

# **The Basics of Naming Chemical Compounds For Chemistry 134**

## **Part III –Acids/Bases, Hydrates, and Molecular Compounds**

# Goals

After completion of this module, you will be able to write the names and formulas of:

- Acids
- Bases
- Hydrated compounds
- Molecular compounds

By the end of this module, you will be well versed in naming inorganic compounds.

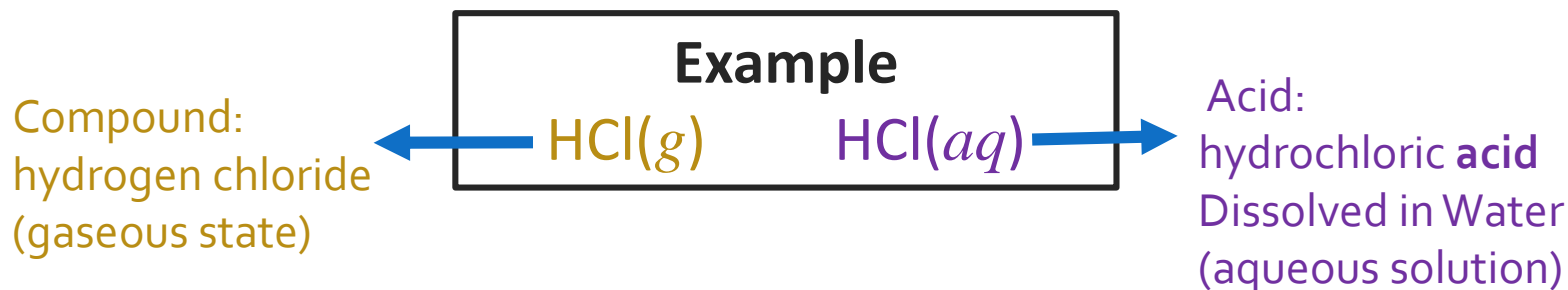
# Naming Acids and Bases

Compounds that dissociate in water to  
produce  $\text{H}^+$  or  $\text{OH}^-$  ions

# Acid Nomenclature

**Arrhenius definition of an Acid:** Acids are neutral compounds that produce free **hydrogen ions ( $H^+$ )** when dissolved in water.

We only use **acid** nomenclature if the compound is dissolved in water (aqueous, denoted by **(aq)**). Otherwise, name it as a compound.



- The **cation** in an Arrhenius acid is the hydrogen ion ( $H^+$ )
- The **anions** vary:
  - **Binary acid** - anion is single non-metal
    - Example : HF, HCl etc.
  - **Oxyacids** - anion is an oxoanion
    - Example :  $H_2SO_4$ ,  $HNO_3$

# Binary Acid Nomenclature

- If the anion in the acid ends in *-ide*, change the ending to *-ic* acid and add the prefix *hydro-*.

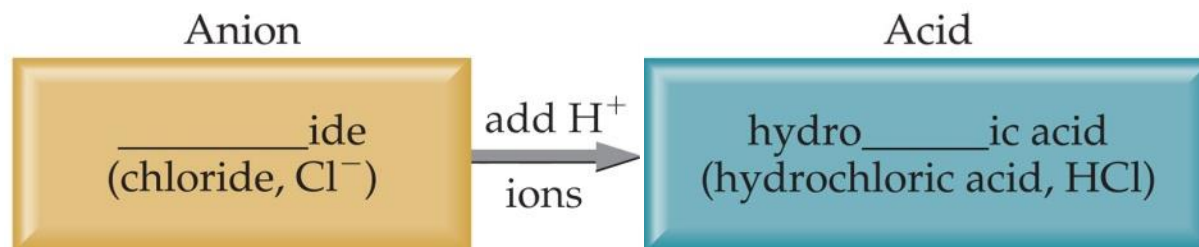
Example:

HCl : hydrochloric acid

HBr : hydrobromic acid

HI : hydroiodic acid

NOTE: Think "My **ride** has **hydraulics**"



# Binary Acids Nomenclature

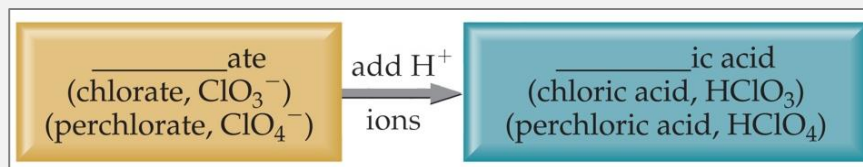
Some examples of naming acids in aqueous solutions versus their pure substances.

