Chapter 2
Atoms, Molecules and Ions

- How can we classify these substances?
- What are their distinguishing characteristics?
- Can we classify them simply on the basis of appearance?

2.1 Atomic Theory

- How do the Law of Conservation of Mass and the Law of Definite Proportions lead to the idea that matter is composed of atoms?
  - Mass is conserved in a chemical reaction
  - All samples of a pure substance have the same composition
- What would we expect to see if matter were continuous, say like peanut butter?

Dalton's Atomic Theory

- Examine Dalton's Atomic Theory.
  ❶All matter is composed of atoms, indivisible particles that are exceedingly small.
  ❷All atoms of a given element are identical, both in mass and in chemical properties. However, they are different from atoms of other elements.
  ❸Atoms are not created or destroyed in chemical reactions.
  ❹Atoms combine in simple, fixed, whole-number ratios to form compounds.

- What evidence is there for or against each of the postulates? What modifications are necessary to make this consistent with modern atomic theory?
- What is a chemical reaction?
- A chemical reaction is a way of rearranging atoms into new combinations.

What do atoms look like?

- See the electron microscope images of I_2 and of the molecular art drawn with CO molecules (Figure 2.8).
- See the image of graphite. Are these images proof of atoms? How do we see atoms?
- Video of $CuSO_4 \cdot 5H_2O$. What can we see about atoms, molecules, and ions from video generated by electron microscopy?

2.2 The Discovery of Atomic Structure

- Tesla coil and fluorescent bulb. What does an experiment like this have to do with the structure of an atom?
- Why does the beam bend?

The Nuclear Atom

- Examine the diagram of Rutherford's alpha ray experiment. What is the implication of this experiment?

2.3 The Modern View of Atomic Structure

- What are the particles that make up an atom and how do they differ from one another?
- proton mass = 1 charge = +1
- neutron mass = 1 charge = 0
- electron mass = "0" charge = -1
- atoms have equal numbers of protons and electrons so they are electrically neutral

Atomic Structure and Isotopes

- How do we distinguish between atoms?
- Do all atoms of an element have the same composition?
- How do we count nuclear particles?
- What implication does this have for the masses of atoms?
- Notation: superscript for mass number, which is the sum of the number of protons and neutrons
- Notation: subscript for atomic number, which is the number of protons (and electrons)

Nuclear Particles

- How many of each particle in these atoms?

$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$
$^{12}_{6}C$ $^{14}_{7}N$ $^{15}_{7}N$
$^{18}_{8}O$ $^{17}_{8}O$ $^{16}_{8}O$ $^{15}_{8}O$
$^{238}_{92}U$ $^{234}_{92}U$

2.4 The Periodic Table

- What trends would be predicted for the reaction of the alkali metals with air or water?
- Video: Chemistry at Work videodisc on Group I + water trends; Na/K + H_2O video

2.5 Molecules and Molecular Compounds

- Molecule consists of two or more atoms bound together.
- List of formulas: C_5H_{10}, C_6H_{12}, C_2H_4, CH_2 - How are these related?
- H_2O_2, H_2O - How do these differ?
- Distinguish between molecular formulas and empirical formulas. What do formulas stand for? How are the atoms connected?
- CO_2, $H_2C_2O_4$ - Are these empirical formulas?

Chemical Formulas

- See models of different types: Why do we have different types of models? Color coding: H = white or lt. gray, C = black or dk. gray, O = red, N = blue, S = yellow, Cl = green
- See models in Rasmol.
  CH_4 NH_3
  CCl_4 CO_2
  How are the atoms connected?
  H_2O_2 CH_2Cl_2 H_2SO_4

Chemical Formulas

- S_8, O_2, O_3 - What formulas do we find for elements? Elements with different formulas are called allotropes.
- How many atoms make a molecule? Is there any pattern?
  xenon oxygen phosphorus sulfur ozone

2.6 Ions and Ionic Compounds

- Ions are formed by adding or subtracting electrons from a neutral atom or molecule.
- Cation: positive charge (remove electrons)
- Anion: negative charge (add electrons)
- Ions may be monatomic or polyatomic

Predicting Ionic Charges

- Electron Counts of Stable Ions
- Ions tend to have the same number of electrons as the nearest noble gas.
- Main group ions of a given element tend to be different by two units of charge.
- Transition metals are not as predictable, but +2 and +3 are common.
- Main Group Elements: Note periodicity of charges
- Transition Elements :Not periodic; +2 and +3 common

Practice on Ionic Charges

- Group Work: What is the common charge of an ion of potassium, K?
- Group Work: What is the common charge of an ion of sulfur, S?
- Group Work: What is the common charge of an ion of iron, Fe?

