Nomenclature
Notes and Practice

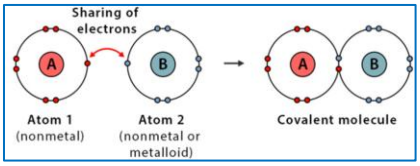
- **Nomenclature** is the collection of rules used to name things. In chemistry, it is useful to have a universal language – agreed upon nomenclature – when naming substances.

- **Purpose:** Understand and use the rules of nomenclature *in English*.

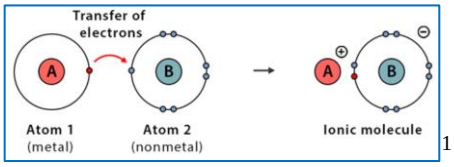
❖ Chemical Bonds:

- ❖ Defined as a **force of attraction (*electrostatic*)** between atoms or ions.
- ❖ By forming bonds, atoms or ions attain a more **stable state** with **minimum energy**.
- ❖ This most often happens when the valence shell is complete, and the atom or ion attains a noble gas electron configuration. This is referred to as the **Octet Rule**.

- ❖ **Covalent bonds** form when atoms **share** electrons.

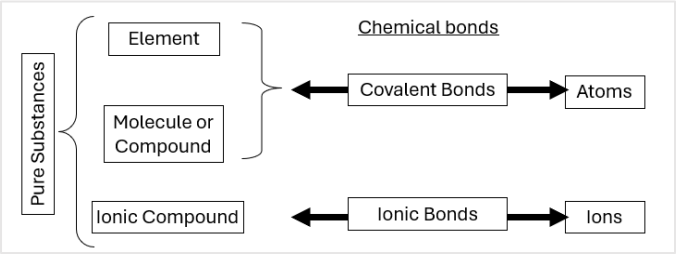


- ❖ **Ionic bonds** form when electrons are **transferred** between atoms.



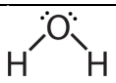
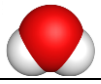
[1]

- ❖ When atoms or ions bond, they form **compounds** and/or **molecules.**
  - **Compound**: when two or more **different atoms** or **ions** bond.
    - Examples: H_2O, NaCl, etc.
  - **Molecule**: when atoms **covalently** bond.
    - Examples: H_2O, O_2, and H_2.
  - All covalent compounds are molecules, but not all molecules are compounds.



[1] https://www.chemistrylearner.com/chemical-bonds/ionic-covalent-metallic-bonds

❖ Representing chemical bonds:

	Chemical Formula	Structural Formula	Space Filling Model
Covalent Molecule:	**H_2O**		
Ionic Compound:	**NaCl**	Na^+Cl^-	*N.A.*

Suggested reading and video (0-5:55): Chemical Bond (LibreTexts Chemistry)

❖ Ionic Compounds

Description	• Ionic compounds form when there is a **transfer** of electrons from metals to nonmetals. • Metals lose (negative) electron(s) and become positively charged **cations**. • Nonmetals gain electron(s) and become negatively charged **anions**.
Case #1	• Ions with fixed charges.
Case #2	• Transition metals with variable charges
Case #3	• Compounds with Polyatomic ions.

