Nomenclature Worksheet Part 1-Ionic compounds[1]

Ionic compounds are composed of cations and anions. Most cations are made from metals. The cation is a positively charged species. Cations have fewer electrons than protons; this gives cations their characteristic positive charge. Cations are formed by an atom losing one, two, or three electrons, which leads to a completely filled outer shell of electrons [a noble gas core with a smaller Z than the atom]. Anions are made from non-metals. Anions have more electrons than protons; this gives anions their characteristic negative charge. Gaining one, two, or three electrons forms anions, which leads to a completely filled outer shell of electrons [a noble gas core with a larger Z than the atom]

Transition metals form cations, but the charges are much harder to predict. Some transition metals have more than one form of a cation. For example iron forms two different cations, iron(II) and iron(III). The iron(II) ion, written Fe^{2+}, is formed by losing 2 outer electrons from the 4s orbital, while losing 2 valence electrons from 4s and one from 3d forms Fe^{3+}. because the transition cations generally have *d* electrons that the nearest noble gas does not have, the octet rule is not followed.

Before we can name a compound we need to practice making a formula for binary ionic compounds. Ionic compounds are written to show the smallest whole number ratio of each ion in the formula. The charge is balanced so that the positive charge equals the negative charge. For example, if I want to build a formula for a compound that contains Mg^{2+} and F^{-}, I would need one Mg^{2+} and two F^{-}. I would write the formula as MgF_2. In the table below, fill in the correct formula for each compound.

	Cl^-	I^-	S^{2-}	Se^{2-}	Br^-	N^{3-}
Na^+						
Mg^{2+}						
Al^{3+}						

[1] This is the first edition of this handout. I know there are some typos. If you see one, please point it out to me so I can fix it. thank you

NH_4^+						

How to name binary ionic compounds:

There two types of cations that we will encounter in nomenclature: Fixed charge and variable charge. Most fixed charge cations are Main-Group Metals (Groups IA, IIA, and IIIA). These metals tend to form *cations* by losing all of their outermost (valence) electrons. *The charge on the cation is the same as the group number.* The cation is given the same name as the neutral metal atom.

Transition (B-group) and Post-Transition (Group IVA and VA) Metals
The charges of the transition metals must be memorized. Many of these ions have common or older names (-*ic* endings go with the higher charge, -*ous* endings go with the lower charge), but we will not use those names in this class. We will use a system known as "the *Stock* system". The Stock system is a systematic method for naming ionic compounds when the cation could have two different forms. A roman numeral in parentheses indicates the charge on the cation. The Roman numeral follows the name of the cation. The 'olde tyme' method of naming chromium ions would be the chromous ion and the chromic ion. Instead, we use chromium(II) and chromium(III) as the preferred method of nomenclature of this type of cation. The Stock system is reserved only for metals with variable charge. Any cation that has a fixed charge, even a cation from a transition metal, does not use the Stock system for nomenclature. See attached periodic table for cations.

The nonmetal elements tend to form *anions* by gaining enough electrons to fill their valence shell with eight electrons. Taking the element stem name and adding the ending "ide" form the name of an anion. Metals combine with nonmetals to give ionic compounds. When naming binary ionic compounds, name the cation first (specifying the charge, if necessary), then the nonmetal anion (element stem + -*ide*). Do NOT use prefixes to indicate how many of each element is present; this information is implied in the name of the compound.

Table 1: Monatomic ions on the periodic table

	IVA		VA		VIA		VIIA
C^{4-}	Carbide	N^{3-}	Nitride	O^{2-}	Oxide	F^{-}	Fluoride
		P^{3-}	Phosphide	S^{2-}	Sulfide	Cl^{-}	Chloride
		As^{3-}	Arsenide	Se^{2-}	Selenide	Br^{-}	Bromide
				Te^{2-}	Telluride	I^{-}	Iodide

Table 2: Monatomic and polyatomic ions by charge.

-1 charged ions	**2- charged ions**	**3- Charged ions**
H^{-} (hydride)	O^{2-}(oxide)	PO_4^{3-} (phosphate)
F^{-} (fluoride)	S^{3}• (sulfide)	PO_3^{3-}(phosphite)
Cl^{-} (chloride}	SO_3^{2-} (sulfite)	N^{3-}(nitride)
Br^{-} (bromide)	SO_4^{2-} (sulfate)	P^{3-}(phosphide)
I^{-} (iodide)	HPO_4^{3-}(hydrogen	
NO_2^{-} (nitrite)	phosphate)	
NO_3^{-} (nitrate)	CO_3^{2-}(carbonate)	
OH^{-} (hydroxide)	$C_2O_4^{2-}$ (oxalate)	
CN^{-} (cyanide)	$Cr_2O_7^{2-}$(dichromate)	
HSO_4^{-} (hydrogen sulfite)		
HSO_4^{-} (hydrogen sulfate)		
$H_2PO_4^{-}$(dihydrogen phosphate)		
HCO_3^{-}(hydrogen carbonate}		
ClO^{-} (hypochlorite)		
ClO_2^{-} (chlorite)		
ClO_3^{-} (chlorate)		
BrO_2^{-} (bromite)		
BrO_3^{-} (bromate)		
IO_2^{-} (iodite)		
IO_3^{-} (iodate)		
$C_2H_3O^{-}$ (acetate)		
MnO_4^{-} (permanganate)		

In the compounds listed below, give the name for the formula, or the formula for the name for compounds formed from cations with monatomic anions.

