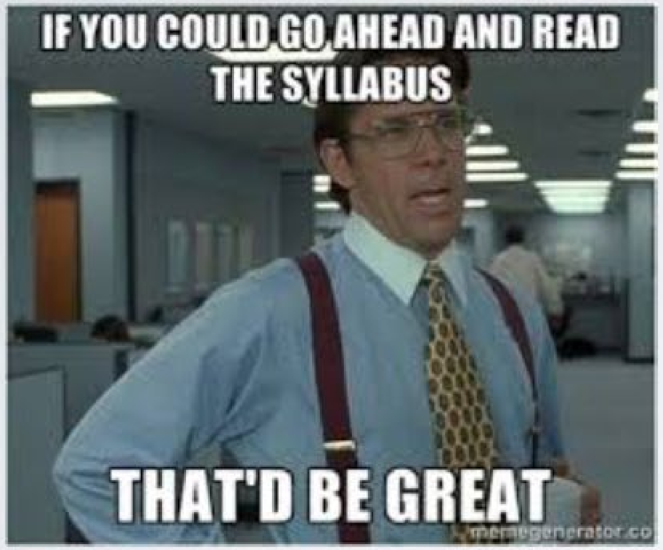
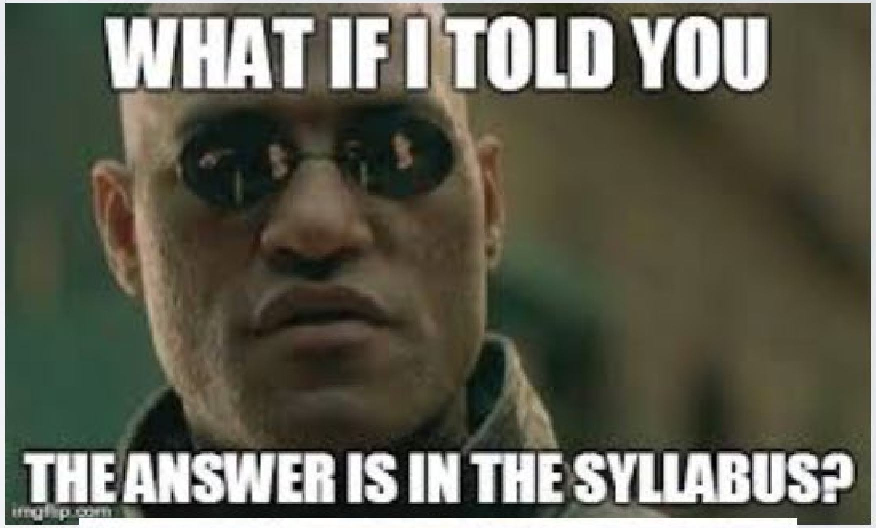
Chem 200

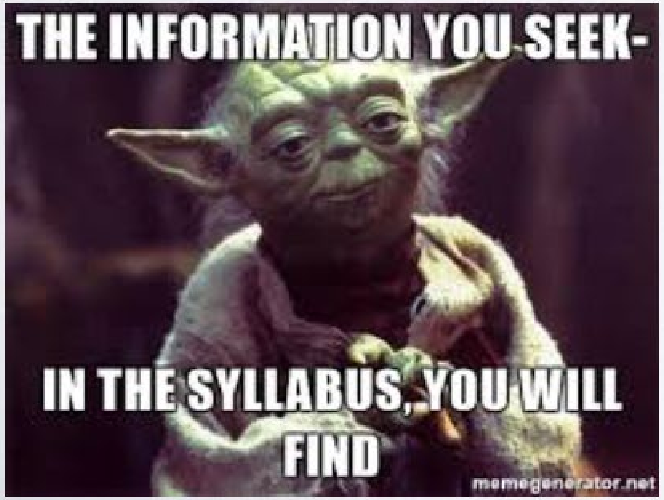
All emails sent to
chem200@sdsu.edu

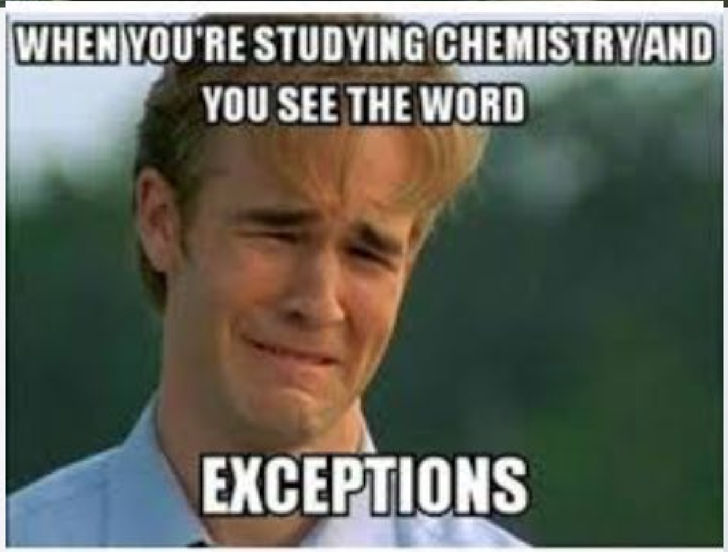
Office hours held virtually through the MSLC.
Tues 9.00 am to 11.00 am

PLEASE READ THE SYLLABUS









IMPORTANT ANNOUNCEMENTS

1. Email chem200@sdsu.edu ONLY unless its regarding lab or discussion which then you need to email your respective TA.

2. Follow the directions in adding OWL that Theresa provided you in Module 1.0 > Adding OWL (READ). She made a video and has a pdf file with directions.

3. **There is no course key for OWL.**

4. **Read the announcements and emails that Theresa, Megan, or your TAs sends out.**

5. Again read the syllabus. A lot of questions are being asked that are in the syllabus. For example, emailing when the lab will be and what will take place can be answered by the syllabus. In the syllabus there is a lab schedule, read, use it, and print it out.

6. And for good measure read the announcements before sending out emails. The majority (98%) of questions can be answered by: the syllabus, videos Theresa has made, and in the announcements.

UPCOMING IMPORTANT DATES

- Safety Quiz due **Friday, February 3rd at 11:59 pm** (in OWL Lab & Canvas), *must pass with >60% to do in-person labs*
- How to write a lab notebook and prelab due **Sunday, February 5th at 11:59 pm**
- Volumetric Prelab due **Sunday, February 5th at 11:59 pm**
- Volumetric Lab Report due **Sunday, February ~~5th~~ 12th! at 11:59 pm**
- Chapter 1-4 Chapter Problem Sets in OWL Lecture due **Thursday, February 9th at 11:59 pm** (**Start Now)**
- Chapter 1-4 Chapter Assessments in OWL Lecture is **Thursday, February 9th at 11:59 pm** (**Start Now**); 2 chances, no time limit
- Exam 1 starts at **3 pm Friday, February 10th and will close on Saturday, February 11th at 3pm** in OWL Lecture; Chapters 1-4. You have 24hrs. *Only 2 hrs once you start; be sure to give yourself a full 2 hr time slot.*

SUPPLEMENTAL INSTRUCTION (SI)

- Study sessions lead by former CHEM 200/202 students that excelled in the previous semesters class.
- Occur 15+ times a week.
- Free to access, no reporting to faculty.

THE MATH AND SCIENCE LEARNING CENTER (MSLC)

Students are encouraged to make use of The Mathematics and Statistics Learning Center (MSLC) for free STEM tutoring, located in the Love Library, Room 328. For a full list of courses tutored, please visit the MSLC website: https://mlc.sdsu.edu/ .

The MSLC is supported by your student success fee. We strongly encourage you to use this wonderful, free resource. Some students believe that they shouldn't need to ask for help, but research has shown that the average grade for students who attend the MLC is almost one full grade higher than those who don't seek such support.

EARLY ATOMIC THEORY

THE SUB-ATOMIC PARTICLES

ISOTOPES AND IONS

MOLECULAR AND IONIC COMPOUNDS

NOMENCLATURE

Chapter 2: Atoms, Molecules and Ions

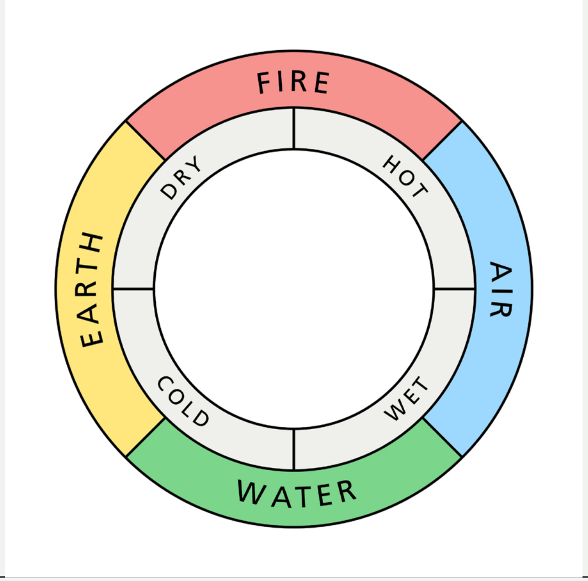
Early Theories About Matter

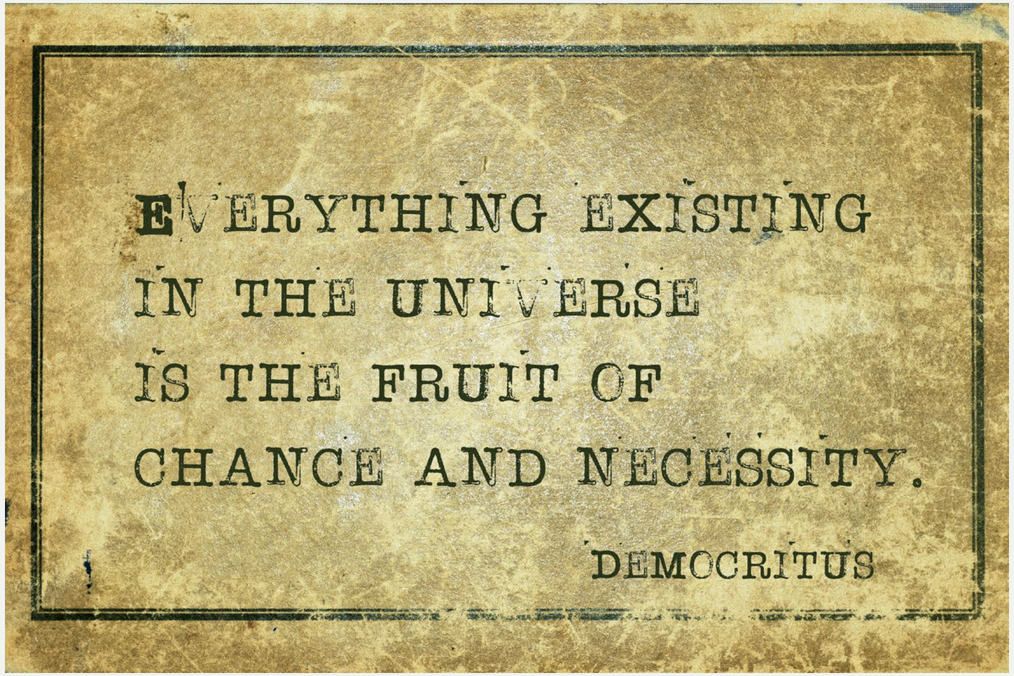
The Greeks:

Can matter be divided into infinitely smaller pieces?

If not, what is the smallest unit of matter?

