University Chemistry I
Chemistry 120, Section A
Chapter 2

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2-1

Atoms

≈ 400 BC Greek - uncuttable

1803 AD John Dalton

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Dalton's Atomic Theory (1808)

1. All matter is made up of indivisible and indestructible particles called atoms.
2. All atoms of a given element are identical in both mass and in properties.
3. Compounds are formed when atoms of different elements combine in the ratio of small whole numbers.
4. Compounds are composed of definite arrangements of atoms, and chemical change occurs when the atoms are rearranged.

2-3

Dalton's Atomic Theory Was Immediately Accepted Because it Could Explain Three Laws

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Dalton's Atomic Theory Could Explain Three Laws

Antoine Lavoisier

Carefully weighed *products* and *reactants* and found that the mass was always equal.

<u>Law of Conservation of Matter</u>- Matter is neither created nor destroyed in a chemical reaction.

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Dalton's Atomic Theory Could Explain Three Laws

Joseph Proust

If you purify water from many sources, it is always H_2O- 11.2% H, 88.8% O

<u>Law of Definite Proportions</u>- In a compound, the constituent elements are always present in a definite proportion by mass.

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Dalton's Atomic Theory Could Explain Three Laws

John Dalton

CO CO_2 never $CO_{1.8}$

Law of Multiple Proportions- In the formation of 2 or more compounds from the same elements, the masses of one element that combine with a fixed mass of a second element are in a ratio of small whole numbers.

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Avogadro's Hypothesis (1811)

- At the same temperature and pressure, equal volumes of different *gases* contain the same number of particles.
- 22.4 liters of oxygen
- 22.4 liters of nitrogen
- Same number of particles! (6.02×10^{23} molecules)

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Early Experiments to Characterize the Atom

Figure 2.4(a) Chang, 9th Ed.

- J. J. Thomson - postulated the existence of electrons using cathode ray tubes.

(a)

2-9

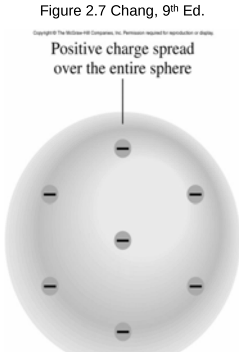
Electron Particle Demonstrations

- CRT
- Paddle wheel
- Canal tube
- (X-ray bombardment of wax)

2-10

Thomson Proposed the Plum Pudding Model of the Atom

Figure 2.7 Chang, 9th Ed.

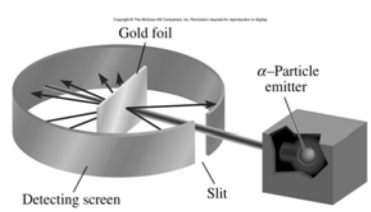


2-11

Early Experiments to Characterize the Atom

Figure 2.8(a) Chang, 9th Ed.

- Ernest Rutherford - explained the nuclear atom, containing a dense nucleus with electrons traveling around the nucleus at a large distance.



(a)

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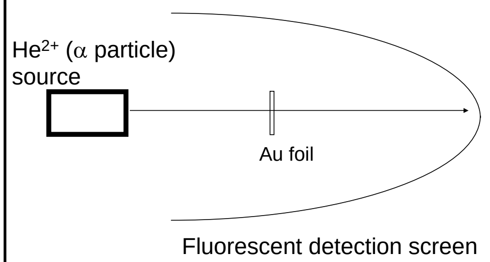
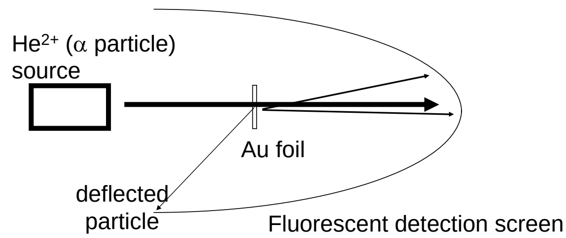
Rutherford's Famous Experiment...



2-13

Rutherford's Famous Experiment...



