INVESTIGATION 4.5.2 HYDROGEN BONDING

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Prediction

(a) According to the theory of energy changes associated with changes in bonding, the temperature change for the mixture of glycerol and water should be greater than the temperature change for ethanol and water. In both cases, additional hydrogen bonds would be formed between the solute molecules and water molecules. However, a glycerol molecule, $C_3H_5(OH)_{3(l)}$, has three hydroxyl groups that can form hydrogen bonds with water molecules. An ethanol molecule, $C_2H_5OH_{(l)}$, has only one hydroxyl group that can form hydrogen bonds with water molecules. Because energy is released when bonds are formed, more hydrogen bonds should mean more energy released and a larger temperature change for glycercol and water.

Experimental Design

(b) The independent variable is the number of hydroxyl groups per alcohol molecule. The dependent variable is the temperature change produced when the alcohol and water are mixed. Some important controlled variables are the volumes of liquids mixed, the particular calorimeter used, and the purity of the alcohol used.

Procedure

(c)

1. Using a 10-mL graduated cylinder, measure 10.0 mL of ethanol and place it into clean, dry, nested polystyrene cups (calorimeter).
2. Place a thermometer into the ethanol and measure its temperature to one decimal place.
3. Using a different 10-mL graduated cylinder, measure 10.0 mL of pure water.
4. Measure the temperature of the water in the graduated cylinder.
5. Quickly pour all of the water into the ethanol and place the lid on the cups.
6. Swirl the mixture and measure the highest temperature reached by the mixture.
7. Dispose of the mixture into the sink, and rinse and dry the calorimeter.
8. Repeat Steps 1 to 7 two more times.
9. Repeat Steps 1 to 8 using glycerol instead of ethanol.

Evidence/Analysis

Ethanol and Water Mixture			
Trials	**Initial temperature (°C)**	**Final temperature (°C)**	**Temperature change (°C)**
ethanol water	22.2 22.0	29.2	7.1
ethanol water	22.0 22.0	29.2	7.2
ethanol water	22.2 22.2	29.2	7.0

Glycerol and Water Mixture			
Trials	**Initial temperature (°C)**	**Final temperature (°C)**	**Temperature change (°C)**
glycerol water	23.4 22.2	28.5	5.7
glycerol water	23.5 22.4	28.4	5.5
glycerol water	23.4 22.4	28.2	5.3

- Glycerol was very viscous and flowed very slowly out of the graduated cylinder. It was hard to tell how long to wait for this liquid to flow out.
- The initial temperatures were averaged together before subtracting them from the final temperature.

(d) According to the evidence collected, the average temperature change of the ethanol-water mixture was noticeably higher than the glycerol-water mixture.

Evaluation

(e) The evidence is questionable because the design did not take into account the fact that the same volume of two different liquids would contain different numbers of molecules. This is a flaw in the design that needs to be corrected. The materials were of suitable quality to provide reasonable evidence. The procedure appears to be adequate because the steps were sufficiently clear and included multiple trials to increase the reliability of the evidence. The difficulty experienced with pouring the viscous glycerol could be eliminated by measuring the mass used instead of the volume. This change would also make it easier to compare or control the number of molecules of the alcohol used.

(f) I am not very certain about the evidence because of the flaw identified in the design. Measurements of the temperature and volume also provide some experimental error but this is not expected to be a major factor.

(g) The evidence is sufficiently uncertain to make a judgment of the prediction quite unreliable. It is hard to tell if the disagreement of the evidence with the prediction is due to the flaw identified or other factors related to the mixing and bonds breaking and forming. The experiment needs to be redesigned and redone.

INVESTIGATION 4.6.1 CLASSIFYING MYSTERY SOLIDS

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Experimental Design

(a) The class of each solid is identified by observing the appearance, electrical conductivity, solubility in water, electrical conductivity in water, and effect of heating (relative melting point).

Materials

(b) tweezers
stirring rod
conductivity tester
4 small beakers
distilled water
hot plate
vials with mystery solids

Procedure

(c)
1. Observe the appearance of each solid.
2. Test a crystal of each solid for electrical conductivity.
3. Place a crystal of each solid on a hot plate at a low heat setting. Observe the solids as the heat is slowly increased.
4. Test the electrical conductivity of pure water in a clean, dry beaker.
5. Place a few crystals of each solid in separate beakers and add about 10 mL of water to each. Stir to dissolve as much as possible.
6. Test the electrical conductivity of each mixture.
7. Dispose of solids into the waste basket and liquids in the sink.

Evidence

Properties of the Mystery Solids

Solids	1	2	3	4
Appearance	clear, colourless	clear, colourless, some white patches	silvery grey	clear, colourless
Conductivity of solid	none	none	good	none
Effect of heating	no change	no change	none	melts quickly and turns black
Solubility in water	did not dissolve	dissolved	did not dissolve	dissolved
Conductivity in water	none	good	none	none