Estimation of absolute zero

Apparatus

+/- 25 kPa differential pressure sensor

Temperature sensor - metal housing.

Large round flask 500 ml.

Length of clear plastic tubing approx 3 mm inside diameter.

Delivery tubing or hard plastic tubing.

3 way Luer fit tap

2 Hole bung (holes to seal round temperature and delivery tubing)

Retort stand and clamp

Large beaker

Ice, heater, water

Data recording setup.

Single graph pane layout

Recording setup

10 second intersample time

Continuous data collection.

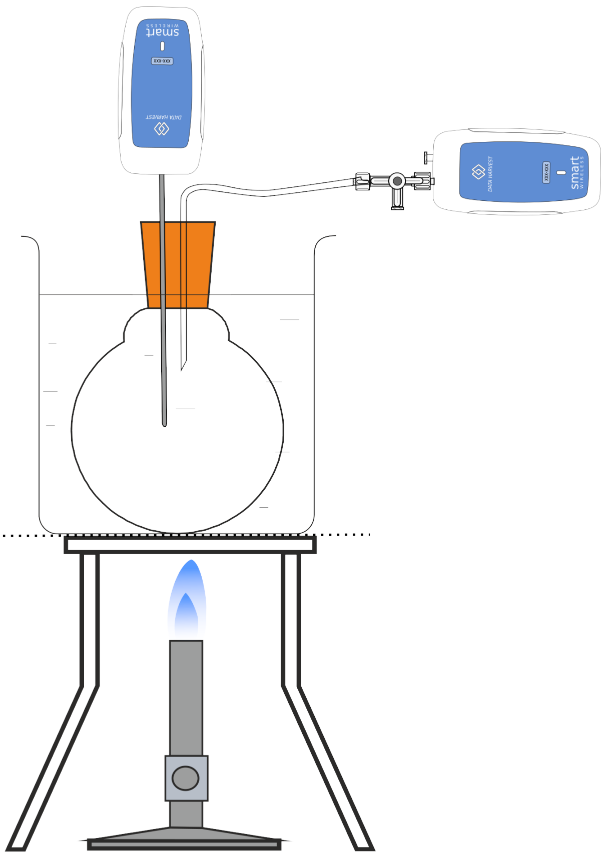
When start selected. When stop selected

Introduction.

For an ideal gas, pressure is created by the kinetic interactions of the gas particles. If we reduce the energy to the particles the kinetic interactions will diminish. We know that P/T creates a constant and a plot of pressure (absolute) against temperature (absolute) shows the direct proportionality between the two variables. Extension of a plot of absolute pressure against absolute temperature down to P = 0 should give us the point where temperature cannot be decreased - Absolute Zero.

The diagram of the apparatus is a typical setup, you may find that the apparatus you are given varies, for example the round bottomed flask may be a conical flask, the temperature sensor is in the water next to the flask not inside.

Pressure is Absolute pressure P, you may have an apparatus that collects pressure p. With the latter you will have to correct. Make sure you know what the pressure in the room is before collecting data.



Method

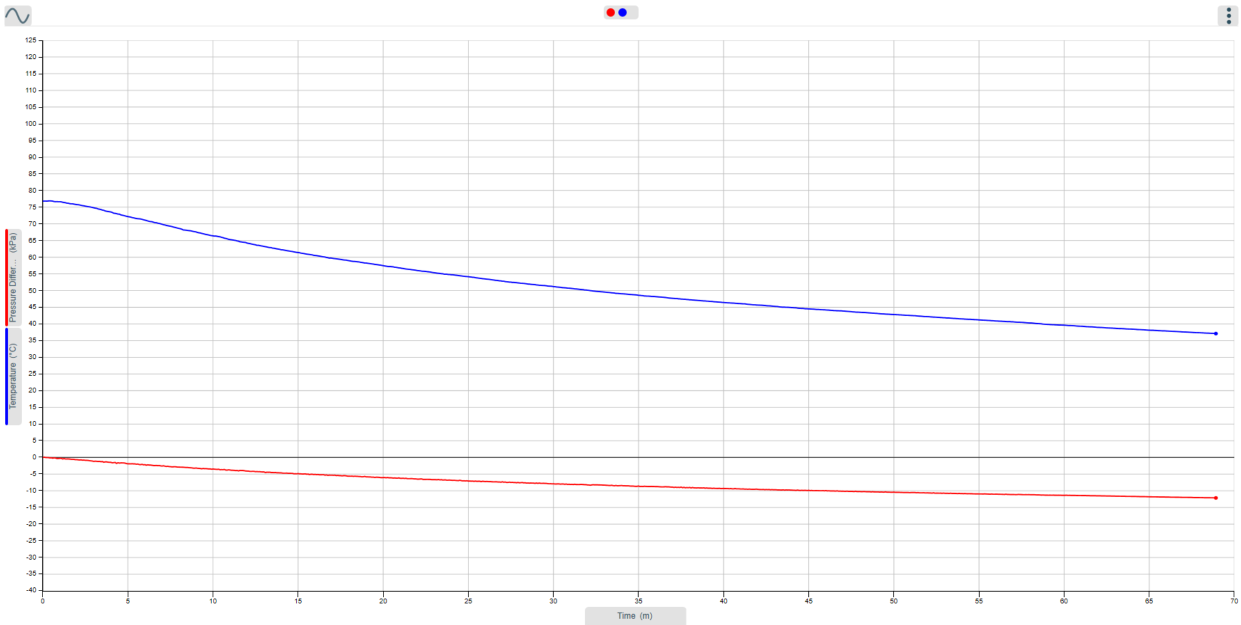
Your teacher will modify the instruction to match your specific apparatus. The best results come from a cooling water bath and you may have the apparatus preheated.

