Physics 4C Lab 6: *Absolute Zero*

The objective of this lab exercise is to calculate a value of absolute zero using a method similar to that used by Lord Kelvin in the 19th century.

If we vary the temperature of an ideal gas in a sealed container, we can expect that the pressure and the volume of the gas will change in response, according to the *ideal gas law*. However, if we use a *rigid* container so the volume is not allowed to change, ***then only the pressure will vary with the temperature.***

Kelvin used this principle to support his belief that there is some "absolute" lowest possible temperature. He postulated that the temperature that reduced the *absolute pressure* of gas to zero would be as low as a temperature could be. A temperature below this "absolute zero" would be impossible, because a pressure lower than zero is not physically possible.

For a sealed, rigid container, i.e. constant number of moles and constant volume, we can start with the ideal gas law and combine the constants to create a simple expression for the temperature and corresponding pressure:

$$pV = nRT$$

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

$$p = B\,T$$

Note that I've used "B" as a new constant that is a combination of the constants n, R and V. The result is a simple expression that shows pressure and temperature are directly related. We know that the ideal gas law requires temperatures to be measured in Kelvins… *but Kelvin did not have the Kelvin scale available to him in his time! He measured in Celsius.*

We will also measure in Celsius… but how do we reconcile the need for Kelvin temperatures in the ideal gas law with our use of Celsius temperatures? We can replace T_K in the ideal gas law with $T_C + T_A$ where we know T_A should be 273 (that is, temperature in Kelvin is temperature in Celsius plus 273.)

If we make this replacement in our equation, the result is:

$$p = B\,T_K$$

$$p = B\,(T_C + T_A)$$

$$p = B\,T_C + B\,T_A$$

Note that this is still the same equation, from the ideal gas law, but algebraically modified to allow us to use Celsius temperature measurements. If we measure the pressure of the gas for a range of corresponding temperatures, we can graph ***pressure vs temperature*** and find the best-fit line. The equation above tells us that the slope will be **B** and the y-intercept will be **B** $\mathbf{T_A}$. This also means that the ***x-intercept*** of the best fit line should be:

$$x - intercept = -\frac{y{-}intercept}{slope} = -\frac{B\,T_A}{B} = -T_A$$

The x-intercept is the value of temperature at which the pressure (on the y-axis) becomes zero. In other words, by definition the x-intercept represents Kelvin's "absolute zero".

Procedure

- Clamp the pressure gauge apparatus to the vertical rod and ensure that it is secure.

- Set up the temperature probe with the Pasco black box; choose the "Digits" display and "Start". Verify that the probe is measuring temperature properly.

- Place the metal ball of the apparatus in the glass beaker, with the glass beaker on the hot plate. ***Ensure that the metal ball is not touching the sides or bottom of the beaker.***

- Pour water into the beaker so that the metal ball is completely submerged. ***Use the minimum amount of water necessary to submerge the ball.***

- Place the temperature probe in the water and verify that the temperature probe is working.

- Turn on the hot plate to slowly heat the water. As the temperature rises, measure the pressure at regular intervals – determined by the markings of the pressure gauge – and the corresponding temperature.

- Create a data table for your temperature and pressure data and a graph of pressure vs temperature. Use the y-intercept and slope of the best-fit line to calculate the x-intercept, i.e. your value of *absolute zero*. **See the examples below.**

Finding Absolute Zero

T (^oC)	p (kPa)
83.5	120.0
77.0	117.5
70.4	115.0
57.0	112.5
51.5	110.0
45.3	107.5
38.1	105.0
29.8	102.5
22.5	100.0
0.7	93.0

Calculations

Calculate the value of the x-intercept

$$\textit{x-intercept} = \frac{-\text{ y-int}}{\text{slope}} = \frac{-\ 92.9\ \text{kPa}}{0.324\ \text{kPa}\ /\ ^oC} = -287\ ^oC$$