Lesson Plan: The Hot and Cold of it all: Analysis of Antifreeze/Coolant Solutions

FOR THE TEACHER

Summary
In this lesson students will analyze the effectiveness of different brands of antifreeze/coolants and their ability to protect an engine in cold climates. Students will conduct a lab investigation to examine the freezing point depression in samples that have been diluted with distilled water. Students will also determine the specific heat capacities of antifreeze/coolant products as compared to pure water and explain how it relates to thermal energy transfer in the internal combustion engine.

Grade Level
High School

NGSS Alignment
This lesson will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-1**: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- **HS-PS3-4**: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
- **Scientific and Engineering Practices**:
  - Analyzing and Interpreting Data
  - Engaging in Argument from Evidence

Objectives
By the end of this lesson, students should be able to:

- Draw conclusions from experimental data in which they compare and contrast different antifreeze/coolant products.
- Support conclusions with valid arguments based on experimental evidence.
- Explain the process by which an internal combustion engine is cooled.
- Relate the cooling process to thermal heat transfer and heat capacity.

Chemistry Topics
This lesson supports students’ understanding of:

- Solutions
- Colligative properties (freezing point depression)
- Energy
- Specific heat capacity
- Thermal energy transfer

Time
**Teacher Preparation**: 30-45 minutes
**Lesson**: 60 minutes (Engage), 2 hours (Explore), 30 minutes (Explain)
Elaborate: 30 minutes
Evaluate: 60 minutes

Materials
- 4 Different brands of antifreeze/coolant (full strength)
- Thermometer or temperature probe with appropriate computer interface
- 100-mL beakers
- Ring stand and clamps
- 100-mL graduated cylinders
- Rock salt
- Crushed ice
- Stirring rods
- Nalgene or other non-glass beaker
- Electronic balance

Safety
- Always wear safety goggles and aprons when handling chemicals and glassware in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- Ethylene glycol SDS
- Propylene glycol SDS

Teacher Notes
- **Engage**: Essential questions should be presented to students:
  1. How does the cooling system in an internal combustion engine work?
     - Students will be given a diagram that illustrates how the cooling system works in an internal combustion engine.
     - Students write a brief explanation of the purpose for each component.
  2. What is the best antifreeze/coolant for an automobile engine? What criteria should be considered when selecting one brand over another?
     - On the first day of the lesson, students will be presented with a request from an automobile dealer in northern Vermont to analyze different brands of antifreeze/coolant so that they can make recommendations to their customers.
     - Students will engage in a brainstorming session in which they will identify key factors to consider when selecting an antifreeze/coolant product.
  3. How do products containing propylene glycol compare with those made with ethylene glycol?
     - Students will research the properties of both compounds and prepare a table of advantages/disadvantages or pros/cons of each one.

- **Explore**: Students perform both of the included lab investigations.
- **Explain**: Students will discuss and analyze experimental findings from investigations.
- **Elaborate**: Students will integrate essential questions and initial research into a coherent explanation of their experimental findings.
- **Evaluate**: Student groups will prepare and submit a product, in the format of their choosing to present their experimental findings and make the connection to the cooling system in an internal combustion engine. (For example: Students could produce a narrated pictorial account
of their investigation, a video, or commercial that advertises the product that gave the optimal results).

- This information focused on the history of the Water Cooling System in Model T Ford engine may be helpful for a teacher to review before the lesson.

- This diagram of a cooling system may be helpful to share with students.
FOR THE STUDENT

Lesson

The Hot and Cold of It All:
A Study of Antifreeze/Coolant Products in Automobiles

Background
When automobile internal combustion engines operate, a large amount of heat is generated in the process. Therefore, a system must be in place to ensure that the engine does not overheat and stop running or become seriously damaged. There is also a need to consider how to maintain the cooling system in extremely cold weather.

How does a product keep the engine from overheating and from freezing at the same time?

Important Scientific Terms to know:
- Internal combustion engine
- Specific Heat Capacity
- Freezing Point Depression
- Colligative Properties
- Percent by volume (solutions)
- Solvent, solute, solution
- Coolant
- Dilution
- Antifreeze
- Specific heat capacity
- Heat energy formula: $Q = mc\Delta T$

Pre-lab Questions
When answering these questions it is imperative that all sources are properly cited. The citation must be in the MLA format, simply providing the web address is not acceptable.

1. Describe or define the meaning of each scientific term listed above

2. Compare the specific heat capacities of pure water, ethylene glycol and propylene glycol. Which one requires more heat energy to raise its temperature?

3. How can one substance function as both coolant and antifreeze at the same time?

4. What happens to the freezing point of pure water when a solute is dissolved in it?

Materials
- 4 Different brands of antifreeze/coolant
- Thermometer or temperature probe
- 150-mL beakers
- Test tubes
- 100-mL graduated cylinders
- Rock salt
- Crushed ice
- Stirring rods
- Ring stand/clamp
- Wash bottle
- Distilled water
- Nalgene beakers (for ice bath)
- Electronic balance
- Styrofoam cups
- 500 mL beakers
- hotplate
Safety
- Always wear safety goggles and aprons when handling chemicals and glassware in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.

Objective
Is there a difference in the capacity of different brands of antifreeze to prevent freezing at temperatures below 0°C?
In this procedure you will be determining the temperature at which different test solutions reach their freezing points.

