Name _____ Class _____ Date _____

# Metallic Bonding

## Section Review 6.4

**DIRECTIONS:** Write on the line at the right of each statement the letter preceding the word or expression that best completes the statement.

1. Compared to nonmetals, the number of valence electrons in metals tends to be (a) smaller; (b) greater; (c) about the same; (d) almost triple that of nonmetals. _____ 1
2. In metals, the valence electrons are considered to be (a) attached to particular positive ions; (b) shared by all of the atoms; (c) immobile; (d) involved in covalent bonds. _____ 2
3. In *s*-block and *d*-block metals, the number of valence electrons in the outermost *s* sublevel is usually (a) 1 or 2; (b) 2 or 3; (c) 4; (d) 8. _____ 3
4. The fact that metals are malleable and ionic crystals are brittle is best explained in terms of their (a) chemical bonds; (b) London forces; (c) heats of vaporization; (d) polarity. _____ 4
5. The property of metallic luster is most closely related to the metal's (a) electron sea; (b) covalent bonds; (c) brittle crystalline structure; (d) positive ions. _____ 5
6. As light strikes the surface of a metal, the electrons in the electron sea (a) allow the light to pass through; (b) become attached to particular positive ions; (c) fall to lower energy levels; (d) absorb and re-emit the light. _____ 6

**DIRECTIONS:** Write on the line at the right of each statement the word or expression that best completes the meaning when substituted for the corresponding number.

7. A __(7)__ bond is a type of chemical bond that results from the attraction between positive ions and surrounding mobile electrons. _____ 7
8. The property called __(8)__ is the ability to be shaped or extended by physical pressure. _____ 8
9. __(9)__ is the property of being able to be drawn into a wire. _____ 9
10. Metals are referred to as __(10)__ , which means shiny. _____ 10

**DIRECTIONS:** Fill in the spaces below by checking either metallic solid or ionic solid, depending on which type of solid is associated with the property on the left.

| | Property | Metallic Solid | Ionic Solid | |
|---|---|---|---|---|
| 11. | ductile | | | 11 |
| 12. | brittle | | | 12 |
| 13. | nonconductive | | | 13 |
| 14. | malleable | | | 14 |
| 15. | lustrous | | | 15 |

## The metallic bond

15. Describe bonding in metallic solids. _____

_____

16. What are the significant physical properties of metallic solids? _____

_____

## Hydrogen bonding

17. Draw a diagram to illustrate hydrogen bonding between molecules of HF.

18. Under what circumstances do hydrogen bonds form? _____

_____

19. What properties are associated with compounds containing hydrogen bonds? _____

_____

_____

## Van der Waals forces

20. What is the source of van der Waals forces? _____

_____

_____

21. What factors determine the magnitude of the van der Waals forces acting between molecules?

_____

_____

22. What properties of molecules are associated with van der Waals forces? _____

_____

_____

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CHAPTER 15 REVIEW ACTIVITY

Text Reference: **Section 15-6**

# Orbital and Dot Diagrams and Molecular Shape

Orbital diagrams and dot diagrams like those shown below can be used to show the electron configurations of atoms and the shifts in electrons that occur during bonding. In the orbital diagram, each arrow represents an electron in a particular orbital. In the dot diagram, each dot represents a valence electron.

Carbon:


Orbital Diagram

Dot Diagram

Note that the orbital diagram represents the hybridization of the four orbitals of the valence shell: each orbital (one *s* and three *p*) is half filled. All four orbitals are therefore available for bonding.

Such bonding is called $sp^3$ bonding. It allows for four bonds of the same character and generally results in a tetrahedral shape for a molecule (or portion of a molecule) in which the carbon atom is bonded to four other atoms (for example, $CH_4$).

Bonding that involves three *p* orbitals ($p^3$ bonding) generally results in a pyramidal molecular shape. Bonding involving two *p* orbitals ($p^2$ bonding) generally results in a bent, non-linear molecule. Bonding involving one *p* orbital (*p* bonding) results in a linear molecule.

