Chem 150, Spring 2015

Unit 1 - Molecular Structures

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3.1 Covalent Bonds and the Octet Rule

- Group 8A elements are called Noble Gases and do not normally form chemical compounds. All of these elements also have a full valence shell, which leads to stability
- Representative elements tend to form compounds such that they fill their valence shells (octet rule).
- Known as the octet rule because this normally results in compounds in which each atom had 8 electrons in its most outer shell.

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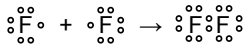
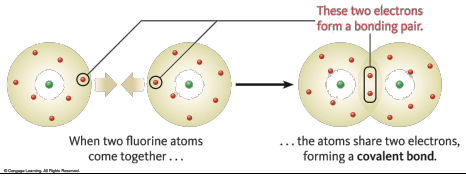
Lewis Structures and Molecules

- Fluorine has 7 valence electrons, and is found as F_2. In this form, both elements have a share in 8 electrons.
- Lewis structures can be used to represent these molecules.





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Bonds

- A chemical bond occurs when two atoms are attracted enough to each other to stay together.
- A covalent bond occurs when electrons are shared between two atoms.
- A pair of shared electrons is known as a bonding electron pair.
- Lone pairs or non-bonding pairs of electrons are the electrons not involved in the covalent bond.

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Try It!

Question:
Draw the Lewis dot structure for a molecule that contains one chlorine atom (Cl) and one fluorine (F) atom.

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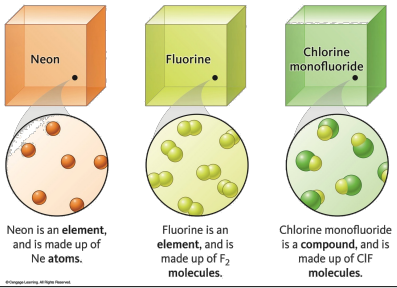
Atoms, Molecules and Compounds

- A group of two or more atoms (identical or different) is a molecule.
- A combination of two or more different elements is a compound.
- All compounds are molecules but not all molecules (like H_2, F_2, etc) are compounds.



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Hydrogen

- Hydrogen atoms need only one electron to fill the valence shell to achieve the electron arrangement of Helium.

$$H^{\circ} + {}^{\circ}H \rightarrow H{:}H$$

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Try It!

Question:
Draw the Lewis dot structure for a molecule that contains one oxygen atom (O) and two hydrogen (H) atoms.

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Covalent Bonds for All Representative Elements

TABLE 3.1 Covalent Bond Formation in Groups 4A Through 8A

	Group 4A	Group 5A	Group 6A	Group 7A	Group 8A
Number of Valence Electrons	4	5	6	7	8
Number of Empty Spaces in the Valence Shell	4	3	2	1	0
Number of Covalent Bonds Formed	4	3	2	1	0
Example of a Typical Molecule	 Methane	 Ammonia	 Water	 Hydrogen fluoride	These elements do not form molecules.

Elements with 5 or more empty spaces rarely form covalent bonds to fill their empty valence shell.

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Try It!

Question:
Draw the Lewis dot structure for a molecule that contains two oxygen atoms (O).

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3.2 Double and Triple Bonds

- One shared pair of electrons (2 total electrons) is a single bond.
- Double bonds form when atoms share two pairs of electrons (4 total electrons).

- Triple bonds form when atoms share three pairs of electrons (6 total electrons).
- Any atom that can form at least 2 bonds can form a double bond and any atom that can form at least 3 bonds can form a triple bond.

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Try It!

Question:
Hydrogen cyanide is a deadly gas, which halts cellular respiration. Draw the Lewis dot structure for hydrogen cyanide.

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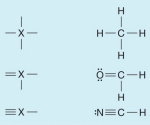
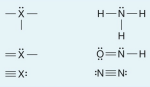
Bonding Patterns for Electrically Neutral Atoms

TABLE 3.2 Bonding Patterns for Electrically Neutral Atoms

Group Number	Normal Number of Covalent Bonds	Possible Bonding Patterns	Examples
4A	4		
5A	3		
6A	2		
7A	1		

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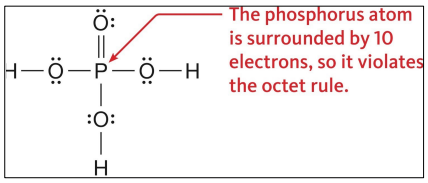
Bonding Patterns for Electrically Neutral Atoms

There are some exceptions, including non-metals in the third period and higher can violate the octet rule by sharing in more than 8 electrons.



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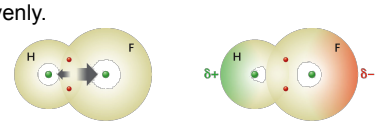
3.3 Electronegativity and Polar Bonds

- Atoms of different elements can form polar covalent bonds.
  - Atoms of some elements are able to attract electrons in a bond stronger than others.
  - Polar bonds occur when electrons are shared unevenly.



Fluorine attracts the electrons more than hydrogen in HF, so fluorine is partially negative and hydrogen is partially positive.

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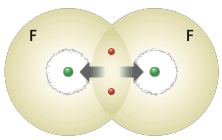
Nonpolar Covalent Bonds

- Two identical atoms have equal attraction to electrons in a bond, and therefore share them equally.
- This results in the formation of a nonpolar covalent bond in which atoms are not charged.



