Name: _____

Academic Chemistry: Unit 4
Bonding

Day	Date	Classwork	Homework
1	Thursday, March 5	After Test Introduction to Bonding (p.1-4)	Work on Periodic Table Project!!!
2	Friday, March 6	PhET- Ionic & Covalent Compound Properties Types of bondings (pg. 6) Naming Molecular Compounds POGIL (p.7-10) Notes: Covalent Compounds (pg 11)	Naming Covalent Compounds Practice WS (p.12) Work on Periodic Table Project!!!
3	Monday, March 9	Teacher Work Day- NO SCHOOL	Naming Covalent Compounds Practice WS (p.12) Work on Periodic Table Project!!!
4	Tuesday, March 10	Naming Covalent Compounds Practice WS (pg 13) Lewis Dot Structures for atoms (pg 14) Lewis Structures Notes (p.15) Lewis Structure Practice (pgs 16)	Lewis Structure Practice (pgs 17)
5	Wednesday, March 11	**Quiz: Covalent Naming** Lewis Structure Practice (pg 18) Notes on VSEPR (pg 19)	Practice VSEPR Shapes (pgs 16-18) Work on Periodic Table Project!!!
6	Thursday, March 12	Notes: Polar vs Nonpolar (pg 20) Polar vs Non-Polar practice (pgs 16-18) VSEPR pre-lab	Practice all things covalent Finish Pre-lab
7	Friday, March 13	VSEPR Lab **Quiz: Covalent - properties, naming, lewis structure, VSEPR, and Polarity** CW: Naming Ionic Compounds (pgs 21-24)	Finish CW Work on Periodic Table Project!!!
8	Monday, March 16	**Periodic Table Project due today in class!!** Notes: Naming Binary Ionic Compounds (pg 25) CW: Practice Naming Ionic Compounds (pg 26)	Practice naming Ionic Compounds (pgs 26)
9	Tuesday, March 17	Notes: Naming Ionic Compounds with Transition Metals (pg 27) CW: Practice naming ionic with transition metals (pg 28)	Practice naming Ionic compounds (pg 28)
10	Wednesday, March 18	**Quiz - Naming/ Formula Writing for Ionic** Notes: Naming Ionic Compounds with Polyatomic Ions (29-35) CW: practice Naming Ionic Compounds with Polyatomic Ions (pg 36)	Mixed Naming (pg 39)
11	Thursday, March 19	Mixed Naming Practice (pgs 37-38) Properties Review (pg 42-43)	Test Review
12	Friday, March 20	Unit 4 Bonding Test	

Bonding Unit Objectives:

1. Identify the properties of ionic, covalent, and metallic bonds.
2. Write the name of ions.
3. Name ionic compounds given their formulas.
4. Write the formula of ionic compounds given their names.
5. Name covalent compounds given their formulas.
6. Write the formula of covalent compounds given their names.
7. Identify all of the diatomic elements.
8. Identify the bond type given a compound.
9. Draw Lewis structures.
10. Predict the shape of a compound using VSEPR.
11. Determine whether a compound is polar or nonpolar.

Name _____ Class _____ Date _____

CHAPTER 3 Chemical Compounds

SECTION 1

Ionic and Covalent Compounds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are ionic compounds?
- What are covalent compounds?

National Science Education Standards

PS 1a, 1b

What Are Ionic and Covalent Compounds?

Many things are made of combinations of elements called *compounds*. Sugar, salt, gasoline, and chalk are all compounds. They have atoms of more than one element joined together. How are the compounds alike and how are they different?

Scientists *classify*, or group, chemical compounds by the kinds of chemical bonds they have. A **chemical bond** joins atoms together to form compounds. The compounds are grouped by their bonding as either *ionic* or *covalent*.

Bonding happens between valence electrons of different atoms. *Valence electrons* are electrons in the outermost energy level of an atom. The type of compound that forms depends on what happens to the valence electrons. ☑

STUDY TIP

Work in Pairs Make flash cards with all of the vocabulary words in this section. Also make flash cards of the words in *italics* in this section.

On the other side of the card, write the definition of the word. Practice saying the words and their definitions.

READING CHECK

1. Identify What determines the type of compound that forms when atoms bond?

_____

_____

What Makes a Compound Ionic?

An ionic bond is an attraction between ions that have opposite charges. Compounds that have ionic bonds are called **ionic compounds**.

Ionic compounds can be formed by the chemical reaction between a metal and a nonmetal. Metal atoms become positively charged ions when electrons move from the metal atoms to the nonmetal atoms. The nonmetal atoms become negatively charged ions. ☑

Na^{1+} Cl^{1-}

A sodium atom has lost an electron to a chlorine atom. The result is a positively charged sodium ion and a negatively charged chlorine ion. The attraction of the ions is called an ionic bond.

READING CHECK

2. Describe What kind of ions do metals form? What kind of ions do nonmetals form?

_____

_____

_____

_____

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What Are the Properties of an Ionic Compound?

Ionic compounds form strong bonds because of the attraction between oppositely charged ions. There are several properties that tell you a compound is ionic.

