Chapter 9

"Chemical Names and Formulas"

Section 9.1
Naming Ions

- OBJECTIVES:
  - Identify the charges on monatomic ions by using the periodic table, and name the ions.

Section 9.1
Naming Ions

- OBJECTIVES:
  - Define a polyatomic ion and write the names and formulas of the most common polyatomic ions.

Section 9.1
Naming Ions

- OBJECTIVES:
  - Identify the two common *endings* for the names of most polyatomic ions.

Atoms and Ions

- Atoms are electrically neutral.
  - Because there is the same number of protons (+) and electrons (-).
- Ions are atoms, or groups of atoms, with a charge (positive or negative)
  - They have *different* numbers of protons and electrons.
- Only *electrons* can move, and **ions** are made by gaining or losing electrons.

An Anion is…

- A negative ion.
- Has gained electrons.
- Nonmetals can gain electrons.
- Charge is written as a superscript on the right.

F^{1-} Has gained one electron (-ide is new ending = fluoride)

O^{2-} Gained two electrons (oxide)

A Cation is…

- A positive ion.
- Formed by losing electrons.
- More protons than electrons.
- Metals can lose electrons

K^{1+} Has lost one electron (no name change for positive ions)

Ca^{2+} Has lost two electrons

Predicting Ionic Charges

<u>Group 1A</u>: Lose 1 electron to form 1+ ions

H^{1+} Li^{1+} Na^{1+} K^{1+} Rb^{1+}

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
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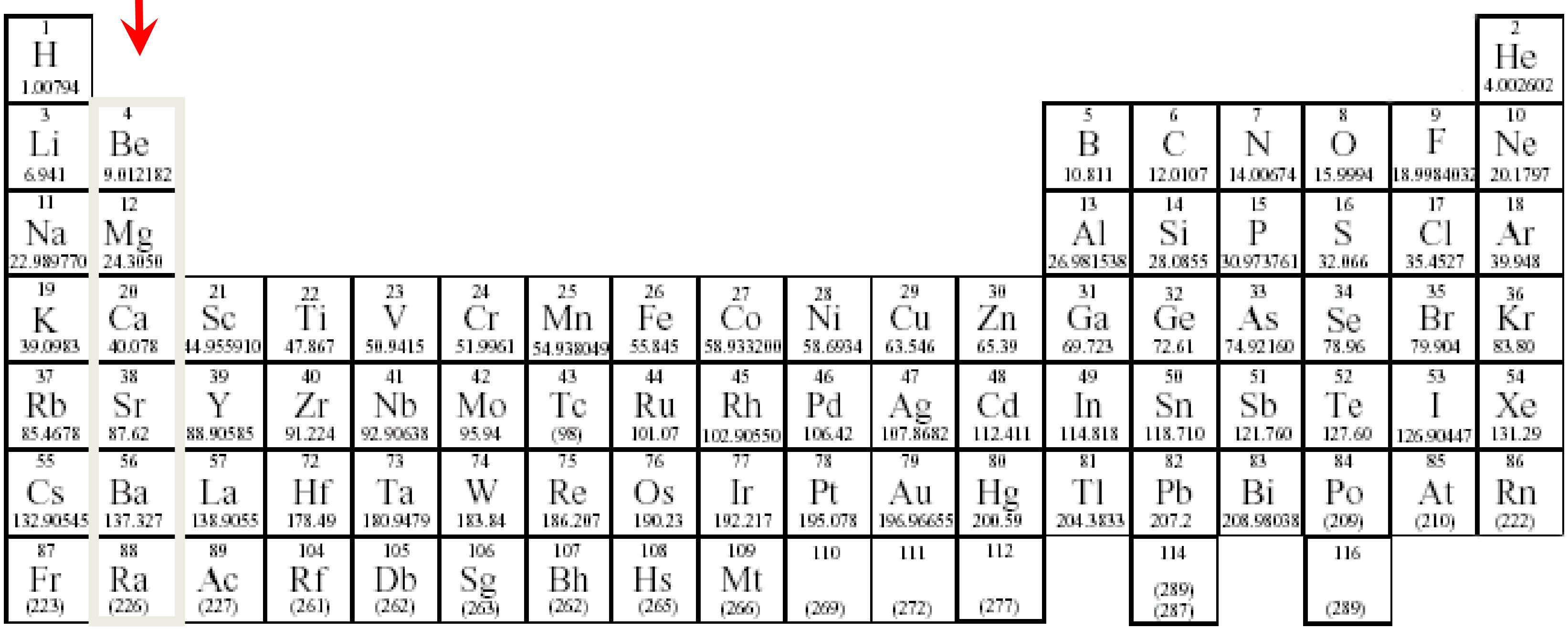
Predicting Ionic Charges