The key to success is that the apparatus airtight. Once data recording has started keep an eye on the data to spot any rapid changes of pressure that is not connected to a slower change in temperature. If you are cooling the water it needs to be at 90 Celsius before starting, if you are heating up the water is should start as low as possible 2-3 Celsius

1. With the apparatus set up, link the sensors to the software. Make sure the 3 way valve is open to equalise pressure both inside and outside the apparatus.

2. Use the details in the data recording setup to give a 10 second period between data collection.
3. Watch the live data to determine by how much and in which direction the temperature data is changing. Once the temperature data is stable, either static or falling very slowly close the tap to seal the apparatus. Immediately click on start.
4. Leave recording for at least 30 minutes or a temperature fall of 30 degrees.
5. Click stop and save the data.
6. Analyse and modify the data to correct for Absolute pressure.

Example of data at end of collection

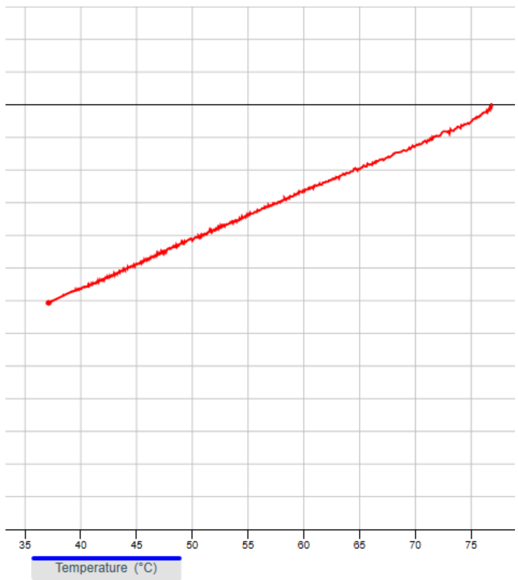


Analysis

The first step in the analysis is to check for the quality of the data, we are looking for a good straight line correlation between temperature and pressure.

- Click on the x axis label to read Temperature.
- Click on the y axis label to read pressure.
- Click on both axis labels and convert to min - max scale.

The example shows some good data, note how the graph gives a very straight line relationship.



Correcting pressure to absolute pressure P.

Find the pressure in the room in the same units as the sensor kPa. This will be something like 101.3 kPa. This value will be a major cause of error if not correctly recorded.

Use Calculation to apply the function ax + b,

Name = abs.pressure,

decimals = at least 3,

series unit kPa,

formula ax + b,

value for a =1,

value for b = “room pressure”,

series for x = Differential pressure.

Change the axis to y = abs.pressure and x = temperature.

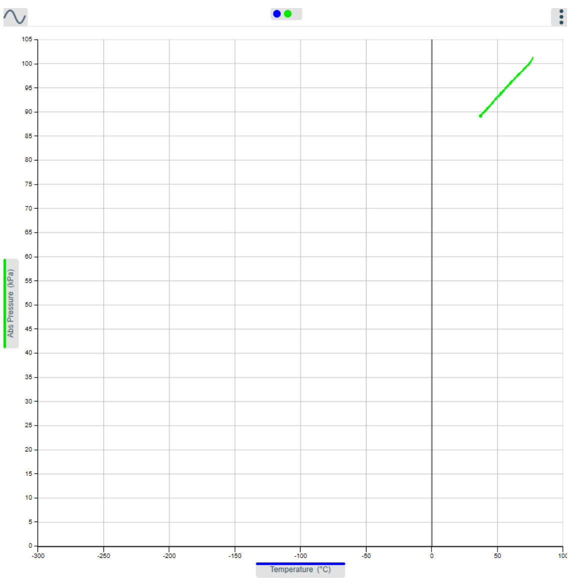
Change the scale to:

Temperature, user range = (your max temp) Max, -300 Min.

Pressure, Zero to Max.

Once completed you should have a graph similar to the example

You can now print the graph out in landscape and use a ruler to draw a best fit line back to pressure = 0. Remember to use a ruler scale or similar to provide the minor ticks on the axis.



Questions.

1. Find the gradient of your data line.

2. Find the y intercept.

3. Use y = mx + c (m = gradient, c = y axis intercept) to find x, absolute zero. Re arrange to make x the subject, plug in your values and solve.

4. How does the calculated value match to the graphically found value?

5. A group of students did a practical very similar to one you have just done, they were able to use data collected with solid carbon dioxide around the vessel. In the time available for the practical they collected the following data.

