Section 3.3: Polar Bonds and Polar Molecules

Mini Investigation: Evidence for Polar Molecules, page 103
A. The polar liquids will all exhibit some type of bending toward charged materials. The non-polar liquids will not be deflected by the charged materials.
B. No apparent difference should occur when using the acetate strip compared to using the vinyl strip. Deflection occurs whether the material is positively or negatively charged. Answers may vary as to whether this result was expected or not.
C. Answers may vary. Sample answer: The polar water molecules arranged themselves so that their negative poles were closer to the positively charged material (or so that their positive poles were closer to the negatively charged material).
D. Answers may vary. Sample answer: If you held a vinyl strip beside a stream of hexane, a non-polar liquid, the charged vinyl strip would not deflect the stream of hexane.

Research This: Waste Wisdom, page 105
A. Answers may vary depending on consumer product researched. Sample answer: Paint should not be placed in regular garbage or poured down the drain because it contains toxic ingredients and can pollute waterways. In Toronto, you can drop off unused paint and empty paint cans at a Household Hazardous Waste depot or hazardous waste disposal event. As well, paint dealers often offer paint recycling. Statistics Canada reports that, “in 2005, 29% of households had leftover paint they wanted to be rid of. More than half of these households used special waste depots or returned it to the supplier for disposal…. Only a small proportion of households put it in the trash or used some other method of disposal.” I think most people know that paint should not be put in the regular garbage due to public information campaigns, and they do not want to harm the environment, so they find proper ways to dispose of it.
B. Answers may vary. Sample answer: Another way to protect the environment from hazardous household waste is to produce fewer hazardous products. There will always be some people who do not dispose of hazardous products safely, either due to ignorance or lack of responsibility. Fewer unsafe products would mean less harm to the environment.
Tutorial 1 Practice, page 107

1. (a) Hydrogen bromide, HBr, has one hydrogen atom and one bromine atom in each molecule.

\[ \text{H} \quad \text{Br} \]

There is one covalent H–Br bond.

\[
\Delta \text{EN} = \text{EN}_{\text{Br}} - \text{EN}_{\text{H}} \\
= 3.0 - 2.2 \\
= 0.8
\]

Therefore, the single H–Br bond is polar covalent.

\[ \delta^+ \quad \text{H} \quad \text{Br} \quad \delta^- \]

A diatomic molecule made up of two different molecules is always polar. Therefore, hydrogen bromide is a polar molecule.

(b) There are two atoms of nitrogen in a molecule of nitrogen gas, N₂.

\[ \text{N} \equiv \text{N} \]

There are three covalent N–N bonds. There is no electronegativity difference between the two identical atoms. Therefore, the bond is non-polar. A diatomic molecule made up of two identical molecules is always non-polar. Therefore, nitrogen is a non-polar molecule.

(c) Hydrogen sulfide, H₂S, has two hydrogen atoms and one sulfur atom in each molecule.

\[
\begin{align*}
\text{H} & \quad \text{S} \\
\text{S} & \quad \text{H}
\end{align*}
\]

There are two covalent S–H bonds.

\[
\Delta \text{EN} = \text{EN}_{\text{S}} - \text{EN}_{\text{H}} \\
= 2.6 - 2.2 \\
= 0.4
\]

Therefore, each S–H bond is polar covalent.

\[ \delta^+ \quad \text{H} \quad \delta^- \\
\delta^- \quad \text{S} \quad \delta^+ \\
\delta^+ \quad \text{H} \quad \delta^+
\]

The shape of the molecule is asymmetrical. Therefore, hydrogen sulfide is a polar molecule.
(d) Ethane, \( \text{C}_2\text{H}_6 \), has two carbon atoms and six hydrogen atoms in each molecule. 

\[
\begin{array}{cc}
| & | \\
H & H \\
| & | \\
H & C & C & H \\
| & | \\
H & H \\
\end{array}
\]

There are six covalent C–H bonds and one covalent C–C bond. 

\[
\Delta EN = EN_C - EN_H \\
= 2.6 - 2.2 \\
= 0.4
\]

Therefore, each C–H bond is polar covalent. There is no electronegativity difference between the two carbon atoms, so the C–C bond is non-polar.

\[
\begin{array}{cc}
\delta^+ & \delta^+ \\
\delta^- & & \delta^- \\
\delta^+ & & \delta^+
\end{array}
\]

The shape of the molecule is symmetrical. Also, the molecule is composed of carbon and two or more atoms of the same element (hydrogen). Therefore, ethane is a non-polar molecule.

