

Chapter 2

Atoms, Molecules, and Ions

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The Atomic Theory of Matter

- Democritus (460–370 bce) and other early Greek philosophers described the material world as made up of tiny, indivisible particles that they called atomos, meaning “indivisible” or “uncuttable.”
- Plato and Aristotle did not embrace the atomic ideas of Leucippus and Democritus.
 - Matter had no smallest parts.
 - Different substances were composed of various proportions of fire, air, earth, and water.
- John Dalton (1766–1844) offered convincing evidence that supported the early atomic ideas of Leucippus and Democritus

Dalton's theory

- Dalton's Postulates

Dalton's Atomic Theory

1. Each element is composed of extremely small particles called atoms.



An atom of the element oxygen



An atom of the element nitrogen

2. All atoms of a given element are identical, but the atoms of one element are different from the atoms of all other elements.



Oxygen



Nitrogen

3. Atoms of one element cannot be changed into atoms of a different element by chemical reactions; atoms are neither created nor destroyed in chemical reactions.

Oxygen



Nitrogen

4. Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.



N

+



O



NO

Elements

Compound



The law of conservation of mass

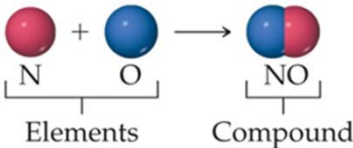
- The total mass of materials present after a chemical reaction is the same as the total mass present before the reaction

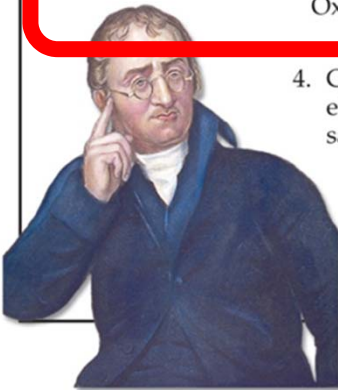
Dalton's Atomic Theory

- Each element is composed of extremely small particles called atoms.

An atom of the element oxygen An atom of the element nitrogen
- All atoms of a given element are identical, but the atoms of one element are different from the atoms of all other elements.

Oxygen Nitrogen
- Atoms of one element cannot be changed into atoms of a different element by chemical reactions; atoms are neither created nor destroyed in chemical reactions.

Oxygen Nitrogen
- Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.

Elements Compound



The law of constant composition

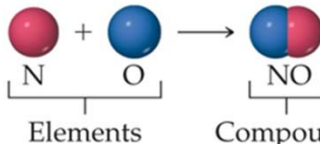
- All samples of a given compound, regardless of their source or how they were prepared, have the same proportions of their constituent elements.

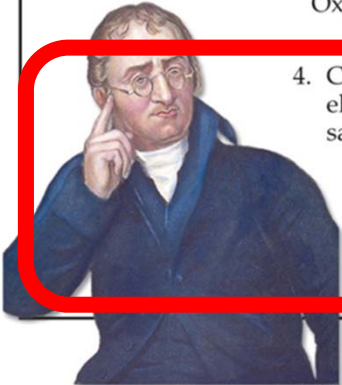
Dalton's Atomic Theory

1. Each element is composed of extremely small particles called atoms.

An atom of the element oxygen An atom of the element nitrogen
2. All atoms of a given element are identical, but the atoms of one element are different from the atoms of all other elements.

Oxygen Nitrogen
3. Atoms of one element cannot be changed into atoms of a different element by chemical reactions; atoms are neither created nor destroyed in chemical reactions.

Oxygen Nitrogen
4. Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.

Elements Compound



Law of Multiple Proportions

- When two elements (call them A and B) form two different compounds, the masses of element B that combine with 1 g of element A can be expressed as a ratio of small whole numbers.
- An atom of A combines with either one, two, three, or more atoms of B (AB_1 , AB_2 , AB_3 , etc.).

The Discovery of Atomic Structure

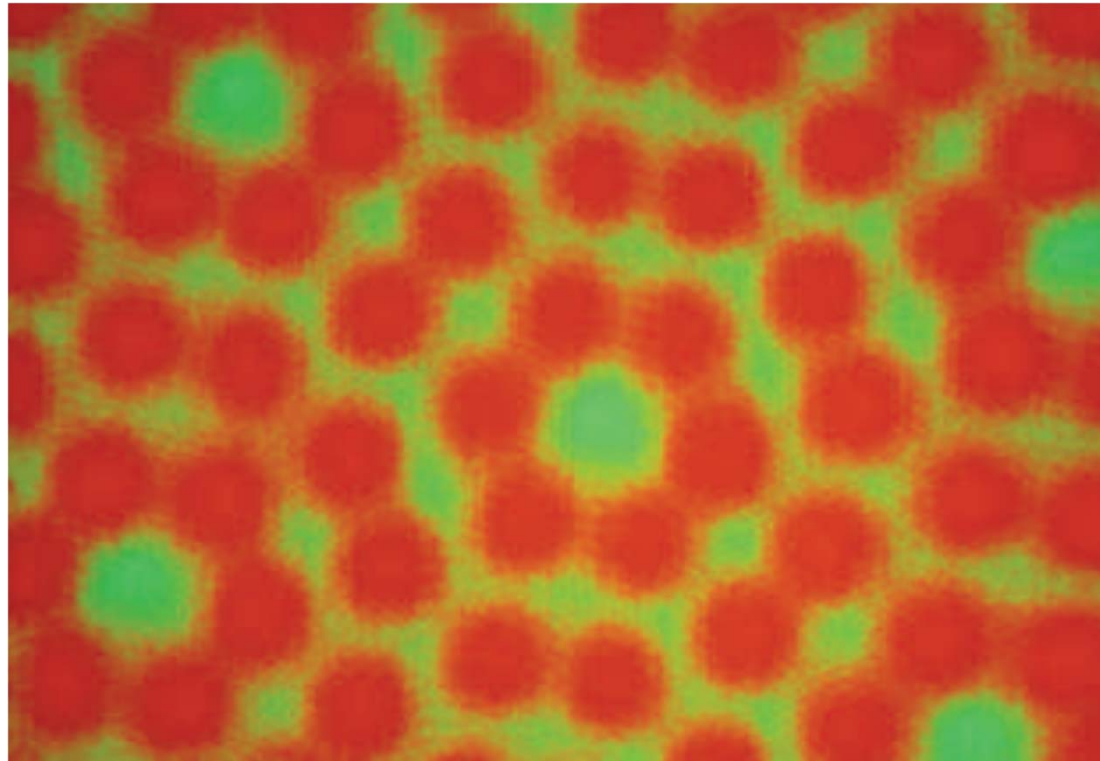


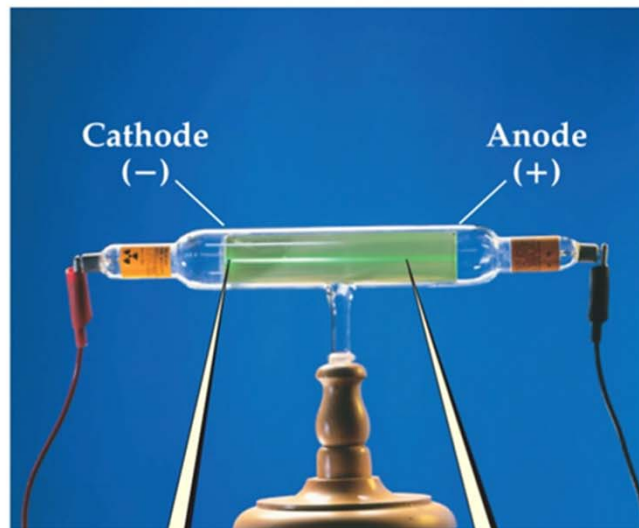
Figure 2.2 An image of the surface of silicon. The image was obtained by a technique called scanning tunneling microscopy. The color was added to the image by computer to help distinguish its features. Each red sphere is a silicon atom.

