Chemistry Unit 5

Primary reference: *CHEMISTRY*, Addison-Wesley

Topic	Essential Knowledge	Study Support
Scientific Investigation 1.5 **SOL 1f**	Practice safe use of chemicals and equipment Recall that percent error = $\frac{\text{experimental} - \text{theoretical (true)}}{\text{theoretical (true)}} \times 100$	
Atomic Structure and Periodic Relationships **2.5** **SOL 2d,e,f,g,h,i**	Going down a group on the Periodic Table, each element has one more principal energy level filled with electrons than the element above it, so the outer electrons are farther away from the nucleus. Thus, the size of the atoms increases going down a group. Therefore **the atomic radius increases going down a group**. Going from left to right across a period of the Periodic Table the valence electrons are all in the same principal energy level, but the number of protons in the nucleus increases. Thus, the nucleus is more positively charged and attracts the electrons more strongly. Therefore**, the atomic radius decreases going from left to right across a period**. The **shielding effect** is constant across a given period and increases within a given group from top to bottom. Cations are smaller than their parent atom, anions are larger. **Ionization energy** is the energy needed to remove a valence electron from an atom. **Ionization energy increases going from left to right across a period** of the periodic table because the atomic radius decreases, which means that the valence electrons are held more tightly by the nucleus. **Ionization energy decreases going down a group** because the valence electrons are further away from and more loosely held by the nucleus. **Electronegativity** is the ability of an atom in a bond to attract electrons. The **electronegativity increases across a period** of the periodic table (because the atomic radius decreases, which means that the valence electrons are held more tightly by the nucleus). The noble gases have virtually no electronegativity as the valence shell is full. The **electronegativity decreases down a group** (because the valence electrons are further away from and more loosely held by the nucleus).	**Ch 14**: Read pp. 398-406.
Nomenclature, Formulas, and Reactions **3.5** **SOL 3c, 3d**	Elements with low ionization energies or high electronegativities have high **reactivities**. Alkali metals lose electrons easily to become cations, whereas halogens easily gain electrons to become anions.. Bonds form between atoms to achieve stability (meeting the **octet rule)**. In **covalent bonds**, atoms share electrons. In **ionic bonds**, atoms transfer electrons. A covalent molecule can be represented by **Lewis structures** where each bonding pair of electrons is represented by a pair of dots or single line. Covalent bonds may be single, double or triple. Valence Shell Electron Pair Repulsion **(VSEPR)** Theory is used to predict the shape of a molecule around a central atom. The shapes include: **linear, trigonal planar, tetrahedral, pyramidal**, and **bent**.	**Ch 16** Read pp. 437-443 on covalent bonding. Read pp. 455-457 on VSEPR theory.
Molar Relationships 4.5 **SOL 4b**	**Theoretical Yield** is the amount of reaction product calculated using stoichiometry. **Actual Yield** is the amount of product recovered (usually some is lost). **Percent yield** is the ratio of actual yield to theoretical yield, multiplied by 100. The equation is **% yield =** $\frac{\textbf{experimental yield}}{\textbf{theoretical (true) yield}} \times 100$	**Ch 9**: Read pp 256-258 on percent yield
Phases of Matter and Kinetic Molecular Theory **5.5** **SOL 5b**	The following mathematical relationship between the pressure, volume and temperature of a gas is used to describe the behavior of gases: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ An Ideal Gas does not exist, but this concept is used to model gas behavior. A Real Gas exists, has intermolecular forces and particle volume, and can change states. The Ideal Gas Law states that $\boxed{PV = nRT}$. R is the ideal gas law constant and has two values depending on the pressure units. They are **R = 8.314 L·kPa/mol·K and R = 0.0821 L·atm/mol·K**	**Ch 12**: Review pages 330-332 on pressure, volume and temperature. Read pp. 339-340 on the combined gas law. Read pp. 341-345 on the ideal gas law.

