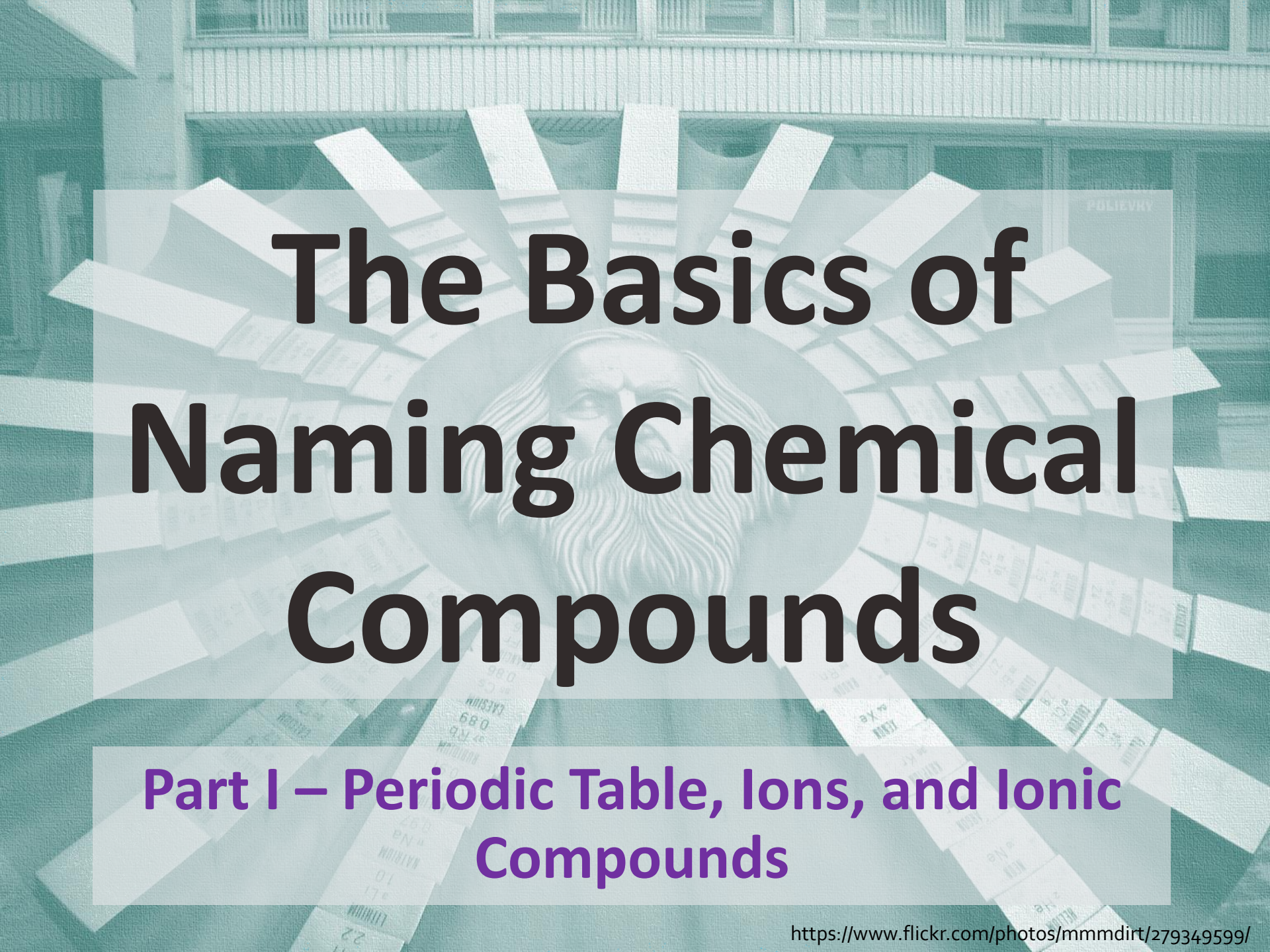


The Basics of Naming Chemical Compounds

Part I – Periodic Table, Ions, and Ionic Compounds

https://www.flickr.com/photos/mmmdirt/279349599/

Goals

After completing this module, you will be able to:

- Write **names** and **symbols** of common elements. Spell element names correctly.
- Locate **metals, nonmetals and metalloids** on the periodic table. Distinguish between **main-group** elements and **transition** metals.
- Associate the location of the element on the periodic table with the naming convention.
- Identify the **charges of common** ions formed from elements.
- Name/identify fundamental chemical **formulas for ionic compounds**.

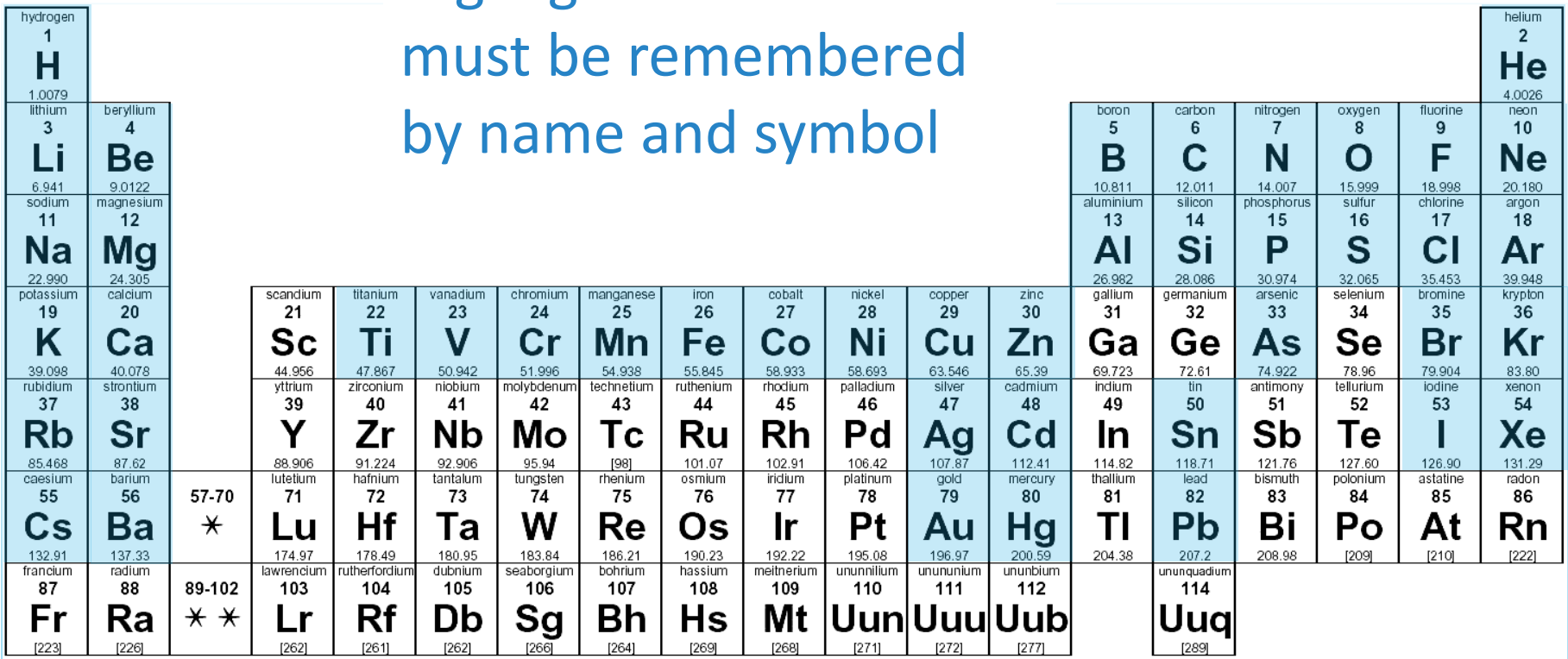
The Periodic Table

- The Periodic Table of Elements is a tabular arrangement of the chemical elements, organized on the basis of their atomic numbers (i.e., the number of protons in their nuclei) and recurring chemical properties.

