Abstract

Examining Water Vapor Pressure as a Function of Temperature

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This demonstration experiment is a variation of an activity developed while at the Institute for Chemical Education at the University of Wisconsin-Madison. The experiment is meant to study the partial pressure for water vapor. In chemistry, many experiments that measure gases, require the gases to be collected by water displacement and whenever analysis is done, the pressure of water vapor must be taken into account. Normally a chart the water vapor pressure is used and students never really understand how the numbers in the chart are determined. This experiment would allow the student to see how the vapor pressure of the water changes as a function of temperature and make an abstract concept fairly concrete. To accomplish this, a Vernier pressure sensor is connected by tubing to a stoppered 500 ml filtering flask with 25 ml of warm water. The side arm of the flask is connected to a vacuum pump and the assembly placed in a constant temperature bath. Once the system is brought down to near 0 torr, a temperature probe is used to measure the temperature bath while the pressure sensor measures the water vapor pressure. The students are then able to compare water vapor pressure to that of temperature and observe what was impossible to do in the past.

Proposal

Introduction: This demonstration experiment is a variation of an activity developed while at the Institute for Chemical Education at the University of Wisconsin-Madison.

The experiment is meant to study the partial pressure for water vapor. In chemistry, many experiments that measure gases, require the gases to be collected by water displacement and whenever analysis is done, the pressure of water vapor must be taken into account. Normally a chart the water vapor pressure is used and students never really understand how the numbers in the chart are determined. This experiment would allow the student to see how the vapor pressure of the water changes as a function of temperature and make an abstract concept fairly concrete.

In order to do the experiment, you would need the following equipment:

* 500 ml KIMAX Filtering Flask
* Lead Flask Ring to weigh down the filtering flask
* 1 Hole #7 Black Rubber Stopper

Vacuum Pump with Belt Guard with a Gauge and Stopcock Assembly
Extra Heavy Wall Black Rubber Tubing and Tubing Clamps

Additionally, if you desire a hardcopy of your data you would need an EBM or Macintosh computer and either of the following to collect the data in real time:

- TI-CBL System
- TI-83 Calculator
- TI-Graph Link
- Pressure Sensor & CBL-DIN Adapter
- Standard temperature probe system and quick response temperature probe **or**
- Universal Lab Interface (ULI) Package
- Pressure Sensor
- Standard temperature probe system and quick response temperature probe or
- Digital Multimeter and 12 volt DC supply (additional wiring will be necessary)
- Pressure Sensor
- Standard temperature probe system and quick response temperature probe

Additionally you will need to obtain the following

- ice cubes
- a hot plate, Bunsen burner, or propane burner
- a 1000 ml beaker or large coffee can

Laboratory experiment

Purpose: To determine the partial pressure of water as a function of temperature

Procedure:

Obtain a **500 ml KIMAX** or PYREX vacuum filtering flask.

Place a small piece of glass tubing into a 1 -holed #7 rubber stopper and then secure a 1 foot section of heavy walled rubber vacuum tubing to the glass tubing.

Secure the other end of the tubing to a Pressure sensor (purchased from Vemier Software).

The pressure sensor would then be connected to either a MultiPurpose Lab **Interface (MPLI)** unit, a Universal Lab Interface (ULI) Unit or a Calculator Based Lab (CBL) Unit. If none of these are available, you would need to power the pressure sensor and connect it to a digital multimeter.

The first three options are preferred since you can calibrate the sensor to give pressure readings instead of voltages.

Next, connect and secure vacuum hose from the side arm of the filter flask to a vacuum pump (if available- to a pressure gauge of the vacuum pump). Place one additional tube clamp over this hose so the system can be pinched closed after a vacuum is established. Place a lead ring over the filtering flask to stabilize the flask and prevent it from tipping over. Now add about 25 ml of warm water into the filtering flask and insert the rubber stopper into the top of the filter flask. Turn on the vacuum pump and allow the water to degas of the oxygen present in the water. Bring the pressure down to close to 0 torr. Now pinch closed the tubing running to the vacuum and turn the vacuum off. Bleed the pump and disconnect the apparatus from the pump.

Now place the filter flask submerge it to the side arm into a 100 ml Beaker (or coffee can) filled partially with ice water. This container will serve as a ***constant*** temperature water bath.