IONIC COMPOUNDS ARE BRITTLE

Ionic compounds tend to be brittle at room temperature. That means they break apart when hit. They break because their ions are arranged in a pattern that happens over and over again. The pattern is called a *crystal lattice*. Each ion in a lattice bonds to the ions around it that have the opposite charge. ☑

READING CHECK

3. Describe What is a crystal lattice?

_____

_____

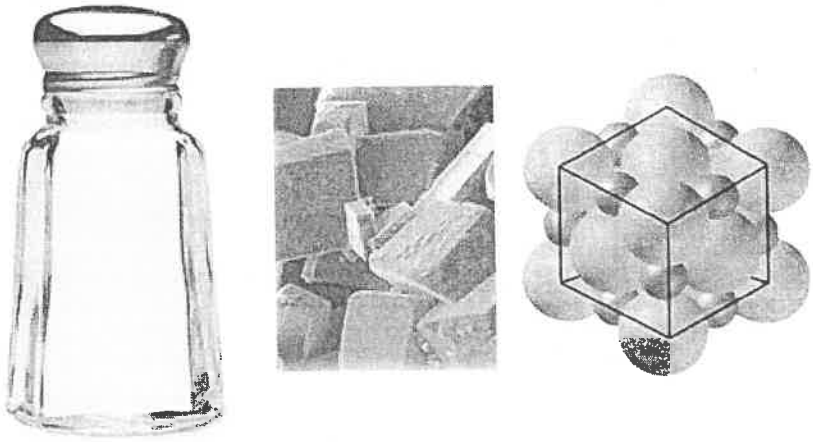
_____

_____

_____

When you hit an ionic compound, the ions move and the pattern changes. Ions that have the same charge line up and repel each other. That makes the crystals break.

Sodium chloride crystals (shown below) all have a regular cubic shape. The shape is due to the way sodium and chloride ions are arranged in the crystal lattice.



Sodium chloride crystals all have a regular cubic shape because of the way sodium and chloride ions are arranged.

IONIC COMPOUNDS HAVE A HIGH MELTING POINT

Because of the strong bonds that hold ions together, ionic compounds don't melt easily. They have a high melting point. For example, sodium chloride must be heated to 801°C before it will melt. ☑

READING CHECK

4. Explain What causes ionic compounds to have high melting points?

_____

_____

_____

IONIC COMPOUNDS ARE SOLUBLE

Many ionic compounds are highly *soluble* in water. That means they dissolve easily in water. Water molecules attract each of the ions of an ionic compound and pull them away from each other.

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2

IONIC COMPOUNDS CONDUCT ELECTRICITY

When an ionic compound dissolves in water, it forms a solution that can conduct an electric current. It conducts electricity because its ions are now free to move to complete an electric circuit. When ionic compounds are solids, their ions are not free to move. They will not conduct an electric current. ☑

READING CHECK

5. Explain Why do ionic compounds dissolved in water conduct an electric current?

What Makes A Compound Covalent?

Many of the compounds in your body are covalent compounds. **Covalent compounds** form when atoms share electrons. The bond that forms when atoms share electrons is called a *covalent bond*. Atoms share electrons to fill their outermost energy level. This forms a group of atoms, each having a full valence shell.

The group of atoms that make up a covalent compound is called a *molecule*. A molecule is the smallest particle that you can divide a compound into and still have the same compound. For example, if you break water down further, it isn't water anymore. It is hydrogen and oxygen.

STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

6. Identify Give three ways covalent compounds often differ from ionic compounds.

What Are the Properties of Covalent Compounds?

The properties of covalent compounds are very different from the properties of ionic compounds. This table lists the properties of covalent compounds.

Properties of Covalent Compounds

Property	Description
Solubility in water	Some covalent compounds do not dissolve in water. For example, oil does not dissolve in water. When mixed with water, the water molecules stay together and the oil molecules stay together.
Melting point	Normally, covalent compounds have lower melting and boiling points than ionic compounds. This is due to weaker forces of attraction in a covalent compound than in an ionic compound.
Electrical conductivity	Most covalent compounds do not conduct electricity when dissolved in water. This is because most covalent compounds that dissolve in water form solutions that do not have ions.

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Name _____ Class _____ Date _____

Section 1 Review

NSES PS 1a, 1b

SECTION VOCABULARY

chemical bond an interaction that holds atoms or ions together **covalent compound** a chemical compound that is formed by the sharing of electrons	**ionic compound** a compound made of oppositely charged ions

1. **Compare** How does the melting point of ionic compounds compare to that of covalent compounds?

_____

2. **Make Inferences** Examine the table below. Use the information in the table to help you decide if the compound is ionic or covalent. Write *ionic* or *covalent* in the box next to each compound.

Compound	Property	Ionic or covalent
A	low melting point	
B	smallest particle is a molecule	
C	water solution conducts an electric current	
D	high melting point	

3. **Describe** Why do ionic compounds tend to be brittle?

_____

_____

_____

4. **Explain** Solid crystals of ionic compounds do not conduct an electric current. Why does the solution conduct electricity when the crystals dissolve in water?

_____

5. **Describe** Describe how a metal and a nonmetal can combine by forming an ionic bond.