Procedure
PART I: Freezing Point Depression
1. Prepare 100 mL diluted samples of each antifreeze/coolant product by creating a 50:50 solution of each with distilled water.
2. Set up an ice bath using crushed ice and distilled water in a Nalgene (or other non-glass) beaker.
3. Suspend a test tube containing 20 mL of refrigerated, pure distilled water in the ice bath as your control.
4. Place the thermometer or temperature probe in the test tube containing the water.
5. Slowly add rock salt to the ice bath. Gently stir the water in the test tube and monitor the temperature as it starts to decrease. Record the temperature at which ice crystals begin to appear.
6. Repeat steps 3 through 5 for the diluted antifreeze/coolant samples. Record all temperature data in table.
7. If directed by your teacher, also conduct testing on 20 mL full strength samples of each antifreeze/coolant.
8. Dispose of all solutions in waste container provided by your teacher.
9. Rinse all glassware and measuring devices with distilled water. Make sure everything has been wiped dry before putting away.

Data
PART I: Freezing Point Depression

<table>
<thead>
<tr>
<th>Product Brand name (indicate dilute or full strength)</th>
<th>Indicate the ingredient: Ethylene Glycol (EP) or Propylene Glycol (PG)</th>
<th>Temperature (°C) at which freezing is observed</th>
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</thead>
<tbody>
<tr>
<td>Water</td>
<td>n/a</td>
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</table>
Analysis:
1. A 50:50 mixture of antifreeze/coolant to water is the accepted dilution for use in automobile cooling systems. Compare the freezing temperatures of all substances tested in your experiment. Make a claim (a statement that you believe to be true), based on your findings, that justifies the use of a 50:50 mixture rather than pure water. ALL CLAIMS must be supported with data from your experiment.

2. Did you find any significant differences between different brands of antifreeze/coolant products with respect to freezing temperatures? EXPLAIN.

3. Why do you think that distilled water is used as opposed to regular tap water in the diluted samples? Be specific in your response.

Objective
How does the ratio of antifreeze/coolant to water affect the specific heat capacity of the solution? Why is that important?
In this investigation you will be determining the specific heat capacity of one brand of full strength and diluted (50:50) antifreeze/coolant product to answer the question.

Procedure
Part II: Specific heat capacity
1. Assemble “coffee cup” calorimeter by nesting two Styrofoam cups and placing them in a 500 mL beaker for support.
2. Measure and record the mass of a clean, dry Styrofoam cup that will be used for your investigation. The other cup will remain in the beaker.
3. Measure 100 mL of cool (room temperature) distilled water in a graduated cylinder and pour into the massed Styrofoam cup. Measure and record the mass of the cup and water together.
4. Place the thermometer or temperature probe into the water, wait for reading to stabilize and record initial temperature of the water.
5. Measure 100 mL of full strength antifreeze/coolant product using a graduated cylinder.
6. Pour the antifreeze/coolant into a 150-mL beaker and place on a hot plate. Heat until the temperature reaches 60 °C. Record exact initial temperature.
7. Using insulated beaker tongs, pick up the beaker from hotplate and pour into the coffee cup calorimeter containing the distilled water. Stir gently to mix.
8. Record highest temperature reached.
9. Measure and record the mass of final mixture.
10. Properly dispose of solution in waste beaker provided by your teacher.
11. Rinse out Styrofoam cup with distilled water and dry thoroughly.
12. Perform at least three trials for each sample.
13. Repeat steps 2-9 with diluted (50:50) sample of the antifreeze/coolant.
# Data

**PART II: Specific Heat Capacity**

## Product information

<table>
<thead>
<tr>
<th>Antifreeze/coolant Product Brand name:</th>
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</thead>
<tbody>
<tr>
<td>Does product contain Ethylene Glycol or Propylene Glycol?</td>
</tr>
</tbody>
</table>

## Temperature data collection of Full Strength Sample:

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Initial temp of water (°C)</th>
<th>Initial temp of full strength sample (°C)</th>
<th>Final temp of full strength sample mixture (°C)</th>
<th>Change in temp of water (°C)</th>
<th>Change in temp of full strength sample (°C)</th>
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## Temperature data collection of Diluted Sample:

<table>
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<tr>
<th>Trial #</th>
<th>Initial temp of water (°C)</th>
<th>Initial temp of diluted sample (°C)</th>
<th>Final temp of diluted sample mixture (°C)</th>
<th>Change in temp of water (°C)</th>
<th>Change in temp of diluted sample (°C)</th>
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Product information

| Antifreeze/coolant Product Brand name: |
| Does product contain Ethylene Glycol or Propylene Glycol? |

<p>| Mass data collection of Full Strength Sample: |</p>
<table>
<thead>
<tr>
<th>Trial #</th>
<th>Mass of empty Styrofoam cup (g)</th>
<th>Mass of distilled water (g)</th>
<th>Mass of final mixture (full strength) (g)</th>
<th>Mass of full strength sample (by subtraction) (g)</th>
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Calculations
1. Find “q” for the distilled water for each trial using this formula ($c_{water}$ = 4.184 J/g °C)

$$q = m \times c \times \Delta T$$

2. Use the “q” value for each trial to solve for “c” of antifreeze/coolant samples.

Analysis:
1. How did your experimental values compare to the reference values for specific heat capacity of your tested antifreeze/coolant product?

2. Identify and explain any significant sources of error.
Independent Extension
Explain an experimental method by which the dilution of an unknown sample of antifreeze/coolant could be determined.