Unit 2

Atoms, Molecules and Ions

Objectives

- Identify three scientific laws and explain what each means.
- Discuss Dalton's Atomic Theory and what components are still considered accurate today.
- Identify the experiments that led to the nuclear atomic model and explain what was learned about each.
- Describe atomic structure and define atomic number and mass number
- Determine the atomic number and mass number of an isotope.
- Discuss the properties of the Alkali Metals, Alkaline Earth Metals, Transition Metals, Halogens and Noble Gases.
- Identify metals, nonmetals and metalloids on the periodic table and classify their properties.
- Describe the different types of compounds.
- Classify some properties of ionic compounds
- Interpret, predict, and write formulas for ionic and molecular compounds
- Name ionic and molecular compounds

Outline

- Unit 2: Atoms, Molecules and Ions
- Early Ideas about Chemistry
  - Scientific Laws
    - Law of Conservation of Matter
    - Law of Definite Proportions
    - Law of Multiple Proportions
  - John Dalton and the Atomic Theory
- Discoveries Leading to the Nuclear Atomic Model
  - Cathode Rays
  - Milikan's Oil Drop Experiment
  - Rutherfold's Gold Foil Experiment
- Structure of the Atom
  - Overview of the Atomic Structure
  - Isotopes
    - Atomic Number
    - Mass Number
  - Ions
- Introduction to the Periodic Table
  - Organization
  - Groups and Families
- Types of Chemical Bonds
  - Introduction to Bonding
  - Covalent Bonds
  - Ionic Bonds
    - Polyatomic Ions
- Chemical Formulas
  - Molecular Formulas
  - Formulas of Ionic Compounds
    - Binary Ionic Compounds
      - Metals and Nonmetal designations
      - Use of the Stock System for Transition Metals
    - Ionic Compounds Containing Polyatomic Ions
  - Acids
- Naming Molecules
  - Molecular Compounds
  - Ionic Compounds
    - Type I Ionic Compounds
    - Type II Ionic Compounds
  - Acids and Bases
  - Hydrates

Early Ideas about Chemistry

- Chemistry dates back to ancient Greece.
  - Wanted to explain reactions they observe.
- Alchemy was the “science” that first developed.
  - A few elements were discovered.
  - Were able to prepare a few simple compounds.
- Modern chemistry developed in 18th century.
  - Robert Boyle
  - Charles Dalton

Law of Conservation of Mass

- Mass is neither created nor destroyed in a chemical reaction.

- It changes form.

Law of Definite Proportions

- A given compound will always contain the same proportion of elements by mass.

- H_2O will always contain 2 H and 1 O atom

- H_2O will always contain
  - 2 x 1.01 g H = 2.02 g H
  - 1 x 16.00 g O = 16.00 g O

Law of Multiple Proportions

- When two elements form a series of compounds the ratios of the masses of the second element that combine with 1 gram of the first element can always be reduced to small whole numbers.

- Simplified: If two elements combine in different ratios, the compounds are different.

Law of Multiple Proportions

- Water is always H_2O 1 H : 2 O
- Hydrogen peroxide is always H_2O_2 2 H : 2 O
- They cannot be the same because the ratios are different.

Law of Multiple Proportions

- CO and CO_2 are different compounds because the ratios of the atoms are different.

Concept Check

- Which of the following represents the law of multiple proportions?
  - Na and Na_2O
  - H_2O and H_2S
  - NO and NO_2
  - MgO and $MgCl_2$

Dalton's Atomic Theory

- Every element is made of small, indestructible particles called atoms.
- The atoms of a given element are identical. Atoms of different elements are different in some way.
- Compounds are formed when atoms of different elements combine with one another.
- The same compounds always contain the same relative numbers and types of atoms.
- Chemical reactions rearrange atoms (in the way they are bound together) but are not changed themselves in the chemical reaction

Dalton's Atomic Theory

Which of these points still holds true today?