_____

_____

_____

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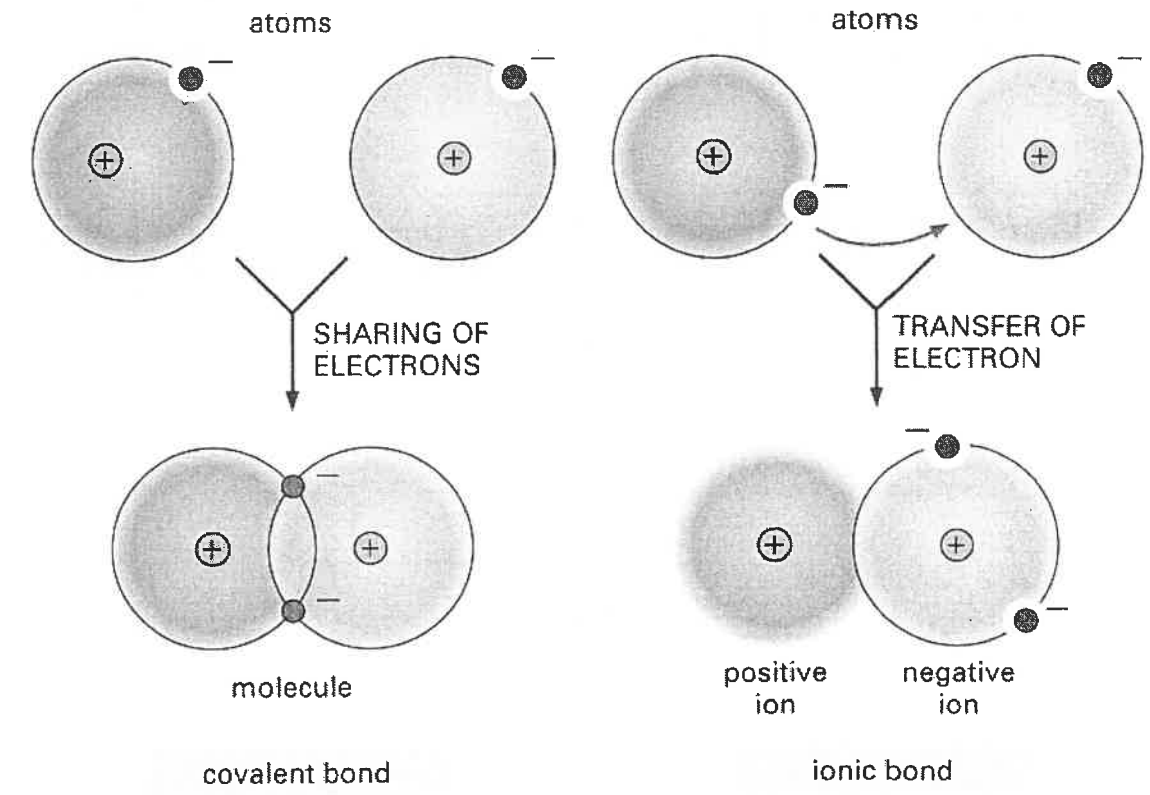
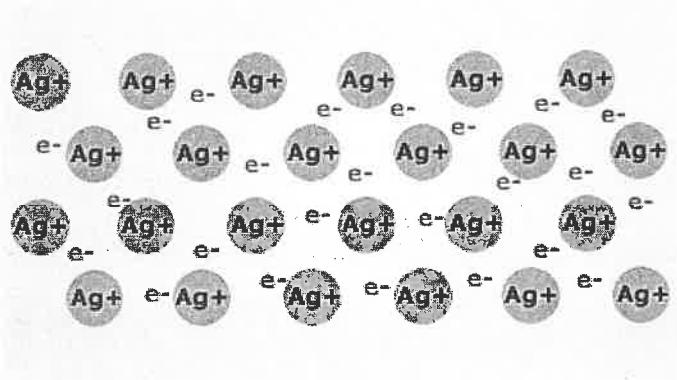


Figure 2.6 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Metallic Bond



Chemical Bonding

Ionic Bond	**between a Metal and Non-Metal**	**(M + NM)**
Covalent Bond	**between a Non-Metal and Non-Metal**	**(NM + NM)**
Metallic Bond	**between a Metal and Metal**	**(M+ M)**

Determine if the elements in the following compounds are metals or non-metals. Describe the type of bonding that occurs in the compound.

Compound	Element 1 (metal or non-metal?)	Element 2 (metal or non-metal?)	Bond Type
NO_2	N = non-metal	O = non-metal	covalent
NaCl			
SO_2			
PO_4^{3-}			
$MgBr_2$			
CaO			
H_2O			
K_2O			
Cu-Zn alloy			
O_2			
$CuCl_2$			
NO_2^-			
TiO_2			
HF			
Rb_2S			
Au-Ag mixture			
Fe_2O_3			
$C_6H_{12}O_{22}$			

Naming Molecular Compounds

How are the chemical formula and name of a molecular compound related?

Why?

When you began chemistry class this year, you probably already knew that the chemical formula for carbon dioxide was CO_2. Today you will find out why CO_2 is named that way. Naming chemical compounds correctly is of paramount importance. The slight difference between the names carbon monoxide (CO, a poisonous, deadly gas) and carbon dioxide (CO_2, a greenhouse gas that we exhale when we breathe out) can be the difference between life and death! In this activity you will learn the naming system for molecular compounds.

Model 1 – Molecular Compounds

Molecular Formula	Number of Atoms of First Element	Number of Atoms of Second Element	Name of Compound
ClF			Chlorine monofluoride
ClF_5	1	5	Chlorine pentafluoride
CO			Carbon monoxide
CO_2			Carbon dioxide
Cl_2O			Dichlorine monoxide
PCl_5			Phosphorus pentachlroride
N_2O_5			Dinitrogen pentoxide

1. Fill in the table to indicate the number of atoms of each type in the molecular formula.
2. Examine the molecular formulas given in Model 1 for various molecular compounds.
   a. How many different *elements* are present in each compound shown?

   b. Do the compounds combine metals with metals, metals with nonmetals, or nonmetals with nonmetals?

   c. Based on your answer to *b*, what type of bonding must be involved in molecular compounds?

3. Find all of the compounds in Model 1 that have chlorine and fluorine in them. Explain why the name "chlorine fluoride" is not sufficient to identify a specific compound.

4. Assuming that the name of the compound gives a clue to its molecular formula, predict how many atoms each of these prefixes indicates, and provide two examples.

   mono-

   di-

   penta-

7

Model 2 – Prefixes and Suffixes

Prefix	Numerical Value
mono-	
di-	
tri-	
tetra-	
penta-	
hexa-	
hepta-	
octa-	
nona-	
deca-	

Molecular Formula	Name of Compound
BCl_3	Boron trichloride
SF_6	Sulfur hexafluoride
IF_7	Iodine heptafluoride
NI_3	Nitrogen triiodide
N_2O_4	Dinitrogen tetroxide
Cl_2O	Dichlorine monoxide
P_4O_{10}	Tetraphosphorus decoxide
B_5H_9	Pentaboron nonahydride
Br_3O_8	Tribromine octoxide
ClF	Chlorine monofluoride

5. Examine the prefixes in Model 2. Fill in the numerical value that corresponds to each prefix.
6. What suffix (ending) do all the compound names in Model 2 have in common?