Formula	Pure Substance	Aqueous Solution
HCl	hydrogen chloride	hydrochloric acid
HBr	hydrogen bromide	hydrobromic acid
HI	hydrogen iodide	hydroiodic acid
H <sub>2</sub> S	hydrogen sulfide	hydrosulfuric acid
HCN	*hydrogen cyanide	hydrocyanic acid

\*Note: CN<sup>-</sup> (cyanide) follows the binary compound rules despite it being polyatomic.

# Oxyacid Nomenclature- “ate” vs. “ite” Oxoanion

If the anion in the acid ends in **-ate**, change the ending to **-ic** acid.



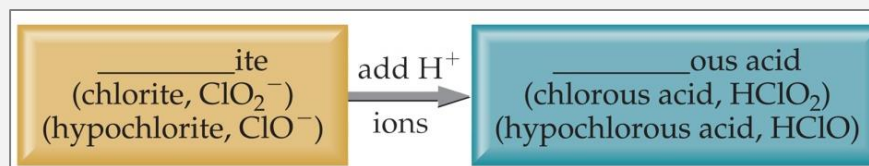
Examples:

$\text{HClO}_3$ : chloric acid

$\text{HClO}_4$ : perchloric acid

NOTE: Think “I **ate** something **icky**”

If the anion in the acid ends in **-ite**, change the ending to **-ous** acid.



Examples:

$\text{HClO}_2$ : chlorous acid

$\text{HClO}$ : hypochlorous acid

NOTE: Think “Sprite is **delicious**”

# Common Oxoanions and Their Corresponding Oxyacids

Element	Oxoanion		Oxyacid	
nitrogen	$\text{NO}_3^-$	nitrate	$\text{HNO}_3$	nitric acid
phosphorus	$\text{PO}_4^{3-}$	phosphate	$\text{H}_3\text{PO}_4$	phosphoric acid
	$\text{PO}_3^{3-}$	phosphite	$\text{H}_3\text{PO}_3$	phosphorous acid
sulfur	$\text{SO}_4^{2-}$	sulfate	$\text{H}_2\text{SO}_4$	sulfuric acid
	$\text{SO}_3^{2-}$	sulfite	$\text{H}_2\text{SO}_3$	sulfurous acid
chlorine	$\text{ClO}^-$	hypochlorite	$\text{HClO}$	hypochlorous acid
	$\text{ClO}_2^-$	chlorite	$\text{HClO}_2$	chlorous acid
	$\text{ClO}_3^-$	chlorate	$\text{HClO}_3$	chloric acid
	$\text{ClO}_4^-$	perchlorate	$\text{HClO}_4$	perchloric acid

# Common Organic Acids

Formula	Name
$\text{HCOOH (CH}_2\text{O}_2\text{)}$	formic acid
$\text{CH}_3\text{COOH}$ $\text{(C}_2\text{H}_4\text{O}_2\text{)}$	acetic acid
$\text{HOCCOOH}$ $\text{(C}_2\text{H}_2\text{O}_4\text{)}$	oxalic acid

# Base Nomenclature

**Arrhenius definition of base:** A base is a substance that ionizes in water to produce hydroxide ions ( $\text{OH}^-$ ).

- The **cations** are commonly metals from the 1A, 2A and transition groups.
- The **anion** in an Arrhenius base is  $\text{OH}^-$ .

These are named using the same rules as ionic compounds.

Examples:

Formula	Name
$\text{NaOH}$	sodium hydroxide
$\text{Al(OH)}_3$	aluminum hydroxide
$\text{Hg}_2(\text{OH})_2$	mercury(I) hydroxide mercurous hydroxide
$\text{Cu(OH)}_2$	copper(II) hydroxide cupric hydroxide
$\text{Pb(OH)}_2$	lead(II) hydroxide plumbous hydroxide

# Exercise 1

Give the names or formulas of the following acids and bases. If an acid or a base can be named by both the Stock and the Classical systems, provide both names.