- Every element is made of small, indestructible particles called atoms.
- The atoms of a given element are identical. Atoms of different elements are different in some way.
- Compounds are formed when atoms of different elements combine with one another.
- The same compounds always contain the same relative numbers and types of atoms.
- Chemical reactions rearrange atoms (in the way they are bound together) but are not changed themselves in the chemical reaction

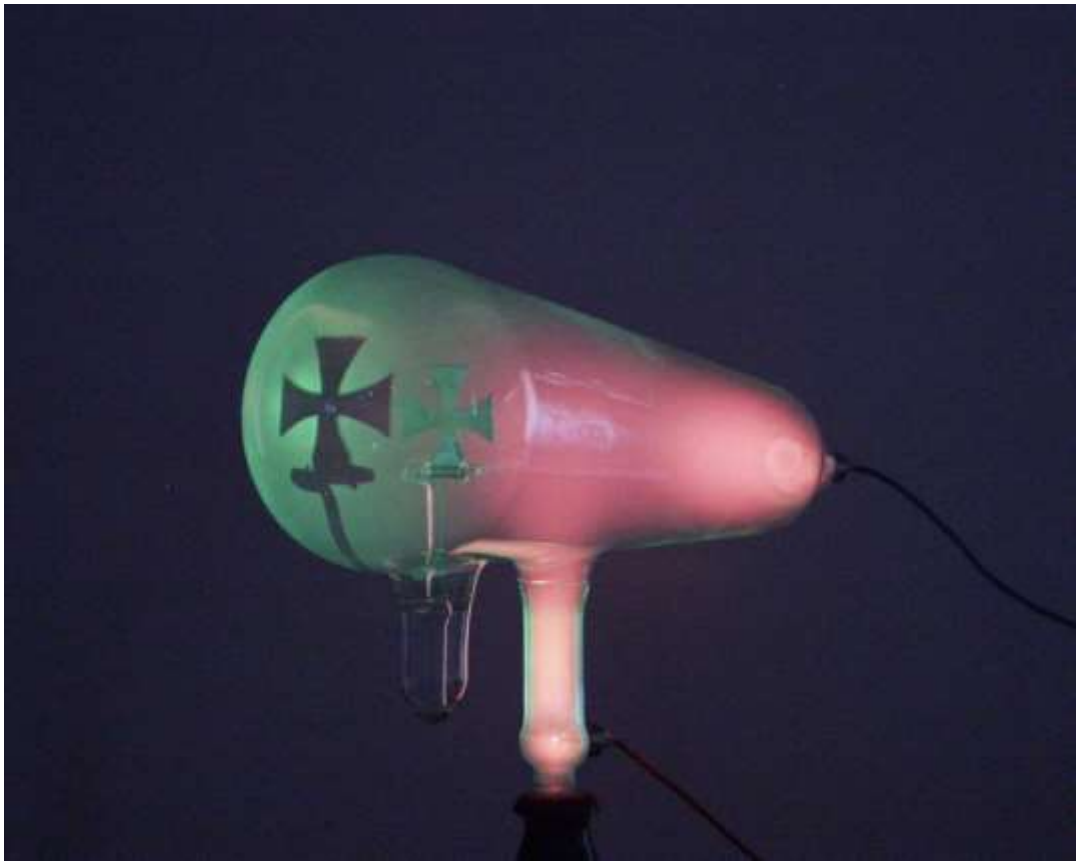
Discoveries Leading to Nuclear Atomic Model:

- Dalton's atom were solid, homogeneous and indivisible.

- J.J. Thompson sought to test that theory.

Cathode Ray Tubes

- Vacuum Tube
- Voltage
- Demonstrated charge was present in the atom:



- Discovery of particles making up the atom: electron (which has a charge and mass.
- Must also have positively charged particles (proton)

