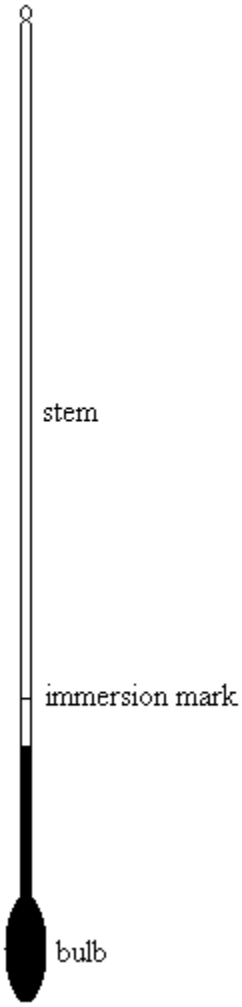
CHEM 109
Introduction to Chemistry
Revision 3.1

Laboratory Exercise: Calibration of a Thermometer

In this exercise we will calibrate a stem-type thermometer and then use it to correctly measure the Air temperature of the laboratory.

One of the most common types of laboratory thermometers is the liquid-expansion thermometer. In this type of thermometer, an expansion liquid, usually Mercury or Alcohol, fills a glass bulb attached to a long stem with a uniformly bored expansion column. When heated, the liquid expands up the bore until the bulb reaches thermal equilibrium with the material whose temperature is being measured. The expansion of the liquid is such that the height it reaches in the stem is linear with temperature. These thermometers are typically marked with equal spacings along the stem. They are then calibrated at two different "fixed point" temperatures. Alcohol thermometers are of lower accuracy than Mercury thermometers, but are more commonly used in the chemistry laboratory because Mercury is toxic and difficult to clean-up in the case of breakage. The lower accuracy of an Alcohol thermometer is due to two reasons: (1) Alcohol is more volatile than Mercury and so will vaporize into the space above the liquid in the stem; and (2) Alcohol tends to "wet" the sides of the stem's bore such that when the temperature drops, part of the liquid remains along the wall of the bore.



As with any measuring device, the accuracy of the device can only be judge by calibration of the device. Calibration is such that a measurement is performed whose result is well known. The instrument is then adjusted such that its reading gives this result. Or, a correction factor is determined such that subsequent readings can be corrected for the known instrument error. For a stem thermometer, because the markings along the stem cannot be adjusted, a Correction Curve is prepared such that thermometer readings can be converted to accurate temperatures. Known temperature baths for calibration can be generated using the Ice Point and the Boiling Point of Water. These temperature baths are called "fixed points" because of their use as calibration markers for thermometers.

Procedure

Thermometer Identification

1. If possible, note the manufacturer, serial number and manufacture date of the thermometer.

2. Note the temperature Range of the thermometer.

3. Note the precision of the thermometer. (What is the "uncertain" digit to which readings can be made?)

4. Note whether or not the thermometer is a Total Immersion or Partial Immersion type. Partial Immersion thermometers will have an Immersion Mark and are designed so that only that part of the stem is exposed to the temperature being measured. Total Immersion thermometers are designed so that both the bulb and the entire liquid column must be exposed to the temperature being measured.

5. Check to make sure that the liquid in the stem of the thermometer has not separated. If it has, ask your laboratory instructor for a new thermometer.

Calibration at the Ice Point of Water

1. Fill a styrofoam container with crushed Ice. (You will have to share a container with another group, so become friendly with your neighbors.)

2. Add enough **pre-cooled distilled** Water to cover the Ice, but not so much Water such that the Ice floats.

3. Thoroughly stir the Ice-Water mixture.

4. Hang your thermometer by a string from a clamp attached to a ring-stand until it is appropriately inserted into the Ice-Water.

5. Allow the temperature shown by the thermometer to stabilize. (~10 minutes is required to establish thermal equilibrium.) After 3 minutes at the stable temperature, record the temperature to the correct precision.

6. The Ice Point of Water is remarkably stable at $0.00^{o}C$.

Calibration at the Boiling Point of Water

1. Set up a hot plate with a 500 mL Florence Flask resting on it. The flask should be supported by a clamp from a ring stand.

2. Fill the flask about **half full** with distilled Water. Add a few boiling chips to promote smooth boiling.

3. Hang the thermometer from the ring stand as before such that the immersion mark is in the neck of the flask. (Once at reflux, both the Water and its vapor will be at the boiling point. Using a Florence Flask helps promote the reflux. Why?)