**Draw orbital and dot diagrams for the atoms below, and predict the type of bonding ($sp^3$, $p^3$, $p^2$, or *p*) characteristic of each and the approximate shapes of the molecules that would result from such bonding.**

**1.** Oxygen (element no. 8)

**a.** Orbital **b.** Dot

**c.** Type of bonding _____ **d.** Shape _____

**2.** Fluorine (element no. 9)

**a.** Orbital **b.** Dot

**c.** Type of bonding _____ **d.** Shape _____

**3.** Nitrogen (element no. 7)

**a.** Orbital **b.** Dot

**c.** Type of bonding _____ **d.** Shape _____

**4.** Silicon (element no. 14)

**a.** Orbital **b.** Dot

**c.** Type of bonding _____ **d.** Shape _____

## Orbital and Dot Diagrams and Molecular Shape (continued)

**5.** Phosphorus (element no. 15)

**a.** Orbital

**b.** Dot

**c.** Type of bonding _____

**d.** Shape _____

**Draw orbital and dot diagrams for each of the compounds below, and, in each case, state the type of bonding for the central atom and the shape of the molecule.**

**6.** Oxygen difluoride ($OF_2$)

**a.** Orbital

**b.** Dot

**c.** Type of bonding _____

**d.** Shape _____

**7.** Nitrogen trifluoride ($NF_3$)

**a.** Orbital

**b.** Dot

**b.** Type of bonding _____

**d.** Shape _____

**8.** Carbon tetrafluoride ($CF_4$)

**a.** Orbital

**b.** Dot

**c.** Type of bonding _____

**d.** Shape _____

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# 8–1 Review and Reinforcement

## *The Shape of Small Molecules*

*On the line at the left, write the term from the list that matches each description below.*

trigonal planar
*sp* orbital
symmetry
unshared pair
fullerenes
VSEPR theory
ball-and-stick model
bond angle
hybrid orbital
$sp^2$ orbital

_____ **1.** a visual model of molecular geometry

_____ **2.** combination of one *s* orbital with one *p* orbital

_____ **3.** the geometric angle between two adjacent bonds

_____ **4.** a pair of valence electrons not involved in a bond

_____ **5.** the theory that states that the pairs of valence electrons are arranged as far apart as possible in small molecules

_____ **6.** name for a triangular flat molecule

_____ **7.** the type of hybrid orbital in a triangular flat molecule

*Complete the following table by filling in the molecular shape and bond angles for each of the molecules listed.*

| | Molecule | Molecular Shape | Bond Angles |
|---|---|---|---|
| **8.** | $H_2O$ | | |
| **9.** | $CHCl_3$ | | |
| **10.** | $BF_3$ | | |
| **11.** | $NH_3$ | | |
| **12.** | $CO_2$ | | |

*Draw a ~~ball-and-stick~~ model for each of the following molecules in the space provided. Label the bond angles in your drawings.*

**13.** $PCl_3$

**14.** $H_2S$

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## *8–1 Review and Reinforcement (continued)*

**15.** $CBr_4$

**16.** $C_2F_2$

**17.** $C_2H_6$

*Draw a ~~ball-and-stick~~ structural model for each of the following and identify the hybrid orbitals in each molecule or ion.* + Predict the molecular shape (geometry).

**18.** ~~$BeCl_2$~~ $CCl_4$

**19.** $BF_3$

**20.** $NH_4^+$

**21.** $OF_2$

**22.** $PF_3$

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# 8–2 Review and Reinforcement

## *Polarity*

*Complete each of the following sentences by filling in the appropriate word or phrase from the list below.*

nonpolar
polar
negative
shape
equally
unequally
electric
polarity
molecule

1. In a polar bond, electrons are shared _____ between two atoms.
2. A molecule that is composed of only one kind of atom is a(n)_____ molecule.
3. The _____ of a molecule, as well as the polarity of its bonds, determines the polarity of the molecule.
4. In a polar molecule, one end of the molecule is positive and the other end is _____.
5. Polar molecules align themselves in a(n) _____ field.
6. The _____ of a large molecule helps to determine its shape.

*Identify each of the following molecules as a polar or nonpolar molecule. Write your answer on the line provided.*

7. HF _____
8. $F_2$ _____
9. $H_2O$ _____
10. $O_3$ _____
11. $CBr_4$ _____
12. $C_2H_4$ _____

*Solve each of the following problems as directed. Show all your work.*

13. Illustrate the molecular shape of each of the following molecules. Identify each molecule as polar or nonpolar.

    **a.** $BFI_2$

    **b.** $NH_2Cl$

**d.** $BF_3$

**g.** $CCl_4$

**e.** $H_2O$

**h.** $NF_3$

*Answer each of the following questions in the space provided.*

**14.** Why is HCl a polar molecule while $Cl_2$ is a nonpolar molecule?

**15.** Explain why water has different properties from carbon dioxide. Base your answer on the molecular structure of these substances.

**16.** The proteins in many cells contain both polar and nonpolar sidechains. The nonpolar sidechains are usually found on the inside of the protein, while the polar sidechains are found on the outside facing the cell's cytoplasm, which is mostly water. Explain why proteins assume this type of structure.

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* Use VSEPR Theory or "central" atom bonding type to predict molecular shape.