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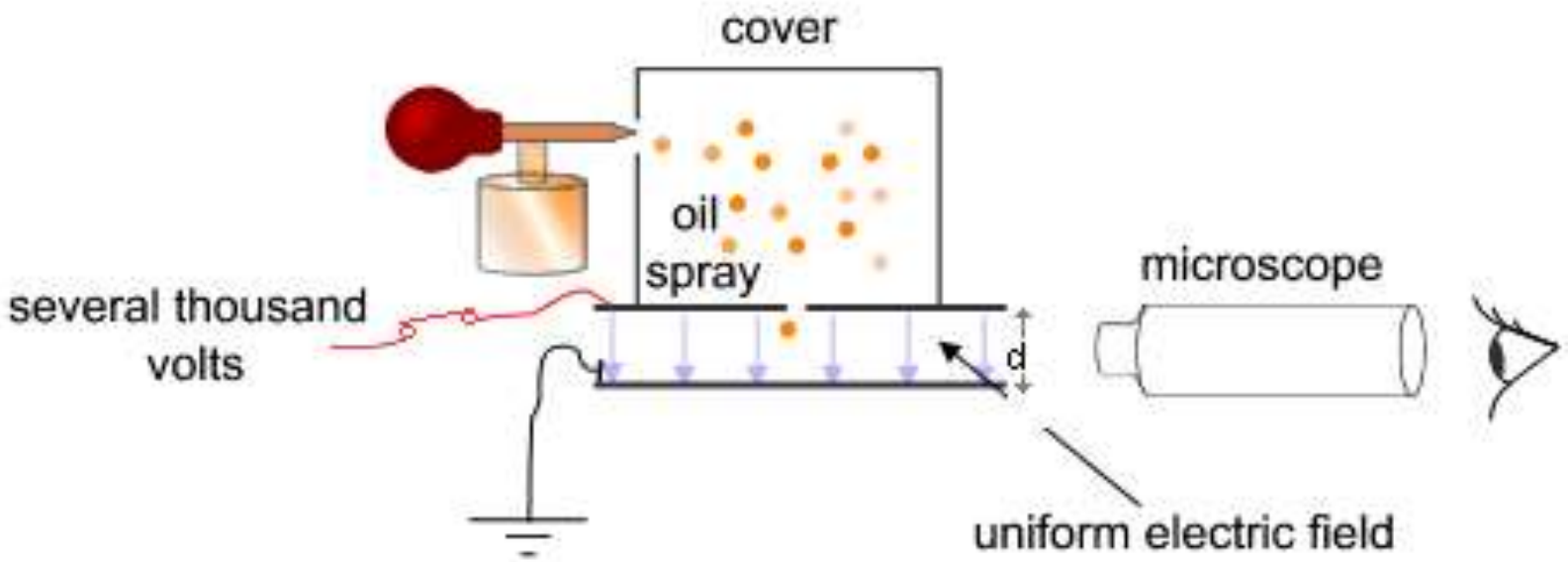
Milikan's Oil Drop Experiment

- Sought to clarify charge/mass ratio of electron



- Found charge of electron.
- Calculated mass of electron.

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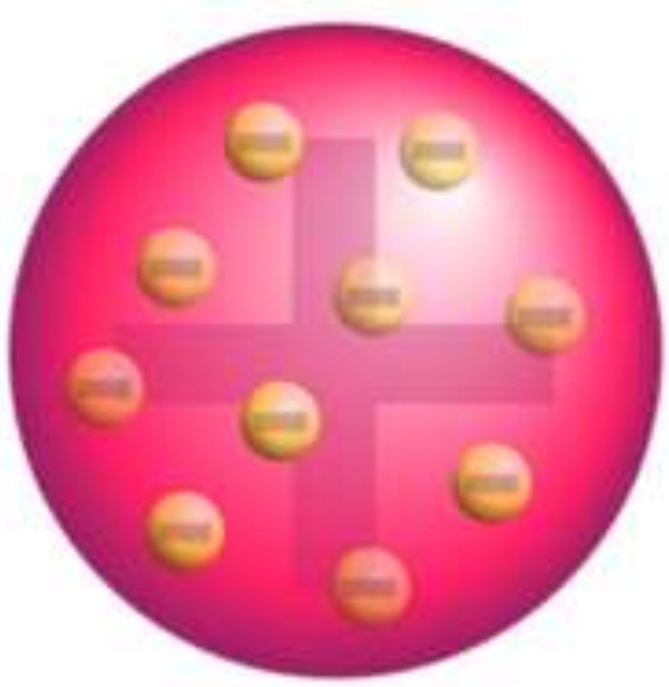
Atomic Model

- Modified by Thompson and Milikan to include subatomic particles
- Plum Pudding
- Rutherford wanted to test this model.



