Instruction Manual

Manual No. 012-08504A

Absolute Zero Apparatus

Model No. TD-8595

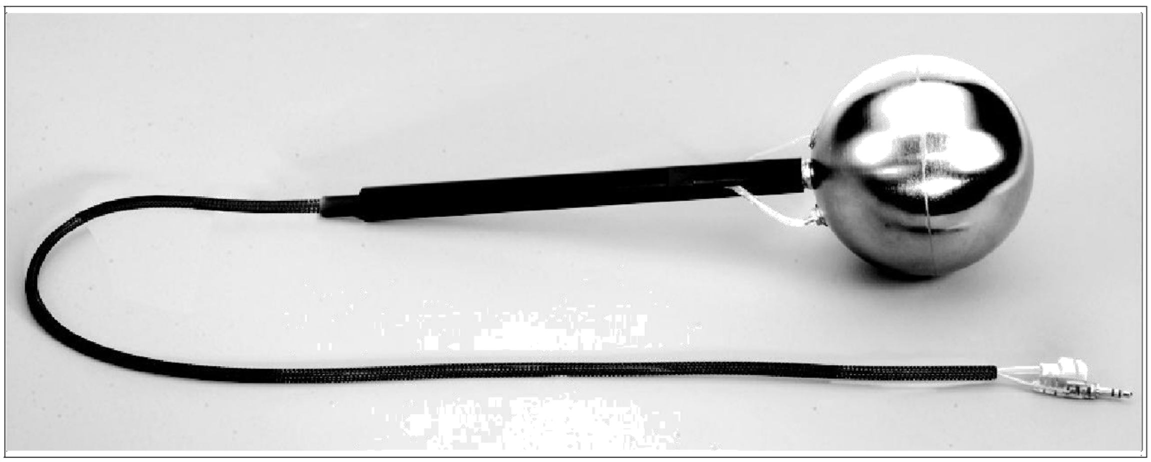

Table of Contents

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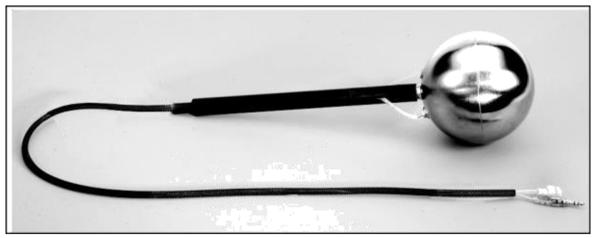
Equipment List



Included Equipment	Replacement Model Number*
1. Absolute Zero Apparatus	TD-8595

*Use Replacement Model Numbers to expedite replacement orders.

Additional Equipment Required	Replacement Model Number*
A PASCO computer interface*	Various (See PASCO catalog.)
Capstone software	Various (See PASCO catalog.)
Steam Generator or Hot Plate (or other means of heating water)	TD-8556 or SE-8767
Absolute Pressure Sensor or combination Pressure/Temperature Sensor	PS-2107 or CI-6532A or PS-2146
Temperature Sensor or Thermistor Sensor*	PS-2125 or CI-6527A
Ice (approximately 2 cups)	N/A
A computer	N/A

*A Fast Response Sensor is molded into the Absolute Zero Apparatus and works with any PASPORT interface. If you have a *ScienceWorkshop* interface, you will need a Thermistor Sensor (instead of a PS-2125 Temp. Sensor) to use the Absolute Zero Apparatus.

Introduction

The Absolute Zero Apparatus consists of a Fast Response Temperature Sensor and plastic tubing (with pressure connector) mounted into a hollow copper sphere. When the sphere is submerged in a water bath and connected to a temperature sensor, pressure sensor, and a computer interface, Capstone records and displays the temperature and pressure.

The Fast Response Temperature Sensor plugs into any PASPORT Temperature Sensor box or a *ScienceWorkshop* Thermistor Sensor, allowing the Absolute Zero Apparatus to be used with both PASCO's PASPORT and *ScienceWorkshop* interfaces.

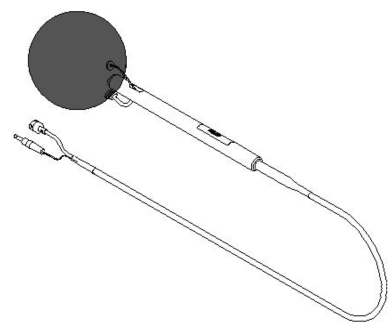


Figure 1: Absolute Zero Apparatus

The Absolute Zero Apparatus is used to experimentally determine the temperature of absolute zero (in degrees Celsius). Absolute zero, by definition, is the point at which a gas exerts zero pressure. With a computer, the Absolute Zero Apparatus can help students to observe the relationship between temperature and pressure and use DataStudio to mathematically extrapolate to find absolute zero.

