Major Divisions of Chemistry

- Physical Chemistry – applies the theories of physics
- Analytical Chemistry – identifies what and how much is present
- Organic Chemistry – carbon compounds
- Inorganic Chemistry – non-carbon compounds
- Biochemistry – chemical reactions that occur in living organisms

88 Naturally Occurring Elements

- Either singly or in chemical combination, the 88 naturally occurring elements comprise virtually all matter.
- Their chemical and physical properties affect us continually.
- This chapter (#11) discusses
  - the Classification of matter
  - the Elements
  - the Periodic Chart
  - the Naming of Compounds

Classification of Matter

- In Chapter 5 we saw that matter can be classified by its physical phase or state
  - Solid
  - Liquid
  - gas
  (Matter is anything that has mass)
- Chemists use this classification, but also divide matter into several other classifications
  - Pure Substance – element or compound
  - Mixture – homogeneous or heterogeneous
Pure Substance

- Pure Substance – a type of matter in which all samples have fixed composition and identical properties
  - Element – all atoms have same # of protons (gold, sulfur, oxygen)
  - Molecule - two or more of the same atoms chemically combined in a definite fixed ratio.
  - Compound – two or more different elements chemically combined in a definite, fixed ratio by mass (pure salt, topaz crystal, distilled water)
- A compound can be broken into its separate components only by chemical processes

Natural minerals - good examples of Compounds of Pure Substances

- Faceted Topaz
- Al₂SiO₄(OH,F)₂
- Halite NaCl “rock salt”
- Rhodochrosite MnCo₃

Compound vs. Component Elements
Compounds are typically different from the individual components

<table>
<thead>
<tr>
<th>Property</th>
<th>Zinc Sulfide</th>
<th>Zinc</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>White powder</td>
<td>Silvery</td>
<td>Yellow powder</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>3.98</td>
<td>7.14</td>
<td>2.07</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>1700</td>
<td>281</td>
<td>113</td>
</tr>
<tr>
<td>Conducts electricity as a</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Conducts electricity as a</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Soluble in carbon disulfide</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Mixture

- Mixture – type of matter composed of varying proportions of two or more substances that are only physically mixed and not chemically combined
  - Homogeneous (a solution)– uniform throughout (coffee, alloy). Technically, it should be mixed/uniform at the atomic level.
  - Heterogeneous – non-uniform (pizza, oil/water), at least two components can be observed
- Formed and broken down by physical processes (dissolving, evaporation)
Chemical Classification of Matter

- Matter: Anything that has mass and occupies space.
- Pure substance: Fixed composition and properties.
- Mixture: Variable composition and properties.
- Physical processes:
  - Element: Its atoms have same number of protons.
  - Compound: Several elements chemically combined.
- Homogeneous mixture: Uniform
- Heterogeneous mixture: Nonuniform

Liquid Solutions

- Solvent: the liquid or the substance in the larger quantity
- Solute: the substance dissolved in the solvent or the smaller quantity

Aqueous Solutions

- Aqueous Solution (aq): a solution in which water is the solvent
  - When dissolved & stirred the distribution of the solute is the same throughout (homogeneous)
- Unsaturated Solution: more solute can be dissolved in the solution at the same temp.
- Saturated Solution: maximum amount of solute is dissolved in the solvent

Saturated Solution

- A dynamic equilibrium exists between the solute dissolving and the solute crystallizing
**Solubility**

- Solubility – the amount of solute that will dissolve in a specified volume or mass of solvent (at a given temperature and pressure) to produce a saturated solution
- If the temperature is raised the solubilities for most solids increase

**The Effect of Temperature on Solubilities of Salts in Water**

- Usually hotter water will dissolve more solute

**Supersaturated Solutions**

- When unsaturated solutions are prepared at high temperatures and then cooled, the saturation point may be reached as the solution cools
- However, if no crystals are present, crystallization may not take place
- Result → Supersaturated Solution – contains more than the normal maximum amount of dissolved solute at the given temperature
Solubility of Gases