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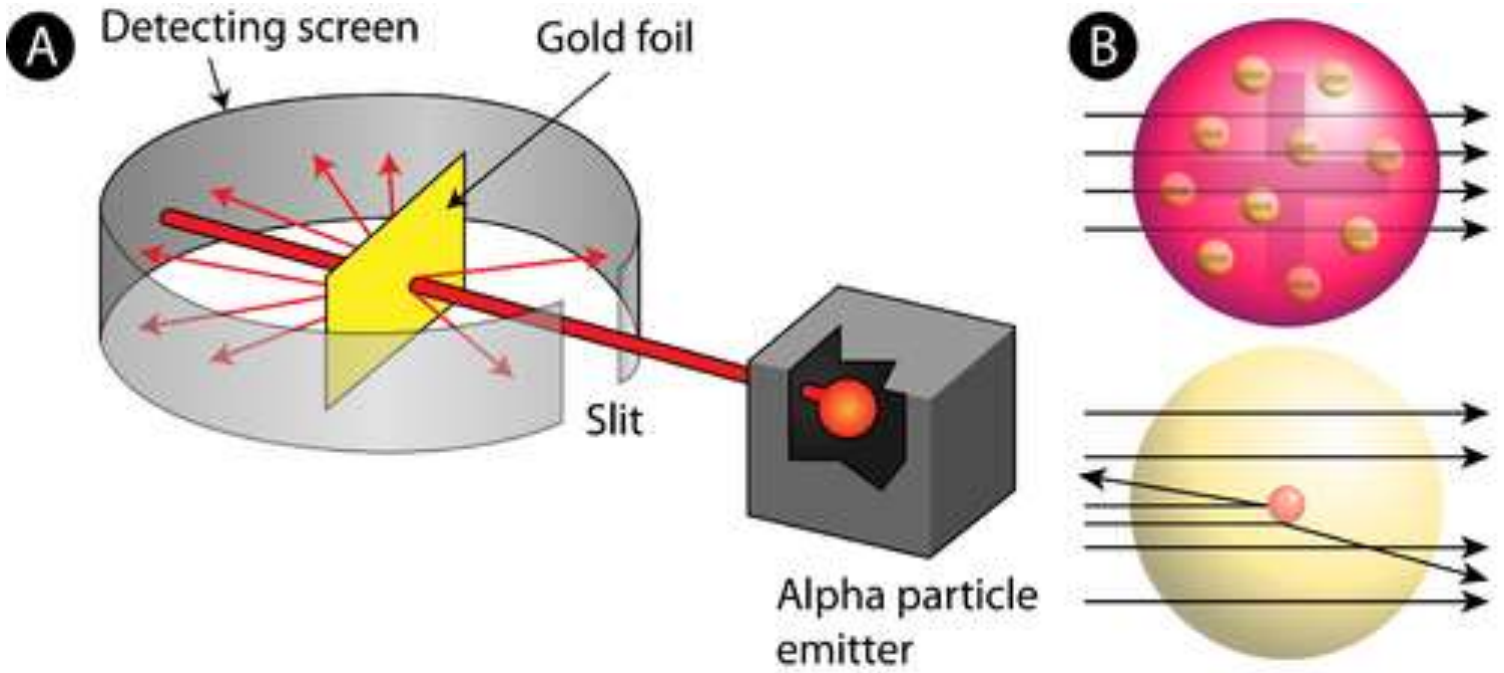
Rutherford's Gold Foil Experiment

- Found most of atom is empty space.
- Small dense nuclear center containing positive charges.



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Nuclear Atomic Model

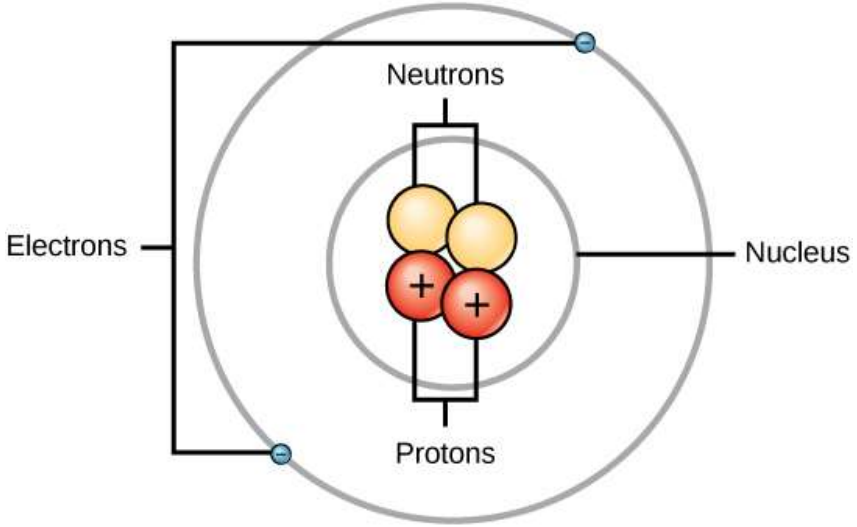
- Atom contains:

Particle	Charge	Location	Mass
Electron	-1	Orbits around nucleus	1/1840 amu
Proton	+1	In Nucleus	1 amu
Neutron	0	In Nucleus	1 amu

- Charge comes from electrons and protons.
- Mass comes from neutrons and protons.
- Nucleus is dense and small compared to atomic size.

