Section 3.5: Hydrogen Bonding and Water

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A. Answers are determined from experimental observations. Sample answer: The intermolecular forces and hydrogen bonding that occurs in water allows for the cohesive properties of the water. When these bonds are broken, the material placed on the surface of the water will sink to the bottom.
B. Answers are determined from experimental observations. Sample answer: The addition of the dish detergent to the beaker caused the paper clip to sink to the bottom of the beaker.
C. Answers are determined from experimental observations. Sample answer: Powdered sulfur, baby powder and baking soda were able to increase the surface tension of water, while dish soap, detergent, vegetable oil were able to decrease the surface tension of water. Salt and sugar had no effect on the surface tension of water. The substances that were able to decrease the surface tension of water were able to break the intricate network of hydrogen bonds which provides the high surface tension in water.
D. Answers may vary. Sample answer: Substances that decrease the surface tension of water are called surfactants. A household use of surfactants is detergents that make water less likely to stick to itself and more likely to interact with oil and grease. A commercial use of surfactants is dispersants used to break up ocean oil spills.

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1. (a) Four unusual properties of water are a high boiling and melting point, low density in the solid state, high surface tension, and high specific heat capacity.
   (b) Water’s high boiling and melting points are due to the strong intermolecular forces of hydrogen bonds. The low density of ice is caused when hydrogen bonds arrange the molecules into a crystalline structure where there is more space between the molecules than there is in liquid water. Water’s high surface tension is caused by its hydrogen bonds, which hold water molecules tightly together and cause it to take a shape that has the smallest possible surface area. Water’s high specific heat capacity will be explained in future chemistry courses.
2. (a) The force that is primarily responsible for the special properties of water is hydrogen bonding.
   (b)
3. The molecules in liquid water are closer together and much more jumbled than the molecules in ice. The relatively higher energy of liquid water molecules overcomes the hydrogen bonds resulting in more water molecules per unit volume (hence a greater density). Water molecules in ice, however, are organized in a much more uniform structure (a crystal lattice) because the hydrogen bonds are strong enough to keep the less energetic molecules in place. This results in fewer molecules per unit volume and hence a smaller density.

4. If water were a non-polar molecule, it would have a relatively low boiling point and melting point, a lower heat capacity, a lower surface tension, and it would be denser as a solid than as a liquid.

5. Answers may vary. Sample answer: Examples of ways that life on Earth would be different if water were a non-polar molecule would include effects from the inability of water to form strong hydrogen bonds. Water would not have its high specific heat capacity, so weather systems would be very different. Water would not have high surface tension, so bugs could not stand on water, water could not go up trees, and raindrops would not be the way they are. Ice would not float on liquid water. Lakes would freeze from the bottom up. This would change the potential of lakes as a habitat and allow more evaporation, since water evaporates faster than ice. More water in the atmosphere would contribute to weather changes. Sample diagram:

6. Liquid water is most dense when it has a temperature of 4 ºC. As the water gets colder, it turns to ice, which floats on the water. This leaves an insulated liquid habitat below in which aquatic life can survive through a Canadian winter.

7. Answers may vary. Sample answer: Point-source pollution is pollution that originates from a single, identifiable source, such as a discharge pipe from a factory or sewage plant. Nonpoint-source pollution is pollution that enters a body of water from diffuse sources, such as polluted runoff from agricultural areas draining into a river. Direct sources of pollution are those, such as factories, refineries, and waste treatment plants, which release toxic substances directly into urban water supplies. Indirect sources of pollution include contaminants that enter the water supply through soil and groundwater or from the atmosphere via rainwater.