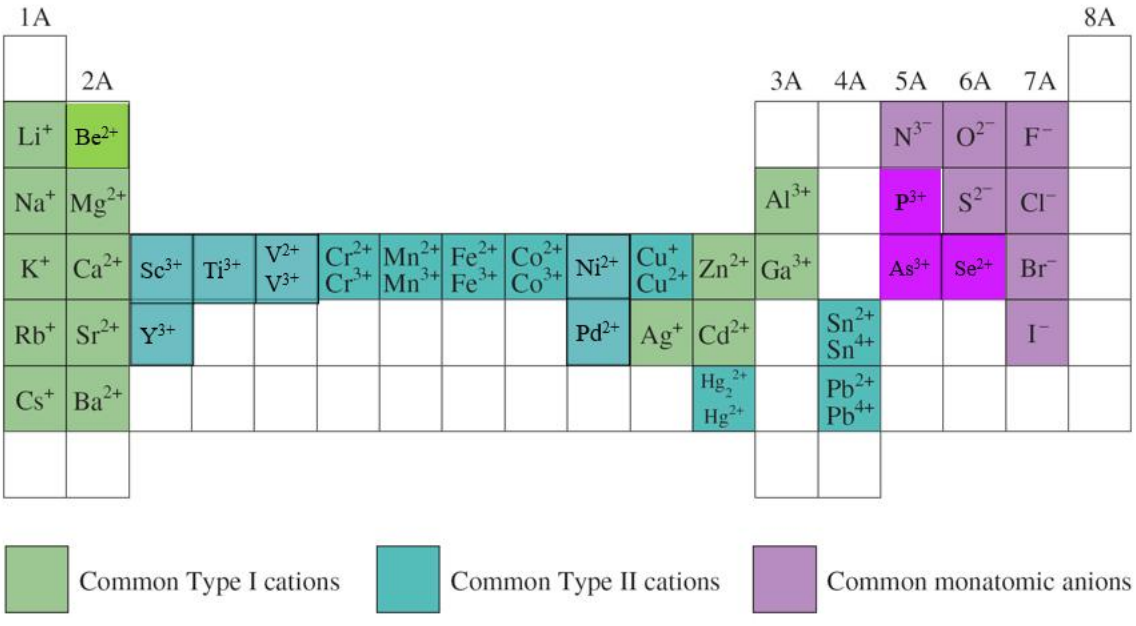


Figure 2: This table shows some common ions. Notice that some Transition Metals have multiple charges. These need to be **memorised**.

Case #1 Binary Ionic Compounds

- Ions with fixed charges.
- Groups 1A to 7A. Recall: Group number and the Octet Rule.

- **Group 1A** = lose one electron and gain a positive charge = +1. Ex: Na^{1+}
- **Group 2A** = lose two electrons = +2. Ex. Mg^{2+}
- **Group 3A** = lose three electrons = +3. Ex. Al^{3+}

- **Group 5A** = 5 (group # = valence electrons) + 3 (gain three electrons) = 8 (octet) = -3. Ex. N^{3-}
- **Group 6A** = gain two electrons = 8 (octet) – 6 (group #) = -2. Ex. O^{2-}
- **Group 7A** = gain one electron = 8 (octet) – 7 (group #) = -1. Ex. F^{1-}

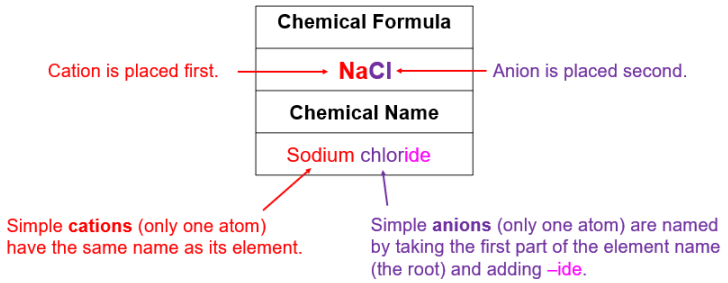
Nomenclature

- Cation: Written first and name is not changed.
- Anion: Name the nonmetal by taking the first part of its name (the root), dropping the ending, and adding "-ide".

Names and Charges of Common Ions:

Cation	Name	Anion	Name*
H^+	hydrogen	H^-	hydride
Li^+	lithium	F^-	fluoride
Na^+	sodium	Cl^-	chloride
K^+	potassium	Br^-	bromide
Cs^+	cesium	I^-	iodide
Be^{2+}	beryllium	O^{2-}	oxide
Mg^{2+}	magnesium	S^{2-}	sulfide
Ca^{2+}	calcium		
Ba^{2+}	barium		
Al^{3+}	aluminum		
Ag^+	silver		
Zn^{2+}	zinc		

*The root is given in color.



- **Net charge** of an ionic compound is always zero; meaning, charges must equal 0
- Examples:
  - NaCl
    1(1+) + 1(1-) = 0
    One sodium ion, Na^+, is needed to balance the charge of one chloride ion, Cl^-.
  - Na_2O
    2(1+) + 1 (2-) = 0
    Two sodium ions are needed to balance the charge of oxygen, O^{2-}.

Examples

- MgO = magnesium oxide
- Al_2S_3 = aluminium sulfide

Professor Dave: Naming Ionic Compounds (video 5:43)

- **Complete the following table on binary ionic compounds.** The first is done for you.

	Formula	**Cation**	**Anion**	**Name**
	$CaCl_2$	*Ca^{2+}*	*Cl^-*	*Calcium chloride*
1)		Al^{3+}	O^{2-}	
2)	LiH			
3)	K_3P			
4)				Aluminum nitride
5)	NaI			
6)		Mg^{2+}	S^{2-}	
7)				Sodium oxide
8)		Sr^{2+}	Br^-	

Case #2 Transition Metals	• Some Transition metals can form 2 or more cations and have variable charges.

