1 Bonding and Compounds

Do you know any jokes about sodium hypobromite? NaBrO

1.1 Types of Bonds Overview

Chemical compounds are formed by the joining of two or more atoms. When atoms bond, their valence electrons are redistributed in ways that make the atoms more stable. The way the electrons are redistributed depends on the type of bond formed.

A chemical bond is a mutual attraction between the nuclei and valence electrons of different atoms that binds atoms together.

Ionic Bonds

- These bonds are the result of the electrical attraction between positive ions and negative ions.
- The ions are formed because atoms completely give up their electrons to other atoms.

Ionic Bonding Process:

1. In an ionic bond, electrons are transferred from one atom to another.
2. The transfer creates a positive ion and a negative ion.
3. Cations and anions are attracted to each other due to the electrostatic attraction between positive and negative ions, so they are bound together.

- These bonds usually occur between a metal and a nonmetal, creating an ionic compound, also known as a salt.
- Both ions end up with an octet of electrons in their valence shell.
- Salts are neutral because they have an equal positive and negative charge.
- Metals lose electrons and nonmetals gain electrons in an ionic compound.

Covalent Bonds

- These bonds are the result of the sharing of electron pairs between two atoms.
- In a covalent bond, the electrons are "owned" by both of the two bonded atoms.

The Covalent Bonding Process:

1. Covalent bonds are the result of sharing electrons between two atoms.
2. Because the atoms must stay together to share, molecules are formed.
3. The molecules are neutral because they have the same number of protons and electrons.

- Covalent bonds usually occur between two nonmetals.
- Covalent bonding results in individual molecules.

Metallic Bonding

- In pure metals or alloys, there are usually vacant valence orbitals. The vacant orbitals overlap from one atom to another, allowing the outermost electrons to roam freely throughout the entire metal.
- These are called delocalized electrons. These mobile electrons, a "sea of electrons", move throughout the entire metal.
- Metallic bonds are a result of the attraction between metal nuclei and the surrounding sea of electrons.

The Metallic Bonding Process:

1. Metal atoms have overlapping empty orbitals.
2. Each metal atom loses its valence electrons to roam freely throughout the metal.
3. The metal is held together because the free-floating electrons and positive metal cores are attracted to each other.

Exercise What type of bonding is present in phosphorus decoxide?

1.2 Ionic Nomenclature

3 main types of compounds

- Type 1 - Ionic Compounds
  - A positive ion and a negative ion.
  - A metal and a nonmetal.
  - A metal and a polyatomic ion.
- Type 2 - Covalent Compounds
  - Made of more than one nonmetal atom
- Type 3 - Acids
  - Made up of positive hydrogen ions paired with negative ions.
  - These compounds appear to be covalent but behave like ionic compounds.

Exercise What type of compound is Copper (II) bromide?

Ionic Formulas and Nomenclature

- Chemical formulas show the number of atoms in a compound.
- "Nomenclature" is a naming system.
- The "nomenclature" system for people is first and last names.
- The typical "nomenclature" system for marriages is that the man keeps his last name and the bride changes her last name.

How to name ionic compounds

1. Make sure the compound is ionic by looking for a metal.
2. Name the cation and then the anion. Remember that nonmetal monatomic ions end in "-ide".
3. Write the ion symbols with their charges.
4. Cross the charges over and take the absolute value. These numbers become the subscripts. Reduce the subscripts if they are divisible by an integer.

Exercise Write the chemical formula for Zinc nitride.

If a polyatomic ion needs a subscript, put parenthesis around the polyatomic ion to show that more than one polyatomic ion is present.

Exercise - Write the chemical formula for Tin(IV) Sulfate.

To name an ionic compound, name the positive ion then name the negative ion. Easy peasy. Remember nonmetal ions end in -ide.

Exercise What is $Zn(OH)_2$?

Transition Metal Names

- If the metal has more than one possible charge you must know which one it is.
- Do a reverse cross of the subscripts to determine the charge of the metal.

Exercise What is $NiPO_4$?

1.3 Covalent & Acid Nomenclature

Covalent compounds contain only nonmetals (also called molecular compounds).

To name a covalent compound

- name the first element
- then name the second one and change its ending to -ide
- Use prefixes to show how many atoms of each element you have.

Exercise What is the formula for Tetraphosphorus decasulfide?

Exercise What is PCl_5?

- Acids are an important class of hydrogen-containing compounds and are named in a special way.
- Acids are defined as substances whose molecules produce hydrogen ions when dissolved in water.
- When we encounter acids, it will be written with H as the first element.

Writing and Naming Acids

- composed of an anion connected to enough H^+ ions to totally neutralize or balance the anion's charge. Criss-cross!
- name of an acid is related to the name of its anion... Three acid naming rules:
  - If the anion ends with ide, the acid is hydro_____ic acid.
  - If the anion ends with ate, the acid is _____ic acid.
  - If the anion ends with ite, the acid is _____ous acid.

Exercise What is HCN?

Exercise What is the formula for Dichromic Acid?

1.4 Mole Problems

1 mol is 6.022×10^{23} of anything

Molar Mass The molar mass concept works the same way with compounds as it did with pure elements. You simply add the molar mass of each atom within the formula.