Discovery of Subatomic Particles

- In Dalton's view, the atom was the smallest particle possible. Many discoveries led to the fact that the atom itself was made up of smaller particles.
- The atom is composed of subatomic particles:
 - Electrons
 - Protons
 - Neutrons

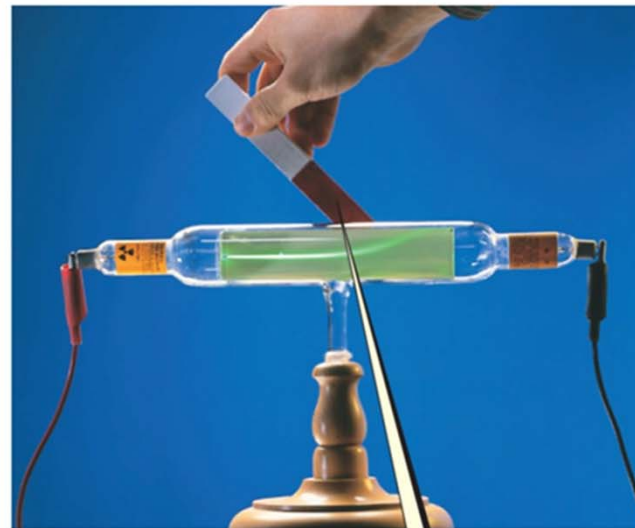
The Electron (Cathode Rays)

- Streams of negatively charged particles were found to emanate from cathode tubes, causing fluorescence.
- J. J. Thomson is credited with their discovery (1897).



Electrons move from the negative cathode to the positive anode.

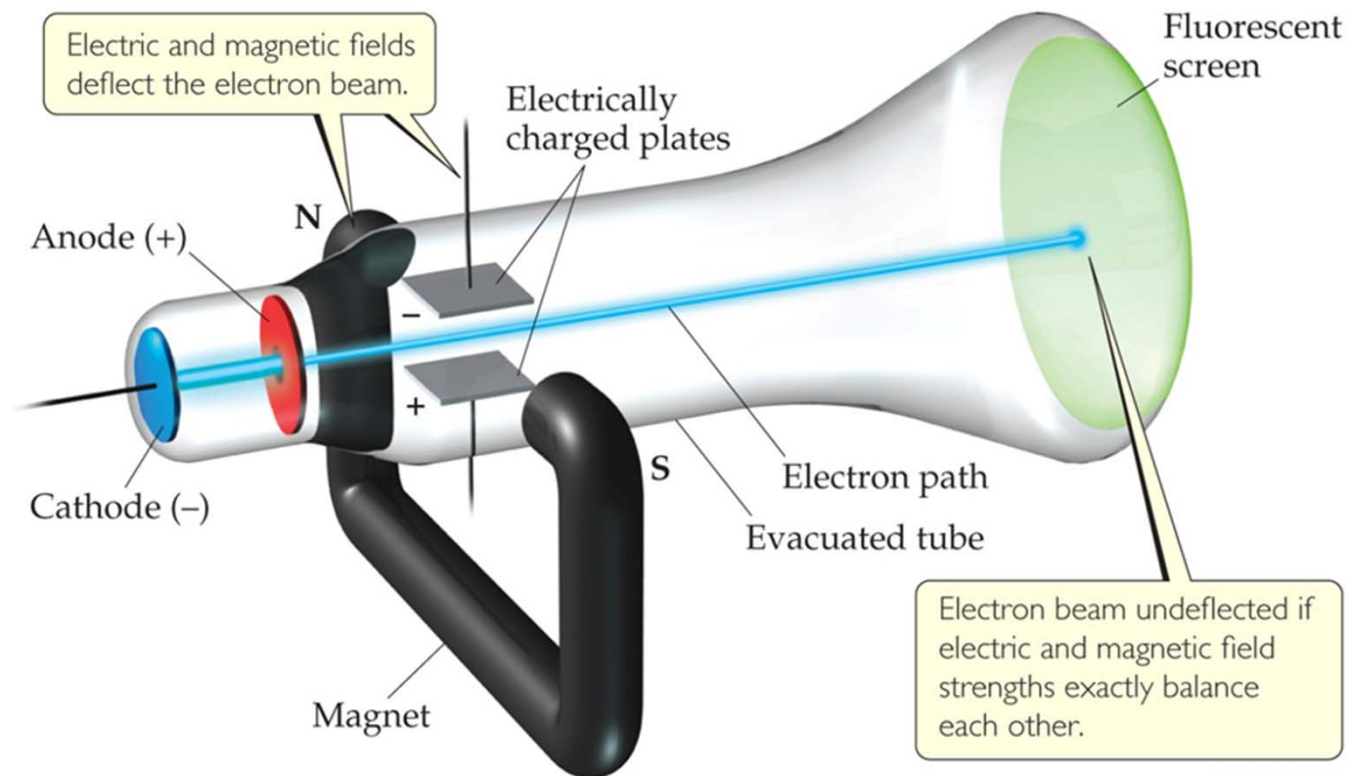
The tube contains a fluorescent screen that shows the path of the cathode rays.



The rays are deflected by a magnet.

The Electron

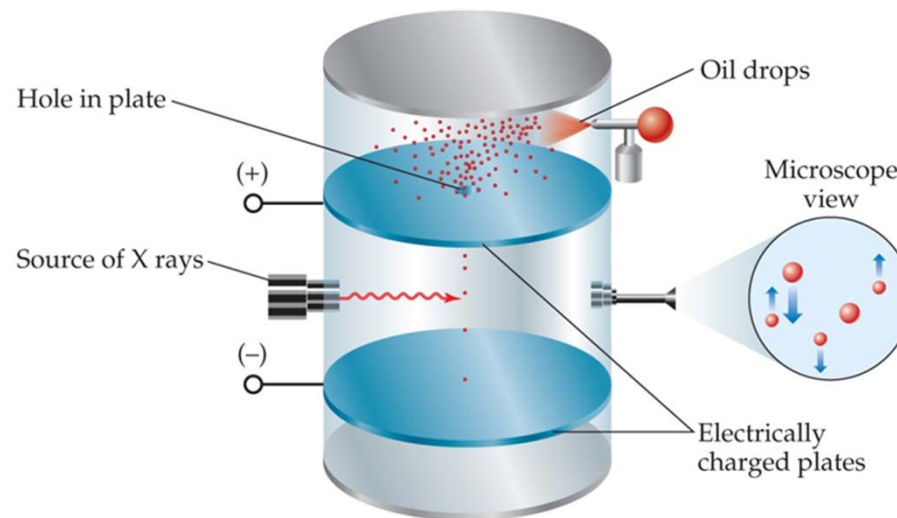
- Thomson measured the charge/mass ratio of the electron to be 1.76×10^8 coulombs/gram (C/g).



* The coulomb (C) is the SI unit for electrical charge.

Millikan Oil-Drop Experiment (Electrons)

- Robert Millikan determined the charge on the electron in 1909



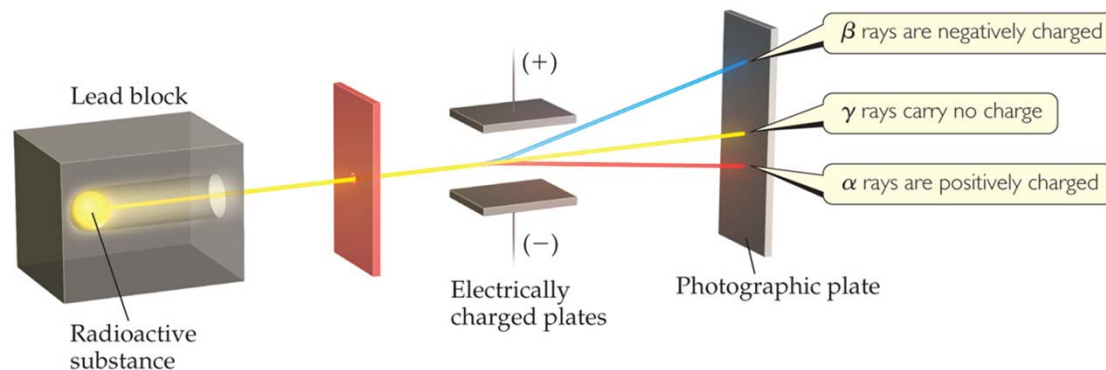
The measured charge on any drop was always a whole-number multiple of -1.60×10^{-19} , the fundamental charge of a single electron.

