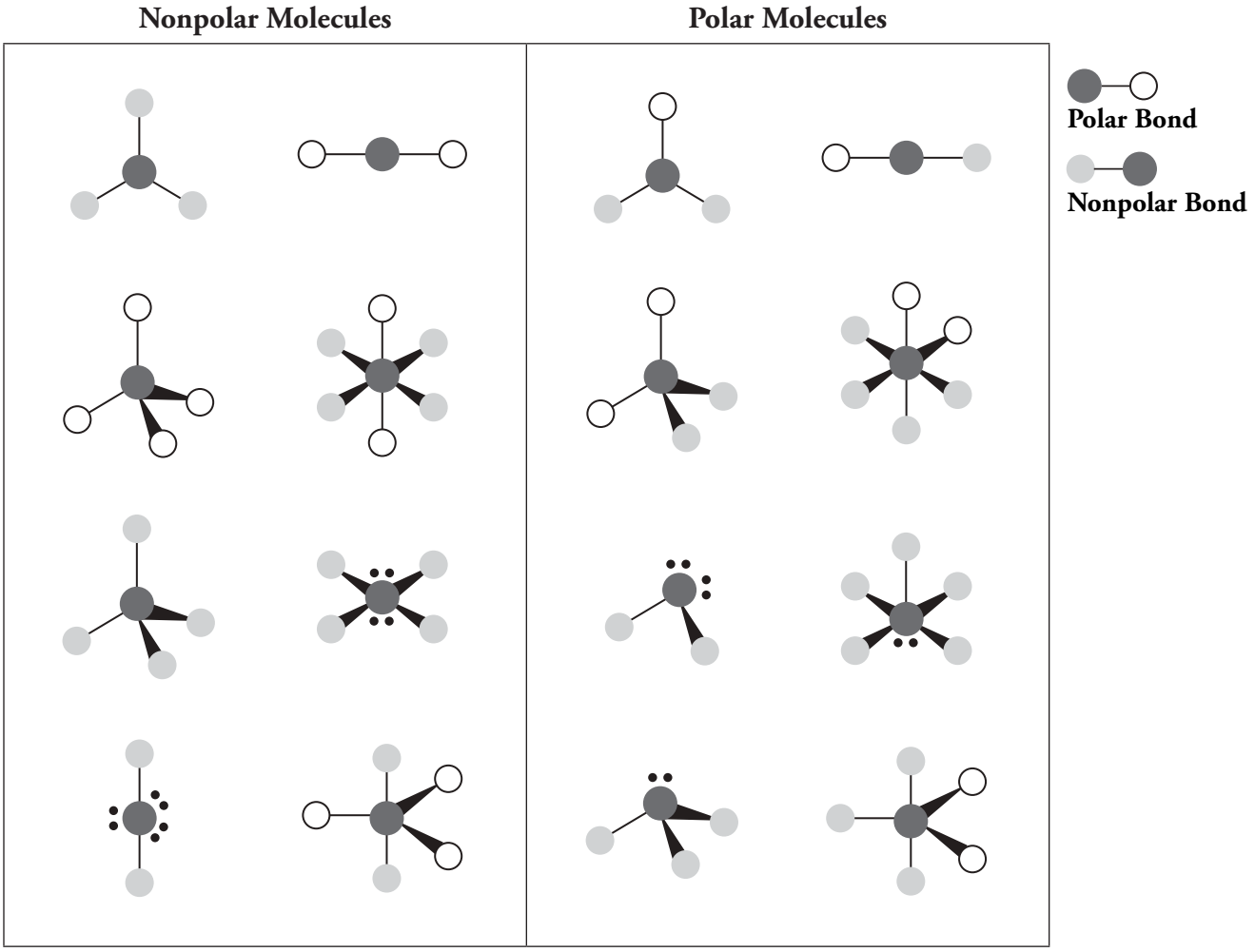
Polar and Nonpolar Molecules

What makes a molecule polar?

Why?

The physical properties of a substance are dictated in part by whether or not a molecule is polar. For example, oil and water do not mix because water is polar whereas oil is nonpolar. Another example is carbon dioxide and water. At room temperature, carbon dioxide is a gas while water is a liquid because carbon dioxide is nonpolar while water is polar. In this activity, you will explore the factors that contribute to a molecule's polarity or nonpolarity.

Model 1 – Examples of Nonpolar and Polar Molecules



1. Consider Model 1. How is a polar bond differentiated from a nonpolar bond?

2. Formaldehyde has the chemical formula CH_2O, and it is trigonal planar. Draw this molecule using open and shaded circles as it might be shown in Model 1.

3. Label each diagram in Model 1 with the three-dimensional electronic shape that it represents.

4. According to Model 1, can the shape of a molecule explain polarity? Justify your reasoning.

5. Refer to Model 1. Circle the correct word to complete each sentence.

   a. Nonpolar molecules (never, may, always) contain polar bonds.

   b. Polar molecules (never, may, always) contain polar bonds.

6. A student states "Polar molecules are just molecules that contain polar bonds. If there are no polar bonds, then the molecule is nonpolar." Do you agree or disagree with this statement? Justify your reasoning using evidence from Model 1.

7. How is a lone pair of electrons illustrated in Model 1?

8. Refer to Model 1. Circle the correct word to complete the sentence.

   a. Nonpolar molecules (never, may, always) contain lone pairs of electrons.

   b. Polar molecules (never, may, always) contain lone pairs of electrons.

9. Is the presence or absence of a lone pair of electrons sufficient to explain the polarity of molecules? Justify your reasoning using evidence from Model 1.