Theory:

For an ideal gas, the absolute pressure is directly proportional to the absolute temperature of the gas.

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

Thus a plot of temperature vs. pressure will result in a straight line.

$$y = (slope)x + b$$

The slope of the line depends on the amount of gas in the thermometer, but regardless of the amount of gas, the intercept of the line with the temperature axis should be at absolute zero. If we instead plot the temperature in degrees Celsius, the intercept will not be zero, but rather the temperature of absolute zero in degrees Celsius.

Equipment Setup (for use with Capstone)

1. Plug the Fast Response Temperature stereo plug into a PASPORT Temperature Sensor box or into a *ScienceWorkshop* Thermistor Sensor.
2. PASPORT users: Plug the Temperature Sensor box into a PASPORT interface.

   Or

   Science Workshop users: Plug the Thermistor Sensor into a *ScienceWorkshop* interface.
3. Connect the Pressure port connector to a Pressure Sensor. Plug the Pressure Sensor into the computer interface.
4. Set up your experiment in Capstone. In Capstone, open a Graph display and plot temperature vs. pressure. Use manual sampling, with no keyboard input.
5. Submerge the sphere into a bucket of ice water.
6. In Capstone, click Preview to begin collecting data. (For suggested experiments, see pages 6 to 9 of this manual.)

Suggested Experiments

Experiment I: Determining Absolute Zero while Keeping the Number of Gas Moles (n) Constant.

Equipment required:	
Absolute Zero Sphere (TD-8595)	One bucket of hot water, one bucket of cold water, ice
Absolute Pressure Sensor (PS-2107) or (CI-6532A)	Capstone software
Temperature Sensor (PS-2125) or Thermistor Sensor (CI-6527A)	Steam Generator (TD-8556) or Hot Plate (SE-8767)

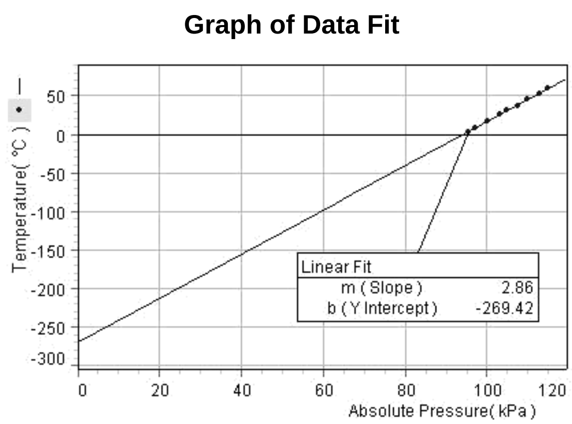
Procedure:

1. Start with the water as hot as possible.
2. Connect the hose fitting from the Absolute Zero Apparatus to the Pressure Sensor. Connect the stereo plug from the apparatus to the Temperature Sensor.
3. Open the Capstone file called "Absolute Zero.cap". Click Preview.
4. Place the sphere of the apparatus in the water bath, and keep the sphere completely submerged.
5. Watch the Digits display of temperature. When the display stops changing (in the hundredths place), click the Keep Sample button. Do **not** stop recording.

Figure 1-1: Experiment Set up

6. Cool the water bath by adding cold water or some ice cubes. When the container becomes too full, dump out some of the water, but always have enough water to keep the apparatus completely submerged. Cool the bath by about 10^{o}C, and repeat step (4).
7. Repeat steps 4 through 6, for temperatures down as low as you can go, and then click Stop to end recording.
8. In the Graph display, click on the **Fit** button and select a linear curve fit. The y-intercept is your value for absolute zero.

