10 Notes **Unit 2: Laws, Properties & Mols**
Ch. Atoms, Molecules, Ions

5 Chemical Laws:

I. Law of Conservation of Mass** (Lavoisier):
Mass cannot be created or destroyed.

II. Law of Definite Proportion** (Proust):
A given compound always contains exactly the same proportion of elements by mass.

III. Law of Multiple Proportions** (Dalton):
When 2 elements form more than 1 compound,
for a fixed mass of one element,
the masses of the second element are related to each other by small whole numbers (1, 2, 3 etc.)

	mass of Fe	mass of Cl	
$FeCl_2$	56 g	70 g	
$FeCl_3$	56 g	105 g	105:70 → 3:2
	(fixed)		**Subscripts must be whole numbers!

H_2O, H_2O_2

IV. Dalton's Atomic Theory**:
A) Each element is made up of tiny particles called atoms.
B) The atoms of a given element are identical; the atoms of different elements are different.
C) A compound always has the same ratio and types of atoms.
(like Law of Definite Proportions)
D) Chemical reactions involve reorganization of the atoms to form new compounds (the atoms themselves are unchanged). (like Law of Conservation of Mass)

V. Avogadro's Hypothesis**:
At the same temperature and pressure, equal volumes of different gases contain the same number of particles. (22.4 L = 1 mol = 6.022×10^{23} molecules of the gas)

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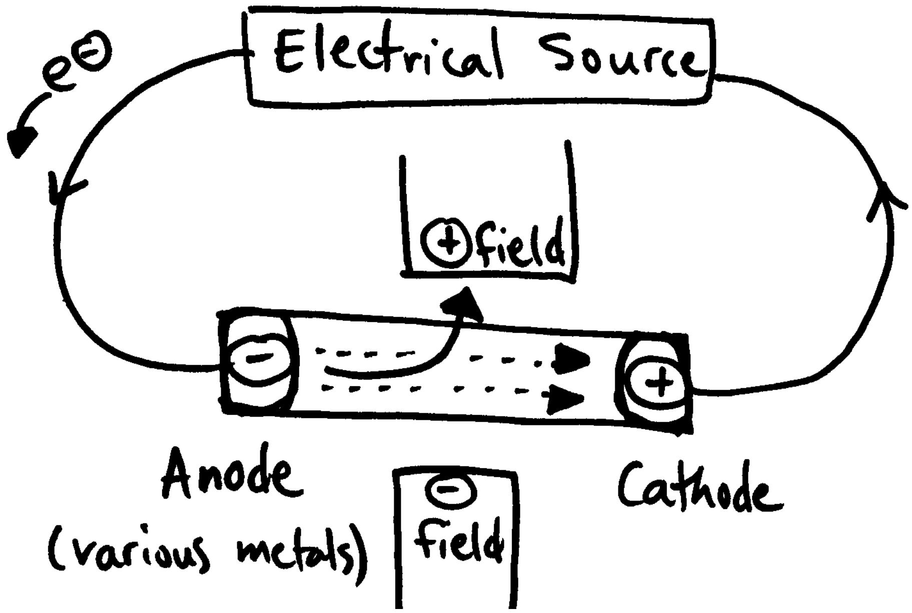
Atomic Models

J.J. Thompson and the Cathode Ray Tube



When a high voltage is applied, a cathode ray is produced. The particles he called electrons were (-), since they went toward an applied (+) electrical field and were repelled by an applied (-) electrical field.
**Since electrons were produced from electrodes of various metals, he postulated that all atoms must contain (-) electrons.

Millikan's Oil Drop Experiment
A falling oil drop can be halted by adjusting a voltage across 2 plates. With the voltage and the mass of an e^-, he could calculate the charge on a single e^-. (The charge on an oil drop is always a whole number multiple of the charge on a single e^-, so an e^- is not divisible into other particles.)

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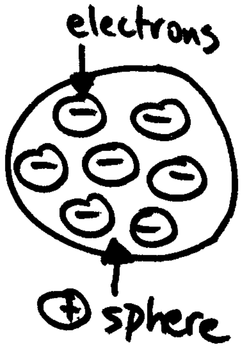
#11 Notes **Atomic Models continued**

A) Plum Pudding Model (J.J. Thompson)**

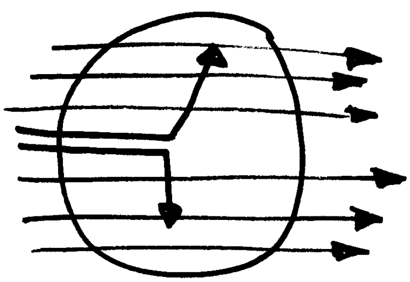
All atoms contain (-) electrons. Since atoms are neutral, there must also be (+) somewhere.