$$\text{Charge} \times \frac{\text{mass}}{\text{charge}} = \text{mass}$$

$$\text{Electron mass: } -1.60 \times 10^{-19} \text{ } e \times \frac{g}{-1.76 \times 10^8 \text{ } e} = 9.10 \times 10^{-28} \text{ g}$$

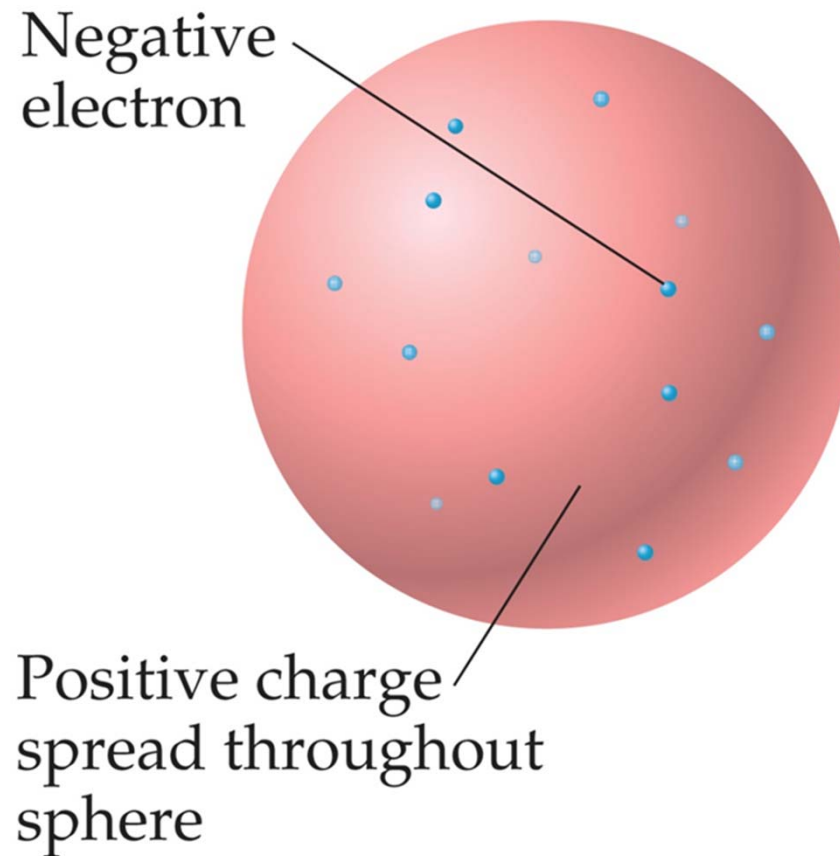
Radioactivity

- In 1896 the French scientist Henri Becquerel (1852–1908) discovered that a compound of uranium spontaneously emits high-energy radiation. This spontaneous emission of radiation is called radioactivity.
- Three types of radiation were discovered by Ernest Rutherford:
 - α particles (positively charged, +2)
 - β particles (negatively charged, -1, like electrons)
 - γ rays (uncharged)



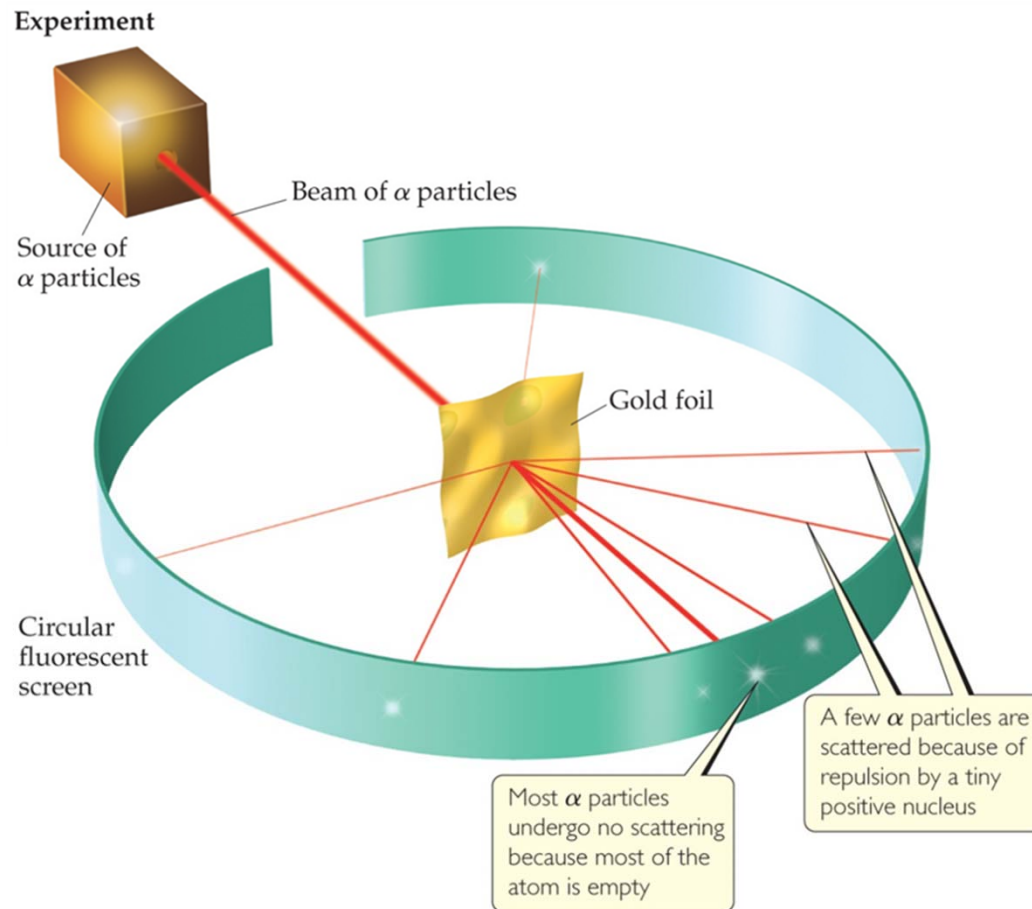
The Nuclear Model of the Atom

- J. J. Thomson's plum-pudding model of the atom.



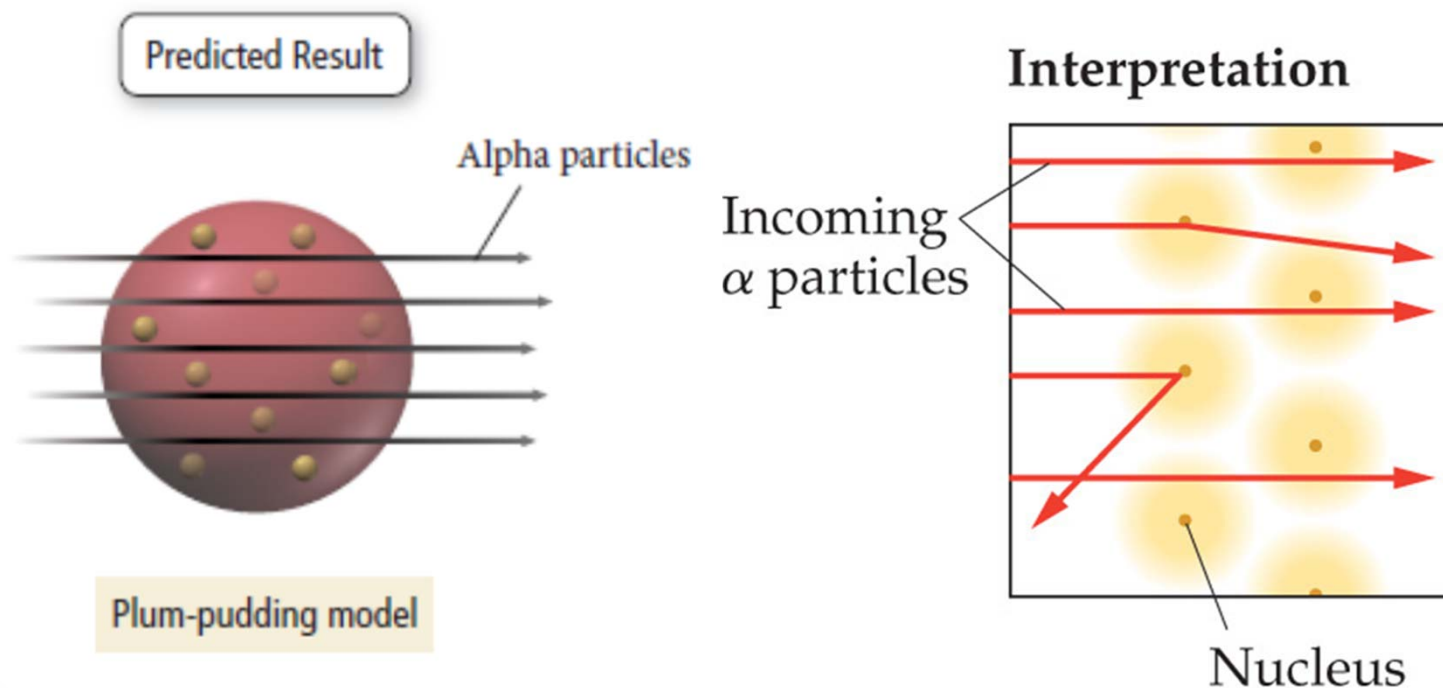
Rutherford's Gold Foil Experiment

- Ernest Rutherford shot α particles at a thin sheet of gold foil and observed the pattern of scatter of the particles.



