


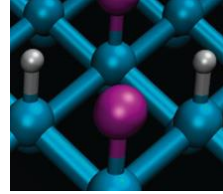

Chapter 2

Atoms and Molecules

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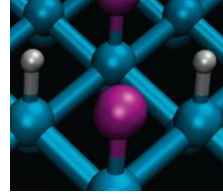
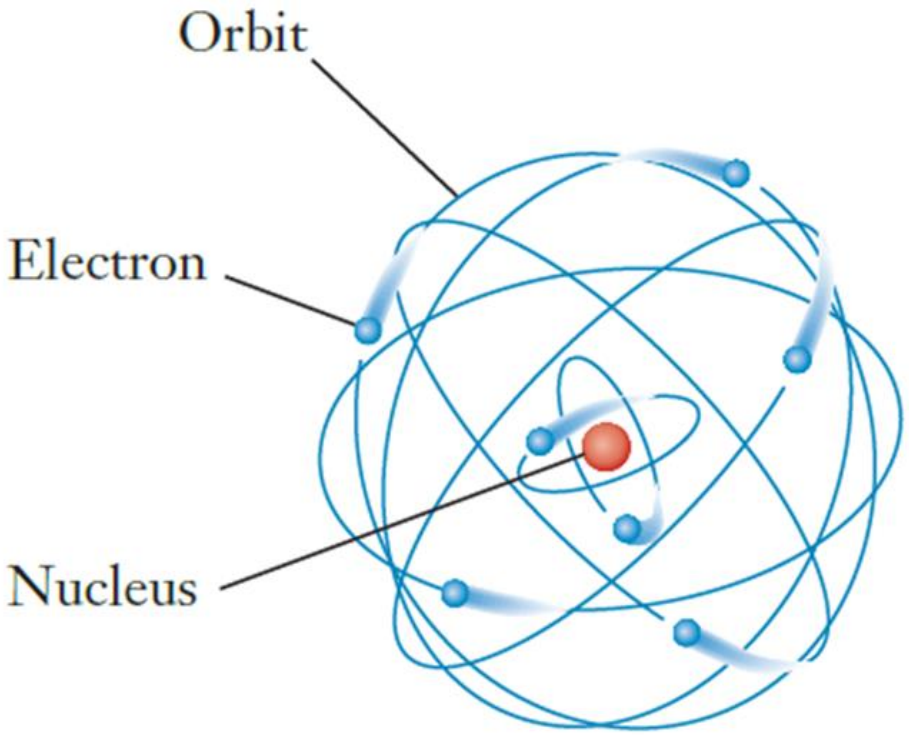
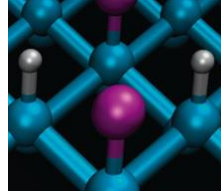
Atoms Resembling a Solar System





- Solar system depiction of atomic structure
  - Emphasizes proton, neutron, and electron distribution; *does not accurately depict current accepted model of atomic structure*

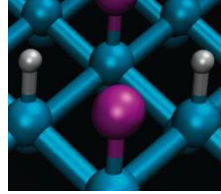
Atomic Number and Mass Number



- Atomic number: Number of protons in a particular atom
  - Identifies an element
- Mass number: Sum of the number of protons and number of neutrons in a nucleus
- 1 **atomic mass unit or amu** $= 1.6605 \times 10^{-24}$ g
- Protons and neutrons are nearly 2000 times more massive than electrons

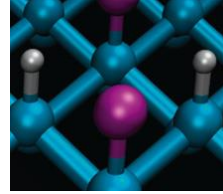
Particle	mass (amu)
Proton	1.007
Neutron	1.009
Electron	0.00055

Isotopes



- Atoms of an element that differ in the number of neutrons in their nucleus
- Isotopic abundances
  - Percentages describing the relative amounts of each isotope

Mass Spectrometer



- Mass spectrometers can measure the masses of atoms, isotopes, and molecules
- Measures accurately the number of particles with a given mass