Atomic Number (Z)

- Number of protons – does NOT change for an atom.
- Given on Periodic Table.
- All Helium atoms have atomic number 2



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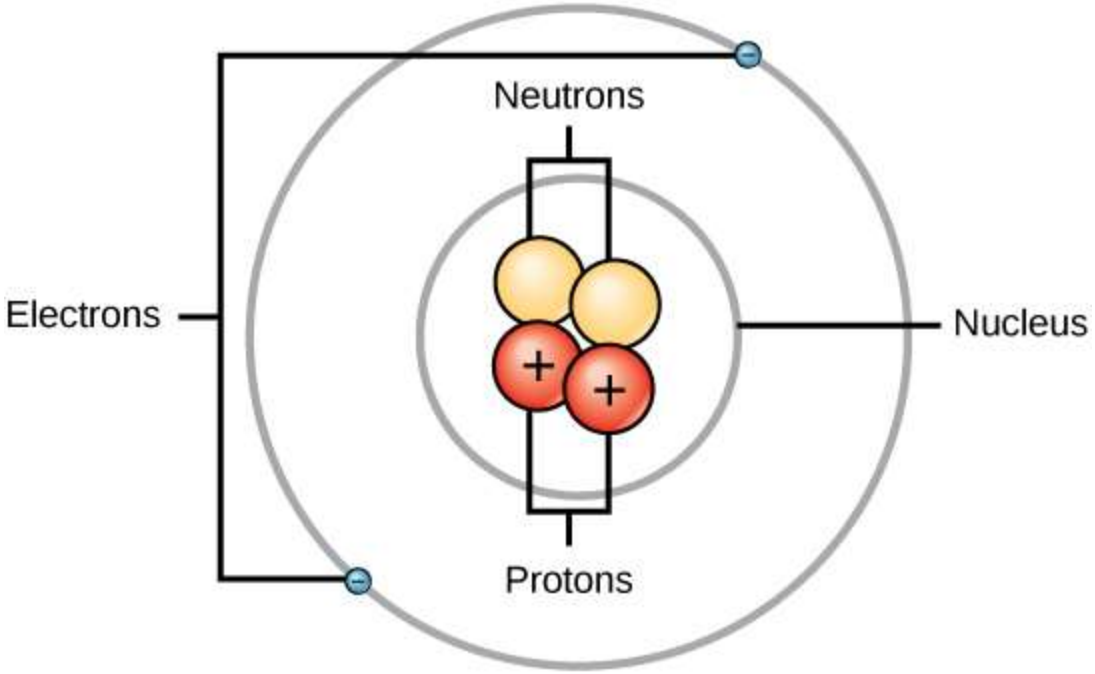
Mass Number (A)

- Number of Protons + Number of Neutrons
- This can change: Isotopes



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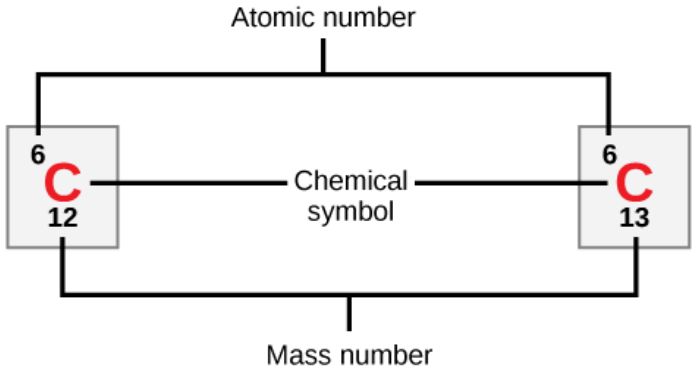
Isotopes

- Contain same number of protons (same atomic number)
- Different number of neutrons (different mass numbers)
- On Periodic Table:



- Isotope symbols have mass number on top (^{14}C vs ^{12}C

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Concept Check

- What is the mass number of an atom of Oxygen containing 10 neutrons?

- What is its symbol?

^{18}O

Concept Check

- An element has an atomic number of 14 and a mass number of 29. What is the element?

- How many protons, neutrons and electrons does it have?

