Chem With Com

Polyatomic Ions and Nomenclature

- Chapter 3.7 (Ionic and Molecular Compounds)
- Chapter 4.3 (Nomenclature)

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

Polyatomic Ions and Neutral Compounds

- Chapter 3.7 (Ionic and Molecular Compounds)

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Polyatomic Ions (many atoms with a charge)

Name	Formula
ammonium	NH_4^+
hydronium	H_3O^+
peroxide	O_2^{2-}
hydroxide	OH^-
acetate	CH_3COO^-
cyanide	CN^-
azide	N_3^-
carbonate	CO_3^{2-}
bicarbonate	HCO_3^-
nitrate	NO_3^-
nitrite	NO_2^-
sulfate	SO_4^{2-}

Name	Formula
hydrogen sulfate	HSO_4^-
sulfite	SO_3^{2-}
hydrogen sulfite	HSO_3^-
phosphate	PO_4^{3-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphate	$H_2PO_4^-$
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	ClO^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
permanganate	MnO_4^-

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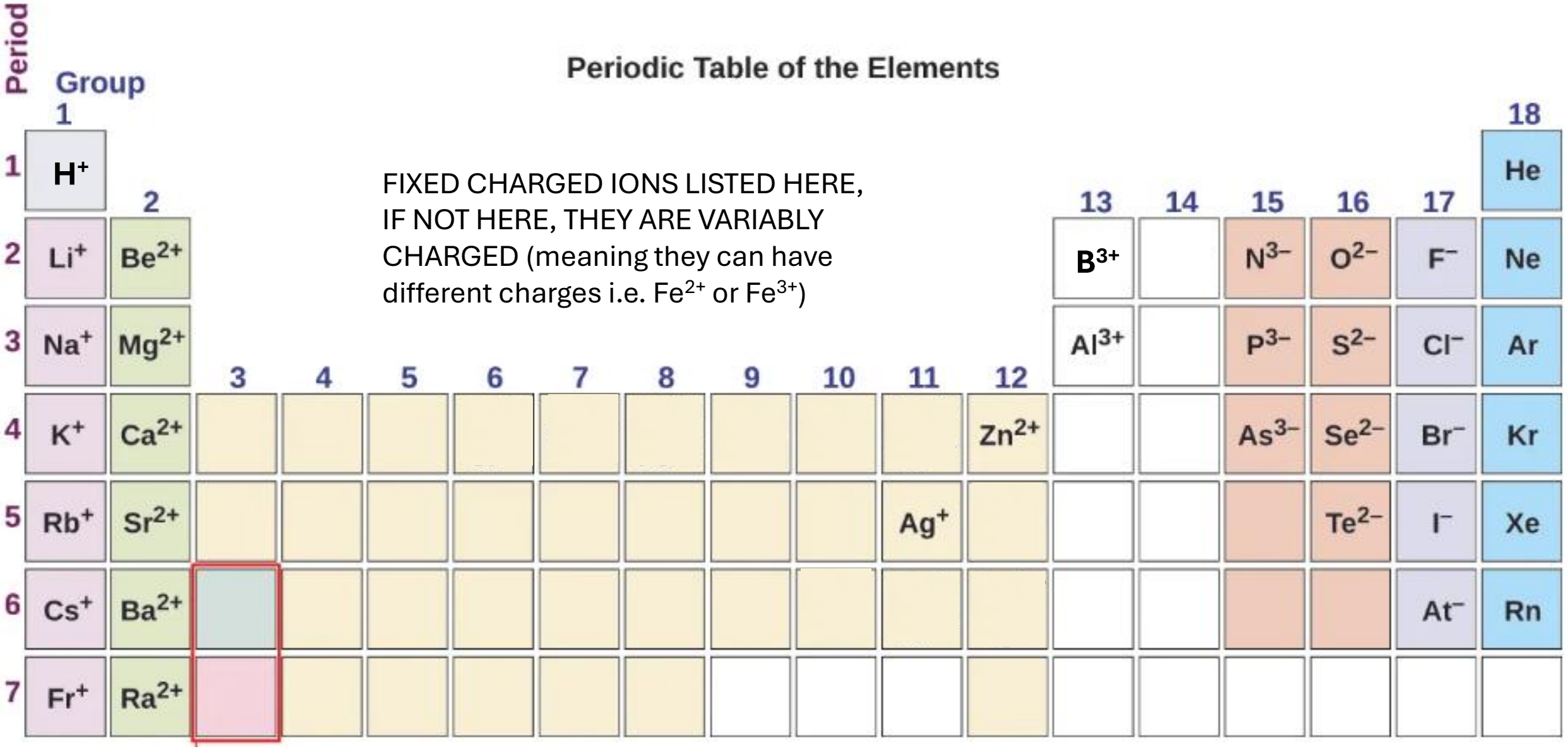
carbonate	CO_3^{2-}
bicarbonate	HCO_3^-
nitrate	NO_3^-
nitrite	NO_2^-
sulfate	SO_4^{2-}