7. Carefully examine the names of the compounds in Model 2. When is a prefix NOT used in front of the name of an element?

8. Consider the compound NO.
   a. Which element, nitrogen or oxygen, would require a prefix in the molecule name? Explain your answer.

   b. Name the molecule NO.

9. Find two compounds in Model 2 that contain a subscript of "4" in their molecular formula.
   a. List the formulas and names for the two compounds.

   b. What is different about the spelling of the prefix meaning "four" in these two names?

10. Find two compounds in Model 2 that contain the prefix "mono-" in their names.

    a. List the formulas and names for the two compounds.

    b. What is different about the spelling of the prefix meaning "one" in these two names?

11. Identify any remaining names of compounds in Model 2 where the prefixes that do not exactly match the spelling shown in the prefix table.

12. Use your answers to Questions 9–11 to write a guideline for how and when to modify a prefix name for a molecular compound. Come to a consensus within your group.

13. Would the guideline you wrote for Question 12 give you the correct name for NI_3 as it is given in Model 2? If not, modify your guideline to include this example.

14. All of the compounds listed in Model 2 are binary molecular compounds. Compounds such as CH_3OH or PF_2Cl_3 are not binary, and compounds such as NaCl or $CaCl_2$ are not molecular. Propose a definition for "binary molecular compounds."

15. Collaborate with your group members to write a list of rules for recognizing and naming binary molecular compounds from their chemical formulas.

16. For each of the following compounds, indicate whether or not your naming rules from Question 15 will apply. If not, explain why the naming rules do not apply.

FeI_3 ICl_5 $HBrO_4$

17. Using the rules your group developed in Question 15, name each of the following molecular compounds.

Molecular Formula	Molecule Name
PBr_3	
SCl_4	
N_2F_2	
SO_3	
BrF	

18. Write molecular formulas for the following compounds.

Molecular Formula	Molecule Name
	Disulfur decafluoride
	Carbon tetrachloride
	Oxygen difluoride
	Dinitrogen trioxide
	Tetraphosphorus heptasulfide

Naming Covalent/ Molecular Compounds

Covalent Compounds

_____1. carbon dioxide

_____2. dinitrogen pentoxide

_____3. diphosphorus pentoxide

_____4. dinitrogen monoxide

_____5. dinitrogen tetroxide

_____6. phosphorus pentoxide

_____7. carbon tetrachloride

8. P_4O_{10}_____

9. S_2O_3_____

10. CS_2_____

11. SO_2_____

12. BF_3_____

13. PO_2_____

14. $SiCl_4$_____

C. NmNm

1) Name of 1st element (with prefix if more than one atom)
2) prefix for number of atoms- root of nonmetal name –ide ending

mon(o)- 1	tri- 3	penta-5	hepta-7	nona-9
di- 2	tetra- 4	hex(a)- 6	octa-8	deca-10

ex. N_2O dinitrogen monoxide; NO_2 nitrogen dioxide

Name the following:

1. SO_3 _____
2. $AsCl_3$ _____
3. N_2O_3 _____
4. P_2O_5 _____
5. $GeCl_4$ _____
6. XeF_6 _____
7. SF_4 _____
8. NO_3 _____
9. SiO_2 _____
10. CO _____

Write formulas for the following:

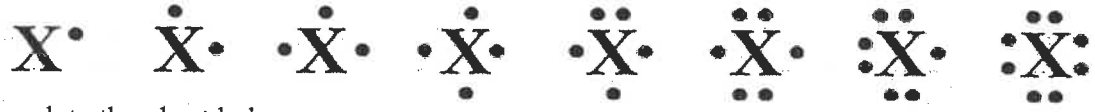
11. Sulfur dioxide _____
12. Phosphorous trichloride _____
13. Nitrogen monoxide _____
14. Carbon tetraflouride _____
15. Dinitrogen pentoxide _____
16. Sulfur trioxide _____
17. Carbon monoxide _____
18. Phosphorous pentachloride _____
19. Arsenic tribromide _____
20. Nitrogen triiodide _____

Name:_____

Lewis Dot Structures for Atoms Date:_____ Period:_____

In a Lewis dot structure of an atom, dots are placed around the symbol of the atom. The number of dots is equal to the number of valence electrons. One dot is placed on each side before doubling up. General pattern (use the actual symbol, not an X):

1 2 3 4 5 6 7 8



Complete the chart below:

Element	# of Valence Electrons	Lewis Dot Structure
Hydrogen (H)		
Lithium (Li)		
Sodium (Na)		
Potassium (K)		
Beryllium (Be)	2	
Magnesium (Mg)		
Calcium (Ca)		
Boron (B)		
Aluminum (Al)		
Carbon (C)		
Silicon (Si)		
Nitrogen (N)		
Phosphorus (P)		
Fluorine (F)		
Chlorine (Cl)		
Bromine (Br)		
Helium (He)		
Neon (Ne)		

Lewis Dot Structures

Lewis Structures Classwork

	Molecule	Lewis Structure	Bonded Atoms	Lone Pairs	Shape	P/NP
1.	SeH_2					
2.	BF_3					
3.	H_2O					
4.	CCl_4					
5.	NH_3					
7.	NH_2^{1-}					
8.	CO_2					

	Molecule	Lewis Structure	Bonded Atoms	Lone Pairs	Shape	P/NP
9.	NO_3^{1-}					
10.	HCN					
11.	GaI_3					
12.	SO_3					
13.	CO_3^{2-}					
14.	NCl_3					
15.	CS_2					

	Molecule	Lewis Structure	Bonded Atoms	Lone Pairs	Shape	P/NP
16.	HOCl					
17.	PH_3					
19.	SO_3^{2-}					

VSEPR Shapes

Polar vs. Non Polar

Naming Ionic Compounds

What are the structural units that make up ionic compounds and how are they named?