1. HF (aqueous solution)
2.  $\text{H}_2\text{SO}_3$
3.  $\text{H}_2\text{CO}_3$
4.  $\text{H}_2\text{S}$  (pure substance)
5.  $\text{Hg}_2(\text{OH})_2$
6.  $\text{Fe}(\text{OH})_2$
7.  $\text{H}_3\text{PO}_4$
8. nitric acid
9. aluminum hydroxide
10. ferric hydroxide
11. cuprous hydroxide
12. hydrocyanic acid
13. nitrous acid
14. sulfuric acid

# Naming Hydrates

(compounds associated with  
water molecules)

# Naming Hydrates

**Hydrates** – Compounds that have a specific number of water molecules associated with them. (Ex:  $\text{BaCl}_2 \cdot 6\text{H}_2\text{O}$ )

- The hydrated compound is named as any other ionic compound.
- It is then followed by water molecules which are named using “*prefix-hydrate*”.
- The prefix indicates the number of water molecules. (See table)

## Examples:

- |  |  |
|--|--|
| 1. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ | copper(II) sulfate <b>penta</b> hydrate<br><i>cupric sulfate pentahydrate</i>    |
| 2. $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ | magnesium sulfate <b>hepta</b> hydrate   |
| 3. $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ | cobalt(II) chloride <b>hexa</b> hydrate<br><i>cobaltous chloride hexahydrate</i> |

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

## Exercise 2

Give the names or formulas. Provide both stock and classical names if necessary.

1.  $\text{LiCl}\cdot\text{H}_2\text{O}$
2.  $\text{MgSO}_4\cdot 7\text{H}_2\text{O}$
3.  $\text{CoCl}_2\cdot 6\text{H}_2\text{O}$
4.  $\text{CuSO}_4\cdot 5\text{H}_2\text{O}$
5.  $\text{Na}_2\text{SO}_4\cdot 10\text{H}_2\text{O}$
6. barium chloride dihydrate
7. sodium carbonate decahydrate
8. ferrous sulfate hexahydrate
9. strontium nitrate tetrahydrate
10. manganese(II) nitrate tetrahydrate

# Naming Binary Molecular Compounds

(containing two nonmetal elements that form covalent bonds)

# Molecular Compounds (Covalent Compounds)

- The **distinct feature** of all molecular compounds is the **covalent bond** formed between two or more **non-metals**.
- Unlike ionic bonds where only one combination of atoms makes the compound neutral (electrons are transferred from an atom to another), **electrons** here are **shared** between the atoms in molecular compounds resulting in the possibility of **multiple combinations** for neutrality.
- Hence, naming of molecular compounds is different from ionic compounds.
- To name molecular compounds, we need to know the trend of elements electronegativity in the periodic table.



Water, H<sub>2</sub>O



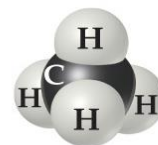
Hydrogen peroxide, H<sub>2</sub>O<sub>2</sub>



Carbon monoxide, CO



Carbon dioxide, CO<sub>2</sub>




Methane, CH<sub>4</sub>



C<sub>2</sub>H<sub>6</sub>

# Nomenclature of Binary Molecular Compounds

\*Electronegativity increases towards right



1A 1	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 H																	2 He
2 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3 Na	12 Mg	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10			1B 11	2B 12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	113	114	115	116		118

Metals	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
Metalloids	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No
Nonmetals														

Pattern of Electronegativity in periodic table

Electronegativity increases



- The least electronegative element is listed first in the formula, the most electronegative last.
- Example :  
nitrogen monoxide (NO)  
Nitrogen is less electronegative than oxygen and is written first in the formula.

Details of electronegativity will be discussed later in the course.

# Nomenclature of Binary Molecular Compounds

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

- A prefix (see the table) is used to denote the number of atoms of each element in the compound. (*mono-* is not used on the first element listed, however)
- When naming the first element, the name of the element is used.
- When naming the second element, take the first part of the element name and add the suffix “ide” to it. (Example: chloride)

Examples :

CO<sub>2</sub>- carbon dioxide

CCl<sub>4</sub> – carbon tetrachloride

# Nomenclature of Binary Molecular Compounds

- If the prefix ends with “a” or “o” and the name of the element begins with a vowel, the two successive vowels are often **elided** into one.
  - For oxides, the ending “a” in the prefix is sometimes omitted.

## Example:

$N_2O_5$  : Two nitrogens- **di**

$N_2O_5$  : Five oxygens – **penta**

$N_2O_5$ : **dinitrogen pentoxide** (because **pentaoxide** would be awkward to pronounce, “*penta*” becomes “*pent*” here.)