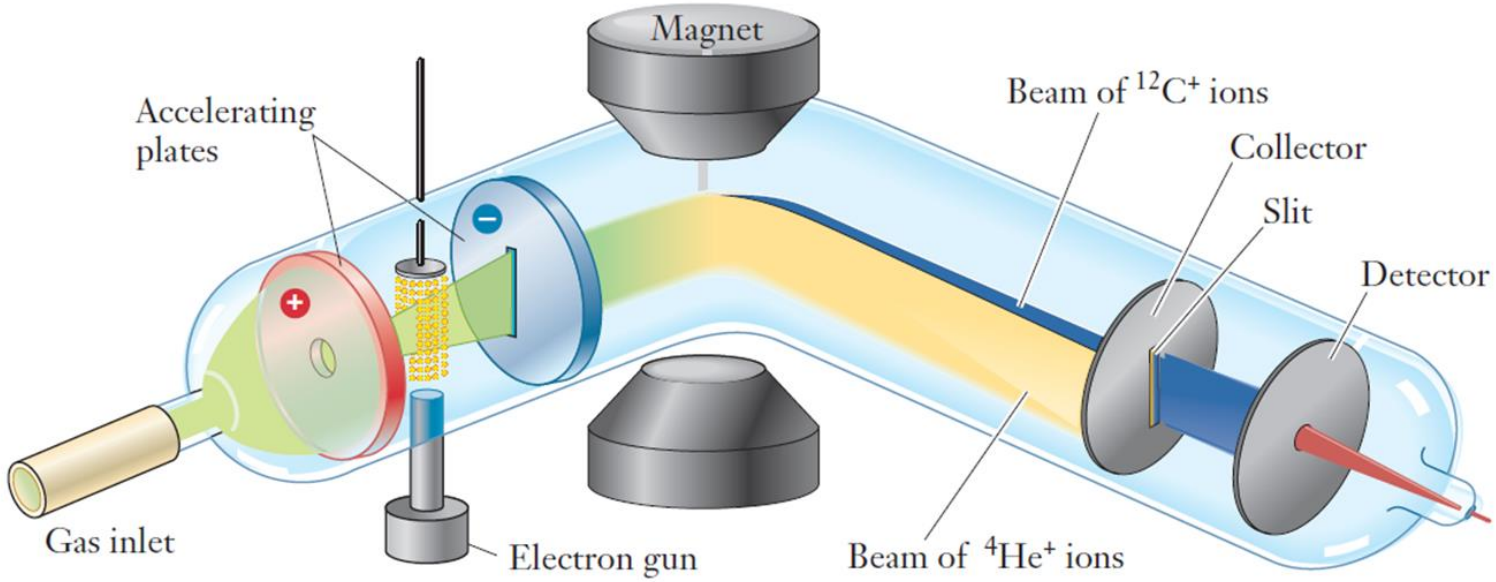
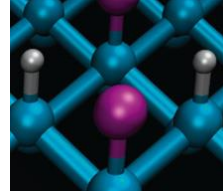
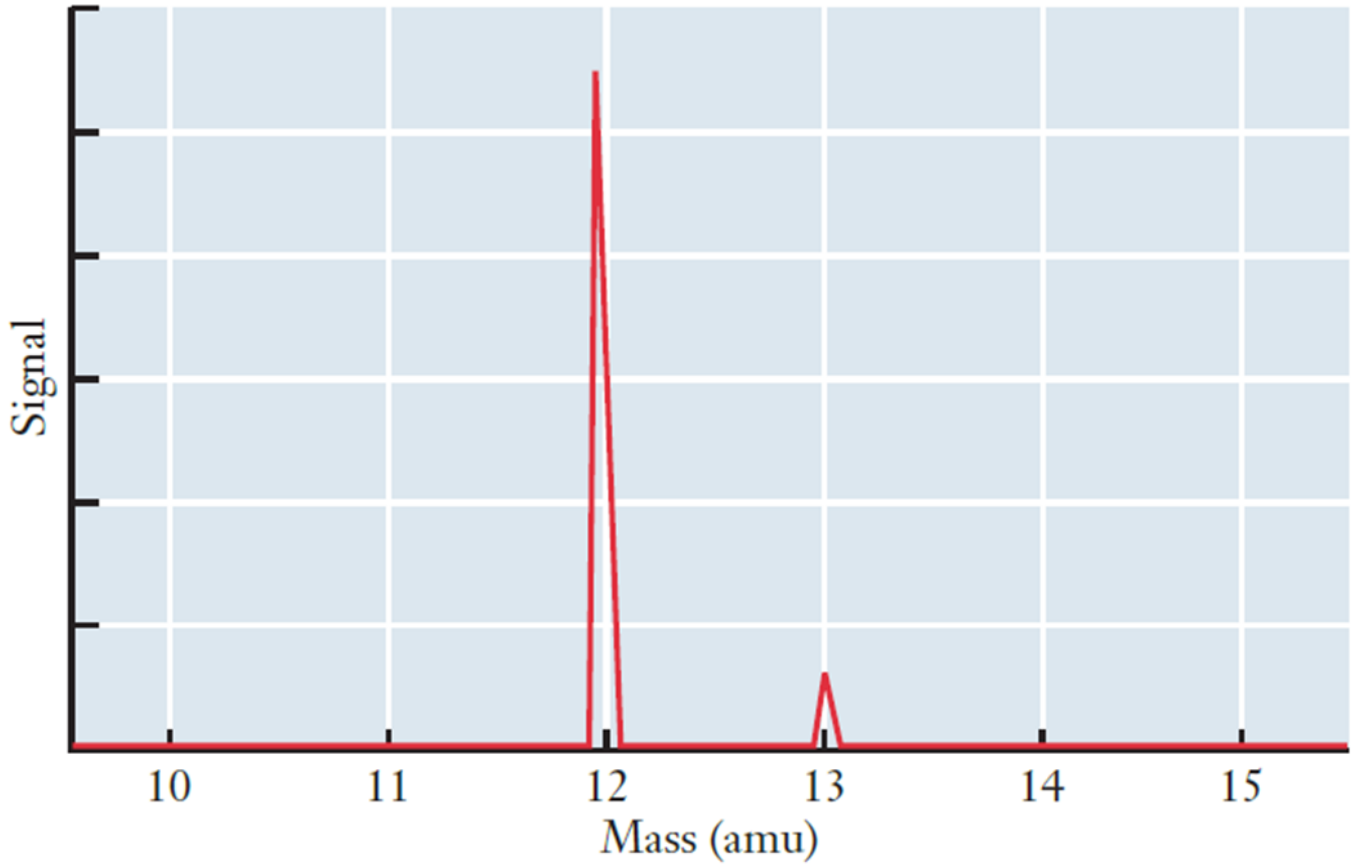
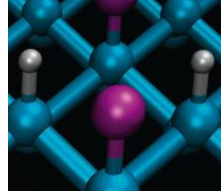