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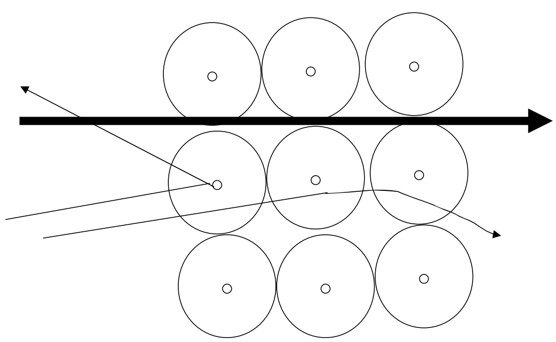
...and His Interpretation of the Results



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Modern View of the Atom

Figure 2.14 Zumdahl and Zumdahl, 6th Ed.
See Fig. 2.9 Chang

- Very small
- equal number of protons and electrons
- Nucleus: protons and neutrons
- electron cloud
- sports stadium analogy

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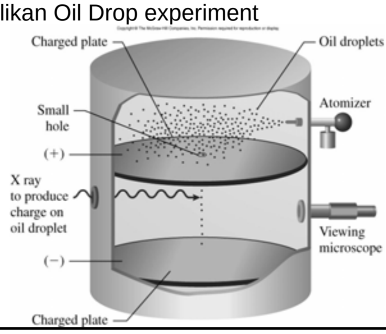
Determining Charge and Mass of Particles

Figure 2.5 Chang, 6th Ed.

- The Millikan Oil Drop experiment



2-17

The Mass and Charge of the Electron, Proton, and Neutron

Particle	Mass *kg*	Mass *amu*	Charge*
Electron	9.11×10^{-31}	0.00055 (0)	1–
Proton	1.67×10^{-27}	1.0087 (1)	1+
Neutron	1.67×10^{-27}	1.0073 (1)	0

*The charge on an electron is -1.60×10^{-19} C

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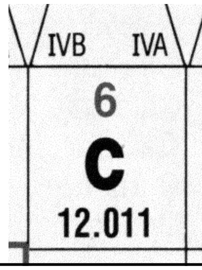
The *Atomic Number* Indicates the Number of Protons

$_{6}C$
Carbon

The number of protons determines what element the atom is.

An atom contains an equal number of protons and electrons



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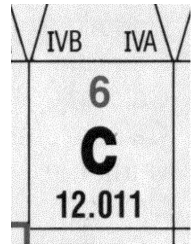
The *Mass Number* Indicates the Mass of the Atom

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

carbon-12



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Atomic Number and Mass Number Are Used to Determine Number of Neutrons

Atomic number- indicates the number of protons

Mass number- the mass of the atom

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$

12-6= 6 neutrons 13-6= 7 neutrons

Isotopes- atoms of the same element having different numbers of neutrons.

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Atomic Mass and Atomic Weight

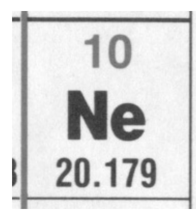
Atomic Weight- the average mass of the isotopes of an element

EX: ^{20}Ne ^{21}Ne ^{22}Ne

90.92% 0.26% 8.82%

$$(0.9092)(20)+(0.0026)(21)+(0.0882)(22)$$
$$=18.184+0.0546+1.9404$$

=20.179



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Chemical Bonds

- Chemical bonds are the forces that hold atoms together in compounds. Covalent bonds result from atoms sharing electrons.

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Ions

Cation: A positive ion
Mg^{2+}, NH_4^{+}

Anion: A negative ion
Cl^{-}, SO_4^{2-}

Ionic Bonding: Force of attraction between oppositely charged ions.

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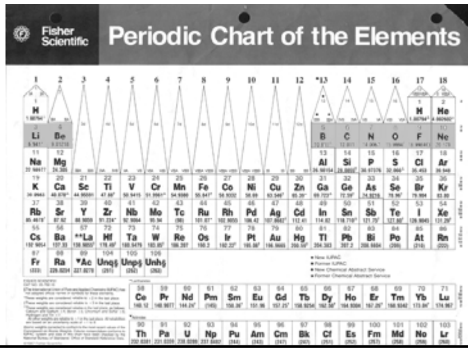
The Periodic Table
Groups vs. Periods