<u>Group 2A</u>: Loses 2 electrons to form 2+ ions

Be^{2+} Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+}



Predicting Ionic Charges

B^{3+} Al^{3+} Ga^{3+}

Group 3A: Loses 3 electrons to form 3+ ions

1 H 1.00794																	2 He 4.002602
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19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
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Predicting Ionic Charges

Neither! Group 4A elements rarely form ions (they tend to share)

<u>Group 4A</u>: Do they *lose* 4 electrons or *gain* 4 electrons?

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
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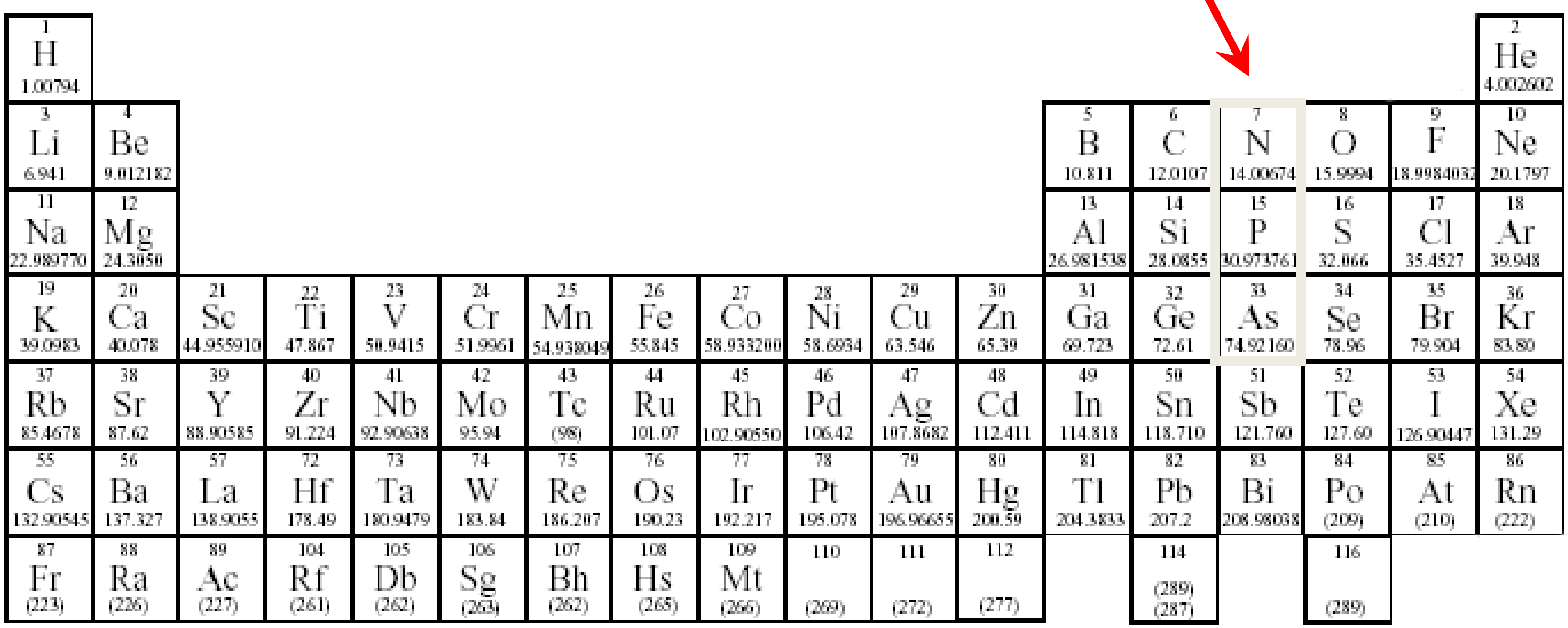
Predicting Ionic Charges

