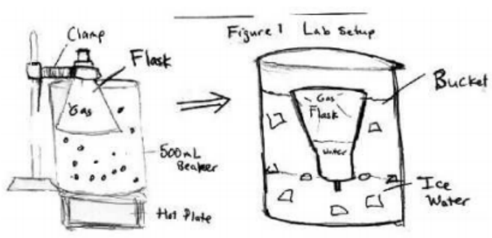
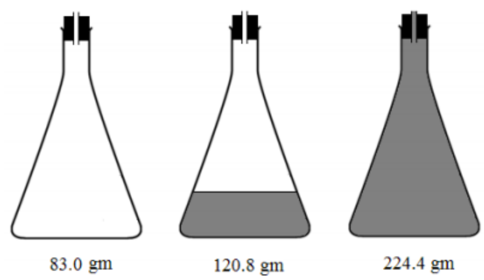
11.16: Using Charles' Law to Determine Absolute Zero

A simple experiment to determine absolute zero using Charles' Law is illustrated below. An Erlenmeyer flask is weighed and placed in a boiling water bath and allowed to come to thermal equilibrium. The temperature is measured and found to be 99.0 ^{o}C. The flask is then submerged, inverted, in an ice bath (0.20 ^{o}C) and allowed to come to thermal equilibrium. The contraction of the air in the flask at the lower temperature draws water into the flask. The flask is carefully removed, the outside dried and it is weighed. Finally, the flask is filled with water (as shown below on the right) and weighed. The mass measurements are converted to high and low temperature gas volumes and Charles's Law, V = a· T+ b, is used to calculate absolute zero.



Sketch by Matt Zimmer



Convert mass measurements to high and low temperature gas volumes:

High temperature: $V_h := \frac{224.4gm-83.0gm}{1\frac{gm}{mL}}$ = 0.141 L; T_h := 99.0 Celsius

Low temperature: $V_l := \frac{224.4gm-120.8gm}{1\frac{gm}{mL}}$ = 0.104 L; T_l := 0.20 Celsius

An algebraic method is used to calculate absolute zero. Three equations are required because there are three unknowns: a, b, and T_0. Absolute zero is interpreted as the temperature at which the gas volume goes to zero. This is the last equation in the set of equations used to calculate a, b and T_0.

$$\begin{pmatrix} V_h = aT_h + b \\ V_1 = aT_l + b \\ 0 = aT_0 + b \end{pmatrix} \Big|_{float,4}^{solve,\begin{pmatrix} a \\ b \\ T_o \end{pmatrix}} \rightarrow \left[0.3826\frac{mL}{Celsius}\ 103.5mL\ (-270.6)Celsius\right]$$

The correct value for absolute zero is -273.2 ^{o}C. So this result is in error by approximately 1%.