**Answer Key: Simulation: Ionic and Covalent Bonding**

**Background**

In this investigation you will bond select atoms. Based upon the types of atoms that you choose to combine, you will create either an ionic compound or a covalent compound. You will have the opportunity to analyze the differences between these different types of compounds and to predict the number of atoms needed to create each, as well as learn how to appropriately name them.

1. Describe the difference between an atom and a molecule:
   Atoms are the smallest single unit of a particular element and are the smallest functional unit of matter; atoms are neutral, and each element has its own unique type of atom. Molecules are neutral groups of more than one atom stuck together with a covalent bond (sharing electrons); they can be more than one atom of the same element or of different elements.

2. Where are metal atoms located on the periodic table? Where are non-metal atoms located on the periodic table?
   Metals are on the left and center of the periodic table and they make up about 80% of the elements, so they take up the most space on the periodic table. Nonmetals are in the upper right corner of the periodic table, as well as hydrogen, the very first element on the upper left. They only make up about 15% of the elements.

3. What subatomic particle(s) participate in chemical bonding?
   Electrons are the subatomic particles that participate in chemical bonding.

4. In your own words, define *valence electron*.
   Valence electrons are the outermost electrons on an atom, and they are the ones that form an atom’s bonds, since they are on the outside and accessible to other atoms that might form bonds. They can be exchanged between atoms or shared.

5. How can you determine the number of valence electrons in an atom using the periodic table?
   The group numbers can help determine the number of valence electrons. Group 1A elements have 1 valence electron, 2A have 2, 3A have 3, etc. through 8A. This skips over the transition metals (the elements in the “B” groups in the middle section of the periodic table), as their valence electrons are not as easily determined. If there are no letters in your periodic table group numbers and they just go from 1-18, subtract 10 from groups 13-18 and that is the number of valence electrons. (Again, this skips the transition metals.)

6. Draw a Lewis Dot Structure for the following atoms:
   a. Strontium (Sr)  
   b. Carbon (C)  
   c. Iodine (I)  
   d. Xenon (Xe)
   ![Sr, C, I, Xe Lewis Dot Structures]

*Check your answers before moving on to the next portion of the activity.*
Procedure
Using your computer, tablet or mobile device, navigate to the website: http://www.teachchemistry.org/bonding. You should see the picture below on your screen.

![Choose elements from the periodic table to bond.](image)

**Part 1: Ionic Bonding**
1. Choose Sodium (Na).
   a. What type of element is it?
   Metal
   b. How many valence electrons does it have?
   1
2. Choose Fluorine (F).
   a. What type of element is it?
   Nonmetal
   b. How many valence electrons does it have?
   7
3. Answer the question on the screen, “What type of bond is this combination likely to form?”
   a. Circle: Ionic or Covalent?
   b. Choose the appropriate number of atoms to make the bond. Record the number of each atom below:
   1 Na, 1 F
4. Watch the final animation closely (it will play continuously).
   a. Describe the change in the number of valence electrons in the atoms as the bond is successfully formed:
   The sodium gives its one valence electron to fill the one empty space in the valence shell in the fluorine atom
   b. What does the positive (+) charge indicate (mention specific subatomic particles in your answer)?
   The + charge means that there are now more protons than electrons in that atom, as the sodium atom lost one electron (giving it to the fluorine).
c. What does the negative (-) charge indicate (mention specific subatomic particles in your answer)?
   The – charge means that there are now more electrons than protons in that atom, as the fluorine atom took one electron from the sodium.

d. What is the final overall charge?
   The final overall charge is 0 – Na is +1 and F is -1, so they balance each other out.

e. Record the name and molecular formula for the compound below:
   NaF, Sodium Fluoride

   \textit{Reset the selected data using the reset symbol.}

5. Choose Calcium (Ca).
   a. What type of element is it?
      Metal
   b. How many valence electrons does it have?
      2

6. Choose Chlorine (Cl).
   a. What type of element is it?
      Nonmetal
   b. How many valence electrons does it have?
      7