^{29}Si

14 p

15 n

14 e

Concept Check

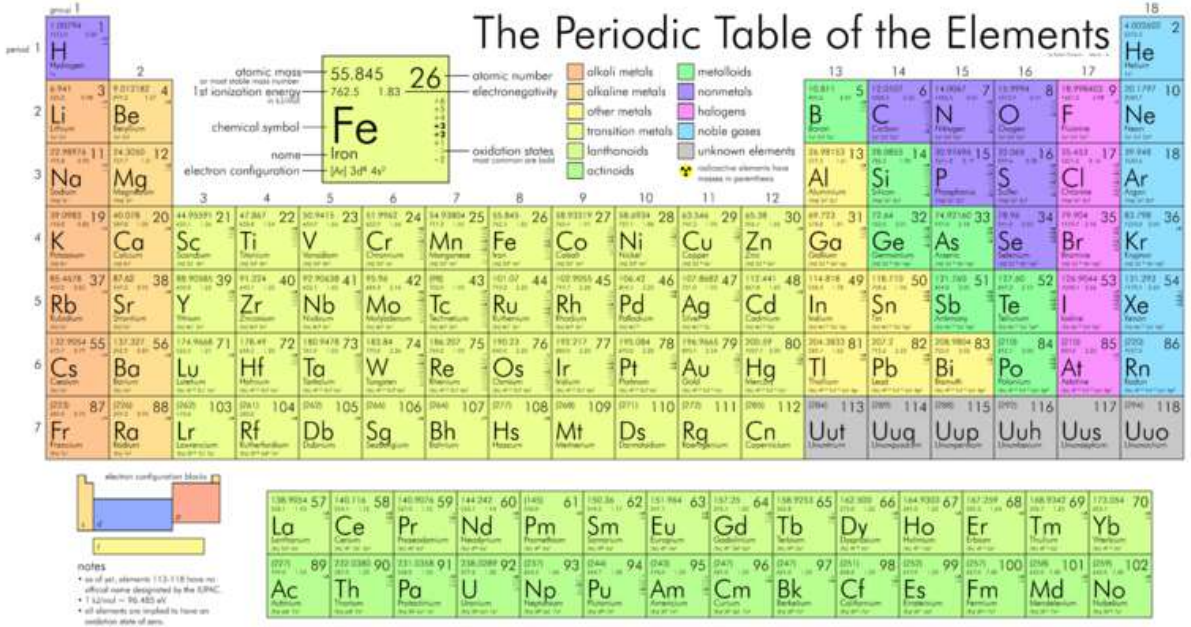
- An element X^{2+} contains 20 protons and 21 neutrons, what is the atomic number and mass number of the element?

- Write the symbol for the isotope.

$^{41}Ca^{2+}$

Periodic Table

- An introduction:
- Metals vs. nonmetals
- Groups or families – columns with similar properties
- Periods – horizontal rows with variable properties.



Periodic Table PD http://commons.wikimedia.org/wiki/File:Periodic_table_large.png

Groups

- Alkali metals – form ions with 1+ charge. Highly reactive.
- Alkaline Earth metals – reactive metals that form ions with a 2+ charge.
- Transition Metals – metals with variable charges and properties.
- Halogens – Reactive nonmetals that form ions with 1- charge.
- Noble Gases – nonreactive nonmetals. Full shell of electrons (neither want to lose nor gain electrons.

Concept Check

- Name a halogen in the 5th period?

I

- What is the alkaline earth metal in the 3rd period?

Mg

Concept Check

- What charge do halogens usually have when they form ions?

1-

- Do metals form positive or negatively charged ions? Why, do they lose or gain electrons?

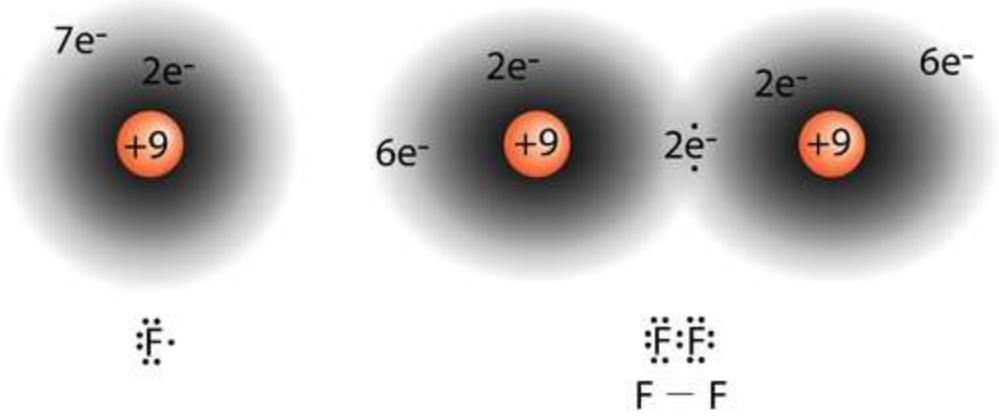
+ (lose e-)

Chemical Bonds

- Molecules are groups of atoms chemically bonded that contain no net charge.
- Occur by forming either
  - Covalent bonds
  - Ionic Bonds

Covalent Bonds

- Formed by sharing a pair electrons.
- Involve 2 or more nonmetals.
- Result in a molecule.
- Can be single (1 pair), double (2 pair) or triple bonds (3 pair).



