### Thermometer Calibration

**Background Information**

The most common device for measuring temperature is the thermometer. The typical thermometer used in general chemistry labs has a range from -20^\circ C to 120^\circ C. Most laboratory thermometers are constructed of glass and therefore are very fragile. Older thermometers contain mercury as the temperature sensing liquid while newer thermometers contain a red colored fluid. The mercury thermometers are hazardous if they break because mercury vapors are poisonous over long periods of inhalation and the mercury vaporizes slowly and so when it is spilled, the lab is toxic for several months unless every drop of mercury is picked up. The red colored liquid thermometers are also hazardous if they break because the liquid is flammable and may be toxic. Great care should be exercised when handling thermometers of either kind.

The typical laboratory thermometer contains a bulb (reservoir) of temperature sensing fluid at the bottom; it is this portion of the thermometer which actually senses the temperature. The glass barrel of the thermometer above the liquid bulb contains a fine capillary opening in its center, into which the liquid rises as it expands in volume when heated. The capillary tube in the barrel is very uniform in its cross-section all along the length of the thermometer. This insures that the fluid will rise and fall uniformly when heated or cooled.

(NOTE: laboratory thermometers look like clinical thermometers for taking people's temperatures but they are not the same. The clinical thermometer has a constriction in the tube so that after the temperature goes up and the thermometer is removed from the heat source, the liquid will not go back down. Such clinical thermometers must be shaken to lower the temperature reading before each use. Lab thermometers have no such constriction and hence the temperature reading immediately starts down when the heat source is removed. For that reason, lab thermometers must be read while the bulb is still in contact with the material whose temperature is being taken.)

Because thermometers are so fragile, it is a good idea to check them, now and then, to make sure they are still working properly. To check a thermometer, a process of calibration is used. To do this, you will determine the reading given by your thermometer in two systems whose temperature is known with certainty. If the readings of your thermometer differ by more than one degree from the true temperatures, it should be removed from use.

A mixture of ice and water which has reached equilibrium has a temperature of exactly 0^\circ C and will be used as the first calibration point. The second calibration point will be boiling water whose exact temperature must be determined using the barometric pressure in the lab.

**Pre-Lab Questions**

1. Why is a mixture of ice and water, rather than ice alone, used in calibrating a thermometer?
2. Why does the boiling point of a liquid vary with the barometric pressure?
3. What is the boiling point of pure water at 380 Torr?
4. What is the boiling point of pure water at 800 Torr?
5. Food products such as cake mixes often list special directions for cooking the products in high altitude areas. Why are special directions needed? Would a food product needing such directions require a longer or shorter time period to cook under such conditions?

**Purpose**

In this experiment, you will check a thermometer for errors by determining the temperature of two stable equilibrium systems.

**Apparatus and Materials**

* Thermometer
* 400 \ mL beaker
* 250 \ mL beaker
* distilled water
* ice
* hot plate
* stirring rod
* boiling chips.

**Safety Issues**

Mercury thermometers are hazardous if they break because mercury vapors are poisonous over long periods of inhalation and the mercury vaporizes slowly and so when it is spilled, the lab is toxic for several months unless every drop of mercury is picked up. The red colored liquid thermometers are also hazardous if they break because the liquid is flammable and may be toxic. Great care should be exercised when handling thermometers of either kind.

**Procedure**

Fill a 400 \ mL beaker with ice and add tap water until the ice is covered with water. Stir the mixture is a stirring rod for one minute. Dip the thermometer into the ice water mixture so that the thermometer bulb is approximately centered in the mixture (not near the bottom or sides). Leave the thermometer in the mixture for two minutes and then read the thermometer to the nearest 0.2 \ degree while the thermometer is still in the ice water bath. Record the temperature.

Allow the thermometer to return to room temperature by resting it is a safe place on the laboratory table.

Half fill a 250 \ mL beaker with distilled water and place it on a hot plate. Add 2 or 3 boiling chips to the water. Heat the water to boiling. Dip the thermometer into the boiling water making sure the thermometer does not get near the bottom, sides, or top of the water. Hold it there for 2 \ minutes and record the temperature reading to the nearest 0.2 \ degree.

Ask your instructor for the current barometric pressure reading in the laboratory room, look up the actual boiling point of water at this pressure and record.

**Data**

Actual freezing point of water = \_\_\_\_\_\_\_\_\_\_\_\_

Freezing point determined by your thermometer = \_\_\_\_\_\_\_\_\_\_\_\_

Difference between correct and trial values = \_\_\_\_\_\_\_\_\_\_\_\_

Barometric pressure in the room = \_\_\_\_\_\_\_\_\_\_\_\_

Actual boiling point of water at this pressure = \_\_\_\_\_\_\_\_\_\_\_\_

Boiling point determined by your thermometer = \_\_\_\_\_\_\_\_\_\_\_\_

Difference between correct and trial values = \_\_\_\_\_\_\_\_\_\_\_\_

**Post-Lab Questions**

1. Calculate the percent error of your measurement of the freezing point of water.

\% \ \text{error} = \frac{actual \ value - trial \ value}{actual \ value} \times 100 =

2. Calculate the percent error of your measurement of the boiling point of water.

\% \ \text{error} = \frac {actual \ value \ - \ trial \ value}{actual \ value} \times 100 =

| Actual Boiling Point of Water versus Various Room Pressures | |
| --- | --- |
| **Room Pressure (mm of Hg)** | **Boiling Point of Water** (^\circ C) |
| 750 | 99.6 |
| 751 | 99.7 |
| 752 | 99.7 |
| 753 | 99.8 |
| 754 | 99.8 |
| 755 | 99.8 |
| 756 | 99.9 |
| 757 | 99.9 |
| 758 | 99.9 |
| 759 | 100.0 |
| 760 | 100.0 |
| 761 | 100.1 |
| 762 | 100.1 |
| 763 | 100.1 |
| 764 | 100.2 |
| 765 | 100.2 |
| 766 | 100.2 |
| 767 | 100.2 |
| 768 | 100.3 |
| 769 | 100.3 |
| 770 | 100.3 |