N^{3-} Nitride

P^{3-} Phosphide

As^{3-} Arsenide

Group 5A: Gains 3 electrons to form 3- ions



Predicting Ionic Charges

O^{2-} Oxide

S^{2-} Sulfide

Se^{2-} Selenide

Group 6A: Gains 2 electrons to form 2- ions

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
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Predicting Ionic Charges

F^{1-} Fluoride Br^{1-} Bromide

Cl^{1-} Chloride I^{1-} Iodide

<u>Group 7A</u>: Gains 1 electron to form 1- ions

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
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Predicting Ionic Charges

Group 8A: Stable noble gases do not form ions!

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
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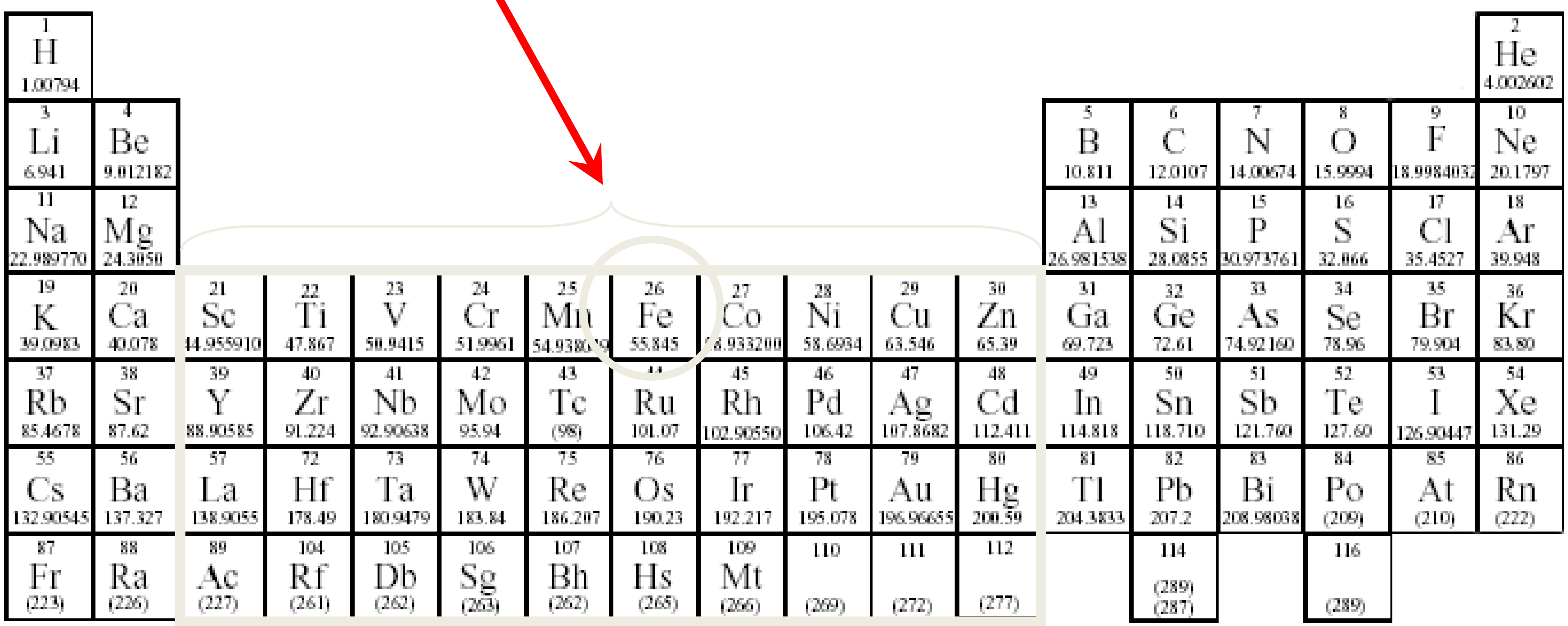
Predicting Ionic Charges