(e) Tetrachloroethene, \( \text{C}_2\text{Cl}_4 \), has two carbon atoms and four chlorine atoms in each molecule.

\[
\begin{array}{cc}
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
\end{array}
\]

There are four covalent C–Cl bonds and two covalent C–C bonds. 

\[
\Delta EN = EN_{\text{cl}} - EN_C \\
= 3.2 - 2.6 \\
= 0.6
\]

Therefore, each C–Cl bond is polar covalent. There is no electronegativity difference between the two carbon atoms, so the C–C bonds are non-polar.
The shape of the molecule is symmetrical. Also, the molecule is composed of carbon and two or more atoms of the same element (chlorine). Therefore, tetrachloroethene is a non-polar molecule.

(f) Phosphine, \( \text{PH}_3 \), has one phosphorus atom and three hydrogen atoms in each molecule.

There are three covalent \( \text{P–H} \) bonds.

\[
\Delta\text{EN} = \text{EN}_\text{P} - \text{EN}_\text{H} = 2.2 - 2.2 = 0
\]

Therefore, each \( \text{P–H} \) bond is non-polar covalent.

However, the shape of the molecule is asymmetrical with a lone pair on top. Therefore, phosphine is a polar molecule.
Section 3.3 Questions, page 108

1. From most polar to least polar:
   (a) K–Br, H–Br, O–F, C–H
   (b) C–F, O–H, C–O, H–H

2. 

   \[ \delta^+ \quad \delta^- \quad \delta^+ \quad \delta^- \]
   
   \[ \text{H–Br} \quad \text{C–F} \]

3. 

4. (a) \( \text{O}_2 \) is a symmetrical molecule because the two covalent bonds are arranged symmetrically between the two oxygen atoms.
   (b) \( \text{H}_2\text{O} \) is an asymmetrical molecule because the covalent bonds are arranged asymmetrically about the oxygen atom.
   (c) \( \text{CO}_2 \) is a symmetrical molecule because the covalent bonds are arranged symmetrically about the central carbon atom.
   (d) \( \text{CH}_4 \) is a symmetrical molecule because the covalent bonds are arranged symmetrically about the central carbon atom.
   (e) \( \text{NH}_3 \) is an asymmetrical molecule because the covalent bonds are arranged asymmetrically around the nitrogen atom, with a lone pair on top.
5. (a) CCl₄ has one carbon atom and four chlorine atoms in each molecule.

\[
\begin{align*}
\text{\Cl} & \text{\Cl} \\
\text{\Cl} & \text{\Cl} \\
\text{\Cl} & \text{\Cl}
\end{align*}
\]

There are four covalent C–Cl bonds.

\[
\Delta EN = EN_{Cl} - EN_{C} = 3.2 - 2.6 = 0.6
\]

Therefore, each C–Cl bond is polar covalent.

\[
\begin{align*}
\text{\Cl} & \text{\Cl} \\
\text{\Cl} & \text{\Cl} \\
\text{\Cl} & \text{\Cl}
\end{align*}
\]

The shape of the molecule is symmetrical. Also, the molecule is composed of carbon and four atoms of the same element. Therefore, CCl₄ is a non-polar molecule.

(b) H₂O has one oxygen atom and two hydrogen atoms in each molecule.

\[
\begin{align*}
\text{\H} & \text{\H} \\
\text{\O}
\end{align*}
\]

There are two covalent O–H bonds.

\[
\Delta EN = EN_{O} - EN_{H} = 3.4 - 2.2 = 1.2
\]

Therefore, each O–H bond is polar covalent.
The shape of the molecule is asymmetrical. Also, the molecule is composed of oxygen and two other atoms of the same element. Therefore, $\text{H}_2\text{O}$ is a polar molecule.