"Atomos"- Indivisible



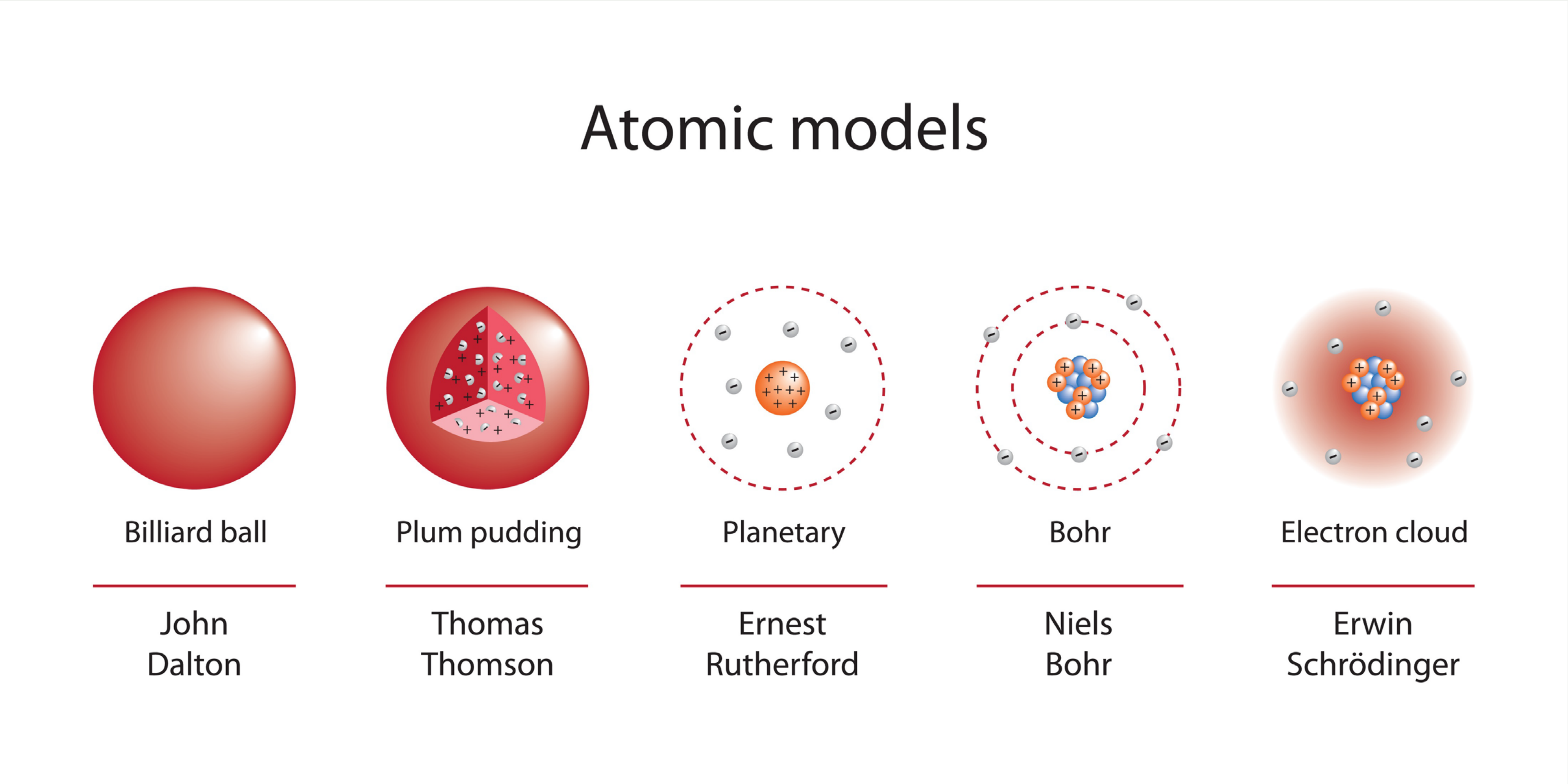


Early Theories about Matter

Alchemists-

Tried to “transmute” lead into gold, among other things.

Very secretive, not sharing knowledge


Atomic models
Billiard ball
John Dalton
Plum pudding
Thomas Thomson
Planetary
Ernest Rutherford
Bohr
Niels Bohr
Electron cloud
Erwin Schrödinger

Dalton’s Atomic Theory

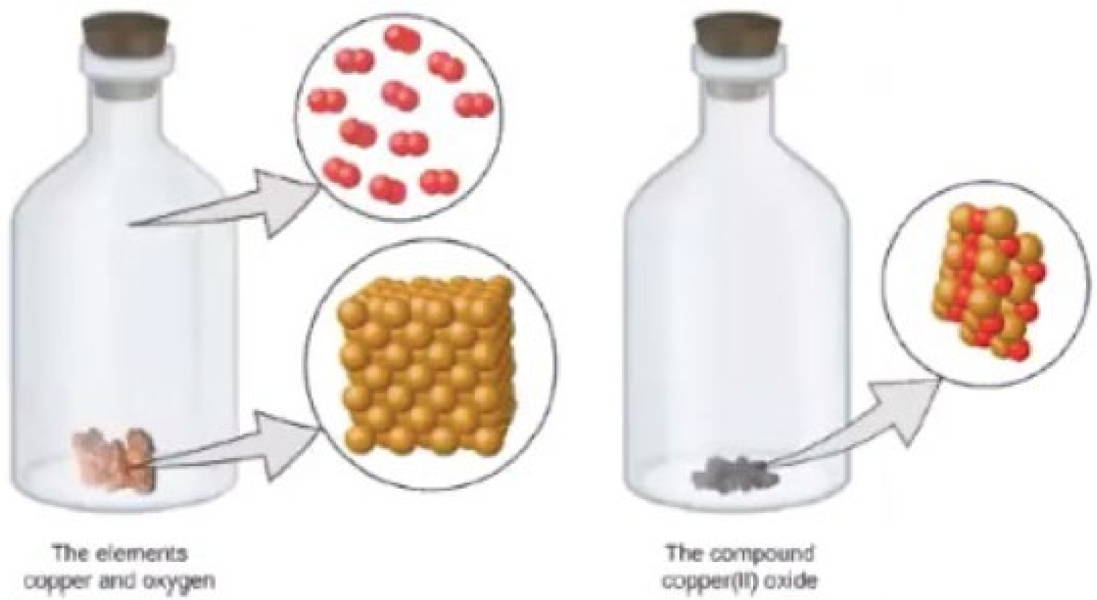


Figure 2.4 When the elements copper (a shiny, red-brown solid, shown here as brown spheres) and oxygen (a clear and colorless gas, shown here as red spheres) react, their atoms rearrange to form a compound containing copper and oxygen (a powdery, black solid). (credit copper: modification of work by http://images-of-elements.com/copper.php)

1. Matter consists of atoms
2. Atoms are the smallest unit of an element that still has the properties of that element
3. Elements consist of only one type of atom
4. Atoms of one element differ in properties from atoms of another element
5. A compound is made from atoms of tow or more different elements combined in small whole number ratios (Law of Constant Composition)
6. During chemical reactions, atoms are not created or destroyed but rather rearranged to form different compounds (Law of Conservation of Mass)

Law of Constant Composition

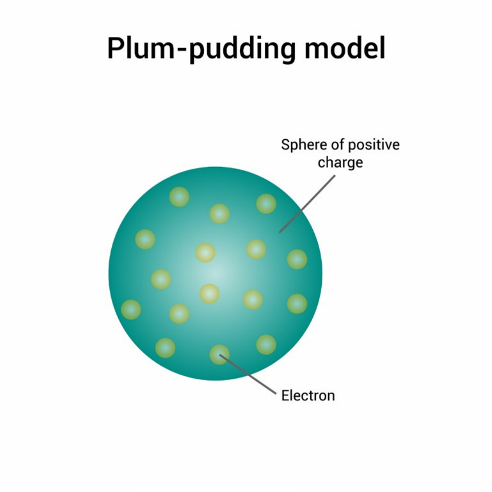
All samples of a Pure Compound contain the same elements in the same proportions

Constant Composition of Isooctane

Sample	Carbon	Hydrogen	Mass Ratio
A	14.82 g	2.78 g	$\frac{14.82 \text{ g carbon}}{2.78 \text{ g hydrogen}} = \frac{5.33 \text{ g carbon}}{1.00 \text{ g hydrogen}}$
B	22.33 g	4.19 g	$\frac{22.33 \text{ g carbon}}{4.19 \text{ g hydrogen}} = \frac{5.33 \text{ g carbon}}{1.00 \text{ g hydrogen}}$
C	19.40 g	3.64 g	$\frac{19.40 \text{ g carbon}}{3.63 \text{ g hydrogen}} = \frac{5.33 \text{ g carbon}}{1.00 \text{ g hydrogen}}$

Table 2.1

J.J. Thomson



Discovery of Electrons

Calculated the mass to charge ratio for electrons

https://youtu.be/o1z2S3ME0cI

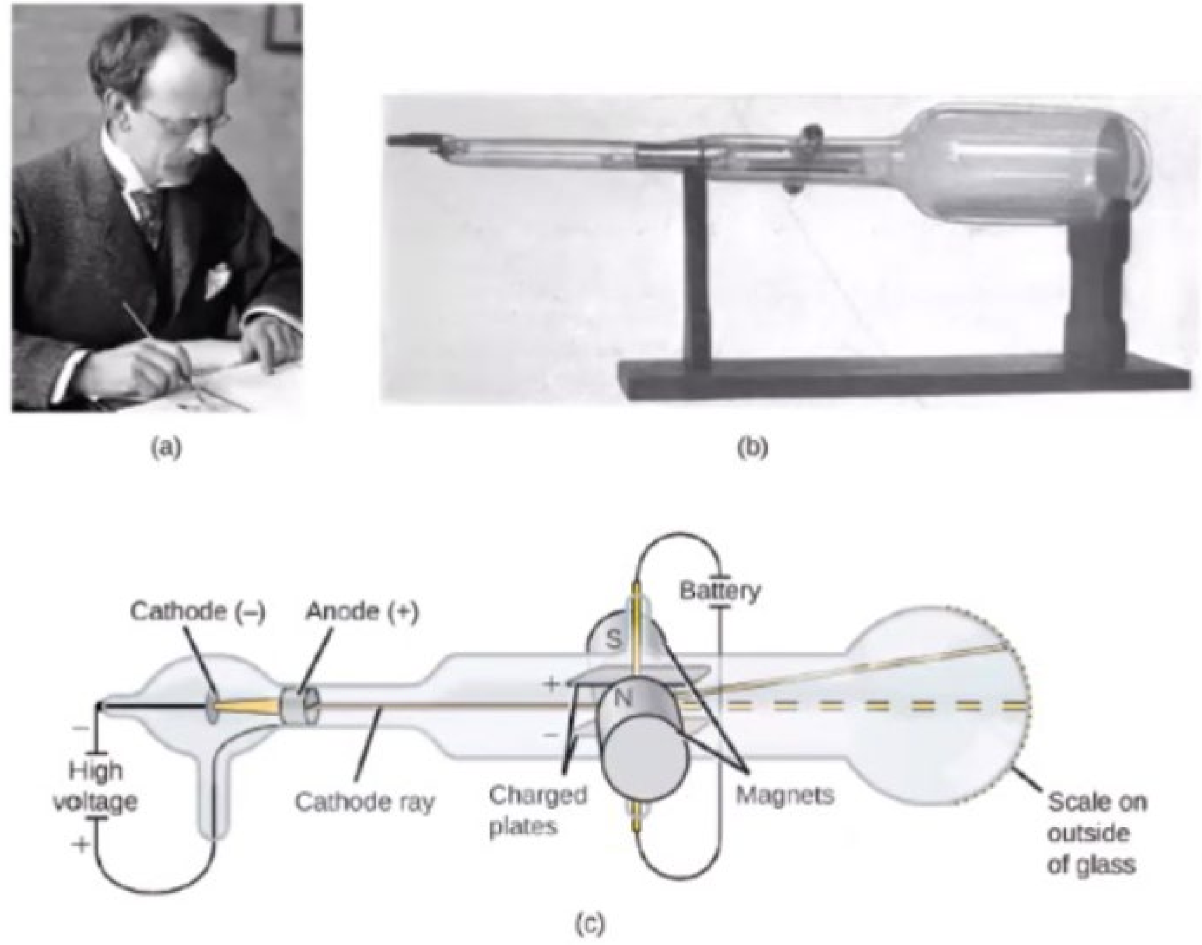
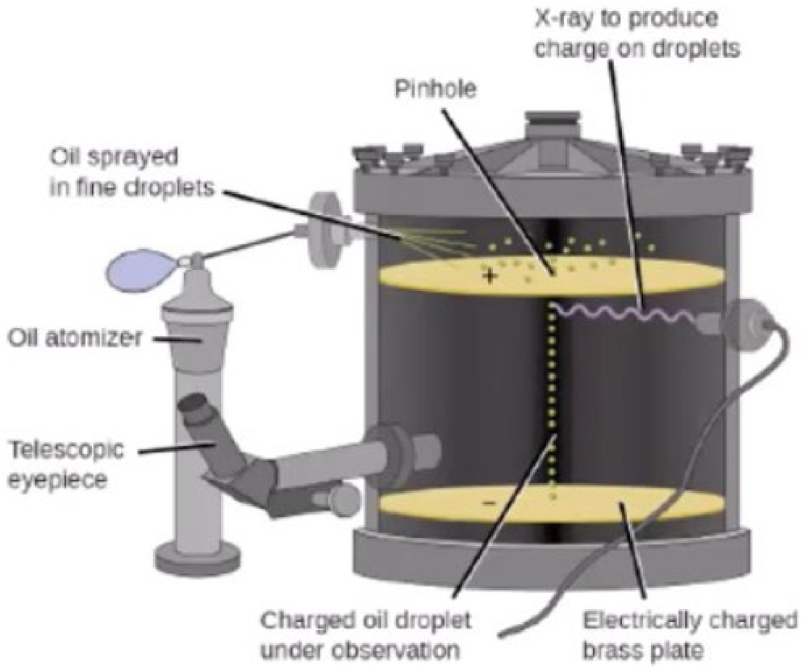


