Chapter 2.5

The Names and Formulas of Compounds

1. Binary Ionic Compounds
2. Polyatomic Ions
3. **Hydrates**
4. Molecular Compounds
5. **Acids – Bases**

- Chemical nomenclature – a system of names used in chemistry
- Classical system – based on Latin names
- IUPAC (International Union of Pure and Applied Chemistry)

Chapter 2.5

Binary Ionic Compounds

- consist of two types of monatomic ions (ions consisting of one charged atom).
- simplest compounds
- In the formula of a binary ionic compound, the metal cation is always written
- first, followed by the nonmetal anion.
- The name of the metal is stated in full and the name of the nonmetal ion has an -ide suffix;
- example,NaCl(s) is sodium chloride
- Example LiBr(s) is lithium bromide.
- Binary ionic compounds can be made up of more than two ions, providing they are of only two kinds:
- aluminum oxide Al_2O_3(s).

Chapter 2.5

Binary Ionic Compounds (cont'd)

1. Write the symbol of each of the elements in the order in which they appear in the name of the compound.
2. Write the valence number (electrons lost or gained in forming that element's most stable ion) above the symbol of each of the elements.
3. Crisscross the numbers written above the symbols such that the valence number of one element becomes a subscript on the other.
4. Divide each subscript by the highest common factor. The resulting subscripts indicate the ratio of ions present in the compound.
5. Omit any subscript equal to 1 from the formula.

Chapter 2.5

Binary Ionic Compounds (cont'd)

- Multivalent elements - metals that can have more than one valence, or charge,
- Most transition metals and some representative metals
- iron can form an Fe2+ ion or an Fe3+ ion, although Fe3+ is more common.
- Your periodic table shows the most common ion of each element first, with one alternative ion charge below.
- It does not list all of the possible ions of the element.
- The IUPAC system of naming compounds containing multivalent ions is very simple.
- The name of the metal ion includes the charge on the ion, indicated by Roman numerals in brackets.
- CuCl(s) (in which copper has a charge of 1+) is copper(I) chloride,
- $CuCl_2$(s) (in which copper has a charge of 2+) is copper(II) chloride.
- This system of naming is sometimes referred to as the Stock system.

Chapter 2.5

Binary Ionic Compounds (cont'd)

- The classical nomenclature system vs IUPAC
- compounds containing multivalent metals with no more than two possible charges.
- the Latin name for the element along with the suffix –ic was applied to the larger charge, and the suffix -ous was applied to the smaller charge.
- cuprous chloride (CuCl(s))
- cupric chloride (CuCl2(s)).

Table 2: Classical and IUPAC Names of Common Multivalent Metal Ions

Metal	Ion	Classical name	IUPAC name
iron	Fe^{2+} Fe^{3+}	ferrous ferric	iron(II) iron(III)
copper	Cu^{+} Cu^{2+}	cuprous cupric	copper(I) copper(II)
tin	Sn^{2+} Sn^{4+}	stannous stannic	tin(II) tin(IV)
lead	Pb^{2+} Pb^{4+}	plumbous plumbic	lead(II) lead(IV)
antimony	Sb^{3+} Sb^{5+}	stibnous stibnic	antimony(III) antimony(V)
cobalt	Co^{2+} Co^{3+}	cobaltous cobaltic	cobalt(II) cobalt(III)
gold	Au^{+} Au^{3+}	aurous auric	gold(I) gold(III)
mercury	Hg_2^{2+} Hg^{2+}	mercurous mercuric	mercury(I) mercury(II)

Chapter 2.5

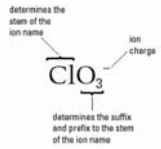
Polyatomic Ions

- A covalently bonded group of atoms with an overall charge
- We treat polyatomic ions much like regular monatomic ions when we write them in formulas or chemical equations.
- Polyatomic ions that include oxygen are called oxyanions. One example is
- the nitrate ion,NO_3
- (Compounds involving the nitrate ion are often used in the processing of foods, particularly cured meats, where they are often used to control colour. Potassium nitrate and sodium nitrate are added to foods to control the growth of microorganisms.)
- determining the name of a compound containing an oxyanion,
- first part of the name is easy: It is the name of the metal cation. The second part requires more thought:
- We have to consider the three parts of the ion indicated

Chapter 2.5

Polyatomic Ions (cont'd)

- four polyatomic ions formed from combinations of Cl and O.
- Note that all of these oxyanions have the same charge
  - ClO^- is the hypochlorite ion
  - ClO_2^- is the chlorite ion
  - **ClO_3^- is the chlorate ion**
  - ClO_4^- is the perchlorate ion.
- Note that in each name the stem is –chlor–.
- The suffixes and prefixes vary according to the number of oxygen atoms in the ion