• The solubility of gases increases with increasing pressure
  – Example: manufacture of soft drinks, CO₂ is forced into the beverage at high pressure
• Once the soft drink is opened, the pressure inside the container is reduced to normal atmospheric pressure and the CO₂ starts escaping
• The solubility of gases decreases with increasing temperature (hot soft drinks quickly lose their CO₂)

Occurrence of the Elements

• Human Body = 65% oxygen & 18% carbon
• Earth’s Crust = 47% oxygen & 27% silicon
• Analyses of electromagnetic radiation from space indicates that the universe consists of:
  – Hydrogen – 75% (simplest element)
  – Helium – 24% (second most simple element)
  – Others – 1%
• Earth’s Atmosphere = 78% nitrogen, 21% oxygen, and about 1% argon
• Earth’s Core = 85% iron & 15% nickel

Relative Abundance (by Mass) of Elements in Earth’s Crust

Note that 74% of the mass of the Earth’s crust is composed of only two elements – oxygen & silicon

Atoms

a) The individual units (atoms) packed in a repeating pattern
b) Noble gases that occur as single atoms
c) Diatomic atoms (hydrogen, oxygen, nitrogen…)

Relative Abundance (by Mass) of Elements in Earth’s Crust

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Molecules / Compounds

- Molecule – an electrically neutral particle composed of two or more atoms chemically combined
- If the atoms are that same element, then the molecule is of an element
  - Element examples: H₂ or N₂
- If the atoms are different elements, then the molecule is of a compound
  - Compound examples: H₂O or NH₃

A molecule is formed when two or more atoms join together chemically. A compound is a molecule that contains at least two different elements. All compounds are molecules but not all molecules are compounds.

Seven common elements that exist as diatomic molecules

- These atoms (H, N, O, F, Cl, Br, I) are too reactive to exist as independent atoms.
- When writing formulas with these seven elements we use the diatomic form:
  
  \[ \text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl} \]

Representations of Molecules/Compounds

- Hydrogen (H₂)
- Water (H₂O)
- Ammonia (NH₃)
- Methane (CH₄)

Allotropes

- Allotrope – two or more forms of the same element that have different bonding structures in the same physical phase
- Example: Diamond and Graphite
- Both pure Diamond and pure Graphite are each 100% carbon (C), and are both solid
- But the atomic arrangement of the carbon atoms is different
Three Allotropes of Carbon
Diamond, Graphite, and Buchminsterfullerene (C\textsubscript{60})

Oxygen also has two Allotropes
Oxygen gas (O\textsubscript{2}) and Ozone (O\textsubscript{3})

The Periodic Table

- The periodic table puts the elements in order of increasing atomic number, into seven horizontal rows, called ‘periods’
- The elements’ properties show regular trends going up or down these periods
- In 1869 the Russian Chemist, Mendeleev, published the original periodic table
- The fifteen vertical columns in the periodic table are called ‘groups’
### One way to Classify the periodic table

Representative Elements (green)

Transitional Elements (blue)

Inner Transition Elements (purple)

### Metals & Nonmetals another way to classify the elements

- A metal is an element whose atoms tend to lose electrons during chemical reactions (+)
- A nonmetal is an element whose atoms tend to gain (or share) electrons (-)
- The metallic character of the elements increases as one goes down a group, and decreases across (always considered left to right) a period

### General Properties of Metals & Nonmetals

<table>
<thead>
<tr>
<th>Metals</th>
<th>Nonmetals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good conductors of heat and electricity</td>
<td>Poor conductors of heat and electricity</td>
</tr>
<tr>
<td>Malleable—can be beaten into thin sheets</td>
<td>Brittle—if a solid</td>
</tr>
<tr>
<td>Ductile—can be stretched into wire</td>
<td>Nonductile</td>
</tr>
<tr>
<td>Possess metallic luster</td>
<td>Do not possess metallic luster</td>
</tr>
<tr>
<td>Solids at room temperature (exception: Hg)</td>
<td>Solids, liquids, or gases at room temperature</td>
</tr>
<tr>
<td>Usually have 1 to 3 valence electrons</td>
<td>Usually have 4 to 8 valence electrons</td>
</tr>
<tr>
<td>Lose electrons, forming positive ions</td>
<td>Gain electrons to form negative ions or share electrons</td>
</tr>
</tbody>
</table>
Electron Configuration & Valence Electrons

