Senior High School

Department of Education
National Capital Region
SCHOOLS DIVISION OFFICE
MARIKINA CITY

Physical Science

First Quarter - Module 2

Polarity of Molecules

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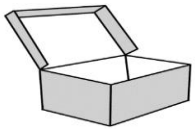


What I Need to Know

Molecules come in infinite varieties, so to help the complicated chemical world make a little more sense, we classify and categorize them. One of the most important classification is the polarity of a molecule, which describes a kind of symmetry - not just of the molecule, but of the charge. A molecule can be polar or non-polar.

Polar covalent bonds occur when electron pairs are unequally shared. **Nonpolar covalent bonds** occur when electron pairs are shared equally. There are two factors that determine the polarity of molecules. These are:

1. The polarity of the bonds between atoms which can be studied based on electronegativity; and
2. The geometrical shape of the molecule which can be predicted via the valence shell electron pair repulsion shortly known as the VSEPR theory.

The module is divided into 2 lessons, namely

- Lesson 1 – Electronegativity
- Lesson 2 – Molecular Geometry

After reading and studying this lesson, you are expected to demonstrate the following skills to

- **determine if a molecule is polar or nonpolar given its structure (S11/12PS-IIIc-15);** and
- **relate the polarity of a molecule to its properties. (S11/12PS-IIIc-16).**

Specifically, you should be able to

1. find the electronegativity of elements in the periodic table;
2. explain the VSEPR theory in relation to the Lewis Structure;
3. draw the geometry of molecules using the VSEPR theory; and
4. distinguish the difference between a polar and nonpolar molecule.

What I Know

Read the question carefully and encircle the letter of the correct answer.

1. Which of the following **DOES NOT** have an electronegativity ≥ 3.0?
   A. Bromine B. Chlorine C. Nitrogen D. Oxygen

2. Which of the following is the correct definition for electronegativity?
   A. It is the amount of energy to attract or bond electrons.
   B. It is the amount of energy required to remove an electron.
   C. It is half the distance between the nuclei of two bonded atoms.
   D. All the above correctly explain the definition of electronegativity.

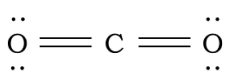
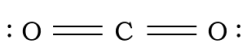
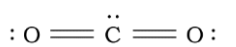
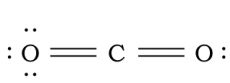
3. Which member of the alkaline metals has the highest electronegativity?
   A. Lithium B. Potassium C. Rubidium D. Sodium

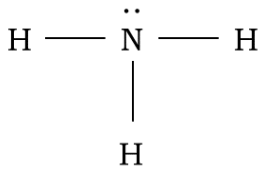
4. Which of the following molecules is polar?
   A. CF_4 B. CHF_3 C. CCl_2 D. CCl_4

5. Which of the following is the correct order for the Pauling electronegativity values?
   A. F > O > Br > C
   B. F > O > C > Br
   C. O > F > Br > C
   D. F > Br > O > C

6. Which of the following elements is the most electropositive?
   A. Br B. Cl C. F D. I

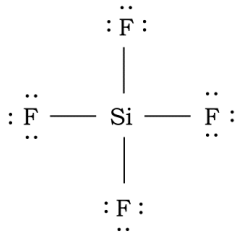
7. What is a covalent bond?
   A. It is a bond between metalloids.
   B. It is a bond between metals and nonmetals.
   C. It is a bond that shares electrons metallically.
   D. It is a bond that shares electrons with non-metals.

8. Which is a correct Lewis structure for carbon dioxide (CO_2)?
   A. 
   B. 
   C 
   D. 



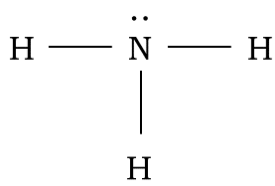
9. What is the correct formula for this molecule?

A. NH
B. N_3H
C. NH_3
D. NH_4



10. What is the correct formula for this molecule?

A. Si_4F
B. SiF_4
C. SiF
D. Si_4F_4

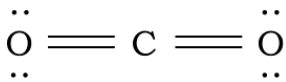


11. How is the structure below described?

A. Electronegative
B. Ionic
C. Nonpolar
D. Polar

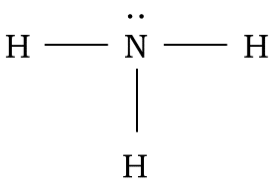
12. What is the molecular geometry of the Lewis Structure below?

