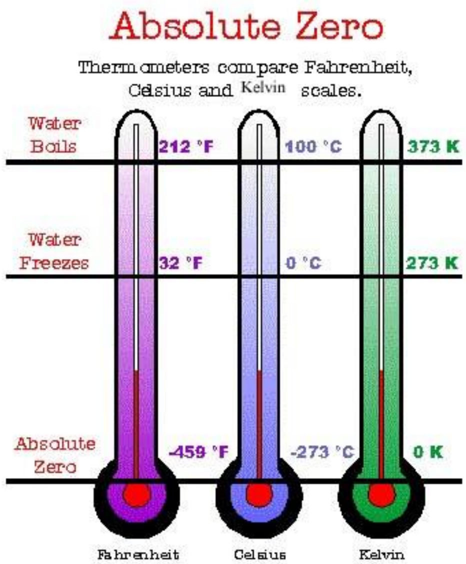
I. Objectives

1. Use an absolute zero device to calculate absolute zero.
2. Calculate the equation of a line using least squares.

II. Introduction

This lab utilizes glassware and hot water, so be sure to wear appropriate safety gear.



Temperature gives us an idea of how hot or cold an object is. The temperature of an object depends on how fast the atoms and molecules which make up the object oscillate.

As an object is cooled, the oscillations of its atoms and molecules slow down. For example, as water cools, the slowing oscillations of the molecules allow the water to freeze into ice.

In all materials, a point is eventually reached at which all oscillations are the slowest they can possibly be. The temperature which corresponds to this point is called absolute zero. Oscillations never come to a complete stop, even at absolute zero (http://www.pa.msu.edu/~sciencet/ask_st/012992.html).

III. Calculations

The ideal gas law is:

$$PV = nRT$$

which can also be written as:

$$\frac{P}{T} = \frac{nR}{V}$$

When the volume V of a gas sample is kept constant, the relationship between pressure and temperature of the sample is:

$\frac{P}{T}$ = a constant, where P is in PSI (although it may be in other units) and T is in kelvins.

This relation can be represented by a straight line graph passing through absolute zero. This law only holds for the gaseous state and real gases liquify before absolute zero is reached. If the slope of the line is accurately established at higher temperatures, its slope may be extended with a ruler to intercept at absolute zero.

This equation is the equation of a line in the form of $y = mx + b$, where

x = pressure P in PSI

y = temperature T in kelvins

m = slope

b = y-intercept, our calculated temperature for absolute zero.

We will use a process called least squares to determine m. The derivations for the equations are somewhat complicated, so we'll just use the results.

The slope m is:

$$m = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\Sigma(x_i - \bar{x})^2}$$

and the y–intercept b is:

$$b = \bar{y} - m\bar{x}$$

The equation of the line is:

$$\bar{y} = m\bar{x} + b$$

or simply

$$y = mx + b$$

IV. Equipment and Materials

Absolute zero apparatus, three 2,000 mL beakers per group, one hot plate per group, ice, three thermometers per group, calculator

V. Procedure

1. Prepare three temperature baths: hot water at approximately 80^0C, room temperature water, and ice water at 0^0C. Be sure to put enough water in the beakers so that the absolute zero apparatus will be totally covered when submerged in each beaker.

2. Follow the directions in the order given.

3. Totally immerse the bulb into the hot water for at least 5 minutes, holding it by the white handle, and record the ending equilibrium temperature in ^{0}C and pressure in PSI in Table 1 below.

4. Remove the absolute zero apparatus from the hot water and let it sit on the lab bench for at least 5 minutes.

5. Totally immerse the bulb into the room temperature water for at least 5 minutes, holding it by the white handle, and record the ending equilibrium temperature in ^{0}C and pressure in PSI in Table 1 below.

6. Remove the absolute zero apparatus from the room temperature water and let it sit on the lab bench for at least 5 minutes.

7. Totally immerse the bulb into the ice water for at least 5 minutes, holding it by the white handle, and record the ending equilibrium temperature in ^{0}C and pressure in PSI in Table 1 below.

8. Complete Table 1, including calculating and recording the average PSI pressure $\bar{x}$, and the average kelvin temperature y_i .

9. Graph temperature T in kelvins versus pressure P in PSI, using P for the x-coordinate and T for the y-coordinate. You must include the linear best fit line generated by the spreadsheet program, not a hand drawn line, to connect the points on the graph. Staple the graph to the lab.

10. Complete Table 2.

VI. Data

Table 1 Pressure and Temperature

A	B	C	D	E	F	G	H
Solution	Pressure P in PSI, x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	Temper-ature in ^{0}C	Temper-ature T in kelvins, y_i	$y_i - \bar{y}$	$(x_i - \bar{x})(y_i - \bar{y})$
hot water							
room temperature water							
ice water							
	$\bar{x} =$				$\bar{y} =$		

Table 2 Least Squares Data and Calculations

A	B	C	D	E
$\sum(x_i - \bar{x})(y_i - \bar{y})$	$\sum(x_i - \bar{x})^2$	$m = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\Sigma(x_i - \bar{x})^2}$	$b = \bar{y} - m\bar{x}$	Equation of line $y = mx + b$

VII. Discussion Questions

1. What is the theoretical pressure at absolute zero?

2. What is the equation for the least squares fit line you determined in this lab?

3. Using that equation, by how many kelvins was the temperature you calculated different from absolute zero? What factors, other than mathematical errors, could account for this difference?

4. Your results may have provided a negative kelvin temperature, however, we know that a negative kelvin temperature isn't possible. Why not?