Chapter 2.5

Polyatomic Ions (cont'd)

- ClO^- is the hypochlorite ion
- ClO_2^- is the chlorite ion
- **ClO_3^- is the chlorate ion**
- ClO_4^- is the perchlorate ion.
- The ate oyanion is the most common ion
- The per–ate oxyanion has one more oxygen atom than does the –ate oxyanion.
- The -ite oxyanion has one fewer oxygen atom than does the -ate oxyanion.
- The hypo–ite oxyanion has one fewer oxygen atom than the -ite oxyanion.
- If you know the ate you can easily get the others


Table 3: IUPAC Names and Formulas of Some Common Polyatomic Ions

Name	Formula
acetate	$C_2H_3O_2^-$
bromate	BrO_3^-
carbonate	CO_3^{2-}
hydrogen carbonate (bicarbonate)	HCO_3^-
hypochlorite	ClO^-
chlorite	ClO_2^-
chlorate	ClO_3^-
perchlorate	ClO_4^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
cyanide	CN^-
hydroxide	OH^-
iodate	IO_3^-
permanganate	MnO_4^-
nitrite	NO_2^-
nitrate	NO_3^-
phosphate	PO_4^{3-}
hydrogen phosphite	HPO_3^{2-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphite	$H_2PO_3^-$
dihydrogen phosphate	$H_2PO_4^-$
sulfite	SO_3^{2-}
sulfate	SO_4^{2-}
hydrogen sulfide (bisulfide)	HS^-
hydrogen sulfite (bisulfite)	HSO_3^-
hydrogen sulfate (bisulfate)	HSO_4^-
thiosulfate	$S_2O_3^{2-}$
ammonium	NH_4^+

Chapter 2.5

Hydrates

- hydrate: a compound that contains water as part of its ionic crystal structure (theoretical definition); a compound that decomposes to an ionic compound and water vapour when heated (empirical definition)
- Eg. silica gel
  - The tiny white pouch when they open the box containing a newly purchased pair of boots.
  - The pouch contains a white, crystalline powdered desiccant (a substance that absorbs water) called silica gel (SiO2(s)).
  - The pouch keeps the air inside the box dry so mildew and other moulds will not grow.
- Similarly absorbent compounds are included in such diverse products as powdered foods, talcum powder, and cat litter.

Chapter 2.5

Hydrates (cont'd)

- Naming hydrates or writing chemical formulas with H_20
- The water molecule is given the name hydrate
- The coiefficient in front of the H20 is prefexed using a greek prefix
- Eg $CuSO_4$-$5H_2O$
- Copper(11) sulfate pentahydrate
- When heat is applied to a hydrate, it will decompose to produce water vapour and an associated ionic compound, indicating that the water is loosely held to the ionic compound.
- The water molecules are assumed to be electrically neutral in the compound.
- When this water, called water of hydration, is removed, the product is referred to as anhydrous.

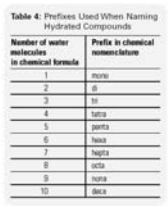


Table 4: Prefixes Used When Naming Hydrated Compounds

Number of water molecules in chemical formula	Prefix in chemical nomenclature
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

Chapter 2.5

Molecular Compunds

- If a binary compound is formed from two nonmetals, it is classified as a molecular compound.
- Even though there are fewer nonmetals than metals, there is a wide variety of compounds formed from the combination of two nonmetals
- two nonmetals may combine to form more than one compound.
- example,N2O, NO, and NO2 are three of the several binary compounds that can be formed from nitrogen and oxygen.
- In naming compounds formed from two nonmetals, a Greek prefix is attached to the name of each element in the binary compound indicating the number of atoms of that element in the molecule.
- If there is only one of the first type of atom, we leave out the prefix "mono."

Chapter 2.5

Molecular Compounds

- write the IUPAC name for the chemical compound represented by the formula N_2O.
- Looking at the first element, you can see that the subscript after the nitrogen is two, so the prefix for nitrogen is "di."
- Looking at the second element, you can see that there is only one oxygen atom, so the preefix for oxygen will be "mono."
- Therefore, the formula's IUPAC name is dinitrogen monoxide.
- Once again, hydrogen is an exception to this rule:
- common practice is not to use the prefix system for hydrogen.
- example, we do not call H_2S dihydrogen sulfide, but simply hydrogen sulfide.