Figure 2.6 (a) J. J. Thomson produced a visible beam in a cathode ray tube. (b) This is an early cathode ray tube, invented in 1897 by Ferdinand Braun. (c) In the cathode ray, the beam (shown in yellow) comes from the cathode and is accelerated past the anode toward a fluorescent scale at the end of the tube. Simultaneous deflections by applied

Oil Drop Experiment



Oil drop	Charge in coulombs (C)
A	4.8×10^{-19} C
B	3.2×10^{-19} C
C	6.4×10^{-19} C
D	1.6×10^{-19} C
E	4.8×10^{-19} C

Figure 2.7 Millikan's experiment measured the charge of individual oil drops. The tabulated data are examples of a few possible values.

Determined the magnitude of the elemental charge

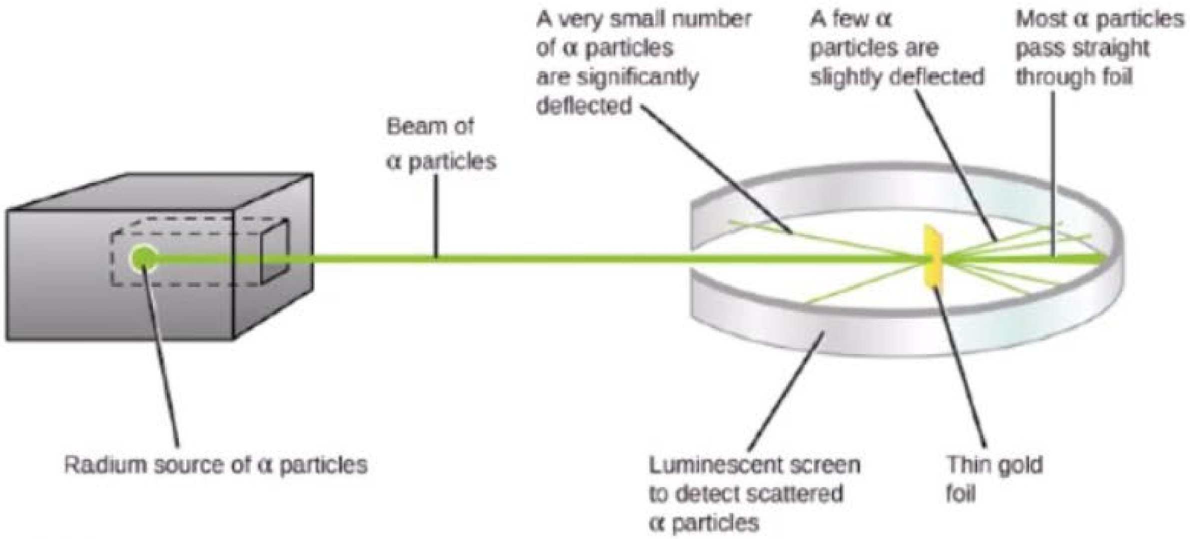


Figure 2.9 Geiger and Rutherford fired α particles at a piece of gold foil and detected where those particles went, as shown in this schematic diagram of their experiment. Most of the particles passed straight through the foil, but a few were deflected slightly and a very small number were significantly deflected.

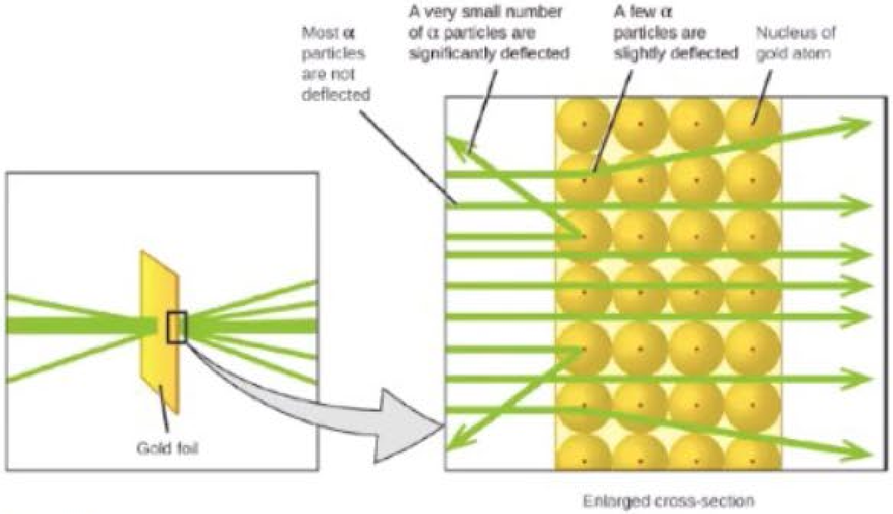
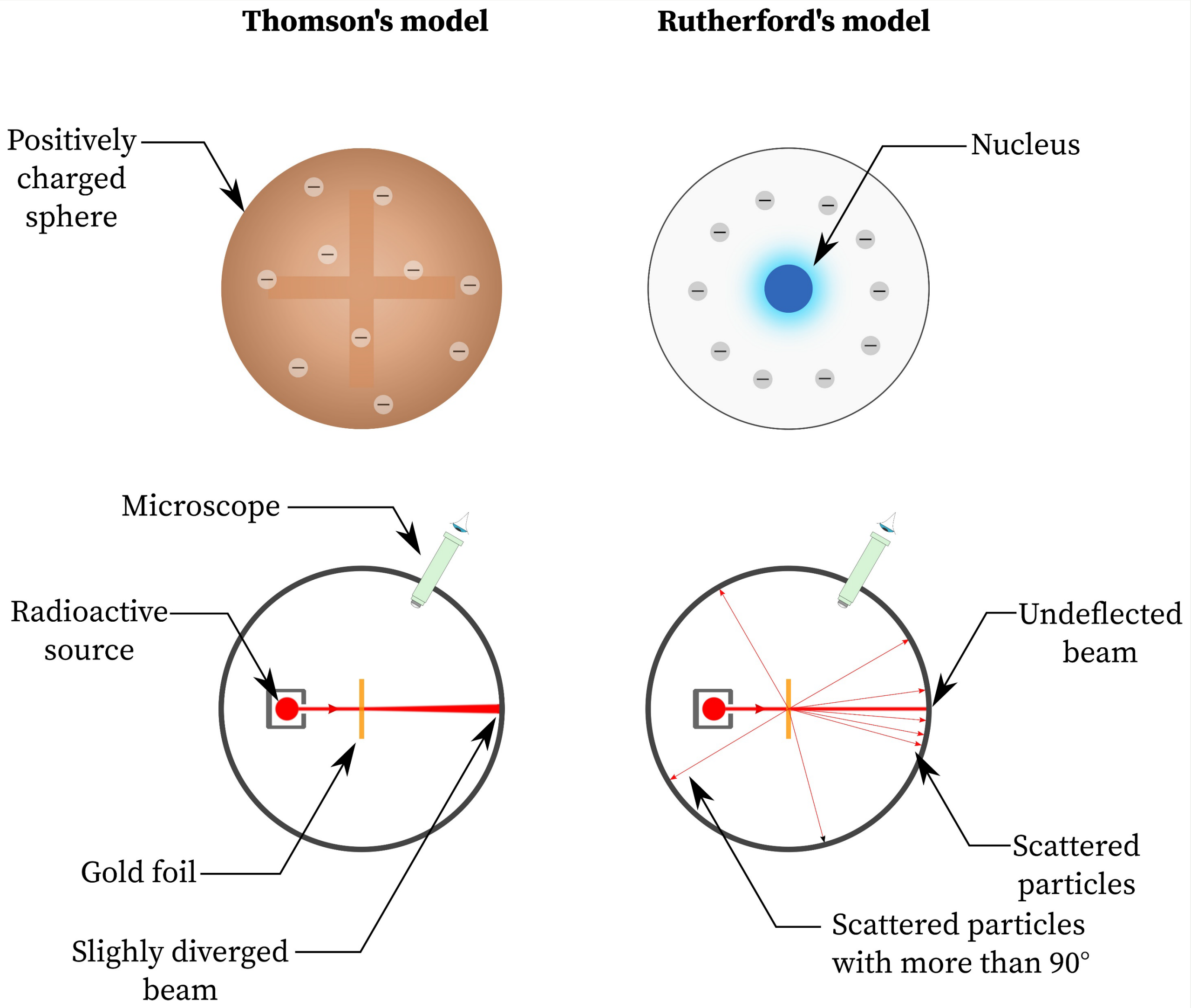


Figure 2.10 The α particles are deflected only when they collide with or pass close to the much heavier, positively charged gold nucleus. Because the nucleus is very small compared to the size of an atom, very few α particles are deflected. Most pass through the relatively large region occupied by electrons, which are too light to deflect the rapidly moving particles.