- Electrons are located in energy levels or shells that surround the nucleus
  - Level 1 – maximum of 2 electrons
  - Level 2 – maximum of 8 electrons
  - Level 3 – maximum of 18 electrons
- The chemical reactivity of the elements depends on the order of electrons in these energy levels

Valence Electrons

- The outer shell of an atom is known as the valence shell
- The electrons in the outer shell are called the valence electrons
- The valence electrons are the electrons involved in forming chemical bonds – so they are extremely important
- Elements in a given group all have the same number of valence electrons (and hence similar chemical properties)

We will basically only discuss the representative elements – Groups 1A - 8A

Guidelines: Shell Electron Configurations

- The number of electrons in a neutral atom is the same as the element’s atomic number (Z)
- The number of shells that contain electrons will be the same as the period number that it is in
- For the A group (representative) elements, the number of valence electrons is the same as the group number
The Periodic Nature of Atomic Size

- The atomic size of the elements also varies periodically (refer to the Periodic Table) – from 0.074 nm (H) to 0.47 nm (Cs)
- Atomic size increases down a group
- Atomic size decreases across a period
- The atoms on the far left are the largest due to less charge (fewer protons) in the nucleus and the outer electrons are more loosely bound

Relative Atomic Sizes

Note - the Periodic Table can be used to determine relative atomic size
Ionization Energy – also Periodic

- Ionization energy – the amount of energy that it takes to remove an electron from an atom
- Ionization energy increases across a period due to additional protons in the nucleus
- Ionization energy decreases down a group because of the additional shells situated between the nucleus and the outer electron shell.

Ionization Energy Trend

Chemical Formulas

- In order to easily and conveniently discuss chemistry we can use their chemical formulas
- Chemical formulas are written by putting the elements' symbols adjacent to each other – usually w/ the more metallic element first
- A subscript following each symbol designates the number of atoms \( \rightarrow \) \( \text{H}_2\text{O} \)
- Some compounds have special names

Some Compounds with Special Names

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>( \text{H}_2\text{O} )</td>
</tr>
<tr>
<td>Ammonia</td>
<td>( \text{NH}_3 )</td>
</tr>
<tr>
<td>Methane</td>
<td>( \text{CH}_4 )</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>( \text{N}_2\text{O} )</td>
</tr>
<tr>
<td>Nitric oxide</td>
<td>( \text{NO} )</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>( \text{HCl(\text{aq})} )</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>( \text{HNO}_3(\text{aq}) )</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>( \text{H}_3\text{C}_2\text{O}_3(\text{aq}) )</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>( \text{H}_2\text{SO}_4(\text{aq}) )</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>( \text{H}_2\text{CO}_3(\text{aq}) )</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>( \text{H}_3\text{PO}_4(\text{aq}) )</td>
</tr>
</tbody>
</table>
Naming a Binary Compound for a Metal and Nonmetal

- Binary = two-element compound
  - First give the name of the metal
    - The one on the left of the periodic table
  - Then give the name of the non-metal
    - The one on the right of the periodic table
  - Then change the non-metal ending to “ide”

- NaCl sodium chloride
- Al₂O₃ aluminum oxide
- Ca₃N₂ calcium nitride

“ide” Nomenclature Examples

<table>
<thead>
<tr>
<th>Element Name</th>
<th>-ide Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine</td>
<td>Bromide</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Chloride</td>
</tr>
<tr>
<td>Fluorine</td>
<td>Fluoride</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Hydride</td>
</tr>
<tr>
<td>Iodine</td>
<td>Iodide</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Nitride</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Oxide</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Phosphide</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Sulfide</td>
</tr>
</tbody>
</table>

Compounds of Two Nonmetals

- The more metallic or less nonmetallic element (farther left or farther down periodic chart) is usually written first in the formula and named first
- The second element is named using the “ide” ending
- Greek prefixes are used to designate the number of atoms in the molecule

Examples:
- HCl hydrogen chloride
- CS₂ carbon disulfide
- PBr₃ phosphorus tribromide
- IF₇ iodine heptafluoride
Groups of Elements

