PRACTICAL EXERCISE INSTRUCTIONS|**FINDING ABSOLUTE ZERO**

Introduction

You should be able to perform this exercise in your kitchen using the equipment usually found there plus a small list of items you might need to buy - see the list of apparatus below. This exercise should take about an hour but I recommend that you set up the manometer and leave it in your refrigerator overnight.

A manometer is an instrument used to measure pressure relative to atmospheric pressure. It consists of transparent fluid-filled U-tube with one end open to the atmosphere and the other end is connected, usually by a rubber tube, to the vessel or pipe in which the pressure is to be measured. The difference between the measured and atmospheric pressures causes a difference in the water levels in the two branches of the U-tube. The height difference between the water levels is called the gauge pressure and is often given units of mm H_2O. It can be converted into the more usual SI unit of N/m^2 (or Pa) by multiplying by the density of water and the gravitation constant, g in appropriate units.

For simplicity in this experiment, nothing will be connected to the manometer. Instead, one end of the U-tube be blocked to trap a constant mass of air. The temperature of the entire system will be reduced causing a change in the volume and pressure of the trapped air. The pressure change will be measured using the manometer in the usual way. This practical requires some skill and probably you will need several attempts before you can complete it successfully.

Objective

To demonstrate by experiment the behaviour of an ideal gas when subject to a temperature change and to estimate the value of absolute zero (in degrees Centigrade). On successful completion of this practical exercise, you should have extended your ability to record and present data from an experiment, analyse the data and draw appropriate conclusions.

Apparatus

A beaker of water (or malt vinegar[1]), a digital kitchen probe thermometer[4], a U-tube manometer[2], a refrigerator, a 1mL plastic syringe[3] and a small piece of putty[4].

Procedure

1. Fill the manometer to about one third full. When used to measure gauge pressure, the manometer would be filled to the zero value on its scale, so that pressures above and below atmospheric can be measured. However, this experiment is easier with a large volume of empty tube in which to trap air; hence fill the manometer to about the lower 60 mark on the scale and record the value on the scale, H_{start}.

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[1] Water is free but clear and maybe difficult to see. Malt vinegar is cheap (£0.25 for 250ml) and red so easier to see but smelly.

[2] I used this plumber's manometer for £6.37 at http://www.my-tool-shed.co.uk/search.php?input_search=Monument+175C+U+Gauge+or+Manometer&stock=1

[3] You can buy a pack of syringes for £1.23 at http://www.amazon.co.uk/Disposable-Toolbox-eJuice-Injector-Syringes/dp/B009GIOU0I/ref=pd_bxgy_86_img_y

[4] I used Blu-tack.

2. Seal one end of the U-tube with a small piece of putty. Leave the other end open.

3. Based on a calibration experiment, each unit on the manometer scale corresponds to a volume of 15.85mm^3 in the manometer tube and there is 640 mm^3 of tube above the scale on each side of the U-tube. Hence, the volume of trapped air will be, in cubic millimetres,

$$V_{start} = 640 + \left((H_{start} + 120) \times 15.85\right) \qquad (1)$$

4. Strap the digital thermometer adjacent to the U-tube with some tape without obstructing manometer scale or the fluid level in the tube. Record the temperature and then place the manometer with putty and thermometer in the refrigerator.

5. Remove the apparatus from the fridge when it has reached the temperature of the fridge, typically about 3°C. The trapped air will have contracted pulling the fluid round the U-tube. Immediately record the temperature and the fluid height in the sealed arm of the U-tube, H_{temp}. Repeat the measurements at two degree increments until the temperature returns to room temperature when the water should be level in both arms of the U-tube.

6. For each manometer reading calculate the gauge pressure,

$$P_{gauge} = \left(H_{start} - H_{temp}\right) \times \rho g \qquad (2)$$

where ρ is the density of water and g is the gravitational acceleration, then the absolute pressure is,

$$P_{abs} = P_{atmos} + P_{gauge} \qquad (3)$$

7. Calculate the volume of the trapped air in the plugged side of the manometer, V_{temp} by (i) calculating the change in volume relative to the room temperature value as

$$\Delta V = C \times \left(H_{start} - H_{temp}\right) \qquad (4)$$

and (ii)

$$V_{temp} = \Delta V + V_{start} \qquad (5)$$

8. Plot the product of the absolute pressure, P_{abs} and volume of the trapped air, V_{temp} on the ordinate as a function of temperature in degrees Kelvin on the abscissa.

Analysis

The usual use of a manometer is to measure pressure relative to atmospheric pressure. The putty placed over one end of the U-tube traps a mass of air between the putty and the column of fluid. When the temperature of the trapped air is decreased, its pressure and volume decrease according to the ideal gas equation

$$PV = mR_{air}T \quad (6)$$

where P is pressure, V is volume, m is the mass of gas, R_{air} is the gas constant for air and T is temperature. The graph from Part B should be an expression of the ideal gas law and the gradient of straight line through the data will provide the value of mR_{air}. Hence if you divide the value of the gradient by the mass of trapped air ($= \rho_{air}V_{start}$), then you will be able to estimate the value of the gas constant (R_{air}=289.6 J/kgK).

Your straight line through the data plotted in Part B should pass through absolute zero.

Conclusions

- What was your value for the gas constant for air, R_{air}? What was the percentage error relative to the textbook value?
- By how much did your estimate of absolute zero deviate from zero?
- What are the likely sources of error? How could the experiment be improved both with and without additional resources?

Notation

Symbol	Meaning	SI Unit
C	Volume calibration constant	
H_{start}	Fluid height in manometer at start of part B	m
H_{temp}	Fluid height in manometer at measured temperature	m
m	Mass	kg
M_e	Mass of empty manometer	kg
M_f	Mass of full manometer	kg
M_{start}	Mass of manometer at start of part B	kg
P	Pressure	Pa
R_{air}	Gas constant for air	J/kg.K
T	Temperature	K
V_{start}	Volume of trapped air in manometer at start of part B	m^3
V_{temp}	Volume of trapped air at measured temperature	m^3
ΔV	Change in volume of trapped air relative to volume at room temperature	m^3
ρ	Density	kg/m^3