Chapter 2
Nomenclature

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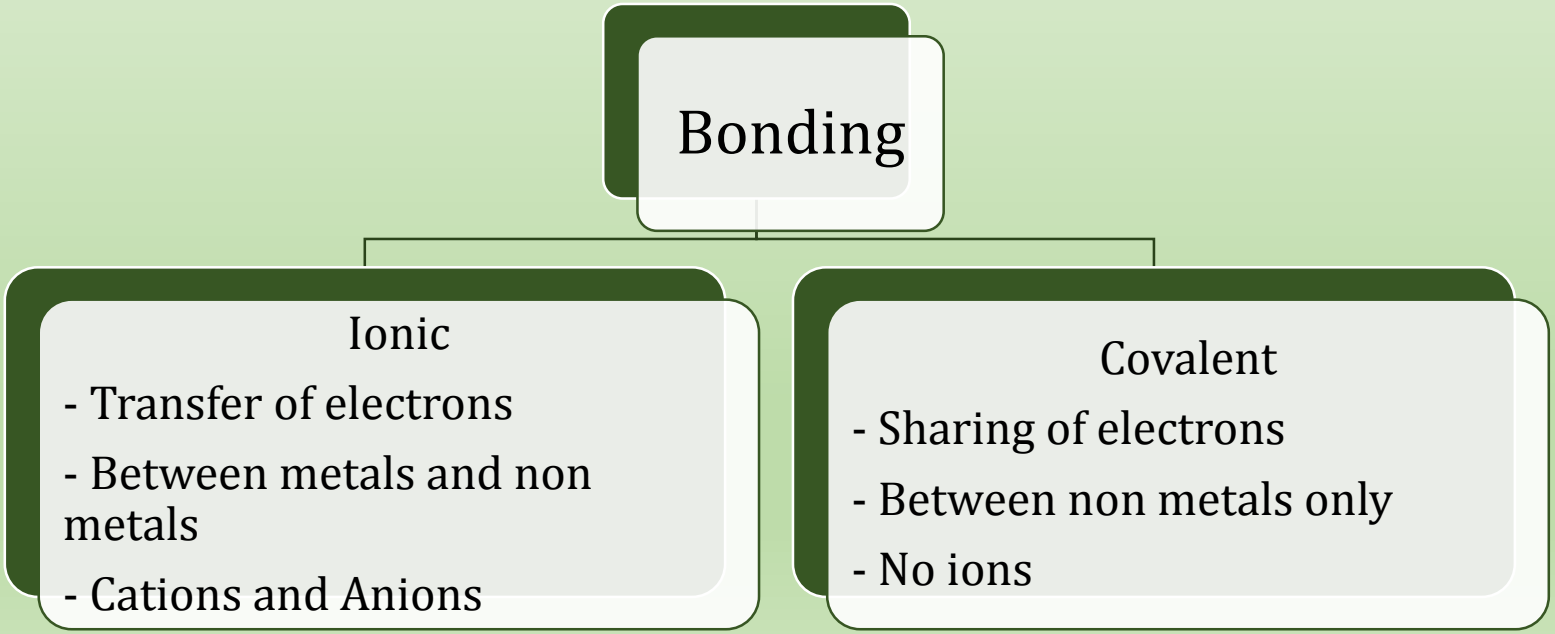
Introduction

- Compounds are elements combined in different proportions.
- There are two main types of combinations (bonding) as shown below.
- Nomenclature is of three kinds – two different types for ionic – one for main group and one for transition metals; and one type for covalent.



Molecules and Formula Units

- Covalent compounds are called molecules.
- Formula unit is the smallest ratio of cations to anions in an ionic compound. In solid state ionic compounds a specific number of ions are associated with each other. These form the crystal structure.
- There are seven diatomic gases/molecules whose names are the same as the element names:

  H_2, O_2, N_2, F_2, Cl_2, Br_2 and I_2.

Representing Combinations

- Empirical Formula – lowest ratio of combination of elements e.g. H_2O, CH_2O.
- Molecular Formula – actual ratio of elements in a compound. For ionic compounds the empirical formula is also the molecular formula (formula unit). For covalent compounds sometimes the empirical formula can be multiplied by an integer to give the molecular formula.