Nomenclature	• Cation:
	  ○ Written first and name doesn't change (as for all cations).
	  ○ MUST include a Roman numeral to indicate charge.
	• Anion:
	  ○ Name the nonmetal by taking the first part of its name (the root), drop the ending, and add "-ide" (as for all compounds).

Names and Charges of Some Transition Metals:

Ion	Systematic Name	Older Name
Fe^{3+}	iron(III)	ferric
Fe^{2+}	iron(II)	ferrous
Cu^{2+}	copper(II)	cupric
Cu^{+}	copper(I)	cuprous
Co^{3+}	cobalt(III)	cobaltic
Co^{2+}	cobalt(II)	cobaltous
Sn^{4+}	tin(IV)	stannic
Sn^{2+}	tin(II)	stannous
Pb^{4+}	lead(IV)	plumbic
Pb^{2+}	lead(II)	plumbous
Hg^{2+}	mercury(II)	mercuric
Hg_2^{2+}*	mercury(I)	mercurous

*Mercury(I) ions always occur bound together in pairs to form Hg_2^{2+}.

Chemical Formula
Fe_2O_3
Chemical Name
Iron (III) oxide

Roman numeral indicates the charge of the cation.

- **Net charge** of an ionic compound is always zero.
- Example:
  - Fe_2O_3
    $2(3+) + 3(2-) = 0$
    Two iron ions, each with a charge of +3, are needed to balance three oxygen ions, each with a change of -2.

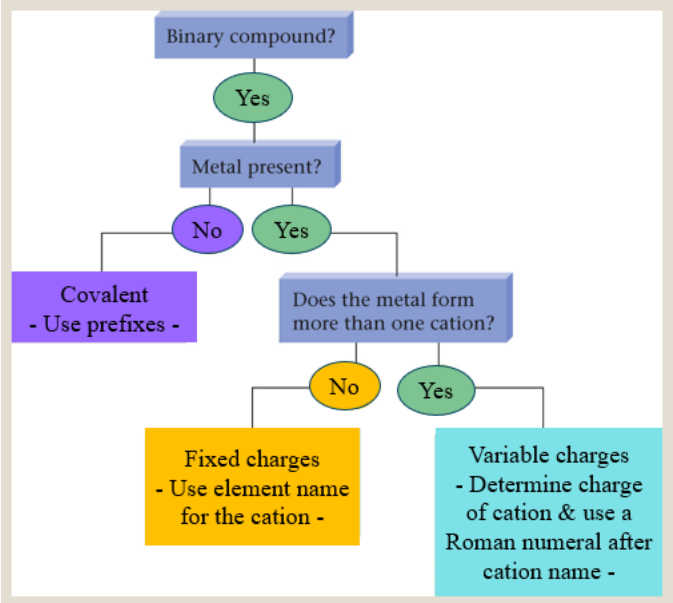
Examples	• CuO = copper (II) oxide • $FeCl_2$ = iron (II) chloride

Naming Ionic Compounds with Transition Metals (10:09)

- **Complete the following table on ionic compounds with transition metals.** The first is done for you.

	Name	Formula
	Copper (I) chloride	*CuCl*
1)		$CuCl_2$
2)	Lead (IV) sulfide	
3)		$PbCl_2$
4)	Chromium (III) phosphide	
5)		Co_2O_3
6)	Tin (IV) phosphide	
7)		MnO_2
8)	Iron (II) sulfide	

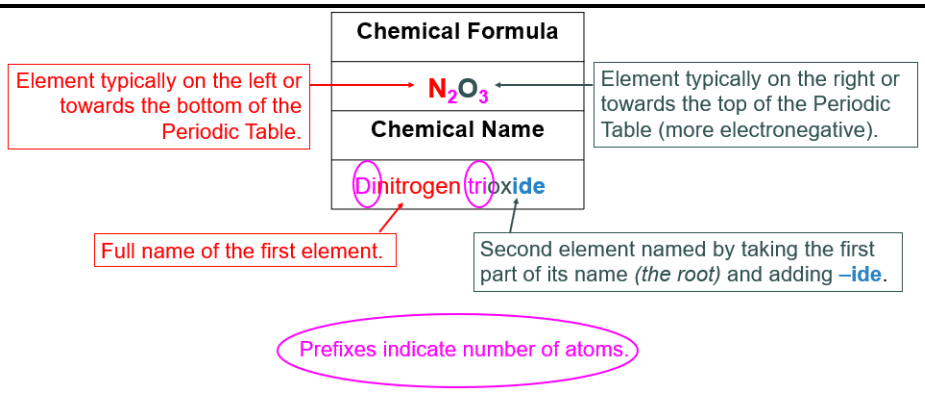
Flowcharts for Naming Binary Compounds:



❖ Binary Covalent Compounds

Description	When two non-metals **share** electrons and bond.
Nomenclature	• **Prefix System:** Prefixes are needed to indicate # of atoms in a compound because nonmetals bond in **varying** proportions. • The first element in the formula is written *first* and its name is not changed. NOTE: The prefix *mono-* is NEVER used if there is only one atom of the first element. • The second element is named by taking the first part of its name (the root), dropping the ending, and adding "-ide". Other than the use of prefixes, this is the same for Ionic compounds. • When a prefix ends in "a" or "o", *and* the element begins with a vowel, **the *a* or *o* is dropped** in the prefix (ex. monooxide = monoxide), which makes it easier to pronounce.

Prefix	Meaning
Mono -	1
Di -	2
Tri -	3
Tetra -	4
Penta -	5
Hexa -	6
Hepta -	7
Octa -	8
Nona -	9
Deca -	10



Examples	• CO, carbon monoxide • N_2O_5, dinitrogen pentoxide

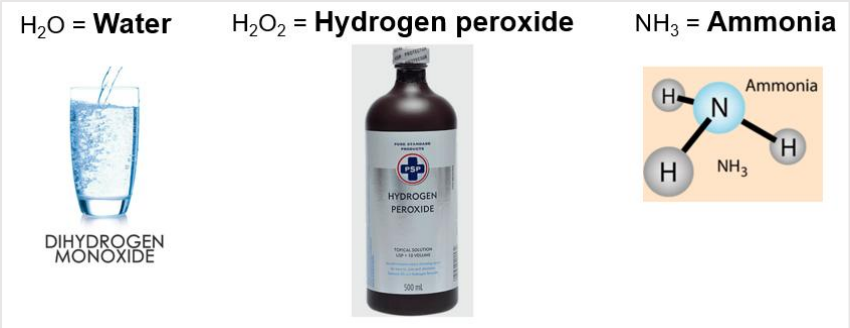


Figure 1: Certain compounds have specific names. The ones shown here must be **memorized**.

- **Complete the following table on covalent compounds** (The first is done for you)**:**

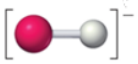
	Formula	First nonmetal	Second nonmetal	Name

	PCl_5	*Phosphorus*	*pentachloride*	*Phosphorus pentachloride*
1)	CO_2			
2)		dinitrogen	difluoride	
3)				Tricarbon tetranitride
4)	H_2O_2			
5)		Sulfur	hexafluoride	
6)				Diphosphorus trioxide
7)	N_2O_3			
8)	$SiBr_4$			

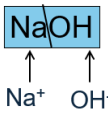
Case #3 Polyatomic Ions	• Polyatomic ions are charged species containing two (or more) atoms covalently bonded.
Nomenclature	• Naming is the same as for all ionic compounds. • Memorize the Polyatomic Table *or learn the rules*.

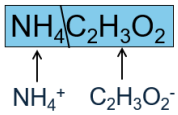
Ion	Name	Ion	Name
Hg_2^{2+}	Mercury(I)	CO_3^{2-}	Carbonate
NH_4^+	Ammonium	HCO_3^-	Hydrogen carbonate (bicarbonate is a widely used common name)
NO_2^-	Nitrite		
NO_3^-	Nitrate	ClO^- or OCl^-	Hypochlorite
SO_3^{2-}	Sulfite	ClO_2^-	Chlorite
SO_4^{2-}	Sulfate	ClO_3^-	Chlorate
HSO_4^-	Hydrogen sulfate (bisulfate is a widely used common name)	ClO_4^-	Perchlorate
		$C_2H_3O_2^-$	Acetate
OH^-	Hydroxide	MnO_4^-	Permanganate
CN^-	Cyanide	$Cr_2O_7^{2-}$	Dichromate
PO_4^{3-}	Phosphate	CrO_4^{2-}	Chromate
HPO_4^{2-}	Hydrogen phosphate	O_2^{2-}	Peroxide
$H_2PO_4^-$	Dihydrogen phosphate	$C_2O_4^{2-}$	Oxalate
NCS^- or SCN^-	Thiocyanate	$S_2O_3^{2-}$	Thiosulfate

Examples



Ammonium hydroxide, NH_4OH





Oxyanion Series: Polyatomic anions that contain atom(s) of nonmetal(s) and varying numbers of oxygen atoms.