**(-) electrons are randomly scattered in a spherical cloud of (+) charge.

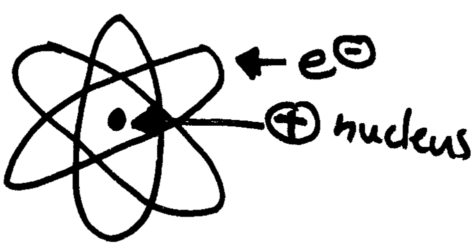
B) Rutherford's Gold Foil Experiment

Radioactivity was discovered by Becquerel in 1896. (α - particles are helium atoms)



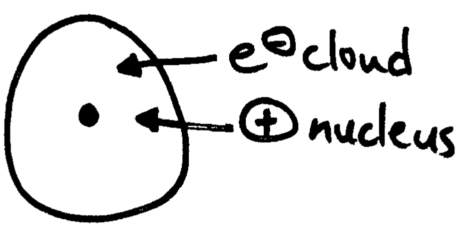
When α – particles are shot at an Au atom, the center repels the α – particles, so there must be a concentration of charge in the center.

Rutherford Model**



**A (+) nucleus is surrounded by orbiting (-) electrons.

C) Modern Model **



**A (+) nucleus (diameter 10^{-13} cm), containing (+) protons and neutral neutrons is surrounded by an electron cloud (diameter 10^{-8} cm).

{Tennis ball nucleus 4.5 cm, e- cloud out 4.5 km ≈ 2.8 mi}

**electrons are in layers of many differently shaped orbitals (s, p, d, f)

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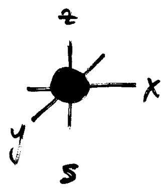
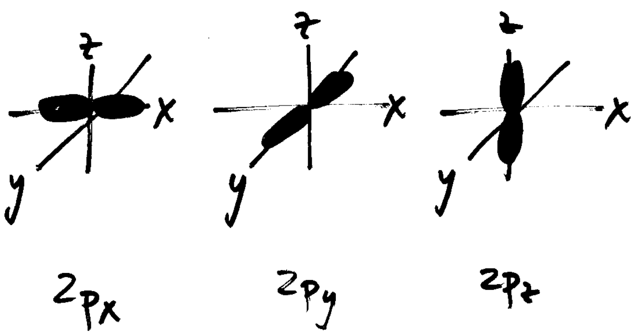
Electron Orbital Diagrams

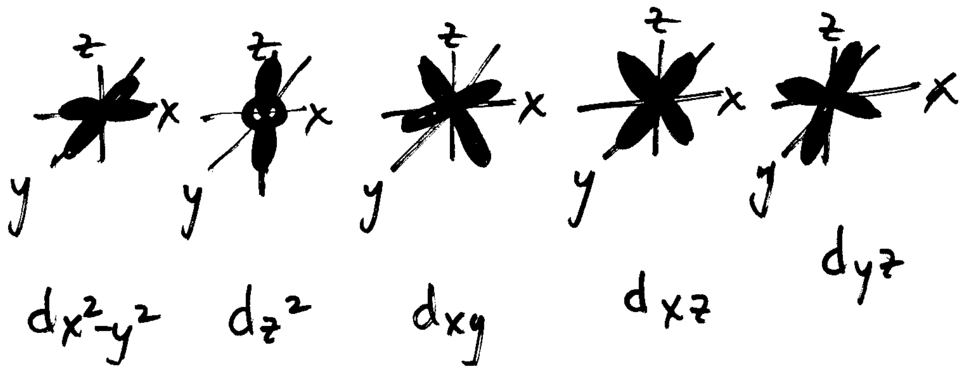
I. s – orbitals (1 type)