A. Bent
B. Linear
C. Planar
D. Tetrahedral



13. What molecular geometry does the molecule exhibit?

A. Linear
B. Tetrahedral
C. Trigonal planar
D. Trigonal pyramidal

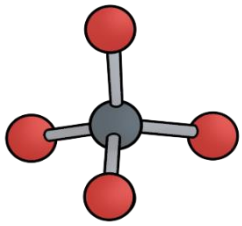


14. Which substance would form a triple bond when bonded covalently?

A. Fluorine B. Nitrogen C. Oxygen D. Water

15. What is the molecular geometry for this molecule?

A. Bent
B. Tetrahedral
C. Trigonal planar
D. Trigonal pyramidal



Lesson 1 Electronegativity

What's In

Linus Pauling was the original scientist to describe the phenomenon of electronegativity and described it as "the power of an atom in a molecule to attract electrons to itself." One way to determine whether a chemical bond is nonpolar or polar covalent is through the property of the bonding atoms called **electronegativity**.

Electronegativity Described

1. It measures the tendency of an atom to attract electrons (or electron density) towards itself.
2. It determines how shared electrons are distributed between the two atoms in a bond.
3. The more strongly an atom attracts the electrons in its bonds, the larger its electronegativity.
4. The electronegativity of an atom can be observed on its movement in the atomic number and in the atomic radius.

Electronegativity as Arranged on the Periodic Table

5. Electronegativity generally increases as you move from left to right across a period and decreases as you move down a group. Thus, it can be inferred that:
    1. The nonmetals, which lie in the upper right, tend to have the highest electronegativities. Fluorine (EN = 4.0), Oxygen (EN = 3.5), Nitrogen (EN = 3.0), and Chlorine (EN = 3.0) have significantly high electronegativity.
    2. Fluorine is the most electronegative element of all (EN = 4.0).
    3. Metals tend to be less electronegative elements, and the group 1 metals have the lowest electronegativities with Francium (EN = 0.7), Cesium (EN = 0.7), and Rubidium (EN = 0.8).
    4. Noble gases are excluded because these atoms do not share electrons with other atoms.

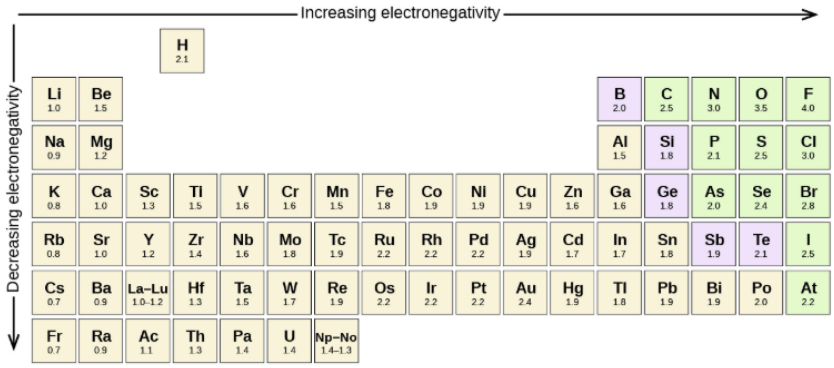


Figure 1.1. Electronegativity on the Periodic Table

Source: *"Electronegativity on the Periodic Table." Digital Image. Frontlearners. Accessed August 8, 2020.*

What's New

Activity 1.1

Determine the electronegativity of the following elements based on Figure 1.1 and write your answer on the space allotted on the table.

No.	Element	Electronegativity
1	Carbon	
2	Hydrogen	
3	Chlorine	
4	Bromine	
5	Nitrogen	
6	Fluorine	
7	Phosphorus	
8	Magnesium	

What Is It

Based on the periodic table, how would you know if a covalent bond is polar or non-polar? Here are some of the notes you must consider:

- **Polar covalent bonds** occur when electron pairs are unequally shared. The difference in electronegativity between atoms is significant or large (greater than 0.5 to 2.0).
    - The separation of charges makes the bond polar.
    - It creates an electric dipole. **Dipole** refers to "two poles," meaning there is a positive and a negative pole within a molecule.
    - The negative dipole is the atom that is more electronegative and can pull other electrons towards it to become more negative. The positive dipole goes with the lesser electronegative atoms that give up their electrons.

