Chapter 20

Chemical Bonds

Stability in Bonding

- matter around you is in the form of uncombined elements
  - oxygen, copper
- under the right conditions, they will form compounds
- Examples
  - Statue of Liberty – copper
    - turn green, no luster (Copper Sulfate)
  - Car bumper – iron
    - turns red, no luster (Iron Oxide)

New Properties

- elements combine to create a new substance with **new properties**
- Example

  Sodium and Chlorine → Sodium Chloride
  - Na – soft solid, highly reactive with water, luster
  - Cl – green gas, poisonous
  - NaCl – white crystalline solid, not poisonous

Formulas

- **chemical formula**
  - chemical shorthand that uses symbols to tell what elements are in a compound and their ratios
  - Example: H_2O (water)
    - 2 hydrogen atoms
    - 1 oxygen atom
    - subscript tells how many atoms of each element

Atomic Stability

- the electric forces between oppositely charged electrons and protons hold atoms and molecules together
  - this force (attraction) causes compounds to form

Chemical Stability

- noble gasses rarely form compounds because they are chemically stable
  - 8 valence electrons (octet rule)
    - except for Helium, only has 2
- elements will **gain**, **lose**, or **share** electrons to attain this stability

Stability is Reached!!

- when atoms **gain**, **lose**, or **share** electrons, an attraction forms between the atoms, pulling them together to form a compound
  - Metals lose electrons
  - Nonmetal gain electrons
- **chemical bond**
  - force that holds atoms together in a compound
  - 2 types
    - ionic bond (transfer electrons)
    - covalent bond (share electrons)

Ionic Bonding

- **ion**
  - charged particle that has either more or fewer electrons than protons
  - **cation** – positively charged ion (metals)
  - **anion** – negatively charged ion (nonmetals)
- it is the electric forces between oppositely charged particles, such as ions, that hold compounds together

A Bond Forms

- lets go back to our example of sodium and chlorine
- Na – 1 e^- in its outer energy level (group 1A)
- Cl – 7 e^- in its outer energy level (group 7A)
  - metals lose, nonmetals gain
- Na becomes Na^+
  - has one more proton than electrons
- Cl becomes Cl^-
  - has one more electron than protons

A Bond Forms

- neutral charge
  - the positive and negative charges of the ions cancel each other
  - known as electrically neutral

$$Na^+Cl^-$$

Ionic Bond

- **Ionic bond**
  - attraction between oppositely charged ions in an ionic compound
  - **transfer** of electrons takes place between a metal and a nonmetal
- **formula unit**
  - smallest sample of an ionic compound

Writing Formulas and Naming Binary Ionic Compounds

- **binary compound**
  - is composed of two elements
- **oxidation number**
  - the relationship between an element's position on the periodic table and the number of electrons it gains or loses
  - metals (+, equals the group number)
  - nonmetals (-, equals how many more they need to get 8)

- some metals may have more than one oxidation number
- we use Roman Numerals to indicate which charge is being used
  - iron (II) has an oxidation number of 2+

Special Ions	
Name	Oxidation Number
Copper (I)	1+
Copper (II)	2+
Iron (II)	2+
Iron (III)	3+
Chromium (II)	2+
Chromium (III)	3+
Lead (II)	2+
Lead (IV)	4+

- some transition metals only have one oxidation number
  - **Zinc (Zn) is always 2+**
  - **Silver (Ag) is always 1+**

Names of Anions

- when nonmetals gain electrons, they become negatively charged (more electrons)
- when they become an anion, their name acquires an *–ide* suffix

nonmetal	anion
carbon	carbide
nitrogen	nitride
phosphorus	phosphide
oxygen	oxide
sulfur	sulfide
fluorine	fluoride
chlorine	chloride
bromine	bromide
iodine	iodide

Writing Formulas using Oxidation Numbers

- write the symbol for both the metal and nonmetal
- write the oxidation number for each element as a superscript
- cross and drop the **number only** (not the charge)
- if you can reduce the ratio, do so
  - lead (IV) oxide → Pb_2O_4 reduces to PbO_2

Practice

1. calcium fluoride
2. copper (II) oxide
3. silver bromide

PRACTICE!!!

Write the formulas for the following compounds.

1. potassium iodide
2. iron (II) chloride
3. strontium bromide
4. lead (IV) sulfide
5. aluminum nitride

Compounds with Complex Ions

- baking soda has the formula $NaHCO_3$
- this is an ionic compound that is not binary
- some compounds are composed of more than two elements
  - they contain polyatomic ions

- **polyatomic ion**
  - a positively or negatively charged, covalently bonded group of atoms
  - polyatomic ions as a whole contains two or more elements

ammonium	$(NH_4)^+$
nitrate	$(NO_3)^-$
hydroxide	$(OH)^-$
carbonate	$(CO_3)^{2-}$
sulfate	$(SO_4)^{2-}$
phosphate	$(PO_4)^{3-}$

Writing formulas with polyatomic ions

- Follow the same rules for binary ionic compounds.
- When you cross and drop, if there is more than one molecule of the polyatomic ion, it is written in parentheses.
- Example
  - aluminum sulfate
  - Barium hydroxide

Practice

1. sodium sulfate _____
2. copper (II) carbonate _____
3. nickel (II) phosphate _____
4. potassium hydroxide _____
5. silver nitrate _____
6. ammonium nitrate _____

Naming Ionic Compounds

1. sodium nitrate _____
2. calcium phosphate _____
3. potassium oxide _____
4. nickel (II) carbonate _____
5. copper (I) chloride _____
6. zinc sulfide _____
7. lead (IV) nitrate _____
8. lithium hydride _____

Writing Names from Formulas for Ionic Compounds

1. Write the name of the positive ion.
   - metal or polyatomic ion (ammonium)
2. If it is a metal that has more than one oxidation number, you put the number in parentheses as a Roman Numeral.
   - any element other than main groups 1-3, Zn, and Ag
3. Write the name of the negative ion.
   - non-metal (with –ide suffix) or polyatomic ion

Determining the Charge of the metal ion (cation)

- Ionic compounds
  - cation is always first, anion is second
1. Determine the charge of the anion in the compound.
   - $CuSO_4^{2-}$
2. Using the charge of the anion, determine the charge of the cation to balance the charge to 0 (make it neutral).
   - ask yourself → What would the charge of Cu be to make the compound neutral?