Temperature Celsius	Temperature Kelvin	Pressure kPa
100		88.0
50		77.5
0		67.1
-50		56.7

Complete the table and calculate the value for absolute zero the group estimated.

6. What is the significance of p and P for pressure and t and T for temperature?

7. Why do we use Kelvin and not Celsius?

8. Why would you not get to zero volume in non ideal gas?

9. What gas in the air sample used in the apparatus would lead to an error in the estimation?

Calculating absolute zero worked example and help

The value of absolute zero can be calculated using the gradient and the intercept of the y axis.

You will need to calculate the gradient, use a good linear section of data with a large separation between pairs of x,y co-ordinates.

Our linear equation is y = mx + c

y is the volume

m is slope / gradient

x is temperature

c is the y axis intercept

Some students have collected data and made a graphical extension to find a value of Absolute zero of -270, they now want to verify the data by calculation. They will do this by algebriacally manipulating the linear equation to solve for when Volume (y in the equation) is equal to 0 (zero).

The gradient for their data gives a value of 0.292 kPa per degree.

By zooming in the data and using a straight edge they have extended the data to find the Y axis with a good degree of certainty. This is 77.4 kPa (illustrated in diagram below).

The first step is to make y = zero to give 0 = mx + c

Now plug in the numbers we have - 0 = (0.292 x T) + 77.4

Subtract C from both sides to give (0 - 77.4) = (0.292 x T) +(77.4 - 77.4)

To give -77.4 = (0.292 x T)

Divide by 0.292 to make T the subject

-77.4/0.292 =T

-265

The zero volume of the gas is at -265 Celsius.

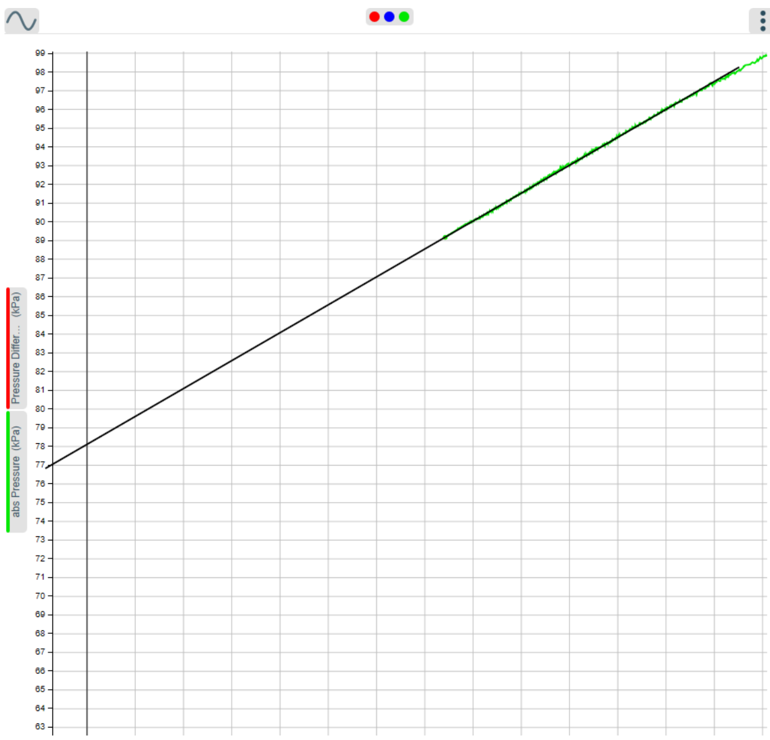
Graphical Value of abs zero = -270

Calculated value of abs zero = -265

2% between the values.

Within 1% for graphical and 3% by calculation.

Which would you use? And why?



Time (h:m:s)	Pressure Differential (kPa)	Temperature (°C)	abs Pressure (kPa)
00:00:00	-1.03	75.01	100.270
00:00:05	-1.09	74.92	100.210
00:00:10	-1.18	74.80	100.120
00:00:15	-1.12	74.70	100.180
00:00:20	-1.16	74.65	100.140
00:00:25	-1.21	74.47	100.090
00:00:30	-1.18	74.39	100.120
00:00:35	-1.29	74.28	100.010
00:00:40	-1.24	74.12	100.060
00:00:45	-1.44	74.05	99.860
00:00:50	-1.35	73.87	99.950
00:00:55	-1.34	73.77	99.960
00:01:00	-1.43	73.70	99.870
00:01:05	-1.46	73.63	99.840
00:01:10	-1.47	73.56	99.830
00:01:15	-1.61	73.41	99.690
00:01:20	-1.55	73.19	99.750
00:01:25	-1.50	73.15	99.800
00:01:30	-1.78	73.05	99.520
00:01:35	-1.57	72.93	99.730
00:01:40	-1.69	72.92	99.610
00:01:45	-1.63	72.69	99.670
00:01:50	-1.63	72.59	99.670
00:01:55	-1.64	72.50	99.660
00:02:00	-1.70	72.38	99.600
00:02:05	-1.84	72.27	99.460
00:02:10	-1.92	72.17	99.380
00:02:15	-1.90	72.09	99.400
00:02:20	-1.93	72.01	99.370