- Will usually stay together
- “Behaves” like monoatomic ions
- Collectively, the molecule has lost or gained 1 or more electrons

Ions and the Periodic Table

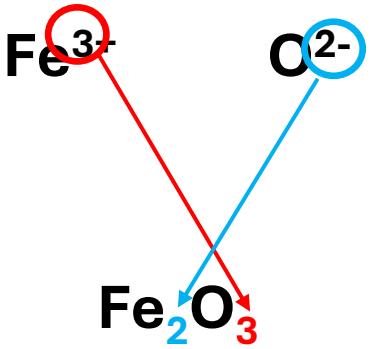


Ionic Bonds (ionic compounds)

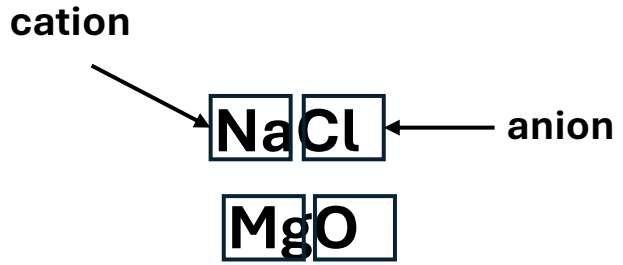
Metal + Nonmetal

(cation) Positive Charge Ion + Negative Charged Ion (anion)

		Neutral Compound
Na^{1+}	Cl^{1-}	NaCl
Mg^{2+}	O^{2-}	MgO
Ca^{2+}	F^{1-}	CaF_2
Fe^{3+}	O^{2-}	Fe_2O_3

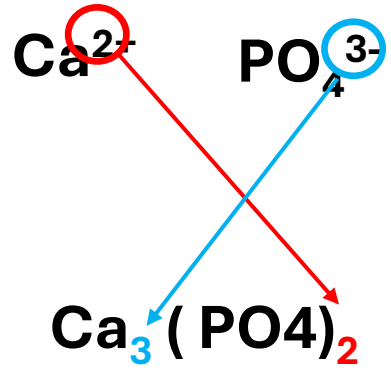


- Total charges should add up to 0
- Criss cross apple sauce shortcut (then use empirical formula
- In this class, ionic compounds will be made up of one anion and one cation



Ionic Bonds (ionic compounds)

cation + anion		Neutral Compound
Na^{1+}	NO_3^{1-}	$NaNO_3$
Mg^{2+}	SO_4^{2-}	$MgSO_4$
NH_4^{1+}	O^{2-}	$(NH_4)_2O$
Ca^{2+}	PO_4^{3-}	$Ca_3(PO4)_2$



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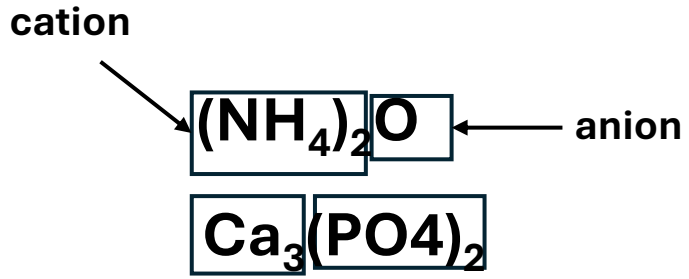

Practice Problems

1. Write the formula for a compound containing sodium and oxygen
2. Write the formula for a compound containing barium and nitrogen
3. Write the formula for a compound containing sodium and hydroxide
4. Write the formula for a compound containing ammonium and sulfur
5. Write the formula for a compound containing ammonium and carbonate

Nomenclature Info and Covalent Compounds

- Chapter 3.7 (Ionic and Molecular Compounds)
- Chapter 4.3 (Nomenclature)

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Nomenclature Classifications

- Molecular Compound – two nonmetals
- Ionic Compound – cation and anion (can be polyatomic ions)
- Acid – H (hydrogen) on the left side of the molecule or the word acid in the name. An acid is something that can donate a H to water.
- Hydrate – a water attached (i.e. molecule•$4H_2O$)

