ChemQuest 24

Intermolecular Forces

Name: ______________________________

Date: ________________

Information: Determining if a Bond is Polar

In general the greater the difference in electronegativity between two bonding atoms, the greater the polarity of the bond. A general rule of thumb is that if the difference in electronegativity is less than 0.5 then the bond is considered *nonpolar*. If the difference is greater than 0.5, the bond is considered *polar*.

Critical Thinking Questions

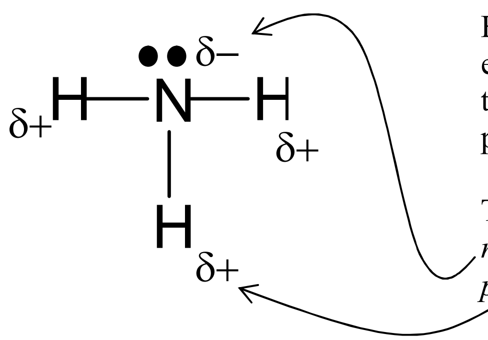
1. Determine if the following bonds are polar or nonpolar.

A) C—Si	B) N—O	C) C—F	D) Si—O	E) P—Cl
Polar	Nonpolar	Polar	Polar	Polar

Information: Is the Molecule Polar?

If a molecule has polar bonds in it, there is a good possibility that the molecule is polar. For example, consider the polar molecule ammonia, NH_3. There are three N—H bonds in the molecule. A drawing of the molecule is shown below:

Figure 1: NH_3



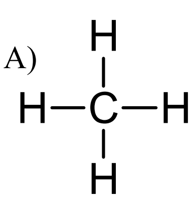
Because N has a greater electronegativity than H, the bonding electrons are pulled closer to N.

Therefore N is *partially negative* and each H is *partially positive*.

Critical Thinking Questions

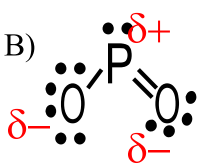
2. Given the following Lewis structures, label the partial positive and partial negative atoms. Remember: for an atom to be partially positive or negative, it must be involved in a polar bond!

A)

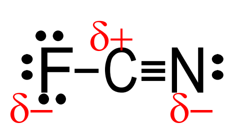


C—H bonds are nonpolar, so there are no partial charges needed for CH_4.

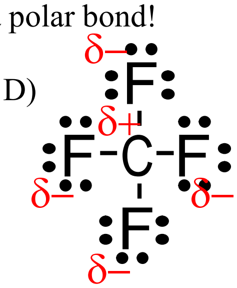
B)



C)



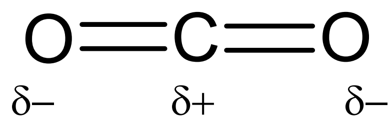
D)



Information: The Tug-of-War Principle

Not all molecules with polar bonds are polar, however! Consider carbon dioxide, CO_2, below:

Figure 2: CO_2



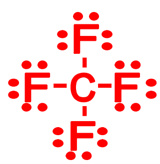
Because O has a greater electronegativity than C, the O atoms are *partially negative* and the C atom is *partially positive*.

Because the oxygen atoms are pulling in equal and opposite directions, they cancel each other out. Overall, CO_2 is therefore nonpolar even though there are polar bonds within the molecule.

The pulling on electrons is almost like a tug of war. If the electrons are being pulled *equally* and *oppositely*, then the pulling cancels out just as if two people were pulling on a rope in equal and opposite directions—the rope won't move.

Critical Thinking Questions

3. Carbon tetrafluoride, CF_4, has polar bonds in it, but the molecule isn't polar overall. Use a Lewis structure to explain why CF_4 is nonpolar.



Each fluorine atom pulls the electrons equally and oppositely. The pulls cancel each other. Therefore, even though the molecule has polar bonds within it, the molecule is overall **nonpolar.**

4. The structure in question 2B is polar, but CO_2 (see Figure 2) is nonpolar. Explain why.

The oxygens' pull is equal and opposite. Thus, like CF_4 in question 3, the symmetry of the molecule causes it to be overall nonpolar.

5. Which molecules from question 2 are polar?

B and C. B is polar because the oxygens are not symmetrical and do not pull in exactly opposite directions. C is polar because the F and the N do not pull with equal force even though they pull in opposite directions.

Information: Polarity and Attraction

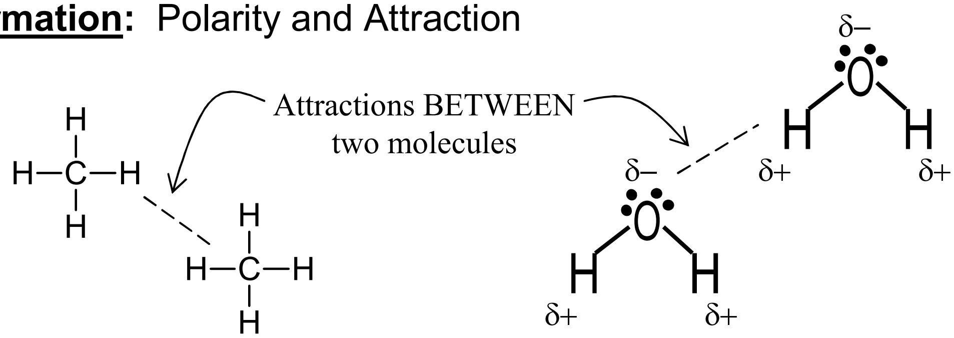


Figure 3: Attraction between two methane molecules

Figure 4: Attraction between two water molecules

Critical Thinking Questions

6. In Figure 4, there are partial positive and partial negative charges depicted. Why are there no partial positive or partial negative charges on the methane molecules in Figure 3? (Hint: Are C—H bonds polar?)