  E.g. $(CH_2O) \times 6 = C_6H_{12}O_6$ (glucose)
- Structural Formula – 3D representation of the ionic or covalent compound.

- Example: H_2O_2 is molecular formula, HO is the empirical formula of that compound.

Ionic Compounds

- Formed from metals and non metals.
- Metals lose electrons to form cations.
- Non metals lose electrons to form anions.
- Electrons transfer from metals to non metals.
- Final unit is electrically neutral.

Metals lose e^-	**Cation formed E.g.**	**Non Metals gain e^-**	**Anion formed E.g.**
Group I $1e^-$ lost	Li^+, Na^+	Group V $3e^-$ gain	N^{3-}, P^{3-}
Group II $2e^-$ lost	Mg^{2+}, Ca^{2+}	Group VI $2e^-$ gain	O^{2-}, S^{2-}
Group III $3e^-$ lost	Al^{3+}	Group VII $1e^-$ gain	Cl^-, Br^-

Naming Ionic Compounds – Main Group

- Naming cations
  - Name the element and add the word “ion”
  - Example: Na^+, sodium ion
- Naming Anions
  - Name the element and modify the ending to “-ide”
  - Example: Cl^-(chloride), O^{2-} (oxide)
- Naming ionic compounds: leave the name of the metal as is, change the name of the non metal to element ending with ***–ide***. For example, sodium chloride, calcium oxide.
- Note: The name does not say anything about the ratio of the elements. This is because there is only one combination possible for main group elements .
- There are two exceptions –

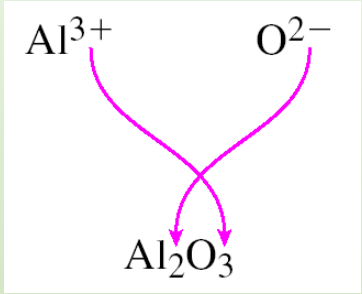
  Pb in Group IV has two ions Pb^{2+} and Pb^{4+}; and

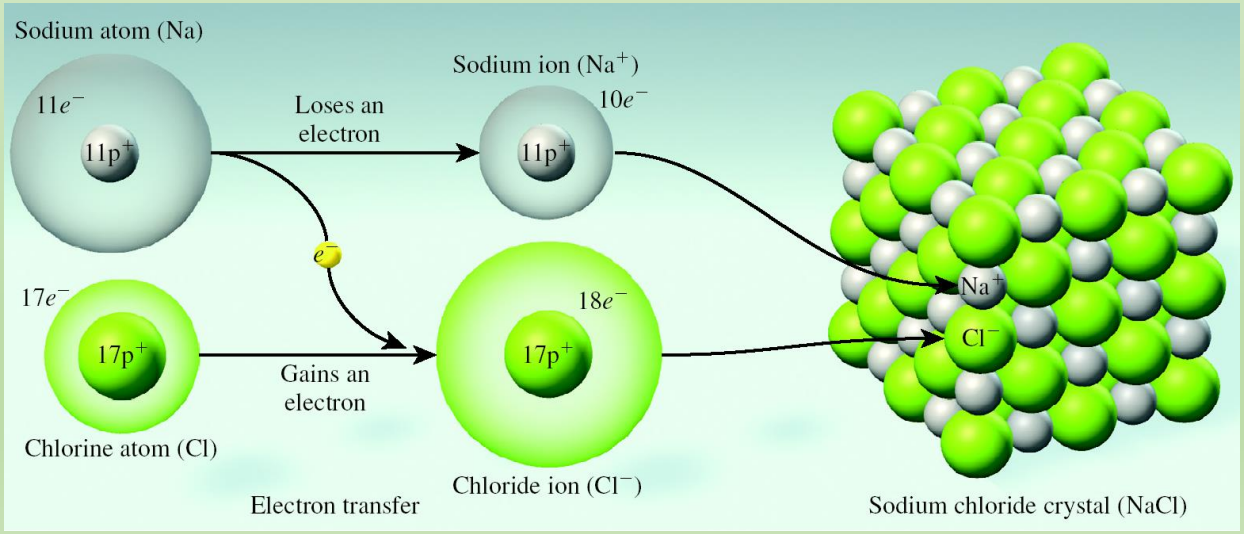
  Tl in Group III has two ions Tl^+ and Tl^{3+}

Forming Compounds (Formula Units)

Compound formed is electrically neutral so the sum of the charges on the cation(s) and anion(s) in each formula unit must be zero. The cris-cross method is given below to easily form compounds.

