Explore Student Guide

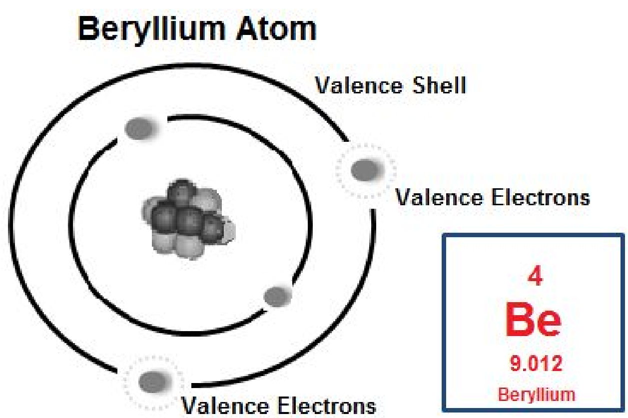
Name: ______________________________ Date: __________

Background: Properties of Ionic and Covalent Bonds

Chemical nomenclature is the term that is given to the process of naming chemical compounds. These rules are established by the International Union of Pure and Applied Chemistry (IUPAC). There are over 100 elements on the periodic table, which combine or bond with each other to create numerous chemical compounds. An element can be identified by its atomic number, or the number of protons located in its nucleus. Electrons are located outside of the nucleus and are arranged in orbitals that make up the energy levels in the electron cloud.

There are only a certain number of electrons that each energy level can hold. Electrons located in the **s** and **p** orbitals of the outermost energy level of the representative (main group) elements are called valence electrons. These electrons have the highest energy. The valence electrons of transition metals are located in **s** and **d** orbitals. These expanded orbitals allow some of these metals to form ions with variable charges. It is the valence electrons that are involved in ionic and covalent bonding. The properties of a substance are determined, in part, by the chemical bonds that hold them together.

The number of valence electrons for the representative elements (main group elements) can be determined by looking at the group A number on the periodic table. As all elements in the same group contain the same number of valence electrons, they all have similar properties. The number of valence electrons for group B elements (transition elements) varies as many have multiple oxidation states, such as Fe^{2+} and Fe^{3+}. All the metals share similar properties, however, due to the number of valence electrons in the outer shell.



The number of valence electrons in an atom of an element also determines its chemical properties, as valence electrons are either transferred or shared when bonds form between atoms, creating compounds. So why do atoms bond with one another?

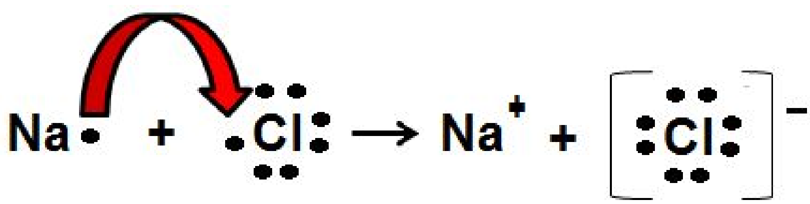
Atoms bond together to satisfy the octet rule, which states that atoms gain, lose, or share electrons to achieve the stable state of eight valence electrons, except for He^{2-}. When atoms have bonded and fulfilled the octet rule, their electron configuration is identical to that of a noble gas. This explains why the resulting compound has greater stability.

Explore Student Guide

Part I: Naming and Building Ionic Bonds

Two main types of chemical bonds hold atoms together, ionic bonds and covalent bonds. Ionic bonds form when electrons are “transferred” from one atom to another. Covalent bonds form when valence electrons are “shared” between atoms. Ionic bonds generally form when a metal bonds with a nonmetal, while covalent bonds form only when nonmetals bond with each other. Ionic bonds may also include polyatomic ions—ions made up of more than one atom.

Ionic compounds contain cations and anions bonded together. Generally, a metal transfers one or more electrons to a nonmetal. This results in a positive charge on the metal (cation) and a negative charge on the nonmetal (anion). These opposite charges form a strong attractive force, or ionic bond. A general term used for an ionic compound formed from a metal and a nonmetal is a salt. For example, sodium (Na^+) combines with chlorine (Cl^-) to make sodium chloride (NaCl), or table salt. The sodium ion has one valence electron and donates this electron to chlorine, with seven valence electrons. This gives both atoms a noble gas configuration.



An ionic bond forms when a metal "loses" its valence electron and "transfers" it to a nonmetal.