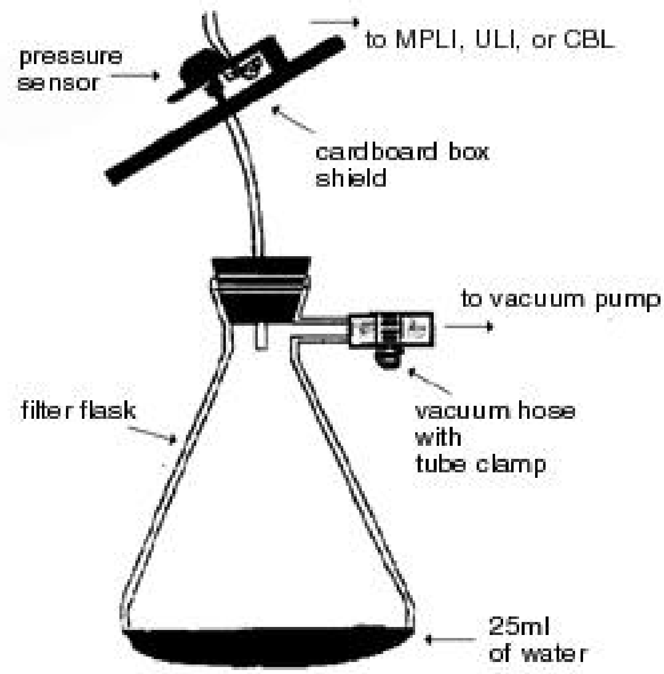
Slowly warm this water and take readings in the flask as well as the water. Warm the temperature slowly to about 85 C. Now slowly let the water cool and take readings again to verify your readings. If you wish to cool all the way back to ice water, you will need to periodically add small amounts of ice.

Using the data collected, plot temperature vs. pressure. If you are using the MPLI or ULI, the program running on the computer has a plot routine which will plot one input vs. another.

If you are using the CBL unit, you can use the graphing calculator to plot the data.

In any case, observe the data and compare it to that listed in most chemistry textbooks.

FIGURE#1



to MPLI, ULI, or CBL
pressure sensor
cardboard box shield
to vacuum pump
filter flask
vacuum hose with tube clamp
25ml of water

Equipment

Vacuum Pump with Belt Guard	VWR/Sargent-Wech	V*TL 140OB-0 1
Gauge and Stopcock Assembly	VWR/Sargent-Wech	S-71820-05
500 mi KIMAX Filtering Flask	Flinn Scientific	GP4073
Lead Flask Ring	VWR/Sargent-Wech	WLS-3448 I -C
Tubing Clamps Assembly	VWR/Sargent-Wech	WLS-73770-A
Extra Heavy Wall Black Rubber Tubing	VWR/Sargent-Wech	WLS-73535-E
Universal Lab Interface (ULI) Package	Vernier Software	ULM-S
Pressure Sensor	Vernier Software	PS-DIN
CBL-DIN Adapter (2)	Vernier Software	CBL-DIN
Standard Temperature Probe	Vernier Software	TPA-DIN

Revised experiment

(handout given during demonstration)

Examining Water Vapor Pressure as a Function of Temperature

Introduction:

This demonstration experiment is **meant to study the partial** pressure for water vapor. In chemistry, many experiments that measure gases, **require the** gases to be collected by water displacement and whenever analysis is done, the pressure of water vapor must be taken into account. Normally a chart of the water vapor pressure is used and students never really understand how the numbers in the chart are determined. This experiment would allow the student to see how the vapor pressure of the water changes as a function of temperature and make an abstract concept fairly concrete.

In order to do the experiment, you would need the following equipment:

* 25 x 150 mm PYREX Test Tube

* 2 Hole #4 rubber stopper

* a Plastic T connector

* Two 500 ml PYREX Beaker

* Hot Plate/Stirrer

* Some thin Latex tubing for siphoning water

* Vacuum Pump with Belt Guard with a Gauge and Stopcock Assembly

* Extra Heavy Wall Black Rubber Tubing and Tubing Clamps

* ice cubes

Additionally, if you desire a hardcopy of your data you would need an IIBM or Macintosh computer and either of the following to collect the data in real time:

- TI-CBL System
- TI Graphing Calculator
- Pressure Sensor & CBL-DIN Adapter
- Standard temperature probe system and quick response temperature probe or
- Logger Pro for the EBM or Data Logger for the Mac
- Universal Lab Interface (ULI)
- Pressure Sensor
- Standard temperature probe system and quick response temperature probe

Procedure:

Obtain a 25 x 150 mm PYREX Test Tube. Place a small plastic T connector into one of the holes of a #4 Two Hole Rubber Stopper and then secure a 3 foot section of heavy walled rubber vacuum tubing to the T connector and the vacuum pump with an auto parts hose clamps. Place a pinch clamp over this hose so the system can be pinched closed after a vacuum is established. Secure another piece of heavy walled rubber vacuum tubing to the T connector and to a pressure sensor (purchased from Vemier Software) with hose clamps. The pressure sensor would then be connected to either a MultiPurpose Lab Interface (MPLI) unit, a Universal Lab Interface (LJLI) Unit or a Calculator Based Lab (CBL) Unit. To the other hole of the rubber stopper, insert the standard temperature probe (purchased from Vemier Software). Seal around the holes of the rubber stopper with vacuum grease. Try to keep the part of the rubber stopper that touches the test tube dry and clean.

Get a liter container or several smaller containers and Put ice water in them. Obtain some thin latex tubing and remove air within the tubing. Submerge the tubing for now. Later you will use the tubing to siphon the warm water out of the beaker.

Obtain a hot plate/stirrer or Bunsen burner and heat up about 400 n-d of water. Place about 25 n-d of warm water into the test tube and insert the test tube in the water as you heat the water to boiling. As you approach boiling insert the stopper and probe and make sure the apparatus is sealed. Turn on the vacuum pump and allow the water to degas of the oxygen present in the water. Bring the pressure down to close to 0 torr. Now pinch closed the tubing running to the vacuum and turn the vacuum off. Bleed the pump and disconnect the apparatus from the pump. Now place the test tube back in the hot water and bring to a boil. The pressure sensor readings can be affected by heating the air around it. Therefore it is advisable to suspend the sensor as far from the hot plate as possible. I used a ring stand.

If you are using a ULI, set the time of the experiment to 900 second with 3 samples per second. Hook the pressure sensor and the temperature sensor to DIN I and DIN 2. Calibrate the sensors and set up the graph to plot pressure (in mm Hg) on the y-axis and temperature (in 'Q on the x-axis.

Once you have the temperature of the apparatus near 90C, turn off the hot plate. Start collecting data. When the temperature starts **lowering, slowly add** ice water and siphon out the warm water. If you keep the flow slow and at a constant rate both ways, you should be able to reduce the temperature to about 9C in 15 rninutes. Once the data is collected, observe the plot Pressure vs. Temperature. If you want to compare the data to that of the theory, I recommend you paste the data to Microsoft Excel or a comparable spreadsheet. I have included two runs that I did at my school: one using the ULI and one using the CBL and a TI-83. In any case, observe the data and compare it to that listed in most chemistry textbooks. You will find astonishing reproducibility considering the equipment being used and the 15 minute time frame of the demonstration. To obtain even better results, you will need to run the experiment for a longer time because you will want to reach equilibrium at each temperature. (If you desire further information feel free to contact me.)