# Examples for Naming Molecular Compounds

Compound formula	Name
CO	carbon monoxide ( <b>not monocarbon monoxide</b> )
CO <sub>2</sub>	carbon dioxide
NF <sub>3</sub>	nitrogen trifluoride
N <sub>2</sub> O <sub>4</sub>	dinitrogen tetroxide ( <b>not dinitrogen tetraoxide</b> )
S <sub>2</sub> F <sub>10</sub>	disulfur decafluoride

**\*\*Note:** Greek prefixes are only used for molecular compounds. They are not used to name **ionic** compounds (metals with nonmetals).

*Na<sub>2</sub>O is named "sodium oxide"*

*not "disodium oxide" and not "disodium monoxide"*

# Naming Irregular Molecular Compounds

- An exception to the use of Greek prefixes involves molecular compounds containing hydrogen.
- Traditionally, many of these compounds are called either by their common names or by names that do not specifically indicate the number of H atoms present.

## Examples:

$\text{CH}_4$  – methane

$\text{PH}_3$  – phosphine

$\text{H}_2\text{S}$  – hydrogen sulfide

$\text{NH}_3$  – ammonia

$\text{H}_2\text{O}$  – water

$\text{SiH}_4$  – silane

## Exercise 3

Give the names or formulas for the following binary molecular compounds.