We call this "molar mass" for molecular compounds and "formula mass" for ionic compounds. Generally, though, we use the term molar mass for atomic mass in grams of any compound, ionic or covalent, or any element.

Exercise Calculate the molar mass of H_2O

Exercise Calculate the molar mass of calcium chloride.

If parenthesis appear ina formula, the number outside the parenthesis multiplies by every atom inside the parenthesis, just like a coefficient in math.

Exercise Calculate the molar mass of $Ca(NO_3)_2$

Exercise How many moles are equal to 3.905×10^{23} formula units of calcium hydroxide?

Exercise How many nitric acid molecules are in 4.20 g of HNO_3?

1.5 Percent Composition

Percent composition of a compound:

$$\%\text{ composition} = \frac{\#\text{ of atoms of element} \times (\text{MM of element})}{\text{MM of compound}} \times 100$$

where "MM" is molar mass

You must know the CORRECT formula of the compound to calculate percent composition.

Exercise What is the % copper in copper(II) carbonate?

Round percent composition answers to 4 sig figs.

Hydrates are ionic compounds that can trap water in their crystalline structure when they form. The water is part of the structure, and it is a definite ratio of the compound.

Anhydrous compounds have no water in their crystalline structure.

To calculate the % water in the hydrate, use the same formula as before, but water is the part on top.

Exercise Calculate the % water in copper(II) sulfate pentahydrate.

Exercise Calculate the % water in magnesium sulfate heptahydrate.

1.6 Empirical & Molecular Formulas

Questions typically look like this:

- You are given the percent composition of a compound.
- You determine the formula based on the percentages.

Let's rhyme to solve these:

- Percent to mass
- Mass to mole
- Divide by least
- Multiply 'til whole

Exercise What is the formula of a compound that is 25.9% nitrogen and 74.1% oxygen?

So far you have calculated the simplest formula. We will now take this further. The empirical formula is the just the lowest possible ratio. The molecular formula, the actual makeup of a molecule, may be different.

If possible, you want to give the molecular formula. It is more descriptive of the actual molecular makeup. To do this, you must know the molar mass of the molecule.

Note: Ionic compounds never have molecular formulas, since the definition of the formula of an ionic compound is the lowest possible ratio. Only molecular, or covalent compounds, can have a molecular formula.

How to determine molecular formula:

1. Divide the true molar mass by the empirical formula's molar mass to get an integer.
2. Multiply the subscripts of the empirical formula by this integer.

Exercise A compound has the empirical formula CH. The molar mass of the compound is 78.110 g. What is the molecular formula of the compound?

1.7 Oxidation Numbers

"Oxidation numbers" are an accounting system used to keep track of electrons in a chemical reaction.

The oxidation state of a free element is 0.

The oxidation state for a monatomic ion is equal to its charge.

The algebraic sum of the oxidation numbers of all the atoms in a compound must be zero.

Similarly, the algebraic sum of the oxidation numbers of all the atoms in a polyatomic ion must equal the charge of the polyatomic ion.

Really useful rules:

- In compounds, the more electronegative element is always negative.
- In compounds, hydrogen is usually $+1$, unless it is bonded to a metal. In that case it is a hydride and the number is -1.
- In compounds, oxygen is usually -2. However, if it is a peroxide, it is -1. If it is bonded to fluorine, oxygen will be $+2$. This is rare.
- The oxidation number for alkali metals in compounds is always $+1$. The oxidation number for alkaline earth metals in compounds is always $+2$.

Oxidation numbers do not have to be the same ones found on the periodic table. In fact, they will not always be whole numbers! Rule 3 cannot be violated! Remember, oxidation numbers are just an accounting system for keeping track of electrons.

Exercise Write the oxidation numbers for each element in I_2.

Exercise Write the oxidation numbers for each element in MnO_4^-.

Chapter Problems

1. Write the correct chemical formula for manganese (III) oxide
2. What is the correct name of the ionic compound CsCl
3. Name the compound $Cd(C_2H_3O_2)_2$
4. Write the formula for silver hydrogen carbonate
5. Write the formula for pentaphosphorus decoxide.
6. Write the name of the compound $Au_2(SO_4)_3$
7. Write the formula for the compound sodium chlorate
8. Write the formula for hypochlorous acid
9. What is the ionic/covalent name for H_3PO_4 and the acid name.
10. How many molecules are in 25.5 g of iron(III) hydroxide?
11. How many ions are in 5.58×10^{24} formula units of tin(IV) nitrate.
12. What is the percent sulfur in sodium thiosulfate?
13. What mass of oxygen would you have in a 7.5 g sample of zin sulfite?
14. What is the empirical formula of a compound that is 24.3% carbon, 4.1% hydrogen, and 71.6% chlorine?
15. What is the molecular formula of a gas that is 30.5% nitrogen and 69.5% oxygen? The molecular mass of the compound is 91.8 grams.
16. Determine the oxidation number of the sulfur atom in SO_3
17. Give oxidation numbers for Pt in $PtCl_6^{2-}$.