# CHEMISTRY 110 CHAPTER 2: ATOMS, MOLECULES, AND IONS WEEK 2

Be familiar with Figures 2.4 (Cathode-Ray Tube), 2.8 (Behavior of α, β, and γ Particles), 2.5 (Millikan's Oil Drop Experiment), 2.10 (Rutherford's Experiment)

*Know James Chadwick's role in neutron discovery.*

## ELECTRIC CHARGE AND ITS BEHAVIOR

Electric charge is due to electrons (negatively charged particles outside the nucleus). It has the following attributes:

a. Charges can be positive (as in a proton) or negative (as in an electron).

b. Like charges repel (negative next to negative repel or north with north for a magnet) while opposite charges attract (north and south poles of a magnet).

c. Charge can be moved from one object to another by contact or induction (placing a charged object near another).

d. The attractive or repulsive force between unlike charges increases as the charges become closer together.

## IONIC SUBSTANCES

Some substances when placed in water or melted can conduct electricity. This is due to the formation of ions.

**Negative ion = anion** **Positive ion = cation**

***Examples:*** $Na^+$, $Cu^{+2}$, and $Al^{+3}$ are cations; Cl-, $P^{-3}$, and $O^{-2}$ are anions.

The work of Michael Faraday and Svante Arrhenius provided initial insight into ions and their properties.

**GRAMS to ATOMS, ATOMS to GRAMS Conversion Examples**

If the mass of a H atom is $1.673 \times 10^{-24}$ g, a 5 L sample of hydrogen gas ($H_2$) has how many atoms? <u>Note</u>: Density of $H_2$ = 0.090 g/L

**<u>Using Factor Label:</u>**

**Example 1**: $5.0\ \cancel{L}\ H_2 \times \frac{0.090\ \cancel{g}}{\cancel{1\ L}} \times \frac{1\ \text{Hydrogen atom}}{1.673 \times 10^{-24}\ \text{g}} = 2.7 \times 10^{23}$ atoms

**Example 2**: If the mass of a Na atom = $3.82 \times 10^{-23}$ g, how much would $1.92 \times 10^{25}$ atoms weigh?

$1.92 \times 10^{25}\ \cancel{\text{atoms Na}} \times \frac{3.82 \times 10^{-23}\ g\ Na}{1\ \cancel{atom\ Na}} = 733$ g Na

**See Table 2.1 p. 45 for Masses of Subatomic Particles, Symbols, and Charges**

**ATOMIC NUMBERS**

This represents the number of protons of an atom. (The number above the symbol of the element in the periodic table.)

**Each element has a unique atomic number**.

**<u>Examples:</u>** Sodium (Na) = 11; Uranium (U) = 92; Helium (He) = 2

**ATOMIC MASSES (ATOMIC WEIGHTS)**

Based upon atomic mass units (a.m.u.)

The a.m.u. = mass of a C-12 atom ÷ 12;
mass of a C-12 atom = $1.9927 \times 10^{-23}$ g ÷ 12 = $\underline{1.6606 \times 10^{-24}\ \text{g}}$.

The atomic mass or weight is the number below the symbol in the periodic table.

**Examples**: Oxygen (O) = 16.00; Chlorine (Cl) = 35.45; Na = 22.99
*After the first exam, we will round these to the nearest hundredth place.*

The atomic mass of an element takes into account that there are isotopes of that element which differ in atomic mass.

**ISOTOPES**

*Elements of the same atomic number (same identity) but different atomic masses.*

Differences in the atomic masses are due to different numbers of **neutrons** in each atom.
**NOTE: Neutrons do NOT affect the identity of an element, only protons do.**

**MASS NUMBER**

Mass number is the number of protons + number of neutrons in an atom.
For instance, carbon (atomic number 6) can have 6 neutrons (mass number = $6\ p^+ + 6\ n^o = 12$), 7 neutrons ($6\ p^+ + 7\ n^o = 13$), or 8 neutrons ($6\ p^+ + 8\ n^o = 14$) among others but the element is still carbon!

**The number of neutrons can be found be taking the number of protons and subtracting it from the mass number.**

<u>EXAMPLE</u>: How many neutrons would the U-238 ($^{238}U$) isotope of uranium possess?

$n^o$ = mass number – $p^+$ = 238 – 92 $p^+$ = 146 $n^o$

Knowing the atomic and mass numbers, abbreviations (symbols) for isotopes can be written.

Where E = the element symbol, A = mass number, Z = atomic number

Hence, A – Z = number of neutrons.

$\frac{A}{Z}$E represents an isotope.