7. Answer the question on the screen, “What type of bond is this combination likely to form?”
   a. Circle: Ionic or Covalent?
      Ionic
   b. Choose the appropriate number of atoms to make the bond. Record the number of each atom below:
      1 Ca, 2 F

8. Watch the final animation closely (it will play continuously).
   a. Why were more than 2 total atoms needed to create this compound?
      There are more than two atoms because the calcium had two electrons to give away, and the chlorine could only accept one more electron to fill its valence shell. A second chlorine atom was needed to take the second valence electron from the calcium so all the atoms could empty or fill their valence shells.
   b. Explain what happened to the valence electrons in each atom.
      Calcium loses two valence electrons to empty its valence shell, and each chlorine gains one of those electrons to fill their valence shells.
   c. What is the final overall charge?
      The final overall charge is 0 – Ca is +2 and each of the two Cl are -1, so they balance each other out.
   d. Record the name and molecular formula for the compound below:
      CaCl\textsubscript{2}, Calcium Chloride
e. Have you noticed a pattern between the charge of the ion and the number of valence electrons it has? Explain how you can predict the charge based on the number of valence electrons, or the location of the element on the periodic table.

A full valence shell is 8 electrons. If an atom’s valence shell is less than half full (4 e−), it will lose its valence electrons and its charge will be positive, equaling the number of electrons lost. If an atom’s valence shell is more than half full, it will gain valence electrons and its charge will be negative, equaling the number of electrons gained.

// Reset the selected data using the reset symbol. //

9. Using a periodic table, complete the table below, then use the simulation to check each of your predictions:

<table>
<thead>
<tr>
<th>Atom #1</th>
<th>Number of Valence Electrons</th>
<th>Prediction of charge</th>
<th>Atom #2</th>
<th>Number of Valence Electrons</th>
<th>Prediction of charge</th>
<th>Molecular Formula</th>
<th>Name of compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>1</td>
<td>1+</td>
<td>O</td>
<td>6</td>
<td>2−</td>
<td>Na₂O</td>
<td>Sodium Oxide</td>
</tr>
<tr>
<td>K</td>
<td>1</td>
<td>1+</td>
<td>F</td>
<td>7</td>
<td>1−</td>
<td>KF</td>
<td>Potassium Fluoride</td>
</tr>
<tr>
<td>Mg</td>
<td>2</td>
<td>2+</td>
<td>Cl</td>
<td>7</td>
<td>1−</td>
<td>MgCl₂</td>
<td>Magnesium Chloride</td>
</tr>
<tr>
<td>Ca</td>
<td>2</td>
<td>2+</td>
<td>N</td>
<td>5</td>
<td>3−</td>
<td>Ca₃N₂</td>
<td>Calcium Nitride</td>
</tr>
<tr>
<td>Al</td>
<td>3</td>
<td>3+</td>
<td>S</td>
<td>6</td>
<td>2−</td>
<td>Al₂S₃</td>
<td>Aluminum Sulfide</td>
</tr>
</tbody>
</table>

**Part 2: Covalent Bonding**

1. You will first investigate 5 diatomic molecules. Diatomic molecules are made up of 2 atoms.

a. Select 2 fluorine atoms. How many valence electrons are in each fluorine atom?
   7
b. Is a fluorine atom a metal or a non-metal?
   Nonmetal
c. Did the combination of these atoms create a covalent or ionic bond?
   Covalent
d. How are the valence electrons organized to form a bond between these atoms?
   The unpaired valence electron in each of the fluorine atoms is shared between the two atoms to complete both valence shells.
e. How is this different from the ionic bonds formed in the previous part of the activity?
   The electrons are shared between the two atoms and count towards both atoms’ final electron count, rather than one giving and the other receiving electrons.

f. What shape does this molecule form?
   Linear

2. a. Select 2 oxygen atoms. How many valence electrons are in each oxygen atom?
   6

   b. Is an oxygen atom a metal or a non-metal?
   Nonmetal

   c. Did the combination of these atoms create a covalent or ionic bond?
   Covalent

   d. How are the valence electrons organized to form a bond between the atoms?
   The two unpaired electrons in each of the oxygen atoms are shared between the two atoms to complete both valence shells.