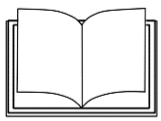
- **Nonpolar covalent bonds** occur when electron pairs are shared equally or the difference in electronegativity between atoms is less than 0.5.

Examples of substances having polar and nonpolar covalent bonds are shown in Table 1.1.

Table 1.1. Samples of Polar and Nonpolar Covalent Bonds in terms of EN

Polar Covalent Bond	Nonpolar Covalent Bond
1. HCL Hydrogen (EN = 2.1) – partial positive pole Chlorine (EN = 3.0) – partial negative pole Looking at the difference of their respective electronegativities: Δ EN = 3.0 – 2.1 Δ EN = 0.9	**1. H_2** Hydrogen (EN = 2.1) Δ EN = 2.1 – 2.1 Δ EN = 0 Not a Dipole **2. Cl_2** Chlorine (EN = 3.0) Δ EN = 3.0 – 3.0 Δ EN = 0

2. HF Hydrogen (EN = 2.1) Fluorine (EN = 4.0) Δ EN = 4.0 – 2.1 Δ EN = 1.9 **3. CF_4** Carbon (EN = 2.5) Fluorine (EN = 4.0) Δ EN = 4.0 – 2.5 Δ EN = 1.5	Not a Dipole **3. HI** Hydrogen (EN = 2.1) Iodine (EN = 2.5) Δ EN = 2.5– 2.1 Δ EN = 0.4 A dipole



What's More

Activity 1.2

Complete the table below by determining the change in the electronegativity of the compounds and identifying if it is polar or nonpolar covalent bond.

Compound	What is the change (Δ) in Electronegativity?	Is it a polar or nonpolar covalent bond?
1. H_2O		
2. NaCl		

3. Aluminum Chloride		
4. Hydroxide		
5. Methane		
6. Carbon Dioxide		

What I Have Learned

Activity 1.3

Briefly discuss the following. Write your answers on a separate sheet of paper.

1. Explain the formation of a covalent bond.
2. How would you determine the polarity of a bond by looking at its electronegativity?

What I Can Do

Activity 1.4

Draw a horizontal bar that depicts the ability of atom to attract electrons in a chemical bond. Draw it on the space provided on the table. Take 1 cm to represent 2 values of electronegativity.

Example: Hydrogen= 1.10 : 0.55 cm, Fluorine: 4.00 : 2.00 cm

1							18
H	2	13	14	15	16	17	
Li	Be	B	C	N	O	F	
Na	Mg	Al	Si	P	S	Cl	
K	Ca	Ga	Ge	As	Se	Br	
Rb	Sr	In	Sn	Sb	Te	I	

Assessment

Read the question carefully and encircle the letter of the correct answer.

1. Compared with halogens, an alkali metal in the same period has _____ electronegativity.
   A. better
   B. larger
   C. same
   D. smaller

2. Arrange the following elements from highest to lowest electronegativity- **K, Sc, Ca, Zn, Br**.
   A. Sc, K, Br, Zn, Ca
   B. Br, Zn, Sc, Ca, K
   C. Ca, Zn, Br, K, Sc
   D. K, Ca, Sc, Zn, Br

3. Who calculated the electronegativity values?
   A. Bohr
   B. Paul
   C. Pauling
   D. Zeeman

4. What elements have zero electronegativity by looking at the periodic table?
   A. Metalloids
   B. Metals
   C. Noble gases
   D. Nonmetals

5. Which of the following elements is the most electropositive?
   A. B B. C C. Cl D. N

6. Which of the following elements is the most electronegative?
   A. B B. Cl C. N D. O

7. Which of the following statements is **TRUE** about electronegativity?
   A. Electronegativity decreases from left to right within a period and increases from top to bottom within a group.
   B. Electronegativity increases from left to right within a period and increases from top to bottom within a group.
   C. Electronegativity increases from left to right within a period and decreases from top to bottom within a group.
   D. Electronegativity stays the same from left to right within a period and increases from top to bottom within a group.

