MODULE 4-COMPOUNDS

CHEMICAL NOMENCLATURE OR NAMING IONIC AND MOLECULAR COMPOUNDS

REF : CHAPTER 5 OF TEXTBOOK

TOPICS COVERED:

- ✓ CLASSIFICATION OF COMPOUNDS FOR NOMENCLATURE PURPOSE
- ✓ TYPES OF BINARY IONIC COMPOUNDS
- ✓ NOMENCLATURE FOR BINARY IONIC COMPOUNDS
- ✓ NOMENCLATURE FOR IONIC COMPOUNDS CONTAINING POLYATOMIC IONS
- ✓ NOMENCLATURE FOR BINARY MOLECULAR/ COVALENT COMPOUND
- ✓ NOMENCLATURE FOR ACIDS
- ✓ NOMENCLATURE RULES: A SUMMARY

NAMING COMPOUNDS

- THE **I**NTERNATIONAL **U**NION OF **P**URE AND **A**PPLIED **C**HEMISTRY, IUPAC, HAS SET RULES FOR NAMING COMPOUNDS.
- IN 1921, IUPAC FORMED A COMMISSION ON THE NOMENCLATURE OF INORGANIC CHEMISTRY.
- IN 1940 IUPAC SET THE RULES FOR THE NAMING AND CLASSIFICATION OF INORGANIC COMPOUNDS.
- THESE RULES, REFERRED TO AS **IUPAC NOMENCLATURE** ARE STILL IN USE TODAY.

NOMENCLATURE

CHEMICAL NOMENCLATURE IS THE SYSTEM OF NAMES USED TO DISTINGUISH COMPOUNDS FROM EACH OTHER. WE WILL CONSIDER HOW TO NAME:

- **BINARY *IONIC* COMPOUNDS,** WHICH CONTAIN A METAL AND A NONMETAL.
- **BINARY *MOLECULAR* COMPOUNDS,** WHICH CONSIST ONLY OF NONMETALS. (FOR NAMING PURPOSES METALLOIDS ARE TREATED AS NONMETALS)
- **BINARY AND ACIDS,** COMPOUNDS THAT RELEASE HYDROGEN IONS WHEN DISSOLVED IN WATER.

IONIC COMPOUNDS

LET'S BEGIN BY REVIEWING WHAT WE KNOW ABOUT *IONIC COMPOUNDS*…

- THE **BONDING** IN ***IONIC COMPOUNDS*** CONSISTS OF THE ATTRACTION BETWEEN OPPOSITELY CHARGED **IONS** – *NOT* ATOMS ANYMORE.
- THEY DON'T FORM MOLECULES, BUT **CRYSTAL LATTICES**.
- THE **CHARGE** FOR THE *FORMULA UNIT* MUST BE **NEUTRAL**.
- THE REACTION OF A METAL AND A NONMETAL ALWAYS FORMS AN *IONIC COMPOUND*.
- OTHER *IONIC COMPOUNDS* MIGHT CONTAIN ONE OR MORE **POLYATOMIC IONS**.

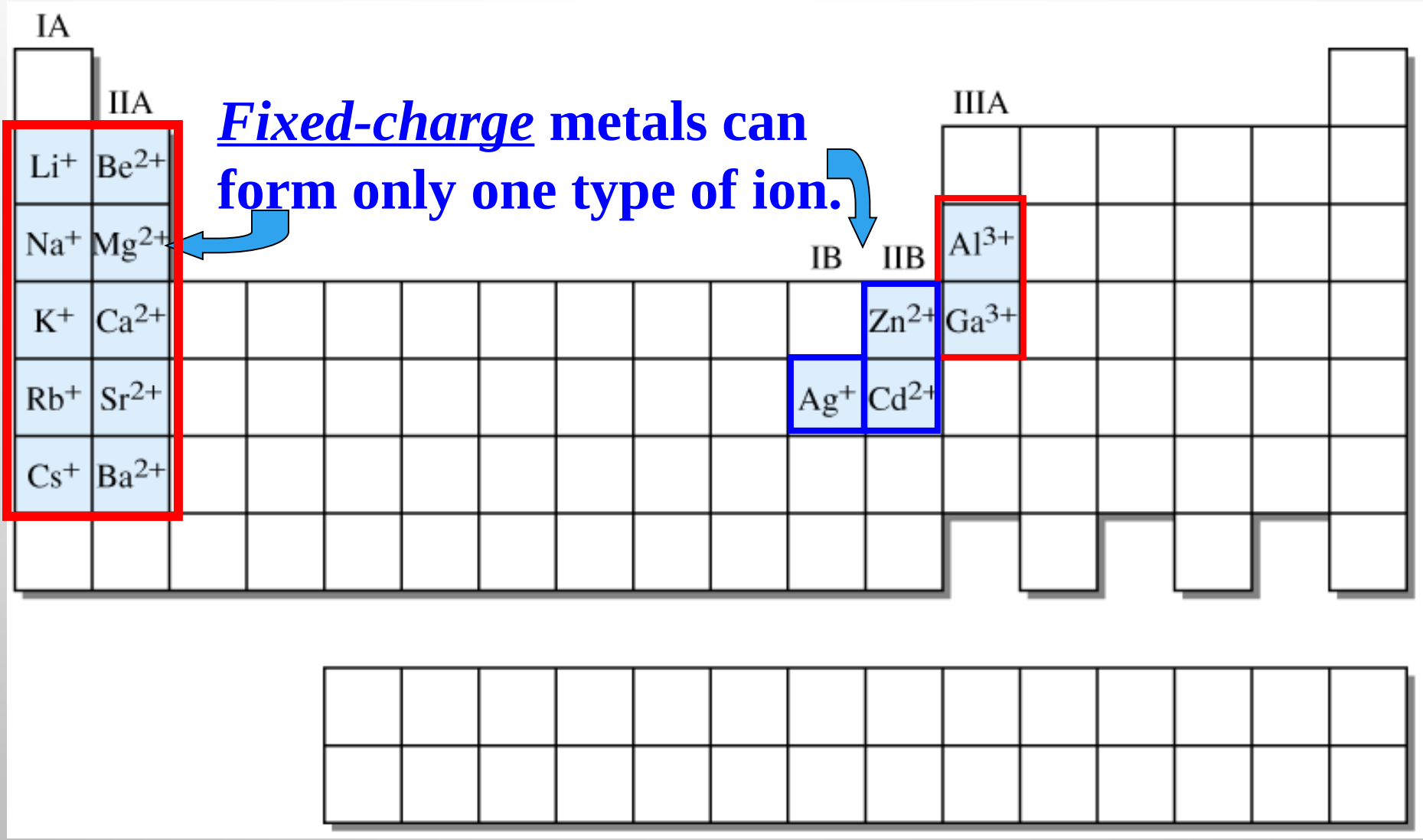
FOR NOMENCLATURE PURPOSES, THERE ARE **TWO** TYPES OF METAL IONS:

FIXED CHARGE METAL IONS ONLY FORM ONE TYPE OF POSITIVE ION – ALWAYS HAS THE SAME CHARGE.

VARIABLE CHARGE METAL IONS CAN FORM MORE THAN ONE TYPE OF POSITIVE ION – USE NOMENCLATURE TO KNOW THE MAGNITUDE OF THE CHARGE.

WHICH ONES ARE FIXED AND WHICH ONES ARE VARIABLE?

FIXED-CHARGE METAL IONS



VARIABLE-CHARGE METAL IONS

- WHICH METALS HAVE A VARIABLE CHARGE?

The rest of them!

Can you think of at least one you have seen in lab?

Cu

VARIABLE-CHARGE METAL IONS

Examples shown for some common metals with variable charges

Element	Ions Formed
Chromium	Cr^{2+} and Cr^{3+}
Cobalt	Co^{2+} and Co^{3+}
Copper	Cu^{+} and Cu^{2+}
Gold	Au^{+} and Au^{3+}
Iron	Fe^{2+} and Fe^{3+}
Lead	Pb^{2+} and Pb^{4+}
Manganese	Mn^{2+} and Mn^{3+}
Tin	Sn^{2+} and Sn^{4+}

NAMING BINARY IONIC COMPOUNDS

- WHEN NAMING ***IONIC COMPOUNDS*****,** WE NAME THE **POSITIVELY-CHARGED** SPECIES FIRST **(THE CATION) AND THE NEGATIVELY-CHARGED SPECIES SECOND (THE ANION).**
- **METAL IONS** (*FIXED* OR VARIABLE) TAKE THE NAME OF THE **METAL** FROM WHICH THEY COME**.**
- **NONMETAL IONS** ARE NAMED BY TAKING THE <u>STEM</u> OF THE **NONMETAL** AND ADDING ***–IDE*****.**

ATOM lithium (Li)

CATION Li^+

NAME OF CATIO lithium ion

ATOM	magnesium (Mg)
CATION	Mg^{2+}
NAME OF CATION	magnesium ion

ATOM strontium (Sr)

CATION Sr^{2+}

NAME OF CATIO strontium ion

ATOM

sodium (Na)

CATION

NAME OF CATIO

ATOM

calcium (Ca)

CATION

NAME OF CATIO

NAMING BINARY IONIC COMPOUNDS

- THE **NEGATIVELY CHARGED** SPECIES, **NONMETALS** AND **METALLOIDS (**OR **POLYATOMIC** IF APPLICABLE**) IS** NAMED SECOND.
- **NONMETAL IONS** ARE NAMED BY TAKING THE **STEM** OF THE NONMETAL AND ADDING ***–IDE*.**
- **POLYATOMIC IONS** BRING THEIR OWN NAME TO THE COMPOUND.