   e. How is this bond different from the bond in the fluorine molecule in question 1?
   There was only 1 pair of electrons shared between the two fluorine atoms in the fluorine molecule, but there are 2 pairs of electrons shared between the two oxygen atoms in the oxygen molecule, since both of them had two unpaired electrons that each needed a partner.

   f. What shape does this molecule form?
   Linear

3. Make predictions in the following table. Once completed, check your answers using the simulation.

<table>
<thead>
<tr>
<th>Lewis dot structure for single atom</th>
<th>Cl</th>
<th>S</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lewis dot structure for diatomic molecule (Cl2, S2, N2)</td>
<td>Cl:Cl</td>
<td>S:S</td>
<td>N:N</td>
</tr>
<tr>
<td>Molecular formula</td>
<td>Cl2</td>
<td>S2</td>
<td>N2</td>
</tr>
<tr>
<td>Name of shape</td>
<td>Linear</td>
<td>Linear</td>
<td>Linear</td>
</tr>
</tbody>
</table>
4. More than two atoms can also be combined to form a covalent molecule. These molecules may form different shapes and will also follow a particular naming system. Select the following combinations of atoms, and complete the rest of the table as you interact with the simulation:

<table>
<thead>
<tr>
<th>1st atom choice</th>
<th>2nd atom choice</th>
<th>Predict Formula</th>
<th>Molecular Name</th>
<th>Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>F</td>
<td>SF₂</td>
<td>Sulfur Difluoride</td>
<td>Bent</td>
</tr>
<tr>
<td>N</td>
<td>Cl</td>
<td>NCl₃</td>
<td>Nitrogen Trichloride</td>
<td>Trigonal Pyramidal</td>
</tr>
<tr>
<td>Cl</td>
<td>F</td>
<td>CIF</td>
<td>Chlorine Monofluoride</td>
<td>Linear</td>
</tr>
</tbody>
</table>

Part 3: Critical thinking

1. What are the differences between ionic and covalent bonds? Be sure to refer to valence electrons in your response. In ionic bonds, one atom (a metal) gives away electrons because its valence shell is less than half full and it is easier to empty it than to fill it up. The reverse is true for the other atom (a nonmetal) – its valence shell is mostly full, so it takes electrons from a mostly-empty atom that wants to get rid of electrons to complete its valence shell. This results in one atom being positive and the other being negative, but the overall charge is 0. In covalent bonds, two atoms (both nonmetals) share electrons between them to get full valence shells. Since both are nonmetals and have mostly full valence shells, neither wants to get rid of electrons entirely, which is why they share and neither atom has a charge.

2. How is naming ionic and covalent compounds different? Use specific examples in your answer. Ionic compounds give the name of the metal atom (unchanged) followed by the name of the nonmetal atom with the ending changed to “-ide” (ex: magnesium chloride). Covalent compounds (both nonmetals) also change the ending of the second element to “-ide” but in addition they use prefixes to indicate the number of atoms of each type in the compound (ex: nitrogen trichloride, NCl₃).

3. Based on your knowledge of ionic and covalent bonds, complete the missing portions of the following table:

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Ionic or Covalent?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium bromide</td>
<td>BeBr₂</td>
<td>Ionic</td>
</tr>
<tr>
<td>Phosphorus trifluoride</td>
<td>PF₃</td>
<td>Covalent</td>
</tr>
<tr>
<td>Sulfur diiodide</td>
<td>SI₂</td>
<td>Covalent</td>
</tr>
<tr>
<td>Strontium phosphide</td>
<td>Sr₃P₂</td>
<td>Ionic</td>
</tr>
<tr>
<td>Cesium nitride</td>
<td>Cs₃N</td>
<td>Ionic</td>
</tr>
<tr>
<td>Dinitrogen monoxide</td>
<td>H₂O</td>
<td>Covalent</td>
</tr>
</tbody>
</table>