Gold Foil Experiment

Discovery of the Nucleus


Thomson's model
Rutherford's model
Positively charged sphere
Nucleus
Microscope
Radioactive source
Undeflected beam
Gold foil
Scattered particles
Slighly diverged beam
Scattered particles with more than 90°

The Subatomic Particles

Properties of Subatomic Particles

Name	Location	Charge (C)	Unit Charge	Mass (amu)	Mass (g)
electron	outside nucleus	-1.602×10^{-19}	1−	0.00055	0.00091×10^{-24}
proton	nucleus	1.602×10^{-19}	1+	1.00727	1.67262×10^{-24}
neutron	nucleus	0	0	1.00866	1.67493×10^{-24}

Table 2.2

Isotopes

Nuclear Compositions of Atoms of the Very Light Elements

Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Mass (amu)	% Natural Abundance
	${}^{2}_{1}H$ (deuterium)	1	1	1	2.0141	0.0115
	${}^{3}_{1}H$ (tritium)	1	1	2	3.01605	— (trace)
helium	${}^{3}_{2}He$	2	2	1	3.01603	0.00013
	${}^{4}_{2}He$	2	2	2	4.0026	100
lithium	${}^{6}_{3}Li$	3	3	3	6.0151	7.59
	${}^{7}_{3}Li$	3	3	4	7.0160	92.41
beryllium	${}^{9}_{4}Be$	4	4	5	9.0122	100
boron	${}^{10}_{5}B$	5	5	5	10.0129	19.9
	${}^{11}_{5}B$	5	5	6	11.0093	80.1
carbon	${}^{12}_{6}C$	6	6	6	12.0000	98.89
	${}^{13}_{6}C$	6	6	7	13.0034	1.11
	${}^{14}_{6}C$	6	6	8	14.0032	— (trace)
nitrogen	${}^{14}_{7}N$	7	7	7	14.0031	99.63
	${}^{15}_{7}N$	7	7	8	15.0001	0.37
oxygen	${}^{16}_{8}O$	8	8	8	15.9949	99.757
	${}^{17}_{8}O$	8	8	9	16.9991	0.038
	${}^{18}_{8}O$	8	8	10	17.9992	0.205
fluorine	${}^{19}_{9}F$	9	9	10	18.9984	100
neon	${}^{20}_{10}Ne$	10	10	10	19.9924	90.48
	${}^{21}_{10}Ne$	10	10	11	20.9938	0.27
	${}^{22}_{10}Ne$	10	10	12	21.9914	9.25

Table 2.4

Ions

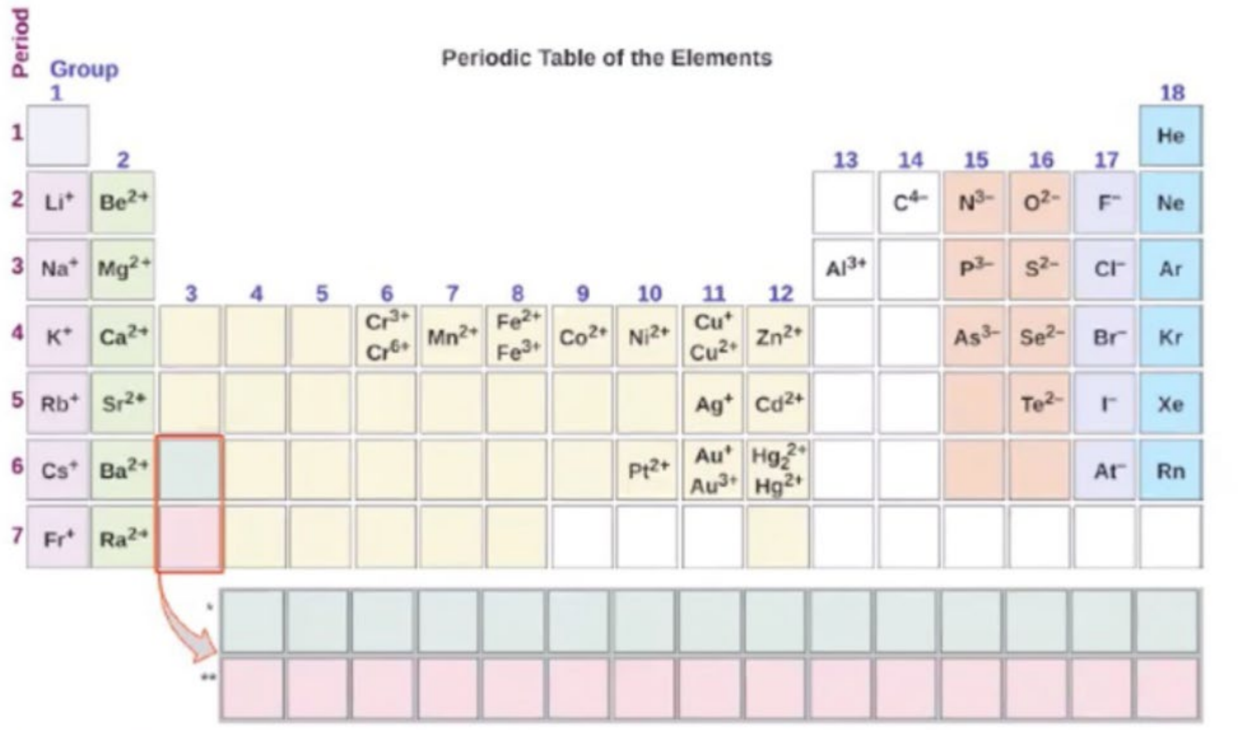
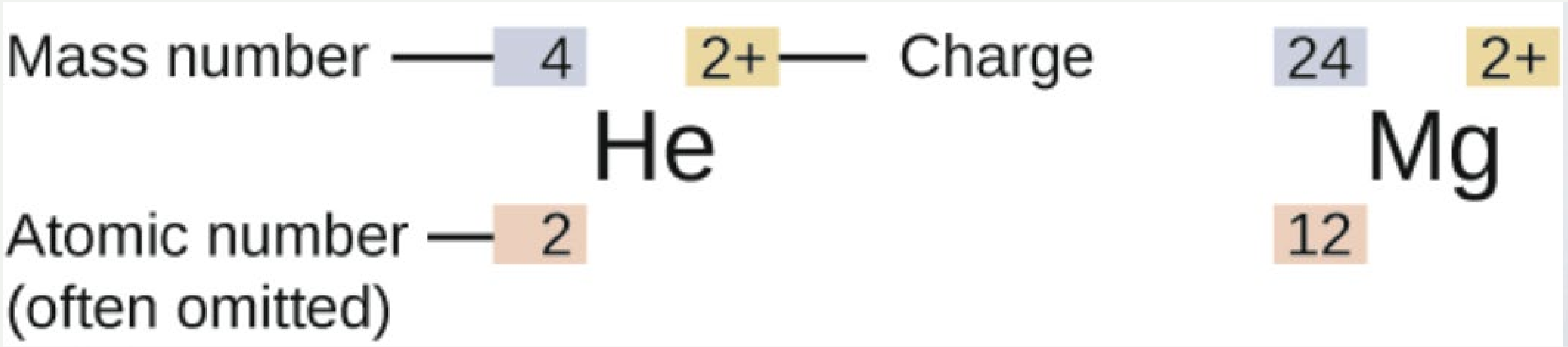
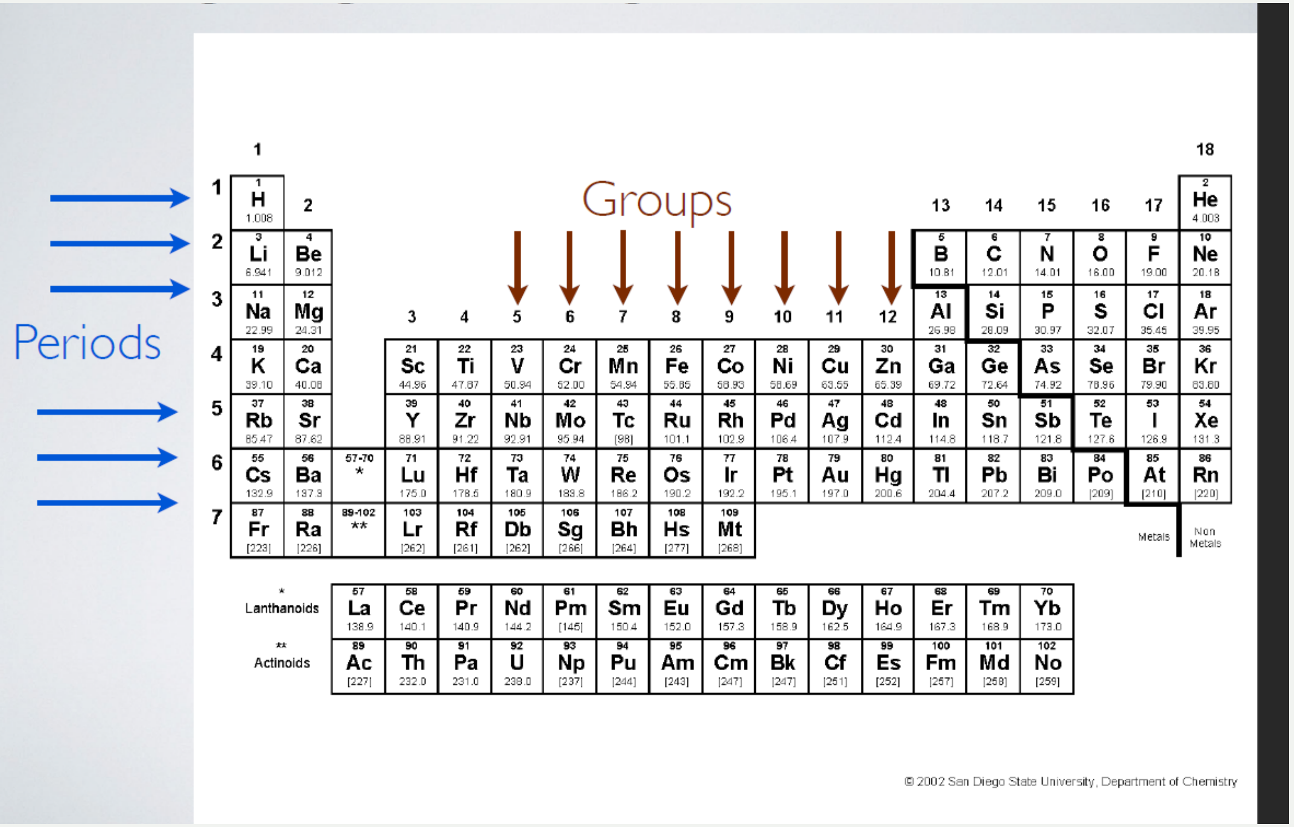


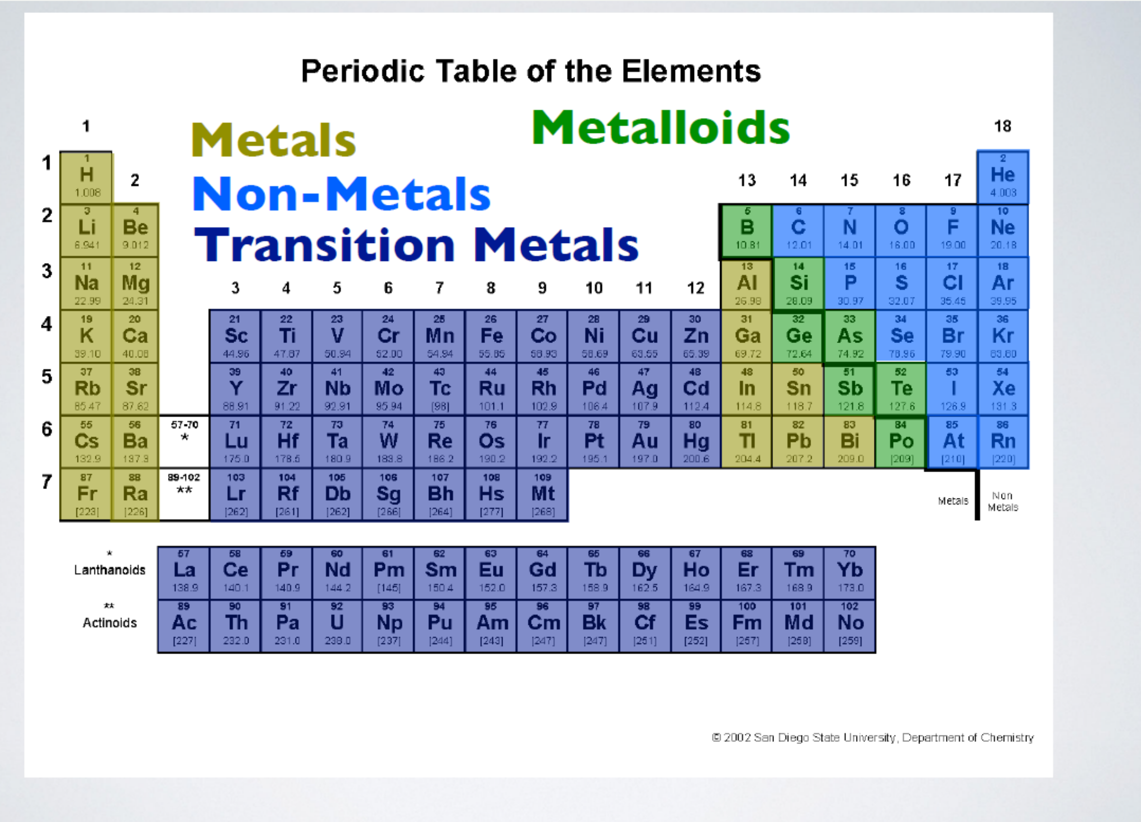
Figure 2.29 Some elements exhibit a regular pattern of ionic charge when they form ions.