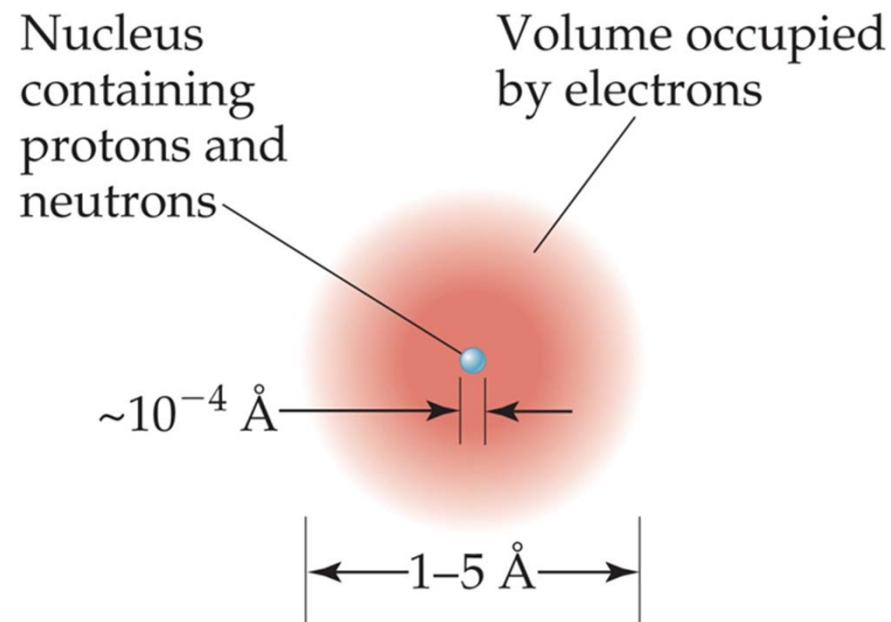
Rutherford's Gold Foil Experiment

- The Rutherford experiment gave an unexpected result. A majority of the particles did pass directly through the foil, but some particles were deflected, and some (approximately 1 in 20,000) even bounced back.



The Nuclear Atom

- Rutherford postulated a very small, dense nucleus with the electrons around the outside of the atom.
- Most of the volume is empty space.
- Atoms are very small; $1 - 5 \text{ \AA}$ or $100 - 500 \text{ pm}$.



angstrom ($\text{\AA}$), where $1 \text{ \AA} = 1 \times 10^{-10} \text{ m}$

Subatomic Particles

- Protons (+1) and electrons (−1) have a charge; neutrons are neutral.
- Protons and neutrons have essentially the same mass (relative mass 1). The mass of an electron is so small we ignore it (relative mass 0).
- Protons and neutrons are found in the nucleus; electrons travel around the nucleus

Periodic Table

- Each element is identified by a unique atomic number and with a unique chemical symbol.
- The chemical symbol is either a one- or two-letter abbreviation listed directly below its atomic number on the periodic table.

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Atomic Mass

- Atoms have extremely small masses.
- The heaviest known atoms have a mass of approximately 4×10^{-22} g.
- A mass scale on the atomic level is used, where an atomic mass unit (amu) is the base unit.
 - $1 \text{ amu} = 1.66054 \times 10^{-24} \text{ g}$

Table 2.1 Comparison of the Proton, Neutron, and Electron

Particle	Charge	Mass (amu)
Proton	Positive (1+)	1.0073
Neutron	None (neutral)	1.0087
Electron	Negative (1-)	5.486×10^{-4}

Atomic Numbers, Mass Numbers,

- The atoms of each element have a characteristic number of protons. The number of protons in an atom of any particular element is called that element's **atomic number**.
- The mass number, is the number of protons plus neutrons in the atom

Mass number (number of
protons plus neutrons)

$^{12}_6\text{C}$ ← Symbol of element

Atomic number (number
of protons or electrons)

Quiz:

- What does "X" represent in the following symbol? $^{80}_{35}\text{X}$
- Determine the number of protons, neutrons and electrons in the following $^{40}_{18}\text{X}$

Isotopes

- Isotopes are atoms of the same element with different masses.
- Isotopes have different numbers of neutrons, but the same number of protons

Table 2.2 Some Isotopes of Carbon^a

Symbol	Number of Protons	Number of Electrons	Number of Neutrons
^{11}C	6	6	5
^{12}C	6	6	6
^{13}C	6	6	7
^{14}C	6	6	8

^aAlmost 99% of the carbon found in nature is ^{12}C .

Quiz

- How many protons, neutrons and electrons does sulfur-31 and sulfur-32 have?

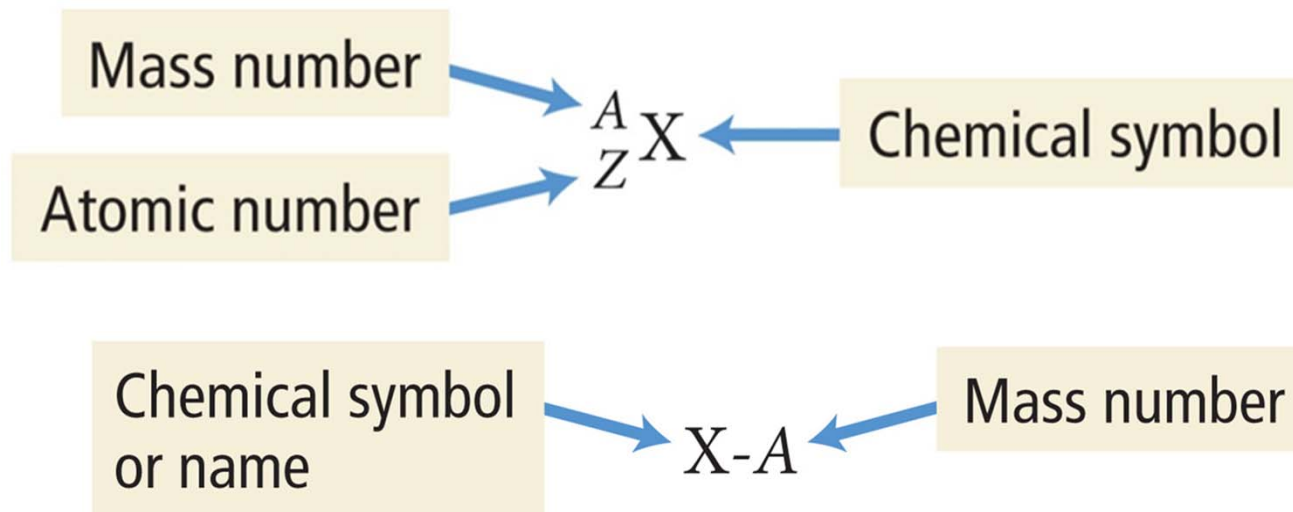
Determining the Number of Subatomic Particles in Atoms

- How many protons, neutrons, and electrons are in an atom of

(a) ^{197}Au , (b) strontium-90?

Note: Gold has atomic number 79.

The atomic number of strontium is 38.