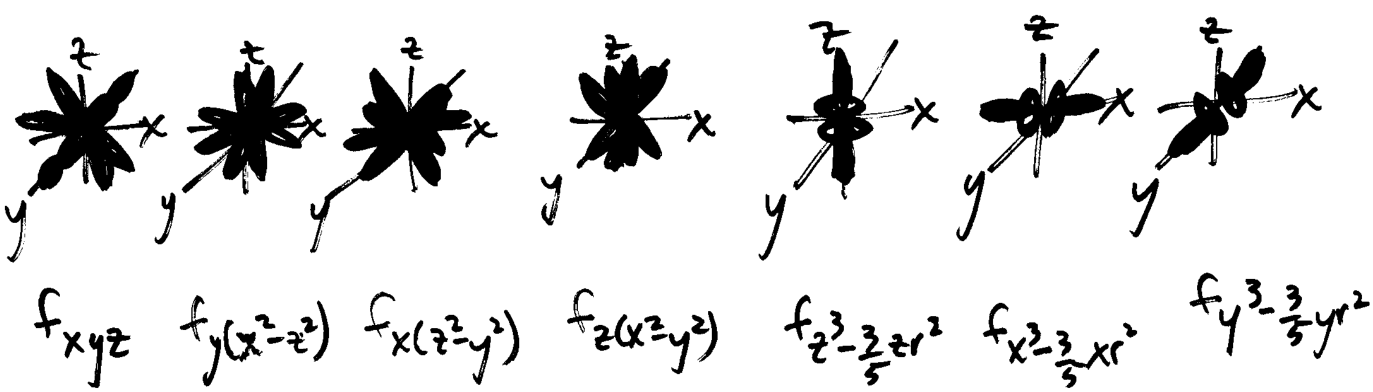
II. p – orbitals (3 types)



III. d – orbitals (5 types)



IV. f – orbitals (7 types)



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Isotopes** are atoms of the same element, but with different mass. They contain different amounts of neutrons.

	Mass	Charge
Electron	9.109×10^{-31} kg	-1
Proton	1.672×10^{-27} kg	+1
Neutron	1.675×10^{-27} kg	neutral

Atomic # = # of Protons = # of Electrons
Mass # = # of Protons + # of Neutrons {To find mass}
Mass # – Atomic # = # of Neutrons {To find neutrons}

Given:	neutrons	protons	electrons	charge	
Ca = $^{40}_{20}Ca$ (find neutrons)	40-20 = 20	20	20	0	
^{235}U = $^{235}_{92}U$	235 – 92 = 143	92	92	0	
Ca^{2+} = $^{40}_{20}Ca^{2+}$	40-20= 20	20	20-2=18	2+	(+) charge = lose electrons
F^{1-} = $^{19}_{9}F^{1-}$	19-9 = 10	9	9+1= 10	1-	(-) charge = gain electrons

Given: 26 protons, 30 neutrons, +3 charge.

26 + 30 = $^{56}_{26}Fe^{+3}$ (find mass)	30	26	26 -3 = 23	3+	(+) charge = lose electrons

VI. Periodic Table**

A) Metals: left side of table
- Conduct heat and electricity
- Malleable, ductile
- Lustrous
- Lose e^- to form (+) ions

B) Nonmetals: right side of table
- Gases or brittle solids
- Poor conductors
- Gain e^- to form (-) ions

C) Metalloids (Semi-metals, Semiconductors):
- Properties of metals and nonmetals
- B, Si, Ge, As, Sb, Te, Po, At

See Periodic Table with Group Names and label groups/families:
Alkali Metals, Alkaline Earth Metals, Transition Metals, Halogens, Noble Gases, Lanthanides, Actinides, Metals, Nonmetals, Metalloids.

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#12 Notes

VII. Bonds

Chemical Bonds are the force that holds atoms together.

Covalent Bonds: are when electrons are shared.

(molecules have covalent bonds)

Ionic Bonds: are when electrons are transferred.

(ionic solids/ salts have ionic bonds)

NaCl

Loses 1 e^- ↓ ↓ Gains 1 e^-

Na^+ Cl^- → NaCl Na's e^- is transferred to the Cl.

Cations (+) Anions (-)

Polyatomic Ions: are covalently bonded atoms with a charge

NH_4^{1+}, SO_4^{2-}

VIII. Writing Formulas for Ionic Compounds

The ions charges must (be multiplied to) make neutral compounds.

