

Date: _____

Your Name: _____



**NEW ENGLAND
COMMON ASSESSMENT PROGRAM**

Released Science Inquiry Task

Antifreeze

2011

Grade 11

Science

Directions:

You will be analyzing the results of an investigation described in a short story called “Antifreeze” and applying what you learn to answer a set of questions. Thoroughly explain all of your answers. You may include drawings or labeled diagrams to help you answer the questions.

This Word Bank provides definitions for words used in the investigation. You may refer back to this page throughout this session.

Word Bank

Antifreeze	a substance added to water to lower the freezing point of the water
Concentration	the amount of a solute per unit volume of a solvent
Corrosion	the process of wearing away gradually, usually by chemical reaction
Dry ice	a solid form of carbon dioxide that has a temperature of -78.5°C
Ethylene glycol	a toxic organic chemical that is used primarily as an antifreeze
Propylene glycol	an organic chemical that is used as antifreeze and also recognized by the Food and Drug Administration as a safe food additive
Radiator	part of the cooling system in an automobile engine; where antifreeze solution is added to the cooling system
Solute	dissolved matter in a solution
Solvent	a substance capable of dissolving another substance(s)
Toxic	poisonous

Antifreeze

Mr. Jones is the advisor for the automotive club at the local high school. At today's meeting, he made an exciting announcement: "One of my former students donated a 1968 Ford Mustang for us to restore and maintain. He bought the car in Miami and just moved it to New England on a flatbed trailer. This car has never been in freezing temperatures or driven on salted roads."

Cathy and Anthony were very excited. "Wow! What kind of work does it need?" Anthony asked.

Mr. Jones said, "First, we need to make sure it is in good mechanical condition. You will check the tires, the oil, the battery, and the radiator fluid. My former student knows there is ethylene glycol antifreeze in the radiator but is not sure if the concentration is appropriate for a New England winter."

Mr. Jones told the club if the water in a car's cooling system freezes, it can crack the engine block and destroy the engine. To protect against this, antifreeze is added to the water in engine cooling systems. Antifreeze lowers the temperature at which water freezes, which prevents engine damage even on a winter night in New England. Mr. Jones showed the club this label from a container of antifreeze.

Mountain Antifreeze

A high-quality winter antifreeze/summer coolant.
Protects your engine from corrosion.

Dilution ratios: A solution of 60% antifreeze and 40% water will give freeze protection of -55°C . For best overall performance, a 50% solution of antifreeze is recommended for engine protection for temperatures between -35°C and 108°C . Never use pure antifreeze in radiator.

WARNING: Contains ethylene glycol. **Severe poisoning danger to humans and pets.** Do not leave in an open container. In the event of consumption, contact the local Poison Control Center immediately.

The first task Mr. Jones gave Cathy and Anthony was to test the radiator fluid to determine the antifreeze concentration. Winter was coming and he did not want the donated car to freeze up when left in the parking lot overnight.

To decide how much antifreeze needed to be added to the radiator, Mr. Jones decided to have the students investigate the following research question:

Research Question

What is the relationship between the concentration of antifreeze in a solution and its freezing point?