Figure 2.5: Mass Spectrum of Elemental Carbon





Atomic Symbols

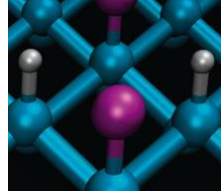


- Information regarding atomic structure that is written in scientific shorthand

$$ {}^{A}_{Z}\mathrm{X} $$

  - X is the atomic symbol for element
  - Superscript *A* is the mass number
  - Subscript *Z* is the atomic number

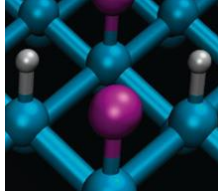
Table 2.1: Atomic Symbols

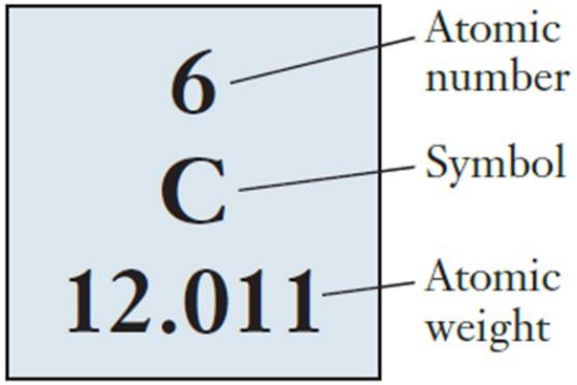


Names and symbols of some common elements whose symbols are not related to their English names

Name	**Symbol (name origin)**
Gold	Au (aurum)
Iron	Fe (ferrum)
Lead	Pb (plumbum)
Mercury	Hg (hydrargyrum)
Silver	Ag (argentum)
Sodium	Na (natrium)

Atomic Masses

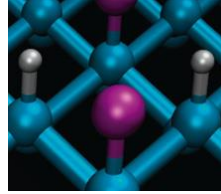




- Entry for carbon on the periodic table
  - Z = 6
  - Element symbol - C
  - Atomic weight = 12.011 (99 atoms of carbon-12 and a single atom of carbon-13)