<u>Group B elements</u>: Many **transition** **elements have *more than one* possible oxidation state.**

Note the use of **Roman numerals** to show charges

Iron (II) = Fe^{2+}

Iron (III) = Fe^{3+}



Naming cations

- Two methods can clarify when more than one charge is possible:

1) **Stock system** – uses ***roman numerals*** in parenthesis to indicate the numerical value
2) **Classical method** – uses root word with ***suffixes*** (-ous, -ic)
    - Does not give true value

Naming cations

- We will use the **Stock system**.
- Cation - if the charge is always the same (like in the Group A metals) just write the name of the metal.
- Transition metals can have more than one type of charge.
  - Indicate their charge as a ***roman numeral*** in parenthesis after the name of the metal (Table 9.2, p.255)

Predicting Ionic Charges

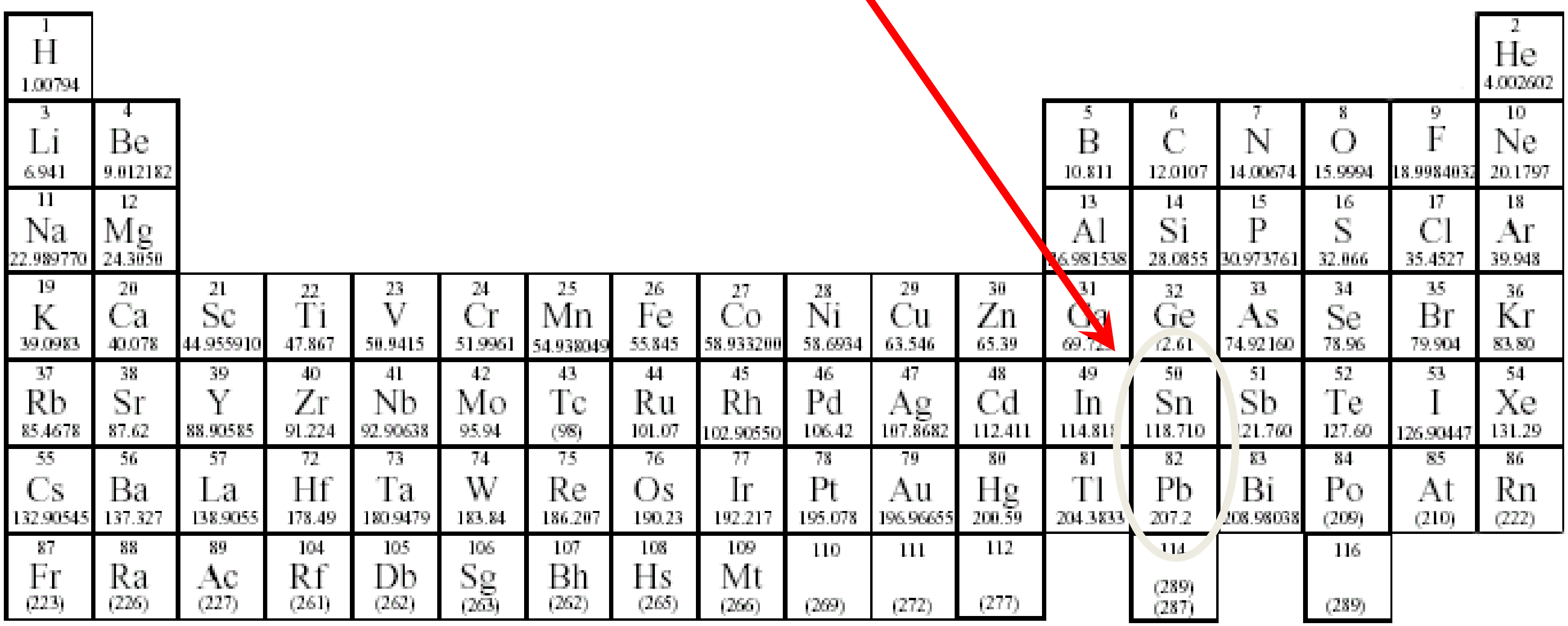
Some of the post-transition elements also have *more than one* possible oxidation state.