Polyatomic Ions (many atoms with a charge)

Name	Formula
ammonium	NH_4^+
hydronium	H_3O^+
peroxide	O_2^{2-}
hydroxide	OH^-
acetate	CH_3COO^-
cyanide	CN^-
azide	N_3^-
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Name	Formula
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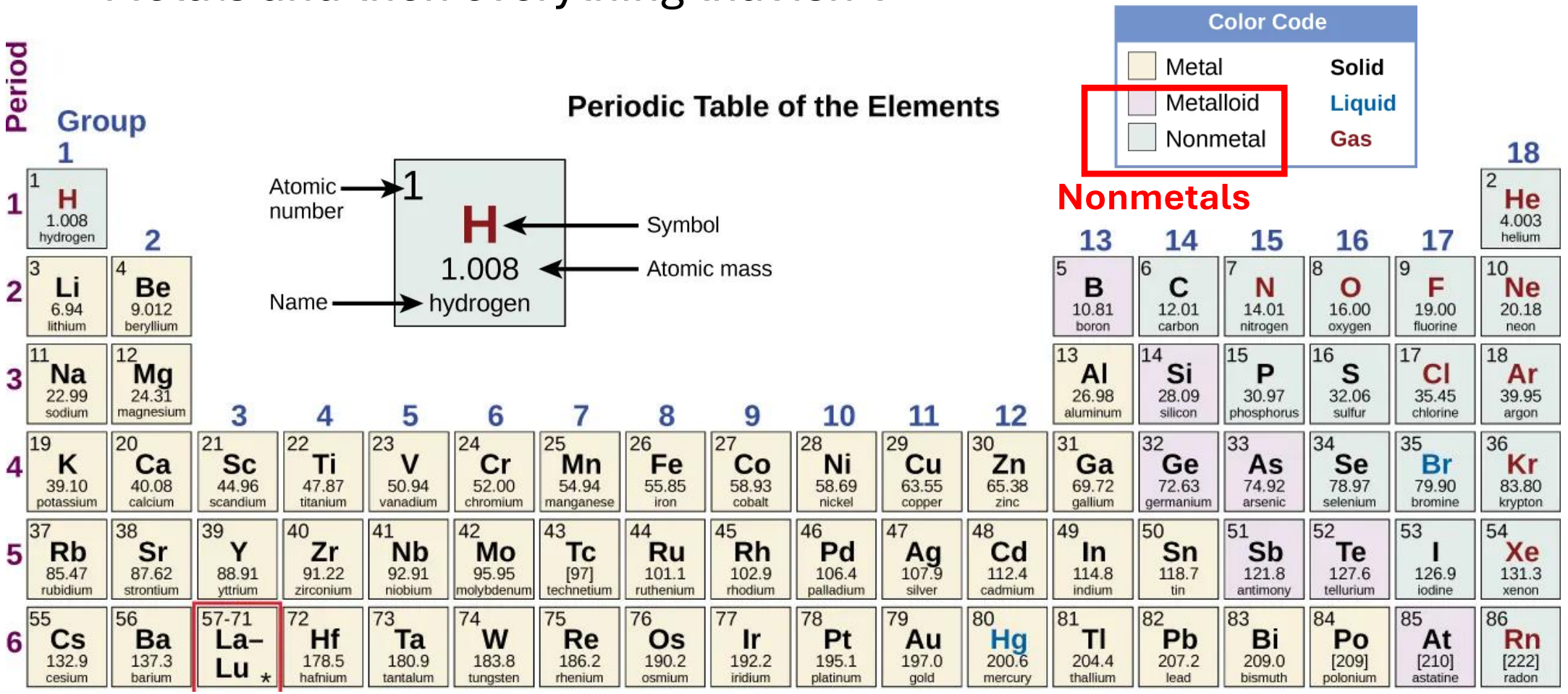
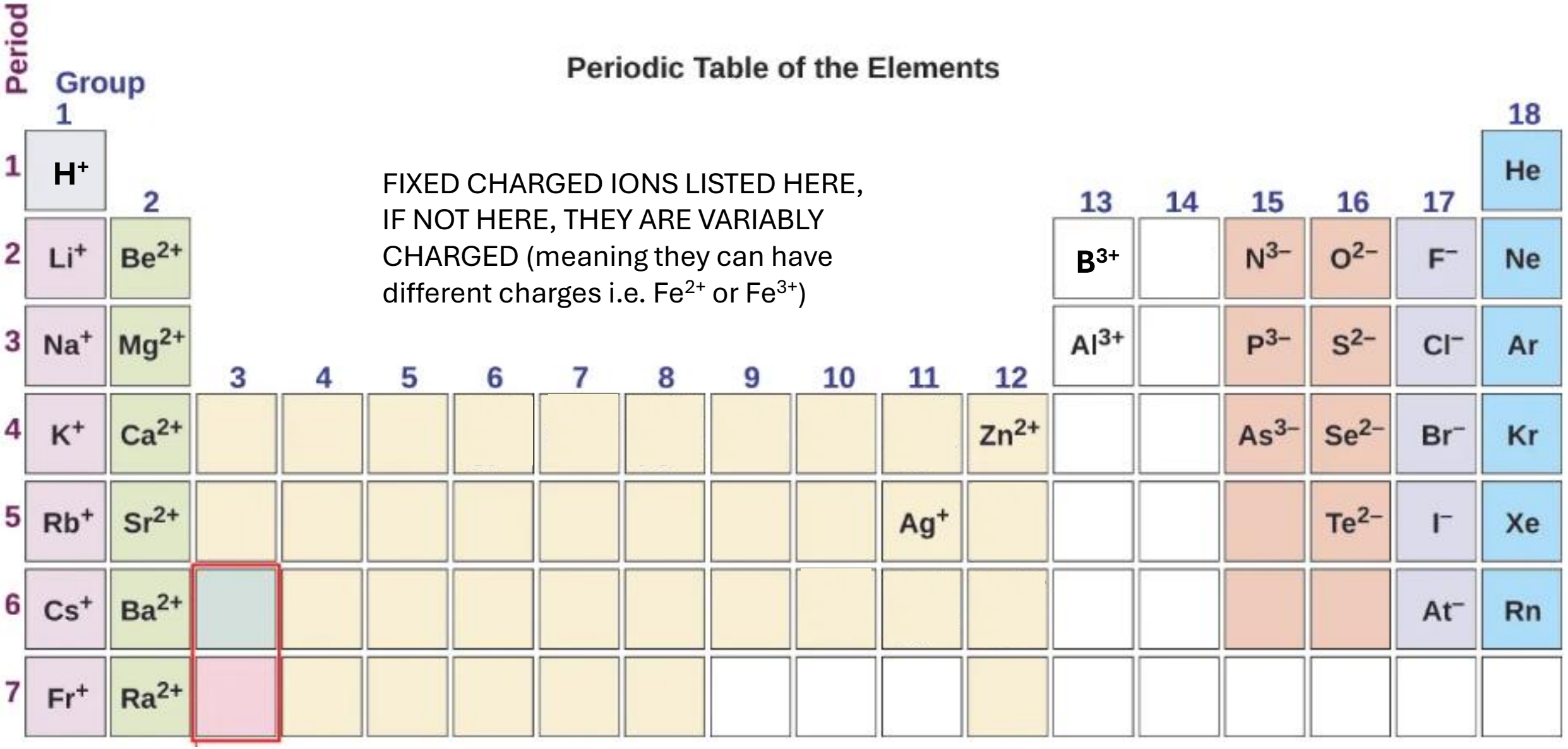
dihydrogen phosphate	$H_2PO_4^-$
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	ClO^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
permanganate	MnO_4^-