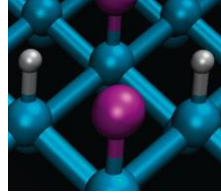
$$^{12}_{6}C$$

Atomic Masses



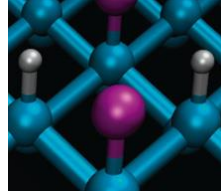
- Atomic weight of an element is the *average* of the atomic masses of the naturally occurring isotopes of the element
  - Carbon-12 = 12.000000 × 0.9893 = 11.87
  - Carbon-13 = 13.003355 × 0.0107 = 0.139
  - Weighted average mass = 11.87 + 0.139 = 12.01

Ions



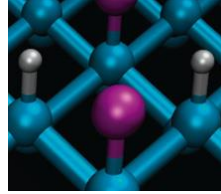
- Formed when the number of protons is not equal to the number of electrons in an atom
  - Ions with more protons than electrons are called cations
    - Net positive charge
  - Ions with more electrons than protons are called anions
    - Net negative charge
- Monatomic ion: Derived from a single atom
- Polyatomic ion: Derived from a group of atoms with an overall charge

Ions and Their Properties



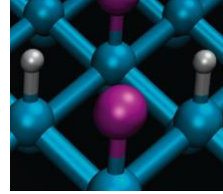
- An element and its ion have the same chemical symbol but different properties
  - Sodium metal atoms lose an electron to form sodium cations
    - Sodium metal reacts violently with water
  - Chlorine gas molecules gain electrons to form chlorine anions (chloride)
    - Chlorine gas reacts violently with sodium metal
  - Ionic compounds containing sodium cation and chlorine anion dissolve in water without reacting

The Periodic Table



- Based on the periodic law
    - Shows that when arranged properly, the elements display a regular and periodic variation in their chemical properties
- Periods
    - Horizontal rows on the periodic table
- Groups
    - Vertical columns on the periodic table

Periodic Table of the Elements



Periods	1A (1)	2A (2)	IIIB (3)	IVB (4)	VB (5)	VIB (6)	VIIB (7)	VIIIB (8)	VIIIB (9)	VIIIB (10)	IB (11)	IIB (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	1 H 1.01																	2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc [97.9]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 * La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
7	87 Fr [223]	88 Ra [226]	89 # Ac [227]	104 Rf [261]	105 Db [262]	106 Sg [263]	107 Bh [262]	108 Hs [265]	109 Mt [266]	110 Uun [269]	111 Uuu [272]	112 Uub [277]	113 Uut (?)	114 Uuq [285]	115 Uup (?)	116 Uuh [289]	117 Uus (?)	118 Uuo [293]

Groups

3 ← Atomic number
Li ← Symbol
6.94 ← Atomic weight

[ ] Estimates

* Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
# Actinides	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [248]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

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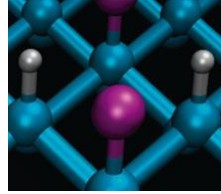
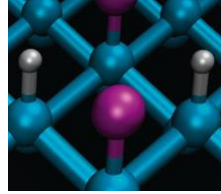
Chemical Formulas



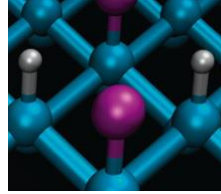
- Describe a compound in terms of the elements the compound contains
- Chemical compound: A pure substance made up of atoms of two or more elements joined together by chemical bonds
- Types of chemical formulas
  - Molecular formulas indicate the elements and number of atoms of each element actually contained in a discrete unit of a compound
  - Empirical formulas tell the relative ratio between the numbers of atoms of the different elements present in a molecule

Writing Chemical Formulas



- Indicate the types of atoms in the substance by their atomic symbols
- The number of atoms for each element is indicated by a subscript to the right of the chemical symbol
- Groups of atoms can be designated using parentheses
  - Subscripts outside these parentheses mean that all atoms enclosed in the parentheses are multiplied by the value indicated in the subscript