Due to the strength of this electrostatic attraction, ionic compounds have physical properties that include high melting and boiling points. They generally exist as crystalline solids. Ionic compounds make good electrolytes. When dissolved in water or melted, the resulting solution is able to conduct electricity.

Two Types of Ionic Compounds

1. Binary ionic compounds consist of two monoatomic ions, a cation (such as Na^+) and an anion (such as Cl^-), forming a salt (NaCl, or table salt).

2. Polyatomic ionic compounds consist of a monatomic cation (such as K^+) and a polyatomic anion (such as ClO_3^-), forming a salt ($KClO_3$, or potassium chlorate). Sometimes the cation is a polyatomic ion, as in the ammonium ion (NH_4^+). Most polyatomic ions, however, are anions.

Explore Student Guide

Part I: Naming and Building Ionic Bonds, continued

Procedure:

1. Create at least five to six ionic compounds using the ionic bonding puzzle pieces provided by your teacher. You will also determine the chemical formula and chemical name of each compound. Three of the ionic compounds must contain a polyatomic ion.

2. Cut out the puzzle pieces and separate into two groups, cations and anions. Use the table from the Student Reference Sheet: Naming Rules for Ionic Compounds to guide you in selecting cations and anions.

3. Choose a positive ion from the list of cations in the table. Write it and its charge on a cation puzzle piece. Next, choose a negative ion from the list of anions. Write it and its charge on an anion puzzle piece. Be sure to look at the charge of the ion you have chosen to determine the size of the puzzle piece you will need.

4. Remember, a cation is always bonded to an anion. You may balance the charges by using the crisscross method, and reduce to simplest ratio if needed. See examples below for balancing the charge to zero (or neutral).

$Al^{3+}O^{2-}$ or Al_2O_3 $\qquad$ $Ca^{2+}O^{2-}$ or $Ca_2O_2 = CaO$ (use simplest ratio)

5. Tape the puzzle pieces together to form an ionic bond. Pieces must match up correctly. For example, a cation like Ca^{2+} will require two of the Cl^{-} ion pieces to fit together.

6. Once you have taped the pieces together, write the ion name and charge on the front, and the chemical formula and name on the back. Use the proper IUPAC nomenclature rules to name each compound.

   front of puzzle piece: **Ca^{2+} Cl^{-}** back of puzzle piece: **$CaCl_2$ = calcium chloride**

7. Polyatomic ions are tightly bound groups of atoms that behave as a unit and carry a charge. Group these ions together with parentheses in a chemical formula if more than one ion is needed to balance the charge. For example, if you combine Cu^{2+} with NO_3^{-}, then you will need two NO_3^{-} to balance the charge. Therefore, write $Cu(NO_3)_2$. The subscript 2 after the polyatomic ion indicates two of these anions are required to balance the charges.

8. Some cations have multiple oxidation states, such as Fe^{2+} and Fe^{3+}. Indicate the cation charge with Roman numerals, such as iron (II) chloride, or iron (III) chloride, respectively.

Explore Student Guide

Part II: Naming Rules for Acids and Bases (General Rules)

Acids. Most hydrogen compounds are acids, conduct electricity, and follow special naming rules. Acids that dissolve in water (aqueous solutions) produce H^+ ions. H^+ serves as the cation and will combines with an anion. Acids, such as HCl, that have only one H^+ ion per acid molecule (essentially a proton) are called monoprotic acids. Those that have more than one H^+ ion are called polyprotic acids. Diprotic acids yield two H^+ ions per acid molecule, triprotic yield three H^+ ions, and so on. Acids can be also be classified as oxyacids (containing oxygen) or non-oxyacids (without oxygen). Acids and bases are also named following the IUPAC naming rules as follows:

Non-oxyacids. Change the hydrogen to "hydro," and change the ending "-ide" to "-ic." HCl is hydrochloric acid, HBr is hydrobromic acid, and HCN is hydrocyanic acid. All of these are monoprotic acids.