1. potassium sulfide	
2. iron(III)iodide	
3. tin(II) bromide	
4. copper(II) bromide	
5. mercury (I) chloride	
6. cobalt(II) nitride	
7. Bi_2S_3	
8. $AuCl_3$	
9. Al_2O_3	
~~10.~~ $CoCl_2$	
11. SrF_2	
12. Li_3P	
13. CaO	
14. Al_2S_3	

Polyatomic ions-Ions with more than one element

Before we can name a compound we need to practice making a formula for polyatomic ionic compounds. Ionic compounds are written to show the smallest

whole number ratio of each ion in the formula. Like binary compounds, the charge is balanced so that the positive charge equals the negative charge but polyatomic ions require an additional format feature. We use parentheses to indicate the number of ions in the formula. For example, if I want to build a formula for a compound that contains Mg^{2+} and OH^{-}, I would need one Mg^{2+} and two OH^{-}. I would write the formula as $Mg(OH)_2$. In the table below, fill in the correct formula for each compound.

	SO_4^{2-}	NO_3^{-}	PO_4^{3-}	CO_3^{2-}
Na^{+}				
Mg^{2+}				
Co^{3+}				
NH_4^{+}				
K^{+}				
Sc^{3+}				
Ba^{2+}				

Polyatomic Ions

Polyatomic ions are ions that are composed of two or more atoms that are linked by covalent bonds, but that still have a net deficiency or surplus of electrons, resulting in an overall charge on the group. A metal plus a polyatomic ion yields an ionic compound. The positive ion is given first, followed by the monatomic or polyatomic anion. The rules for naming polyatomic ions are similar to monatomic anions . The name is based on the elemental root + an ending. You can see from Table 2, that most of the polyatomic ions are oxy-anions. They have a nonmetal and oxygen. These ions end in 'ite' for the ions with a lower number of oxygen atoms, and 'ate' for a higher number of oxygen. When you compare two ions that seem similar like sulfite and sulfate, we see the number of oxygen atoms in these ions differ by 1. Some ions are considered polyatomics but do not end in ite. They are listed below as well. There are two

polyatomic cations that you will need to know for this class: ammonium (NH_4^+) and hydronium ion (H_3O^+). We will not use hydronium in nomenclature, but you will see it when we study acid base reactions.

How to name polyatomic ionic compounds:

The rules are the same as naming binary ionic compounds. We are still linking a cation to an anion. Polyatomic ions are charged units and do not separate in to separate elements in water. We use parentheses and subscripts to denote the number of polyatomics in the formula. Make sure that you follow the rules for naming cations.

1. Name the cation first (specifying the charge, if necessary), then the polyatomic ion as listed in the table above. Do NOT use prefixes to indicate how many of each element is present; this information is implied in the name of the compound.
2. The subscripts in the formula must produce an electrically neutral formula unit. (That is, the total positive charge must equal the total negative charge.)
3. The subscripts should be the smallest set of whole numbers possible.
4. If there is only one of a polyatomic ion in the formula, do not place parentheses around it.

In the compounds below, give the name if a formula is given or give the formula if a name is given.

1. nickel(III) carbonate	
2. calcium nitrate	
3. copper(II) acetate	
4. potassium permanganate	
5. silver acetate	
6. zinc chromate	
7. ammonium carbonate	
8. tin (II) permanganate	
9. nickel(III) iodite	

10. mercury (I) chloride	
11. aluminum hydrogen phosphate	
12. copper(II) bromide	
13. magnesium hydrogen sulfate	
14. CuCN	
15. $Cr(HCO_3)_3$	
16. $AuCl_3$	
17. Na_2SO_3	
18. $(Hg_2)_3(PO_4)_2$	
19. $KMnO_4$	
20. $NaNO_2$	
21. Al_2O_3	
~~22.~~ $CoCl_2$	
23. $Ca(NO_3)_2$	
24. $FeCrO_4$	
25. $Zn(ClO_3)_2$	
26. $Sn(CrO_4)_2$	

27. $Na_2Cr_2O_7$	
28. $Mg(HSO_4)_2$	
29. $CoSO_4$	
30. $CuNO_3$	