(c) $\text{HF}$ has one hydrogen atom and one fluorine atom in each molecule.

\[
\begin{align*}
\text{H} & \quad \text{F} \\
\end{align*}
\]

There is one covalent $\text{H} \text{– F}$ bond.

\[
\Delta \text{EN} = \text{EN}_\text{F} - \text{EN}_\text{H}
\]

\[
= 4.0 - 2.2
\]

\[
= 1.8
\]

The single $\text{H} \text{– F}$ bond is therefore polar covalent.

\[
\begin{align*}
\delta^+ & \quad \text{H} \quad \delta^- \\
& \quad \text{F} \quad \text{F} \\
\end{align*}
\]

A diatomic molecule made up of two different molecules is always polar. Therefore, $\text{HF}$ is a polar molecule.

(d) $\text{CF}_4$ has one carbon atom and four fluorine atoms in each molecule.

\[
\begin{align*}
\text{F} & \quad \text{C} \quad \text{F} \\
\text{F} & \quad \text{F} \\
\end{align*}
\]

There are four covalent $\text{C} \text{– F}$ bonds.

\[
\Delta \text{EN} = \text{EN}_\text{F} - \text{EN}_\text{C}
\]

\[
\begin{align*}
\text{F} & = 4.0 - 2.6 \\
& = 1.4
\end{align*}
\]

Therefore, each $\text{C} \text{– F}$ bond is polar covalent.

The shape of the molecule is symmetrical. Also, the molecule is composed of carbon and four atoms of the same element. Therefore, $\text{CF}_4$ is a non-polar molecule.
(e) CH₃Cl has one carbon atom, three hydrogen atoms, and one chlorine atom in each molecule.

\[
\begin{align*}
\text{H} & \quad \text{C} \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl}
\end{align*}
\]

There are three covalent C–Cl bonds and one covalent C–H bond.

\[
\begin{align*}
\Delta EN &= EN_{\text{Cl}} - EN_{\text{C}} \\
&= 3.2 - 2.6 \\
&= 0.6
\end{align*} \quad \begin{align*}
\Delta EN &= EN_{\text{C}} - EN_{\text{H}} \\
&= 2.6 - 2.2 \\
&= 0.4
\end{align*}
\]

Therefore, each bond is polar covalent.

The molecule has a positive side and a negative side. Also, it is asymmetrical, and it is made up of carbon and atoms of two other elements. Therefore, CH₃Cl is a polar molecule.

6. Polar liquids will bend toward charged materials. Charged materials will not deflect non-polar liquids. Therefore, 

(a) Carbon tetrachloride, CCl₄(l), is non-polar, because it was unaffected by the charged strips. (Also, it is a symmetrical molecule, and the chemical formula is carbon and one other element.)

(b) Methanol, CH₃OH(l), is polar, because the charged strips attracted it. (Also, it is an asymmetrical molecule, and the chemical formula is carbon and two other elements.)

(c) Hexane, C₆H₁₄(l), is non-polar, because it was unaffected by the charged strips. (Also, it is a symmetrical molecule, and the chemical formula is carbon and one other element.)

(d) Nitrogen trichloride, NCl₃(l), is polar, because the charged strips attracted it. (Also, it is an asymmetrical molecule, and the chemical formula is nitrogen and three atoms of one other element.)

7. Answers may vary. Sample answer: The pros of replacing conventional cleaning fluid with carbon dioxide are that carbon dioxide is non-toxic and an available byproduct from many industries, plus it keeps clothes free of chemicals. The cons are the higher costs of purchasing and maintaining the equipment required.
8. Answers may vary. Sample answer: In both ball-and-stick and space-filling molecular models, colours and sizes are used to distinguish one type of atom from another. Space-filling models show the space filled by the electrons around the atoms and thus how much space the molecule occupies, but it is difficult to see the bond patterns and the structure of the molecule past the first layer of atoms. In ball-and-stick models, the spheres are much smaller and they do not provide a realistic sense of a molecule’s size. However, the smaller balls allow a clearer view of the atoms and chemical bonds throughout the model. They also show the angles between the bonds. For example, here is an example of each type of model for water, H₂O.