Why?

When working in chemistry, it is often convenient to write a chemical in symbols. For example we might write down the substance table salt as NaCl. In talking about chemistry however, it is a bit tacky to say "en-ay see-ell" when we want to refer to a substance. Also, in formal writing we should use the name of the compound rather than its symbols. Therefore we need to learn how to say the proper names of ionic substances.

Model 1 – Ion Charges for Selected Elements

1	H^+										
2	Li^+	Be^{2+}							N^{3-}	O^{2-}	F^{1-}	
3	Na^+	Mg^{2+}	Transition elements				Al^{3+}		P^{3-}	S^{2-}	Cl^{1-}	
4	K^+	Ca^{2+}	Fe^{2+} Fe^{3+}	Ni^{2+} Ni^{3+}	Cu^+ Cu^{2+}	Zn^{2+}					Br^{1-}	
5	Rb^+	Sr^{2+}			Ag^{1+}			Sn^{2+} Sn^{4+}			I^{1-}	
6		Ba^{2+}				Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				

Cations → ← Anions

1. Based on the information in Model 1:
   a. Identify three elements that form only one cation.

   b. Identify three elements that form only one anion.

   c. Identify three elements that form more than one cation.

   d. In what region of the periodic table are these "multiple ion" elements usually located?

2. Consider the ions of potassium (K) and sulfur (S). Write chemical formulas for all possible ionic compounds involving these ions, using the simplest ratio(s) of potassium (K) and sulfur (S). Keep in mind that the sum of the charges in an ionic compound must equal zero.

3. Consider the ions of iron (Fe) and sulfur (S). Write chemical formulas for all possible ionic compounds involving these ions, using the simplest ratio(s) of iron (Fe) and sulfur (S). Keep in mind that the sum of the charges in an ionic compound must equal zero.

21

Model 2 – Ionic Compound Names (Metals that form one ion)

NaCl	Sodium chloride	Zn_3P_2	Zinc phosphide
CaS	Calcium sulfide	Al_2O_3	Aluminum oxide
Ag_2S	Silver sulfide	$SrCl_3$	Strontium chloride

4. Circle the symbol for the metal in each of the compounds in Model 2.
5. Which element comes first in the name and formula of the compounds in Model 2—the metal or the nonmetal?

6. Use the table of ions in Model 1 to answer the following questions:
   a. In the compound zinc phosphide, what is the charge on the zinc ion?

   b. In the compound zinc phosphide, what is the charge on the phosphide ion?

7. Explain why a 3 to 2 ratio of ions is necessary for the compound zinc phosphide.

8. The compound carbon dioxide has a name that gives you a hint as to how many oxygen atoms are in the compound. Is there anything in the name "zinc phosphide" that indicates there are three zinc and two phosphorus ions in the formula unit?

9. Is there any other ratio of zinc and phosphorus ions that could exist? For instance, could you have Zn_2P or ZnP_2? Explain your answer.

10. Explain why you don't need to specify the number of ions in the compound when you are naming ionic substances like those in Model 2.

11. Model 2 is labeled "Metals that form one ion." What other metals that also form only one ion could be included in the Model 2 list? Model 1 may be helpful in this regard.

12. Describe how the names of the nonmetal elements in Model 2 are changed when they are in their anion forms.

13. Name the following ionic compounds using what you learned from Model 2.

    Li_2O MgF_2 Al_2S_3 K_3N

22

14. Provide the chemical formula for each of the following ionic compounds.

    Barium chloride Magnesium oxide

15. Consider the two chemical formulas you wrote in Question 3 for compounds of iron and sulfur. Would the name "iron sulfide" be sufficient to uniquely identify either of those compounds? Explain.

Read This!

When the metal in an ionic compound always forms an ion with the same charge, you need not indicate that charge as part of the compound name. However, some atoms have the ability to form more than one type of ion. This can make naming confusing. You can't simply refer to a compound of copper and oxygen as "copper oxide." People won't know which compound you are referring to—CuO or Cu_2O.

Model 3 – Ionic Compound Names (Metals that form multiple ions)

Cu_2O	Copper(I) oxide	PbO	Lead(II) oxide
CuO	Copper(II) oxide	PbO_2	Lead(IV) oxide
SnF_2	Tin(II) fluoride	$FeCl_2$	Iron(II) chloride
SnF_4	Tin(IV) fluoride	$FeCl_3$	Iron(III) chloride

16. Model 3 is labeled "Metals that form multiple ions." What other metals that form multiple ions could be included in Model 3? Model 1 may be helpful in this regard.

17. Describe the most obvious difference between the names in Model 3 and those in Model 2.

18. Do the Roman numerals in the names in Model 3 relate to the number of cations or number of anions in the formula unit? Support your answer by citing two specific examples.

19. Keeping in mind that the sum of the charges in an ionic compound must equal zero, use the chemical formulas in Model 3 to answer the following questions:

    a. Identify the charge on the copper cations in copper(I) oxide and copper(II) oxide, respectively.

    b. Identify the charge on the iron cations in iron(II) chloride and iron(III) chloride, respectively.

20. What do the Roman numerals in the compounds described in Question 19 indicate?

21. Fill in the table below using what you've learned from Model 3.

Compound	Charge on Cation	Name of the Compound
$PbCl_4$	Pb^{4+}	Lead(IV) chloride
Fe_2O_3		
SnO		
$CuBr_2$		

22. For each of the compounds in the table below, determine the type of metal in the compound and then name the compound using the correct naming method.