Each isotope in a sample of an element or a compound containing that element is taken into account in the overall atomic mass. *The greater the abundance of an isotope, the more influence it has on the atomic mass.*

Example: An element *A* occurs as 3 isotopes. Analysis of a sample of *A* showed:

| Isotope | Mass | % |
|---|---|---|
| 1 | 12.0 a.m.u. | 99.9 |
| 2 | 13.0 a.m.u. | 0.05 |
| 3 | 14.0 a.m.u. | 0.05 |

Determine the atomic mass of the element.

Atomic mass = sum of averages (fractional percentages) of all isotopes.

Atomic mass = isotope 1 + isotope 2 + isotope 3

**= (12.0 x 0.999) + (13.0 x 0.0005) + (14.0 x 0.0005) = 12.0 g**

***Be familiar with Figures 2.18 (Molecular Models) and 2.21 (Formation of an Ionic Compound).***

## Ions and the Formulas

**An ion is an atom that has gained or lost one or more electrons. A positive ion has lost one or more electrons, while a negative ion has gained one or more electrons.**

When Na+ and Cl− ions come together, an ionic bond forms, and the compound sodium chloride (NaCl) results.

When an ion forms, electrons are gained or lost. For cations (positive), equations can be written showing an electron given off.

**Example:** $Ca \rightarrow Ca^{2+} + 2\ e-$

***This equation indicates that calcium lost 2 electrons (2 e-) and so has 2 extra protons in the nucleus than electrons outside the nucleus. 2 extra protons = 2 extra positive charges so a $2^+$ or $^+2$ notation is used.***

Conversely, when a negative ion forms (an anion), electrons are gained.

**Example:** $S + 2\ e- \rightarrow S^{2-}$

**Two extra electrons outside the nucleus than protons inside the nucleus are indicated by a $2^-$ or $^-2$.**

Example: $Br + e- \rightarrow Br^-$

**IMPORTANT:** PROTONS ARE NEVER GIVEN OFF OR GAINED, ONLY ELECTRONS. TO DO SO WOULD CHANGE THE IDENTITY OF THE ELEMENT. THIS DOES NOT HAPPEN DURING CHEMICAL CHANGE.

***Naming Cations for Elements***

Cations for elements, mainly metals, are simply named using the name of the metal followed by ion.

**Examples:** $Li^+$ would be named a lithium ion; $Mg^{+2}$ would be named a magnesium ion.

## Naming Anions for Elements

When an element gains electrons (usually a non-metal such as oxygen), it is named using the prefix for the non-metal followed by the addition of the suffix –ide.

***Examples:*** $N^{-3}$ would be named nitride (nitrogen – ogen + ide), not nitrogen;

$As^{-3}$ would be named arsenide (arsenic – ic + ide.)

**See Table on p. 60 for more examples.**

## Predicting Charges: Be familiar with Figure 2.20, pg. 56.

Charges of some elements can be predicted knowing where the element is on the periodic table.

For instance, Group IIA are all positive 2 as ions (2+); group VIA are all negative 2 as ions (2-)

**Figure 2.20 on pg. 56 gives more examples of this.**

**Writing Formulas for Ionic Compounds**

The method of nomenclature for these compounds consists of naming the cation (positive) ion first followed by naming the anion (negative) ion second.

**Examples:** sodium azide (used in airbags); potassium iodide (used sometimes in iodized salt); calcium chloride (used to melt snow and ice)

The formula for **sodium azide** would be $NaN_3$.

$$Na^{+} + N_3^{-} \rightarrow NaN_3$$

***NOTE:*** When no number is given with charge, it is understood to be 1.

The formula for **potassium iodide** would be KI.

$$K^{+} + I^{-} \rightarrow KI$$

The formula for **calcium chloride** would be $CaCl_2$.

$$Ca^{+2} + 2\ Cl^{-} \rightarrow CaCl_2$$

**In the above example, it takes 2 Cl- ions to balance the charge of 1 $Ca^{+2}$.**

**-2 (from 2 Cl-) + 2 (from one $Ca^{+2}$) = 0.**

***For a neutral compound, the charges must add to 0!*** Hence, it is often necessary as in the above example to use more than one ion in the formula to balance the charges.

**Suppose the formula for aluminum bromide was desired. If aluminum has a +3 charge, how many bromide ions are needed to balance it?**

$$Al^{+3} + 3\ Br^{-} \text{--->} \quad AlBr_3$$

$$+3 \text{ (from 1 } Al^{+3}\text{)} + -3 \text{ (from 3 Br-)} = 0$$

Write the formula for the following using the given ions.

a. $Sr^{2+}$ and $P^{3-}$

b. $Ba^{2+}$ and $F^{-}$

c. $Sn^{4+}$ and $O^{2-}$

**Naming Binary (Containing 2 elements) Compounds**

**Name for the metal followed by the name of the non-metal – suffix + ide**

Examples: CsTe = cesium tellurium – ium + ide = cesium telluride

BeS = beryllium sulfur – ur + ide = beryllium sulfide

See Table 2.5 for names of anions (negative ions) and examples of compound names ending in –ide. Also can use handout.