Methane (CH_4) is nonpolar. (The difference in electronegativity values between carbon and hydrogen is small. See also, question 2A.)

7. One of the above diagrams shows the attraction between two polar molecules and the other diagram shows the attraction between two nonpolar molecules. Which is which?

Figure 4 shows polar molecules since water is polar. Figure 3 shows nonpolar molecules.

8. Which of the two situations pictured below would result in the greatest attraction? Explain your choice.

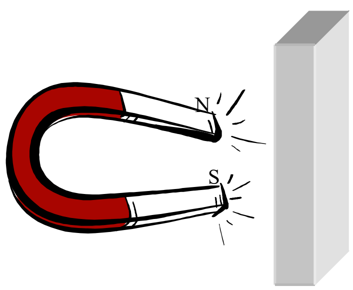


Diagram A: a magnet attracting to a piece of metal

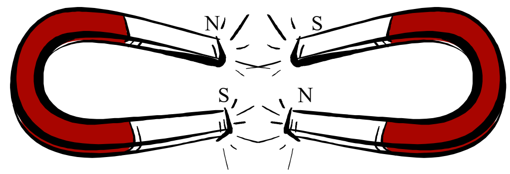


Diagram B: a magnet attracting to another magnet

Explain your choice:

Diagram B, because two magnets will stick to each other with greater force because attraction is provided by both magnets.

9. Is Figure 3 or Figure 4 more like Diagram B?

Figure 4

10. Which attraction do you think is the greatest—the attraction between polar molecules or the attraction between nonpolar molecules? Explain.

Just like the magnets in Diagram B above depict a greater attraction, so also the polar molecules in Figure 4 depict a greater attraction.

Information: Names of the Forces

Dipole-dipole forces (or dipolar forces): The attractions between two polar molecules.

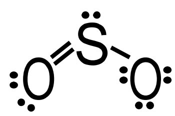
London disperson forces: The attractions between two nonpolar molecules.

Critical Thinking Questions

11. What is the name of the attraction that exists between two CH_4 molecules (like in Figure 3)?
    London dispersion forces

12. What is the name of the attraction that exists between two H_2O molecules (like in Figure 4)?
    Dipole-dipole or dipolar foces. (Later we will see that in water this is called hydrogen bonding.)

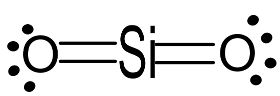
13. a) Is SO_2 polar or nonpolar? (Don't forget to consider the "tug-of-war principle".)



Polar. S and O have a high enough electronegativity difference AND the oxygen atoms do not pull in equally opposite directions.

b) What type of force exists between two SO_2 molecules? Dipole-dipole (or dipolar) because this is the name for the force between two polar molecules.

14. What type of force exists between two SiO_2 molecules? The structure is given below.



London dispersion forces because SiO_2 is nonpolar. Even though the Si—O bonds have a high electronegativity difference, the oxygen atoms pull in equal and opposite directions, cancelling each other.

15. a) Hopefully your answer to question 12 and question 13b was "dipole-dipole forces". Both H_2O (question 12) and SO_2 (question 13b) have dipole-dipole forces as their main form of intermolecular force. Which compound—SO_2 or H_2O—has bonds with the greatest electronegativity difference?
    H_2O

b) Given your answer to part a, do you think the dipole-dipole forces are strongest between two SO_2 molecules or two H_2O molecules? Two H_2O molecules.

Information: Hydrogen Bonding

The dipole-dipole forces between water molecules are quite strong (question 13b). They are so strong and important, that they are given a special name, "hydrogen bonding".

Hydrogen bonds are dipole-dipole forces; they are *not* a bond like a covalent or ionic bond. Hydrogen bonds can only form between molecules that contain a hydrogen atom bonded to fluorine, nitrogen, or oxygen.

Critical Thinking Questions

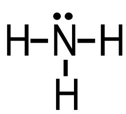
16. Why do you think that a molecule must contain fluorine, nitrogen or oxygen in order for hydrogen bonding to occur? (Hint: look at their electronegativity values.)

    They are the three most electronegative atoms on the periodic table.

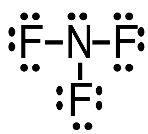
17. Which compounds, if any, from question 2 exhibit hydrogen bonding?

    None of them—none have a hydrogen atom bonded to N, O, or F.

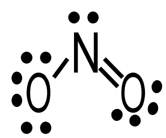
18. Identify which type of intermolecular forces (dipole-dipole, London dispersion , or hydrogen bonds) exist between molecules of…

A) 

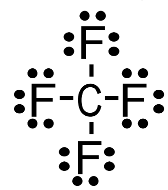
Hydrogen Bonding

B) 

Dipole-dipole (dipolar)

C) 

London dispersion forces

D) 

London dispersion forces