Al^{3+} and O^{2-} Al_2O_3



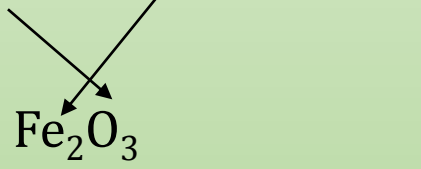


Naming Ionic Compounds – Transition Metals

- Cations from transition metals with some exceptions
  - Name element
  - Indicate charge of metal with Roman numeral
  - Add word "ion"
  - Example: Cu^{2+} , copper(II) ion, Fe^{3+}, Iron (III) ion

Example: form the compounds between the following ions.

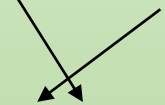
Fe^{3+} and O^{2-}



Fe_2O_3

Iron (III) oxide

Mn^{4+} and S^{2-}



$Mn_2S_4 = MnS_2$

Manganese (IV) sulfide

More on Ions

- Main group elements give and take definite number of electrons.
- Transition metals however give a different number of electrons. There is no point memorizing the charges; it is better to look at the formula unit or name to figure out the charge (valency) on the metal.
- The table below gives ALL the cations and anions you need from PT.

1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
Li^+													C^{4-}	N^{3-}	O^{2-}	F^-	
Na^+	Mg^{2+}											Al^{3+}		P^{3-}	S^{2-}	Cl^-	
K^+	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+} Mn^{3+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}	Ni^{2+} Ni^{3+}	Cu^+ Cu^{2+}	Zn^{2+}				Se^{2-}	Br^-	
Rb^+	Sr^{2+}									Ag^+	Cd^{2+}		Sn^{2+} Sn^{4+}		Te^{2-}	I^-	
Cs^+	Ba^{2+}										Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				

Polyatomic Ions

- These are ions (cations and anions) formed from combination of non metals.
- Most polyatomic ions are anions meaning they have excess electrons. (*Where are these excess electrons coming from?* From the metals they combine with).

Positive Polyatomic Cations

H_3O^+ hydronium ion (exists only in acidic solutions)

NH_4^+ ammonium ion (formed from NH_3: ammonia)

Simple Polyatomic Anions

OH^- hydroxide

CN^- cyanide

Polyatomic Ions Containing Oxygen

(*all end in "ate" or "ite"*)

Formula	Name
CO_3^{2-}	Carbonate
HCO_3^-	Hydrogen carbonate
SO_4^{2-}	Sulfate
HSO_4^-	Hydrogen sulfate
SO_3^{2-}	Sulfite
HSO_3^-	Hydrogen sulfite
NO_3^-	Nitrate
NO_2^-	Nitrite
PO_4^{3-}	Phosphate
HPO_4^{2-}	Hydrogen phosphate
$H_2PO_4^-$	Dihydrogen phosphate
$C_2H_3O_2^-$ CH_3COO^-	Acetate

Formula	Name
CrO_4^{2-}	Chromate
$Cr_2O_7^{2-}$	Dichromate
MnO_4^-	Permanganate
SCN^-	Thiocyanate
$S_2O_3^{2-}$	Thiosulfate
ClO^-	Hypochlorite
ClO_2^-	Chlorite
ClO_3^-	Chlorate
ClO_4^-	Hypochlorate

Compounds Containing Polyatomic Ions

Polyatomic ions form compounds with cations or anions as usual.

Example:

- Na^+ and OH^- is NaOH – sodium hydroxide
- K^+ and SO_4^{2-} is K_2SO_4 – potassium sulfate
- Ca^{2+} and PO_4^{3-} is $Ca_3(PO_4)_2$ – calcium phosphate
- Cr^{2+} and HCO_3^- is $Cr(HCO_3)_2$ – chromium (II) hydrogen carbonate
- NH_4^+ and NO_3^- is NH_4NO_3 – ammonium nitrate

Naming Covalent Compounds

- Combination of non metals gives covalent compounds
- The first element is named as such and the second one ends with “ide”
- In a number of cases more than one combination is possible for covalent compounds hence “mono”, “di” etc are used to indicate how many atoms are in the compound.
- Note: if the first element is only one then don’t indicate it as “mono”