ATOM bromine (Br)

ANION Br^-

NAME OF ANION stem + bromide ion

ATOM nitrogen (N)

ANION N^{3-}

NAME OF ANION stem

nitride ion

ATOM

phosphorous (P)

ANION

P^{3-}

NAME OF ANION

stem

phosphide ion

ATOM oxygen (O)

ANION O^{2-}

NAME OF ANION stem + oxide ion

ATOM

fluorine (F)

ANION

NAME OF ANION

stem

ATOM	chlorine (Cl)
ANION	
NAME OF ANION	stem

Names for the More Common Nonmetal Ions

Element	Stem	Name of Ion	Formula
Bromine	brom-	bromide ion	Br^-
Carbon	carb-	carbide ion	C^{4-}
Chlorine	chlor-	chloride ion	Cl^-
Fluorine	fluor-	fluoride ion	F^-
Hydrogen	hydr-	hydride ion	H^-
Iodine	iod-	iodide ion	I^-
Nitrogen	nitr-	nitride ion	N^{3-}
Oxygen	ox-	oxide ion	O^{2-}
Phosphorus	phosph-	phosphide ion	P^{3-}
Sulfur	sulf-	sulfide ion	S^{2-}

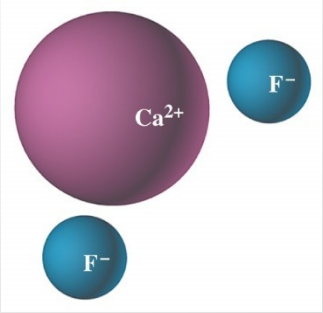
NAMING BINARY IONIC COMPOUNDS THAT CONTAIN A FIXED-CHARGE METAL

- **AGAIN, WHEN NAMING THESE COMPOUNDS, WE NAME THE POSITIVELY-CHARGED SPECIES FIRST (THE CATION) AND THE NEGATIVELY-CHARGED SPECIES SECOND (THE ANION).**

- **THEREFORE…**

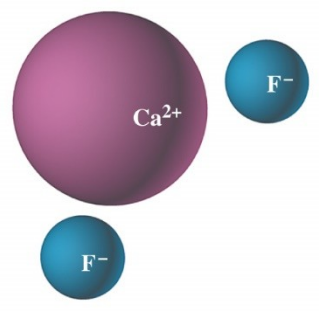
NAME THE COMPOUND: CaF_2

STEP 1 FROM THE FORMULA IT IS A BINARY COMPOUND; ONLY TWO ELEMENTS.



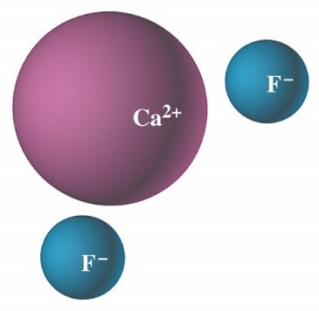
NAME THE COMPOUND: CaF_2

STEP 2 THE COMPOUND IS COMPOSED OF Ca, A METAL AND F, A NONMETAL. Ca FORMS ONLY A 2+ CATION. SO WE CALL THE POSITIVE PART OF THE COMPOUND *CALCIUM*.



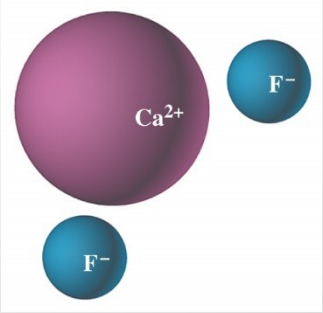
NAME THE COMPOUND: CaF_2

STEP 3 MODIFY THE NAME OF THE SECOND ELEMENT TO THE STEM *FLUOR-* AND ADD THE *–IDE* ENDING TO FORM THE NAME OF THE NEGATIVE PART, *FLUORIDE.*