- There are 118 elements currently listed on the periodic table. About 90 elements are found in nature. The remaining ones have been produced artificially using high energy particle accelerators.

The Periodic Table

Highlighted elements must be remembered by name and symbol



Element Names and Symbols

Each element has a name and symbol.

- The symbol can have up to three letters.
- The first letter must be capitalized and the second and third, if any, are lower case.

Examples:

Name	Symbol
nitrogen	N
chlorine	Cl
ununpentium (this was a temporary placeholder name)	Uup

The symbols of the elements are derived from:

English names

hydrogen – H

calcium – Ca

phosphorus – P

Latin names

ferrum (iron) – Fe

aurum (gold) – Au

cuprum (copper) – Cu

Symbols Derived from the English Names

Symbol	English Name
H	hydrogen
He	helium
Li	lithium
Be	beryllium
B	boron
C	carbon
N	nitrogen
O	oxygen
F	fluorine
Ne	neon
Mg	magnesium

Symbol	English Name
Al	aluminum
Si	silicon
P	phosphorous
S	sulfur
Cl	chlorine
Ar	argon
Ca	calcium
Ti	titanium
V	vanadium
Cr	chromium
Mn	manganese
Co	cobalt

Symbol	English Name
Ni	nickel
Zn	zinc
As	arsenic
Br	bromine
Kr	krypton
Rb	rubidium
Sr	strontium
Cd	cadmium
I	iodine
Xe	xenon
Cs	cesium
Ba	barium

Know the name and symbol for these elements

Symbols Derived from the Latin Names

Element	Symbol	Latin Name	Meaning
sodium	**Na**	natrium	Soda
potassium	**K**	kalium	Potash silver
iron	**Fe**	ferrum	Iron
copper	**Cu**	cuprum	"From Cyprus" where the Romans found copper
silver	**Ag**	argentum	Silver
gold	**Au**	aurum	Shining dawn
mercury	**Hg**	hydrargyrum	Liquid silver
tin	**Sn**	stannum	Tin
lead	**Pb**	plumbum	Heavy

Know the name and symbol for these elements

You'll also need to know the Latin names for Fe, Cu, Sn, and Pb.

Classification of Elements

Elements in the periodic table can be classified as:

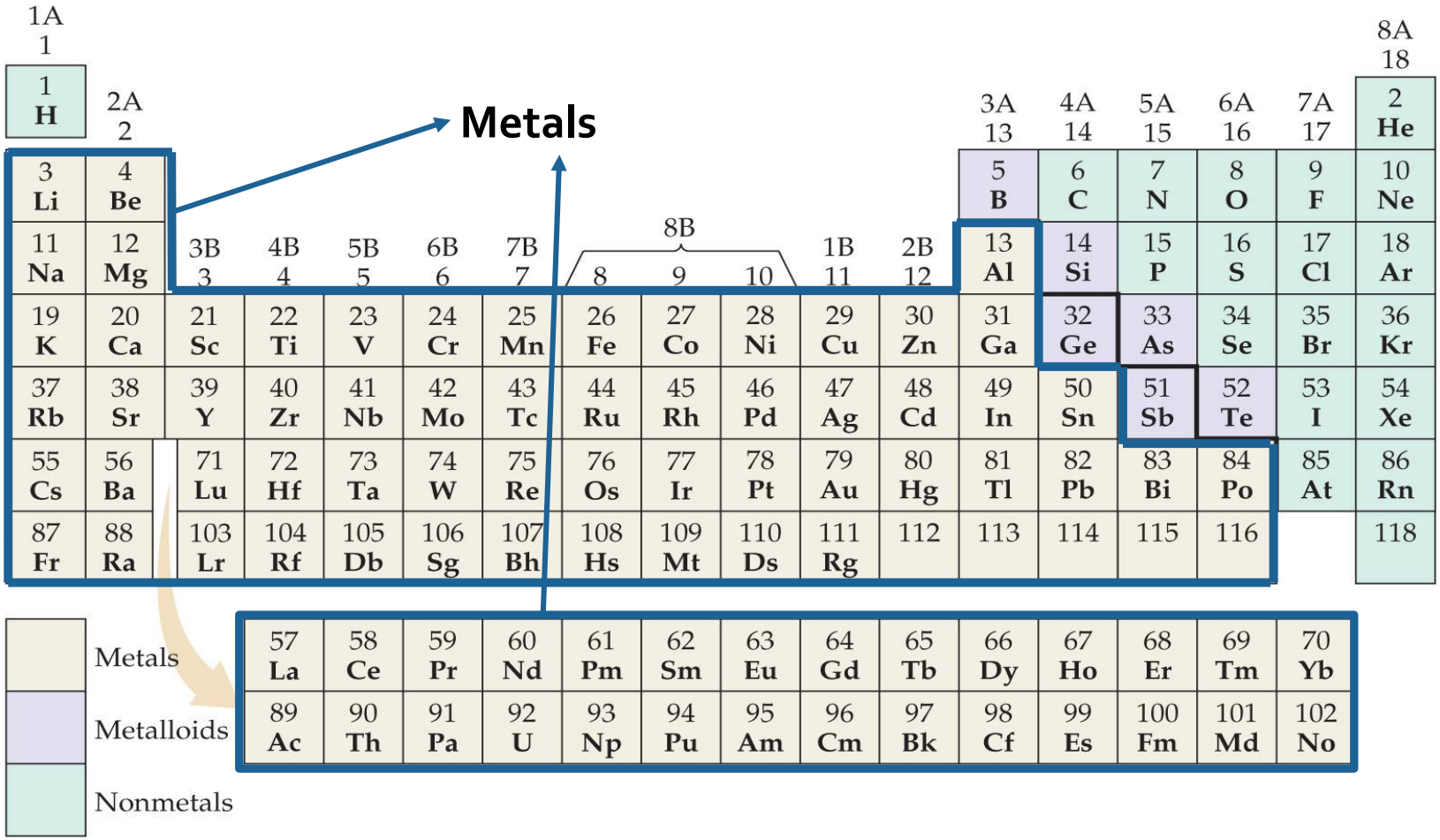
- Metals (most common elements)
- Nonmetals
- Metalloids

We can also classify elements as:

- Main-group elements
- Transition metals

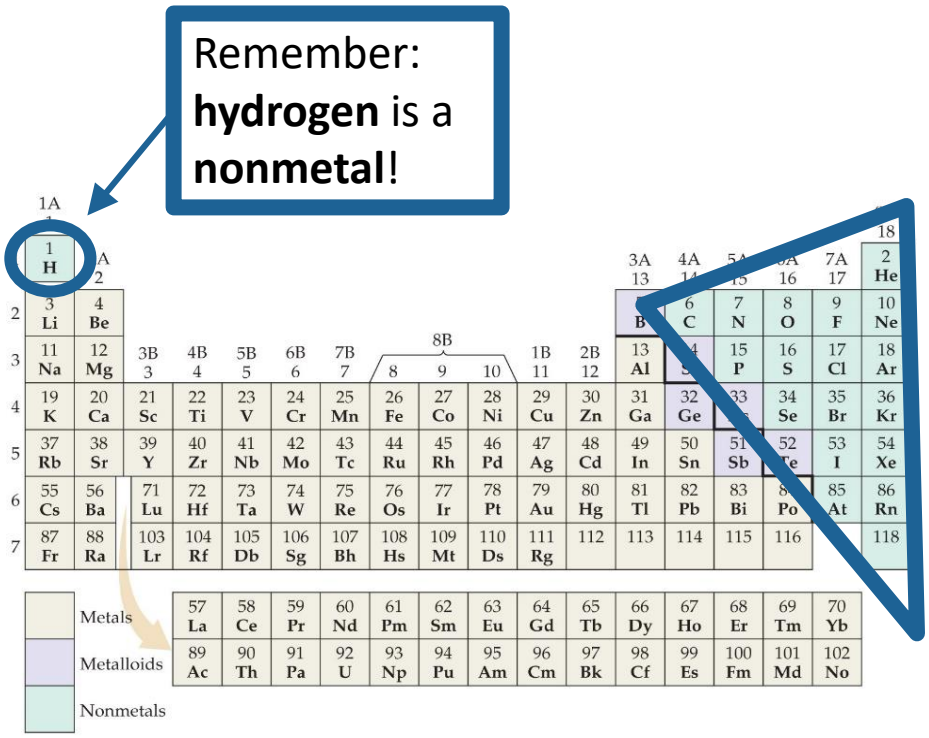
Metals

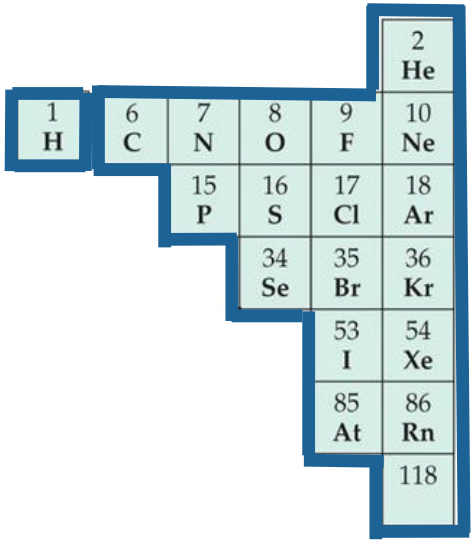
Metals lie on the lower left side of the periodic table.



Nonmetals

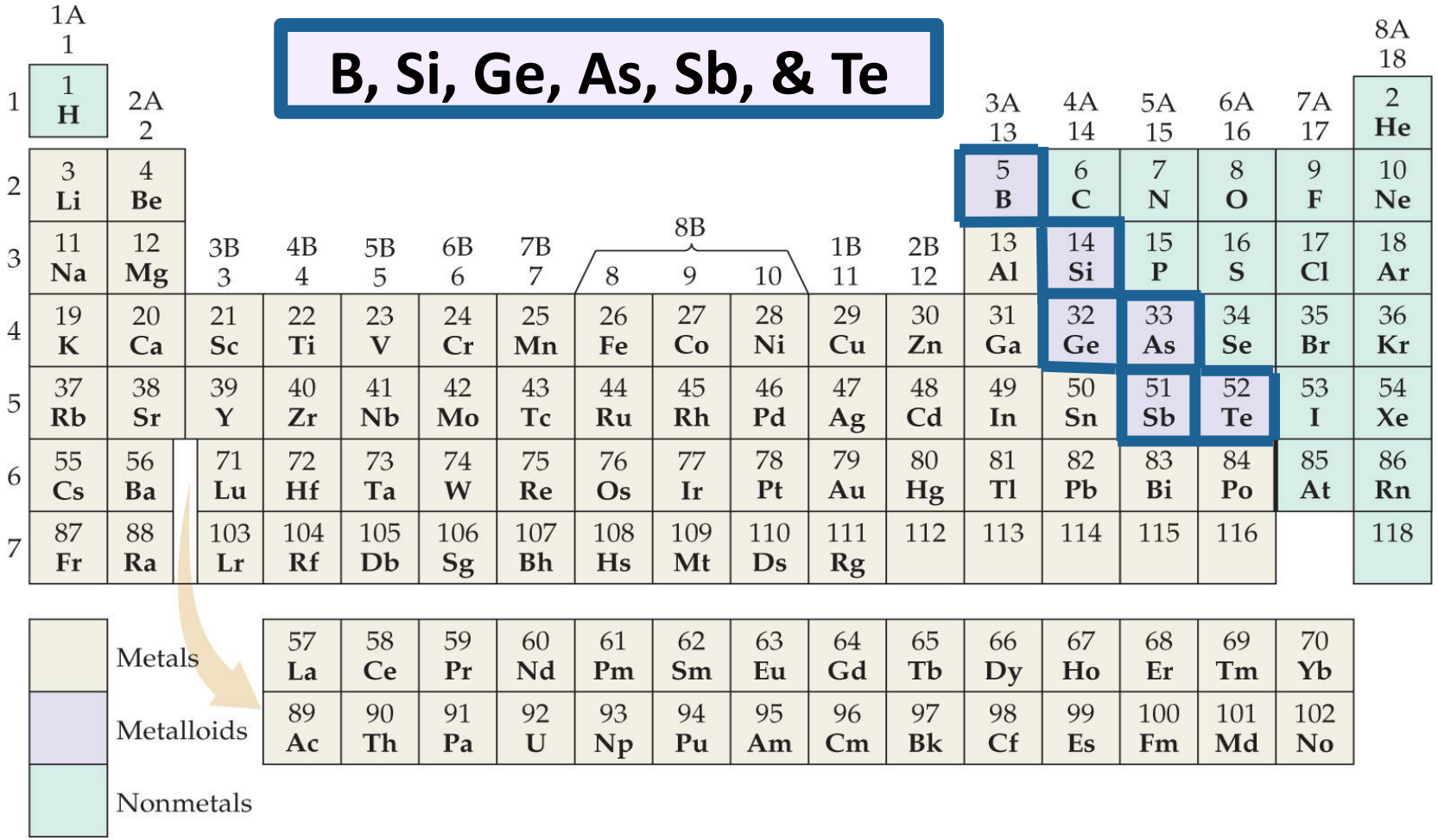
Nonmetals lie on the upper right side of the periodic table (except H which is on the left due to its electron configuration).