Tin (II) = Sn^{2+}

Tin (IV) = Sn^{4+}

Lead (II) = Pb^{2+}

Lead (IV) = Pb^{4+}



Predicting Ionic Charges

Group B elements: **Some transition elements have *only one* possible oxidation state, such as these three:**

Silver = Ag^{1+} **Zinc = Zn^{2+}** **Cadmium = Cd^{2+}**

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
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Exceptions:

- Some of the transition metals have only one ionic charge:
  - **Do not** need to use roman numerals for these:
  - Silver is **always** 1+ (**Ag^{1+}**)
  - Cadmium and Zinc are **always** 2+ (**Cd^{2+}** and **Zn^{2+}**)

Practice by naming these:

- **Na^{1+}**
- **Ca^{2+}**
- **Al^{3+}**
- **Fe^{3+}**
- **Fe^{2+}**
- **Pb^{2+}**
- **Li^{1+}**

Write symbols for these:

- Potassium ion
- Magnesium ion
- Copper (II) ion
- Chromium (VI) ion
- Barium ion
- Mercury (II) ion

Naming Anions

- Anions are always the same charge
- Change the monatomic element ending to – ide
- **F^{1-}** a Fluorine atom will become a Fluoride ion.

Practice by naming these:

- **Cl^{1-}**
- **N^{3-}**
- **Br^{1-}**
- **O^{2-}**
- **Ga^{3+}**

Write symbols for these:

- Sulfide ion
- Iodide ion
- Phosphide ion
- Strontium ion

Polyatomic ions are…

- Groups of atoms that stay together and have an overall charge, and one name.
- **Usually end in –ate or -ite**
- Acetate: $\mathbf{C_2H_3O_2^{1-}}$
- Nitrate: $\mathbf{NO_3^{1-}}$
- Nitrite: $\mathbf{NO_2^{1-}}$
- Permanganate: $\mathbf{MnO_4^{1-}}$
- Hydroxide: $\mathbf{OH^{1-}}$ and Cyanide: $\mathbf{CN^{1-}}$?

Know Table 9.3 on page 257

- Sulf<u>ate</u>: SO_4^{2-}
- Sulf<u>ite</u>: SO_3^{2-}
- Carbon<u>ate</u>: CO_3^{2-}
- Chrom<u>ate</u>: CrO_4^{2-}
- Dichrom<u>ate</u>: $Cr_2O_7^{2-}$

- Phosph<u>ate</u>: PO_4^{3-}
- Phosph<u>ite</u>: PO_3^{3-}

- Ammonium: NH_4^{1+}
  (One of the few positive polyatomic ions)

If the polyatomic ion begins with H, then combine the word hydrogen with the other polyatomic ion present:

H^{1+} + CO_3^{2-} → HCO_3^{1-}

hydrogen + carbonate → hydrogen carbonate ion

Section 9.2 Naming and Writing Formulas for Ionic Compounds

- OBJECTIVES:
  - Apply the rules for *naming and writing formulas* for binary ionic compounds.

Section 9.2 Naming and Writing Formulas for Ionic Compounds

- OBJECTIVES:
  - Apply the rules for *naming and writing formulas* for compounds containing polyatomic ions.

Writing Ionic Compound Formulas

Example: Barium nitrate (note the 2 word name)

1. Write the formulas for the cation and anion, including CHARGES!

$Ba^{2+}(NO_3^-)_2$

Now balanced.

Not balanced!

$= Ba(NO_3)_2$

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion. Use the *criss-cross* method to balance subscripts.

Writing Ionic Compound Formulas

Example: Ammonium sulfate (note the 2 word name)

1. Write the formulas for the cation and anion, including CHARGES!

$$(NH_4^{+})_2 SO_4^{2-}$$

2. Check to see if charges are balanced.

Now balanced.