Join In, 10

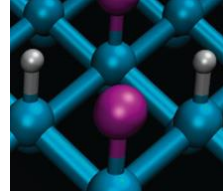


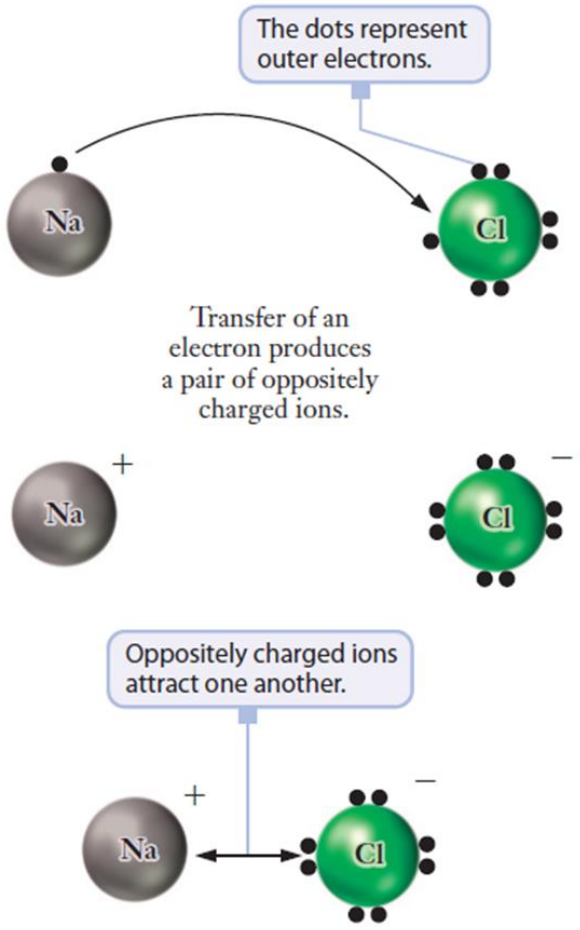
How many atoms are there in $Fe(NO_3)_3$?