Atomic Symbols



The periodic table




Periodic Table of the Elements
Metals
Non-Metals
Transition Metals
Metalloids
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba 57-70 * Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra 89-102 ** Lr Rf Db Sg Bh Hs Mt
Metals
Non Metals
* Lanthanoids La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb
** Actinoids Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No
© 2002 San Diego State University, Department of Chemistry

Atomic Mass vs. Atomic Weight vs. Mass Number

- Atomic Mass= The mass of a single atom
  - A single ^{12}C atom has an atomic mass of exactly 12 amu (defined)
  - A single ^{13}C atom has an atomic mass of 13.003355 amu (to 8 sig figs)
  - A single ^{16}O atom has an atomic mass of 15.994914 amu (to 8 sig figs)
- Atomic Weight (Average Atomic Mass)= The average mass of the isotopes
  - Carbon has an Average Atomic Mass of 12.011 amu
  - Oxygen has an Average Atomic Mass of 15.999 amu
- Mass Number = Number of Protons + Number of Neutrons
  - ^{12}C has 6 protons and 6 neutrons
  - ^{13}C has 6 protons and 7 neutrons

How many protons, neutrons and electrons?

$$^{16}_{8}O^{-2}$$

Mass Spectrometry

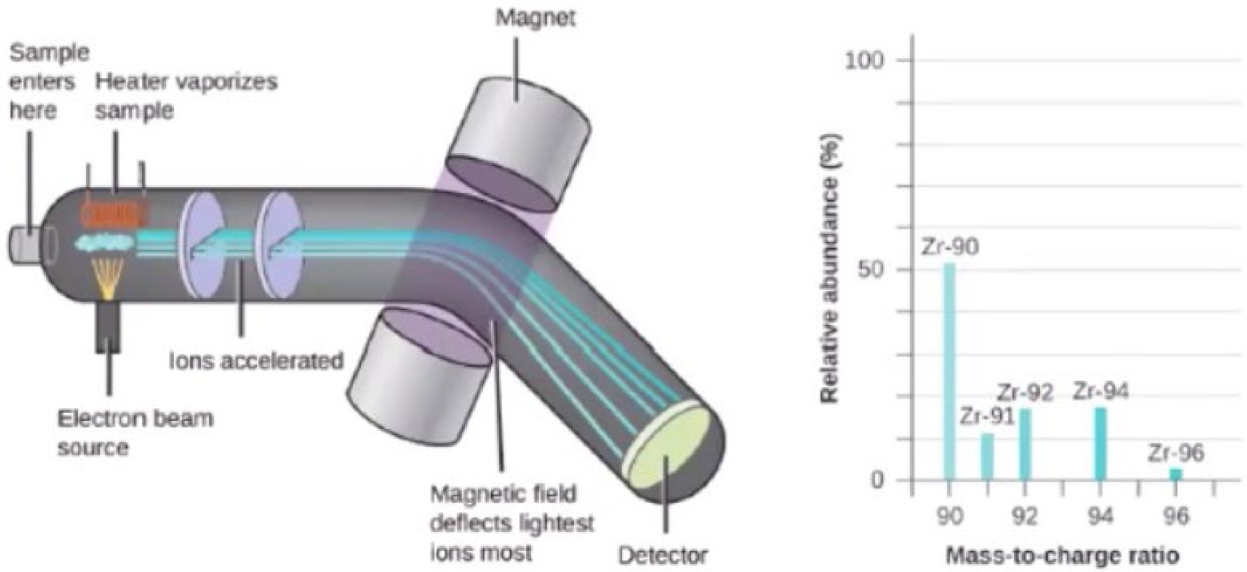


Figure 2.15 Analysis of zirconium in a mass spectrometer produces a mass spectrum with peaks showing the different isotopes of Zr.

Calculating Average Atomic Mass

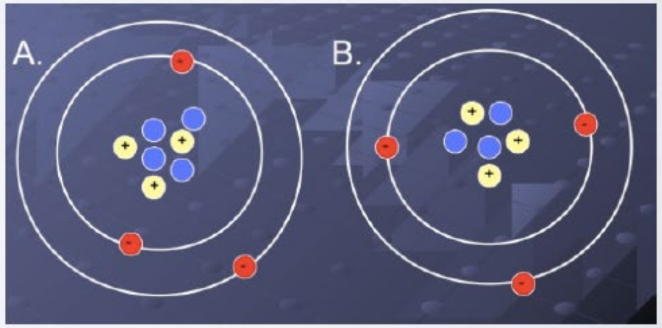
Isotopes of Silicon:	Percent Abundance:	Atomic Mass:
Silicon-28	92.23%	27.97693 amu
Silicon-29	4.68%	28.97649 amu
Silicon-30	3.09%	29.97377 amu

27.97693 amu (0.9223) + 28.97649 amu (0.0468) + 29.97377 amu (0.0309) = 28.09 amu

Finding Percent Abundance

- The average mass for lithium (Li) is 6.94 g/mol. The isotopes of lithium are ^{6}Li and ^{7}Li with respective masses of 6.0151 amu and 7.0160 amu.

- Given this information, what is the abundance of each of the isotopes?



Molecular Formula

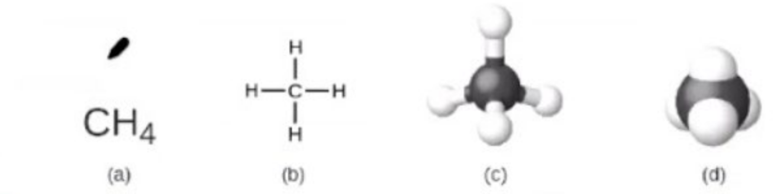


Figure 2.16 A methane molecule can be represented as (a) a molecular formula, (b) a structural formula, (c) a ball-and-stick model, and (d) a space-filling model. Carbon and hydrogen atoms are represented by black and white spheres, respectively.

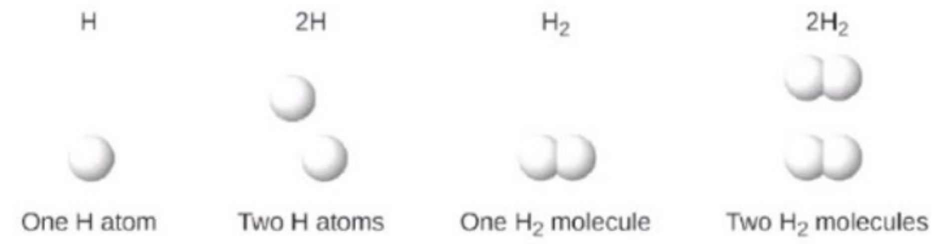


Figure 2.18 The symbols H, 2H, H_2, and $2H_2$ represent very different entities.

Empirical Formula

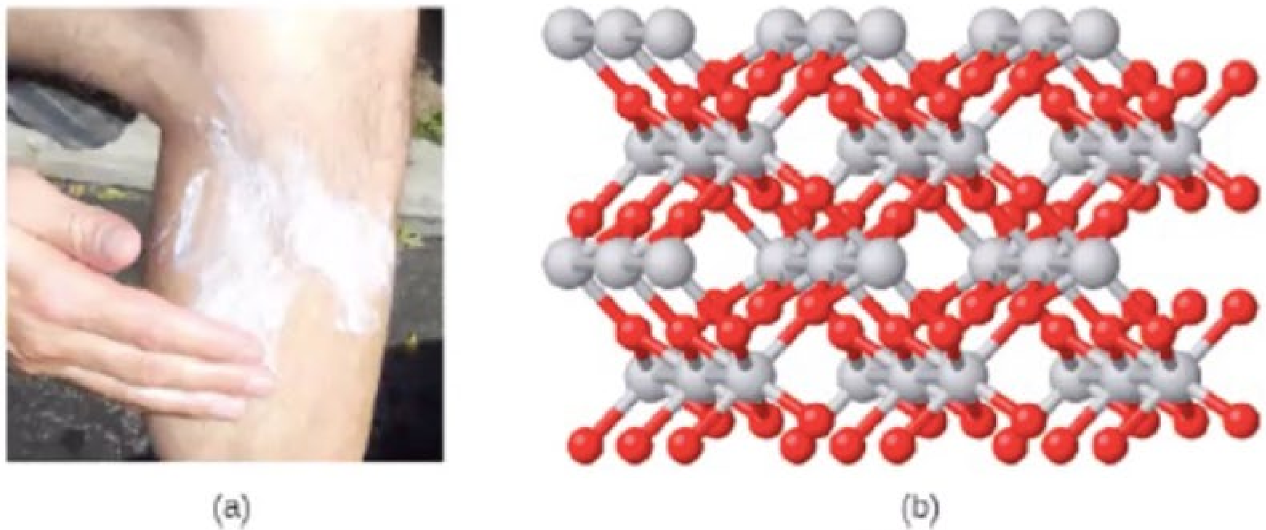


Figure 2.19 (a) The white compound titanium dioxide provides effective protection from the sun. (b) A crystal of titanium dioxide, TiO_2, contains titanium and oxygen in a ratio of 1 to 2. The titanium atoms are gray and the oxygen atoms are red. (credit a: modification of work by "osseous"/Flickr)