Ex. 1) sodium nitrate Na^{1+} NO_3^{-1} → **$NaNO_3$**

Ex. 2) magnesium chloride Mg^{2+} Cl^{1-} → **$MgCl_2$**

X1 X2

+2 -2 = 0

Ex. 3) iron III hydroxide Fe^{3+} OH^{-1} → **$Fe(OH)_3$**

X1 X3

+3 -3 = 0

Ex. 4) lithium phosphate Li^{1+} PO_4^{3-} → **Li_3PO_4**

X3 X1

+3 -3 = 0

Ex. 5) cobalt III sulfite Co^{3+} SO_3^{2-} → **$Co_2(SO_3)_3$**

X2 X3

+6 -6 = 0

Ex. 6) chromium II phosphate Cr^{2+} PO_4^{3-} → **$Cr_3(PO_4)_2$**

X3 X2

+6 -6 = 0

Ex. 7) nickel II arsenide Ni^{2+} As^{3-} → **Ni_3As_2**

X3 X2

+6 -6

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Notes #13 X. Writing Formulas for Covalent Molecules

These compounds contain 2 nonmetals (both (-)), so they will share electrons in different combinations.
Prefixes: mono (1), di (2), tri (3), tetra (4), penta (5), hexa (6), hepta (7), octa (8), nano (9), deca (10). **mono only used on 2nd element

Ex. 1) sulfur tetrafluoride S^{2-} F^{1-} → **SF_4**

Ex. 2) dinitrogen tetroxide N^{3-} O^{2-} → **N_2O_4**

Ex.3) carbon monoxide $C^{?}$ O^{2-} → **CO**

XI. Naming Ionic Compounds

Ex. 1) $Sr(OH)_2$ **strontium hydroxide**

Ex. 2) $Cu(ClO_2)_2$ **copper II chlorite**
ClO_2^{1-} X 2 = -2, so Cu must be +2

Ex. 3) $CrBr_3$ **chromium III bromide**
Br^{1-} X 3 = -3, so Cr must be +3

Ex. 4) $Fe_2(SO_4)_3$ **iron III sulfate**
SO_4^{2-} X 3 = -6, so Fe side must be +6,
But there are 2 Fe, so each must be +3

Ex. 5) Cr_2O_3 **chromium III oxide**
O^{2-} X 3 = -6, so Cr side must be +6,
But there are 2 Cr, so each must be +3

Ex. 6) $Co_3(PO_4)_2$ **cobalt II phosphate**
PO_4^{3-} X 2 = -6, so Co side must be +6,
But there are 3 Co, so each must be +2

Ex. 7) $Ba(NO_3)_2$ **barium nitrate**

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XII. Naming Covalent Molecules

Ex. 1) NO_2 N^{3-} O^{2-} prefixes: **nitrogen dioxide**
(mono never used on 1st element)
**Only the 2nd name gets the "-ide".

Ex. 2) ICl_3 I^{1-} Cl^{1-} **iodine trichloride**

**Think of metalloids as negative.
Metalloids (-) with Nonmetals (-) are covalent: $SiCl_4$ silicon tetrachloride
Metalloids (-) with Metals (+) are ionic: Fe_3As_2 iron II arsenide