- 8
- 11
- 13
- 15

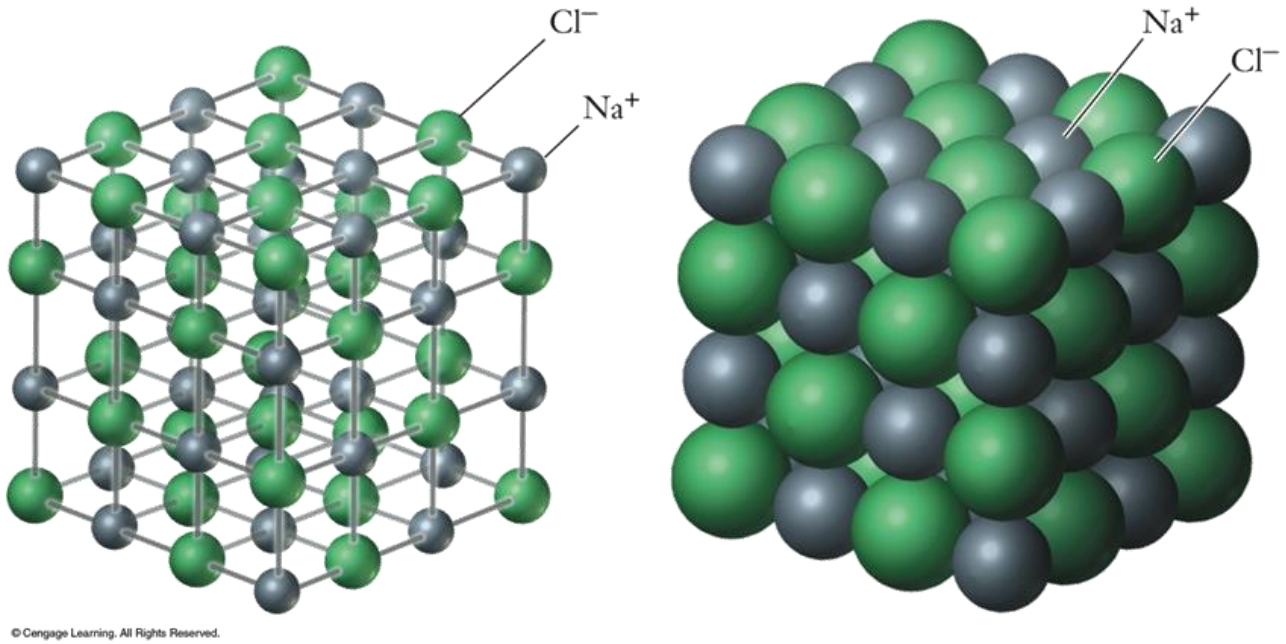
13

Ionic Bonding

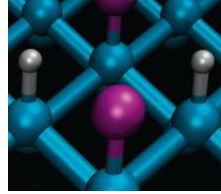


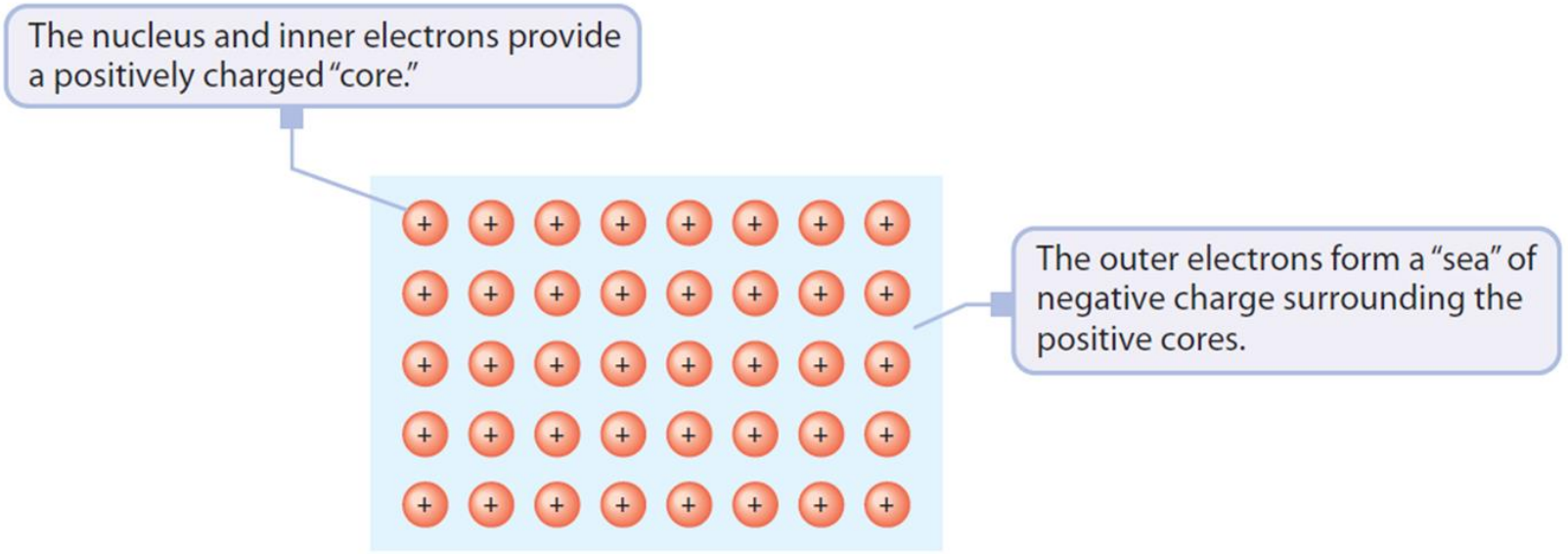


- Ionic bonding occurs when ions assemble into an extended array called a lattice and are held together by the attraction between oppositely charged ions



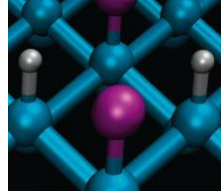
Metallic Bonding

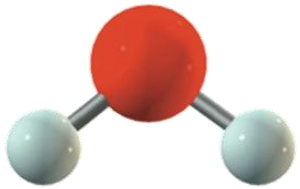




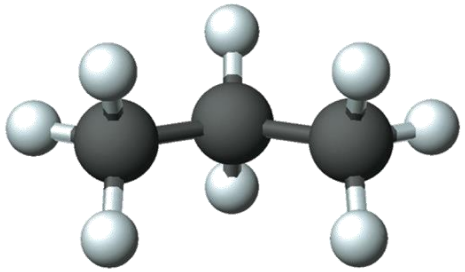
- Positively charged metal nuclei are arranged in a lattice
- Electrons move, more or less, freely throughout the whole lattice
  - Free movement allows metals to conduct electricity

Covalent Bonding





Water, H_2O

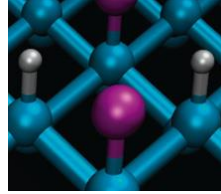


Propane, C_3H_8

Carbon dioxide, CO_2

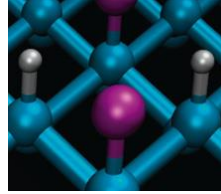
- In covalent bonds, electrons are shared in pairs
  - One pair (single bond), two pairs (double bond), or three pairs of electrons (triple bond) can be shared between two nuclei
    - Results in double bonds or triple bonds
    - Enables formation of long chains in all polymers

