Lesson 11: Covalent Bonding

Reminder: List of Information you can get from the Periodic Table
1. Groups/families and their names
2. Periods
3. Period number = number of electron shells
4. Group # 1A-8A = number of valence electrons
5. Ions most likely formed
6. Location of metals, nonmetals and metalloids
7. Trends in atomic radii
8. Trends in ionization energy
9. Trends in electronegativity
10. s,p,d and f block elements to write electron configuration

Covalent Compounds (AKA molecules)

- **Covalent bonds** are formed by __________________________ between atoms
  - Formed between __________________________ to create neutral molecules.
  - Nonmetal atoms don’t transfer electrons between each other because each needs to ___________ electrons to have __________________________.
  - Covalent bonds are the __________________________ between the __________________________ nuclei of the bonded atoms and one or more _____________ of electrons that are located __________________________ the atoms.

Predict whether the following compounds are ionic or molecular:

a) KI, the compound used as a source of iodine in table salt
b) H₂O₂, the bleach and disinfectant hydrogen peroxide
c) CHCl₃, the anesthetic chloroform
d) Li₂CO₃, a source of lithium in antidepressants
e) SO₂
f) CaF₂
g) N₂H₄
h) Al₂(SO₄)₃
Electrons are **shared** between two nonmetal atoms to form covalent bonds. In a single covalent bond, there are two shared electrons. A single covalent bond containing two electrons is represented as one line.

Naming Covalent (Binary III) Compounds:

When two nonmetallic elements form a molecular compound, several combination ratios are often possible. Carbon and Oxygen can combine to form CO or CO\(_2\). Since these are different molecules with different properties, they need different names.

**Guidelines:**

- 1\(^{st}\) element in the formula is named with the full element name
- 2\(^{nd}\) element is named with the “-ide” ending

Prefixes are used before **both element names** to specify the **number of atoms** of each element present

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Number of Atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>mono-</td>
<td>1</td>
</tr>
<tr>
<td>di-</td>
<td>2</td>
</tr>
<tr>
<td>tri-</td>
<td>3</td>
</tr>
<tr>
<td>tetra-</td>
<td>4</td>
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<tr>
<td>penta-</td>
<td>5</td>
</tr>
<tr>
<td>hexa-</td>
<td>6</td>
</tr>
<tr>
<td>hepta-</td>
<td>7</td>
</tr>
<tr>
<td>octa-</td>
<td>8</td>
</tr>
<tr>
<td>nona-</td>
<td>9</td>
</tr>
<tr>
<td>deca-</td>
<td>10</td>
</tr>
</tbody>
</table>

*never used to name 1\(^{st}\) element*

**Examples:**

1. \(\text{SO}_2\) sulfur dioxide
2. \(\text{SO}_3\) sulfur trioxide
3. \(\text{NO}_2\) nitrogen dioxide
4. \(\text{N}_2\text{O}_4\) dinitrogen tetroxide
5. \(\text{P}_4\text{O}_{10}\) tetraphosphorous decaoxide
The following website (http://openstaxcollege.org/l/16chemcompname) provides practice with naming chemical compounds and writing chemical formulas. You can choose binary, polyatomic, and variable charge ionic compounds, as well as molecular compounds.

Box 1.

1. Write the chemical formulas (with phase symbols) for the substances in containers A – D.
   Bottle A: ________    Bottle B: ________    Bottle C: ________    Bottle D: ________

2. Which container(s) contain a pure element? ________________________

3. Which container(s) contain a gas? _________________________________

4. Draw a mixture of carbon monoxide and hydrogen gas in container E.

5. Compare the properties of the substances in container B vs. C. Are they the same or different?
<table>
<thead>
<tr>
<th>Bond Formation</th>
<th>Ionic Bond</th>
<th>Covalent Bond</th>
<th>Metallic</th>
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</thead>
<tbody>
<tr>
<td>Type of Structure</td>
<td></td>
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<tr>
<td>Physical State</td>
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<td>Melting Point</td>
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<td>Solubility in water</td>
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<td>Electrical Conductivity</td>
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<tr>
<td>Other Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examples</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
III. Identify whether the compound is ionic or covalent and Binary I, II, or III. Then name the compound.

1. N₂O₅
2. Cs₂S
3. PbSO₄
4. Sc₂Se₃
5. XeI₆
6. K₂O
7. PBr₃
8. Pd(NO₂)₄

IV. Identify whether the compound is ionic or covalent. Then write the formula of the compound.

1. Silver nitrate
2. Lanthanum (III) arsenide
3. Silicon tetrafluoride
4. Diphosphorus dichloride
5. Iridium (I) sulfate

Box 2.
Lewis Structures

- Shows how _______________________ are arranged among the atoms in a molecule
- Rules for writing Lewis structures are based on observations of thousands of molecules
- From experimentation, chemists have learned that the most important requirement for the formation of a stable compound is that the atoms achieve ________________________________.