NAME THE COMPOUND: CaF_2

STEP 4 THE NAME OF THE COMPOUND IS THEREFORE *CALCIUM FLUORIDE.*



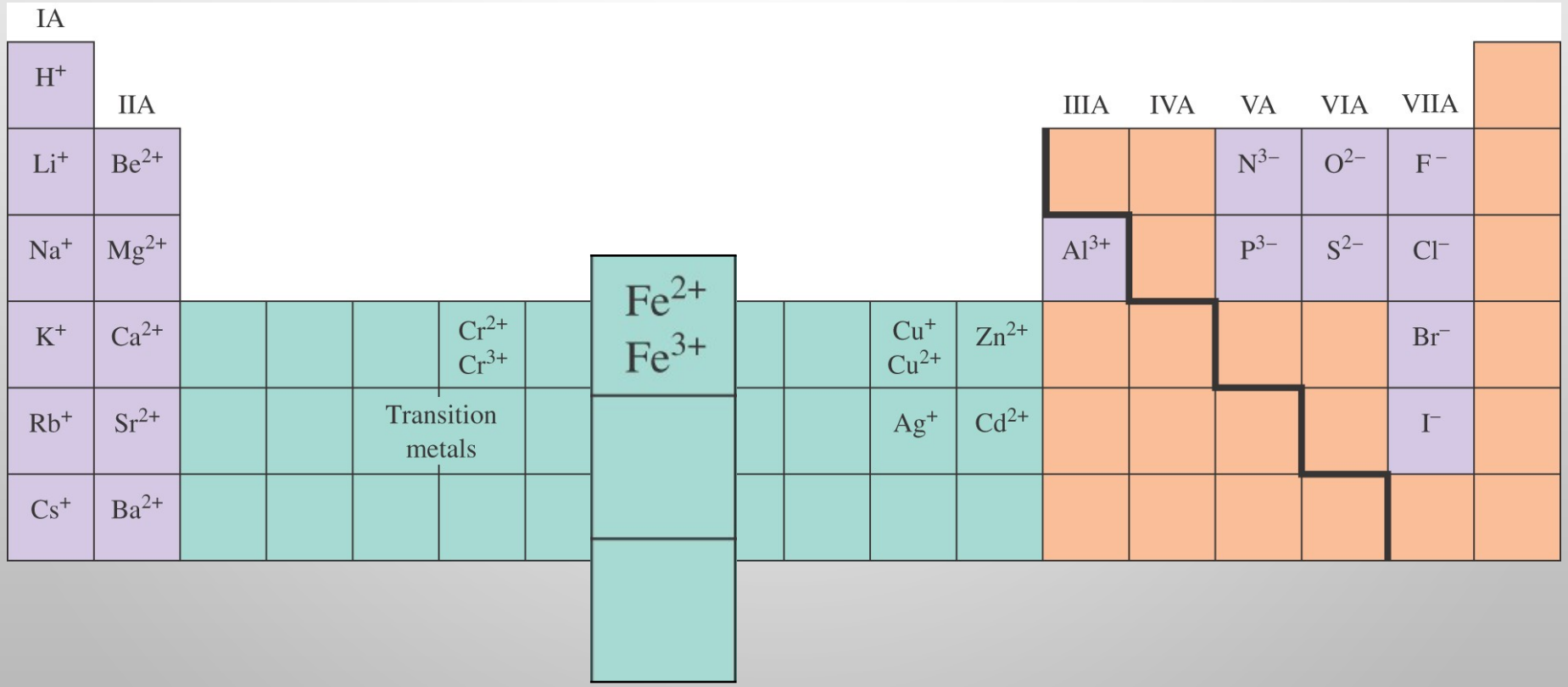
NAMING BINARY IONIC COMPOUNDS THAT CONTAIN A VARIABLE-CHARGE METAL

SUPPOSE YOU WERE ASKED TO NAME THESE TWO COMPOUNDS:

FeS Fe_2S_3

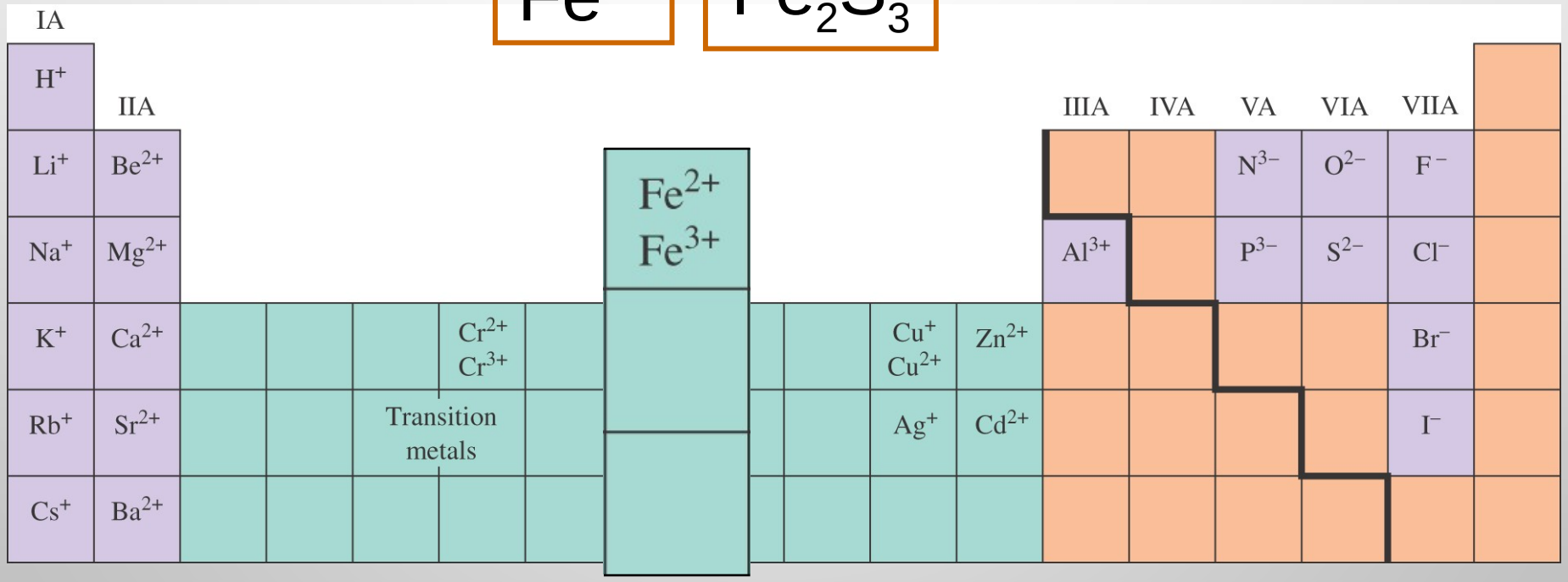
BOTH OF THESE COMPOUNDS EXIST, AND THEY HAVE DIFFERENT PHYSICAL AND CHEMICAL PROPERTIES. WE CAN'T VERY WELL CALL THEM BOTH ***IRON SULFIDE***. WE NEED A DIFFERENT NAMING SYSTEM FOR CASES SUCH AS THESE.