Sample Data (Experiment 1)



Experiment II: Varying the Number of Moles of Gas (n)

Equipment required:	
Absolute Zero Sphere (TD-8595)	One bucket of hot water, one bucket of cold water, ice, one bucket at room temperature
Absolute Pressure Sensor (PS-2107) or (CI-6532A)	Capstone software
Temperature Sensor (PS-2125) or Thermistor Sensor (CI-6527A)	Steam Generator (TD-8556) or Hot Plate (SE-8767)

Experiment Procedure:

1. Prepare three different temperature water baths: A hot-water bath, room temperature bath, and a cold-water bath. Keep the hot-water bath as hot as possible, using a steam generator or hot plate, if available. Use ice for the cold water bath, if available. The room temperature bath needs to be somewhere in the temperature range between the other two baths.
2. Connect the stereo plug from the Absolute Zero Apparatus to the Thermistor Sensor, but leave the hose fitting disconnected.
3. Open the Capstone file.

Figure 2-1: Experiment Setup

4. Place the sphere of the apparatus in the ice-water bath, and connect the hose fitting to the Pressure Sensor. Keep the sphere completely submerged, click the Preview button, and watch the Digits display of temperature.

5. When the temperature stops changing (in the hundredths place), click on the Keep Sample button. Do **not** stop recording.

6. Place the sphere in the room temperature bath and repeat step 5.

7. Place the sphere in the hot-water bath and repeat step 5.

8. Click on the **Stop** button to end recording. Save this data to disk.

9. In the graph display, click on the **Fit** button and select a linear curve fit. The y-intercept is your value for absolute zero.

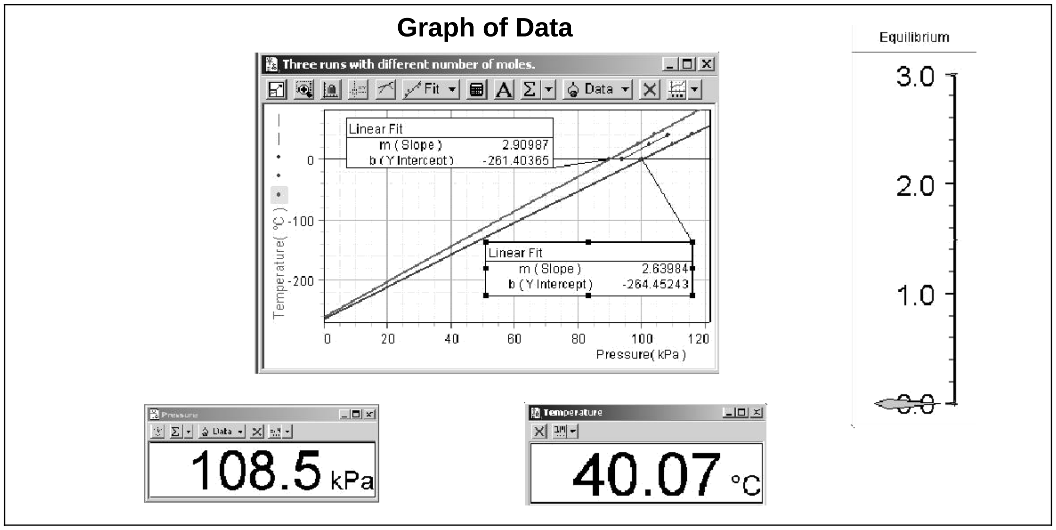
10. Repeat the above procedure using a *different amount of gas (n)* in the sphere. This time, start with the room temperature bath. Disconnect the hose fitting from the Pressure Sensor. Place the sphere in the bath and re-connect the fitting. Take readings for all three baths as before. Plot this data on the same graph, click on the Fit menu button, and choose a linear curve fit. You will now have two lines with different slopes, but about the same intercept.

11. Repeat the above procedure again, starting this time with the hot-water bath. Take the readings in the other two baths, and plot this data on the same graph.

12. Average your three values, estimate the uncertainty, and round your answer to the appropriate number of significant figures. Compare the average of your three values for absolute zero with the accepted value of -273°C.

13. Measure the volume of the sphere. Using the slope of each of the lines, determine the number of moles of gas in the container for each of the three runs.

Sample Data (Exp.2) - Three Runs with Different Molar Amounts



Appendix A: Specifications

Component	Description
Sphere:	Material: copper with hollow center Radius: 2 inches Volume: 32.66 inches Surface area: 50.24 inches
Temperature Probe (Fast Response):	Thermistor is 10,000 Kohms at 25°C, Range: -35 to 135°C, -31 to 279°F, 238 to 408 K Resolution: ±0.01°C Accuracy: ±0.5°C
Tubing:	Polyurethane, 3 feet in length
Stereo plug:	3.5 mm male plug