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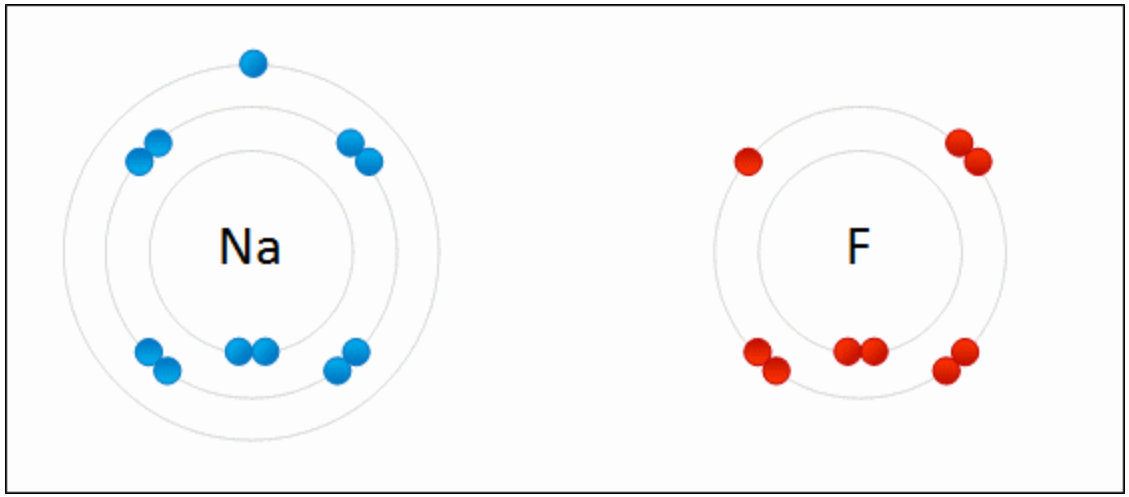
Covalent Compounds

- Usually binary: Contain 2 nonmetals bonded together.

- CO_2 – carbon dioxide
- PCl_3 – phosphorus trichloride
- N_2O_3 – dinitrogen trioxide

Ionic Bonds

- Form because of attraction between two ions
  - A positively charged (cation) ion
  - A negatively charged (anion) ion
- Ion is an atom or group of atoms that contain a net charge. Usually formed to obtain noble gas configuration
- Much stronger bonds than covalent bonds.



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Ionic Compounds

- Can be Binary (2)
  - Metal and nonmetal
  - Type 1: Group 1, 2 or 3 metal and a nonmetal
    - NaF – sodium fluoride
    - K_2O – potassium oxide
  - Type 2: Contains a transition metal and a nonmetal
    - FeO – iron II oxide
    - Fe_2O_3 – iron III oxide
- May contain a polyatomic ion
    - K_2CO_3 – potassium carbonate
    - $(NH_4)_2O$ – ammonium oxide
    - H_2O_2 – hydrogen peroxide
- If begin with H are an acid.
    - HCl – hydrochloric acid
    - H_2SO_4 – sulfuric acid
    - H_2SO_3 – sulfurous acid

Polyatomic Ions

Common Polyatomic Ions			
1-	**2-**	**3-**	**1+**
acetate, CH_3COO^-	carbonate, CO_3^{2-}	arsenate, AsO_3^{3-}	ammonium, NH_4^+
bromate, BrO_3^-	chromate, CrO_4^{2-}	phosphite, PO_3^{3-}	
chlorate, ClO_3^-	dichromate, $Cr_2O_7^{2-}$	phosphate, PO_4^{3-}	
chlorite, ClO_2^-	hydrogen phosphate, HPO_4^{2-}		
cyanide, CN^-	oxalate, $C_2O_4^{2-}$		
dihydrogen phosphate, $H_2PO_4^-$	peroxide, O_2^{2-}		
hydrogen carbonate, HCO_3^-	silicate, SiO_3^{2-}		
hydrogen sulfate, HSO_4^-	sulfate, SO_4^{2-}		
hydrogen sulfide, HS^-	sulfite, SO_3^{2-}		
hydroxide, OH^-			
hypochlorite, ClO^-			
nitrate, NO_3^-			
nitrite, NO_2^-			
perchlorate, ClO_4^-			
permanganate, MnO_4^-			