***Naming Compounds Containing Transition Metals, Lead, Tin, and Other Ions That Can Have Different Positive Charges***

These compounds are named the same way except a Roman numeral may be used to indicate the charge. The Roman numeral is written in parentheses.

For instance, copper can be +1 or +2 depending on the anion it is with. So, a Roman numeral (I) or (II) could be used in naming the compound.

**Example:** CuCl would be named copper (I) chloride while $CuCl_2$ would be named copper (II) chloride

Roman Numerals (one through ten): I, II, III, IV, V, VI, VII, VIII, IX, X

Examples of Naming Using Roman Numerals:

1. AgBr = silver (I) bromide
2. $SnCl_4$ = tin (IV) chloride
3. ZnO = zinc (II) oxide
4. $Pb_3N_2$ = lead (II) nitride
5. HgCl = mercury (I) chloride
6. $HgCl_2$ = mercury (II) chloride

SOMETIMES INSTEAD OF USING ROMAN NUMERALS, THE CLASSICAL (OFTEN LATIN) NAME OF THE METAL ION IS USED.

**See Table 2.4 for these names.**

**Example:** $Cu^{1+}$ is named **cuprous** while $Cu^{2+}$ is named **cupric**.

So, CuCl would be named **cuprous** chloride, while $CuCl_2$ would be named **cupric** chloride.

**Naming Compounds That Contain 2 Non-Metals Bonded to Each Other**

The bond formed between two non-metals is termed a *covalent* bond.

COVALENT COMPOUNDS ARE NAMED USING PREFIXES. THE NUMBER OF ATOMS OF AN ELEMENT INDICATE THE PREFIX USED IN ITS NAME.

Prefixes for 1-10: mono-, di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, nona-, deca-

***NO = nitrogen monoxide, not ~~mononitrogen~~ monoxide. If one element is present first in the name, no prefix is used!***

***Note that the –ide suffix is used here also.***

$CO_2$ = carbon dioxide; $SiCl_4$ = silicon tetrachloride

$N_2O_3$ = dinitrogen trioxide; $I_2O_7$ = diiodine ***heptoxide: NOTE: The a in hepta is dropped as the o- would be next to another vowel –a.***
***$SF_6$ would be named sulfur hexafluoride (no vowel dropped).***

**See Handout for Names of Binary Acids and pg.64 of text.**

**Naming Polyatomic Ion Containing Compounds**

See Handout for a List of Polyatomic Ions.

These compounds are named similarly to binary compounds except the name of a polyatomic ion is used in place of an elemental anion (negative ion) or in some cases cations (positive ions).

**EXAMPLES**

**The compound formed by sodium ions ($Na^+$) and phosphate ions ($PO_4^{-3}$) would be $Na_3PO_4$. There is a subscript 3 with the Na because it takes three +1 charges to cancel one -3 charge. It would be named sodium phosphate.**

**$Ca(MnO_4)$ = calcium permanganate**

**$KBrO_3$ = potassium bromate**

**$LiNO_2$ = lithium nitrite**

**$NH_4NO_3$ = ammonium nitrate**

**$H_2SO_3$ = hydrogen sulfite OR sulfurous ACID**

**$V_2(CO_3)_3$ = vanadium (III) carbonate**

NOTE: Parentheses are used for more than one polyatomic ion.

## Section 2.9: Organic Nomenclature of Alkanes and Alcohols

- An alkane consists of only C and H.
- It is also known as a hydrocarbon.
- Named by a prefix indicating the number of carbon atoms followed by a suffix –ane.
- General formula is $C_nH_{2n+2}$ where n = the number of C atoms.

| Number of C | Prefix | Name |
|---|---|---|
| 1 | Meth- | methane |
| 2 | Eth- | ethane |
| 3 | Prop- | propane |
| 4 | But- | butane |
| 5 | Pent- | pentane |
| 6 | Hex- | hexane |
| 7 | Hept- | heptane |
| 8 | Oct- | octane |
| 9 | Non- | nonane |
| 10 | Dec- | decane |

## Naming/Writing Formulae for ALCOHOLS

- An alcohol consists of an alkane in which one or more H's has been replaced by an –OH group (hydroxyl).

  **Examples:**

  $C_2H_5OH$ (ethanol), $C_3H_7OH$ (propanol), $C_6H_{13}OH$ (hexanol)

- To name an alcohol, use the following:

  Alkane – e + ol

**Examples:**

$CH_3OH$ = methane – e + ol = methanol

$C_4H_7OH$ = butane – e + ol = butanol

$C_8H_{17}OH$ = octane – e + ol = octanol

Structural Formulas