Unit 5 Objectives

Chemistry, Addison-Wesley, 2002

I) Gas Laws
   A) Combined Gas Law
   B) Ideal Gas Law
II) Chemical Periodicity
   A) Development of the Periodic Table (read pages 390-396)
   B) The Modern Periodic Table/Periodic Law (p 124 and 390-396)
   C) Electron Configurations in The Periodic Table (already covered) (p 390-396)
   D) Periodic Trends
      1) Trends in Shielding Electrons and Effective Nuclear Charge (p 400-401)
      2) Trends in Atomic Size (p 398-401)
      3) Trends in Ionization Energy (p401-403)
      4) Trends in Electronegativity (p405-406)
      5) Trends in Ionic Size(p403-404)
   E) Predicting Element Reactivity from Electronegativities and Ionization Energies.
III) Stoichiometry: Percent Yield (Read pages 256-258)
IV) Covalent Bonding:
   A) Single Covalent Bonds
   B) Double and Triple Covalent Bonds
   C) Drawing lewis dot or line structures for Covalent Compounds
      1) Molecules
      2) Polyatomic Ions
   D) VSEPR Theory (3-dimensional molecular structures)

Objectives and (SOLs)

1) (5b) Solve gas law problems using the Combined Gas Law and the Ideal Gas Law.
2) (5b) Explain the difference between a real gas and an ideal gas.
3) (5b) Predict when a gas will behave most ideally.
4) (2i) Describe the contributions of Mendeleev and Moseley to developing the periodic table.
5) (2f) Define atomic radius, ionization energy, electronegativity and shielding effect
6) 2f) Explain how and why atomic radius, ionization energy and electronegativity show periodic trends in terms of shielding electrons, principle energy levels, and nucleus charge
   a) identify how atomic radius changes across a period and down a family.
   b) identify how first ionization energies change across a period and down a family
   c) identify how electronegativity changes across a period and down a family.
   d) predict the size of an ion versus its parent element.
   e) explain the periodic trends (atomic radius, first ionization energy, elecronegativity) in terms of shielding electrons and effective nuclear charge.
7) (4b) Calculate the theoretical yield, actual yield and percent yield of a chemical reaction.
8) (3d) Compare ionic bonding to covalent bonding
9) (3c) Draw Lewis dot or line structures of molecular compounds and polyatomic ions.
10) ((3d) Predict the geometry of simple molecules with one central atom.

Chapter 12 Note Guide Part 2: Combined Gas Law

Gas Law Review
A) Boyle's Law (Volume-Pressure Change)

Math Equation: $P_1V_1 = P_2V_2$
Direct or *Inverse* Relationship?
Which of the 3 variables is constant?

B) Charles's Law for Temperature-Volume Change

Math Equation: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Direct or *Inverse* Relationship?
Which of the 3 variables is constant?

C) Gay-Lussac's Law (Pressure-Temperature Interaction)

Math Equation: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
Direct or *Inverse* Relationship?
Which of the 3 variables is constant?

The Combined Gas Law

1) All these laws can be combined into the Combined Gas Law and used to solve problems where two variables change simultaneously. You can always use this one! Just remove the one that's constant and you will instantly get one of the 3 original ones.

2) Math Equation: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Example 1: A balloon contains 15 liters of Helium in Williamsburg at 99.2 kPa and 25°C. What will be the volume of the balloon on Mount Everest at 34 kPa and -32°C?

Example 2: A 550. mL sample of gas at 25°C occupies 1200 mL at 45°C and 200. kPa. What was the sample's original pressure?

Example 3: A weather balloon has a volume of 42 liters at 1.0 atmospheres and 20°C. As the balloon rises to 15,000 meters, the atmospheric pressure drops to 0.25 atmospheres and the balloon's volume increases to 143 liters. What is the temperature at 15,000 meters?

Example 4: A gas is compressed from 6.82 atm to 70% of the starting pressure, and the temperature is tripled from 150°C. What is the final volume if the initial volume was 333 L?

<u>Advanced</u> Example: A spherical weather balloon (diameter of 1.20 m) starts on the ground at 32°C (which is nearly 90°F). The pressure on the ground is 14.7 psi. The balloon is released into the air; at an unknown height *x* meters above the ground, the diameter of the balloon expands to 1.50 m, and the temperature drops to 12°C. What is the internal pressure of the balloon in kPa at height *x*?

In general, what happens to atmospheric pressure with an increase in altitude?

In general, what happens to atmospheric temperature in the troposphere with an increase in altitude?

The Ideal Gas Law (Putting it all together)

1) Ideal Gas Law accounts for the **amount (moles)** of gas.

2) Math Equation: PV = nRT

P=	T=
V=	R= 8.31 kPa•L/mol•K or 0.0821 atm•L/mol•K
n=	

3) **Caution**: Use the correct units (kPa, Liters, moles, K, and R units)

Example 1: How many moles of helium will be required to fill a balloon to 16 liters in Denver on a nice summer day(83 kPa, 30.°C)?

