ 4f orbitals

Electron Spin

- Electrons have characteristic __________ and _______
  - ______ can be clockwise or counter clockwise
  - Spinning creates a ______________ field
- Wolfgang Pauli (1925) showed how electron spin was important in how electrons are arranged in atoms
  - _________________________states that each orbital can hold at most _____ electrons with ___________ spins
    - s-sublevel holds ___ electrons
    - p-sublevel holds ___ electrons
    - d-sublevel holds ____ electrons
    - f-sublevel holds ____ electrons

Quantum Numbers

- n = principal quantum number.
  - Energy levels ____
- ___= angular momentum quantum number.
  - Sublevels
    - ℓ = __ → s – sublevel
    - ℓ = __ → p – sublevel
    - ℓ = __ → d – sublevel
    - ℓ = __ → f – sublevel
- m_ℓ = magnetic quantum number
  - Orientation of orbital
    - $-\ell \leq m_\ell \leq \ell$
- m_s = spin quantum number
    - s = $\pm$ ½

Electron Configurations

_______________ Configurations

a. The distribution of electrons among the ___________

b. Determining _____________________________ and _____ _____________________________

c. Determined by _____________ the atoms ____________ among _______, _________ and _________ based on a set of stated principles

d. Determining electron configurations

- When electrons occupy the lowest energy level possible, the atom is in its ground state
  - _______________, ______________________

Electron Configurations

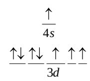
e. Three rules for determining electron configurations

- The _______________________:
  - Electrons are added _______________________________ orbitals ____.
- _____________________________:
  - _____________can hold a ______________ with opposite spins. ____________________can have the ____________ ________________________.

- _______________ : ___________________________________ ______________________________________.
  - Orbitals of equal energy are each occupied by 1e⁻ before any orbital is occupied by a 2nd electron and all e⁻'s singly occupied orbitals must have the same spin.
    - Example: $^{12}_{6}C = \_\_\_\_ e-$ **orbital notation:** $\_\_ \; \_\_ \; \_\_ \; \_\_ \; \_\_$ (1s 2s $2p_x$ $2p_y$ $2p_z$)
  - Full electron configuration C: $1s^2 2s^2 2p^2$
- Diagonal Rule

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d 6f
7s 7p 6d 7f

- More Examples:
  - Write electron configurations for Potassium (19) and Cobalt (27). How many unpaired electrons?
    - Potassium →
    - Cobalt →
- Exceptions to the Aufbau Principle
  - Chromium (24)
    - Expected: $1s^22s^22p^63s^23p^64s^23d^4$
    - Exception: $1s^22s^22p^63s^23p^64s^13d^5$



- Copper (29)
  - Expected: $1s^22s^22p^63s^23p^64s^23d^9$
  - Exception: $1s^22s^22p^63s^23p^64s^13d^{10}$
- Noble Gas Convention and Lewis Dot Diagrams

  ___________________: Those electrons in the outermost energy level that are responsible for bonding.

Let's Try One…

- Let's try Arsenic, As
- How many electrons are in a neutral atom of Arsenic?
  - The same as the number of _______ because it is neutral.
  - The same as the ___________ number.
  - ___________________.
- Here we go!

Noble Gas Notation

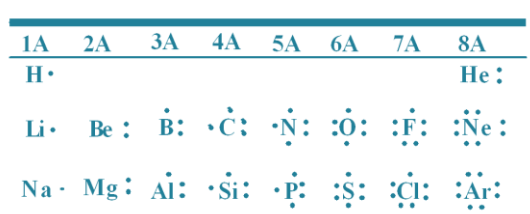
- Noble Gas Notation
  - The symbol of the noble gas immediately preceding the particular atom indicates the electron configuration of all filled shells.
  - For example: Carbon
  - How many electrons?
    - ____

Orbital box diagram | Electron Configuration (condensed) | Noble Gas Notation

Lewis Dot & the Valence Shell

- So what exactly is a valence shell?
  - The ___________________________________ shell
- Lewis Dot Structure
  - An easy way to show valence or "bonding" electrons.
  - The symbol of the element represents the nucleus and all filled shells.
  - Dots are placed around the symbol to represent valence electrons available for bonding.

Lewis Dot Structure



Noble Gas Notation & Lewis Dot Structure

- Alkali Metals:

Element	Noble Gas Notation	Lewis dot Structure
Li	$[He]2s^1$	Li•
Na	$[Ne]3s^1$	Na•
K	$[Ar]4s^1$	K•
Rb	$[Kr]5s^1$	Rb•
Cs	$[Xe]6s^1$	Cs•

a. Lithium

b. Calcium

c. Aluminum

d. Bromine

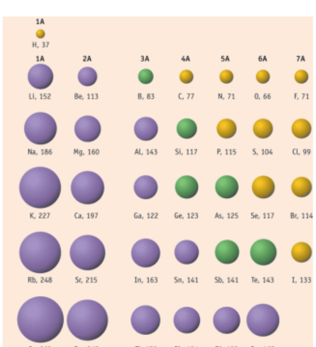
Periodic Trends

- Now that we have a better understanding of electron configuration, let's look at some more trends.
- Let's take a look at two in particular:
  - Atomic Size
  - Ionization Energy

Magnets

- What's important with magnets?
  - _______
  - ___________
- Protons and electrons are like oppositely charged magnets.
  - _________ has a greater affect than ______.

Atomic Size



- Atomic Radii of the "Main Group" elements.
- What do you notice?
  - ________________
  ____
  ________________.

Atomic Size

- As we move from the top of the table to the bottom the size of the atoms _____________. Why?
  - What is important with magnets?
    - ___________________________
  - What is happening to the magnet's size as we move down the columns?
    - _________________________
  - What is happening to the distance between the charges as we move down the column?
    - _________________________.
- If you recall, I mentioned one of this is more important than the other, which one?
  - ___________

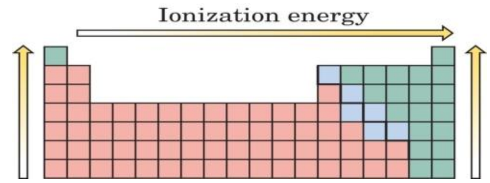
Ionization Energy

- This is the energy required to ________________________ held ______________ from an atom in the gaseous state.
- For example: Sodium, Na
  - When sodium loses an electron, it becomes a sodium ion. It still has 11 protons in its nucleus, but now only 10 electrons outside the nucleus, and therefore, a positive charge!

Na (g) + energy → Na^{+}(g) + e^{-}
Sodium Ionization Energy Sodium Ion electron

Ionization Energy

- A Periodic Property



- In general, increases _____ and to the ____ on the table.

Ionization Energy

- Why does it increase as we move from left to right across a row?

Ionization Energy

- Why does it increase as we move up a row?