Atomic Weights

- Most elements occur in nature as mixtures of isotopes. We can determine the average atomic mass of an element, usually called the element's atomic weight

$$\text{Atomic Weight} = \sum [(\text{isotope mass}) \times (\text{fractional natural abundance})].$$

EX: carbon is composed of 98.93% ^{12}C and 1.07% ^{13}C . The masses of these isotopes are 12 amu (exactly) and 13.00335 amu

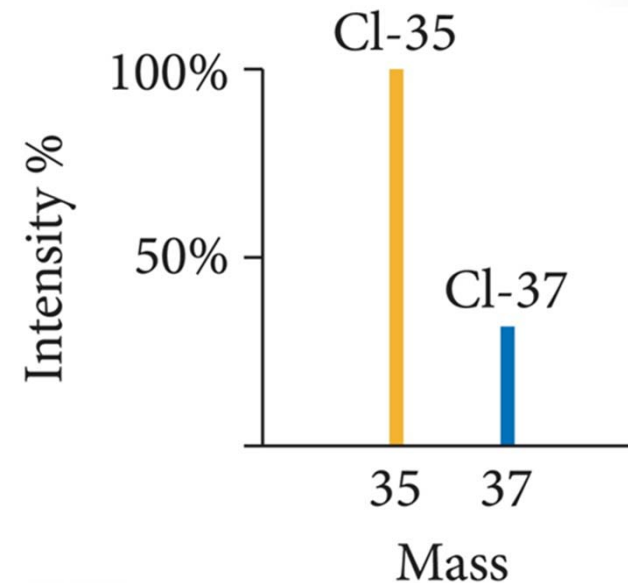
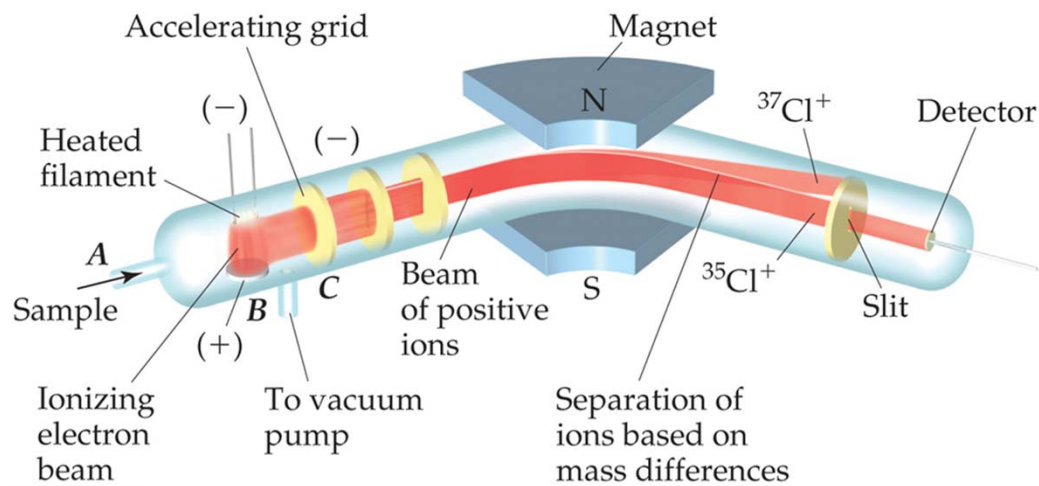
The atomic weight of carbon:
 $(0.9893)(12 \text{ amu}) + (0.0107)(13.00335 \text{ amu}) = 12.01 \text{ amu}$

Quiz

- Calculate the atomic mass of element "X", if it has 2 naturally occurring isotopes with the following masses and natural abundances:
 - X-45: 44.8776 amu 32.88%
 - X-47: 46.9443 amu 67.12%

The Mass Spectrometer

- The most accurate means for determining atomic weights is provided by the mass spectrometer



Periodic Table

- Each element is identified by a unique atomic number and with a unique chemical symbol.
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1 IA TA																2 IIA 2A																3 IIIA 3A																4 IIIA 4A																5 VA 5A																6 VIA 6A																7 VIIA 7A																8 VIIIA 8A																																																																																																																																																																															
1 H Hydrogen 1.008																2 He Helium 4.003																3 Li Lithium 6.941																4 Be Beryllium 9.012																5 B Boron 10.811																6 C Carbon 12.011																7 N Nitrogen 14.007																8 O Oxygen 15.999																9 F Fluorine 18.998																10 Ne Neon 20.180																																																																																																																																															
3 Na Sodium 22.990																4 Mg Magnesium 24.305																5 Al Aluminum 26.982																6 Si Silicon 28.086																7 P Phosphorus 30.974																8 S Sulfur 32.065																9 Cl Chlorine 35.453																10 Ar Argon 39.948																																																																																																																																																																															
11 K Potassium 39.098																12 Ca Calcium 40.078																13 Sc Scandium 44.956																14 Ti Titanium 47.867																15 V Vanadium 50.942																16 Cr Chromium 51.996																17 Mn Manganese 54.938																18 Fe Iron 55.845																19 Co Cobalt 58.933																20 Ni Nickel 58.693																21 Cu Copper 63.546																22 Zn Zinc 65.38																23 Ga Gallium 69.723																24 Ge Germanium 72.631																25 As Arsenic 74.922																26 Se Selenium 78.971																27 Br Bromine 79.904																28 Kr Krypton 84.796															
37 Rb Rubidium 84.458																38 Sr Strontium 87.62																39 Y Yttrium 88.906																40 Zr Zirconium 91.224																41 Nb Niobium 92.906																42 Mo Molybdenum 95.94																43 Tc Technetium 98.907																44 Ru Ruthenium 101.07																45 Rh Rhodium 106.42																46 Pd Palladium 106.42																47 Ag Silver 107.868																48 Cd Cadmium 112.411																49 In Indium 114.818																50 Sn Tin 118.711																51 Sb Antimony 121.760																52 Te Tellurium 127.6																53 I Iodine 126.904																54 Xe Xenon 131.29															
55 Cs Cesium 132.905																56 Ba Barium 137.327																57-71 Lanthanide Series																72 Hf Hafnium 178.49																73 Ta Tantalum 180.948																74 W Tungsten 183.84																75 Re Rhenium 186.207																76 Os Osmium 190.23																77 Ir Iridium 192.22																78 Pt Platinum 195.085																79 Au Gold 196.967																80 Hg Mercury 200.592																81 Tl Thallium 204.383																82 Pb Lead 207.2																83 Bi Bismuth 208.980																84 Po Polonium 209																85 At Astatine 209																86 Rn Radon 222.0175															
87 Fr Francium 223.020																88 Ra Radium 226.025																89-103 Actinide Series																104 Rf Rutherfordium [261]																105 Db Dubnium [262]																106 Sg Seaborgium [266]																107 Bh Bohrium [264]																108 Hs Hassium [269]																109 Mt Meitnerium [268]																110 Ds Darmstadtium [269]																111 Rg Roentgenium [272]																112 Cn Copernicium [277]																113 Uut Ununtrium [278]																114 Fl Flerovium [279]																115 Uup Ununpentium [279]																116 Lv Livermorium [289]																117 Uus Ununseptium [289]																118 Uuo Ununoctium [289]															
57 La Lanthanum 138.905																58 Ce Cerium 140.116																59 Pr Praseodymium 140.908																60 Nd Neodymium 144.243																61 Pm Promethium 144.913																62 Sm Samarium 150.36																63 Eu Europium 151.964																64 Gd Gadolinium 157.25																65 Tb Terbium 158.925																66 Dy Dysprosium 162.500																67 Ho Holmium 164.930																68 Er Erbium 167.259																69 Tm Thulium 168.934																70 Yb Ytterbium 173.055																71 Lu Lutetium 174.967																																																															
89 Ac Actinium 227.028																90 Th Thorium 232.038																91 Pa Protactinium 231.036																92 U Uranium 238.029																93 Np Neptunium 237.048																94 Pu Plutonium 244.064																95 Am Americium 243.061																96 Cm Curium 247.070																97 Bk Berkelium 247.070																98 Cf Californium 251.080																99 Es Einsteinium [254]																100 Fm Fermium 257.095																101 Md Mendelevium 258.1																102 No Nobelium 259.101																103 Lr Lawrencium [262]																																																															
Alkali Metal																Alkaline Earth																Transition Metal																Basic Metal																Semimetal																Nonmetal																Halogen																Noble Gas																Lanthanide																Actinide																																																																																																																																															