	Metal forms only one ion	Metal forms multiple ions	Name
$CaBr_2$			
MgO			
Ag_3N			
$SnCl_2$			
CuF_2			
K_3P			
Zn_3N_2			
HgO			

Naming Binary Ionic Compounds

Writing Formulas & Naming Compounds

I. Binary Compounds

A. MNm

1) name of 1st element
2) root of name of 2nd element with –ide ending

Ex. CaO calcium oxide
K2S potassium sulfide

Name the following:

1. NaF _____
2. K_2O _____
3. LiBr _____
4. $CaCl_2$ _____
5. BaS _____
6. BaF_2 _____
7. Na_2S _____
8. MgI_2 _____
9. K_3N _____
10. BeSe _____

Write formulas for the following

11. Aluminum chloride _____
12. Lithium sulfide _____
13. Calcium phosphide _____
14. Barium fluoride _____
15. Potassium oxide _____
16. Sodium bromide _____
17. Barium nitride _____
18. Lithium oxide _____
19. Aluminum oxide _____
20. Rubidium iodide _____

Naming Ionic w/ Transition Metals

B. TmNm

1) name of **T**ransition **m**etal with Roman numeral
2) root of nonmetal with –ide ending

Ex. CuO copper (II) oxide
Fe_2O_3 Iron (III) oxide

Name the following:

1. CuCl _____
2. $CuCl_2$ _____
3. FeO _____
4. MnS _____
5. Cr_2O_3 _____
6. NiF_2 _____
7. $SnCl_4$ _____
8. Ag_3P _____
9. ZnS _____
10. $HgCl_2$ _____

Write formulas for the following:

11. Mercury (II) sulfide _____
12. Copper(II) nitride _____
13. Iron(III) bromide _____
14. Mercury(I) oxide _____
15. Silver fluoride _____
16. Copper(II) oxide _____
17. Chromium(III) oxide _____
18. Nickel(II) bromide _____
19. Tin (IV) sulfide _____
20. Zinc oxide _____

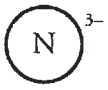
Polyatomic Ions

Can a group of atoms have a charge?

Why?

Do you know you eat a lot of "-ates"? Next time you look at a food label, read the ingredients and you will likely find a number of ingredients that end with "-ate," such as sodium phosphate or calcium carbonate. Did you ever wonder what the chemical formulas of these ingredients look like? In this activity we will explore polyatomic ions, which are groups of atoms that carry a charge. These ions are found in our food ingredients, natural waterways, and many other chemical compounds you encounter every day.

Model 1 – Types of Ions

<table>
<tr><td>Monatomic Ions</td><td>Nitride
 

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 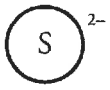

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 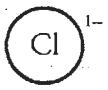
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 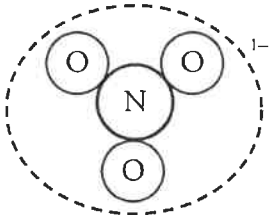

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 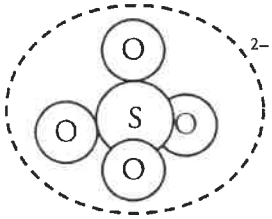

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 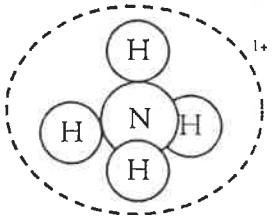

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 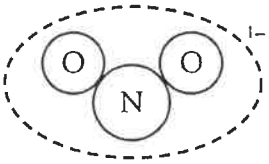

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 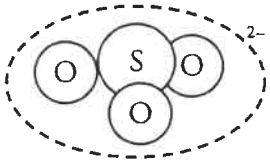

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 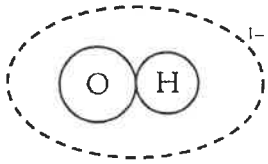
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1. Use Model 1 to complete the table below.

Name of Ion	Nitride	Nitrate	Sulfate	Sulfite	Ammonium
Charge on Ion		-1			
Type and Number of Atoms			1 sulfur 4 oxygen		
Chemical Formula				SO_3^{2-}	

2. Consider the terms "monatomic" and "polyatomic" as they are used in Model 1. Write a definition for each of these terms. It may be helpful to break the words apart (*i.e.*, poly – atomic). Make sure your group comes to consensus.

   Monatomic—

   Polyatomic—

3. What types of elements (metals or nonmetals) are shown in the polyatomic ions in Model 1?

4. What type of bonds (ionic or covalent) hold the atoms together in polyatomic ions? Explain your reasoning.

5. The net charge on a sulfide ion (S^{2-}) is –2. Explain how this ion obtains its charge. Your answer should include a discussion of subatomic particles.

6. The dotted line around each polyatomic ion in Model 1 shows that the group of atoms has a charge. The charge is not on any one atom, but rather on the group of atoms as a whole. Based on your knowledge of monatomic ions, propose an explanation for the net charge on a polyatomic ion. Your answer should include a discussion of subatomic particles.

7. What are the similarities and differences between the nitrate and nitrite ions in Model 1?

8. What are the similarities and differences between the sulfate and sulfite ions in Model 1?

9. The "chlorate" polyatomic ion has a charge of –1 and is composed of one chlorine atom (the central atom) and three oxygen atoms.

   a. Draw a model of a chlorate ion.

b. Write the chemical formula for the chlorate ion, including its charge.

10. In your group discuss what "chlorite" would look like.

a. Draw a model of a chlorite ion.

b. Write the chemical formula for the chlorite ion, including its charge.