- Recall that in the Periodic Table each individual column is called a group.
- All the elements in a group have the same number of valence electrons.
- If one element in a group reacts with a substance – the other elements in the group usually react similarly.
- The formulas of the compounds created are also similar.
- We will discuss four of these groups …

Noble Gases

- They exist as single atoms (monatomic).
- Almost never react and form compounds.
- Noble gases have 8 electrons in their outer shells (except He that has a full shell with 2).
  - Eight electrons in the outer shell is VERY stable.
- “Neon” signs contain minute amounts of various noble gases – electric current → glow!
- Argon gas is used inside light bulbs because even at high temps. it will not react with the tungsten filament (W).
### Alkali Metals – Group 1A (not H)

- Each alkali metal atom has only one valence electron.
- Tends to lose this electron and readily react with other elements – active metals.
- Na & K are abundant (Li, Rb, Cs are rare).
- They are so very reactive with oxygen and water that they must be stored in oil.
- Examples: NaCl, K₂CO₃ (potash), Na₂CO₃ (washing soda), NaOH (lye), NaHCO₃ (baking soda).
- Predict formulas → KCl, LiCO₃.

### Halogens – Group 7A

- Each halogen atom has seven valence electrons.
- Tends to gain an electron and readily react with other elements → active nonmetals.
- Only occur in nature as a compound, but when purified occur as a diatomic molecule (F₂, Cl₂) – generally poisonous.
- F is the most reactive – will corrode Pt, and cause wood, rubber, water to burn on contact.
- Iodine is necessary for proper thyroid function.
- Examples: AlCl₃ (aluminum chloride), NH₄F (ammonium fluoride), CaBr₂ (calcium bromide).
Section 11.6

**Alkaline Earth Metals – Group 2A**

- This group contains two valence electrons, and tend to lose two electrons (→ +2)
- Not as chemically active as alkali metals (1A), and are generally harder and stronger
- Examples: Be$_2$Al$_2$(SiO$_3$)$_6$ – (beryl), Mg(OH)$_2$ (milk of magnesia), CaCO$_3$ (calcite), Ca$_3$(PO$_4$)$_2$ (bones & teeth), BaSO$_4$ (barite); Sr (red) & Ba (green) give color in fireworks
- Ra is radioactive – RaCl$_2$ used on watch dials (glowed in dark) until a number of Swiss dial-painters came down with stomach cancer!!

**Hydrogen – Group 1A**

usually sometimes Group 7A

- Although a nonmetal, H usually reacts like a alkali metal (HCl, H$_2$S)
- But… Sometimes it reacts like a halogen – NaH, CaH$_2$
- At room temp. – colorless, odorless, diatomic
- Lightest element – was used in early dirigibles (balloons)
- Will burn in air to form water

**Questions**

- Matching Questions
  - A pure substance in which all atoms have the same number of protons is called a(n) ___________.
  - A(n) __________________ can be broken into its component elements only by chemical processes
Questions

**Multiple Choice Questions**
- Consider the element magnesium. Which statement is true?
  - It is in Group 5A
  - It is a noble gas
  - A magnesium atom has electrons in nine shells
  - It is an alkaline earth metal.
- Which of these elements will be most like fluorine in its chemical properties?
  - Chlorine
  - Neon
  - Oxygen
  - Hydrogen

**Short Answer Questions**
- Which illustrations in the above figure represents
  - Mixtures?
  - Compound?
  - Only element?
  - Only diatomic molecules?

Exercises
- Classify each of the following materials as an element, compound, heterogeneous mixture, or homogeneous mixture:
  - air?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - pure water?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - diamond?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - soil?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
Questions

Exercises

- Classify each of the following materials as an element, compound, heterogeneous mixture, or homogeneous mixture:
  - a fried egg?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - ozone?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - brass?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - carbon dioxide?
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture

Exercises

- Use the periodic table to find the atomic mass, atomic number, number of protons, and number of electrons for an atom of:
  - Lithium
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - Gold
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - Argon
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture
  - Strontium
    - Element
    - Compound
    - Heterogeneous Mixture
    - Homogeneous Mixture

Don’t forget your homework!!!

Nighty Night