- in order to balance to zero, the charge of copper must be 2+
  - x + (-2) = 0
  - x = 2
- $CuSO_4$ copper (II) sulfate
- $FeCl_3$ _____
- Co_2O_3 _____

Practice

Write the names for the following ionic compounds below.

1. $MgCl_2$ _____
2. $CuBr_2$ _____
3. Na_2SO_4 _____
4. Co_2O_3 _____
5. KNO_3 _____
6. Cs_3PO_4 _____
7. ZnS _____

Practice –Naming and Formulas

1. $Al(OH)_3$
2. Cu_2O_3
3. $ZnSO_4$
4. Rb_2S
5. CsI
6. $Mg_3(PO_4)_2$
7. Calcium bromide
8. Tin (IV) oxide
9. Barium phosphide
10. Potassium nitride
11. Nickel (II) fluoride
12. Magnesium oxide

Compounds with added water

- some ionic compounds have water molecules as part of their structure
- these compounds are called hydrates
- **hydrate**
  - a compound that has water chemically attached to its ions and written into its chemical formula

Greek Prefixes

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

Example

- Cobalt (II) Chloride
  - $CoCl_2$
  - Anhydrous state (no water) → blue
  - Hydrated state (with water) → red
- Cobalt (II) Chloride Hexahydrate
  - $CoCl_2 \cdot 6H_2O$
  - Use the Greek prefixes to tell how many waters

Covalent Bonding

- some nonmetals will be unlikely to gain or lose electrons
- Example: Group 4 elements
  - 4 electrons in outer energy level (would have to gain or lose 4 to be stable)
  - too much energy is needed
  - they share electrons instead

Covalent Bond

- **covalent bond**
  - attraction formed between atoms when they share electrons
  - **sharing** of electrons between 2 or more nonmetals
- **molecule**
  - a neutral particle that forms as a result of electron sharing (smallest sample of a covalent compound)

Writing Formulas for Binary Covalent Compounds

- write the symbol for each element and the appropriate number designated by the prefix as a subscript
- Example:
- dihydrogen monoxide
- carbon tetrachloride

Practice Writing Formulas

- carbon dioxide _____
- phosphorus trichloride _____
- nitrogen trihydride _____
- diphosphorus pentoxide _____
- oxygen difluoride _____

Naming Binary Covalent Compounds

- Write the name of the first element with the appropriate prefix (**never** use mono- with the first element)
- Write the name of the second element with the appropriate prefix and –ide suffix

Naming Binary Covalent Compounds

NO _____
N_2O _____
NO_2 _____
N_2O_5 _____

Single Covalent Bond

- a single covalent bond is made up of 2 shared electrons
- Example
  - fluorine (F_2)

Multiple Bonds

- a covalent bond also can contain more than one pair of electrons
- Example
  - Nitrogen (N_2)

Multiple Bonds

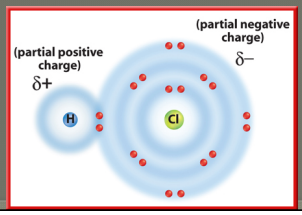
- each shared pair of electrons represents a bond
  - two pairs of electrons represents two bonds or a **double bond (4 electrons)**
  - three pairs of electrons represents three bonds or a **triple bond (6 electrons)**

Unequal Sharing

- electrons are not always shared equally between atoms in a covalent bond
- the strength of the attraction of each atom to its electrons is related to:
  - the size of the atom
  - the charge of the nucleus
  - the total number of electrons the atom contains

Unequal Sharing

- the electrons shared in HCl will spend more time near the chlorine atom than near the hydrogen atom

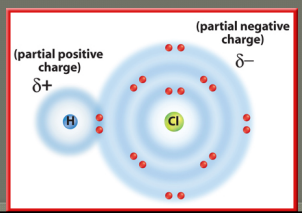


Tug – of - War

- think of the bond as the rope in a tug-of-war
  - the shared electrons as the knot in the center of the rope
- each atom in the molecule attracts the electrons that they share

Unequal Sharing

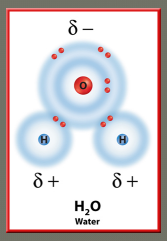
- one example of this unequal sharing is found in a molecule of hydrogen chloride, HCl
- chlorine atoms have a stronger attraction for electrons than hydrogen atoms do



Polar or Nonpolar

- the charge is balanced but not equally distributed
  - this type of molecule is called polar
- **polar molecule**
  - has a slightly positive end and a slightly negative end although the overall molecule is neutral
- water is an example of a polar molecule

Polar or Nonpolar



- **nonpolar molecule**
  - electrons are shared equally in bonds
  - Such a molecule does not have oppositely charge ends
- this is true of molecules made from two identical atoms or molecules that are symmetric, such as CCl_4 (carbon tetrachloride)