8. Which of the elements below has the largest electronegativity?
   A. Mg B. P C. S D. Si

9. What is the EN difference between carbon and oxygen?
   A. 1 B. 2 C. 3 D. 4

10. Which element is more likely to give up an electron between bromine and radium?
   A. Bromine C. Both
   B. Radium D. None

Additional Activities

Briefly discuss the following. Write your answers on the space provided.

1. Which atom is at the negatively polarized end of a bond between carbon and oxygen? Why?

   _____
   _____

2. Which atom is at the positively polarized end of a bond between carbon and oxygen? Why?

   _____
   _____

3. Between oxygen and hydrogen, which end of the bond is negatively polarized?

   _____
   _____

Lesson 2 Molecular Geometry

What's In

Understanding the molecular structure of a compound can help determine the polarity, reactivity, phase of matter, color, magnetism, as well as the biological activity of a compound or substance. For this lesson, you will only focus on polarity, as it is the continuation of electronegativity.

Molecular Geometry Described

- It measures the tendency of an atom to draw in or attract electrons towards itself. It is used to describe the shape and form of a molecule.
- The electron-pair arrangement serves as a guide to the bond angles between terminal and central atoms in a compound.

Valence Electrons

It is essential for this lesson that you know how to find the valence electrons of elements and how to draw first its Lewis Structure. Keep in mind the following points:

- Lewis Structure (Gilbert Newton Lewis) focuses on the valence electrons, which are generally the electrons that are farthest from the nucleus. As a result, they may be attracted as much or more by the nucleus of another atom than they are by their own nucleus.
- On the periodic table, elements in a single vertical column will have the same number of valence electrons.
    - The Group number of a non-transition metal can be used to find the number of valence electrons in an atom of that element. In other words:
        - Group 1: 1 valence electron
        - Group 2: 2 valence electrons
        - Group 13: 3 valence electrons
        - Group 14: 4 valence electrons
        - Group 15: 5 valence electrons
        - Group 16: 6 valence electrons
        - Group 17: 7 valence electrons
        - Group 18: 8 valence electrons (except for helium, which has 2 electrons)

For example, carbon is in group 14, therefore carbon has four valence electrons.

- The elements in groups 3 to 12 are called "transition metals" and behave differently than the rest of the elements when it comes to valence electrons. As electrons are added to an atom, they are sorted into different "orbitals" — different areas around the nucleus. In other words:
  - Group 3: 3 valence electrons
  - Group 4: 2 to 4 valence electrons
  - Group 5: 2 to 5 valence electrons
  - Group 6: 2 to 6 valence electrons
  - Group 7: 2 to 7 valence electrons
  - Group 8: 2 or 3 valence electrons
  - Group 9: 2 or 3 valence electrons
  - Group 10: 2 or 3 valence electrons
  - Group 11: 1 or 2 valence electrons
  - Group 12: 2 valence electrons

For example, Tantalum is in group 5, it has between two and five valence electrons, depending on the bonding pair.

What's New

Activity 2.1

Find the number of valence electrons of the following elements using the Periodic Table of Elements and write your answer on the space allotted on the table.

No.	Element	Number of valence electrons
1	Arsenic	
2	Potassium	
3	Gallium	
4	Bromine	
5	Nitrogen	

What Is It

Lewis Structures

In a Lewis structure, the valence electrons are written as dots and it surrounds the symbol for the element.

One dot is placed on each side first, and when all four positions are filled, the remaining dots are paired with one of the first set of dots, with a maximum of two dots placed on each side. Lewis-dot diagrams of some atoms of the periodic table are as follows:

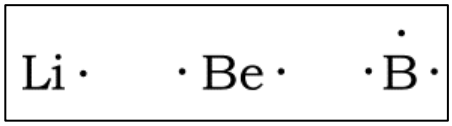


Figure 2.1. Lewis dot Diagram of some atoms in the Periodic Table

- The unpaired electrons represent the area where electrons can be shared to form molecular compounds.

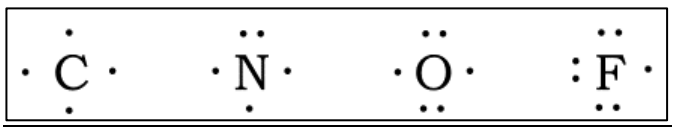


Figure 2.2. Lewis dot Diagram of some atoms with unpaired electrons

- In noble gases, the valence electrons are in filled shells, therefore, they are unavailable for bonding.