# 8–1 Practice Problems

1. What is the molecular shape of carbon tetrachloride ($CCl_4$)? What are the bond angles in this molecule?

2. A molecule of hydrogen cyanide contains 1 hydrogen atom, 1 carbon atom, and 1 nitrogen atom. The carbon is bonded to the hydrogen atom and to the nitrogen atom. Predict the bond angle in this molecule.

3. What is the molecular shape of boron trifluoride ($BF_3$)? What are the bond angles in this molecule?

4. A molecule of beryllium chloride contains a beryllium atom bonded to 2 chlorine atoms. Beryllium has only 4 electrons. Predict the bond angle in this molecule.

5. What is the molecular shape of dihydrogen monosulfide ($H_2S$)? What is the bond angle in this molecule?

6. The molecule $NF_3$ has nitrogen as the central atom with the 3 fluorine atoms bonded to it. Predict the molecular shape and the bond angles in this molecule.

7. What is the molecular shape of phosphorus trichloride ($PCl_3$)? What are the bond angles in this molecule?

8. What is the molecular shape of $OF_2$? What is the bond angle in this molecule?

9. Silicon dioxide contains a silicon atom bonded with double bonds to 2 oxygen atoms. Predict the bond angle in this molecule.

10. What is the molecular shape of $CF_4$? What are the bond angles in this molecule?

Name _____

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Date _____

# Condensed States of Matter

## A. Intermolecular Forces

To explain gas behavior according to the Ideal Gas Law, kinetic molecular theory assumes that molecules exert no attractive forces on each other. To explain liquid behavior and phase changes, intermolecular forces must be taken into account.

1. The forces between molecules include dispersion forces (for nonpolar molecules), dipole–dipole forces (for polar molecules), and hydrogen bonding (for molecules in which hydrogen is attached to fluorine, oxygen, or nitrogen). Indicate, for each of the following substances, the intermolecular force or forces involved.

   a. $C_7H_{16}$ _____

   b. $O_2$ _____

   c. $CH_2Cl_2$ _____

   d. $CH_3NH_2$ _____

   e. $CH_3OCH_3$ _____

   f. $H_2O$ _____

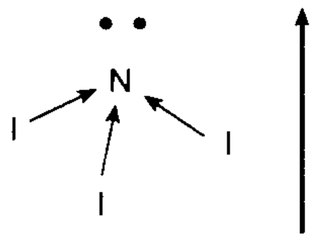
2. What is the relationship between the strength of the intermolecular forces in a substance and the boiling point of that substance?

3. Water has a high boiling point for a substance of its molecular weight. Account for this fact in terms of intermolecular forces.

## D. Molecular Shape and Polarity

The shape of a molecule depends upon both the bonding and nonbonding electron pairs. The shape of the molecule and the electronegativities of the atoms involved determine the overall polarity of the molecule.

Draw each of the following molecules using lines to represent bonds and dots to represent nonbonding pairs. Indicate whether each molecule is linear, trigonal planar, trigonal pyramidal, or tetrahedral. Then refer to the electronegativities of the atoms involved and determine whether each bond is polar. If it is polar, add an arrowhead to the lines representing the bonds, pointing toward the more electronegative atom. Finally, decide whether the molecule as a whole is polar. If it is, draw a large arrow near the molecule to indicate the direction of polarity. The first substance has been done as an example.

| Formula | Representation | Shape | Polarity of Bonds | Polarity of Molecule |
|---|---|---|---|---|
| $NI_3$ |  | trigonal pyramidal | N-I polar | polar |
| $NCl_3$ | | | | |
| $BCl_3$ | | | | |
| $CCl_4$ | | | | |

1. $CCl_4$ has the same shape as a methane molecule. What is the bond angle for $CCl_4$?

2. How can a molecule have polar bonds without being a polar molecule? Which molecules in D have polar bonds in a nonpolar molecule?

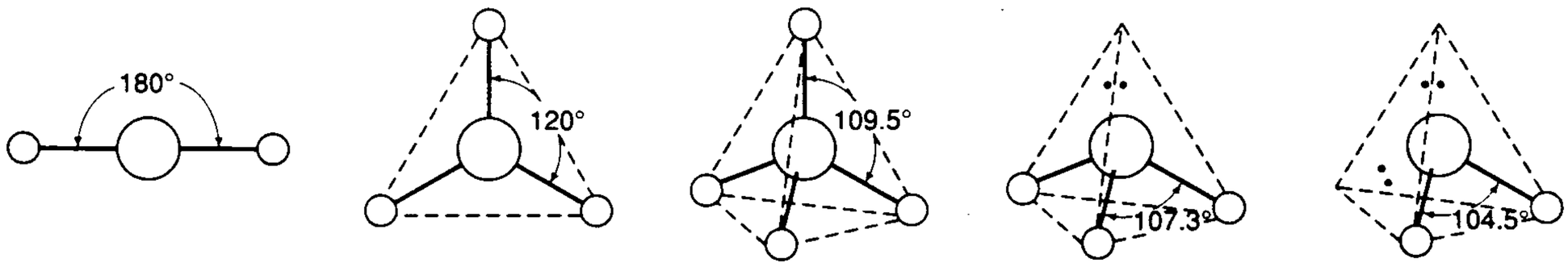


### Critical Thinking

State the octet rule and describe an exception to the rule. Which electron orbitals are likely to be involved in an exception to the rule?