Reminder of the Guidelines:
- dots are used to represent electrons
- only valence electrons are included

Lewis Structures for molecules with covalent bonds:

*The principle of achieving a noble gas configuration applies to these elements as well!

- **Hydrogen**
  - forms stable molecules where it shares two electrons (duet rule)
  - two hydrogen atoms, each with one electron, combine to form $\text{H}_2$

\[
\begin{array}{c}
\text{H}^\cdot + \text{H}^\cdot \\
\text{H}:\text{H}
\end{array}
\]

*By sharing electrons, each hydrogen effectively has two electrons.*

- **Helium**
  - does not form bonds because its valence orbital is already filled (it’s a noble gas)
  - has an electron configuration of $1s^2$

  $\text{He}$:

- **2\textsuperscript{nd} Period Nonmetals**
  - Follow octet rule – stable molecules are formed when atoms are surrounded by 8 electrons

Each F atom is effectively surrounded by 8 electrons, two of which are shared with the other atom.
**Figure 1:** Note the Lewis Dot diagrams and General Lewis Dot Diagrams for each atom. Memorize this pattern to help you draw Lewis Dot Structures.

**Atoms make a predictable number of bonds:**

![Lewis Dot Diagrams](image)

- **Hydrogen** will make 1 bond.  
  - \(8 - 1 = 7\)
- **Carbon** will make 4 bonds.  
  - \(8 - 4 = 4\)
- **Nitrogen** will make 3 bonds.  
  - \(8 - 5 = 3\)
- **Oxygen** will make 2 bonds.  
  - \(8 - 6 = 2\)
- **Fluorine** will make 1 bond.  
  - \(8 - 7 = 1\)

First, draw the Lewis structures for neutral atoms. Then, draw circles to show the formation of covalent bonds between the atoms. Last, draw the final Lewis Structure for each compound. **Atoms share their valence electrons to form covalent bonds.**

1. HCl

2. Cl₂
3. SiH$_4$

4. N$_2$

5. HCN

6. CH$_4$

7. NCl$_3$
V: Fill in the blanks.

Lewis Dot diagrams are a way to show the arrangement of _______________ electrons and _______________ bonds between atoms of nonmetal atoms. First you must add the total number of _______________ from each atom. To form covalent bonds, atoms _______________ their valence bonds to achieve a Noble Gas _______________.

For Lewis Structures, first you draw single bonds between each atom; each covalent bond represents a _______________ of _______ electrons. Sometimes, atoms share more than two electrons and form _______________ and _______________ covalent bonds, as they share 4 or 6 electrons. Electron pairs that are not involved in bonding are called _________________.

VI: Draw Lewis Dot structures for the following molecules.

1. Br₂

2. HF

3. SiF₄

4. CO₂

5. H₂
6. \(\text{H}_2\text{S}\)

7. \(\text{NCl}_3\)

8. \(\text{C}_2\text{H}_4\)

9. boron trichloride

**VII:** Identify the type of covalent bond below (single, double, triple). Then, fill in the blanks below.

\[\begin{array}{ccc}
\ddots & \ddots & \ddots \\
\ddots & \ddots & \ddots \\
\ddots & \ddots & \ddots \\
\end{array}\]

a) The oxygen atoms are sharing _______ electrons total. Each Oxygen has ______ lone pairs.

b) The nitrogen atoms are sharing _______ electrons total. Each Nitrogen has ______ lone pairs.

c) The fluorine atoms are sharing _______ electrons total. Each Fluorine has ______ lone pairs.
Box 3
Predict which of the following compounds are ionic and which are covalent, based on the location of their constituent atoms in the periodic table:

1. Cl₂CO
2. MnO
3. NCl₃
4. CoBr₂
5. K₂S
6. CO
7. CaF₂
8. HI
9. CaO
10. IBr
11. CO₂
12. H₂S

Box 4
From their positions in the periodic table, arrange the atoms in each of the following series in order of increasing electronegativity:

1. C, F, H, N, O
2. Br, Cl, F, H, I
3. F, H, O, P, S
4. Al, H, Na, O, P
5. Ba, H, N, O, As

Box 5
Write the Lewis symbols of the ions in each of the following ionic compounds and the Lewis symbols of the neutral atoms from which they are formed:

1. MgS
2. Al₂O₃
3. K₂O
4. Li₃N
Lewis Structures – Lone pairs practice.
How many lone pairs (unshared pairs of electrons) are on the central atom?

1. PCl₃  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

2. SF₂  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

3. NH₄  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

4. CO₂  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

5. CCl₄  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

6. CH₄  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

7. SO₂  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

8. HCN  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

9. AsF₃  \[\underline{_______}\] lone pairs on the \[\underline{_______}\]

10. ClNO \[\underline{_______}\] lone pairs on the \[\underline{_______}\]