Iron is found in the area of the periodic table we call the transition metals; most of these metals form more than one type of cation, and iron certainly does.



Each ion of iron forms a different compound with the same anion.

Fe^{2+}	FeS
Fe^{3+}	Fe_2S_3



In the Stock System the charge on the cation is designated by a Roman numeral placed in parentheses immediately following the name of the metal.

Cation Charge	+1	+2	+3	+4	+5
Roman Numeral	I	II	III	IV	V

The nonmetal name still ends in *-ide*.

Stock System

Lower Charge			Higher Charge	
Element	**Formula**	**Name**	**Formula**	**Name**
Copper	Cu^{+}	copper (I)	Cu^{2+}	copper(II)
Iron	Fe^{2+}	iron(II)	Fe^{3+}	iron(III)
Lead	Pb^{2+}	lead (II)	Pb^{4+}	lead(IV)
Mercury	Hg_2^{2+}	mercury(I)	Hg^{2+}	mercury(II)
Tin	Sn^{2+}	tin(II)	Sn^{4+}	tin (IV)

compound name

iron(II) chloride

$FeCl_2$

+2 -1

iron(II) chloride

iron(III) chloride

$FeCl_3$

+3 -1

iron(III) chloride

compound name

tin(II) bromide

$SnBr_2$

+2 tin(II)

-1 bromide

tin(IV) bromide

$SnBr_4$

+4 tin(IV)

-1 bromide

SO, THE FIRST THING YOU SHOULD ASK YOURSELF WHEN CONFRONTED WITH THE FORMULA OF A COMPOUND THAT YOU HAVE TO NAME IS THIS:

IS THERE A METAL IN THIS COMPOUND?

IF THE ANSWER IS **YES,** THEN THE COMPOUND IS

IONIC

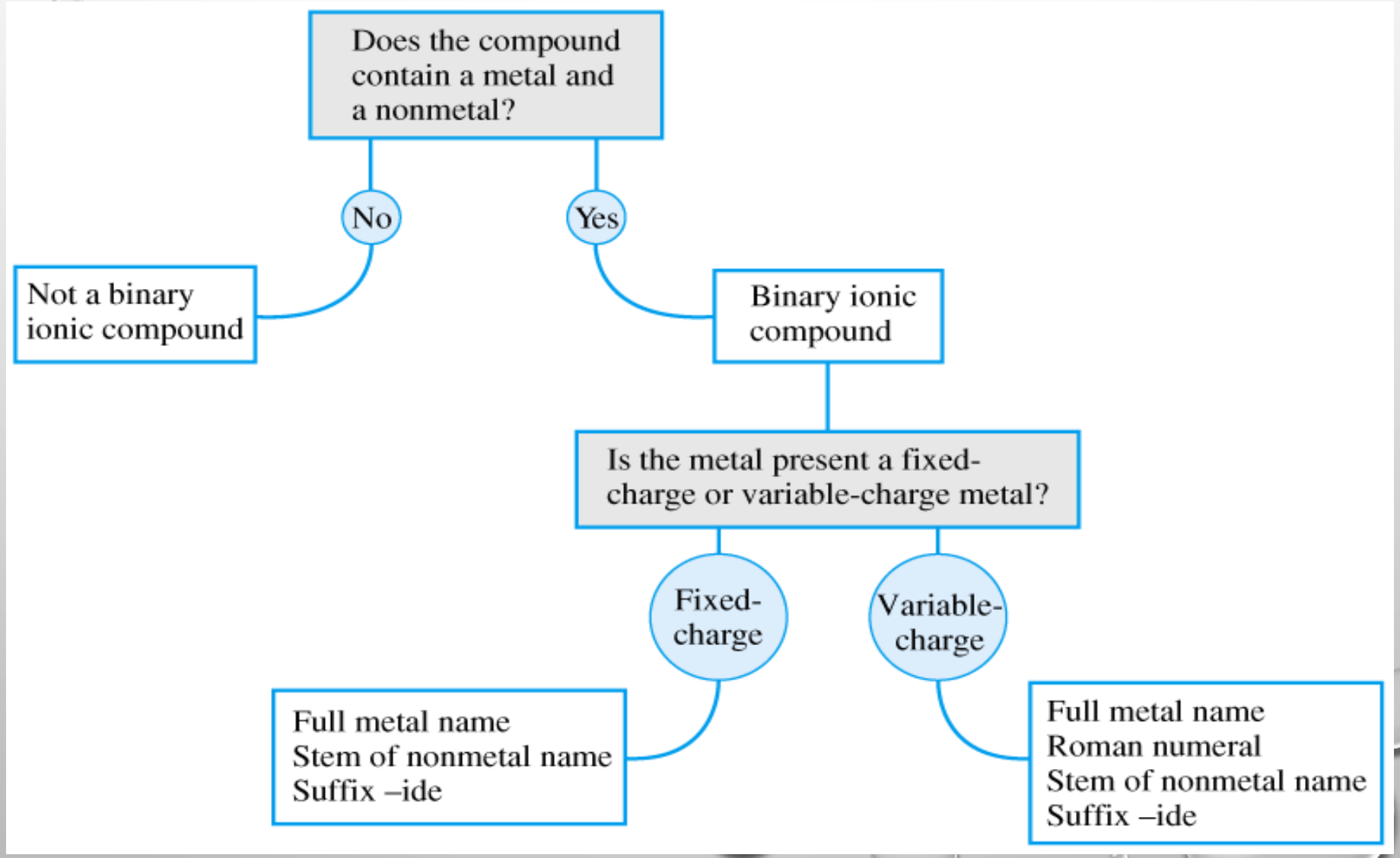
This should prompt a second question:

Is it a *fixed-charge* metal or a variable-charge metal?