PV = nRT where R= 8.31 kPa•L/mol•K or 0.0821 atm•L/mol•K

Example 2: A 25 liter gas cylinder is filled with 139 moles of oxygen at 23 °C. What will be the pressure inside the cylinder in atmospheres?

Example 3: 13 grams of NO_2 is placed in a 2.0 liter tank at 302 Kelvin. What is the pressure inside the tank in atmospheres?

Example 4: How many grams of Xenon gas are needed to pressurize a 5.0 liter tank to 520 kPa at 55˚C?

4) Issues with the Ideal Gas Law

Ideal Gas Behavior	Real Gas Behavior
Gas particles have negligible volume compared to container size	
Gas particles do not attract or repel each other	
Therefore:	Therefore:

Chapter 14: The Periodic Table

I. **Historical Development of the Periodic Table.**

A. 1869: Mendeleev arranges the 63 known elements by increasing atomic number so that regular periodic (repeating) trends appear. He leaves blanks for three missing elements (Ga, Sc, Ge). Note, the noble gases were not isolated until the 1890's***.***

B. 1913 Moseley determines the nuclear charge, number of protons, in the elements and reorders the periodic table by atomic number.

II. **Organization of the Modern Periodic Table**

A. Columns are called _____________ or ________________

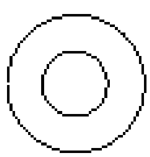
Groups show common physical properties and chemical reactivity.

B. Rows are called __________________.

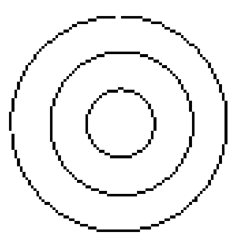
The period number matches the _________________________________ of the valence electrons.

Bohr Models

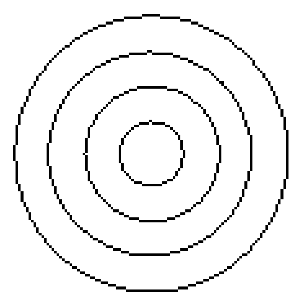
Hydrogen



Lithium



Aluminum



III. **Valence electrons determine the chemical properties of compounds.**

Valence electrons:____

____

A. Noble gases (Group ______) electron configurations

He:

Ne:

Ar:

What are shielding electrons?____

____

In the noble gases, the valence electron shell or outer principle energy level is ________.

B. Representative elements (Groups ___, ___, ___, ___, ___, ___, ___,____)

B:

S:

K:

1. Element's group or family number identifies the number of ______________ electrons.
2. Elements row or _______________ identifies the ______________________________.

C. Element Properties due to valence electrons, nuclear charge, and shielding electrons:

1. Atomic Radius____
2. Ionization Energy____

   ____
3. Electronegativity____

   ____

Chapter 14: Periodic Trends Notes

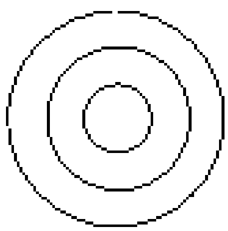
Periodic Law: When elements are arranged in increasing order of atomic number there are trends or patterns in their chemical and physical properties.

Shielding Electrons____

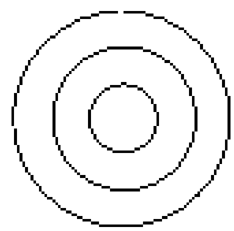
____

- As you move down a group, the number of shielding electrons increases. As you move across a row, the number of shielding electrons stays the same.

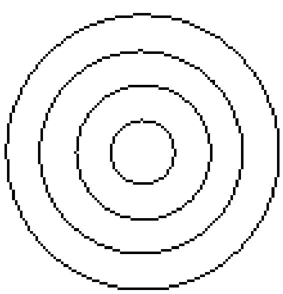
Li:



Ne:



Na:



Effective Nuclear Charge:____

____

- As you move down a group, the effective nuclear charge decreases because the valence electrons are in higher principal energy levels. (Shielded by more electrons and farther away from nucleus.)

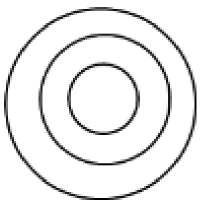
- As you move across a period, the effective nuclear charge increases as the nucleus adds protons (attractive pull for electrons), but the new electrons are added to the same principal energy level. The number of shielding electrons stays constant.