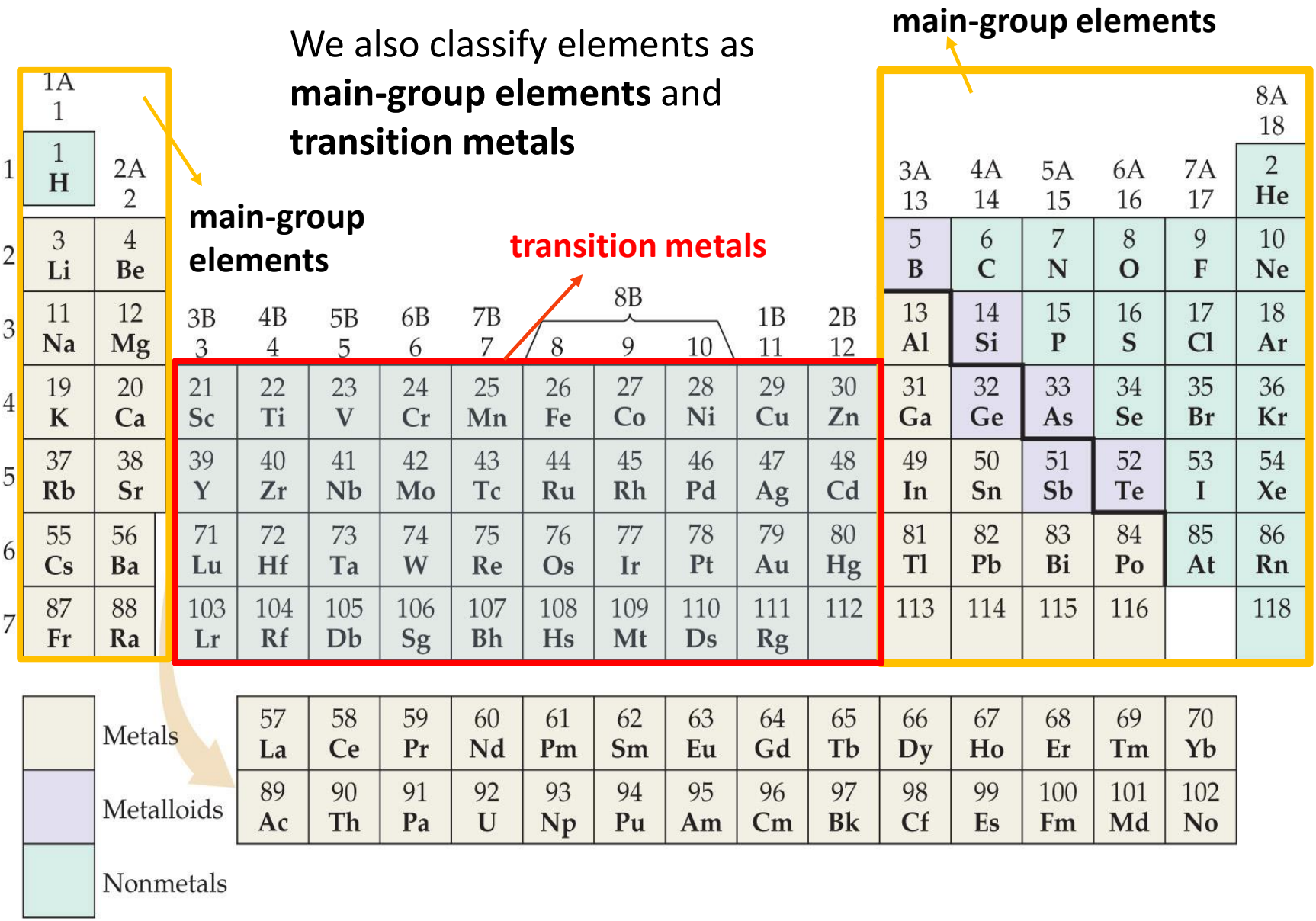
Metalloids

Metalloids are elements whose properties are between metal and nonmetal. These six are the commonly recognized metalloids:



Main Group Elements vs. Transition Metals

We also classify elements as **main-group elements** and **transition metals**



Exercise 1

Write names or symbols of the following elements:

1. Ca
2. K
3. Co
4. Mn
5. Cr
6. Fe
7. P
8. tin
9. silicon
10. gold
11. copper
12. carbon
13. neon
14. bromine

Ions: Losing and Gaining Electrons

The number of protons (designated by the atomic number "***Z***") is what identifies an element.

The 11 protons is what makes this Na (sodium)

In a **neutral atom,** the **number of electrons** is **equal to** the **number of protons** in its nucleus.

The electric charge of protons and electrons has the same value, but opposite sign:

Proton: $+1.602 \times 10^{-19}$ Coulombs, represented as $+1e$.

Electron: -1.602×10^{-19} Coulombs, represented as $-1e$.

Neutral Na atom

Atoms can lose or gain electrons and become charged particles called **ions**. Changing the number of electrons does not change the element's identity.

When a neutral Na atom loses an electron, it becomes a Na^+ ion. It remains the element sodium because it still has 11 protons.

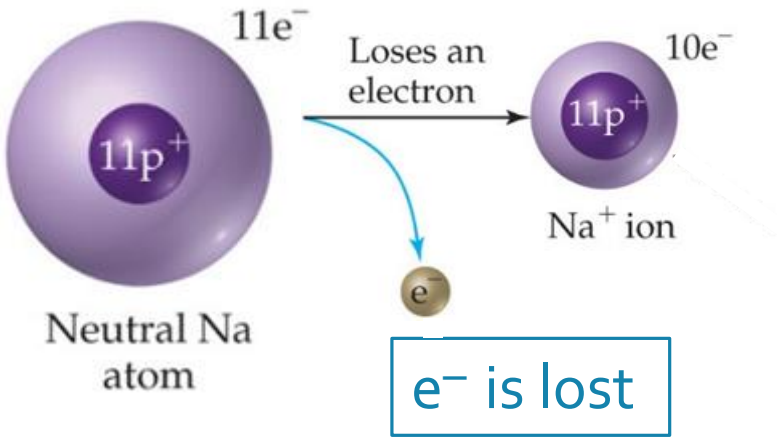
Na^+ ion

Types of Ions

Cation:

ion with a **positive** charge

Metals tend to lose electrons to become cations.



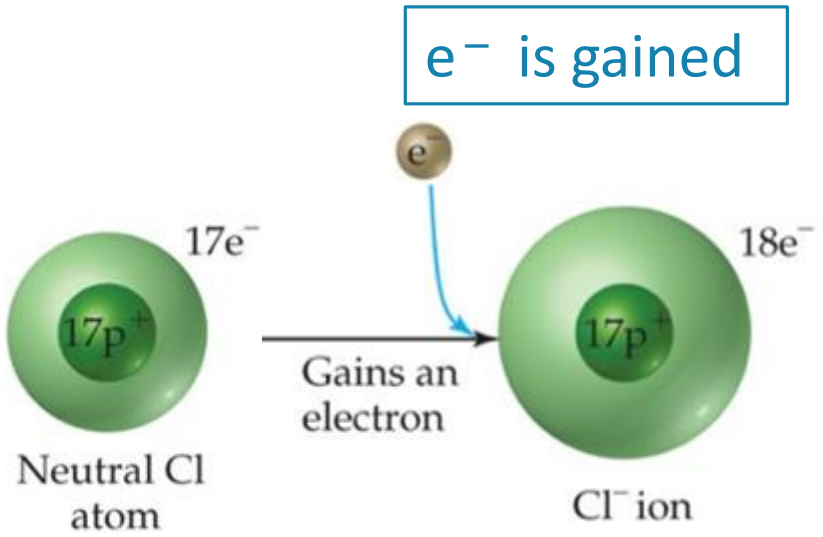
For example, Na^+ has
11 protons and 10 electrons,
so its overall electric charge is:

$$11(+1e) + 10(-1e) = +1e$$

Anion:

ion with a **negative** charge

Non-metals tend to gain electrons to become anions.

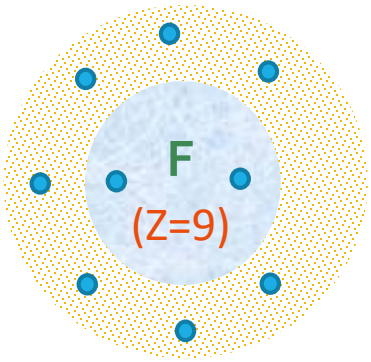


Similarly, Cl^- has
17 protons and 18 electrons,
so its overall electric charge is:

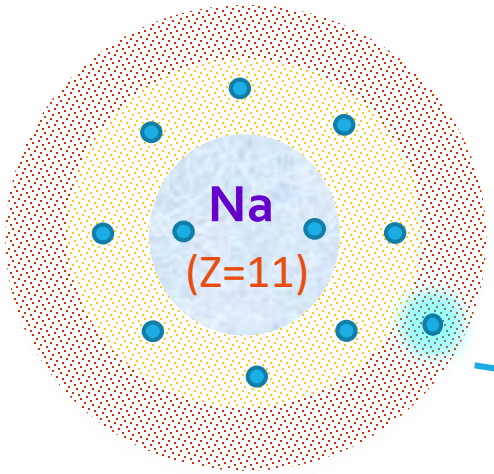
$$17(+1e) + 18(-1e) = -1e$$

Trends in Ion Formation

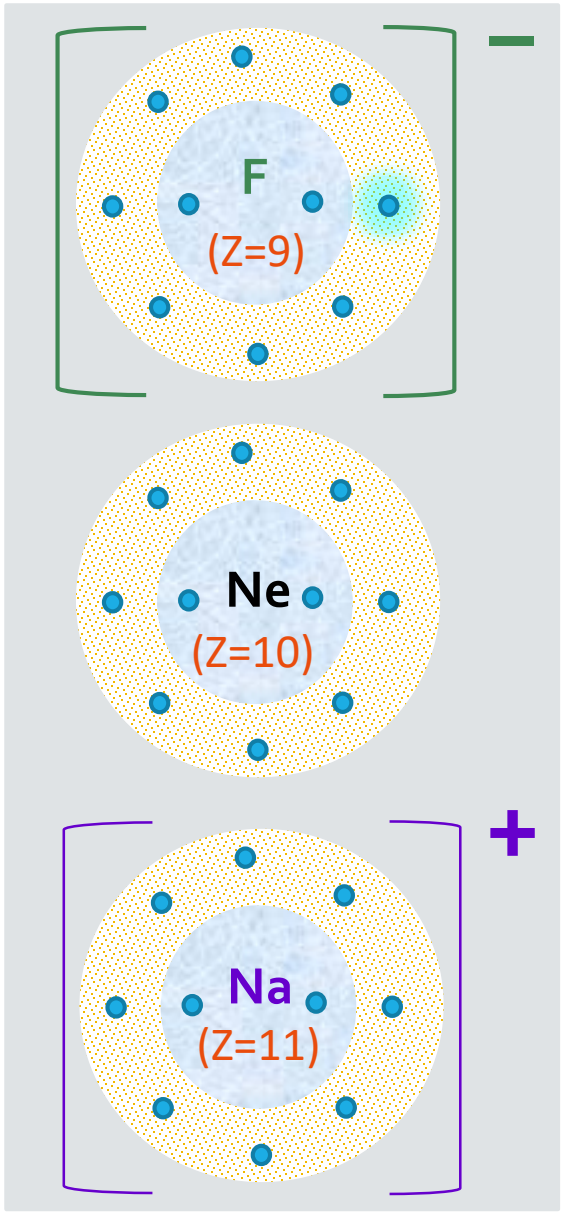
Main group elements tend to form ions that have the same number of electrons as the nearest noble gas.



fluorine gains one e^- to have same number of electrons as the closest noble gas: **neon**.



sodium loses one e^- to have same number of electrons as the closest noble gas: **neon**.

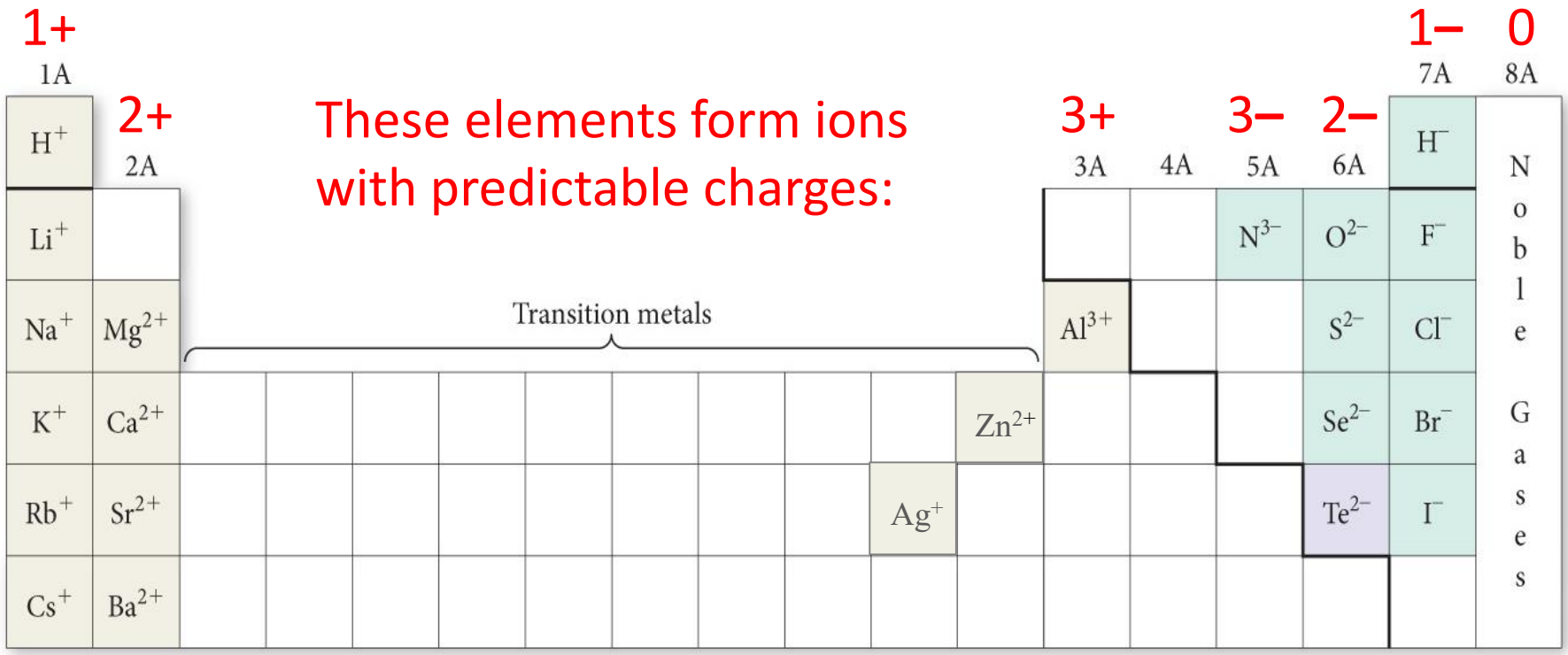


Note: To fully explain why, we use quantum mechanics, which is beyond the scope of this module.

Trend of Ionic Charges in the Periodic Table

This leads to **patterns** of ionic **charges** in the periodic table:

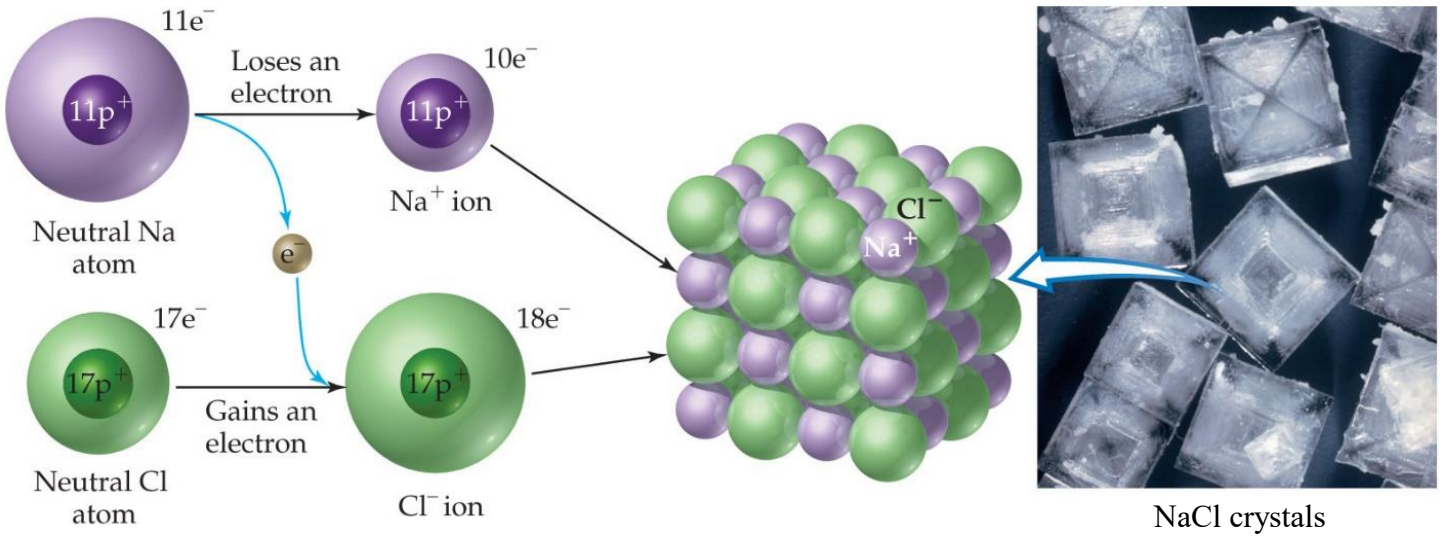
- **Column 1A** (except hydrogen) are called **Alkali** metals. They have a tendency to lose one electron and form **1+** ions.
- **2A** are called **Earth Alkali** metals. They tend to lose two electrons and form **2+** ions.
- **7A** are called **Halogens**. They tend to gain one electron and form **1–** ions.
- **6A** are called **Oxides**. They tend to gain two electrons to form **2–** ions.