Periods and Groups



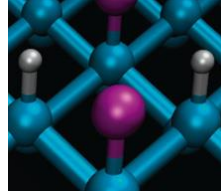
- Common names of specific groups
  - Group 1 - Alkali metals
  - Group 2 - Alkaline earth metals
  - Group 17 - Halogens
  - Group 18 - Noble gases/rare gases
- Table regions
  - Groups 1 to 2 and 13 to18 are main group elements/representative elements
  - Groups 3 to 12 are transition metals
  - Lanthanides and actinides are the elements that appear below the rest of the table

Metals, Nonmetals, and Metalloids



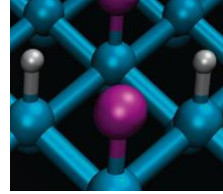
- Metals
  - Are generally located toward the left and bottom of the periodic table
  - Are shiny, malleable, and ductile
  - Conduct electricity and tend to form cations
- Nonmetals
  - Occupy the upper right-hand portion of the periodic table
  - Are not shiny, malleable, or ductile
  - Are predominant or exclusive constituents of most of the molecules that make up the human body
  - Do not conduct electricity and tend to form anions

Metals, Nonmetals, and Metalloids



- Metalloids or semimetals
  - Have chemical properties intermediate of metals and nonmetals
  - Are clustered along a diagonal path in the periodic table between the metals and nonmetals

Figure 2.14: Metals, Nonmetals, and Metalloids



1												13	14	15	16	17	18
1 H	2															1 H	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3	4	5	6	7	8	9	10	11	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	57 La	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	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

Metals
Metalloids
Nonmetals

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	71 Lu
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	103 Lr

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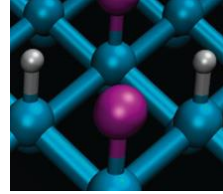
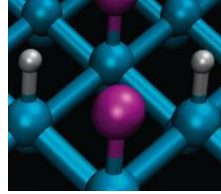
Chemical Nomenclature



- Systematic process of assigning names to chemical compounds
- Binary compounds contain only two elements
  - Covalent binary compounds are named differently from ionic binary compounds
  - Recognizing a compound as ionic or covalent assists in naming
    - A metal and a nonmetal generally combine to form ionic compounds
    - Two nonmetals combine to form a covalent compound
    - Presence of polyatomic ions often indicates ionic bonding

Naming Covalent Compounds

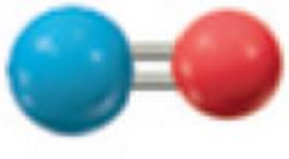


- The first element in the formula retains its full name
- The second element is named by replacing the ending from its name with the suffix *-ide*
  - Both elements are preceded by a number-designating prefix except that when there is only one atom of the first element, it does not use the prefix mono-

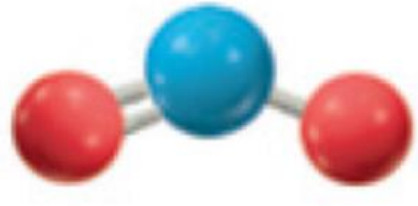
Number	**Prefix**
One	Mono-
Two	Di-
Three	Tri-
Four	Tetra-
Five	Penta-
Six	Hexa-
Seven	Hepta-
Eight	Octa-
Nine	Nona-
Ten	Deca-