Atomic Radius

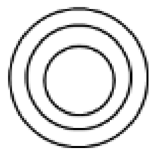
- Group Trend—The atomic radius increases down a family because the valence electrons are in higher principle energy levels and thus farther from the nucleus.
- Periodic trend – The atomic radius decreases across a period because protons are added to the nucleus while the number of shielding electrons stays the same. The greater effective nuclear charge pulls the valence electrons closer to the nucleus.

Let’s compare Li, Ne and Na by drawing Bohr models.

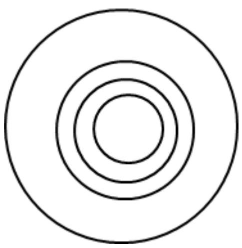
Li:

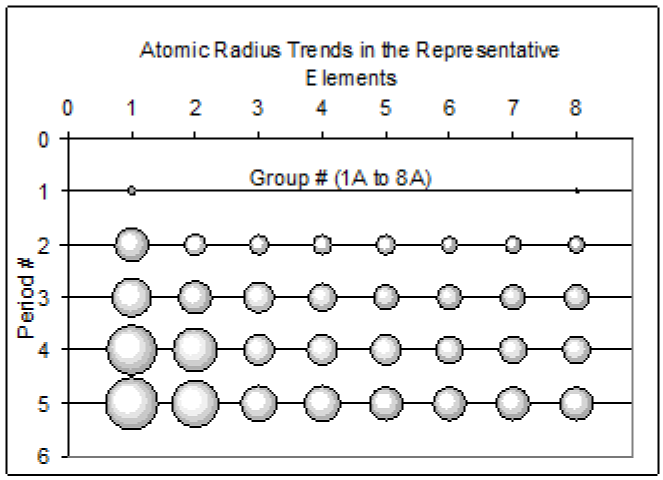


Ne:



Na:





First Ionization Energy: Energy to remove the first valence electron from a neutral atom.

- **Group Trend**: Decreases down a group as valence electrons are in higher principle energy levels and farther from the nucleus. (It takes less energy to remove the valence electron).
- **Periodic Trend**: Increases across a period because the valence electrons are closer to the nucleus.

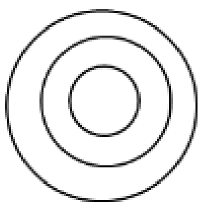
Electronegativity: The tendency of an atom to attract electrons to itself in a chemical bond (tendency to become an anion)

- **Group Trend:** Electronegativity decreases down a group/family because the valence shell is farther from the nucleus so valence electrons feel less electrostatic attraction.

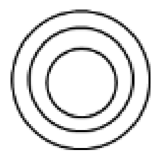
- **Periodic Trend**: Electronegativity increases across a period toward the halogens because the valence shell is closer to the nucleus as you move across a period. BUT, noble gases have a full shell, so new electrons must enter a higher principle energy level.

Let's compare Li, Na, F and Ne.

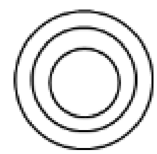
Li:



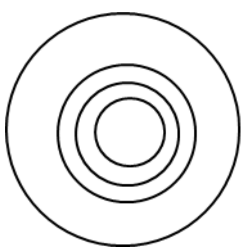
F:



Ne:



Na:



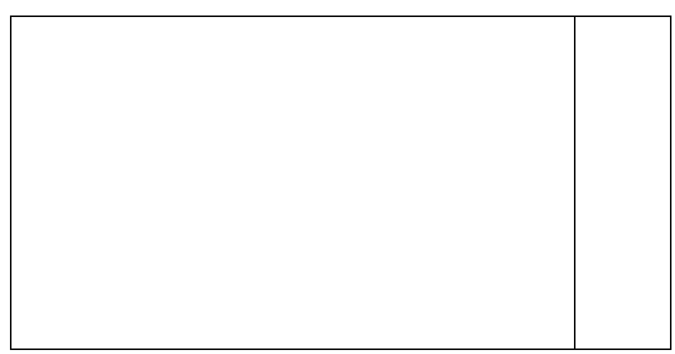
<u>The Electronegativity Rap</u>

E-lec-tro-neg-a-tiv-i-ty
It's where electrons wan-na be
Going up a group is heaven
They don't like period seven
The halogens are really hot
Electrons join them like a shot
Noble gases have a full shell
Electrons aren't wanted, oh well

Summary of periodic trends

To the tune of "Brother John"

Francium's big, Francium's big
Neon's small, Neon's small
Fluorine loves electrons
Flourine loves electrons
Francium don't
Francium don't



Ionic Size

Cations are always ________________ than the original atom.