Model 2 – Common Polyatomic Ions

1+		1–		2–		3–	
ammonium	NH_4^{1+}	acetate	CH_3COO^{1-}	sulfate	SO_4^{2-}	phosphate	PO_4^{3-}
		hydroxide	OH^{1-}	sulfite	SO_3^{2-}		
		nitrate	NO_3^{1-}	carbonate	CO_3^{2-}		
		nitrite	NO_2^{1-}	chromate	CrO_4^{2-}		
		bicarbonate	HCO_3^{1-}	dichromate	$Cr_2O_7^{2-}$		
		permanganate	MnO_4^{1-}				
		perchlorate	ClO_4^{1-}				
		chlorate	ClO_3^{1-}				
		chlorite	ClO_2^{1-}				
		hypochlorite	ClO^{1-}				

11. What is the only polyatomic ion that is a cation?

12. How are bicarbonate and carbonate related?

13. Predict the chemical formula and charge for the bisulfate ion.

14. How are chromate and dichromate related?

15. Bromine forms polyatomic ions with structures similar to those of chlorine. Using the chlorine family of polyatomic ions as a model, predict the name of the BrO_4^{1-} ion.

16. Identify the polyatomic ion in each of these ionic compounds. Write out the name and formula of the ions including their charges.

    a. $CaCO_3$ *b.* $Mg(OH)_2$ *c.* NH_4Cl

Model 3 – Ternary Ionic Compounds

Compound Name	Ion Symbols and Charges		Chemical Formula
Ammonium phosphate	NH_4^{1+}	PO_4^{3-}	$(NH_4)_3PO_4$
Barium nitrite	Ba^{2+}	NO_2^{1-}	$Ba(NO_2)_2$
Ammonium sulfate	NH_4^{1+}	SO_4^{2-}	$(NH_4)_2SO_4$
Aluminum carbonate	Al^{3+}	CO_3^{2-}	$Al_2(CO_3)_3$
Iron(III) hydroxide	Fe^{3+}	OH^{1-}	$Fe(OH)_3$
Potassium nitrate	K^{1+}	NO_3^{1-}	KNO_3

17. How are ternary ionic compounds in Model 3 different from binary ionic compounds (NaCl, MgO, $CaBr_2$, etc.) that you've seen previously? *Hint:* Consider the meaning of the word "**bi**nary."

18. Consider the compound iron(III) hydroxide in Model 3.

    a. How many hydroxide ions (OH^{1-}) are combined with an iron(III) ion (Fe^{3+})?

    b. Is your answer to part *a* the only combination of iron(III) and hydroxide that should exist in nature? Explain.

19. Consider the compound barium nitrite in Model 3.

    a. What does the subscripted "2" *inside* the parentheses of the chemical formula tell you about the compound?

$$Ba(NO_2)_2$$
$$\uparrow$$

b. What does the subscripted "2" *outside* the parentheses of the chemical formula tell you about the compound?

$$Ba(NO_2)_2$$

20. How many atoms of each element are in one formula unit of ammonium phosphate, $(NH_4)_3PO_4$?

nitrogen hydrogen phosphorus oxygen

21. A student writes the chemical formula for the ionic compound calcium hydroxide as $CaOH_2$.

a. Write the chemical formula for each ion in the compound.

Calcium: Hydroxide:

b. Why is the student's chemical formula for the compound calcium hydroxide wrong?

22. Many of the chemical formulas in Model 3 include parentheses. Which one of the following rules summarizes the appropriate use of parentheses in ternary ionic compounds? For the three rules that do not apply in all cases, show at least one counter example from the chemical formulas in Model 3.

Parentheses are used around any ion that is used more than once in a formula unit.

Parentheses are used around any polyatomic ion.

Parentheses are used around any polyatomic ion used more than once in a formula unit.

Parentheses are only used around polyatomic anions used more than once in a formula unit.

23. Write chemical formulas for the following ternary ionic compounds.

a. Calcium sulfate *b.* Copper(II) nitrate *c.* Lithium phosphate

d. Potassium permanganate *e.* Aluminum sulfite *f.* Magnesium bicarbonate

24. Name the following ternary ionic compounds.

a. $BaSO_4$ *b.* NH_4NO_3 *c.* $K_2Cr_2O_7$

d. $Fe(NO_3)_3$ *e.* $Mg(CH_3COO)_2$ *f.* $Al_2(CO_3)_3$

Naming Ionic w/ Polyatomics

II. Compounds with Polyatomic Ions (ternary)

- name the 2 parts (ion names)

Ex. NH_4Cl ammonium chloride
$Ca(NO_3)_2$ calcium nitrate

Name the following:

1. $(NH_4)_2CO_3$ _____
2. $BaSO_4$ _____
3. Li_2SO_3 _____
4. $CrPO_4$ _____
5. $NaC_2H_3O_2$ _____
6. $Ba(OH)_2$ _____
7. $Fe(NO_3)_3$ _____
8. KCN _____
9. $SrCrO_4$ _____
10. $CaCr_2O_7$ _____

Write the formulas for the following:

11. Aluminum sulfate _____
12. zinc nitrite _____
13. Magnesium chlorate _____
14. Sodium bicarbonate _____
15. Calcium hydroxide _____
16. Copper (II) carbonate _____
17. Ammonium sulfide _____
18. Iron (III) acetate _____
19. lithium sulfate _____
20. Strontium phosphate _____

Mixed Compound Practice

Part I.

(1) Circle the Ionic Compounds (2) Write out the name for the following compounds.

1. $NaCl$ _____
2. MnS _____
3. K_2O _____
4. $CuBr_2$ _____
5. $CuBr$ _____
6. CO_2 _____
7. $PbSO_4$ _____
8. Li_2CO_3 _____
9. Na_2CO_3 _____
10. NO_2 _____
11. N_2O_4 _____
12. $Ca(OH)_2$ _____
13. NH_4Cl _____
14. SO_3 _____
15. $AlPO_4$ _____
16. CCl_4 _____
17. CaS _____

18. NH_3 _____

19. MgI_2 _____

20. K_3PO_4 _____

Part II.

(1) Circle the ionic compounds. (2) Write the formulas for the following compounds. Helpful hint: for ionic compounds write the ions with their charges first then write the final answer.