Figure #2

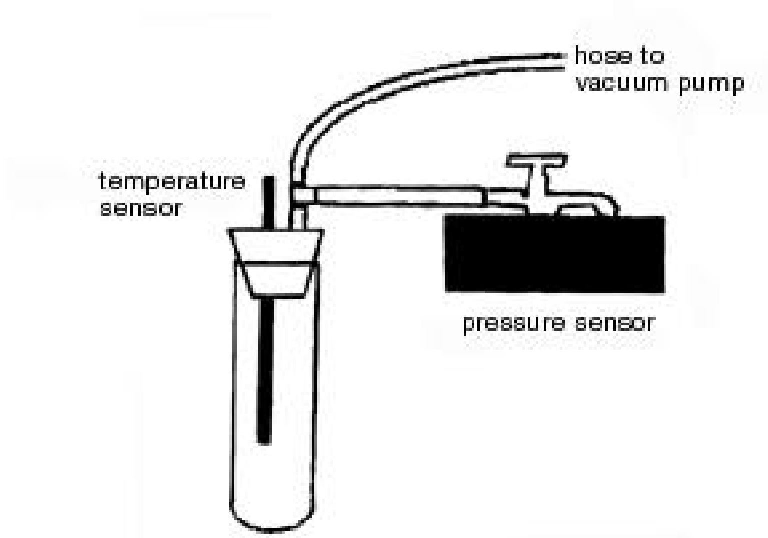
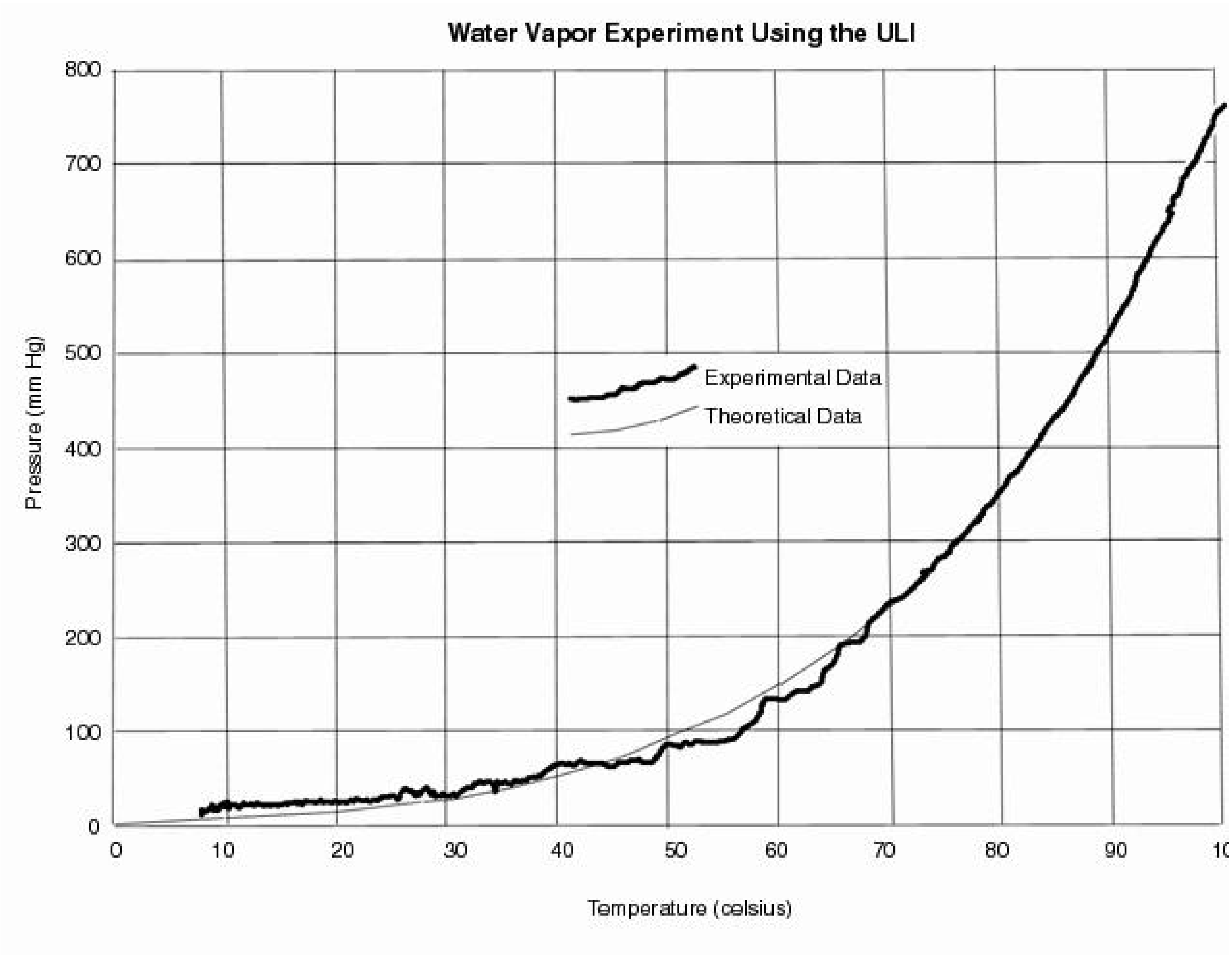
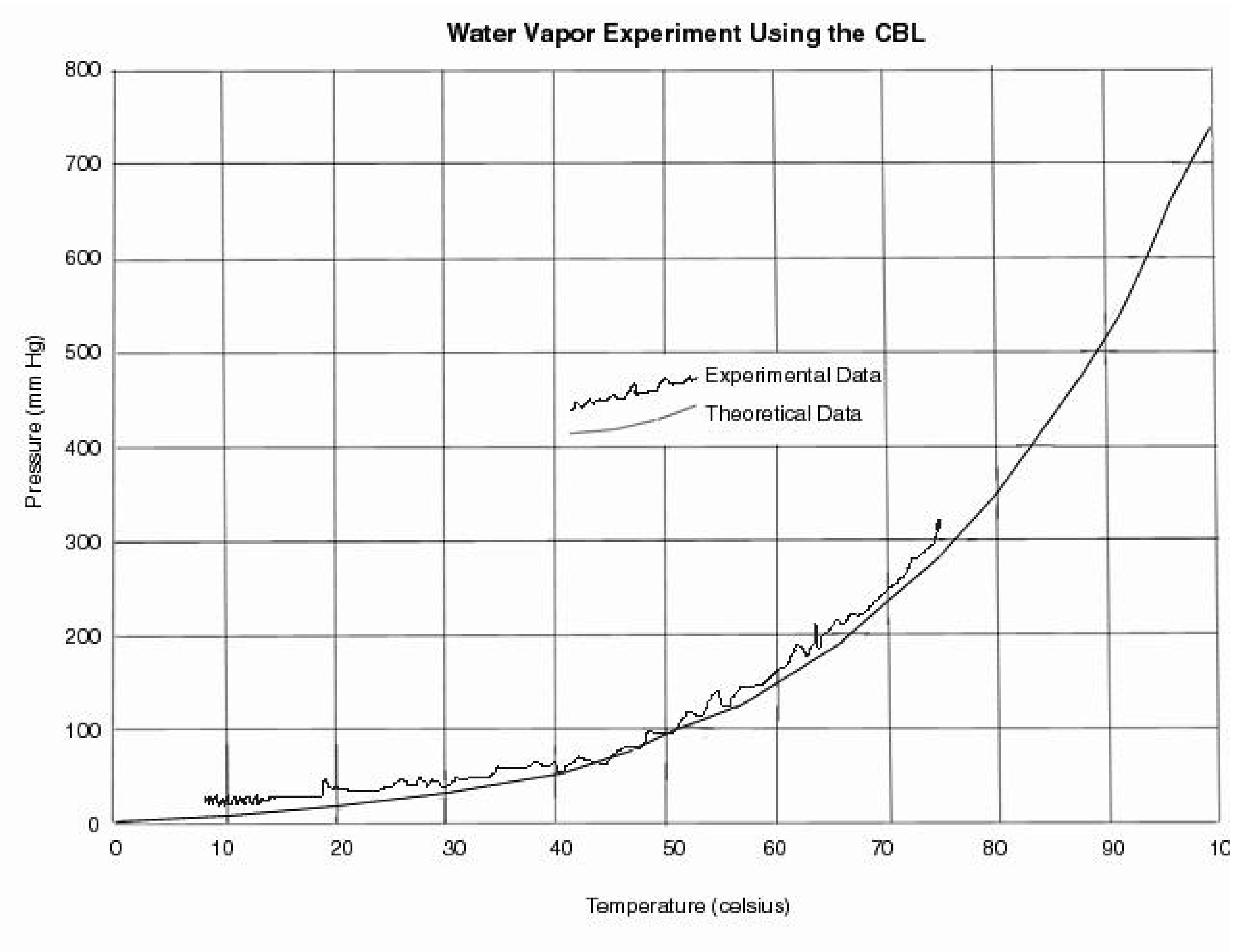


Figure #3



Water Vapor Experiment Using the ULI
800
700
600
500
400
300
200
100
0
Pressure (mm Hg)
Experimental Data
Theoretical Data
0
10
20
30
40
50
60
70
80
90
Temperature (celsius)

Figure #4



Water Vapor Experiment Using the CBL
Pressure (mm Hg)
800
700
600
500
400
300
200
100
0
Experimental Data
Theoretical Data
0
10
20
30
40
50
60
70
80
90
10
Temperature (celsius)