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

Examples

Oxygen difluoride - OF_2

Tetrasulfur tetranitride - S_4N_4

Boron trichloride - BCl_3

Carbon disulfide - CS_2

Nitrogen tribromide - NBr_3

Dinitrogen tetrafluoride - N_2F_4

Acids and Bases

Acids		Bases
1. Give protons 2. Corrosive 3. Sour 4. Found in fruit juices 5. Reacts with metals to give H_2 gas Examples: Mineral acids/Inorganic acids Strong acids - Sulfuric acid, nitric acid, hydrochloric acid Weak acids – phosphoric acid, acetic acid, carbonic acid		1. Accept protons from acids 2. Caustic 3. Bitter 4. Found in cleaners Examples: Inorganic bases Strong bases – sodium hydroxide, potassium hydroxide Weak bases – ammonium hydroxide

Naming Acids

There are two kinds of acids – binary and oxo-acids

Binary acids (Haloacids) Made from hydrogen halide dissolved in water	
HF	Hydrofluoric acid
HCl	Hydrochloric acid
HBr	Hydrobromic acid
HI	Hydroiodic acid

Oxoacids Made from polyatomic anions.	
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
H_3PO_4	Phosphoric acid
H_2CO_3	Carbonic acid

Naming Bases

Most bases are hydroxides: e.g. sodium hydroxide, potassium hydroxide etc.

Some other bases are carbonates and hydrogen carbonates (these are weaker bases) e.g.: sodium carbonate, sodium hydrogen carbonate etc.

Polyatomic Ions and Their Acids

Table 2.8 Some Oxoanions and Their Corresponding Oxoacids

Oxoanion		Oxoacid	
CO_3^{2-}	Carbon*ate ion*	H_2CO_3	Carbon*ic acid*
NO_2^-	Nitr*ite ion*	HNO_2	Nitr*ous acid*
NO_3^-	Nitr*ate ion*	HNO_3	Nitr*ic acid*
PO_4^{3-}	Phosph*ate ion*	H_3PO_4	Phosphor*ic acid*
SO_3^{2-}	Sulf*ite ion*	H_2SO_3	Sulfur*ous acid*
SO_4^{2-}	Sulf*ate ion*	H_2SO_4	Sulfur*ic acid*
ClO^-	*Hypo*chlor*ite ion*	HClO	*Hypo*chlor*ous acid*
ClO_2^-	Chlor*ite ion*	$HClO_2$	Chlor*ous acid*
ClO_3^-	Chlor*ate ion*	$HClO_3$	Chlor*ic acid*
ClO_4^-	*Per*chlor*ate ion*	$HClO_4$	*Per*chlor*ic acid*

Naming Hydrates

- Hydrates are ionic compounds that are associated with water.
- The water gets trapped in the ions when the solid crystallizes, and in some cases the solids absorb water (hygroscopic)
- This water can be removed from the compound by heating the compound.
- Naming is as usual for the ionic compound and then add the water as hydrate with the appropriate prefix of the number of water molecules.

<u>Examples and Names</u>:

$FeSO_4 \cdot 7H_2O$ - Iron(II) sulfate heptahydrate

$CuSO_4 \cdot 5H_2O$ - Copper (II) sulfate pentahydrate

Some Compounds with Common Names

Formula	Common Name	Systematic Name
H_2O	Water	Dihydrogen monoxide
NH_3	Ammonia	Trihydrogen nitride
CO_2	Dry ice	Solid carbon dioxide
NaCl	Salt	Sodium chloride
N_2O	Laughing gas	Dinitrogen monoxide
$CaCO_3$	Marble, chalk, limestone	Calcium carbonate
$NaHCO_3$	Baking soda	Sodium hydrogen carbonate
$MgSO_4 \cdot 7H_2O$	Epsom salt	Magnesium sulfate heptahydrate
$Mg(OH)_2$	Milk of magnesia	Magnesium hydroxide

Keywords/Concepts

- Empirical formula
- Molecular formula
- Structural formula
- Formula unit
- Ionic compounds nomenclature
- Covalent compounds nomenclature
- Transition metal ions
- Polyatomic ions
- Acids and bases
- Hydrates