Periodic Table

Periods — horizontal rows

Groups — vertical columns containing elements with similar properties

Elements arranged in order of increasing atomic number

Steplike line divides metals from nonmetals

1A 1	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	8A 18		
1 H	2 He											3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
2 3 Li	4 Be	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10			1B 11	2B 12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
4 19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr		
5 37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe		
6 55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn		
7 87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113	114 Fl	115	116 Lv	117	118		

Metals

Metalloids

Nonmetals

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Groups

Table 2.3 Names of Some Groups in the Periodic Table

Group	Name	Elements
1A	Alkali metals	Li, Na, K, Rb, Cs, Fr
2A	Alkaline earth metals	Be, Mg, Ca, Sr, Ba, Ra
6A	Chalcogens	O, S, Se, Te, Po
7A	Halogens	F, Cl, Br, I, At
8A	Noble gases (or rare gases)	He, Ne, Ar, Kr, Xe, Rn

Classification of Elements

- Elements in the periodic table are classified as the following:
 - Metals
 - Nonmetals
 - Metalloids (類金屬)

Periods — horizontal rows

Groups — vertical columns containing elements with similar properties

Elements arranged in order of increasing atomic number

Steplike line divides metals from nonmetals

1A 1 1 H	2A 2 2 He																
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10			1B 11	2B 12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Lv	116 Ts	117 Og	118 Uue

☐ Metals
☐ Metalloids
☐ Nonmetals

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Metals

- Metals lie on the lower left side and middle of the periodic table and share some common properties:
 - They are good conductors of heat and electricity.
 - They can be pounded into flat sheets (malleability).
 - They can be drawn into wires (ductility).
 - They are often shiny.
 - They tend to lose electrons when they undergo chemical changes.

Nonmetals

- Nonmetals lie on the upper right side of the periodic table.
- Nonmetals as a whole tend to
 - be poor conductors of heat and electricity.
 - be not ductile and not malleable.
 - gain electrons when they undergo chemical changes
- There are a total of 17 nonmetals:
 - Five are solids at room temperature (C, P, S, Se, and I)
 - One is a liquid at room temperature (Br)
 - Eleven are gases at room temperature (H, He, N, O, F, Ne, Cl, Ar, Kr, Xe, and Rn)

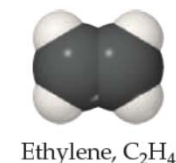
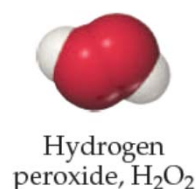
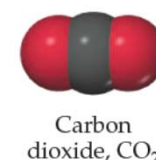
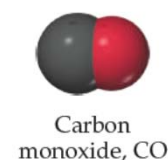
Metalloids (類金屬)

- Metalloids are sometimes called semimetals.
- They are elements that lie along the zigzag diagonal line that divides metals and nonmetals.
- They exhibit mixed properties.
- Several metalloids are also classified as semiconductors because of their intermediate (and highly temperature-dependent) electrical conductivity.

13	14	15	16	17
5 B	6 C	7 N	8 O	9 F
13 Al	14 Si	15 P	16 S	17 Cl
31 Ga	32 Ge	33 As	34 Se	35 Br
49 In	50 Sn	51 Sb	52 Te	53 I

Molecules and Molecular Compounds

- Most of the oxygen in air consists of molecules that contain two oxygen atoms. (chemical formula O_2)
- The subscript tells us that two oxygen atoms are present in each molecule. A molecule made up of two atoms is called a **diatomic molecule**.
- Compounds composed of molecules contain more than one type of atom and are called **molecular compounds**.
- Most molecular substances we will encounter contain only nonmetals.



Types of Formulas

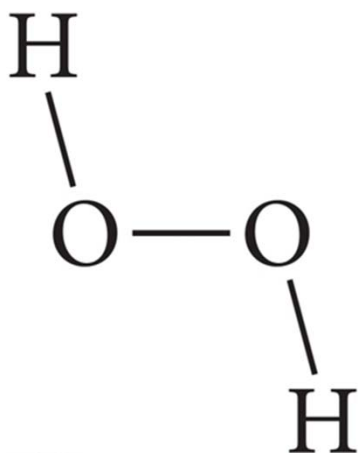
- Empirical formulas give the lowest whole-number ratio of atoms of each element in a compound.
- Molecular formulas give the exact number of atoms of each element in a compound.
- If we know the molecular formula of a compound, we can determine its empirical formula. The converse is not true!

EX:

- For C_4H_8 , the greatest common factor is 4. The empirical formula is therefore CH_2 .
- For C_3H_6 , the greatest common factor is 3. The empirical formula is therefore CH_2 .
- For CCl_4 , the only common factor is 1, so the empirical formula and the molecular formula are identical.

Structural formula

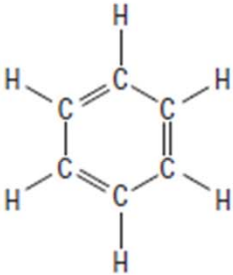
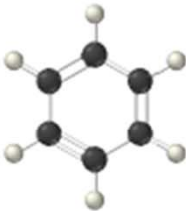
- A structural formula shows which atoms are attached to which, as in the following example



- The atoms are represented by their chemical symbols, and lines are used to represent the bonds that hold the atoms together

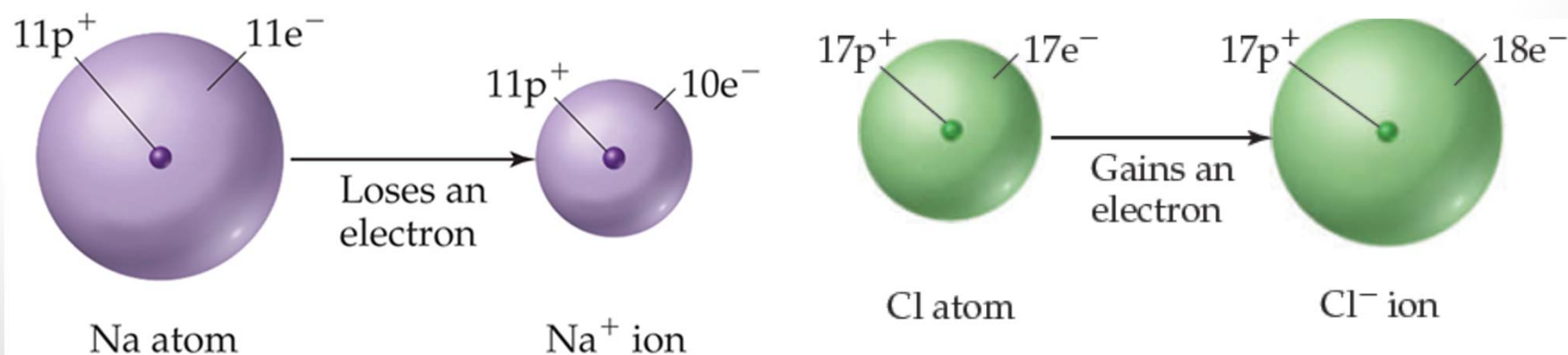
Molecular Models

- A ball-and-stick molecular model represents atoms as balls and chemical bonds as sticks; how the two connect reflects a molecule's shape.
- In a space-filling molecular model, atoms fill the space between each other to more closely represent our best estimates for how a molecule might appear if scaled to visible size.

Name of Compound	Empirical Formula	Molecular Formula	Structural Formula	Ball-and-Stick Model	Space-Filling Model
Benzene	CH	C ₆ H ₆			
Acetylene	CH	C ₂ H ₂	H—C≡C—H		

Ions and Ionic Compounds

- The nucleus of an atom is unchanged by chemical processes, but some atoms can readily gain or lose electrons. If electrons are removed from or added to an atom, a charged particle called an ion is formed. An ion with a positive charge is a **cation**; a negatively charged ion is an **anion**.