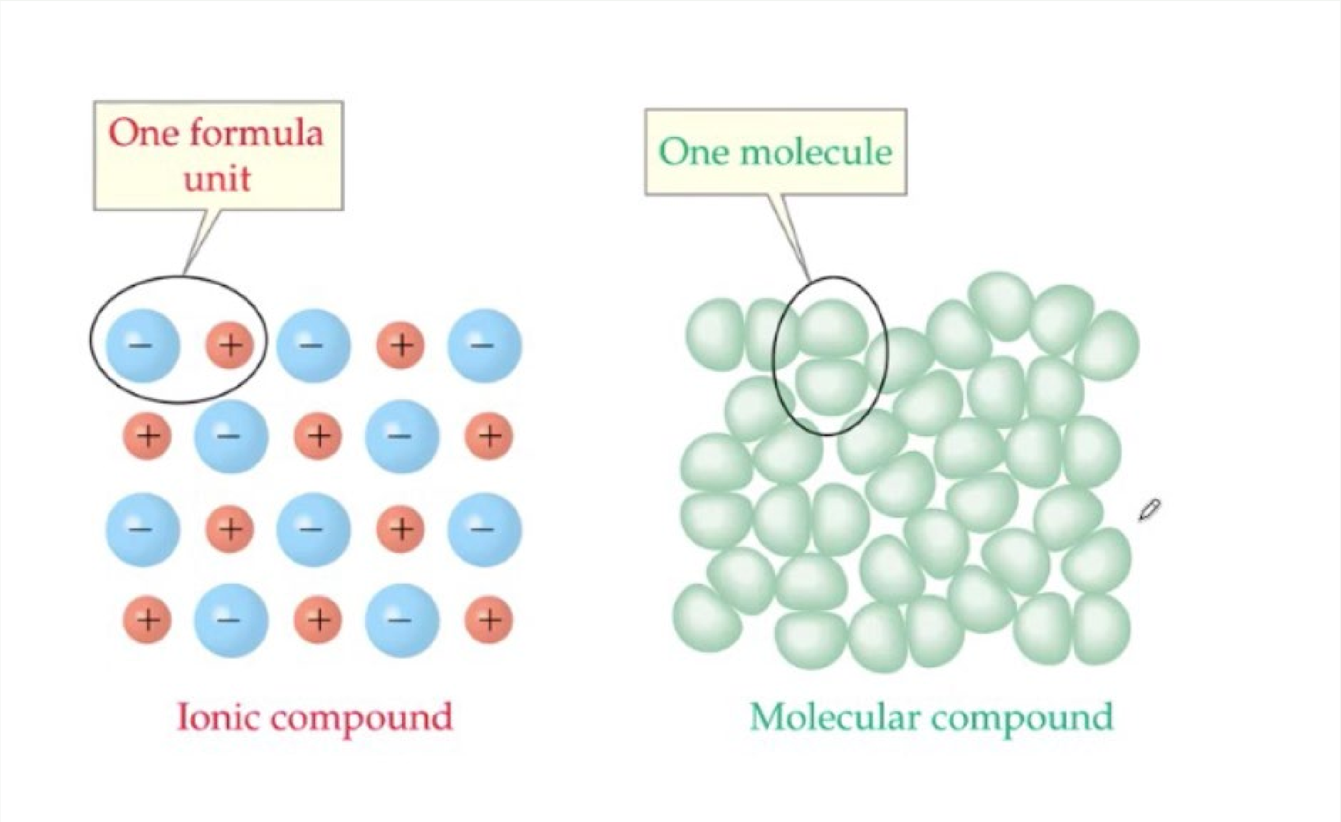
Molecular vs. Empirical Formula

- Molecular Formula:
  - The actual number of atoms that make up each molecule
- Empirical Formula:
  - The lowest whole number ratio of atoms
  - Ionic compounds don’t have molecular formulas, only empirical ones

Lecture Participation: What is the Empirical Formula of Glucose?

The Molecular formula for Glucose is $C_6H_{12}O_6$. What is its empirical formula?

Ionic and Molecular Compounds



Ionic Compounds

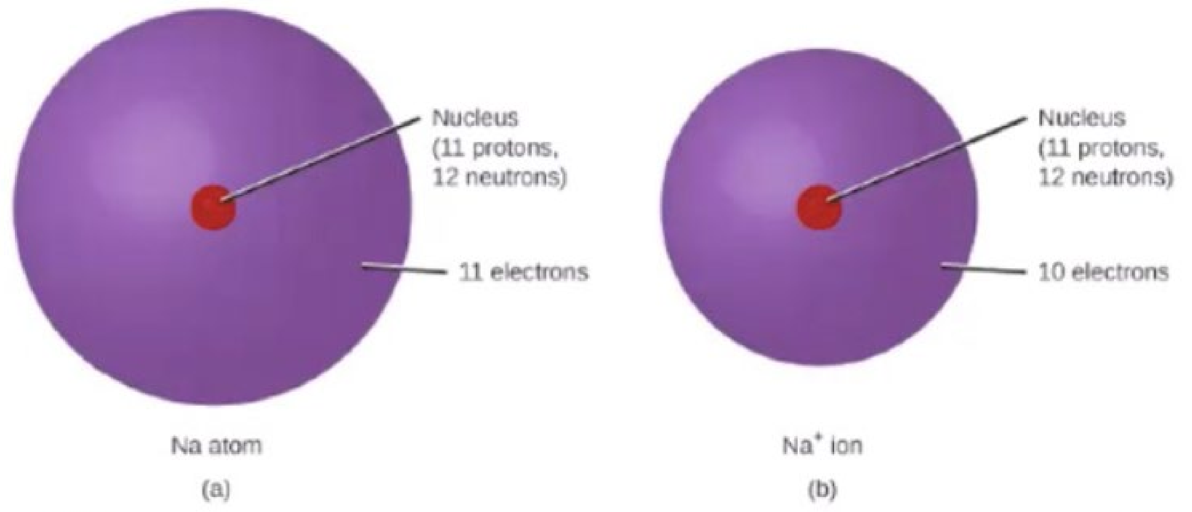


Figure 2.28 (a) A sodium atom (Na) has equal numbers of protons and electrons (11) and is uncharged. (b) A sodium cation (Na^+) has lost an electron, so it has one more proton (11) than electrons (10), giving it an overall positive charge, signified by a superscripted plus sign.

Polyatomic Ions

Common Polyatomic Ions

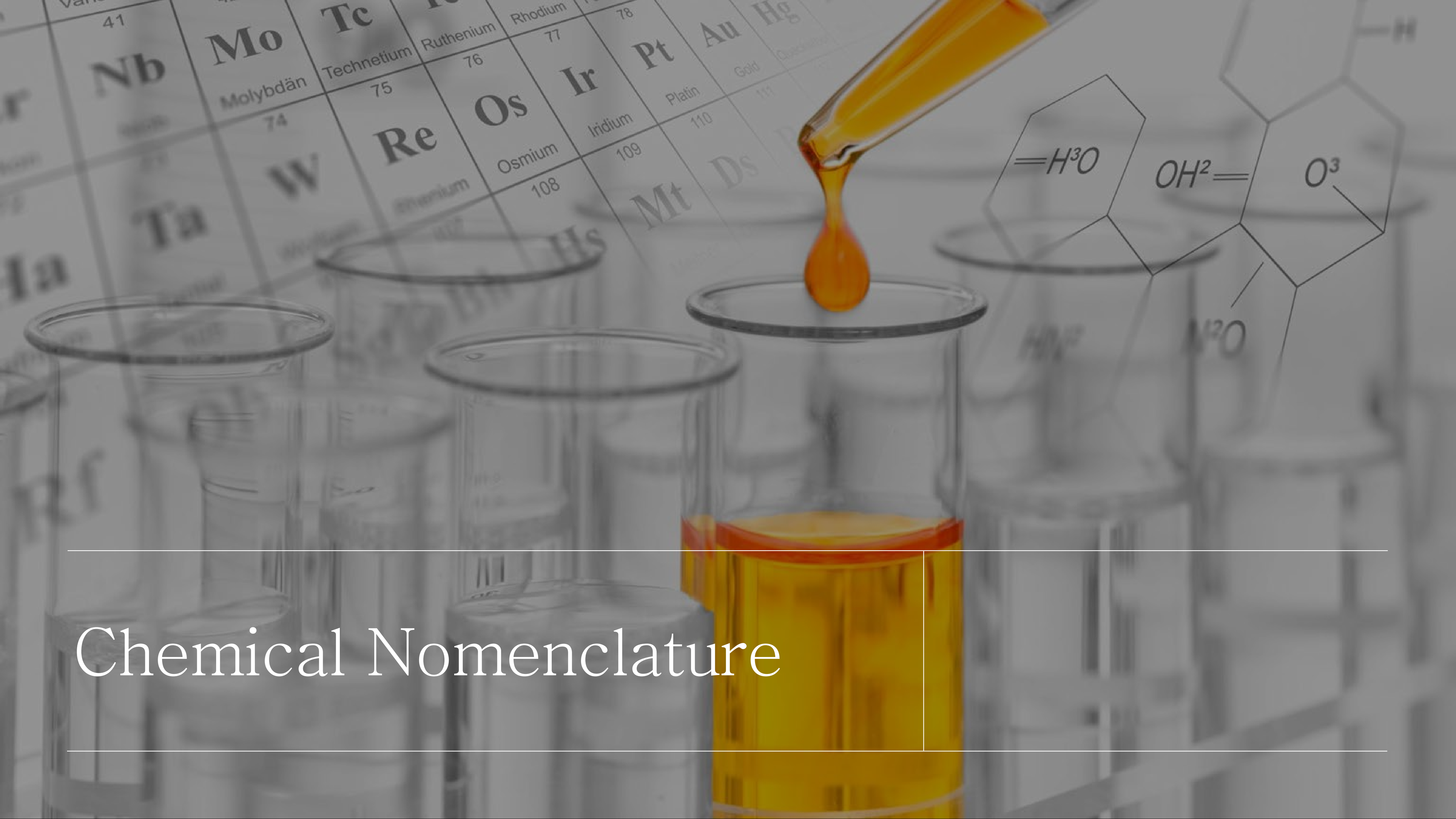
Name	Formula	Related Acid	Formula
hydrogen sulfate	HSO_4^-		
sulfite	SO_3^{2-}	sulfurous acid	H_2SO_3
hydrogen sulfite	HSO_3^-		
phosphate	PO_4^{3-}	phosphoric acid	H_3PO_4
hydrogen phosphate	HPO_4^{2-}		
dihydrogen phosphate	$H_2PO_4^-$		
perchlorate	ClO_4^-	perchloric acid	$HClO_4$
chlorate	ClO_3^-	chloric acid	$HClO_3$
chlorite	ClO_2^-	chlorous acid	$HClO_2$
hypochlorite	ClO^-	hypochlorous acid	$HClO$
chromate	CrO_4^{2-}	chromic acid	$H_2Cr_2O_4$
dichromate	$Cr_2O_7^{2-}$	dichromic acid	$H_2Cr_2O_7$
permanganate	MnO_4^-	permanganic acid	$HMnO_4$

Table 2.5

Common Polyatomic Ions

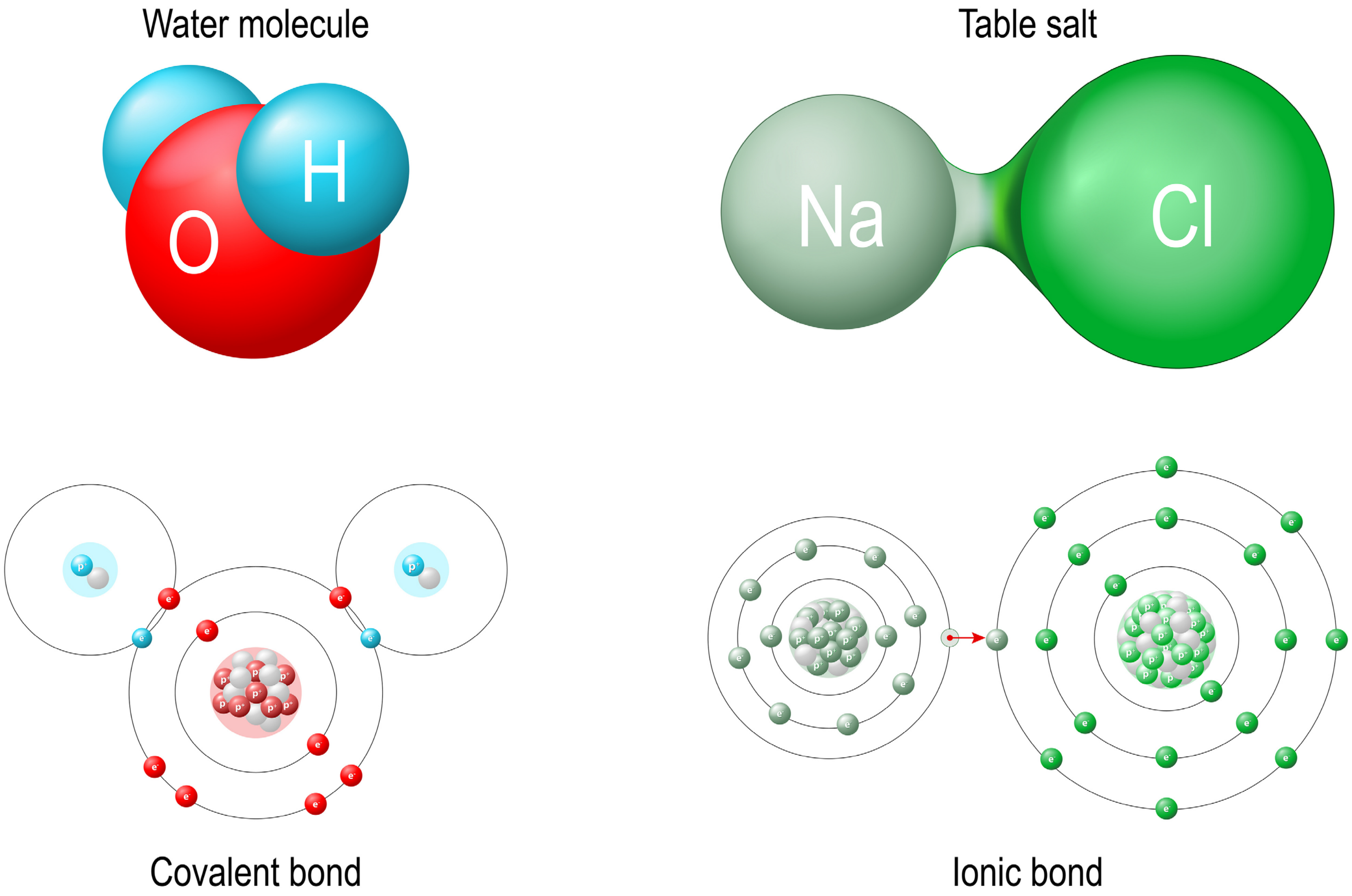
Name	Formula	Related Acid	Formula
ammonium	NH_4^+		
hydronium	H_3O^+		
oxide	O^{2-}		
peroxide	O_2^{2-}		
hydroxide	OH^-		
acetate	CH_3COO^-	acetic acid	CH_3COOH
cyanide	CN^-	hydrocyanic acid	HCN
azide	N_3^-	hydrazoic acid	HN_3
carbonate	CO_3^{2-}	carbonic acid	H_2CO_3
bicarbonate	HCO_3^-		
nitrate	NO_3^-	nitric acid	HNO_3
nitrite	NO_2^-	nitrous acid	HNO_2
sulfate	SO_4^{2-}	sulfiric acid	H_2SO_4