Metals vs Nonmetals (everything else)

- Metals and then everything that isn't



Fixed Charged Ions (these ions always have the same charge)



Variably Charged Ions (not complete list)

1+	2+	3+	4+	5+	6+
Cu^{1+} copper(I)	**Cu^{2+}** copper(II)				
	Fe^{2+} Iron(II)	**Fe^{3+}** Iron(III)			
Au^{1+} gold(I)		**Au^{3+}** gold(III)			
Hg_2^{2+} mercury(I)	**Hg^{2+}** mercury(II)				
		Cr^{3+} chromium(III)			**Cr^{6+}** chromium(VI)
	Pb^{2+} lead(II)		**Pb^{4+}** lead(IV)		
	Sn^{2+} tin(II)		**Sn^{4+}** tin(IV)		

Compounds with Variably Charged Ions

Some Ionic Compounds with Variably Charged Metal Ions	
Compound	**Name**
$FeCl_2$	iron(II) chloride
$FeCl_3$	iron(III) chloride
Hg_2O	mercury(I) oxide
HgO	mercury(II) oxide
SnF_2	tin(II) fluoride
SnF_4	tin(IV) fluoride

Table 4.5

Out-of-date nomenclature used the suffixes *–ic* and *–ous* to designate metals with higher and lower charges, respectively: Iron(III) chloride, $FeCl_3$, was previously called ferric chloride, and iron(II) chloride, $FeCl_2$, was known as ferrous chloride. Though this naming convention has been largely abandoned by the scientific community, it remains in use by some segments of industry. For example, you may see the words *stannous fluoride* on a tube of toothpaste. This represents the formula SnF_2, which is more properly named tin(II) fluoride. The other fluoride of tin is SnF_4, which was previously called stannic fluoride but is now named tin(IV) fluoride.

Nomenclature Prefixes for Covalent Compounds and Hydrates

Nomenclature Prefixes

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

Table 4.6

Molecular Compound

Start Here

Does the molecule have:

- Metals?
- Polyatomic Ions?
- H on left or the word "acid"

YES NO

- Metals?
- Polyatomic ions?
- H on the left or the word acid?

YES

- 1st prefix + first element + 2nd prefix + second element with ending changed to "ide"
- Leave out the prefix for the first element if there is only one of those atoms

- SF_6 sulfur hexafluoride
- N_2O dinitrogen monoxide

Names of Some Molecular Compounds Composed of Two Elements

Compound	Name	Compound	Name
SO_2	sulfur dioxide	BCl_3	boron trichloride
SO_3	sulfur trioxide	SF_6	sulfur hexafluoride
NO_2	nitrogen dioxide	PF_5	phosphorus pentafluoride
N_2O_4	dinitrogen tetroxide	P_4O_{10}	tetraphosphorus decaoxide
N_2O_5	dinitrogen pentoxide	IF_7	iodine heptafluoride

Table 4.7

Number	Prefix
1	Mono
2	Di
3	Tri
4	Tetra
5	Penta
6	Hexa
7	Hepta
8	Octa
9	Nona

Practice Problems

1. Name the compound: N_2O_3
2. Name the compound: Cl_2O_7
3. Name the compound: P_4O_6
4. Write the formula: phosphorous pentachloride
5. Write the formula: iodine heptafluoride
6. Write the formula: carbon tetrachloride
7. Write the formula: dihydrogen monoxide

Nomenclature of Ionic Compounds and Acids

- Chapter 3.7 (Ionic and Molecular Compounds)
- Chapter 4.3 (Nomenclature)

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Polyatomic Ions (the important ones for this chapter end in –ate or –ite)

Name	Formula
ammonium	NH_4^+
hydronium	H_3O^+
peroxide	O_2^{2-}
hydroxide	OH^-
acetate	CH_3COO^-
cyanide	CN^-
azide	N_3^-
carbonate	CO_3^{2-}
bicarbonate	HCO_3^-
nitrate	NO_3^-
nitrite	NO_2^-
sulfate	SO_4^{2-}
phosphite	PO_3^{3-}

Usually $C_2H_3O_2^{1-}$

Name	Formula
hydrogen sulfate	HSO_4^-
sulfite	SO_3^{2-}
hydrogen sulfite	HSO_3^-
phosphate	PO_4^{3-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphate	$H_2PO_4^-$
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	ClO^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
permanganate	MnO_4^-

How to name things:

- Have your periodic table handy that tells you which elements are metals and nonmetals and which elements have fixed charges and what those charges are (preferably the one you created)
- Have your polyatomic ion table handy (preferably the one you created)
- Below (next slide) – start in the upper left hand side where it says “Start Here” and follow the arrows appropriately.

Molecular Compound

Start Here

Does the molecule have:

- Metals?
- Polyatomic Ions?
- H on left or the word "acid"

YES NO

- Metals?
- Polyatomic ions?
- H on the left or the word acid?

YES

- 1st prefix + first element + 2nd prefix + second element with ending changed to "ide"
- Leave out the prefix for the first element if there is only one of those atoms

- SF_6 sulfur hexafluoride
- N_2O dinitrogen monoxide

Names of Some Molecular Compounds Composed of Two Elements

Compound	Name	Compound	Name
SO_2	sulfur dioxide	BCl_3	boron trichloride
SO_3	sulfur trioxide	SF_6	sulfur hexafluoride
NO_2	nitrogen dioxide	PF_5	phosphorus pentafluoride
N_2O_4	dinitrogen tetroxide	P_4O_{10}	tetraphosphorus decaoxide
N_2O_5	dinitrogen pentoxide	IF_7	iodine heptafluoride

Table 4.7

Number	Prefix
1	Mono
2	Di
3	Tri
4	Tetra
5	Penta
6	Hexa
7	Hepta
8	Octa
9	Nona

Continue Here

Does the molecule have:

- Metals?
- Polyatomic ion without an H on the left side of the molecule?

