Boil, Boil, Toil and Trouble
The International Boiling Point Project

Student Post-project Assessment

Read the Following

You are heading up a student scientific task force that has been asked to figure out what causes water to boil. You assemble a team of student scientists all around the country and have them conduct an experiment to measure the boiling point of water. You ask each student to record the following information for the experiment:

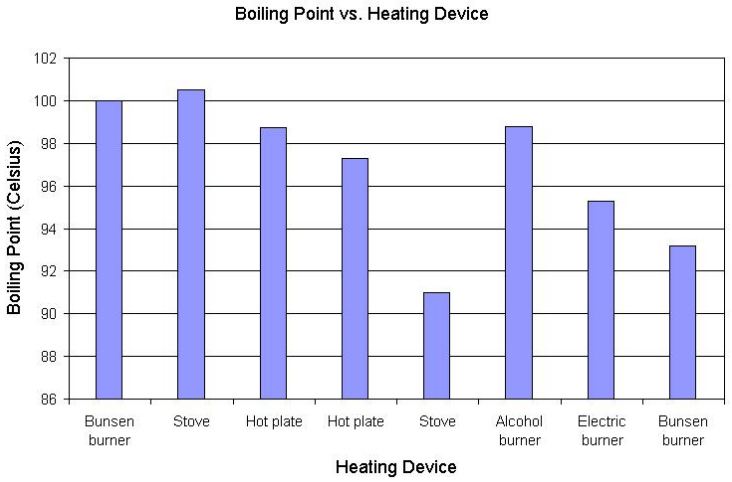
- Location
- Heating device used
- Volume of water used
- Elevation where experiment is performed
- Average boiling point of the water

As the results come in from around the USA you record all the results in a notebook. This is what you have so far:

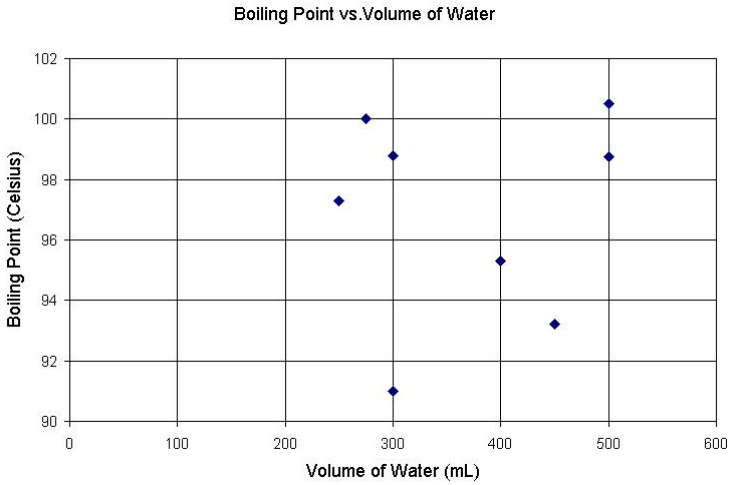
Location	Heating Device	Volume of Water (mL)	Elevation (m)	Avg. Boiling Point (C)
Hoboken, New Jersey	Bunsen burner	275	30.5	100
Hebron, Kentucky	Stove	500	267	100.5
Etna, Maine	Hot plate	500	85.34	98.75
Bucklin, Kansas	Hot plate	250	733	97.3
Aspen, Colorado	Stove	300	3413.76	91
Phoenix, Arizona	Alcohol burner	300	345.9	98.8
Anza, California	Electric burner	400	1219.2	95.3
Laramie, Wyoming	Bunsen burner	450	2209.8	93.2

After staring at the data for a while, you still can't figure out which factor in the experiment (heating device, volume of water, or elevation) has the greatest influence on the boiling point of water. You decide to make some graphs of the data which are shown on the next page.

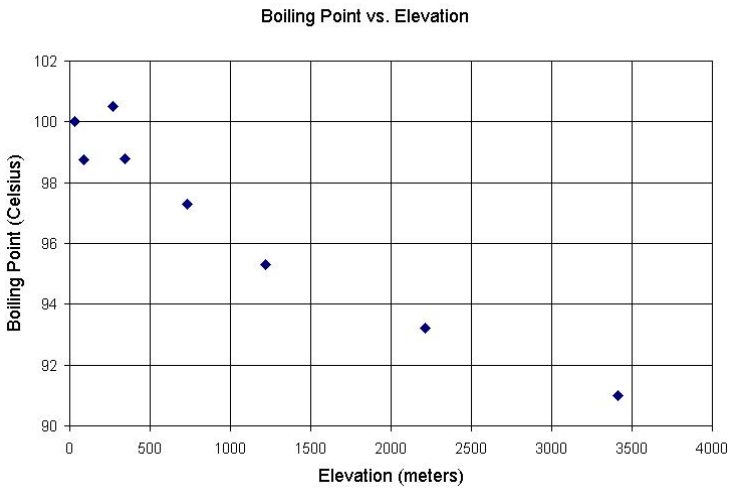
Graph A



Graph B



Graph C



Questions

1. Examine each of the graphs on the previous page.

a) Which graph shows the strongest relationship to the boiling point of water?

b) Explain how a trend line or line of best fit could be used to determine how strong a relationship is.

c) For the graph you selected in part (a), describe the trend you see.

d) Using data from the graph you selected in part (a), give an example that clearly describes the trend shown in the graph.