Not balanced!

$$= (NH_4)_2SO_4$$

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion. Use the *criss-cross* method to balance the subscripts.

Writing Ionic Compound Formulas

Example: Iron (III) chloride (note the 2 word name)

1. Write the formulas for the cation and anion, including <u>CHARGES</u>!

Fe^{3+} Cl^{-}_{3}

Now balanced.

Not balanced!

= $FeCl_3$

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a <u>polyatomic ion</u>. Use the *criss-cross* method to balance the subscripts.

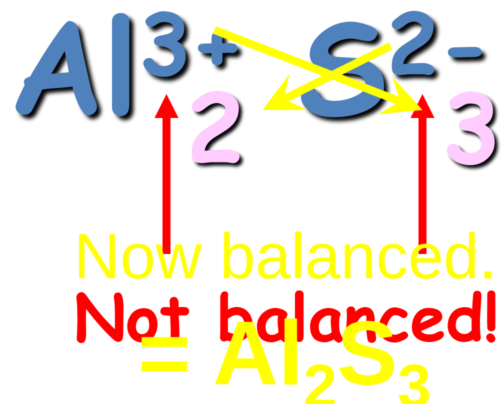
Writing Ionic Compound Formulas

Example: Aluminum sulfide (note the 2 word name)

1. Write the formulas for the cation and anion, including <u>CHARGES</u>!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a <u>polyatomic ion</u>. Use the *criss-cross* method to balance the subscripts.



Writing Ionic Compound Formulas

Example: Magnesium carbonate (note the 2 word name)

1. Write the formulas for the cation and anion, including <u>CHARGES</u>!

2. Check to see if charges are balanced.

Mg^{2+} CO_3^{2-}

They <u>are</u> balanced!

= $MgCO_3$

Writing Ionic Compound Formulas

Example: Zinc hydroxide (note the 2 word name)

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion. Use the *criss-cross* method to balance the subscripts.

$Zn^{2+} (OH^{-})_2$

Not balanced!

Now balanced.

$= Zn(OH)_2$

Writing Ionic Compound Formulas

Example: Aluminum phosphate (note the 2 word name)

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

Al^{3+} PO_4^{3-}

They ARE balanced!

$= AlPO_4$

Naming Ionic Compounds

- 1. Name the cation first, then anion

- 2. Monatomic cation = name of the element

  Ca^{2+} = calcium ion

- 3. Monatomic anion = root + -ide

  Cl^{-} = chloride

  $CaCl_2$ = calcium chloride

Naming Ionic Compounds
(Metals with multiple oxidation states)

- some metals can form more than one charge (usually the transition metals)
- use a Roman numeral in their name:

$PbCl_2$ – use the ***anion*** to find the charge on the cation (chloride is always 1-)

Pb^{2+} is the lead (II) cation

$PbCl_2$ = lead (II) chloride

Things to look for:

1) If cations have ( ), the number in parenthesis is their charge.
2) If anions end in -ide they are probably off the periodic table (Monoatomic)
3) If anion ends in -ate or –ite, then it is polyatomic

Practice by writing the formula or name as required…

- Iron (II) Phosphate
- Stannous Fluoride
- Potassium Sulfide
- Ammonium Chromate
- $MgSO_4$
- $FeCl_3$

Section 9.3
Naming and Writing Formulas for Molecular Compounds

- OBJECTIVES:
  - Interpret the *prefixes* in the names of **molecular compounds** in terms of their chemical formulas.

Section 9.3
Naming and Writing Formulas for Molecular Compounds

- OBJECTIVES:
  - Apply the rules for naming and writing formulas for binary molecular compounds.

Molecular compounds are…

- made of just ***nonmetals***
- smallest piece is a <u>molecule</u>
- can’t be held together by opposite charge attraction
- can’t use charges to figure out how many of each atom (there are *no charges present*)

Molecular compounds are easier!