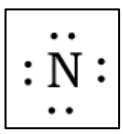


Figure 2.3. Lewis dot Diagram of a Noble Gas - Neon

- The elements in the bond are attracted to the unpaired valence electrons strongly. The unpaired valence electrons are shared by the two atoms, forming a covalent bond:

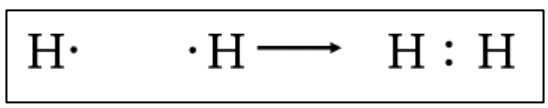


Figure 2.4. Bonding of one element to another

- The shared electrons are represented as a line (—) between the bonded atoms. In Lewis structures, a line represents two dot electrons:

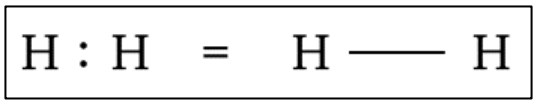


Figure 2.5. A bond between shared electrons-represented by a line

- Atoms tend to form covalent bonds to satisfy the octet rule, with every atom surrounded by eight electrons. (Hydrogen is an exception, since it is in row 1 of the periodic table, and only has the 1s orbital available in the ground state, which can only hold two electrons.)

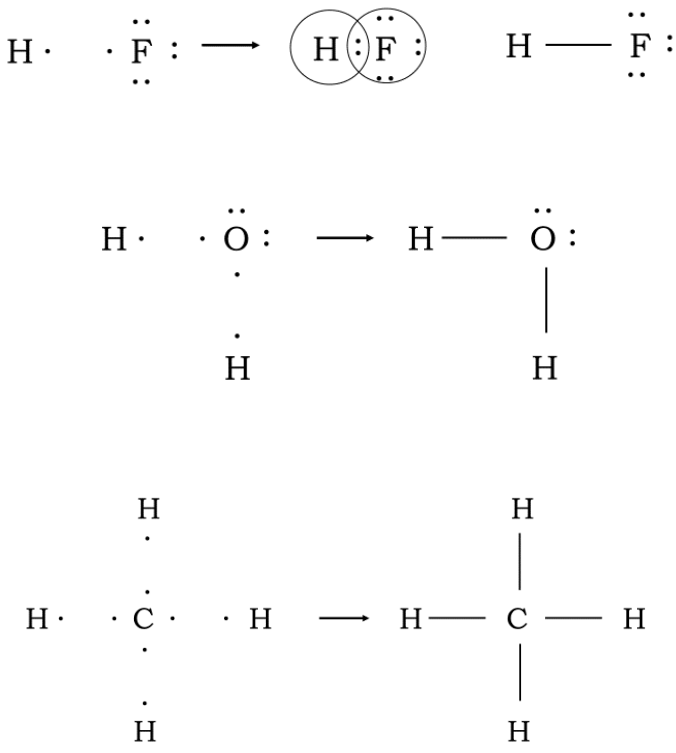


Figure 2.6. Covalent Bonds in an Octet

- The shared pairs of electrons are the bonding pairs.
- The unshared pairs of electrons are the lone pairs or nonbonding pairs.
- Single bond has one pair of electrons being shared. It is also possible to have double bonds, in which two pairs of electrons are shared, and triple bonds, in which three pairs of electrons are shared:

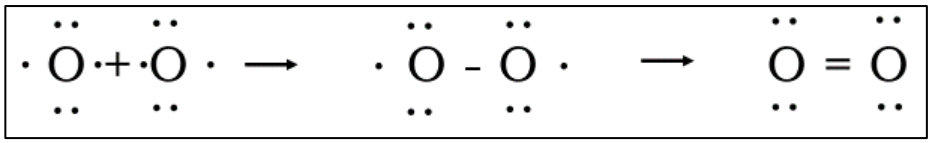


Figure 2.7. Electrons in a Double Bond

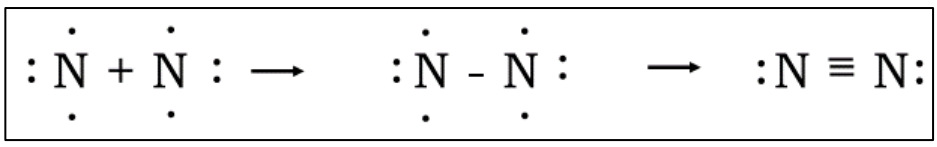


Figure 2.8. Electrons in a Triple Bond

VSEPR Theory

Now, to the main part- the VSEPR theory. The valence shell electron pair repulsion (VSEPR) theory helps predict the spatial arrangement of atoms in a polyatomic molecule. The shapes are designed to minimize the repulsion within a molecule.