2. One of the students participating in the experiment says that the boiling point of water depends on air pressure. Do you agree with her? Explain why or why not.

3. You have an electronic e-pal who lives in South Africa. You decide to ask him to do the experiment and fax you his results. Unfortunately, when his fax printed out some of the ink smeared and you can't see all of the results. This is what you have:

Location	Heating Device	Volume of Water (mL)	Elevation (m)	Avg. Boil Point
Johannesburg, South Africa	Bunsen burner	475	1750	

Using one of the graphs on the previous page, predict what the boiling point of water should be for your friend in South Africa. Explain how you arrived at this answer.

Post-project Assessment
Answer Key and Grading Rubric

TOTAL POSSIBLE POINTS: 10

1. Examine each of the graphs on the previous page.

a) Which graph shows the strongest relationship to the boiling point of water?

Part (a) Answer: Graph C, Boiling Point vs. Elevation shows the strongest relationship to boiling point.	
Points	**Acceptable Response**
1	Correctly states that graph C shows the strongest relationship to boiling point.
Points	**Unacceptable Responses**
0	States that either graph A or B shows the strongest relationship to boiling point. Any other response.

b) Explain how a trend line or line of best fit could be used to determine how strong a relationship is.

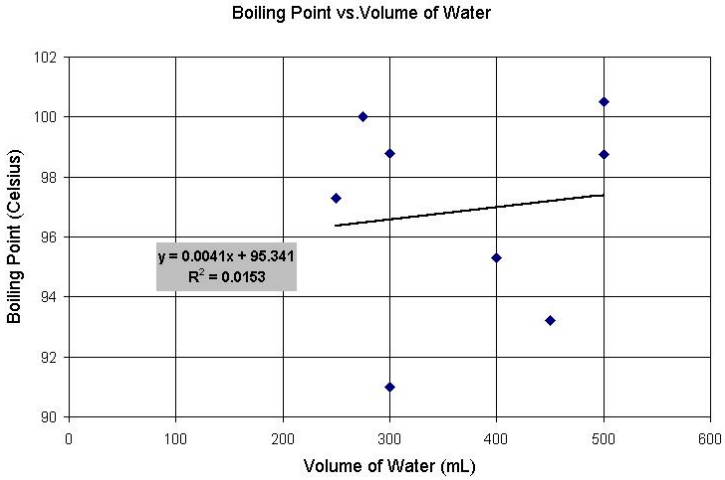
Part (b) Answer: When drawing a line of best fit or trend line, the closer the data points are to the line, the stronger the relationship is. If all the data points lie in a relatively straight line there would be a strong relationship between the two variables. If the data points were scattered there would not be a strong relationship between the two variables.	
Points	**Acceptable Responses**
2	Correctly explains that a strong relationship will be indicated by a straight line in which most of the data points lie on or close to the line.
Points	**Partial Credit Responses**
1	Can explain how to draw a trend line but does not understand how it is used to establish how strong a relationship is.
Points	**Unacceptable Responses**
0	Provides an incorrect explanation.

Additional Notes to Teacher:

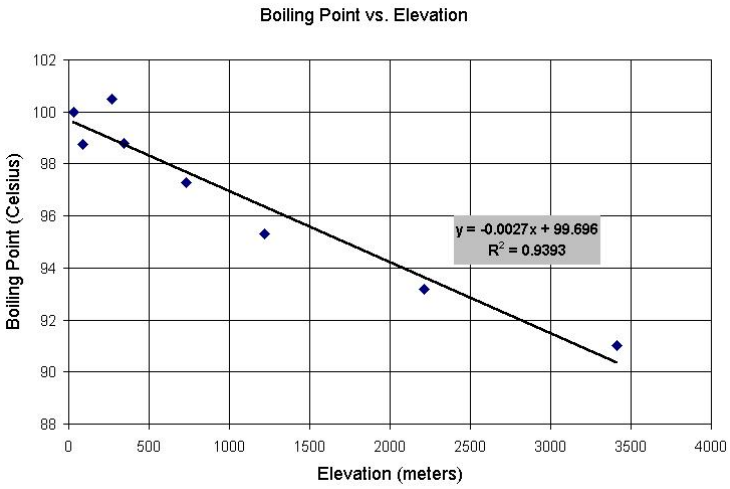
It is not possible to draw a line of best fit or trend line on Graph A. However, one can clearly see that similar devices used to heat water result in very different boiling points. For example, one of the stoves produced a boiling point of 100.5° C and the other stove produced a boiling point of 91°C. In order to

demonstrate a strong relationship between boiling point and heating device, similar devices should produce similar boiling points.