Chapter 2.5

Naming Acids

- Acids are well-known, long-established chemicals.
- originally named decades or even centuries ago, and the use of traditional names persists.
- **Binary acids** (H with another element) are classically named by using the prefix hydro- with the stem of the name of the most electronegative element and the ending -ic.
- The name "hydrogen" does not appear. Instead, the word "acid" is added after the hydro-stem-ic combination,

Table 6: Naming Systems for Binary Acids

Formula	Classical name	IUPAC name
$HF_{(aq)}$	hydrofluoric acid	aqueous hydrogen fluoride
$HCl_{(aq)}$	hydrochloric acid	aqueous hydrogen chloride
$HBr_{(aq)}$	hydrobromic acid	aqueous hydrogen bromide
$HI_{(aq)}$	hydroiodic acid	aqueous hydrogen iodide
$H_2S_{(aq)}$	hydrosulfuric acid	aqueous hydrogen sulfide

Chapter 2.5

Naming Acids (cont'd)

- Let us take, as a simple example, HCl(g). It is a binary compound formed from a combination of hydrogen and a halogen.
- When a gas, it is named hydrogen chloride.
- When it is dissolved in water, the resulting aqueous solution displays a set of specific properties called acidic, and the name of the substance changes
- classical name for HCl(aq) is **hydrochloric acid**.
- IUPAC name is **aqueous hydrogen chloride**.
- Note that the difference between the solution and the pure binary compound is indicated by the presence or absence of the subscript (aq) in the formula.

Table 7: Classical and IUPAC Nomenclature System for Chlorine-Based Oxyacids

Classical name	IUPAC name	Formula
perchloric acid	aqueous hydrogen perchlorate	$HClO_{4(aq)}$
chloric acid	aqueous hydrogen chlorate	$HClO_{3(aq)}$
chlorous acid	aqueous hydrogen chlorite	$HClO_{2(aq)}$
hypochlorous acid	aqueous hydrogen hypochlorite	$HClO_{(aq)}$
hydrochloric acid	aqueous hydrogen chloride	$HCl_{(aq)}$

Chapter 2.5

Naming Acids (cont'd)

Acids with Polyatomics

- named (by the classical system) in the same way as binary acids.
- the IUPAC names for the polyatomic ions end in –ide
- (e.g., the cyanide ion, CN^-)
- the classical name for the acidic solution HCN(aq) will be hydrocyanic acid.

Oxyacids - acids containing Oxygen, Hydrogen and at third element

- A third group of acids is formed from various combinations of oxyanions (negative polyatomic ions consisting of a nonmetal plus oxygen) with hydrogen.
- the best-known example is H_2SO_4(aq), or sulfuric acid, which is one of the most widely produced industrial chemicals in the world.
- It is used to make pharmaceuticals, detergents, and dyes, and is a component of car batteries.

Chapter 2.5

Naming Acids (cont'd)

Oxyacids - acids containing Oxygen, Hydrogen and at third element

- When naming oxyacids, we omit the word hydrogen and add the word "acid." For example, to name the acidic solution with the formula HNO_2(aq),
- first consider the IUPAC name: hydrogen nitrite
- "Nitrite" changes to "nitrous," drop the "hydrogen" from the front of the name, and add "acid" to the end.
- HNO_2(aq) is called nitrous acid.

Table 8: Rules for Naming Acids and Oxyanions

Name of oxyanion	Example	Formula	Classical name of acid	Example
per–ate	persulfate	SO_5^{2-}	*per–ic* acid	persulfuric acid
–ate	sulfate	SO_4^{2-}	*–ic* acid	sulfuric acid
–ite	sulfite	SO_3^{2-}	*–ous* acid	sulfurous acid
hypo–ite	hyposulfite	SO_2^{2-}	*hypo–ous* acid	hyposulfurous acid

Chapter 2.5

Naming Acids (cont'd)

- writing the formula for an acid, you would first have to figure out the names of the ions involved, then their symbols or formulas, then their ratio.
- For example, what is the formula for phosphoric acid?
- The -ic ending indicates the presence of the -ate oxyanion of phosphorus: phosphate. The phosphate oxyanion is PO_4^{3-} with a charge of $3-$.
- The **cation** in oxyacids is always hydrogen, which has a charge of 1+.
- To find the ratio of the ions, use the crisscross method

Chapter 2.5

Naming Bases

- all aqueous solutions of ionic hydroxides are bases. (You will learn more about bases in Chapter 8.)
- Other solutions have also been classified as bases, but for the time being we will restrict our exploration of bases to aqueous ionic hydroxides such as NaOH(aq) and $Ba(OH)_2$(aq).
- a combination of a metal cation with one or more hydroxide anions (metal with OH^-).