Why: The effective nuclear charge on the reduced number of electrons is greater.
The number of principle energy levels decreases.

Example Mg vs Mg^{2+} (136 picometers vs 86 picometer radius)

Anions are always _____________________ than the original atom.

Why: The effective nuclear charge on the increased number of electrons is reduced.

Example: F vs F^- (64 picometers vs 119 picometer radius)

Periodic Trends and Element Reactivity

Reactivity:____

____

The halogens are very reactive due to high electronegativity. So the most reactive halogen is ____________. The alkali metals are very reactive due to low ionization energy. The most reactive alkali metal is ________________.

PERIODIC TRENDS

The term *periodic* means *repeating*. The periodic table has trends that repeat across periods (rows).

Lithium is an alkali metal in **period 2**, and its chemical reactivity is similar to **sodium**, an alkali metal in **period 3**. What is the name of the alkali metal in period 4? ____________________

Helium, **neon**, **argon**, **krypton**, **xenon**… how are they all similar?

They're all nobel (inert or non-reactive) gases, and they're all in the group, but different periods.

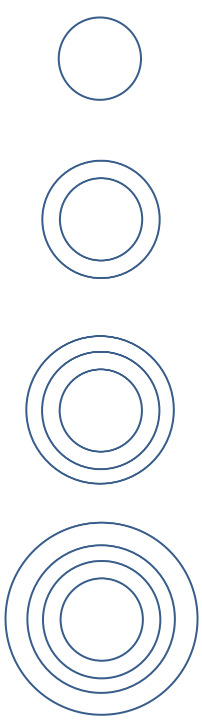
There are 3 main periodic trends to know:

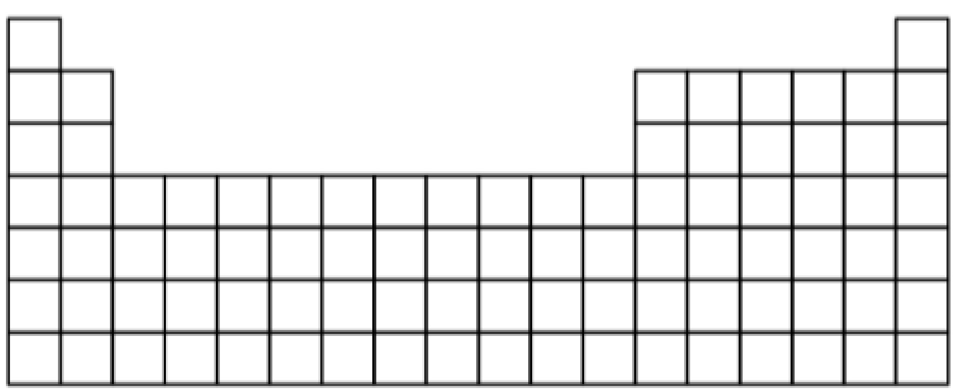
- _______________ ________________: How ***big*** is the atom?
- ________________________________: How much does the atom ***want or hog electrons*** when it's in a compound?
    - You know how sodium has that *1 valence electron that it doesn't really want*?
        - Sodium isn't very electronegative. It really doesn't want to add electrons.
    - …and chlorine has *7 valence electrons*, but it realllllllllly wants 8 so it looks like argon?
        - Chlorine is pretty electronegative. It likes to hog electrons.
- ________________________________: ***How much energy does it take to steal an electron*** from the valence (outer) shell of the atom in the gaseous state?
    - Do you think it's easy to steal sodium's valence electron?
        - YES! It doesn't want it anyway. Sodium's first ionization energy is pretty low.
        - $Na(g) \rightarrow Na^{+}(g) + e^{-}$ … Easy. Doesn't take a lot of energy.
    - Do you think it's easy to a valence electron from chlorine?
        - NO! It wants to add, so taking it away is hard.