Polyatomic anion	Prefix	Suffix	Name		Example:
- ClO^-	*Hypo* -	- *ite*	hypochlorite	Increasing number of oxygens.	NaClO Sodium hypochlorite
- ClO_2^-	*None*	- *ite*	chlorite		$NaClO_2$ Sodium chlorite
- ClO_3^-	*None*	- *ate*	chlorate		$NaClO_3$ Sodium chlorate
- ClO_4^-	*Per* -	- *ate*	perchlorate		$NaClO_4$ Sodium perchlorate

Writing Formulas with Polyatomic Ions (11:20)

- **Complete the following table on ionic compounds with polyatomic ions.** The first is done for you.

	Formula	**Ions**	**Name**
	Na_2SO_4	*Na^+ SO_4^{2-}*	*Sodium sulfate*
1)		Na^+ HSO_4^-	
2)	K_3PO_4		
3)			Lithium nitrate
4)	$Fe(NO_3)_3$		
5)			Sodium sulfite
6)		Ba^{2+} OH^-	
7)	Na_2CO_3		
8)			Ammonium cyanide

❖ Acids

Description	• Acids contain at least one proton (H^+).
Nomenclature	• At this point, all acids are covalent and are divided into acids with and acids without oxygen.

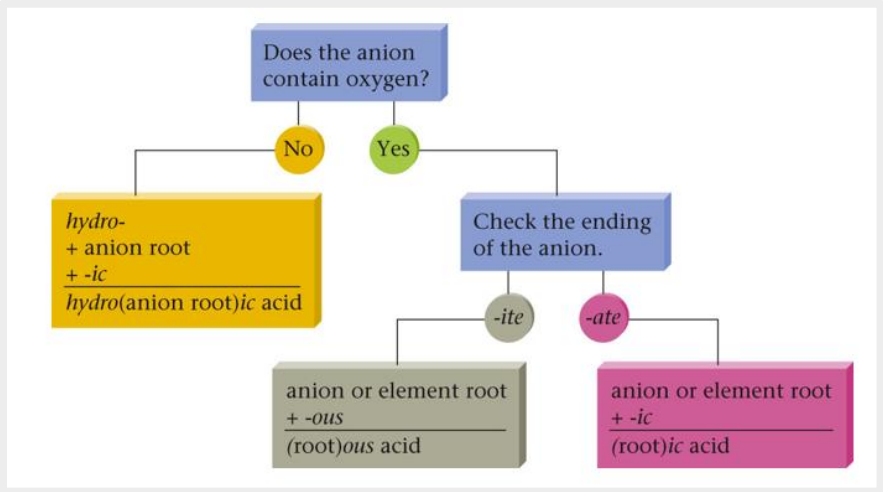
Acids – Without oxygen

- Named with the prefix *hydro-*, the *root of the element,* and the *suffix – ic.*
- If nomenclature is needed, the formula will include the state "aqueous" (aq).
- Examples:
  - HCl (aq) = *hydro*chlor*ic* acid (vs HCl with no state = hydrogen monochloride)
  - HCN (aq) = hydrocyanic acid
  - H_2S (aq) = hydrosulfuric acid

Acids – With oxygen

- Two possibilities:
  1) Anion ends in *-ate*:
     - Suffix *-ic* is added to the anion root (*higher oxidation state).*
     - Example: HNO_3 (hydrogen nitr*ate* is the compound) = Nitric acid
  2) Anion ends in *-ite*
     - Suffix *-ous* is added to the anion root (*lower oxidation state)*
     - Example: HNO_2 (hydrogen nitr*ite*) = Nitrous acid

Flowcharts for Naming Acids:



- **Complete the following table on naming acids.** The first is done for you.