Ionic Compound Formation

When a **metal** interacts with a **nonmetal,** they can form an ionic compound:

An **ionic compound** (such as NaCl) is a chemical compound in which oppositely charged ions (metals and nonmetals) are held together by electrostatic forces.



In this example:

- A sodium atom loses an electron to form a positive ion (cation): Na^+.
- A chlorine atom gains an electron to form a negative ion (anion): Cl^-.
- Na^+ and Cl^- are held together by **electrostatic forces** to form NaCl.

Naming Binary Ionic Compounds

1. The **cation** retains the **element name**

   Sodium (Na) is the name of the element. When a sodium atom loses an electron, it becomes a cation, sodium (Na^+).

2. When naming **anions** that are derived from an atom of the element, the name of the element is **modified, with the suffix –ide** added.

   Chlorine (Cl) is the name of the element. When a chlorine atom gains an electron, it becomes an anion, chloride (Cl^-).

3. When writing the chemical formula, write the symbol of the cation first and then the symbol of the anion.

NaCl → Named as: sodium chloride

Writing Formulas for Ionic Compounds

Compounds are electrically **neutral**. The sum of all the positive charges must equal the sum of all the negative charges.

- Write the symbol for the cation, then the anion, with charges determined from the periodic table:

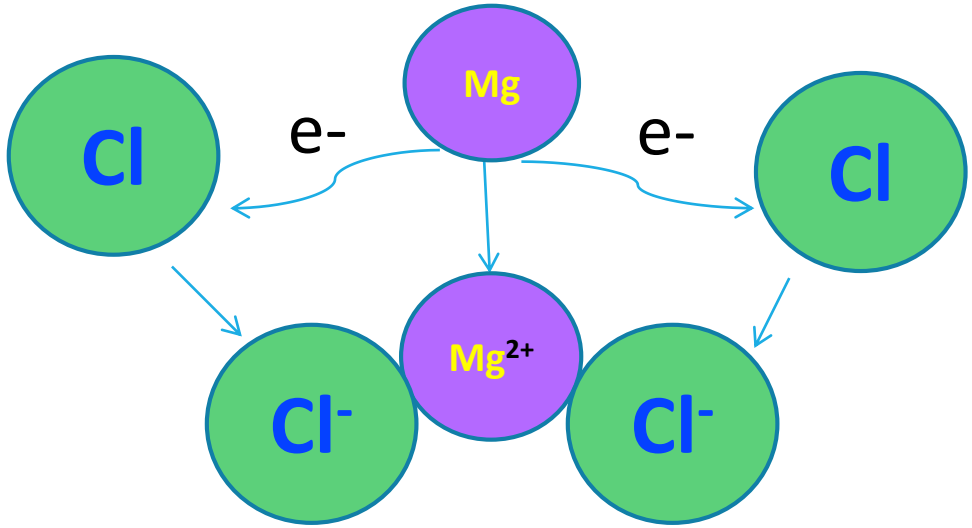
Mg^{2+} Cl^{-}

- Find the smallest number of ions that will balance the overall charge:

1 Mg^{2+} **2** Cl^{-} → $MgCl_2$

$1 \times (+2e) + 2 \times (-1e) = 0$

cations anions neutral compound



The subscript "2" means there are two chloride ions for every one magnesium ion in a magnesium chloride compound.

Writing Formulas for Ionic Compounds

You can also use the criss-cross shortcut method, but make sure you know why this works!

1. Write the individual ions.
2. Write the formula, using the charges as the subscripts on the **other** ion.
3. Simplify the subscripts to the lowest whole number ratio, if necessary.

Example: barium oxide

Ba^{+2} O^{-2}

Ba_2O_2

$$2 \times (+2e) + 2 \times (-2e) = 0$$

BUT we can **simplify** this! We only need **one** of each ion to create a neutral compound:

$$1 \times (+2e) + 1 \times (-2e) = 0$$

$Ba_1O_1 \rightarrow$ BaO

Example: aluminum oxide

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

Al_2O_3

$$2 \times (+3e) + 3 \times (-2e) = 0$$

cations anions

No simplification possible.

Examples of Binary Ionic Compounds

Full Name	Name of Cation	Name of Anion	Chemical Formula
sodium chloride	sodium (Na^+)	chloride (Cl^-)	NaCl
lithium bromide	lithium (Li^+)	bromide (Br^-)	LiBr
calcium iodide	calcium (Ca^{2+})	Iodide (I^-)	CaI_2
aluminum sulfide	aluminum (Al^{3+})	sulfide (S^{2-})	Al_2S_3
potassium oxide	potassium (K^+)	oxide (O^{2-})	K_2O
lithium hydride	lithium (Li^+)	hydride (H^{1-})	LiH
barium nitride	barium (Ba^{2+})	nitride (N^{3-})	Ba_3N_2
strontium phosphide	strontium (Sr^{2+})	phosphide (P^{3-})	Sr_3P_2

Elements That Form More Than One Ion

The highlighted elements commonly form more than one cation.

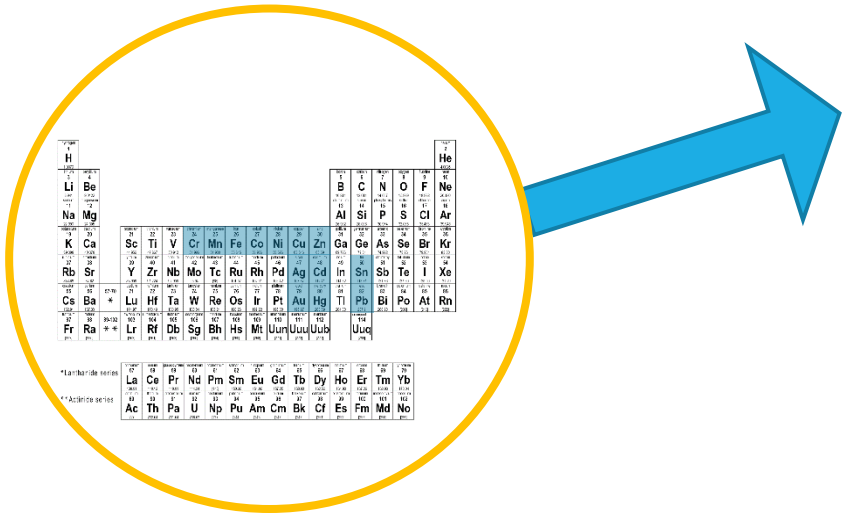
hydrogen 1 **H** 1.0079																	helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122											boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305											aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

transition metals

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

Common Metals That Form Ions with Different Charges

6	7	8	9	10	11	12	14
6+ 3+ Cr^{2+}	7+ 6+ 4+ 3+ 2+ Mn	3+ Fe^{2+}	3+ Co^{2+}	3+ Ni^{2+}	2+ Cu^{1+}	Zn^{2+}	4+ Sn^{2+}
					Ag^{1+}	Cd^{2+}	
					3+ Au^{1+}	2+ Hg^{1+}	4+ Pb^{2+}



Tin (Sn) and Lead (Pb) are main group elements that form cations with different charges. The above elements are ones that will be encountered the most.