Oxyacids. Omit the hydrogen, and change the "-ate" ending of the polyatomic ion to "-ic." Or, change the "-ite" ending of the polyatomic ion to "-ous." Examples of how to name some oxyacids are listed below:

Cation		Anion	Chemical Formula	Name of Acid
H^+	+	NO_3^- (nitrate)	forms HNO_3 (ate becomes ic)	Nitric Acid
H^+	+	NO_2^- (nitrite)	forms HNO_2 (ite becomes ous)	Nitrous Acid
H^+	+	SO_4^{2-} (sulfate)	forms H_2SO_4 (ate becomes ic)	Sulfuric Acid
H^+	+	SO_3^{2-} (sulfite)	forms H_2SO_3 (ite becomes ous)	Sulfurous Acid

Bases. Bases always contain OH^- as the anion and a metal as the cation. Names begin with the first element or cation, and end with hydroxide. Most of the common bases are ionic compounds, and all conduct electricity.

Cation		Anion	Chemical Formula	Name of Base
Na^+	+	OH^-	forms NaOH	Sodium hydroxide
K^+	+	OH^-	forms KOH	Potassium hydroxide
Ca^{2+}	+	OH^-	forms $Ca(OH)_2$	Calcium hydroxide

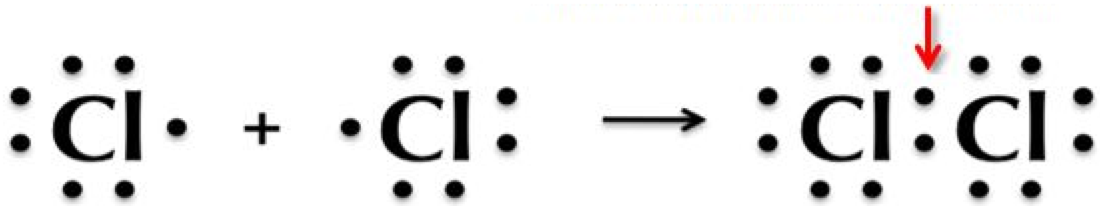
↑ Use parentheses on polyatomic ions, when more than one is needed

Explore Student Guide

Part III: Naming Rules for Covalent Bonds

Two or more atoms that bond together by sharing electrons are said to be covalently bonded and are known as molecules. Covalently bonded atoms within a molecule will achieve a noble gas state by “sharing” their electrons with the other atoms in the molecule. Covalent bonds form only between nonmetals. For example, two chlorine atoms combine to form Cl_2 ,or molecular chlorine, one of the diatomic molecules. In this case, both chlorine atoms contain seven valence electrons. When they combine, the chlorine atoms share their electrons, forming a bonding pair between them that is considered to belong to both atoms. Each chlorine atom has reached a noble gas configuration (stable octet) as well.

These two chlorines are “sharing” an electron, forming a covalent bond.



Molecular Chlorine, Cl_2

All covalent compounds share certain general properties. Covalent compounds may be found in the form of gases, liquids, or solids. As a general rule, they have low melting and boiling points, they are poor electrical conductors in any state, and many are soluble in nonpolar liquids but are not soluble in water.

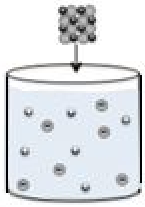
When covalent compounds are able to dissolve in water, the atoms will not separate like ionic compounds. Instead, the molecules will simply separate from each other without breaking the covalent bonds. This means that the bonds between the atoms do not break to create separate ions. The atoms combine with covalent bonds to form molecules. Both the physical and chemical properties of the individual atoms differ from the physical and chemical properties of the compounds they create.

Explore Student Guide

Part III: Naming Rules for Covalent Bonds, continued

Dissolving of Ionic Versus Covalent Compounds

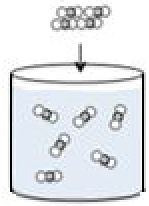
Ionic Compound Dissolving



Forms IONS

The ionic bonds will break apart and ions will form in the liquid.

Covalent Compound Dissolving



Forms MOLECULES

The covalent bonds do NOT separate. The molecules remain bonded together in the liquid.

There are two special things to remember. Water (H_2O) is a covalently bonded molecule because hydrogen, though in group 1A, is not considered a true metal. The seven diatomic molecules are also all covalently bonded.

7 Diatomic Molecules

H_2 N_2 O_2 F_2 Cl_2 Br_2 I_2

In summary, a nonmetal plus a nonmetal forms a covalent bond. In this bond, the valence electrons are being shared between atoms to achieve a stable octet.

For naming, always use the correct Latin numerical prefix on each atom, such as "di-," "tri-," "tetra-," and so on, with the ending of "-ide" on the second atom. The prefix "mono-" is not used on the first atom. Remember, covalent bonds form molecules.