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Group	Name
IA	Alkali metals
IIA	Alkaline earth metals
IIIA	
IVA	
VA	
VIA	(Chalcogens)
VIIA	Halogens
VIIIA	Noble gases

Transition Elements
Lanthanides
Actinides
} Inner transition elements

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Naming Binary Ionic Compounds

$CaCl_2$

1. Name cation first, then anion
2. Monoatomic cation = name of element
   Ca^{2+} = calcium ion
3. Monoatomic anion = root + ide
   Cl = chlorine, so chloride

$CaCl_2$ = calcium chloride

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Naming Binary Ionic Compounds Containing a *Variable Charge Element*

Table 2.4 Zumdahl and Zumdahl, 6th Ed.

Variable Charge Element- metal forms more than one cation

- use Roman numeral in name
- $PbCl_2$
- Pb^{2+} is cation
- Cl is chlorine, so chloride
- $PbCl_2$ = lead(II) chloride

TABLE 2.4 Common Type II Cations

Ion	Systematic Name
Fe^{3+}	Iron(III)
Fe^{2+}	Iron(II)
Cu^{2+}	Copper(II)
Cu^{+}	Copper(I)
Co^{3+}	Cobalt(III)
Co^{2+}	Cobalt(II)
Sn^{4+}	Tin(IV)
Sn^{2+}	Tin(II)
Pb^{4+}	Lead(IV)
Pb^{2+}	Lead(II)
Hg^{2+}	Mercury(II)
Hg_2^{2+}*	Mercury(I)
Ag^{+}	Silver†
Zn^{2+}	Zinc†
Cd^{2+}	Cadmium†

*Note that mercury(I) ions always occur bound together to form Hg_2^{2+} ions.
†Although these are transition metals, they form only one type of ion, and a Roman numeral is not used.

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Naming Covalent Compounds

Compounds between two nonmetals
First element in the formula is named first.
Second element is named as if it were an anion (i.e. use –ide).
Use prefixes to denote how many atoms involved
(Never) use mono-

P_2O_5 = diphosphorus pentoxide

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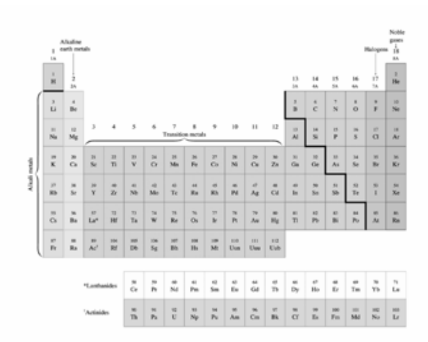
Prefixes to Know

Prefix	Number Indicated
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10
(undeca-	11)

2-30a

Metals and Nonmetals: Dividing Line

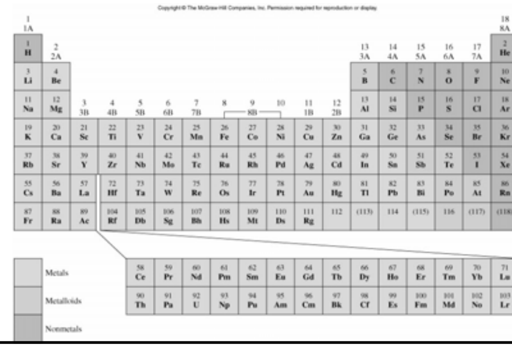
Figure 2.21 Zumdahl and Zumdahl, 6th Ed.



2-30b

Metals and Nonmetals: Dividing Line

Figure 2.10 Chang, 9th Ed.



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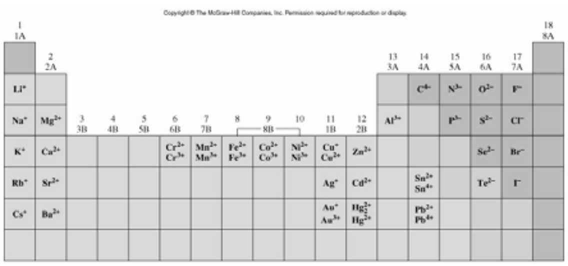
Common Monoatomic Cations and Anions

Figure 2.11 Chang, 9th Ed.