1. Ammonium phosphate _____
2. Iron (II) oxide _____
3. Iron (III) oxide _____
4. Carbon monoxide _____
5. Calcium chloride _____
6. Potassium nitrate _____
7. Magnesium hydroxide _____
8. Aluminum sulfate _____
9. Copper (II) sulfate _____
10. Lead (IV) chromate _____
11. Diphosphorus pentoxide _____
12. Potassium permanganate _____
13. Sodium hydrogen carbonate _____
14. Zinc nitrate _____
15. Aluminum sulfite _____

Mixed Up Ionic Compounds ☺ (M^+NM^-)

1. State the number of electrons lost or gained when these elements form ions. Be sure to specify whether the electrons are lost or gained.

a) Br _____ b) Cu _____ c) Ca _____

2. Write the formulas of the ions for these elements

a) potassium _____ b) beryllium _____ c) sulfide _____

3. Write the formula and charge of each of the following ions.

a) ammonium _____ b) nitrate _____ c) Tin (II) _____

4. Write formulas for compounds formed from these pairs of ions.

a) Ba^{2+}, S^{2-} _____ b) Ca^{2+}, N^{3-} _____

5. Write formulas for these compounds

a) sodium iodide _____ b) potassium sulfide _____

c) tin (II) fluoride _____ d) calcium iodide _____

e) lithium hydrogen sulfate _____ f) chromium(III) nitrite _____

g) barium hydroxide _____ h) sodium bromide _____

6. Name these compounds.

a) ZnS _____ b) BaO _____

c) $NaClO_2$ _____ d) SnO_2 _____

e) $Fe(C_2H_3O_2)_2$ _____ f) K_2CrO_4 _____

g) CaO _____ h) $Ba_3(PO_4)_2$ _____

Mixed Ionic & Covalent Compounds

First identify if the compound is ionic (I) or covalent (C) , the either name it OR write the compound.

1. _____ aluminum nitrate _____
2. _____ $Sr_3(PO_3)_2$ _____
3. _____ Carbon dioxide _____
4. _____ P_4O_{10} _____
5. _____ sodium permanganate _____
6. _____ Na_2O_2 _____
7. _____ Dinitrogen pentoxide _____
8. _____ S_2O_3 _____
9. _____ chromium(II) sulfate _____
10. _____ Mg_3N_2 _____
11. _____ Diphosphorus pentoxide _____
12. _____ CS_2 _____
13. _____ sodium bromide _____
14. _____ $Al_2(SO_3)_3$ _____
15. _____ Dinitrogen monoxide _____
16. _____ SO_2 _____
17. _____ potassium nitrite _____
18. _____ Fe_2S_3 _____
19. _____ Dinitrogen tetroxide _____
20. _____ PCl_5 _____
21. _____ barium hydrogen sulfate _____
22. _____ Al_2O_3 _____
23. _____ Trinitrogen monosulfide _____
24. _____ H_2S _____
25. _____ nickel(III) chlorite _____
26. _____ $Pb(NO_3)$ _____
27. _____ Carbon tetrafluoride _____

40 - optional

Review– Naming Chemical Compounds

The following are a good mix of naming and formula writing problems to help you get some practice.

Name the following chemical compounds:

1) $NaBr$ _____

2) $Ca(C_2H_3O_2)_2$ _____

3) P_2O_5 _____

4) $Ti(SO_4)_2$ _____

5) $FePO_4$ _____

6) K_3N _____

7) SO_2 _____

8) $CuOH$ _____

9) $Zn(NO_2)_2$ _____

10) V_2S_3 _____

Write the formulas for the following chemical compounds:

11) silicon dioxide _____

12) nickel (III) sulfide _____

13) manganese (II) phosphate _____

14) silver acetate _____

15) diboron tetrabromide _____

16) magnesium sulfate _____

17) potassium carbonate _____

18) ammonium oxide _____

19) tin (IV) selenide _____

20) carbon tetrachloride _____

- optional

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Introduction to Bonding

1. Chemical Bond-

2. Most atoms form chemical bonds because _____

_____.

Bonding Comparison Chart

	IONIC	COVALENT	METALLIC
Types of Atoms Involved (metal or nonmetal)			
Method of Bond Formation (transfer of electrons, sharing of electrons, or sea of electrons)			
Type of Structure			
Physical State (solid, liquid, or gas)			
Melting Point (high or low)			
Soluble in Water? (yes or no)			
Conducts Electricity? (yes or no)			
Other Properties (give at least two that have NOT already been given)	1. 2.	1. 2.	1. 2.
Image of what the bonding looks like (Draw it!)			

Multiple Choice Questions

1. In which type of bond are electrons shared between atoms?
A. Ionic B. Covalent C. Metallic

2. Which type of bond creates a crystalline structure?
A. Ionic B. Covalent C. Metallic

3. Which type of bond usually forms between two nonmetals?
A. Ionic B. Covalent C. Metallic

4. Which type of bond forms a structure which is often described as an "electron sea"?
A. Ionic B. Covalent C. Metallic

5. Which bond is characterized by the formation of oppositely charged particles?
A. Ionic B. Covalent C. Metallic

6. In which type of bond are one or more electrons transferred from one atom to another?
A. Ionic B. Covalent C. Metallic

7. Which of the following is NOT a characteristic of ionic substances?
A. Conduct electricity in solution form.
B. Have high melting points.
C. Usually dissolve in water.
D. Are usually gases at room temperature.

8. Which of the following is NOT a characteristic of metallic substances?
A. Are lustrous, malleable, and ductile.
B. Conduct electricity.
C. Have low melting points.
D. Are usually solids at room temperature.

9. Which of the following is NOT a characteristic of covalent substances?
A. Have low melting points.
B. Sometimes dissolve in water.
C. Usually form small, individual molecules.
D. Conduct electricity.

10. Why do atoms form chemical bonds?
A. To increase their potential energy. B. To become more stable.
C. To gain more valence electrons. D. To obtain a higher electronegativity.