Part 1: Forming a Hypothesis

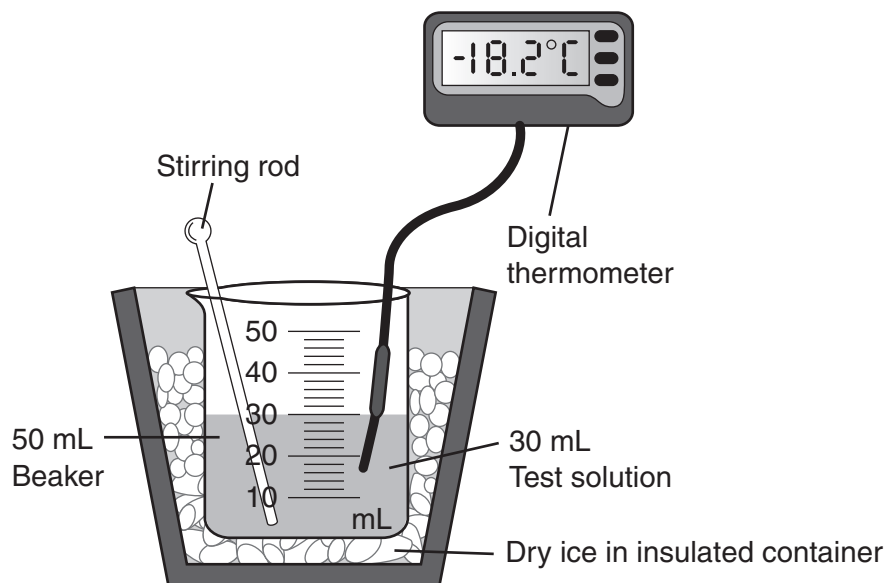
Answer question 1 on page 1 in your Student Answer Booklet.

- 1 Form a hypothesis about the relationship between the concentration of antifreeze in a solution and its freezing point. Use information from the story to explain how you formed your hypothesis.

Setting Up and Conducting the Investigation and Collecting Data

The diagram below shows the setup of Cathy and Anthony's investigation.

Setup of Cathy and Anthony's Investigation



Cathy and Anthony conducted the following investigation using ethylene glycol under Mr. Jones's supervision. He brought the students to a well-ventilated science laboratory to do the investigation. The students put on lab coats to protect their clothing and wore goggles and gloves to protect their eyes and hands. Then the students followed the procedure below.

1. Prepare 10 test solutions of ethylene glycol antifreeze in water, each with between 10 and 100 percent antifreeze.
2. Place dry ice pellets on the bottom of an insulated container. (Dry ice has a temperature of -78.5°C .)
3. Place a beaker with 30 mL of the 10% test solution in the insulated container and fill in around the beaker with dry ice pellets (as shown in the diagram on page 30).
4. Immediately place a digital thermometer and a stirring rod inside the beaker. Observe and stir the test solution as its temperature drops.
5. When ice crystals start to form in the test solution, record the temperature.
6. Repeat steps 3–5 for each test solution.

Answer question 2 on page 1 in your Student Answer Booklet.

- 2 Identify one possible source of error in the procedure of the investigation. Explain why this could be a source of error and how this potential error could affect the results of the investigation.

Data Table 1 shows the data Cathy and Anthony collected as they investigated each test solution.

Data Table 1: Freezing Temperatures of Different Concentrations of Ethylene Glycol

Concentration of Ethylene Glycol (Volume Percent in Water)	Freezing Point (°C)
10	-3.2
20	-7.8
30	-16.2
40	-23.3
50	-35.5
60	-56.6
70	-64.8
80	-45.5
90	-31.6
100	-13.5

(Table data is adapted and compiled from LLTTF - Typical Freezing and Boiling Points of Ethylene Glycol Based Fluids, http://www.engineeringtoolbox.com/ethylene-glycol-d_146.html, and <http://www.eetcorp.com/antifreeze/antifreeze-data.htm>)

Part 2: Organizing, Presenting, and Analyzing Data

Answer question 3 on page 2 in your Student Answer Booklet.

- 3 Use the data in Data Table 1 to construct a graph. Be sure to include all the required elements of a graph.

Answer question 4 on page 3 in your Student Answer Booklet.

- 4 Use evidence from Data Table 1 or your graph to describe the relationship between the ethylene glycol antifreeze concentration and the freezing point of the solution.

When Cathy and Anthony began their investigation, they thought they only needed to test antifreeze solution concentrations ranging from 10 to 50 percent, but Mr. Jones told them to test antifreeze concentrations up to 100 percent.

Answer question 5 on page 3 in your Student Answer Booklet.

- 5 Explain why the test results for solution concentrations ranging from 10 to 100 percent gave a better understanding of the relationship between the ethylene glycol antifreeze concentration and the freezing point of the solution than the test results for concentrations ranging only from 10 to 50 percent. Use specific evidence to support your explanation.

