Learning Objectives

- Covalent bonds have certain characteristics that depend on the identities of the atoms participating in the bond. Two characteristics are bond length and bond polarity.

Electronegativity and Bond Polarity

Although we defined covalent bonding as electron sharing, the electrons in a covalent bond are not always shared equally by the two bonded atoms. Unless the bond connects two atoms of the same element, there will always be one atom that attracts the electrons in the bond more strongly than the other atom does, as shown in Figure \(\PageIndex{1}\). When such an imbalance occurs, there is a resulting buildup of some negative charge (called a partial negative charge and designated \(\delta^-\)) on one side of the bond and some positive charge (designated \(\delta^+\)) on the other side of the bond. A covalent bond that has an unequal sharing of electrons, as in part (b) of Figure \(\PageIndex{1}\), is called a polar covalent bond. A covalent bond that has an equal sharing of electrons (part (a) of Figure \(\PageIndex{1}\)) is called a nonpolar covalent bond.

Figure \(\PageIndex{1}\) Polar versus Nonpolar Covalent Bonds. (a) The electrons in the covalent bond are equally shared by both hydrogen atoms. This is a nonpolar covalent bond. (b) The fluorine atom attracts the electrons in the bond more than the hydrogen atom does, leading to an imbalance in the electron distribution. This is a polar covalent bond.
Any covalent bond between atoms of different elements is a polar bond, but the degree of polarity varies widely. Some bonds between different elements are only minimally polar, while others are strongly polar. Ionic bonds can be considered the ultimate in polarity, with electrons being transferred rather than shared. To judge the relative polarity of a covalent bond, chemists use electronegativity, which is a relative measure of how strongly an atom attracts electrons when it forms a covalent bond. There are various numerical scales for rating electronegativity. Figure 1 shows one of the most popular—the Pauling scale. The polarity of a covalent bond can be judged by determining the difference in the electronegativities of the two atoms making the bond. The greater the difference in electronegativities, the greater the imbalance of electron sharing in the bond. Although there are no hard and fast rules, the general rule is if the difference in electronegativities is less than about 0.4, the bond is considered nonpolar; if the difference is greater than 0.4, the bond is considered polar. If the difference in electronegativities is large enough (generally greater than about 1.8), the resulting compound is considered ionic rather than covalent. An electronegativity difference of zero, of course, indicates a nonpolar covalent bond.

**Figure 1** Electronegativities of Various Elements. A popular scale for electronegativities has the value for fluorine atoms set at 4.0, the highest value.

**Example**

Describe the electronegativity difference between each pair of atoms and the resulting polarity (or bond type).

a. C and H
b. H and H
c. Na and Cl
d. O and H

**Solution**

a. Carbon has an electronegativity of 2.5, while the value for hydrogen is 2.1. The difference is 0.3, which is rather small. The C–H bond is therefore considered nonpolar.
b. Both hydrogen atoms have the same electronegativity value—2.1. The difference is zero, so the bond is nonpolar.
c. Sodium’s electronegativity is 0.9, while chlorine’s is 3.0. The difference is 2.1, which is rather high, and so sodium and chlorine form an ionic compound.
d. With 2.1 for hydrogen and 3.5 for oxygen, the electronegativity difference is 1.4. We would expect a very polar
bond, but not so polar that the O–H bond is considered ionic.

Exercise

Describe the electronegativity difference between each pair of atoms and the resulting polarity (or bond type).

a. C and O
b. N and H
c. N and N
d. C and F

When a molecule’s bonds are polar, the molecule as a whole can display an uneven distribution of charge, depending on how the individual bonds are oriented. For example, the orientation of the two O–H bonds in a water molecule (Figure \(\PageIndex{3}\)) is bent: one end of the molecule has a partial positive charge, and the other end has a partial negative charge. In short, the molecule itself is polar. The polarity of water has an enormous impact on its physical and chemical properties. (For example, the boiling point of water \([100°C]\) is high for such a small molecule and is due to the fact that polar molecules attract each other strongly.) In contrast, while the two C=O bonds in carbon dioxide are polar, they lie directly opposite each other and so cancel each other’s effects. Thus, carbon dioxide molecules are nonpolar overall. This lack of polarity influences some of carbon dioxide’s properties. (For example, carbon dioxide becomes a gas at \(-77°C\), almost 200° lower than the temperature at which water boils.)

![Figure \(\PageIndex{3}\)](Physical Properties and Polarity. The physical properties of water and carbon dioxide are affected by their polarities.)

Concept Review Exercises

1. What does the electronegativity of an atom indicate?
2. What type of bond is formed between two atoms if the difference in electronegativities is small? Medium? Large?

Answers

1. Electronegativity is a qualitative measure of how much an atom attracts electrons in a covalent bond.
2. nonpolar; polar; ionic
Key Takeaways

• Covalent bonds between different atoms have different bond lengths.
• Covalent bonds can be polar or nonpolar, depending on the electronegativity difference between the atoms involved.

Contributors

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