Naming for Metals That Form More Than One Cation

- As noted previously, the cation retains the element name.
- When the metal commonly forms more than one cation, the standard way to indicate the cation's charge is to use a Roman Numeral.

Examples:

Fe^{3+} = iron(III)

Pb^{4+} = lead(IV)

Roman Numerals

One – (I)	Six – (VI)
Two – (II)	Seven – (VII)
Three – (III)	Eight – (VIII)
Four – (IV)	Nine – (IX)
Five – (V)	Ten – (X)

Two Systems for Naming Metals That Form More Than One Cation:

(a) Stock System:

The charges of cations are described by using **Roman numerals**. This is the modern method of naming and is generally used.

Ex. Iron can form two cations: Fe^{2+} & Fe^{3+}

$FeCl_2$: iron(II) chloride (formed from the Fe^{2+} ion)

$FeCl_3$: iron(III) chloride (formed from the Fe^{3+} ion)

(pronounce: iron-two chloride; iron-three chloride)

(b) Classical system:

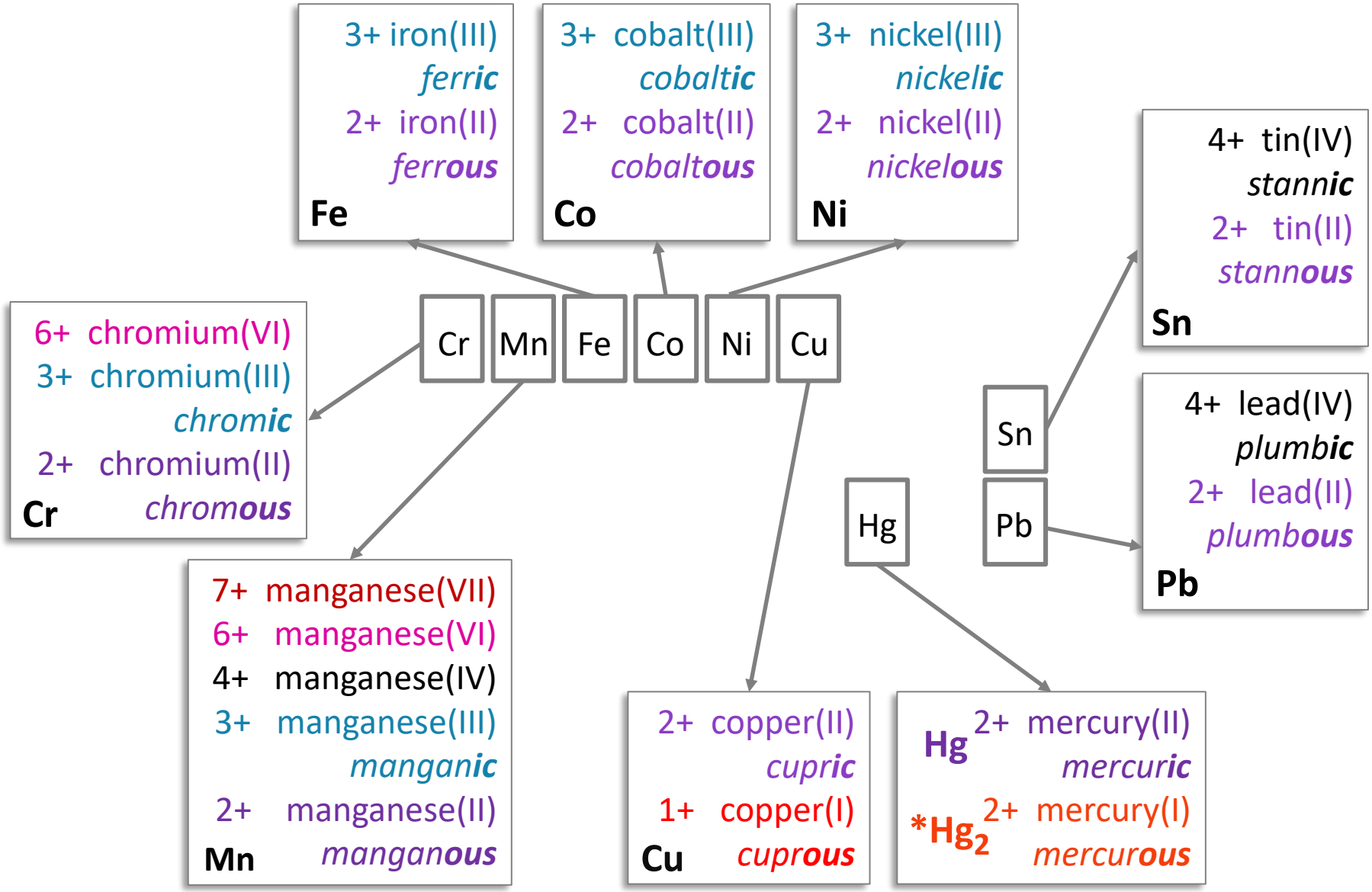
Assign the ending "**ous**" to the cations with fewer positive charges and the ending "**ic**" to the cations with more positive charges.

Ex. Iron can form two cations: Fe^{2+} & Fe^{3+}

$FeCl_2$: ferr**ous** chloride

$FeCl_3$: ferr**ic** chloride

Stock and Classical Naming Systems:

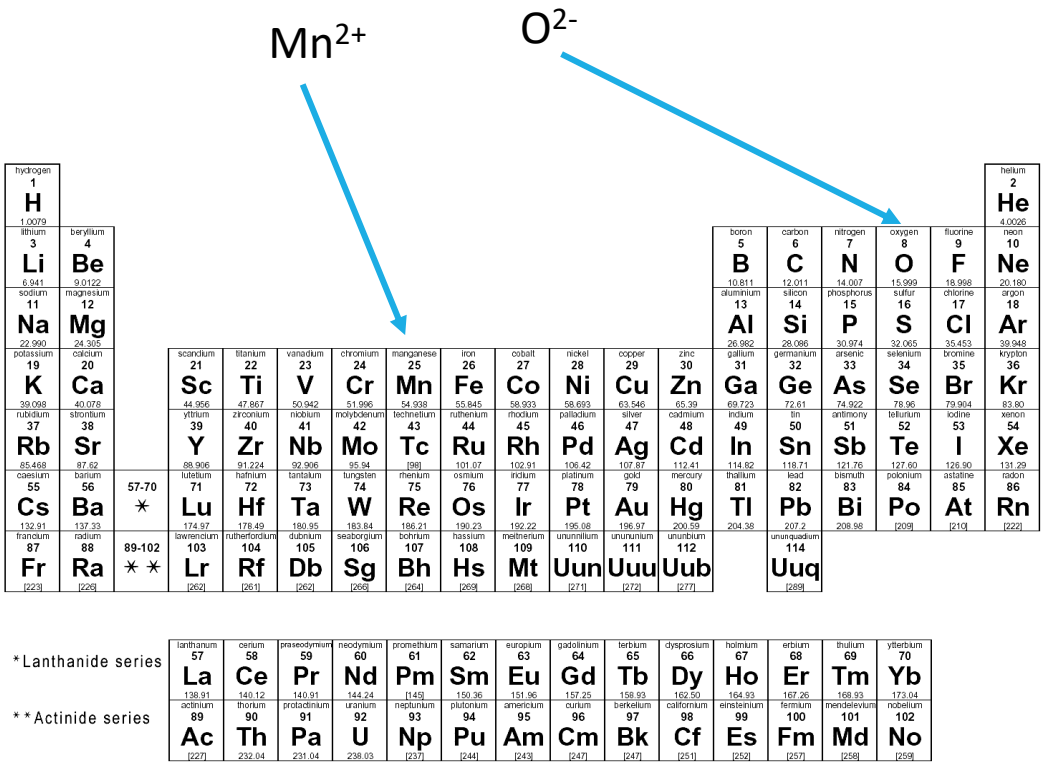


*Note : Hg^{1+} occurs as Hg_2^{2+}

Example 1

What is the name of the compound with the formula MnO?

Manganese ions can have many different charges. We'll need to work backward, using the charge on oxygen to figure out which manganese ion we have in this compound:

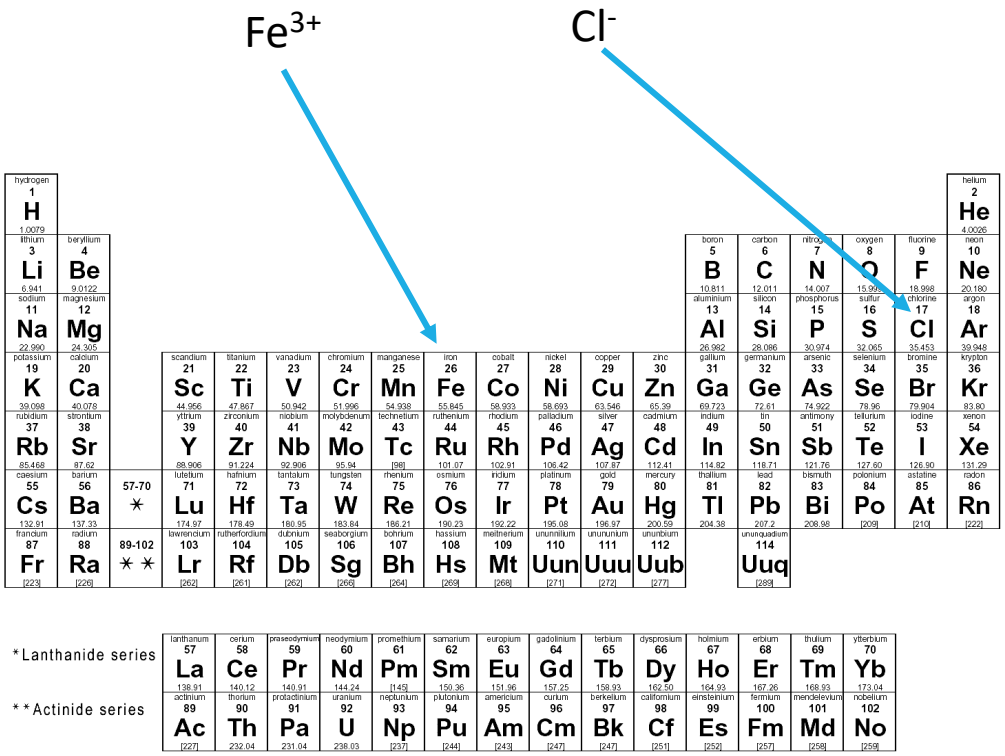


- Notice the compound is **neutral**.
- The charge of the oxygen ion is $-2e$. Because the compound is neutral, the charge of the manganese ion must be $+2e$.
- Follow the previous rules for naming binary ionic compounds:

manganese(II) oxide
manganous oxide

Example 2

What is the name of the compound with the formula $FeCl_3$?



- The compound is neutral.
- We have 3 chloride ions, each with a $-1e$ charge, summing to $-3e$.
- Therefore, the charge of the iron cation must be $+3e$.

iron(III) chloride
ferric chloride

More Examples of Binary Ionic Compounds

Chemical Formula	Name of Cation	Name of Anion	Name (Stock System)	Name (Classical System)
FeF_2	(Fe^{2+}) iron(II), ferrous	fluoride (F^-)	iron(II) fluoride	ferrous fluoride
FeF_3	(Fe^{3+}) iron(III), ferric	fluoride (F^-)	iron(III) fluoride	ferric fluoride
Cu_2O	(Cu^+) copper(I), cuprous	oxide (O^{2-})	copper(I) oxide	cuprous oxide
CuO	(Cu^{2+}) copper(II), cupric	oxide (O^{2-})	copper(II) oxide	cupric oxide
$PbBr_2$	(Pb^{2+}) lead(II), plumbous	bromide (Br^-)	lead(II) bromide	plumbous bromide
$PbBr_4$	(Pb^{4+}) lead(IV), plumbic	bromide (Br^-)	lead(IV) bromide	plumbic bromide

Practice Questions

Write the name or chemical formula for each item listed.

- lead(IV) chloride : _____
- calcium oxide : _____
- NiS : _____
- KCl : _____

Practice Questions

- lead(IV) chloride : Pb^{4+} Cl^{1-} = Pb_1Cl_4 = $PbCl_4$

You don't need to write the 1.

- calcium oxide : Ca^{2+} O^{2-} = Ca_2O_2 = CaO

Simplify the formula.

- NiS : Nickel can form more than one cation, so we start with S. S forms the S^{2-} anion, so we must have the Ni^{2+} cation.

  nickel(II) sulfide (*nickelous sulfide*)

- KCl : potassium chloride

Exercise 2

Give the names or formulas of the following binary ionic compounds. If a compound can be named by both the Stock and the Classical systems, provide both names.

1. PbO
2. NaH
3. Mg_3N_2
4. FeI_3
5. CuCl
6. $CuCl_2$
7. Sr_3P_2
8. aluminum chloride
9. calcium phosphide
10. stannous oxide
11. ferric bromide
12. ferrous bromide
13. strontium nitride
14. nickel(III) chloride

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 the basics of naming, please work through the module again, or request assistance from the SLC staff!

Exercise 1 – Key

Write names or symbols of the following elements

1.	Ca	calcium	8 . tin		Sn
2.	K	potassium	9. silicon		Si
3.	Co	cobalt	10. gold		Au
4.	Mn	manganese	11. copper		Cu
5.	Cr	chromium	12. carbon		C
6.	Fe	iron	13. neon		Ne
7.	P	phosphorus	14. bromine		Br

Exercise 2 - Key

Give the names or formulas of the following binary ionic compounds. If a compound can be named by both the Stock and the Classical systems, provide both names.

1. PbO	**plumbous/lead(II) oxide**
2. NaH	**sodium hydride**
3. Mg_3N_2	**magnesium nitride**
4. FeI_3	**ferric/iron(III) iodide**
5. CuCl	**cuprous/copper(I) chloride**
6. $CuCl_2$	**cupric/copper(II) chloride**
7. Sr_3P_2	**strontium phosphide**
8. aluminum chloride	**$AlCl_3$**
9. calcium phosphide	**Ca_3P_2**
10. stannous oxide	**SnO**
11. ferric bromide	**$FeBr_3$**
12. ferrous bromide	**$FeBr_2$**
13. strontium nitride	**Sr_3N_2**
14. nickel(III) chloride	**$NiCl_3$**