XIII. Mixed Examples

Ex. 1) $K_2Cr_2O_7$ **potassium dichromate**
$Cr_2O_7{}^{2-}$

Ex. 2) PF_5 P^{3-} F^{1-} **phosphorus pentafluoride**

Ex. 3) $Pb(SO_4)_2$ **lead IV sulfate**
SO_4^{2-} X 2 = -4, so Pb must be +4

Ex. 4) N_2O N^{3-} O^{2-} **dinitrogen monoxide**

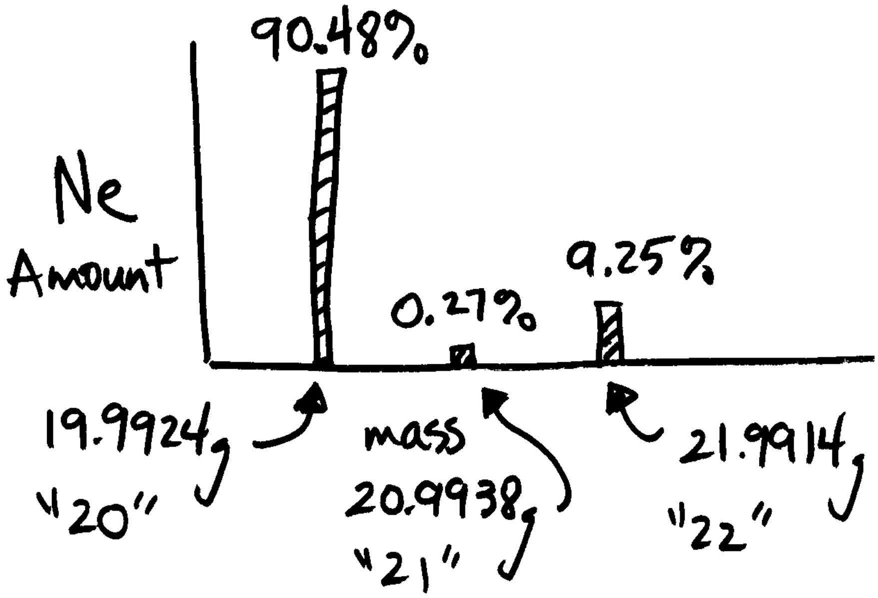
Ex.5) BeF_2 **beryllium fluoride**

#14 Notes Ch. Stoichiometry

I. Atomic Mass

Atomic mass on the periodic table is the average mass of the naturally occurring isotopes weighted by their natural abundance. (This includes electrons and is not rounded to whole numbers, like the atomic mass # in the last chapter.)

Mass Spectrometers show the relative abundance by mass.



Ex. 1) Calculate the average atomic mass of Ne.

(% as decimal) (mass) + (% as decimal) (mass) + (% as decimal) (mass) = average atomic mass

(0.9048) (19.9924 g) + (0.0027) (20.9938 g) + (0.0925) (21.9914 g) =

18.09 + 0.05668 + 2.034 = **20.18 g**

**** or 20.18 amu (atomic mass units)**

This is the mass for one mol of the substance (6.022 X10^{23} atoms).

II. The Mole (Mol)

Molar mass is the mass of 1 mol of a compound.

Ex.1) Find the molar mass of MgF_2.

1 mol Mg = 24.305 g

2 mol F = 2 (18.9884g) = 37.9768 g

62.2818 g in one mol of MgF_2 **= 62.2818 g/mol MgF_2**

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Ex. 2) Find the molar mass of $Fe_2(SO_4)_3$

2 Fe = 2 (55.847 g)
3 S = 3 (32.064 g)
12 O = 12 (15.999 g)
399.8788 g in 1 mol of $Fe_2(SO_4)_3$ = **399.8788 g/mol $Fe_2(SO_4)_3$**

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#15 Notes II. Conversions with the Mol

1 dozen = 12
1 mol = 6.022×10^{23}

107.868 g Ag = 1 mol   1 mol = 6.022×10^{23} atoms Ag (**element**)
(atomic mass)

NaCl:
22.9898g Na
35.453 g Cl
58.443 g NaCl = 1 mol   1 mol = 6.022×10^{23} molecules NaCl (**compound**)
(molar mass)

A) Grams → Mols

Ex. 1) Convert 45.3 g C_2H_6 to mols.

$$\frac{45.3\text{ g } C_2H_6}{} \left| \frac{1\text{ mol}}{30.069\text{ g}} \right. = \mathbf{1.51\text{ mol } C_2H_6}$$

↑ 2 C + 6 H

B) Mols → Grams

Ex. 2) Convert 0.459 mols $Pb(AsO_4)_2$ to grams.

$$\frac{0.459\text{ mols } Pb(AsO_4)_2}{} \left| \frac{485.026\text{ g}}{1\text{ mol}} \right. = 222.6 = \mathbf{223\text{ g } Pb(AsO_4)_2}$$

↑ 1 Pb + 2 As + 8 O

C) Grams → Atoms/Molecules

Ex. 3) Convert 59.32 g $Ca_3(PO_4)_2$ to molecules.

$$\frac{59.32\text{ g } Ca_3(PO_4)_2}{} \left| \frac{1\text{ mol}}{310.174\text{ g}} \right| \frac{6.022 \times 10^{23}\text{ molecules}}{1\text{ mol}} = \mathbf{1.152 \times 10^{23}\text{ molecules } Ca_3(PO_4)_2}$$

↑ 3 Ca + 2 P + 8 O

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D) Atoms/Molecules → Grams

Ex. 4) Convert 4.59 X10^{24} molecules $MgCl_2$ to grams.

$$\frac{4.59 \times 10^{24} \text{ molecules } MgCl_2}{} \left| \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \right| \frac{95.211 \text{ g}}{1 \text{ mol}} = \mathbf{726 \text{ g } MgCl_2}$$

↑ (95.211 g): 1 Mg + 2 Cl

**H_2 = 2 H, O_2 = 2 O

End of Notes (Assignments #16-17 are Review Assignments. There are no notes for these assignments.)

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