In F_2, each atom attracts the electrons equally, so neither atom is charged. F_2 has a **nonpolar covalent bond.**

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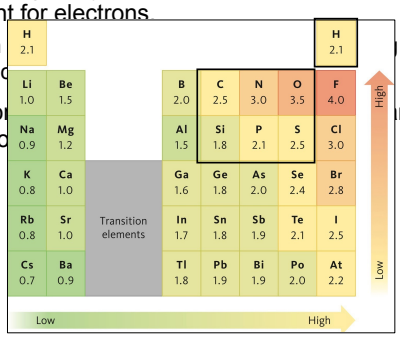
Electronegativity

- Electronegativity measures the attraction of an element for electrons
  - High
- Electro
from bo



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Try It!

Question:
Draw the Lewis dot structure for carbon monoxide and predict whether or not it is a polar molecule.

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3.8 Polyatomic Ions

- Ions can be monatomic, such as Na^+ or Fe^{2+} or Cl^-.
  - For main group, or representative elements, the charge can be predicted from their location on the periodic table.
- Polyatomic ions are ions that are made up of more than one atom, which are covalently bonded together.

Example: NaOH consists of Na^+ and OH^-. OH^-, hydroxide ion, is a polyatomic ion.

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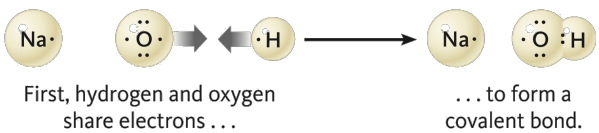
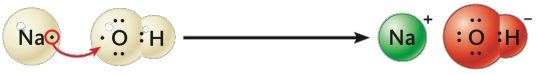
Example: NaOH

Example: NaOH comprises Na^+ and OH^-. OH^-, an hydroxide ion, is a polyatomic ion.



First, hydrogen and oxygen share electrons . . .

. . . to form a covalent bond.



Then sodium gives up an electron to the OH group . . .

. . . to form a pair of ions.

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Common Polyatomic Ions

TABLE 3.10 Formulas and Names of Common Polyatomic Ions

Formula	Name	Example of a Compound That Contains This Ion
NH_4^+	Ammonium	NH_4Cl (ammonium chloride: sal ammoniac)
OH^-	Hydroxide	$Mg(OH)_2$ (magnesium hydroxide: milk of magnesia)
NO_3^-	Nitrate	KNO_3 (potassium nitrate: saltpeter)
CO_3^{2-}	Carbonate	$CaCO_3$ (calcium carbonate: chalk)
SO_4^{2-}	Sulfate	$MgSO_4$ (magnesium sulfate: Epsom salt)
PO_4^{3-}	Phosphate	$Fe_3(PO_4)_2$ (iron(II) phosphate: ferrous phosphate)
HCO_3^-	Hydrogen carbonate (or bicarbonate)	$NaHCO_3$ (sodium hydrogen carbonate: sodium bicarbonate, baking soda)

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Polyatomic Ions in Compounds

- Compounds with polyatomic ions should be balanced in the same way as compounds with monatomic ions.
- Polyatomic ions are treated as a unit. If there is more than one polyatomic ion, parenthesis are used.

Example: What is the formula for calcium nitrate?

Ca^{2+} and NO_3^-. We need 2 NO_3^- to balance the Ca^{2+}, so we use parenthesis.

$$Ca(NO_3)_2$$

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3.9 Recognizing Ionic and Molecular Compounds

- Ionic compounds typically contain a metallic element
  - CaO, $Fe(NO_3)_3$, $NaC_2H_3O_2$
- Molecular (covalent) compounds typically contain only non-metals
  - CO_2, H_2SO_4, CH_3OH, $C_3H_5(NO_3)_3$
- NH_4^+ is an ion, so compounds that contain NH_4^+ are ionic
  - NH_4Cl, $(NH_4)_3PO_4$

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Ionic and Molecular Compounds

- Hydrogen containing compounds, like HCl or H_2SO_4, are molecular structures with covalent bonds, because hydrogen is a non-metal.
- Naming conventions differ for ionic and covalent compounds, so it is important to distinguish them.
- For example:
  - $AlCl_3$ is ionic- aluminum chloride
  - PCl_3 is molecular- phosphorous trichloride

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Ionic and Molecular Compounds

TABLE 3.11 A Comparison of Ionic Compounds Containing Monatomic and Polyatomic Ions

CATION	COMPOUNDS FORMED WITH −1 IONS (Cl^- and NO_3^-)		COMPOUNDS FORMED WITH −2 IONS (S^{2-} and CO_3^{2-})	
Na^+	NaCl (sodium chloride)	$NaNO_3$ (sodium nitrate)	Na_2S (sodium sulfide)	Na_2CO_3 (sodium carbonate)
Mg^{2+}	$MgCl_2$ (magnesium chloride)	$Mg(NO_3)_2$ (magnesium nitrate)	MgS (magnesium sulfide)	$MgCO_3$ (magnesium carbonate)
Al^{3+}	$AlCl_3$ (aluminum chloride)	$Al(NO_3)_3$ (aluminum nitrate)	Al_2S_3 (aluminum sulfide)	$Al_2(CO_3)_3$ (aluminum carbonate)

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Chapter 3—Key Health Science Notes

- In many of the health sciences, you will ***continually*** learn about the naming of medications, both the generic and brand names
  - In some medications that contain ions, the positive ion is named after the negative ion, for example:
    - The chemical name of the cholesterol-lowering medication Lipitor® is generally written *atorvastatin calcium*, although the calcium is a +2 ion

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Next Up

- Unit 2 - Molecular Interactions
  - Readings Chapter 4-1,2,5 & 6 and Chapter 5-3,5 & 6
  - Homework Assignment due on 5. Feb.

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