Name the metal, add the stem of the nonmetal and add -ide

Name the metal, add a Roman numeral for the metal's charge, then add the stem of the nonmetal and -ide

NOMENCLATURE FOR BINARY IONIC COMPOUNDS



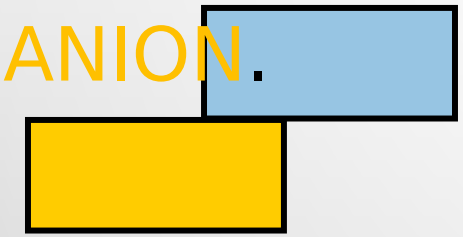
HOW TO NAME IONIC COMPOUNDS WITH POLYATOMIC IONS

SOME POINTS TO HELP REMEMBER THE POLYATOMIC IONS:

1. MOST POLYATOMIC IONS ARE NEGATIVELY CHARGED. ONLY TWO MAIN POSITIVELY CHARGED ONES – AMMONIUM ION AND HYDRONIUM ION
2. FOUR POLYATOMIC IONS HAVE NAMES THAT END IN "IDE" LIKE THE NONMETAL IONS: HYDROXIDE, CYANIDE, AZIDE AND PEROXIDE.
3. NOTE THE "-ATE" AND "-ITE" PAIRS. THEY DIFFER BY THE NUMBER OF OXYGEN ATOMS. THE "-ATE" ALWAYS HAS THE GREATER NUMBER OF OXYGEN ATOMS. (SULFATE SO_4^{2-} AND SULFITE SO_3^{2-})
4. SOME PAIRS DIFFER BY A HYDROGEN ION – CARBONATE (CO_3^{2-}) AND HYDROGEN CARBONATE (HCO_3^-). THE ADDITION OF H REDUCES THE CHARGE.
5. WHEN SULFUR REPLACES AN OXYGEN ATOM, THE PREFIX "THIO-" IS ADDED TO THE NAME. CYANATE ION (OCN^-) - THIOCYANATE SCN^-, SULFATE (SO_4^{2-}) - THIOSULFATE ($S_2O_3^{2-}$)

POLYATOMIC NOMENCLATURE

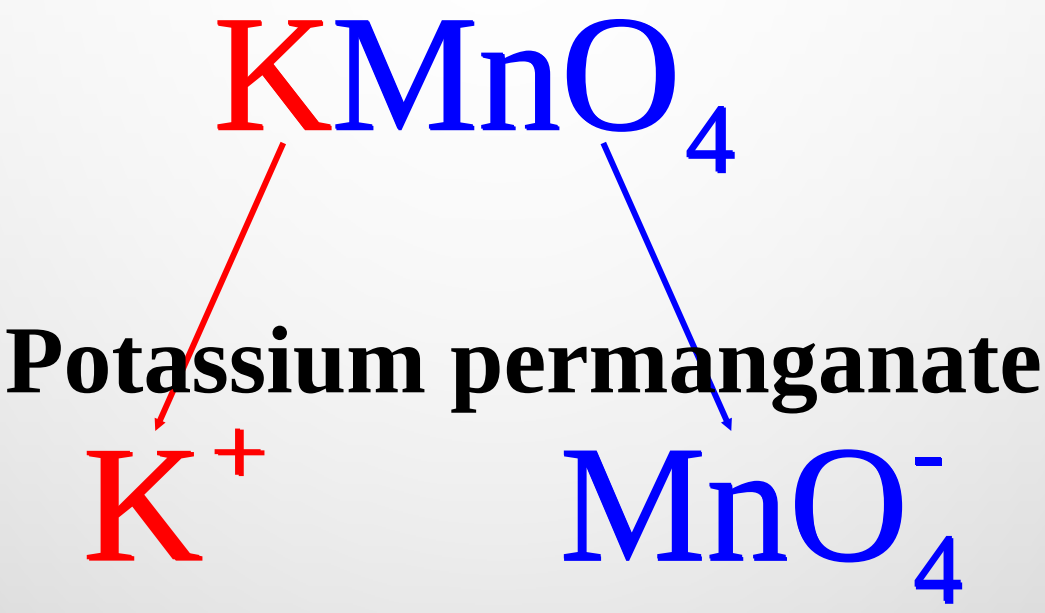
- WHEN NAMING A COMPOUND CONTAINING A POLYATOMIC ION, NAME THE CATION FIRST AND THEN NAME THE ANION.



Na_2CO_3

Sodium carbonate

This is the way the formula is written.



The ions are what is actually present.