- Ionic compounds use *charges* to determine how many of each.
  - You have to figure out charges.
  - May need to criss-cross numbers.
- Molecular compounds: the **name tells you** the number of atoms.
  - Uses **prefixes** to tell you the exact number of each element present!

Prefixes (Table 9.4, p.269)

- 1 = mono-
- 2 = di-
- 3 = tri-
- 4 = tetra-
- 5 = penta-
- 6 = hexa-
- 7 = hepta-
- 8 = octa-

Prefixes

- 9 = nona-
- 10 = deca-
- To write the name, write two words:

Prefix & name   Prefix & name -ide

Prefixes

- 9 = nona-
- 10 = deca-
- To write the name, write two words:

Prefix name   Prefix name -ide

- One exception is we don't write **mono** if there is only one of the first element.

Prefixes

- 9 = nona-
- 10 = deca-
- To write the name, write two words:

Prefix name   Prefix name -ide

- One exception is we don't write mono if there is only one of the first element.
- Normally, we do not have double vowels when writing names (oa oo)

Practice by naming these:

- N_2O = dinitrogen monoxide
  (also called nitrous oxide or laughing gas)
- NO_2 = nitrogen dioxide
- Cl_2O_7 = dichlorine heptoxide
- CBr_4 = carbon tetrabromide
- CO_2 = carbon dioxide
- $BaCl_2$ (This one will not use prefixes, since it is an ionic compound!)

Write formulas for these:

- diphosphorus pentoxide
- tetraiodine nonoxide
- sulfur hexafluoride
- nitrogen trioxide
- carbon tetrahydride
- phosphorus trifluoride
- aluminum chloride (Ionic compound)

Section 9.4
Naming and Writing Formulas for Acids and Bases

- OBJECTIVES:
  - Apply three rules for naming acids.

Section 9.4
Naming and Writing Formulas for Acids and Bases

- OBJECTIVES:
  - Apply the rules in reverse to write formulas of acids.

Section 9.4
Naming and Writing Formulas for Acids and Bases

- OBJECTIVES:
  - Apply the rules for naming bases.

Acids are…

- Compounds that give off hydrogen ions (H^{1+}) when dissolved in water (the Arrhenius definition)
- Will start the formula with H.
- There will always be some Hydrogen next to an anion.
- The **anion** determines the name.

Rules for Naming acids: Name it as a normal compound first

1) If the anion attached to hydrogen ends in -ide, put the prefix hydro- and change -ide to -ic acid

- HCl - hydrogen ion and chloride ion = **hydro**chlor**ic acid**
- H_2S hydrogen ion and sulfide ion = **hydro**sulfur**ic acid**

Naming Acids

- If the anion has oxygen in it, then it ends in -ate or -ite

2) change the suffix **-ate** to **-ic acid** (use no prefix)
   - Example: HNO_3 Hydrogen and nitr**ate** ions = Nitr**ic acid**
3) change the suffix **-ite** to **-ous acid** (use no prefix)
   - Example: HNO_2 Hydrogen and nitr**ite** ions = Nitr**ous acid**

Naming Acids

Normal ending	Acid name is…
_____-ide	hydro-____-ic acid
_____-ate	______-ic acid
_____-ite	______-ous acid

2 additional rules (not mentioned in the book)

4) If the acid has 1 more oxygen than the –ic acid, add the prefix per-
    a. $HClO_3$ (Hydrogen Chlorate) is chloric acid
    b. $HClO_4$ would be perchloric acid
5) If there is 1 less oxygen than the -ous acid, add the prefix hypo-
    - $HClO_2$ (Hydrogen Chlorite) is chlorous acid, then HClO would be hypochlorous acid

Practice by naming these:

- **HF**
- **H_3P**
- **H_2SO_4**
- **H_2SO_3**
- **HCN**
- **H_2CrO_4**

Writing Acid Formulas – in reverse!