If one were to attempt to draw a line of best fit or trend line through the data in Graph B, it would be a relatively flat, horizontal line through the middle of the data similar to the graph below. Many of the points would be way above or way below the line. The further all the points are away from the line, the weaker the relationship is. Examining the data shows that similar volumes of water produce very different boiling points. For example, the volume of 300 mL shows corresponding boiling points of 91°C and 98.8°C. Some may also note that the correlation coefficient for the trend line for this data would be very low.



A line of best fit drawn through the data in Graph C would be similar to the graph below. All of the data points are close to or on the line. One can see a clear trend in the data; as elevation increases, the boiling point decreases. Some may note that the correlation coefficient for the trend line for this data would be very high.



c) For the graph you selected in part (a), describe the trend you see.

Part (c) Answer: Looking at the Boiling Point vs. Elevation graph, one can see that as elevation increases, the boiling point decreases (or vice-versa).

Note: There are no clear trends for the other graphs.

Points	**Acceptable Responses**
1	States that as elevation increases, boiling point decreases (or that boiling point increases as elevation decreases).
Points	**Unacceptable Responses**
0	Any other response.

d) Using data from the graph you selected in part (a), give an example that clearly describes the trend shown in the graph:

Part (d) Answer: Looking at the Boiling Point vs. Elevation graph and the data recorded in the notebook, one can see that as the elevation increases from 733 m to 1219.2 m, the boiling point decreases from 97.3°C to 95.3°C.

Note: There are no clear examples for the other graphs.

Points	**Acceptable Responses**
1	Refers to a specific example that correctly illustrates the trend. OK if student provides estimated numbers from graph instead of exact numbers from notebook as long as trend is correct.
Points	**Unacceptable Responses**
0	Gives an example that does not correctly illustrate the trend in data or provides no example.

2. One of the students participating in the experiment says that the boiling point of water depends on air pressure. Do you agree with her? Explain why or why not.

Answer: Yes, the boiling point of water does depend on atmospheric pressure. Atmospheric pressure usually varies with elevation. The higher the elevation, the lower the atmospheric pressure (and vice-versa). One would expect to see a lower boiling point at higher elevations where the atmospheric pressure is lower.

Optional (higher level response): The less atmospheric pressure that bears down on the surface of the liquid, the easier it is for water molecules to escape into the air. Thus, the water comes to its full rapid boil at a lower temperature in the mile-high city of Denver than it can at sea level in Miami.

Points	**Acceptable Responses**
2	Correctly states that the boiling point depends on atmospheric pressure. Understands that atmospheric pressure is related to elevation or altitude.
Points	**Partial Credit Responses**
1	Correctly states that boiling point depends on atmospheric pressure but does not provide any further explanation or provides an incorrect explanation.
Points	**Unacceptable Responses**
0	Does not understand that atmospheric pressure is related to elevation.

3. You have an electronic e-pal who lives in South Africa. You decide to ask him to do the experiment and fax you his results. Unfortunately, when his fax printed out some of the ink smeared and you can't see all of the results. Using one of the graphs on the previous page, predict what the boiling point of water should be for your friend in South Africa. Explain how you arrived at this answer.

Answer: Graph C should be used because boiling point is most dependent on elevation. At 1750 meters, the boiling point should be approximately 95° C. If students sketch in a trend line, they should look for 1750 m on the x-axis (halfway between 1500m and 2000m), then follow this point up until they hit the trend line. From this point, they would move horizontally to the left until they see where this falls on the y-axis. If students do not draw in a trend line, they can still estimate the boiling point. Any estimate between 94°C and 95°C would be acceptable.

Points	**Acceptable Responses**
3	Uses the elevation graph to find the boiling point of water. Estimates the boiling point to be somewhere between 94°C and 95°C. Explains how the boiling point was determined.
Points	**Partial Credit Responses**
2	Uses the elevation graph to find the boiling point of water and obtains an acceptable answer but does not explain how the answer was obtained. Or uses the correct graph and gives a satisfactory explanation but gives an unacceptable boiling point.
1	Uses the correct graph but does not obtain an acceptable answer nor explain how the answer was obtained.
Points	**Unacceptable Responses**
0	Does not use the correct graph or give an acceptable answer. Provides no explanation for how answer was obtained.