10. Refer to Model 1.

   a. When polar bonds are present in a nonpolar molecule, how are they arranged around the center atom—on the same side of the molecule or on opposite sides of the molecule?

   b. When polar bonds are present in a polar molecule, how are they arranged around the center atom—on the same side of the molecule or on opposite sides of the molecule?

11. Refer to Model 1.

    a. When lone pairs of electrons are present in a nonpolar molecule, how are they arranged around the center atom—on the same side of the molecule or on opposite sides of the molecule?

    b. When lone pairs of electrons are present in a polar molecule, how are they arranged around the center atom—on the same side of the molecule or on opposite sides of the molecule?

12. Consider the term "symmetry" as it is used in the English language. As a group, rank the following shapes from most symmetric to least symmetric.

13. Which set in Model 1, the nonpolar molecules or polar molecules, contains molecules that are symmetric about multiple planes of symmetry?

Read This!

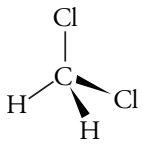
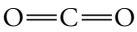
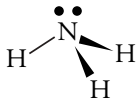
Polar molecules have an unequal distribution of charge around the molecule as a whole. This could be due to a bond being polar or a lone pair of electrons being present. Both would cause a concentration of negative charge on one side or in one area of the molecule due to an unequal distribution of electrons among nuclei. If a molecule has more than one polar bond or lone pair of electrons and they are symmetrically arranged, there is no unequal distribution of charge and the molecule is nonpolar.

14. Suppose a molecule contained two bonds around the center atom, and both those bonds were polar. What would the angle between those two bonds need to be for the molecule to be considered nonpolar? (Assume there are no lone pairs on the center atom.)

15. Suppose a molecule contained four identical bonds around the center atom, and all four of those bonds were polar. What would the angle between any of the four bonds need to be for the molecule to be considered nonpolar? (Assume there are no lone pairs on the center atom.)

16. If a molecule contains only one polar bond and no lone pairs, is there an arrangement that will make that molecule nonpolar? Justify your reasoning.

17. Fill in the table below for each molecule to determine if the molecule is polar or nonpolar. You may want to refer to a table of electronegativity values.

Name	**Dichloromethane**	**Carbon dioxide**	**Ammonia**
Structure			
Does the molecule have polar bonds? If yes, which ones?			
Does the molecule have lone pairs on the center atom?			
If there are polar bonds and/or lone pairs, are they symmetric?			
Is the molecule polar or nonpolar?			

18. Draw the three-dimensional structures for each molecule. Fill in the table for each molecule to determine if the molecule is polar or nonpolar.

Name	**Methane (CH_4)**	**Formaldehyde (CH_2O)**	**Xenon tetrafluoride (XeF_4)**
Structure			
Does the molecule have polar bonds? If yes, which ones?			
Does the molecule have lone pairs on the center atom?			
If there are polar bonds and/or lone pairs, are they symmetric?			
Is the molecule polar or nonpolar?			

19. Determine if the following molecules are polar or nonpolar.

a. Carbon tetrafluoride (CF_4)

b. Water (H_2O)

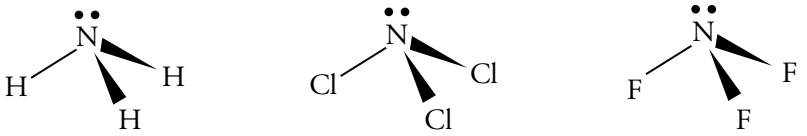
c. Sulfur dioxide (SO_2)

d. Phosphorous pentachloride (PCl_5)

e. Hydrogen sulfide (H_2S)

Extension Questions

Model 2 – A Series of Polar Molecules



Dipole Moment	1.42 D	0.60 D	0.23 D

20. The polarity of a molecule can be quantified as the dipole moment. The dipole moment is either found indirectly through experiment or calculated theoretically. The dipole moment is measured in debyes.

    a. What is the abbreviation for the unit "debye"?

    b. Which molecule in Model 2 is the most polar according to the dipole moments given?

21. Discuss as a group the dipole moment values provided in Model 2. Propose some possible explanations for the changes in the dipole moments between the three molecules. In particular note anything that seems unusual in the data.

22. The dipole moment of a bond or molecule is often represented with an arrow that points toward the more negative side of the bond.

    a. Determine which bonds in Model 2 are polar bonds using a table of electronegativity values. A large difference in electronegativity is characteristic of a polar bond.

    b. For any bond shown in Model 2 that is significantly polar, draw an arrow next to the bond to show the direction of polarity.

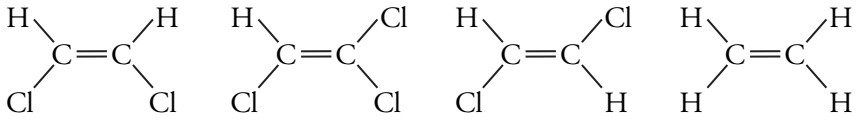
23. The lone pairs in a molecule also provide a dipole. Draw an arrow that points away from the center atom for any lone pairs on the molecules in Model 2.

24. Consider the arrows you have drawn in Model 2. Explain why NH_3 is the most polar of the three molecules.

25. Consider the arrows you have drawn in Model 2. Explain why NF_3 is the least polar of the three molecules.

26. The phosphorus trifluoride molecule (PF_3) has a dipole of 1.03 D. Compare this molecule to the nitrogen trifluoride molecule in Model 2. Propose a reason for the larger dipole in the molecule containing phosphorus.

27. Rank the following molecules in order of polarity from least to most. Use arrows on each molecule to support your answer.



28. Select the molecule in each pair that has the largest dipole moment. Include diagrams and complete sentences to justify your reasoning.

    a. CS_2 vs. SO_2

    b. H_2O vs. OF_2

    c. CF_4 vs. SF_4