- Hydrogen will be listed first
- The name will tell you the anion
- Be sure the charges cancel out.
- Starts with prefix hydro?- there is no oxygen, -ide ending for anion
- no prefix hydro?
  1) -ate anion comes from –ic ending
  2) -ite anion comes from –ous ending

Write formulas for these:

- hydroiodic acid
- acetic acid
- carbonic acid
- phosphorous acid
- hydrobromic acid

Names and Formulas for Bases

- A base is an ionic compound that produces hydroxide ions (OH^{1-}) when dissolved in water (the Arrhenius definition)
- Bases are named the same way as other ionic compounds:
  - The name of the cation (which is a metal) is followed by the name of the anion (which will be hydroxide).

Names and Formulas for Bases

- NaOH is sodium hydroxide
- $Ca(OH)_2$ is calcium hydroxide
- To write the formula:

1) Write the symbol for the metal cation
2) followed by the formula for the hydroxide ion (OH^{1-})
3) then use the criss-cross method to balance the charges.

Practice by writing the formula for the following:

- Magnesium hydroxide
- Iron (III) hydroxide
- Zinc hydroxide

Section 9.5
The Laws Governing Formulas and Names

- OBJECTIVES:
  - Define the laws of definite proportions and multiple proportions.

Section 9.5
The Laws Governing Formulas and Names

- OBJECTIVES:
  - Apply the rules for naming chemical compounds by using a flowchart.

Section 9.5
The Laws Governing Formulas and Names

- OBJECTIVES:
  - Apply the rules for writing the formulas of chemial compounds by using a flowchart.

Some Laws:

- 1. Law of Definite Proportions- in a sample of a chemical compound, the masses of the elements are always in the same proportions.
- H_2O (water) and H_2O_2 (hydrogen peroxide)

Some Laws:

- 2. Law of Multiple Proportions- Dalton stated that whenever two elements form more than one compound, the *different masses of one element* that combine with the *same mass of the other element* are in the ratio of small whole numbers.

SAMPLE PROBLEM 9.1

Calculating Mass Ratios - Page 275

Carbon reacts with oxygen to form two compounds. Compound A contains 2.41 g of carbon for each 3.22 g of oxygen. Compound B contains 6.71 g of carbon for each 17.9 g of oxygen. What is the lowest whole number mass ratio of carbon that combines with a given mass of oxygen?

1 Analyze ***List the knowns and the unknown.***

Knowns

- Compound A = 2.41 g C and 3.22 g O
- Compound B = 6.71 g C and 17.9 g O

Unknown

- Lowest whole number ratio of carbon per gram of oxygen in the two compounds = ?

Apply the law of multiple proportions to the two compounds. For each compound, find the grams of carbon that combine with 1.00 g of oxygen by dividing the mass of carbon by the mass of oxygen. Then find the ratio of the masses of carbon in the two compounds by dividing the larger value by the smaller. Confirm that the ratio is the lowest whole number ratio.

2 Calculate ***Solve for the unknown.***

- Compound A $\frac{2.41 \text{ g C}}{3.22 \text{ g O}} = \frac{0.748 \text{ g C}}{1.00 \text{ g O}}$
- Compound B $\frac{6.71 \text{ g C}}{17.9 \text{ g O}} = \frac{0.375 \text{ g C}}{1.00 \text{ g O}}$

Same mass of oxygen

Compare the masses of carbon per gram of oxygen in the compounds.

$$\frac{0.748 \text{ g C (in compound A)}}{0.375 \text{ g C (in compound B)}} = \frac{1.99}{1} = \text{roughly } \frac{2}{1} = 2:1$$

The mass ratio of carbon per gram of oxygen in the two compounds is 2:1.

Summary of Naming and Formula Writing

- For naming, follow the flowchart- Figure 9.20, page 277
- For writing formulas, follow the flowchart from Figure 9.22, page 278

Helpful to remember...

1. In an ionic compound, the net ionic charge is zero (criss-cross method)
2. An *-ide* ending generally indicates a binary compound
3. An *-ite* or *-ate* ending means there is a polyatomic ion that has oxygen
4. Prefixes generally mean molecular; they show the number of each atom

Helpful to remember...

5. A Roman numeral after the name of a cation is the ionic charge of the cation

- Use the **handout sheets** provided by your teacher!

End of Chapter 9