BINARY MOLECULAR COMPOUNDS

- A BINARY MOLECULAR COMPOUND CONSISTS OF TWO NONMETALS ELEMENTS.
- NAME THE COMPOUND AS THE FORMULA IS WRITTEN.
  - THE LEAST ELECTRONEGATIVE ELEMENT IS NAMED FIRST. USE THE FULL NAME OF THE ELEMENT.
  - THE STEM OF THE SECOND NONMETAL FOLLOWS WITH THE SUFFIX “-IDE.”
  - NUMERICAL PREFIXES ARE USED TO INDICATE THE NUMBER OF **BOTH** ATOMS PRESENT.

Binary Molecular Compounds

A Greek prefix is placed before the name of each element to indicate the number of atoms of the element that are present.

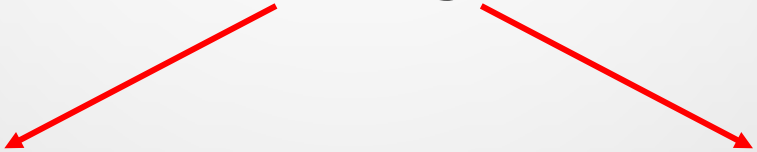
- ***mono* = 1**
- ***Di* = 2**
- ***Tri* = 3**
- ***Tetra* = 4**
- ***Penta* = 5**
- ***Hexa = 6***
- ***Hepta = 7***
- ***Octa = 8***
- ***Nona = 9***
- ***Deca = 10***

BINARY MOLECULAR COMPOUNDS

- EXCEPTION TO THE RULE:
  - BINARY COMPOUNDS WITH HYDROGEN LISTED AS THE FIRST ELEMENT IN THE FORMULA ARE NAMED WITHOUT USING THE PREFIX FOR HOW MANY ATOMS THERE ARE.
  - PREFIX “MONO” IS ALWAYS DROPPED AT THE BEGINNING OF A NAME.