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Polyatomic Ions

- Naming Designation: by Oxygen (varies by series)
  - Per ____ ate
  - ____ ate
  - ____ ite
  - Hypo ____ ite

Formulas

- Molecular formulas use subscripts to denote numbers of atoms. (except 1 which is understood).
- Parentheses are used to designate a group (polyatomic ions)

Naming Covalent Molecules

- Covalent compounds:
  - Name the first element first using the element name.
  - Name the second element by the root of its element name and changing the ending to -ide.
  - Add prefixes to designate how many of each atom is present.
  - Mono is not used on the first element.

1 – mono
2 – di
3 – tri
4 – tetra
5 – penta
6 – hexa
7 – hepta
8 – octa
9 – nona
10 – deca

Naming Covalent Molecules

- Covalent compounds:
  - CO – carbon monoxide
  - SF_4 – sulfur tetrafluoride
  - S_2O_4 – disulfur tetroxide

Concept Check

- What is the formula for
  - Dinitrogen pentoxide N_2O_5
  - Sulfur dioxide SO_2

- What is the name of
  - PF_3 Phosphorus Trifluoride
  - S_2F_6 Disulfur Hexafluoride

Naming Ionic Compounds (Type I)

- Binary Ionic Compounds (without a transition metal)
  - Name the cation first using the element name.
  - Name the anion second by using the root of its element name and changing the ending to -ide.

KCl – Potassium chloride

MgO – Magnesium oxide

Na_2S – Sodium sulfide

Concept Check

- What is the formula for
  - Sodium phosphide Na_3PO_3
  - Calcium nitride Ca_3N_2

- What is the name of?
  - Al_2O_3 Aluminum Oxide
  - KBr Potassium Bromide

Naming Ionic Compounds (Type II)

- Binary Ionic Compounds (with a transition metal)
- Are named the same way except the charge of the metal must be specified with a Roman Numeral.
  - Name the cation first using the element name.
  - Specify the charge of the transition metal by including a Roman Numeral.
  - Name the anion second by using the root of its element name and changing the ending to -ide.

$FeCl_2$ – Iron II chloride
MnO – Manganese II oxide
Cu_2S– Copper I sulfide

- You do not need to specify charge for Zn or Ag.
- You also need to specify charge for Ti, and other metals under the metalloids on right of periodic table.

Concept Check

- What is the formula for
  - Nickel I oxide Ni_2O
  - Chromium VI sulfide CrS_3

- What is the name of
  - VO_2 Vanadium IV Oxide
  - Fe_3N_2 Iron II Nitride

Naming Ionic Compounds Containing a Polyatomic Ion

- Follow the same rules but use the name of the polyatomic ions.

K_2CO_3 – Potassium carbonate

NH_4Cl – Ammonium chloride

Cu_2S – Copper I sulfide

Concept Check

- What is the formula for
  - Manganese V peroxide Mn_2O_5
  - Calcium cyanide $Ca(CN)_2$

- What is the name of
  - NH_4Cl Ammonium Chloride
  - NH_4OH Ammonium Hydroxide

Naming Acids and Bases

- Acids – ionic compounds whose formula begin with an H.
- H+ is donated to solution

Naming Acids and Bases

- Acids not containing O
  - Name by
    - Using prefix hydro-
    - The root of the anion's element name
    - Suffix –ic acid

HCl hydrochloric acid

H_2S hydrosulfic acid

Naming Acids and Bases

- Acids containing O (from a polyatomic ion) are also called oxyacids
  - Name by
    - The root of the anion's name
    - If the anion originally ended in ate – change to –ic acid
    - If the anion originally ended in ite – change to –ous acid

H_2SO_4 sulfuric acid

H_2CO_3 carbonic acid

H_2SO_3 sulfurous acid

Naming Bases

- Bases contain the hydroxide ion in them.
- Follow rules for naming polyatomic ions.

Concept Check

- What is the formula for
  - Hydrocyanic acid HCN
  - Calcium hydroxide $Ca(OH)_2$
  - Phosphoric acid H_3PO_4

- What is the name of
  - $Ca(OH)_2$ Calcium Hydroxide
  - HNO_3 Nitric Acid
  - HNO_2 Nitrous Acid

Study Guides

- Chart to Help with Formula Writing
- Chart to Help with Naming
- Class Activity