The images below are the different shapes under the VSEPR theory.

Note: Symmetry plays an important role in determining the polarity of a molecule.

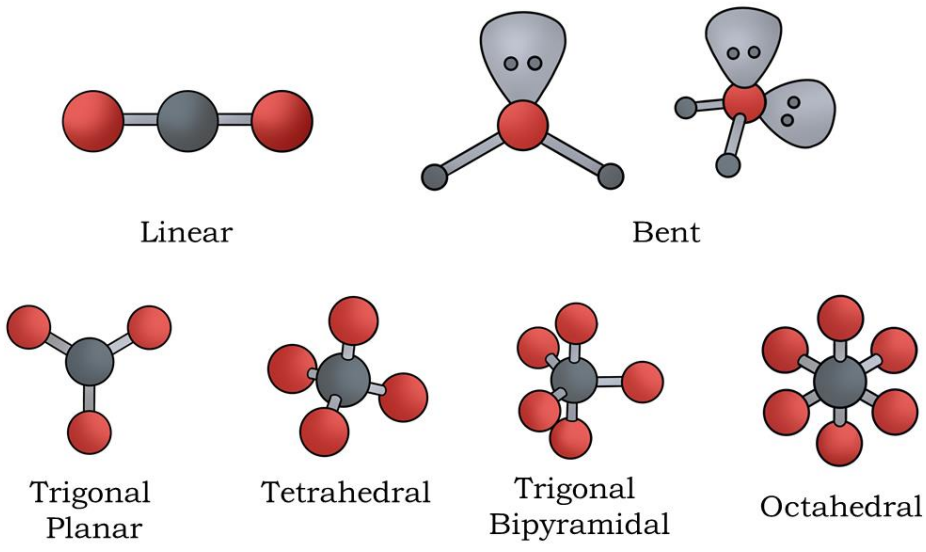


Figure 2.8. Shapes in the VSEPR Theory

Source: *"Classic Molecular Modeling." Digital Image. Molecular Modeling 1: Classic Molecular Modeling of Chemlab. Accessed August 8, 2020.*

Molecules are polar or nonpolar based on the type of covalent bond and its molecular geometry. Note that symmetry plays an important role in determining the polarity of a molecule.

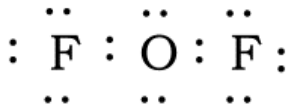
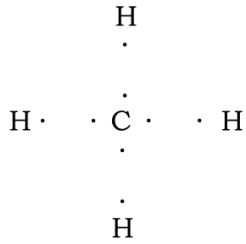
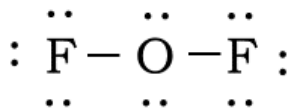
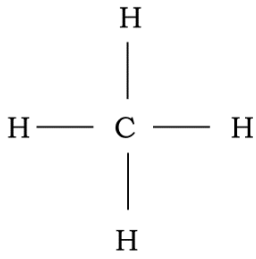
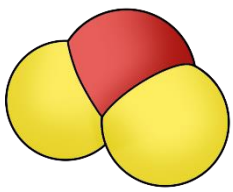
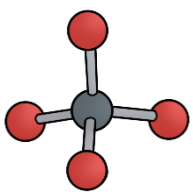
- If the arrangement is symmetrical and the arrows are of equal length, the molecule is nonpolar.
- If the arrows are of different lengths, and if they do not balance each other, the molecule is polar.
- If the arrangement is asymmetrical, the molecule is polar.