NO YES

- H on the left or the word acid?
- Polyatomic ion with an H on the left side of the molecule?

Ionic Compound with a fixed charged metal

- Name of the metal + name of the nonmetal with the ending changed to “ide”
- Make neutral compounds by making sure the charges add up to 0

NaCl	sodium chloride
AgN_3	silver nitride

Is there a:

- Fixed charge metal
- Variably charged metal
- Polyatomic Ion

Ionic Compound with a variably charged metal

- Name of the metal + charge in parentheses + name of the nonmetal with the ending changed to “ide”

Fe_2O_3	iron(III) oxide
SnO	tin(II) oxide
SnO_2	tin(IV) oxide

- How do we know the charges/formulas? We still make neutral compounds and we know one of the charges. For example for SnO_2 we know there are 2 oxygens and each oxygen has a 2- charge so there is a total negative charge of 4-. We need 4+ to make a neutral compound and since there is only 1 tin atom all of the 4+ needs to go on tin so it’s tin(IV).

Ionic Compound with a polyatomic ion

- Read the name of the cation + read the name of the anion and change the ending to “ide”

NH_4Br	ammonium bromide

- If the anion is a polyatomic ion, don’t change the ending

$(NH_4)_3PO_4$	ammonium phosphate

Continue Here

- H on the left or the word acid?

NO YES

- You messed up, go back to the first slide on nomenclature

Is there an oxygen in the acid:

- No
- Yes

Acid without an oxygen

- Hydro + name of the non-H atom/molecule with the ending changed to “ic” + acid

HCl	hydrochloric acid
HCN	hydrocyanic acid

Acid with an oxygen

- Identify the polyatomic ion in the acid and see if it ends in –ate or –ite. Remove all the H’s and whatever is left is the polyatomic ion.

- If ending in “ate” say the base name of the ion and then change the ending to “ic” + acid

HNO_3	(polyatomic ion = nitrate)	nitric acid
H_2CO_3	(polyatomic ion = carbonate)	carbonic acid

- If ending in “ite” say the base name of the ion and then change the ending to “ous” + acid

$HClO_2$	(polyatomic ion = chlorite)	chlorous acid
HClO	(polyatomic ion = hypochlorite)	hypochlorous acid

- Sometimes the base names are weird and don’t exactly follow the rules

H_2SO_4	should be sulfic acid but it’s actually sulfuric acid
H_2PO_3	should be phosphous acid but it’s actually phosphorous acid

- If the acid is written as a gas i.e. HCl (g) or H_2SO_4 (g) then it is not an acid because it cannot donate the hydrogen to water to it would be named as a molecular compound i.e. HCl (g) is hydrogen chloride

Other Situations - hydrates

Regular name of the ionic compound + prefix and “hydrate”

$MgSO_4 \bullet 7H_2O$	magnesium sulfate heptahydrate	epsom salts
$Na_2CO_3 \bullet 10H_2O$	sodium carbonate decahydrate	washing soda

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

How to figure out formulas? Make neutral compounds. Use the information that we know.

- Fe_2O_3 – we know oxygen is 2- and there are 3 of them so the total negative charge is 6-. Since the molecule is neutral, it must have 6+ charges. There are 2 Fe atoms so each Fe atom has a 3+ charge so the name is iron(III) oxide.
- FeO
- PbF_2
- PbF_4

How to figure out formulas? Make neutral compounds. Use the information that we know.

- Sulfurous Acid – since the acid ends in “ous”, the polyatomic ion is sulfite which is SO_3^{2-}, each hydrogen is H^{1+} so you would need 2 hydrogen to make a neutral compound so it is H_2SO_3

- Phosphoric Acid -

- Nitrous Acid -

- Acetic Acid -

More Practice Problems

1. What is the name for this compound: $MgCl_2$

2. What is the name for this compound: $CuCl_2$

3. What is the name for this compound: $(NH_4)_2CO_3$

4. What is the formula for this compound: ammonium sulfate

5. What is the name for this compound: $NaHSO_4$

6. What is the name for this compound: $H_2Cr_2O_7$

7. What is the name for this compound (pay attention to the (g): HCl (g)