dinitrogen trioxide

N_2O_3



indicates two nitrogen atoms

indicates three oxygen atoms

phosphorous pentachloride

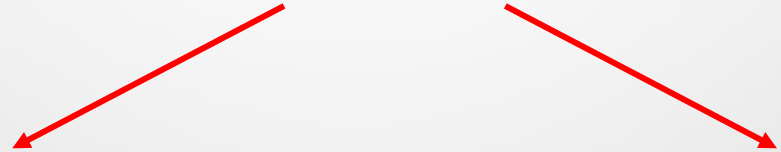
PCl_5

indicates one phosphorous atom

indicates five chlorine atoms

dichlorine heptaoxide

Cl_2O_7



indicates two chlorine atoms

indicates seven oxygen atoms

N_2O_3

DINITROGEN TRIOXIDE

CCl_4

CARBON TETRACHLORIDE

CO

CARBON MONOXIDE

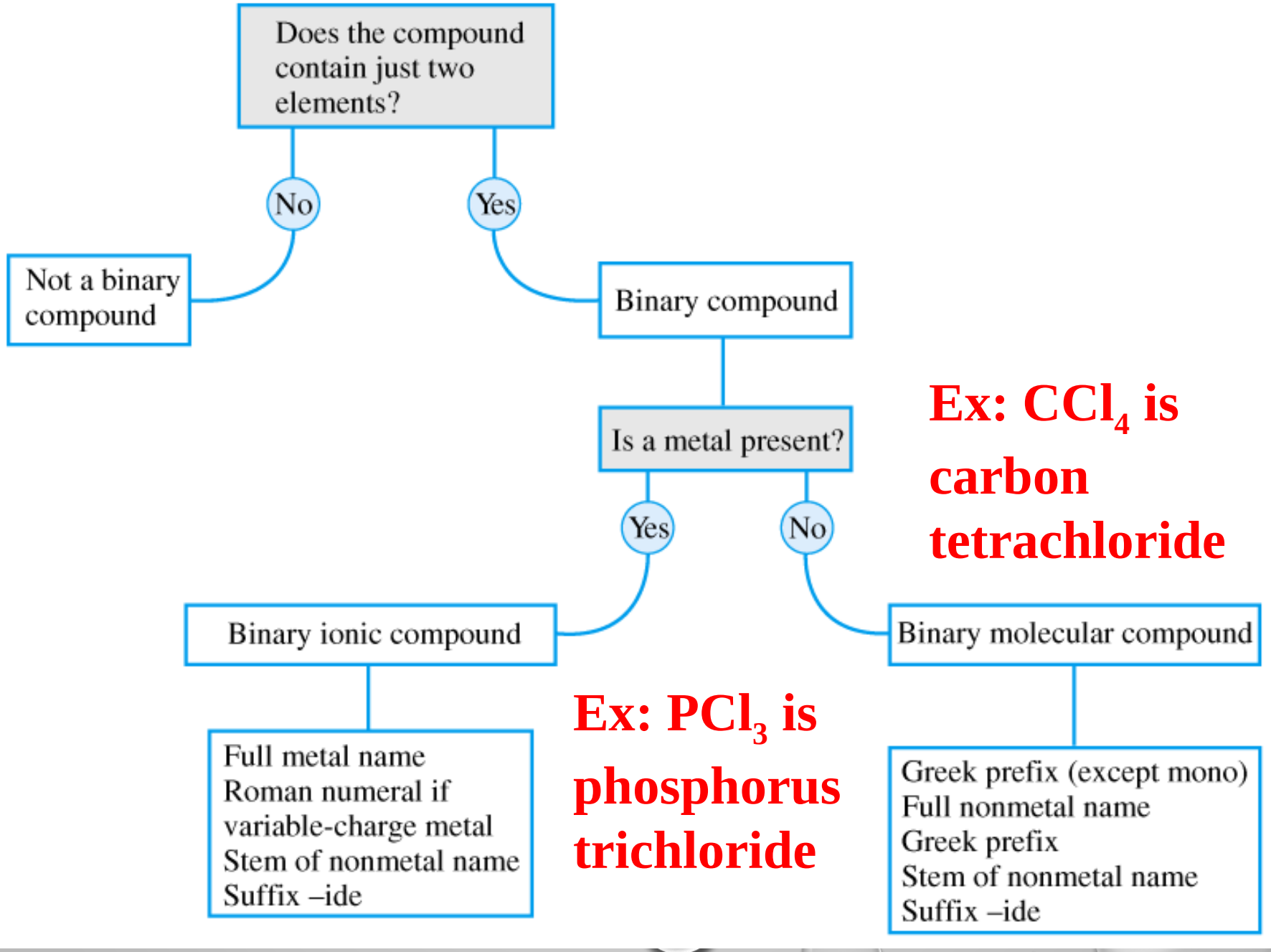
NAME CO_2

CARBON DIOXIDE

NAME PI_3

PHOSPHOROUS

TRIIODIDE


Does the compound contain just two elements?
No
Yes
Not a binary compound
Binary compound
Is a metal present?
Yes
No
Binary ionic compound
Binary molecular compound
Full metal name
Roman numeral if variable-charge metal
Stem of nonmetal name
Suffix –ide
Greek prefix (except mono)
Full nonmetal name
Greek prefix
Stem of nonmetal name
Suffix –ide
Ex: CCl_4 is carbon tetrachloride
Ex: PCl_3 is phosphorus trichloride

COMMON NAMES TO KNOW

H_2O	WATER
H_2O_2	HYDROGEN PEROXIDE
NH_3	AMMONIA
N_2H_4	HYDRAZINE
CH_4	METHANE
C_2H_6	ETHANE
PH_3	PHOSPHINE
AsH_3	ARSINE

OTHER MOLECULAR COMPOUNDS

- THE ABOVE EXAMPLES ARE ALL BINARY COMPOUNDS.
- OTHER MOLECULAR COMPOUNDS WITH MORE THAN 2 ELEMENTS DON’T FOLLOW THESE RULES.
- ORGANIC CHEMISTRY HAS ITS OWN SET OF RULES THAT INCLUDES BOND STRUCTURE.
- WE WILL LOOK AT NAMING TERNARY ACIDS (THREE ELEMENTS).

SOME H-CONTAINING COMPOUNDS DISSOLVE IN H_2O TO GIVE SOLUTIONS WITH PROPERTIES QUITE DIFFERENT FROM THE COMPOUNDS THEMSELVES. THESE SOLUTIONS ARE CALLED *ACIDS*. (CHAP. 14).

BUT NOT ALL H-CONTAINING COMPOUNDS GIVE ACIDIC SOLUTIONS IN H_2O. HOW CAN YOU TELL WHICH IS WHICH? ACIDS CAN BE IDENTIFIED BY THEIR CHEMICAL FORMULAS: H IS THE FIRST ELEMENT SHOWN IN THE FORMULA. E.G.,

ACIDS: HCl, H_2S, H_2SO_4, HNO_3

NONACIDS: NH_3, CH_4, PH_3, SiH_4

An acid is a H-containing molecular compound whose molecules yield hydrogen ions (H^+) when dissolved in H_2O.

Acids produce H^+ in H_2O, but an anion is also produced, depending on the structure of the molecular compound. E.g.,

$$HCl \rightleftharpoons H^+ + Cl^-$$

$$HNO_3 \rightleftharpoons H^+ + NO_3^-$$

$$HCN \rightleftharpoons H^+ + CN^-$$

ACID NOMENCLATURE

Anion Ending	Acid Name
-ide	*hydro-*(stem)*-ic acid*
-ate	(stem)*-ic acid*
-ite	(stem)*-ous acid*

COMMON STUDENT MISSTEPS

- **FOR IONIC COMPOUNDS, FORMULAS MUST BE REDUCED TO SIMPLEST RATIOS. EX: MnO_2, NOT Mn_2O_4** (DON'T REDUCE MOLECULAR COMPOUNDS.)
- **THERE IS A DIFFERENCE BETWEEN AMMONIA (NH_3) AND AMMONIUM ION (NH_4^+).**
- **CHEMICAL FORMULAS DO NOT SHOW IONIC CHARGES. EX: NaCl, NOT Na^+Cl^-**
- **DON'T PUT PARENTHESES UNLESS THEY ARE NEEDED TO SHOW MORE THAN ONE OF THE SAME ION. EX: $NaNO_3$, NOT $Na(NO_3)$**