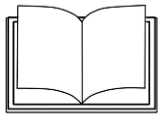
Therefore, the polarity molecules with respect to VSEPR model are the following:

- Linear – nonpolar
- Bent - polar
- Tetrahedral - polar
- Pyramidal - polar
- Trigonal Planar – nonpolar

Table 2.1. Guidelines to determine the VSEPR shape of a molecule

	Example 1: OF_2	Example 2: CH_4
1. Find the total number of valence electrons. Note: The negative sign indicates an extra valence electron.	O= 6 F= 7 (2) 6 + 7 (2) = 20	C= 4 H= 1(4) 4 + 1 (4) = 8
2. Put the least electronegative atom at the center. Note: Hydrogen always goes on the outside.	F O F	H H C H H

3. Put the electrons between atoms to form a chemical bond.		
4. Create the appropriate Lewis structure of the molecule.		
5. Determine the appropriate VSEPR shape for the molecule.	Bent	Tetrahedral
6. Draw the appropriate VSEPR shape. Note: look at the shared and unshared electrons		
POLAR OR NONPOLAR?	**POLAR**	**NONPOLAR**



What's More

Activity 2.2

Draw the Lewis Dot Structure of the following compounds.

No.	Compound	Lewis Dot Structure
1	NH_3	
2	C_2H_4	
3	PCl_5	
4	CN^-	
5	OH^-	

Activity 2.3

Draw the appropriate VSEPR model for the following compounds by following the steps provided.

STEP	Item 1: SO_2	Item 2: BF_3
1. Find the total number of Valence Electrons		
2. Put the least electronegative atom at the center		
3. Put the electrons between atoms to form a chemical bond		
4. Create the appropriate Lewis structure of the molecule		
5. Determine the appropriate VSEPR shape for the molecule.		
6. Draw the appropriate VSEPR shape.		
POLAR OR NONPOLAR?		

Activity 2.4

Briefly discuss the following. Write your answers on the space provided.

1. What is the importance of illustrating the proper Lewis structure of compounds and formulas?

_____
_____
_____

2. How would you determine the polarity of a compound by its structure?

_____
_____
_____

Activity 2.5

Assess the situation given and answer the question that follows.

When things get greasy, we tend to use soap to remove the traces of dirt. Upon washing, we can observe that grease is only removed when you add up a little soap with water. Why? It is because soaps have a structure that allows them to interact strongly with both water and grease. One end of a soap molecule is polar (hydrophilic) and the other one is non-polar (hydrophobic).

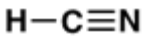
Which end of soap molecule strongly attract water molecules? Which end of soap interacts with grease and oil molecules? Why?

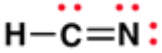
_____
_____
_____

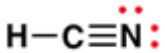
Assessment

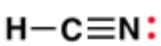
Read the question carefully and encircle the letter of the correct answer.

1. Which is a correct Lewis structure for hydrogen cyanide, HCN?

A. 

B. 

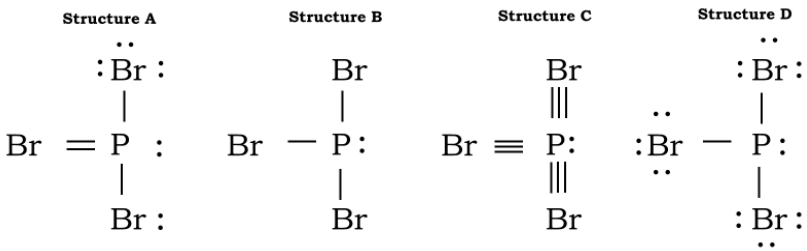
C. 

D. 

2. Which substance would form a double bond when bonded covalently?

A. Fluorine B. Nitrogen C. Oxygen D. Water

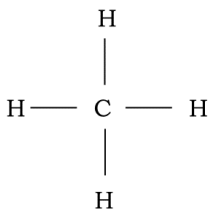
3. Which of the following is the correct Lewis structure for the compound PBr_3?



A. Structure A
B. Structure B
C. Structure C
D. Structure D

4. What is the name of the molecular geometry for this Lewis Structure?

A. Bent
B. Tetrahedral
C. Trigonal planar
D. Trigonal pyramidal



5. How many electrons should carbon have around its Lewis dot model?

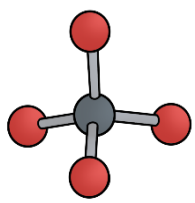
A. 1 B. 3 C. 4 D. 5

6. Which among the choices of substance would be polar?

A. O_2 B. HCl C. CO_2 D. CH_4

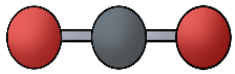
7. What compound could this molecule be?