Table 2.5



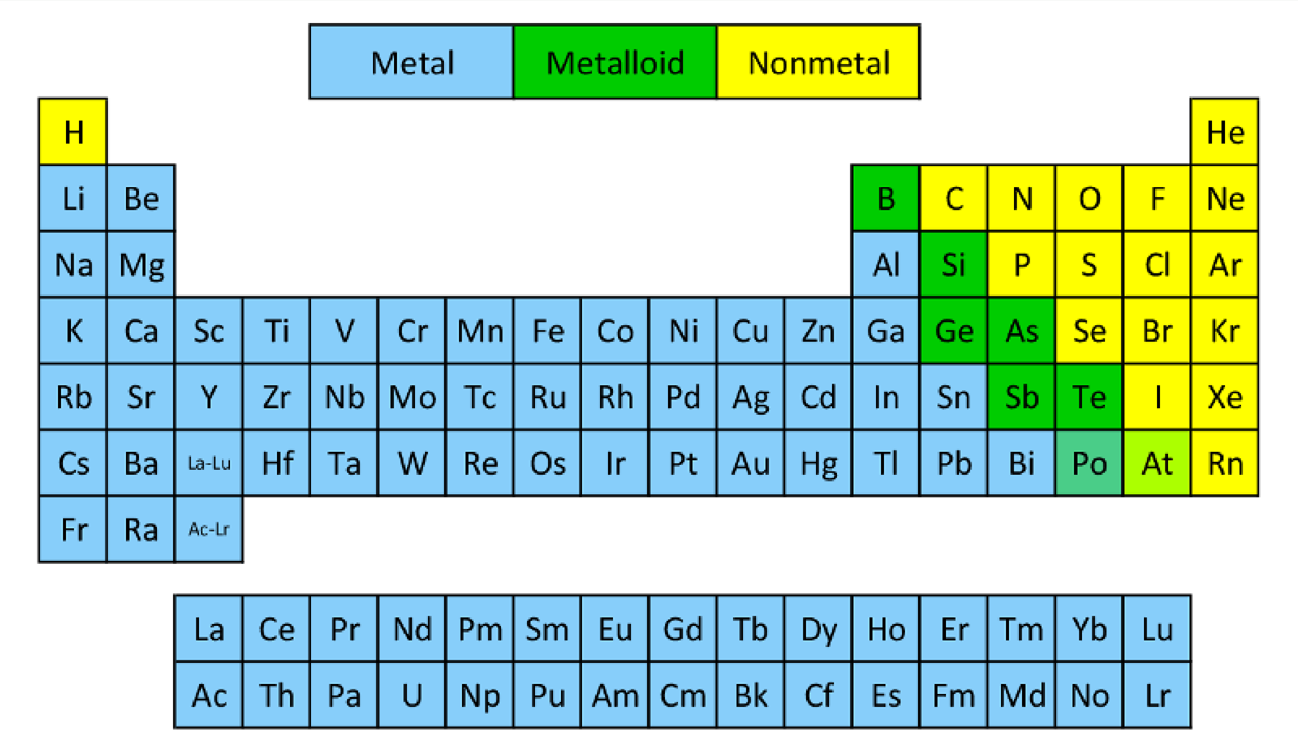
Chemical Nomenclature

Covalent and Ionic Bonds



Ionic compounds

Ionic compounds are formed between a metal and a non-metal. The ionic bond is produced by the electrostatic attraction between the positive and negative ions.



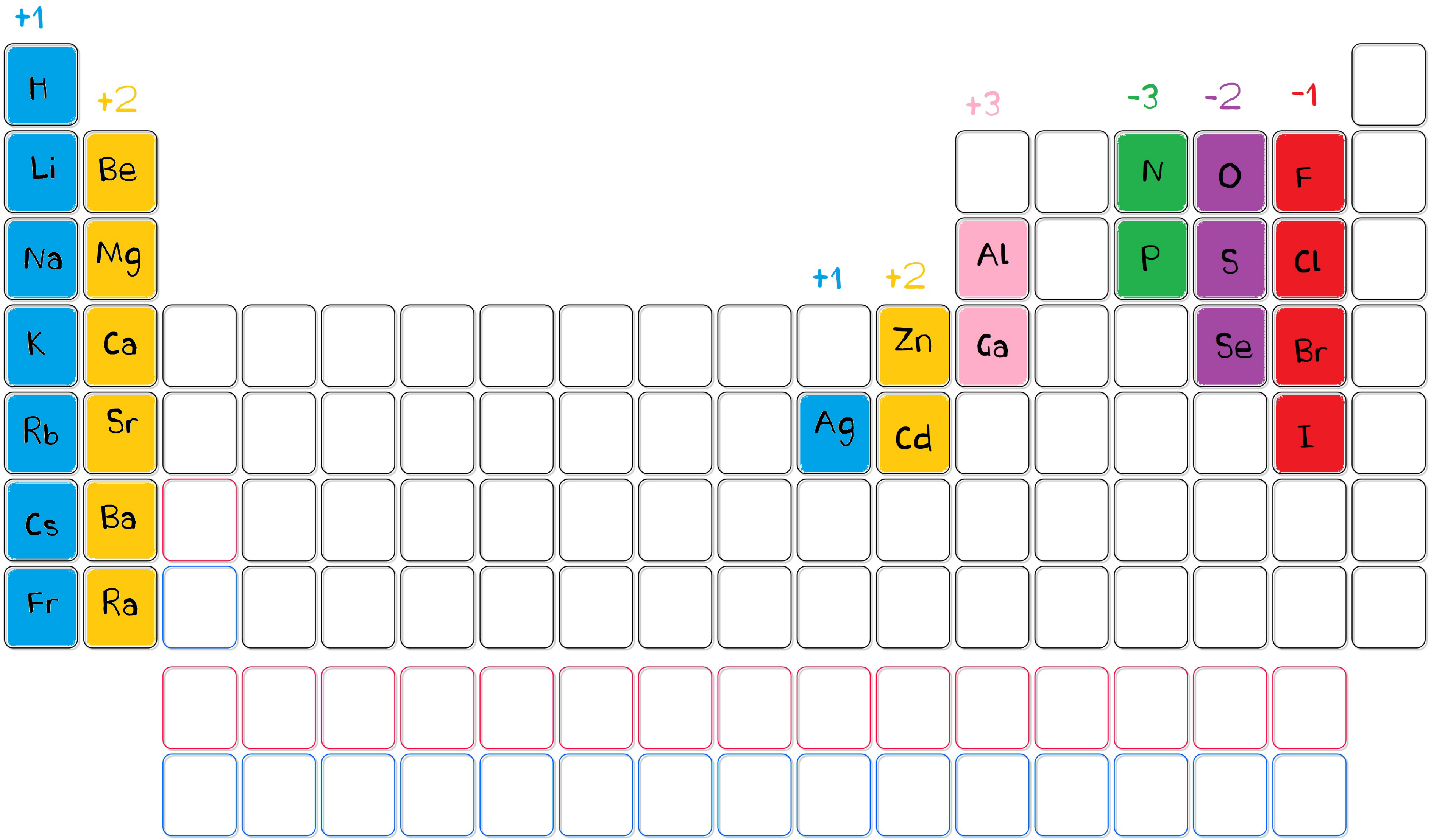
Type I: The cation has a determined charge

Some cations always have the same charge.

These cations form "Type I" Ionic Compounds.

+1 Charge:	Group 1 Metals, Silver (Ag^{+}), and Ammonium (NH_4^{+})
+2 Charge:	Group 2 Metals, Zinc (Zn^{2+}), and Cadmium (Cd^{2+})
+3 Charge:	Aluminum (Al^{3+}), and Gallium (Ga^{3+})

Name of Cation Name of Anion+ide


+1
H
+2
Li
Be
Na
Mg
K
Ca
Rb
Sr
Cs
Ba
Fr
Ra
+1
+2
Zn
Ag
Cd
+3
Al
Ga
-3
N
P
-2
O
S
Se
-1
F
Cl
Br
I

Examples

Mg_3N_2	Magnesium Nitride
CaF_2	Calcium Fluoride
NaI	Sodium Iodide
K_2S	Potassium Sulfide

EXAMPLES

Potassium Chloride	K^+ and Cl^- $\rightarrow$ KCl
Lithium Oxide	Li^+ and O^{2-} $\rightarrow$ Li_2O
Barium Phosphide	Ba^{2+} and P^{3-} $\rightarrow$ Ba_3P_2

Knowledge check

What is the formula for Sodium Nitride?

What is the name of $MgCl_2$?

Type II: The cation can form Ions with different charges

Many metals can form ions with different charges. For example, both Fe^{2+} and Fe^{3+} can form a compound with oxygen, so saying "iron oxide" is not specific. These are Type II Cations

Roman numerals are used to designate the charge of the cation. To determine the charge of the cation you must balance the known charge of the anion.