The two students collected a small sample of fluid from the radiator of the donated car, placed it in a freezer in the school chemistry laboratory, and measured its temperature every 10 minutes. After 30 minutes, the sample was slushy and ice crystals were beginning to form. The students observed that the freezing point of the sample of radiator fluid taken from the donated car was -18.2°C .

Answer question 6 on page 4 in your Student Answer Booklet.

- 6 Use evidence from Data Table 1 or your graph and the freezing point of the sample of radiator fluid (-18.2°C) to estimate the ethylene glycol antifreeze concentration of the radiator fluid in the donated car. Explain your reasoning and use specific evidence to support your explanation.

Cathy and Anthony found the following data from another data source. Data Table 2 shows relationships among ethylene glycol concentration, density, and freezing point.

The students determined the density of the radiator fluid from the donated car is 1.043 g/mL.

Data Table 2: Ethylene Glycol Antifreeze Concentration, Density, and Freezing Point

Percent of Antifreeze in Water	0	10	20	30	40	50	60	70	80	90	100
Density (g/mL)	1.000	1.011	1.023	1.035	1.046	1.058	1.069	1.081	1.092	1.104	1.115
Freezing Point (°C)	0	-2.2	-6.7	-12.8	-20.6	-33.3	-57.0	-64.0	-45.0	-30.0	-13.0

(Data is adapted and compiled from <http://www.ashland.com/pdfs/technical/AD%20Chemicals%20-%20Freeze-Flash%20Point.pdf> and Glycol Concentration Corresponding Freezing Point)

Answer question 7 on page 4 in your Student Answer Booklet.

- 7 Use evidence from Data Table 2 to estimate the ethylene glycol concentration in the radiator fluid of the donated car. Compare data in Data Table 1 or your graph with data in Data Table 2. Identify whether Data Table 1 or Data Table 2 clearly provides the actual antifreeze concentration of the radiator fluid in the donated car. Explain your reasoning and include specific evidence to support your explanation.

Cathy and Anthony carefully cleaned up the lab after the investigation. Mr. Jones warned them that they should never leave antifreeze in an open container because it is very toxic.

While researching antifreeze, Cathy and Anthony learned about another antifreeze called propylene glycol. They wondered how propylene glycol compares to ethylene glycol. They found the following data tables on the Internet.

Data Table 3: Freezing Points of Water/Propylene Glycol Solutions

Concentration of Propylene Glycol (Volume Percent in Water)	Freezing Point (°C)
10	-3
20	-7
30	-11
40	-21
50	-33
60	-49
70	-56
80	-57
90	-59
100	-62

(Adapted from graph used on <http://www.eetcorp.com/antifreeze/antifreeze-data.htm>)

Data Table 4: Antifreeze Facts

Property	Ethylene Glycol	Propylene Glycol
Cost of undiluted antifreeze per gallon	\$22.34	\$25.34
Heat transfer efficiency	good	very good
Toxicity	high	very low
Corrosion protection	excellent	good

(Adapted from <http://www.ppe.com/10cat/0133.pdf> and http://www.engineeringtoolbox.com/ethylene-propylene-glycol-d_904.html)

Mr. Jones had a container of propylene glycol antifreeze. The antifreeze label is shown below.



Cathy and Anthony plan to cover the donated car and leave it outside in the school parking lot for the winter. They need to decide whether to use the ethylene glycol antifreeze or the propylene glycol antifreeze. The students reviewed all of the information from the investigation, including the antifreeze container labels, data tables, and test results.

Part 3: Using Evidence and Applying What You Have Learned

Answer question 8 on page 5 in your Student Answer Booklet.

- 8 After reviewing the same information as the students reviewed, describe one advantage and one disadvantage of **both** types of antifreeze. Include specific information from the investigation in your descriptions.

Identify the antifreeze that you think the students should use. Explain your reasoning and include specific information from the investigation to support your explanation.