A. CH_4
B. CO_2
C. PCl_5
D. BF_3



8. Which molecule among the choices would have this shape (linear)?

A. BF_3
B. CH_4
C. PCl_5
D. CO_2

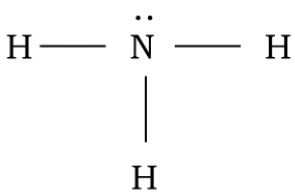


9. Which among the choices of substance is nonpolar?

A. N_2
B. NH_3
C. HCl
D. Water

10. What does this molecule represent?

A. Polar
B. Nonpolar
C. Ionic
D. Non-ionic



Additional Activities

Answer the following questions. Write your answers on the space provided.

1. In cases a compound has "formal charges," what will happen to its Lewis structure?

_____

_____

2. What are the exceptions on the octet rule?

_____

_____

Posttest

Read the question carefully and encircle the letter of the correct answer.

1. Which of the following is the correct definition for electronegativity?
   A. It is the amount of energy to attract or bond electrons.
   B. It is the amount of energy required to remove an electron.
   C. It is half the distance between the nuclei of two bonded atoms.
   D. All the above correctly explain the definition of electronegativity.

2. Which of the following elements is the most electropositive?
   A. Br B. Cl C. F D. I

3. Which is the correct order for the Pauling electronegativity values of the listed atoms?

A. F > O > Br > C
B. F > O > C > Br
C. O > F > Br > C
D. F > Br > O > C

4. Which member of the alkaline metals has the highest electronegativity?

A. Lithium
B. Potassium
C. Rubidium
D. Sodium

5. Which of the following does not have an electronegativity ≥ 3.0?

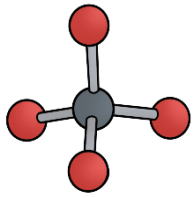
A. Bromine
B. Chlorine
C. Nitrogen
D. Oxygen

6. Which of the following molecules is polar?

A. CF_4 B. CHF_3 C. CCl_2 D. CCl_4

7. What is the molecular geometry for this molecule?

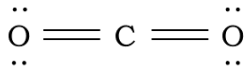
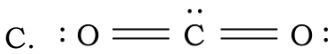
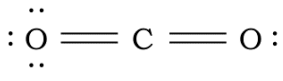
A. Bent
B. Tetrahedral
C. Trigonal planar
D. Trigonal pyramidal



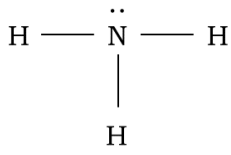
8. What is a covalent bond?

A. It is a bond between metalloids.
B. It is a bond between metals and nonmetals.
C. It is a bond that shares electrons metallically.
D. It is a bond that shares electrons with non-metals.

9. Which is a correct Lewis structure for carbon dioxide (CO_2)?

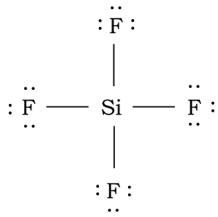
A. 
B. 
C. 
D. 

10. What is the correct formula for this molecule?



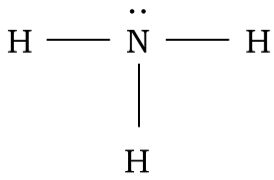
A. NH
B. N_3H
C. NH_3
D. NH_4

11. What is the correct formula for this molecule?



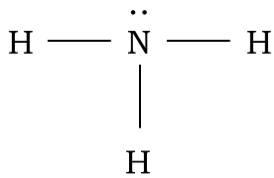
A. Si_4F
B. SiF_4
C. SiF
D. Si_4F_4

12. What molecular geometry does this molecule exhibit?



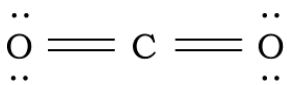
A. Linear
B. Tetrahedral
C. Trigonal planar
D. Trigonal pyramidal

13. How would you describe this structure?



A. Electronegative
B. Ionic
C. Non-polar
D. Polar

14. What is the name of this Lewis Structure?



A. Bent
B. Linear
C. Planar
D. Tetrahedral

15. Which substance would form a triple bond when bonded covalently?
A. Fluorine
B. Water
C. Nitrogen
D. Oxygen

References

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(5) Whitten, K.W, Davis, R.E., Peck, M.L., and G.G. Stanley. *General Chemistry 7th Ed.* Singapore: Thomoson/Brooks/Cole. 2005

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