Name of Cation (Roman Numeral) Name of Anion+ide

Examples:

$FeO \rightarrow$ Iron (II) Oxide

Since oxygen is always O^{2-}, the iron must be Fe^{2+} to balance the charge

$Fe_2O_3 \rightarrow$ Iron (III) Oxide

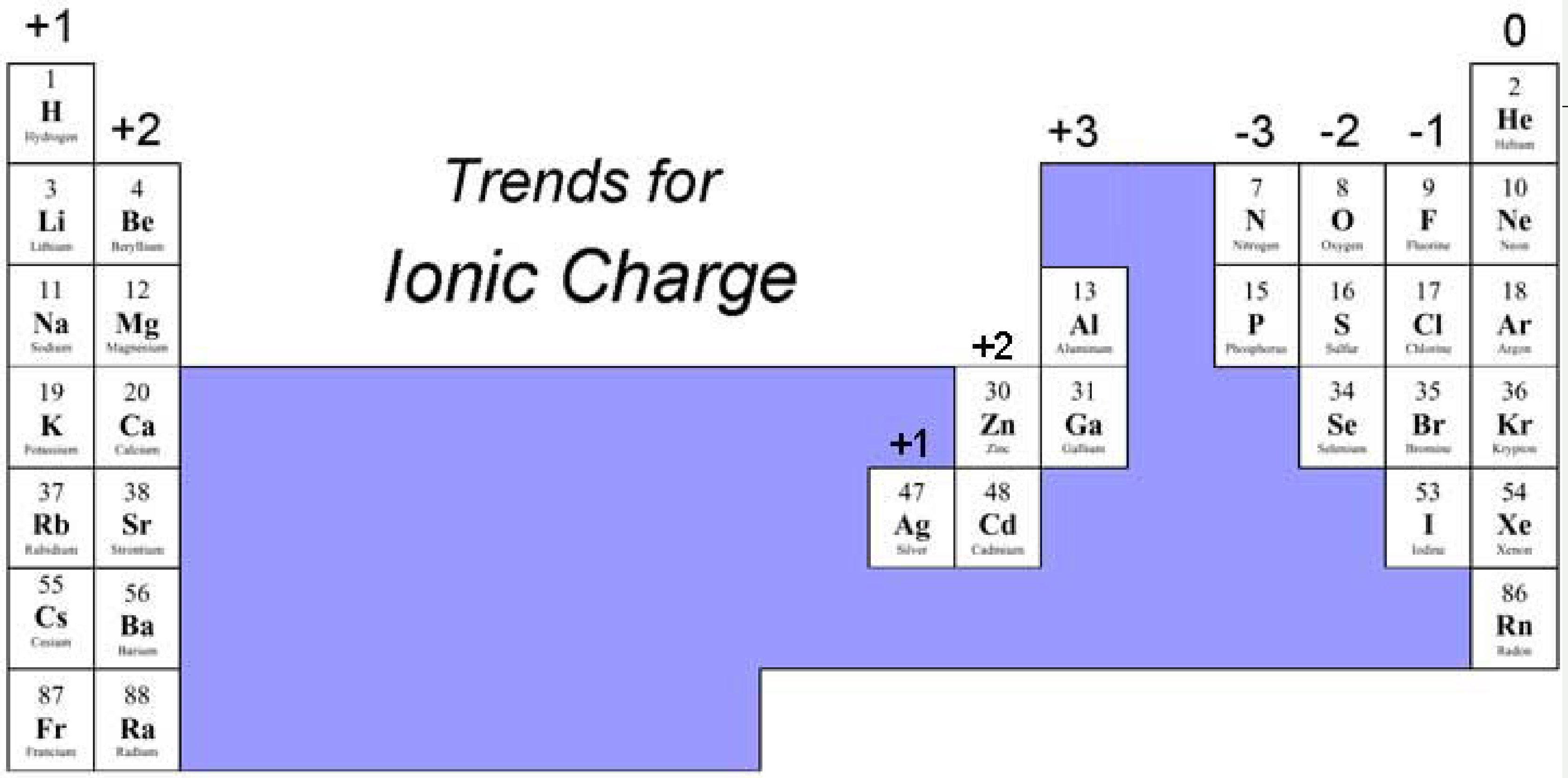
Since oxygen is always O^{2-} there is a total negative charge of -6. The iron ions must have a total charge of +6. Since there are two of them, the iron must be Fe^{3+} to balance the charge.

$PbCl_2 \rightarrow$ Lead (II) Chloride

Since chloride is always Cl^-, there is a total negative charge of -2. Since there is only one for them, the Lead must be Pb^{2+} to balance the charge.

$PbCl_4 \rightarrow$ Lead (IV) Chloride

Since chloride is always Cl^-, there is a total negative charge of -4. Since there is only one for them, the Lead must be Pb^{4+} to balance the charge.



Trends for
Ionic Charge
+1
+2
+3
-3
-2
-1
0
+2
+1
1 H Hydrogen
2 He Helium
3 Li Lithium
4 Be Beryllium
7 N Nitrogen
8 O Oxygen
9 F Fluorine
10 Ne Neon
11 Na Sodium
12 Mg Magnesium
13 Al Aluminum
15 P Phosphorus
16 S Sulfur
17 Cl Chlorine
18 Ar Argon
19 K Potassium
20 Ca Calcium
30 Zn Zinc
31 Ga Gallium
34 Se Selenium
35 Br Bromine
36 Kr Krypton
37 Rb Rubidium
38 Sr Strontium
47 Ag Silver
48 Cd Cadmium
53 I Iodine
54 Xe Xenon
55 Cs Cesium
56 Ba Barium
86 Rn Radon
87 Fr Francium
88 Ra Radium

Knowledge Check

What is the formula for Copper (II) Oxide?

What is the name of Pb_3N_4 ?

Ionic compounds with polyatomic Ions

Both Type I and Type II cations can form Ionic compounds with polyatomic ions.

Common Polyatomic Ions	
Nitrite	NO_2^-
Nitrate	NO_3^-
Sulfite	SO_3^{2-}
Sulfate	SO_4^{2-}
Phosphite	PO_3^{3-}
Phosphate	PO_4^{3-}
Carbonate	CO_3^{2-}
Hydroxide	OH^-

Hypochlorite	ClO^-
Chlorite	ClO_2^-
Chlorate	ClO_3^-
Perchlorate	ClO_4^-
Permanganate	MnO_4^-
Acetate	$C_2H_3O_2^-$
Hydrogen carbonate	HCO_3^-
Ammonium	NH_4^+
Iodate	IO_3^-

Ionic compounds with polyatomic Ions

The names of the polyatomic ions do not change when they are part of a compound. You must know the correct charge of the polyatomic ion in order to balance the charge of the cation. Paratheses are used to indicate multiple polyatomic ions.

Name of Cation Name of Anion

Examples:

Ammonium Phosphate $NH_4^+ + PO_4^{3-} \rightarrow (NH_4)_3PO_4$

Calcium Hypochlorite $Ca^{2+.} + ClO^- \rightarrow Ca(ClO)_2$

Magnesium Phosphite $Mg^{2+} + PO_3^{3-} \rightarrow Mg_3(PO_3)_2$

Chromium (III) Sulfate $Cr^{3+} + SO_3^{2-} \rightarrow Cr_2(SO_3)_3$

Knowledge Check

What is the formula for Potassium Sulfite?

What is the name of $Zn_3(PO_4)_2$?

K_2SO_3, Zinc Phosphate

Common Polyatomic Ions	
Nitrite	NO_2^-
Nitrate	NO_3^-
Sulfite	SO_3^{2-}
Sulfate	SO_4^{2-}
Phosphite	PO_3^{3-}
Phosphate	PO_4^{3-}
Carbonate	CO_3^{2-}
Hydroxide	OH^-
Hypochlorite	ClO^-
Chlorite	ClO_2^-
Chlorate	ClO_3^-
Perchlorate	ClO_4^-
Permanganate	MnO_4^-
Acetate	$C_2H_3O_2^-$
Hydrogen carbonate	HCO_3^-
Ammonium	NH_4^+
Iodate	IO_3^-

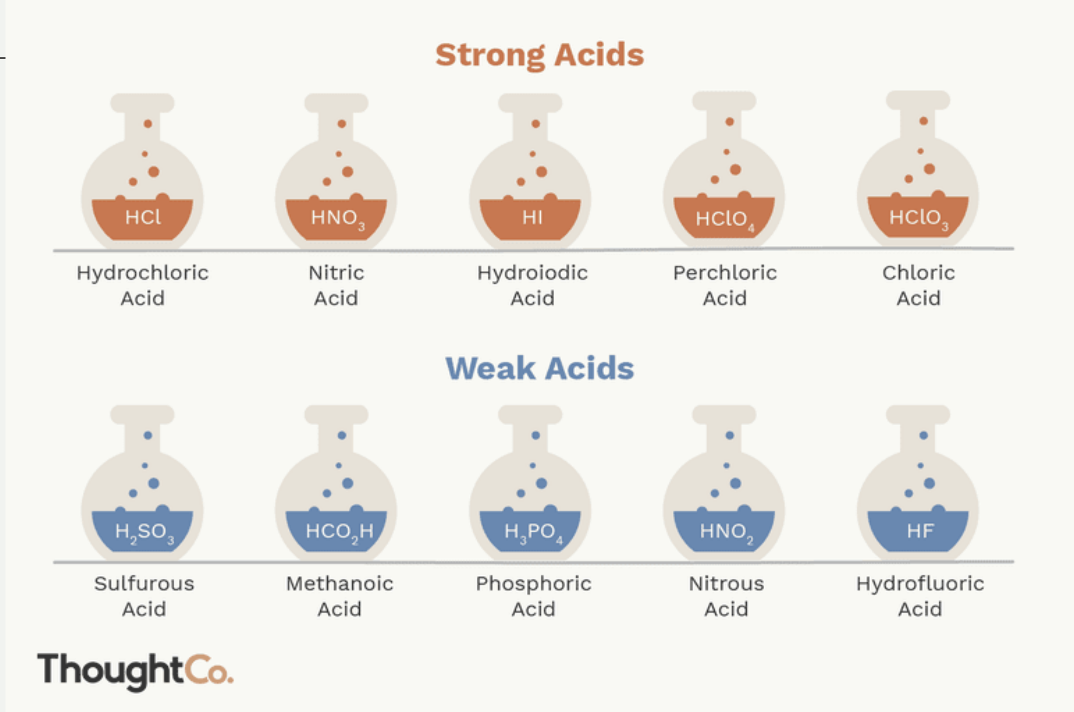
Acids

Ionic compounds containing one or more acidic proton (The cation is H^+)

There are two types of acids we will discuss:

Binary Acids- formed between Hydrogen and a single Element

Oxyacids- formed between Hydrogen and an oxygen containing polyatomic ion



Binary acids

Hydro Name of Anion-ic Acid

HCl	Hydrochloric Acid
HBr	Hydrobromic Acid
H_2S	Hydrosulfuric Acid

Note: it is not incorrect to say "hydrogen chloride", "hydrogen bromide", etc.

Oxyacids

"*-ate* goes to *-ic*, *-ite* goes to *-ous*"

Name of Anion-ic Acid

Name of Anion-ous Acid

H_3PO_4	Phosphoric Acid
H_3PO_3	Phosphorous Acid
HNO_2	Nitrous Acid
HNO_3	Nitric Acid
$HClO$	Hypochlorous Acid
$HClO_3$	Chloric Acid

Remember: Hydrogen is the cation in these compounds. You determine the number of hydrogen by balancing the charge of the anion.

Knowledge Check

What is the formula for perchloric acid?

What is the name of H_2SO_3?

Covalent compounds

Covalent compounds are held together by covalent bonds. The charges do not balance the way they do in ionic compounds.

NO, N_2O, N_2O_2, and NO_2 are all examples of covalent compounds between nitrogen and oxygen so saying “Nitrogen Oxide” is not specific.

Numerical prefixes for covalent compounds

Numerical prefixes are added to the names of covalent compounds to indicate the number of atoms present

The prefix “mono-“ is not used for the first atom named in a compound.

NO	Nitrogen Monoxide
N_2O	Dinitrogen Monoxide
N_2O_2	Dinitrogen Dioxide
NO_2	Nitrogen Dioxide

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

More examples of covalent compounds

PCl_4	Phosphorous Tetrachloride
CO	Carbon Monoxide
CO_2	Carbon Dioxide
P_4O_{10}	Tetraphosphorous decaoxide

Knowledge check

What is the formula for Disulfur Trioxide?

What is the name of N_2O_5?