Exercise

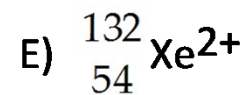
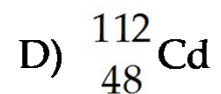
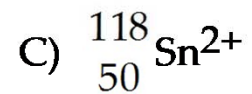
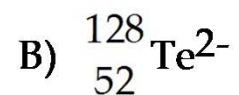
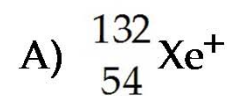
- Give the chemical symbol, including superscript indicating mass number, for (a) the ion with 22 protons, 26 neutrons, and 19 electrons.

Sol:

The number of protons is the atomic number of the element. A periodic table or list of elements tells us that the element with atomic number 22 is titanium (Ti). The mass number (protons plus neutrons) of this isotope of titanium is $22 + 26 = 48$. Because the ion has three more protons than electrons, it has a net charge of $3+$ and is designated $^{48}\text{Ti}^{3+}$.

Quiz

Which species has 54 electrons?



Polyatomic Ion

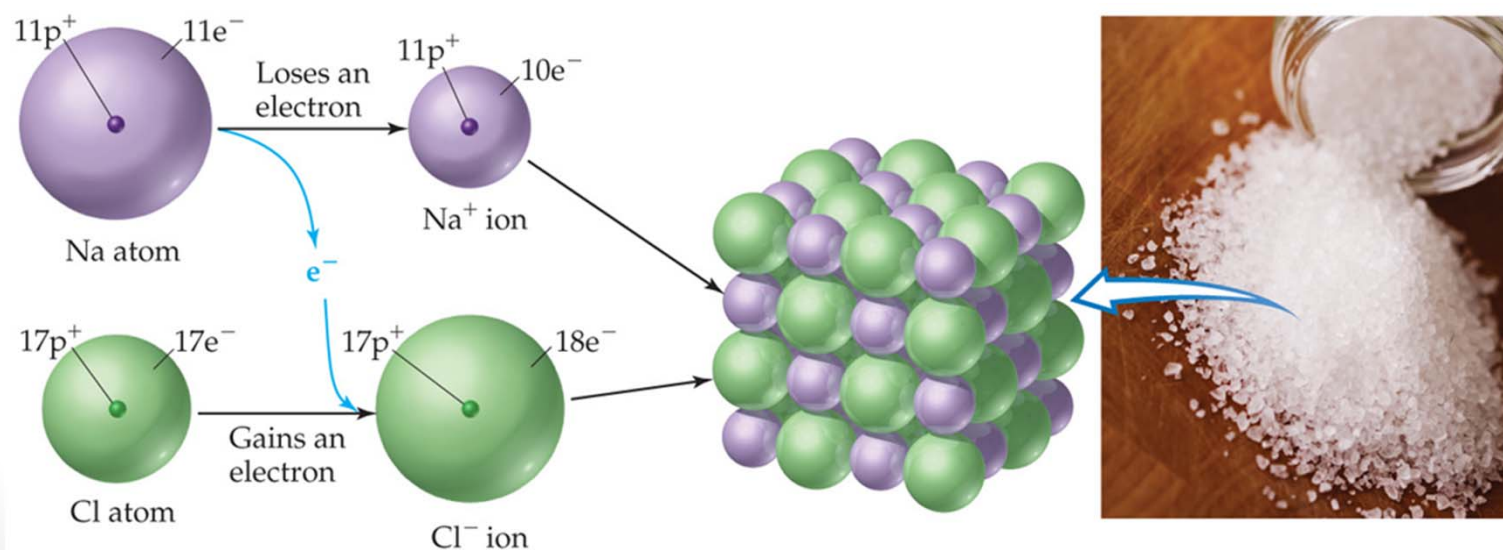
- Many common ionic compounds contain ions that are themselves composed of a group of covalently bonded atoms with an overall charge. This group of charged species is called polyatomic ions.
 - NH_4^+ (ammonium ion)
 - SO_4^{2-} (sulfate ion),

Predicting Ionic Charge

1A	2A									3A	4A	5A	6A	7A	8A
H ⁺												N ³⁻	O ²⁻	H ⁻	N
Li ⁺										Al ³⁺			S ²⁻	F ⁻	O
Na ⁺	Mg ²⁺												Se ²⁻	Cl ⁻	E
K ⁺	Ca ²⁺												Te ²⁻	Br ⁻	S
Rb ⁺	Sr ²⁺													I ⁻	A
Cs ⁺	Ba ²⁺														S

Ionic Compounds

- Ionic compounds are generally formed between metals and nonmetals. (Ex: NaCl)
- Electrons are transferred from the metal to the nonmetal. The oppositely charged ions attract each other. Only empirical formulas are written.



Identifying Ionic and Molecular Compounds

- Which of these compounds would you expect to be ionic: N_2O , Na_2O , CaCl_2 , SF_4 ?

SOLUTION

We predict that Na_2O and CaCl_2 are ionic compounds because they are composed of a metal combined with a nonmetal. We predict (correctly) that N_2O and SF_4 are molecular compounds because they are composed entirely of nonmetals.

Quiz

- The formula for a salt is XBr . The X-ion in this salt has 46 electrons. The metal X is _____

Writing Formulas

- Because compounds are electrically neutral, one can determine the formula of a compound this way:
 - The charge on the cation becomes the subscript on the anion.
 - The charge on the anion becomes the subscript on the cation.
 - If these subscripts are not in the lowest whole-number ratio, divide them by the greatest common factor.



Names and Formulas of Ionic Compounds

- Ionic compounds are usually composed of metals and nonmetals. (EX: MgSO_4)
- Ionic compounds can be categorized into two types, depending on the metal in the compound.
 - The first type contains a metal whose charge is invariant from

Na^+ sodium ion

Zn^{2+} zinc ion

Al^{3+} aluminum ion

- The second type of ionic compound contains a metal with a charge that can differ in different compounds

Fe^{2+} iron(II) ion

Cu^+ copper(I) ion

Fe^{3+} iron(III) ion

Cu^{2+} copper(II) ion

Fe^{2+} ferrous ion

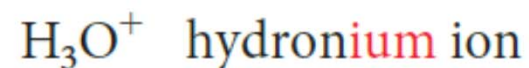
Cu^+ cuprous ion

Fe^{3+} ferric ion

Cu^{2+} cupric ion

Names and Formulas of Ionic Compounds

- Cations formed from nonmetal atoms have names that end in -ium:



Anions

- The names of monatomic anions are formed by replacing the ending of the name of the element with -ide:

Fluorine	F^-	fluor	Fluoride	Oxygen	O^{2-}	ox	Oxide
Chlorine	Cl^-	chlor	Chloride	Sulfur	S^{2-}	sulf	Sulfide
Bromine	Br^-	brom	Bromide	Nitrogen	N^{3-}	nitr	Nitride
Iodine	I^-	iod	Iodide	Phosphorus	P^{3-}	phosph	Phosphide

Names and Formulas of Ionic Compounds

Anions

- Polyatomic anions containing oxygen have names ending in either -ate or -ite and are called oxyanions.
 - the one with more oxygen atoms has the ending -ate
 - the one with fewer has the ending -ite.

For example,

– NO_3^- is **nitrate**
– NO_2^- is **nitrite**

SO_4^{2-} is **sulfate**
 SO_3^{2-} is **sulfite**

Oxyanions

- If there are more than two ions in the series then the prefixes hypo-, meaning less than, and per-, meaning more than, are used.