Atomic Radius Trend of *Neutral* Compounds

(Within periods, and within groups)

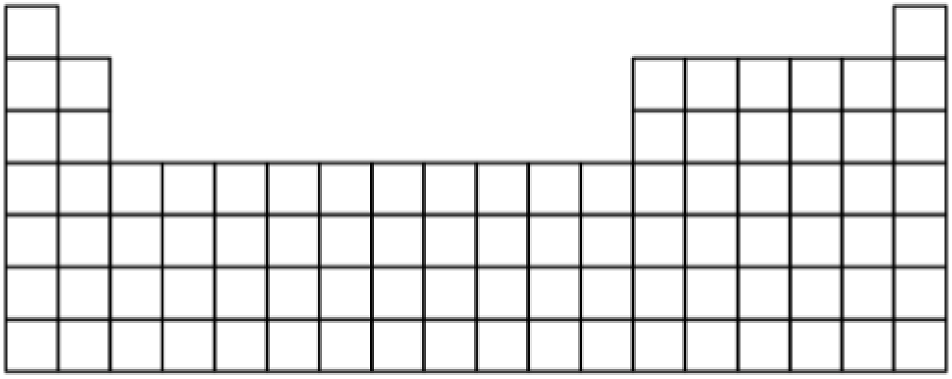
HUGE tip: ____________________ is the largest atom. Atomic size for neutral atoms increases going ___________ a group, and ___________________ going right toward the noble gases.





Electronegativity Trend

HUGE tip: ___________________ is the most electronegative element. Electronegativity (represented by unitless numbers) is increases upward and to the right, toward ___________________.

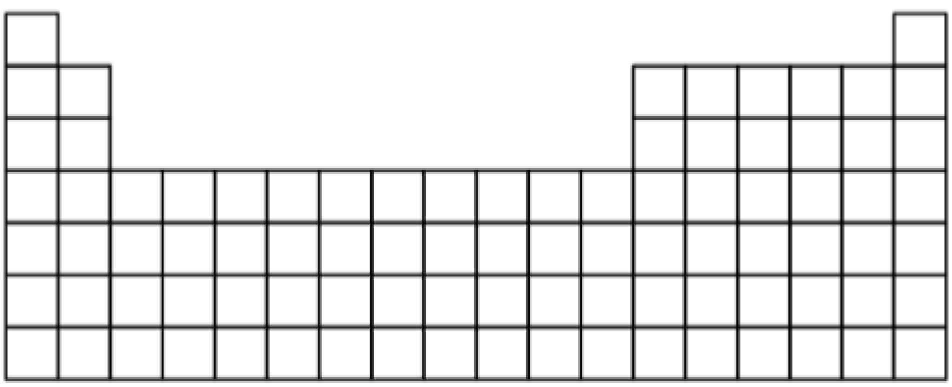


Ionization Energy Trend & Electron Affinity Trend

Ionization Energy: This is the amount of energy (in joules or kilojoules) it *REQUIRES* to remove an electron from an atom.

Electron Affinity: This is the amount of energy that is *RELEASED* when an electron is added to an atom.

HUGE tip: The ____________________ an atom is, the ___________________ it is to remove an electron. (Think of the mom with kids in Walmart example.) So, a larger atom has a lower _________________ energy.



Chapter Nine Part 2: Percent Yield in Stoichiometry Problems

Percent Yield =

Example 1:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

What is the percent yield of product if 2.0 moles of N_2 reacts with excess hydrogen to produce 3.6 moles of ammonia, NH_3?

Step 1: Calculate Theoretical Yield (Do Stoichiometry)

Step 2: Calculate Percent Yield

Example 2:

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

8.2 moles of ethane, C_2H_6, reacts with excess oxygen to produce 22 moles of water. What was the percent yield of water?

Example 3:

$$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s)$$

6.00 grams of aluminum reacted with excess bromine to yield 50.3 g of Aluminum Bromide. Calculate the percent yield for this experiment.

Example 4:

$$2Fe_2O_3 + 3C(s) \rightarrow 3CO_2 + 4Fe$$

250 grams of Iron(III) oxide reacts with excess carbon to form 140 grams of pure iron. What is the percent yield of iron?