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Common Polyatomic Ions

See Table 2.3 Chang

NH_4^+	ammonium	ClO^-	hypochlorite
NO_3^-	nitrate	ClO_2^-	chlorite
NO_2^-	nitrite	ClO_3^-	chlorate
SO_4^{2-}	sulfate	ClO_4^-	perchlorate
SO_3^{2-}	sulfite	CO_3^{2-}	carbonate
HSO_4^-	hydrogen sulfate or bisulfate	HCO_3^{2-}	hydrogen carbonate or bicarbonate
OH^-	hydroxide	$C_2H_3O_2^-$	acetate
CN^-	cyanide	MnO_4^-	permanganate
PO_4^{3-}	phosphate	CrO_4^{2-}	chromate
HPO_4^{2-}	hydrogen phosphate	$Cr_2O_7^{2-}$	dichromate
$H_2PO_4^-$	dihydrogen phosphate	O_2^{2-}	peroxide
Hg_2^{2+}	mercury(I)	$C_2O_4^{2-}$	oxalate

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Naming Ionic Compounds Containing Polyatomic Ions

Three possibilities:

polyatomic cation polyatomic anion

ammonium sulfate $(NH_4)_2SO_4$

or polyatomic cation anion root + *ide*

ammonium chloride NH_4Cl

or cation polyatomic anion

magnesium sulfate $MgSO_4$

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Naming Acids

- no oxygen hydro + Element root + ic acid
  - HCl hydrochloric acid
- contains oxygen
  - identify polyatomic ion
  - change -ate to -ic or -ite to -ous
  - add acid
  - Exceptions are plentiful

HNO_3 nitric acid

HNO_2 nitrous acid

H_2SO_4 sulfuric acid

HCN hydrocyanic acid

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Naming Acids

Table 2.5 Chang, 9th Ed.

TABLE 2.5 Some Simple Acids

Anion	Corresponding Acid
F^- (fluoride)	HF (hydrofluoric acid)
Cl^- (chloride)	HCl (hydrochloric acid)
Br^- (bromide)	HBr (hydrobromic acid)
I^- (iodide)	HI (hydroiodic acid)
CN^- (cyanide)	HCN (hydrocyanic acid)
S^{2-} (sulfide)	H_2S (hydrosulfuric acid)

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Names of Some Oxygen-containing Acids

Polyatomic ion	Acid	Name
Nitrate	HNO_3	nitric acid
Nitrite	HNO_2	nitrous acid
Sulfate	H_2SO_4	sulfuric acid
Sulfite	H_2SO_3	sulfurous acid
Phosphate	H_3PO_4	phosphoric acid
Acetate	$HC_2H_3O_2$	acetic acid

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Naming Bases

- NH_3 has common name of ammonia
- "all the rest" named element + hydroxide
- KOH = potassium hydroxide

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Odds and Ends

Figure 2.16 Chang, 9th Ed.

Allotrope- two or more forms of the same element. For example, carbon exists as graphite and diamond

Ferric and ferrous- don't use

Hydrate- a compound which has water associated but not covalently bound

$CuSO_4 \cdot 5H_2O$ copper(II) sulfate pentahydrate

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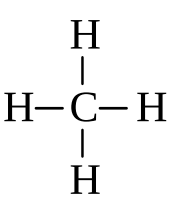
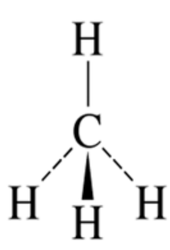
What Do Molecules Look Like?

Figure 2.12 Chang, 6th Ed.

CH_4





Methane

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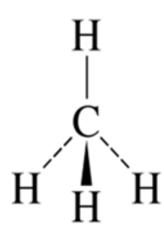
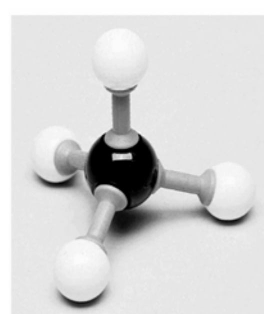
What Do Molecules Look Like?

Figure 2.18 Zumdahl and Zumdahl, 6th Ed.



Methane



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What Do Molecules Look Like?

Figure 2.12 Chang, 9th Ed.