Charges and Formulas of Oxoanions

- Oxoanions generally have the same charge as the simple anion of the same nonmetal.

Practice on Oxoanion Charges

- Group Work: What is the common charge of an ion of SO_3?
- Group Work: What is the common charge of an ion of PO_4?
- Group Work: What is the common charge of an ion of NO_3?
- Group Work: What is the common charge of an ion of CO_3?

Formulas of Binary Ionic Compounds

- How do we distinguish between ionic and covalent compounds?
- Demo of Ionic Formula software. How do we combine ions to construct chemical formulas? What criteria do we use to decide whether a formula is correct?
- Combine ions to obtain electrical neutrality

Examples of Ionic Formulas

- What is the formula of each of these compounds?
- Are formulas of ionic compounds molecular or empirical?
- Are these formulas correct? If not, rewrite as correct formulas. What additional information is needed?

CaCl	Na_2N
HSO_4	KO

- Make formulas from the following ions:

Ba^{2+}, N^{3-}	Cr^{3+}, S^{2-}
Cu^{2+}, SO_4^{2-}	Al^{3+}, NO_3^-

2.7 Naming Inorganic Compounds

- Communication about chemical substances requires a knowledge of names that are assigned to each substance. We will be concerned only about inorganic substances at this point. A systematic nomenclature has been developed for different classes of substances.

Covalent Compounds

- Binary Covalent Compounds
- most metallic least metallic
- prefix-element prefix-element-ide
- SO_3 is sulfur trioxide
- Group Work: Write the name for CO
- Group Work: Write the formula for dinitrogen pentoxide

Ionic Binary Compounds

- Ionic Binary Compounds
- metal nonmetal-ide
- If more than one charge is possible for the metal: metal(CHG) nonmetal-ide, where CHG is in Roman numerals
- Group Work: Write the name for K_2S
- Group Work: Write the name for Mn_2O_3

Ionic Binary Compounds

- Group Work: Write the formula for sodium chloride
- Group Work: Write the formula for titanium(IV) chloride
- Group Work: Write the formula for chromium(III) sulfide

Ternary Ionic Compounds

- Ternary Ionic Compounds
- Some groups have special names; cations are named like a metal, anions like a nonmetal with an -ide ending.
- CN^- = cyanide ion, OH^- = hydroxide ion, NCS^- = thiocyanate ion, O_2^{2-} = peroxide ion, O_2^- = superoxide ion, O_3^- = ozonide ion, NH_4^+ = ammonium ion
- Group Work: Write the name for NaOH
- Group Work: Write the formula for ammonium chloride

Salts Containing Oxoanions

- Most common: -ate
  For halogens, the most common has 3 oxygens.

- Most common: -ate
- Fewer oxygens: -ite
- Still fewer: hypo- -ite
- More oxygens: per- -ate

- Group Work: Write the name for NaClO
- Group Work: Write the formula for sodium chlorate

Binary Acids

- Binary Acids
- When there is no oxygen: hydro- -ic acid
- If not in solution, name as hydrogen -ide
- Group Work: Write the name for HBr(aq); for HBr(g)
- Group Work: Write the formula for hydrosulfuric acid

Oxoacids

- Oxoacids
- Name is based on the name of the oxoanion:

per- -ate	per- -ic acid
-ate	-ic acid
-ite	-ous acid
hypo- -ite	hypo- -ous acid

- Group Work: Write the formula for phosphorous acid

Nomenclature Practice

Write the name or formula,whichever is not given.

- SiO_2
- carbon dioxide
- NO_2
- tetraphosphorus decoxide
- XeF_4
- sodium chloride
- Al_2O_3
- SnO_2
- mercury(II) oxide
- magnesium hydroxide
- barium sulfate
- $CaCO_3$
- copper(II) nitrate
- $SrSO_4$
- lead(II) chromate

- $(NH_4)_2Cr_2O_7$
- sodium peroxide, potassium superoxide
- Cr_2O_3
- chromium(VI) oxide
- HgI_2
- lead(II) iodide
- FeS
- iron(III) oxide
- $TiCl_4$, $TiCl_3$
- $CuSO_4$, $CuSO_4 \cdot 5H_2O$
- iron(III) nitrate hexahydrate
- $FeCl_3 \cdot 6H_2O$
- hydrochloric acid
- $H_2SO_4(aq)$