Chapter 16: Covalent Bonding

Introduction

I) Why do atoms bond?
   A) The new compound has lower energy than lone atoms
   B) atoms take on noble gas configuration (octet rule)

II) Two Types of Compounds/Bonds
   A) Ionic bonding
      1) Composed of a metal ___________ + a nonmetal _____________
      2) Cation gives up valence electrons to anion
      3) Results in charge difference causing attraction and bonding
      4) Example: NaCl

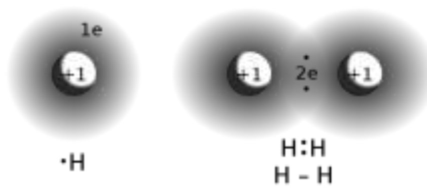
I) Covalent Bonding (found in molecules)

   A) Composed of two or more ___________________

   B) Atoms _____________________________________ electrons to fulfill the octet rule

   C) Examples of sharing one pair of electrons: _____________________________

      H_2



      F_2:

      H_2O

1) Draw the following compounds with single covalent bonds: HF, ClF, H_2**S**, **N**H_3, **C**H_4. Circle the lone pairs.

Lone pair: ____

____

D) Example of sharing two pairs of electrons __________________________________

O_2

E) Example of sharing three pairs of electrons ________________________________

N_2

F) Drawing Lewis Structures (a.k.a. Structural Formulas) of molecular compounds.

Replace pairs of bonding electrons with dashes

Symbol	Represents
	represents a lone pair, or an unshared pair of electrons
	represents a single bond, or one shared pair of electrons
	represents a double bond, or two shared pairs of electrons
	represents a triple bond, or three shared pairs of electrons

Examples: HF, O_2 , N_2, **N**H_3

Chapter 16: Drawing Lewis Structures of Molecular Compounds and Polyatomics

1. Count the valence electrons. For a polyatomic anion, add one electron for each negative charge.
2. Connect the atoms by single bonds around a central atom. Remember, each single bond uses two electrons.
3. Fill the outside atoms with electrons to meet the octet rule. Remember, H can only have two electrons.
4. Use any remaining electrons to fill the octet on the central atom.
5. If the central atom does not have a full octet, share lone pairs from the outside atoms to form double or triple bonds.

Note: If you have an odd number of valence electrons to start with, you will never get octets around all the atoms!

Examples: Indicate the number of lone pairs for each compound

$H_2\mathbf{O}$

$\mathbf{C}O_2$

$\mathbf{S}O_3$

$\mathbf{C}Cl_4$

Chapter 16: VSEPR Theory

Valence **S**hell **E**lectron **P**air **R**epulsion **T**heory

Facts:

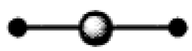
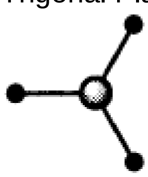
- Structural Formulas are 2-D, but molecules are 3-D structures
- Lone electron pairs repel each other and bonded pairs
- Electron pairs in different bonds repel each other

VSEPR Theory: ____

____

Note: a double or triple bond counts as one electron "region"

Determining Electron Region Geometries and Molecular Geometries

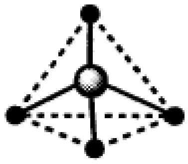
Electron Region Geometry	**Examples:**	**Molecular Geometry (atoms only)**
Linear  angle =	**C**O_2	Molecular Geometry:
Trigonal Planar  angle:	**S**O_3	Molecular Geometry: Angle:
	O_3	Molecular Geometry: Angle:

Why is the O-O-O angle 117º and not 120º?

Effect of Lone Pairs on Geometry: ____

____

____

<table>
<tr><td rowspan="3">Tetrahedral

angle:</td><td>$\mathbf{C}H_4$</td><td>Molecular Geometry:

Angle:</td></tr>
<tr><td>$\mathbf{N}H_3$</td><td>Molecular Geometry:

Angle:</td></tr>
<tr><td>$H_2\mathbf{O}$</td><td>Molecular Geometry:

Angle:</td></tr>
</table>

How to figure out molecular geometry:

1. Draw Lewis structure
2. Determine the Electron Region Geometry
3. Determine the Molecular Geometry

Practice:

<table>
<tr><td>$\mathbf{Cl}O_2^-$</td><td>$\mathbf{S}Cl_2$</td></tr>
<tr><td>$\mathbf{N}H_4^+$</td><td>$\mathbf{P}O_3^{3-}$</td></tr>
</table>

Examples: Draw the structure including lone pairs, then figure out the shape

$H\mathbf{C}N$	O_3
$\mathbf{Si}O_2$	$\mathbf{N}O_2^-$
$\mathbf{N}O_3^-$	$\mathbf{P}O_4^{3-}$
$\mathbf{S}O_3^{2-}$	$\mathbf{C}H_2Br_2$
$\mathbf{N}_2O$	$\mathbf{C}OCl_2$