4. Turn on the hot plate and allow the Water to come to its Boiling Point.

5. Allow the temperature shown by the thermometer to stabilize. (~10 minutes after a rolling-boil has been achieved.) After 3 minutes at the stable temperature, record the temperature to the correct precision.

6. The Boiling Point of Water is extremely sensitive to the atmospheric pressure. You will be provided with the day's atmospheric pressure. Use this, along with the data in the Appendix, to determine the correct

Boiling Point of Water. You may have to interpolate the data in the Table. If so, a computer program that performs interpolation calculations will be provided. What is the Percentage Error in your measurement?

Air Temperature

The Air temperature in the room will be measured by measuring the temperature of a large Water bath that has been allowed to come to thermal equilibrium with the Air.

1. Hang your stem thermometer from the ring stand into the Water bath provided. (Everyone will share the same large bath.)

2. Allow for thermal equilibrium to be established. Make the appropriate readings.

Appendix

Atmospheric Pressure (mmHg)	Boiling Point Water (^{o}C)
760	99.996
750	99.629
740	99.257
730	98.880
720	98.499
710	98.112
700	97.720
690	97.323
680	96.921
670	96.512
660	96.098
650	95.676
640	95.249
630	94.814
620	94.371
610	93.921
600	930463

Data taken from:

http://hyperphysics.phy-astr.gsu.edu/Hbase/Kinetic/vappre.html#c5

See reference for details and approximations.

Data Sheet

Stem Thermometer

Thermometer Identification

Manufacturer _____

Manufacture Date _____

Temp Range _____

Thermo. Precision _____ ^{o}C

Calibration at the Ice Point of Water

Thermo. Reading _____ ^{o}C

Calibration at the Boiling Point of Water

Thermo. Reading _____ ^{o}C

Atm. Pressure _____ mmHg

Corr. BP Water _____ ^{o}C

Percentage Error _____ %

Name: _____ Date: _____

Signature: _____

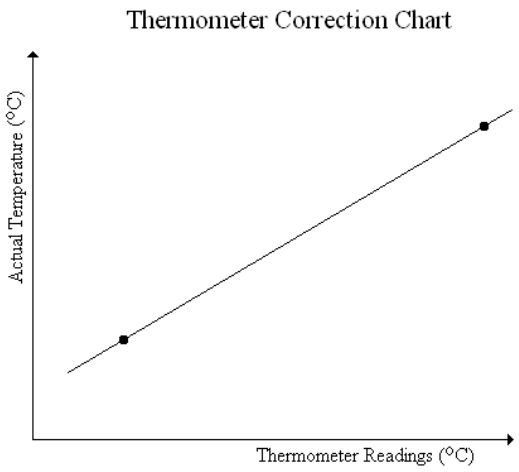
Data Analysis

Construction of Calibration Curve

Stem Thermometer

A Calibration Curve will allow us to convert direct thermometer readings to correct temperature values.

1. Obtain a sheet of graph paper.
2. Along the *x*-axis, plot actual thermometer readings.
3. Along the *y*-axis, plot correct temperatures.
4. Plot your two data points on this graph and draw a straight line between them.
5. Be sure the axes of the graph are correctly labeled and that each label has an appropriate unit.
6. Be sure the graph has a correct title.
7. Be sure the graph fills most of the sheet of paper.
8. An example is below:



Use of Your Calibration Curves

Use your Calibration Curve to determine the "correct" Air temperature for the room as measured by the stem thermometer.

Results:

Air Temp (Stem Thermo) _____ °C

The U.S. government has established the National Institute for Standards and Technology to maintain measurement standards. Data concerning its Thermometry services can be found at:

http://www.nist.gov/calibrations/laboratory_thermometers.cfm

How much would it cost to have the *NIST* calibrate our stem thermometer assuming it were filled with Alcohol?

$ _____

Additional Points to Consider

You do not need to submit answers to these questions. However, you should seriously ponder the answers to these questions as they could reappear on an exam.

- Will "wetting" by the expansion liquid in a stem thermometer along the stem's bore lead to a Systematic or a Random Error in the temperature measurement?
- The Tap Water used in preparing the Ice used in our Ice Point Calibration will contain dissolved salts. What does adding salt to Ice typically do to the Freezing Point? Will this lead to a Systematic or Random Error in our calibration procedure?
- Why do we use a large Water bath to measure the Air temperature in the room?