Naming Covalent Compounds

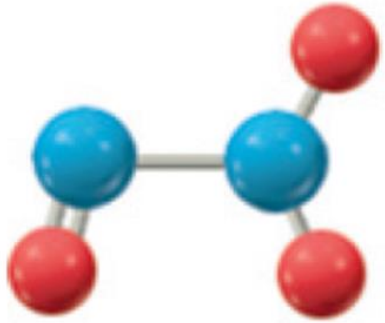
(a) Dinitrogen monoxide, N_2O



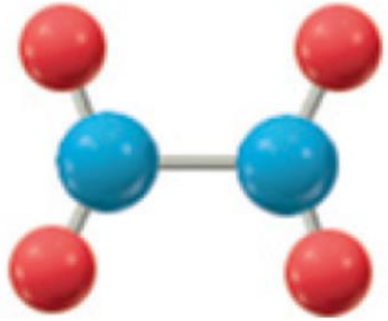
(b) Nitrogen monoxide, NO



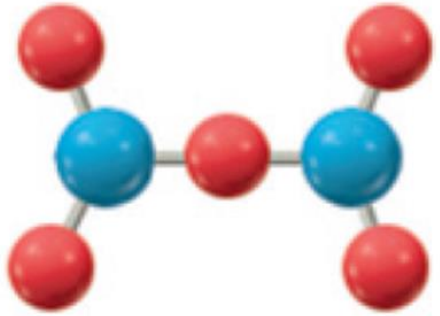
(c) Nitrogen dioxide, NO_2



(d) Dinitrogen trioxide, N_2O_3

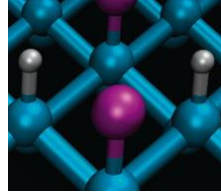


(e) Dinitrogen tetroxide, N_2O_4



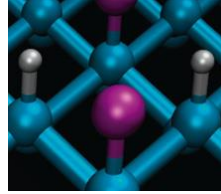
(f) Dinitrogen pentoxide, N_2O_5

Example Problem 2.5



- What are the systematic names of the following compounds?
  - N_2O_5
  - PCl_3
  - P_4O_6

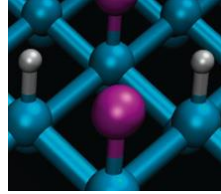
Join In, 17



What is the name of Cl_2O_7?

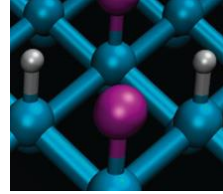
- Chloride oxide
- Dichloride oxide
- Dichlorine oxide
- Dichlorine heptoxide
- Chlorine(VII) oxide

Naming Ionic Compounds



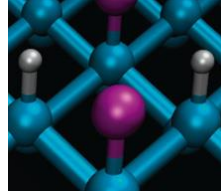
- Rules of nomenclature dictate that the positively charged species, the cation, be specified with enough information about its charge to indicate the complete formula
- Cations with more than one charge (e.g., transition metals) are named using Roman numerals in parentheses indicating the charge, e.g., iron(II)
- Monatomic anions are named by replacing the ending of the element name with the suffix -*ide*, e.g., bromide
- A polyatomic cation or anion is named using its common name

Table 2.5: Common Cations



Sodium ion	Na^+	Potassium ion	K^+
Magnesium ion	Mg^{2+}	Calcium ion	Ca^{2+}
Iron(II) ion	Fe^{2+}	Copper(I) ion	Cu^+
Iron(III) ion	Fe^{3+}	Copper(II) ion	Cu^{2+}
Silver ion	Ag^+	Zinc ion	Zn^{2+}
Ammonium ion	NH_4^+	Hydronium ion	H_3O^+

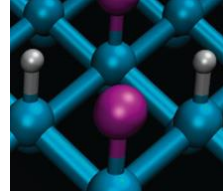
Table 2.6: Naming Ionic Compounds



- The charge and chemical formula for each polyatomic ion should be memorized

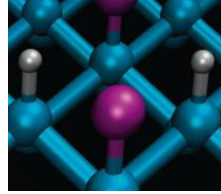
Halides	F^-, Cl^-, Br^-, I^-	Sulfate	SO_4^{2-}
Nitrate	NO_3^-	Hydroxide	OH^-
Phosphate	PO_4^{3-}	Cyanide	CN^-
Carbonate	CO_3^{2-}	Hydrogen carbonate	HCO_3^-

Table 2.8: Oxyanions of Chlorine



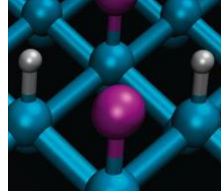
ClO^-	Hypochlorite
ClO_2^-	Chlorite
ClO_3^-	Chlorate
ClO_4^-	Perchlorate

Example Problem 2.6



- Determine the names of the following ionic compounds
  - Fe_2O_3
  - Na_2O
  - $Ca(NO_3)_2$

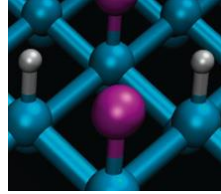
Join In, 18



What is the formula of vanadium (V) oxide?

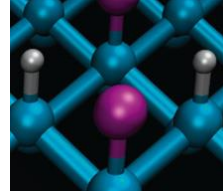
- V_5O
- V_5O_2
- V_2O_5

Polymers



- Very large molecules made up of many smaller molecules linked together
  - Monomers
    - Smaller molecules linked together in polymers
  - Polymer backbone
    - The long chain of bonded carbon atoms formed when monomers link together to form polymers

Polymers



- Polymers used in everyday objects
  - Polyethylene
  - Poly(vinyl chloride), PVC
  - Polyacetylene
- Models showing how atoms are arranged in several polymers
  - Each of these polymers has distinct properties