ClO^- *hypochlorite*

ClO_2^- chlor*ite*

ClO_3^- chlor*ate*

ClO_4^- *perchlorate*

BrO^- *hypobromite*

BrO_2^- brom*ite*

BrO_3^- brom*ate*

BrO_4^- *perbromate*

- Anions derived by adding H^+ to an oxyanion are named by adding as a prefix the word hydrogen or dihydrogen

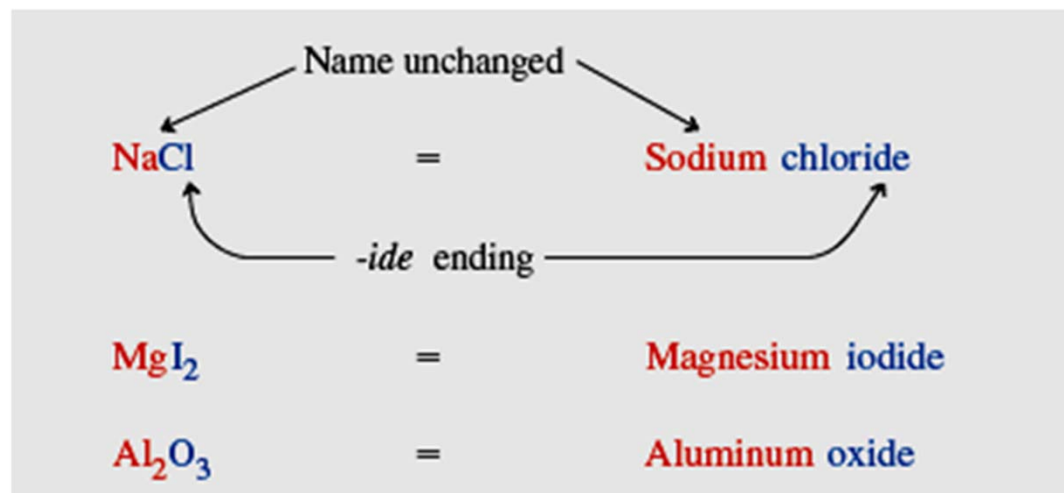
CO_3^{2-} carbonate ion

PO_4^{3-} phosphate ion

HCO_3^- *hydrogen* carbonate ion

H_2PO_4^- *dihydrogen* phosphate ion

Naming Ionic Compounds



CaCl ₂	calcium chloride
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Al(NO ₃) ₃	aluminum nitrate
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Cu(ClO ₄) ₂	copper(II) perchlorate (or cupric perchlorate)
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Names and Formulas of Acids

- Binary acids have H^+ cation and nonmetal anion.

- Write a hydro- prefix.
- Follow with the nonmetal name.
- Change ending on nonmetal name to -ic.
- Write the word acid at the end of the name

EX: HCl hydrochloric acid

- Oxyacids have H^+ cation and polyatomic anion contain oxygen.

- If polyatomic ion name ends in -ate, then change ending to -ic suffix.
- If polyatomic ion name ends in -ite, then change ending to -ous suffix.
- Write word acid at the end of all names

EX: ClO_4^- perchlorate

HClO_4 perchloric acid

ClO^- hypochlorite

HClO hypochlorous acid

Nomenclature of Binary Molecular Compounds

Table 2.3 Numeric Prefixes in Names of Binary Molecular Compounds

Number of Atoms	Prefix	Examples ^a
1	mono	NO nitrogen monoxide
2	di	NO ₂ nitrogen dioxide
3	tri	N ₂ O ₃ dinitrogen trioxide
4	tetra	N ₂ O ₄ dinitrogen tetroxide
5	penta	N ₂ O ₅ dinitrogen pentoxide
6	hexa	SF ₆ sulfur hexafluoride
7	hepta	IF ₇ iodine heptafluoride
8	octa	P ₄ O ₈ tetraphosphorus octoxide
9	nona	P ₄ S ₉ tetraphosphorus nonasulfide
10	deca	As ₄ O ₁₀ tetraarsenic decoxide

^a When the prefix ends in “a” or “o” and the element name begins with “a” or “o,” the final vowel of the prefix is usually dropped for ease of pronunciation. For example, nitrogen *monoxide* and not nitrogen *monooxide*, and

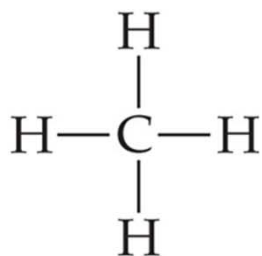
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Nomenclature of Binary Molecular Compounds

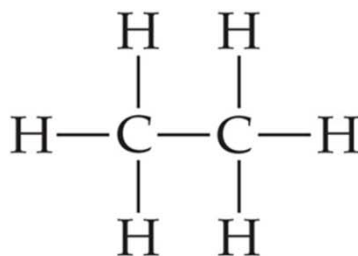
- The ending on the second element is changed to -ide.
 - CO_2 : carbon dioxide
 - CCl_4 : carbon tetrachloride
- If the prefix ends with a or o and the name of the element begins with a vowel, the two successive vowels are often elided into one.
 - N_2O_5 : dinitrogen pentoxide

Nomenclature of Organic Compounds

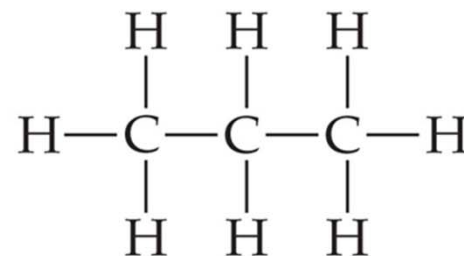
- Organic chemistry is the study of carbon.
- Organic chemistry has its own system of nomenclature.
- The simplest hydrocarbons (compounds containing only carbon and hydrogen) are alkanes.
- The first part of the names just listed correspond to the number of carbons (meth- = 1, eth- = 2, prop- = 3, etc.)



Methane



Ethane

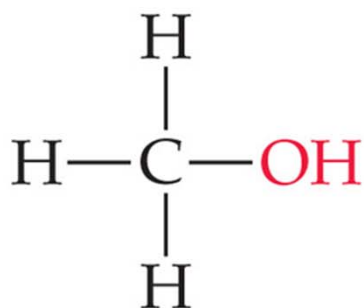


Propane

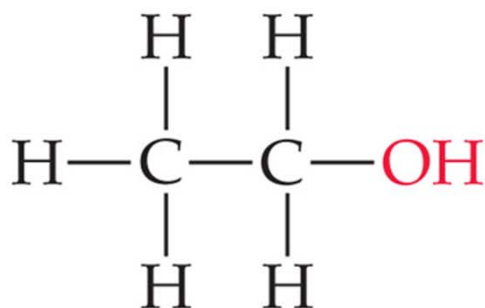
Nomenclature of Organic Compounds

- When a hydrogen in an alkane is replaced with something else (a functional group, like -OH in the compounds above), the name is derived from the name of the alkane.
- The ending denotes the type of compound.

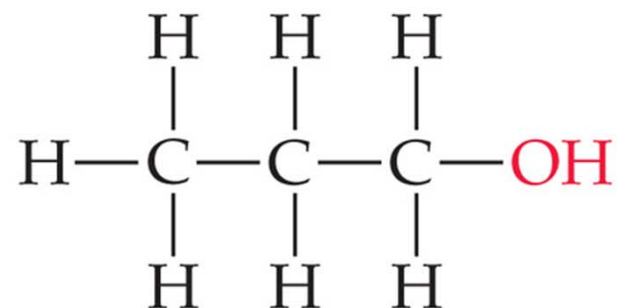
EX: An alcohol ends in -ol.



Methanol



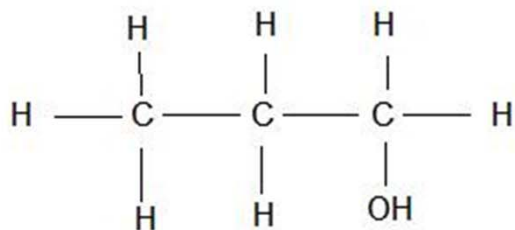
Ethanol



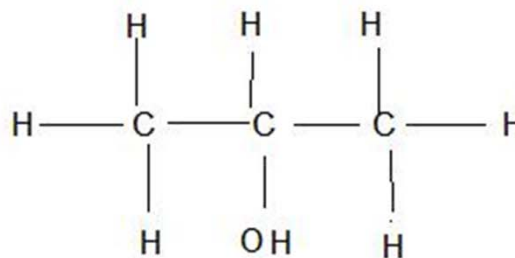
1-Propanol

Isomer

- Compounds with the same molecular formula but different arrangements of atoms are called isomers.
- EX: 1-propanol and 2-propanol are structural isomers



1-propanol



2- propanol

Question

- An ion has 8 protons, 9 neutrons, and 10 electrons. The symbol for the ion is _____
- How many protons (p) and neutrons (n) are in an atom of $^{90}_{38}\text{Sr}$?
- Gallium has an atomic mass of 69.723 amu. The Ga-69 (68.926 amu) is 60.11%. What is the amu of the other isotope?