1. NO

2. SO<sub>2</sub>

3. Cl<sub>2</sub>O<sub>7</sub>

4. PBr<sub>3</sub>

5. SF<sub>6</sub>

6. P<sub>2</sub>O<sub>5</sub>

7. CCl<sub>4</sub>

8. dinitrogen monoxide

9. boron trichloride

10. diarsenic pentoxide

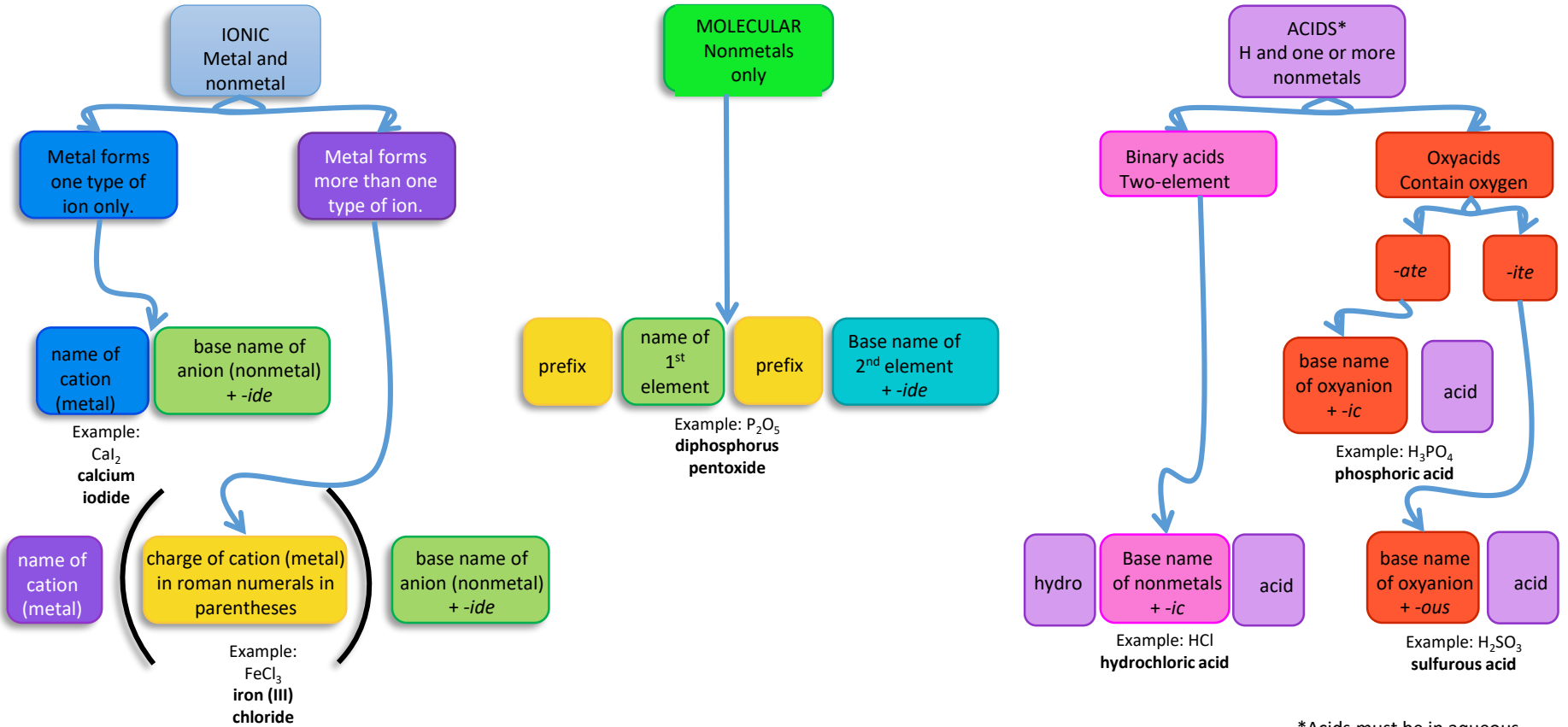
11. sulfur hexachloride

12. nitrogen triiodide

13. carbon tetrabromide

14. triphosphorus tetroxide

# Summary Flowchart



\*Acids must be in aqueous solution.

If you feel you have mastered the objectives of this module, please obtain a posttest from the Science Learning Center personnel.

If you don't feel comfortable with any of the material in this module, please work through the module again, or request assistance from the SLC staff!

# Exercise 1 - Key

Give the names or formulas of the following acids and bases. If an acid or a base can be named by both the Stock and the Classical systems, provide both names.

- |  |                                |
|--|--------------------------------|
| 1. HF (aqueous solution)                 | hydrofluoric acid              |
| 2. $\text{H}_2\text{SO}_3$               | sulfurous acid                 |
| 3. $\text{H}_2\text{CO}_3$               | carbonic acid                  |
| 4. $\text{H}_2\text{S}$ (pure substance) | hydrogen sulfide               |
| 5. $\text{Hg}_2(\text{OH})_2$            | mercurous/mercury(I) hydroxide |
| 6. $\text{Fe}(\text{OH})_2$              | ferrous/iron (II) hydroxide    |
| 7. $\text{H}_3\text{PO}_4$               | phosphoric acid                |
| 8. nitric acid                           | $\text{HNO}_3$                 |
| 9. aluminum hydroxide                    | $\text{Al}(\text{OH})_3$       |
| 10. ferric hydroxide                     | $\text{Fe}(\text{OH})_3$       |
| 11. cuprous hydroxide                    | $\text{CuOH}$                  |
| 12. hydrocyanic acid                     | $\text{HCN}$                   |
| 13. nitrous acid                         | $\text{HNO}_2$                 |
| 14. sulfuric acid                        | $\text{H}_2\text{SO}_4$        |

## Exercise 2 - Key

Give the names or formulas for the following hydrates. If a hydrate can be named by both the Stock and the Classical systems, provide both names.

- |      |   |  |
|------|---|--|
| (1)  | $\text{LiCl} \cdot \text{H}_2\text{O}$              | lithium chloride monohydrate                         |
| (2)  | $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$           | magnesium sulfate heptahydrate                       |
| (3)  | $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$           | cobaltous/cobalt (II) chloride hexahydrate           |
| (4)  | $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$           | cupric/copper (II) sulfate pentahydrate              |
| (5)  | $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ | sodium sulfate decahydrate                           |
| (6)  | barium chloride dihydrate                           | $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$            |
| (7)  | sodium carbonate decahydrate                        | $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  |
| (8)  | ferrous sulfate hexahydrate                         | $\text{FeSO}_4 \cdot 6\text{H}_2\text{O}$            |
| (9)  | Strontium nitrate tetrahydrate                      | $\text{Sr}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ |
| (10) | manganese (II) nitrate tetrahydrate                 | $\text{Mn}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ |

## Exercise 3 - Key

Give the names or formulas for the following binary molecular compounds.

- |              |                        |                              |           |
|--------------|------------------------|------------------------------|-----------|
| 1. NO        | nitrogen monoxide      | 8. dinitrogen monoxide       | $N_2O$    |
| 2. $SO_2$    | sulfur dioxide         | 9. boron trichloride         | $BCl_3$   |
| 3. $Cl_2O_7$ | dichlorine heptoxide   | 10. diarsenic pentoxide      | $As_2O_5$ |
| 4. $PBr_3$   | phosphorus tribromide  | 11. sulfur hexachloride      | $SCl_6$   |
| 5. $SF_6$    | sulfur hexafluoride    | 12. nitrogen triiodide       | $NI_3$    |
| 6. $P_2O_5$  | diphosphorus pentoxide | 13. carbon tetrabromide      | $CBr_4$   |
| 7. $CCl_4$   | carbon tetrachloride   | 14. triphosphorus tetraoxide | $P_3O_4$  |