		Name of Compound		
	Formula	**Hydrogen**	**Anion**	
	HCl (aq)	*Hydrogen*	*chloride*	*Hydrochloric acid*
1)		Hydrogen	bromide	
2)	HI (aq)			
3)				Phosphoric acid
4)				Phosphorous acid
5)		Hydrogen	sulfate	
6)	H_2SO_3(aq)			

❖ Monatomic, Diatomic, or Polyatomic substances

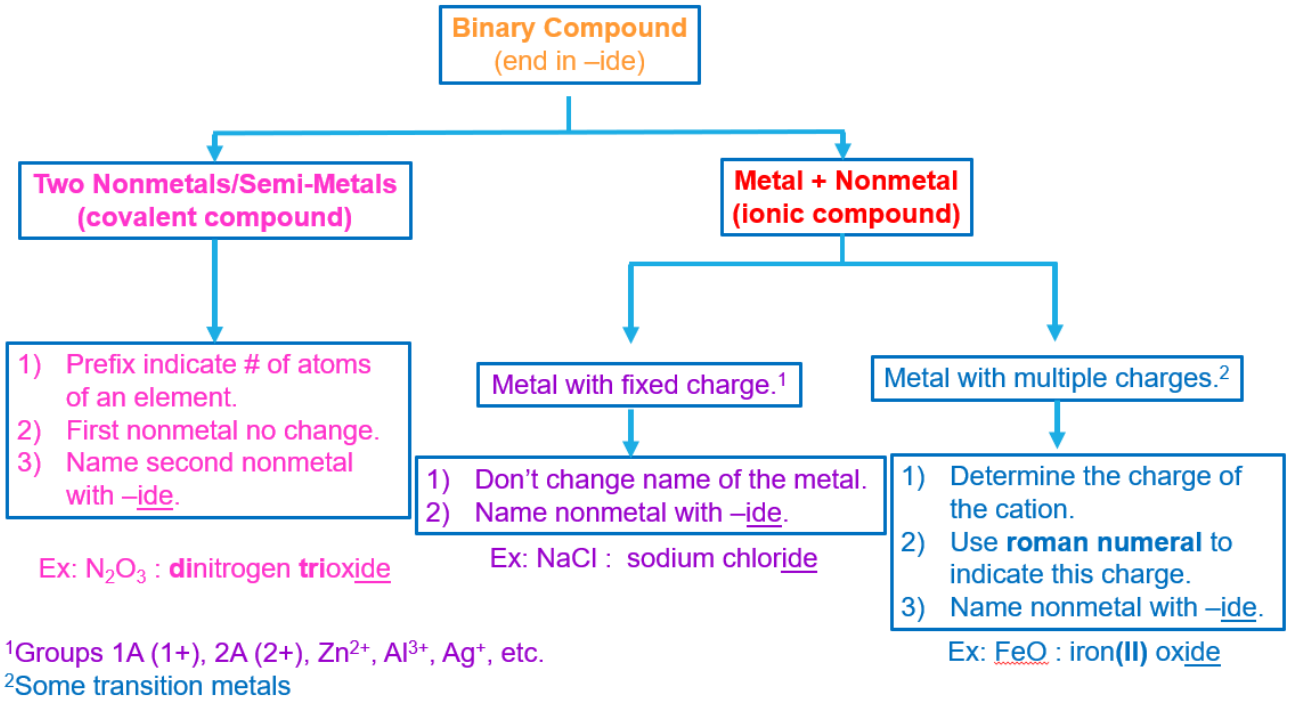
- The Periodic Table depict pure elements at standard conditions of 25℃ and 1 atm. They can exist as monatomic, diatomic, or polyatomic substances.

- **Monatomic gases:**
  - Are naturally stable as single atoms.
- **Diatomic elements:**
  - Natural form of the element is as a molecule with two identical atoms.
- **Polyatomic Elements:**
  - Natural form of the element is as a molecule with more than 3 atoms.

Diatomic Elements	**Polyatomic Elements**	**Monatomic Gases and Elements**
I Have **N**o **Br**ight **O**r **Cl**ever **F**riends (mnemonic)	• Sulfur, S_8 **(s)** • Phosphorus, P_4 **(s)**	• Noble (Inert) Gases (Group VIIIA)
1. Iodine (purple solid), **I_2 (s)** 2. Hydrogen (colourless gas), **H_2 (g)** 3. Nitrogen (colourless gas), **N_2 (g)** 4. Oxygen (colourless gas), **O_2 (g)** 5. Chlorine (greenish yellow gas), **Cl_2 (g)** 6. Fluorine (light yellow gas), **F_2 (g)** 7. Bromine (reddish-brown liquid), **Br_2 (ℓ)**		• Any element NOT listed on this table *(most metals)*

Name of the element	**Group Name**	**Formula**
Bromine or liquid bromine	*Halogen*	*Br_2*
Iron *metal*		
Sodium or elemental sodium		
Argon *gas*		
		N_2
		O_2

Flowchart for Naming Substances:



[1]Groups 1A (1+), 2A (2+), Zn^{2+}, Al^{3+}, Ag^{+}, etc.
[2]Some transition metals