## Part III

Questions 29–35: For each of the following, choose the letter of the drawing below that best represents its shape.




(a) Linear (b) Trigonal planar (c) Tetrahedral (d) Trigonal pyramidal (e) Bent

29. $H_2O$ _____ 30. $AsCl_3$ _____ 31. $BeH_2$ _____ 32. $CO_2$ _____

33. $CH_4$ _____ 34. $AsF_5$ _____ 35. $BF_3$ _____

Select the answer that best completes each statement. Write the letter of each answer in the space provided on the left.

_____ 36. A molecule with polar bonds can be nonpolar if _____.

a. the bonds are ionic
b. the difference in electronegativity is zero
c. the individual dipoles cancel each other
d. no halogens are involved

_____ 37. An important factor in determining whether a molecule with polar bonds will be polar or nonpolar is the molecule's

a. shape b. dipole moment c. stability d. charge

## Critical Thinking

Write the correct answer in the space provided.

38. If a molecule with the formula $AZ_2$ is linear, with the dipoles aligned at 180° and pointing in opposite directions, the molecule will probably be (polar/nonpolar) _____.

## Laboratory Investigation

39. Fill in the table below for $NI_5$.

| | |
|---|---|
| number of lone pairs | |
| number of bond pairs | |
| geometry | |

Select the response that best completes each statement. Write the letter of each answer in the space provided on the left.

_____ 25. The phenomenon in which more than one electron dot structure represents the bonding pattern in a molecule is called _____.

a. triple bonding b. resonance c. polarity d. Lewis structure

_____ 26. Compounds of the noble gases always _____.

a. follow the octet rule
b. have fewer than eight valence electrons
c. lack valence electrons
d. have more than an octet of electrons

Write the correct answer in the space provided.

27. The compound $BeF_2$ is an exception to the octet rule. Draw its electron dot structure.

Mr. Stone

Name_____

Date_____

Period_____

# Bonding 2 Worksheet

**Exceptions to the Octet Rule**
**Polarity in Molecules**
**Molecular Substances**
**Network Solids**
**Ionic Crystals**
**Bond Energy / Bond Strength**

1. Explain what is meant by the term "expanded" octet.

_____

_____

2. What two types of molecular shapes indicate a central atom that has an "expanded" octet?

_____

_____

3. What type of hybrid orbitals will sulfur (S) and phosphorus (P) possess if they have expanded valence shells?

_____

_____

Honors only 4. Indicate which of the following molecules ,if any, that would display resonance: {Experimental evidence suggests that all bonds in each of these molecules are the same as all other bonds in the same molecule.} (circle your answers)

$H_3PO_4$ $NH_3$ $HNO_3$ $CO_2$ $NO_2$ $PO_3$

5. Draw resonance structures for the ozone molecule ($O_3$).

omit

6. Indicate the shape and molecular polarity of the following molecules:

$NI_3$ _____ $NCl_3$ _____

_____ _____

$BCl_3$ _____ $Cl_2O$ _____

_____ _____

$OF_2$ _____ $PH_3$ _____

_____ _____

$CH_3F$ _____ $BH_2Cl$ _____

_____ _____

7. For each of the following molecules, indicate the type of intermolecular force that would bond it to a like molecule.

$H_2$ _____

$CH_2Cl_2$ _____

$CH_4O$ _____

$NF_3$ _____

8. Describe the effect increasing the polarity of molecules has on physical properties.

9. Describe the physical properties of network solids and give an example of a network solid..

10. Describe the Physical properties of ionic solids and give an example of an ionic solid.

11. Which bond is more stable, the H--H bond (436 kJ /mol) or the Cl--Cl bond (243 kJ /mol) ?

    Which of the bonds is shorter?

    Which of the bonds is stronger?

12. In an exothermic reaction which molecules have greater bond strength, reactants or products?

13. Order the chemical reactivity of single, double, and triple bonds from most reactive to least reactive.

14. In an endothermic reaction which are more stable, products or reactants?

15. Define bond energy and bond length.