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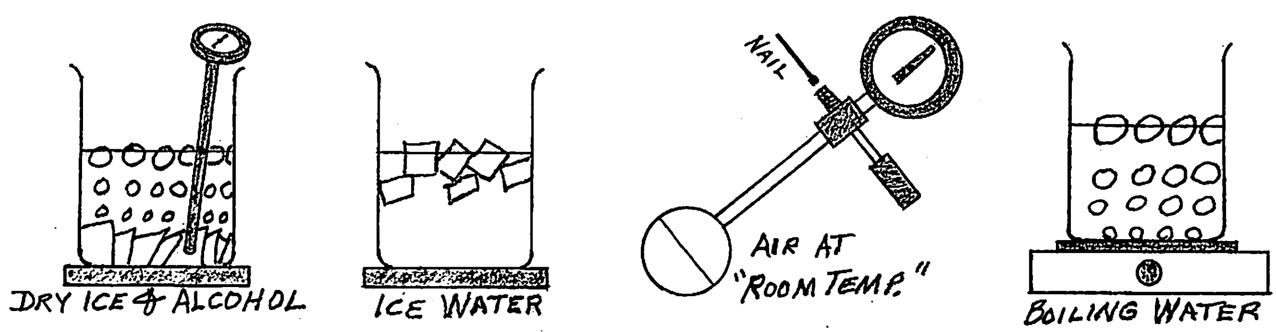
Absolute zero (-273° C or 0 K) - Although the concept of absolute zero, the lowest possible temperature, has been around since 1800 (?) when Charles came up with his famous gas law, the thought of a possible state of matter (molecules) without motion (kinetic energy) still fascinates us. By 1890 (?), Kelvin had come up with the absolute temperature scale, later named in his honor; 0 K had been made equal to -273° C. But why such an odd number, where did it come from?
Fortunately today, we have a commercially available device, the absolute zero demonstrator, and some very good thermometers to work with. Also, when we reach the limits of possible data collection, as we do in this case, we don't hesitate to employ the techniques of graphing and extrapolation from mathematics. Thus, with these simple ingredients, we will pursue the determination of absolute zero or that odd number, -273° C.
A note about the absolute zero demonstrator and the containers. The demonstrator has a metal bulb (constant volume) on one end with a pressure gauge attached on the other. Use the gauge scale provided; don't convert. (My old demonstrator is in lb/in^2.) Also attached is a valve to let air in or out of the apparatus during the experiment. The ideal*are 2000 ml Pyrex beakers. If they are not available, collect 1 gal. "paint thinner" steel cans, cut their tops off, and bend them "round". Regardless, try to use containers only a little larger than the bulb to save on materials, especially dry ice, alcohol, and ice cubes. Remember, the bulb must be totally immersed each time.

*containers

Materials: an absolute zero demonstrator, at least two (3?) mercury thermometers (-20 to 110° C), one Weston Model 2261 dial thermometer (-100 to 40° C)**, containers (glass and/or metal), a heating unit to boil water, water, ice (cubes?), dry ice, alcohol, a brick chisel, hammer, heavy gloves, styrofoam cooler, styrofoam pads, #6 penny finishing nail, millimeter graph paper, ruler

**Weston Instruments, Inc., Newark, NJ 07114

Diagrams:



Procedure: Since the volume of the bulb is constant, the only variable left is the pressure of the air inside the bulb due to any temperature change. In this experiment, the temperature will be changed by the substances (and their temperatures) that the bulb is immersed in. The bulb will be moved from one substance to another, and each time the temperature and pressure will be read and recorded. Further, there will be three different initial pressures in the bulb so that three sets of data can be collected to generate three different graphs.

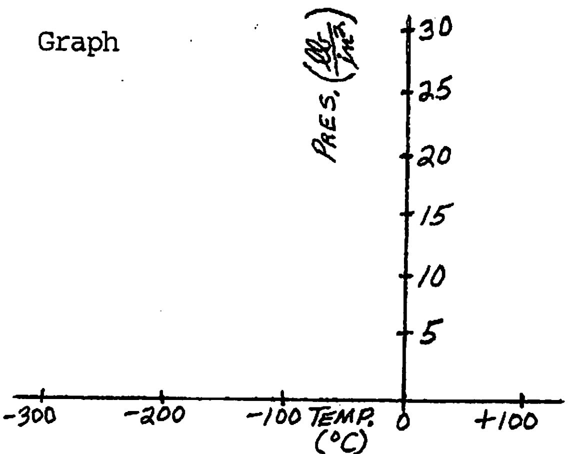
Set up a container with dry ice and alcohol; 7 lb. of dry ice should last an entire school day. If necessary, break up the dry ice in a heavy cardboard box with a brick chisel and hammer. Handle the dry ice with heavy gloves. Always place the dry ice in the container first, and then slowly (carefully) add the alcohol so as not to waste it due to "boil over". Keep the dry ice-alcohol mixture in a styrofoam cooler. Remove it only when taking a measurement, placing it briefly on a styrofoam pad (insulation). Don't expect a reading of -78.5° C (the ideal); instead, expect something around -72° C. Because a mercury thermometer would freeze up, you must use the dial thermometer recommended.

Set up a second container with cold water and ice cubes on a styrofoam pad.

Finally, have a third container with boiling water on an active heating unit.

Data table	T °C	P_1 lb/in²	P_2 lb/in²	P_3 lb/in²
BOILING H_2O				
ICE H_2O				
DRY ICE & ALCOHOL				

Graph



(a) Start with the bulb in ice water with 1 atmosphere (P_1) by pressing the valve in with a nail head and tapping the gauge with your finger to loosen the gauge mechanism. Read and record the pressure and temperature to the nearest tenth (best estimate).

(b) Move the bulb to the boiling water and then the dry ice bath, tapping and reading the pressure gauge each time and recording the pressure and temperature.

(c) While still in the dry ice bath, press the valve in again to return to 1 atmosphere (P_2), and then move to the ice water and boiling water, tapping, reading, and recording each time.

(d) While in boiling water, press the valve in again for 1 atmosphere (P_3) and move through the ice water and dry ice baths, tapping, reading, and recording each time. Thus, you will have collected three data points for three separate graphs.

(e) If, however, dry ice is not available, the use of "room temperature" (20° C?) may be used instead, but the results (quality) may suffer. Measurements will definitely take much longer as you must wait for equilibrium to be reached at room temperature each time.

(f) Plot the three graphs, P_1, P_2, P_3 , on millimeter graph paper as best you can. Draw an "average" straight line through each set of three points. Now "extrapolate" or extend each line down to the temperature axis line. Do they converge on that line at or very near -273° C? Do you now understand where that odd number comes from and where the Kelvin scale (0 K) begins? In all of this, as Charles, Kelvin, and others learned long ago, the temperature and pressure of a gas are in a direct proportion to one another. If you decrease one, you decrease the other; thus, the graphs are straight lines all the way down to 0 K (-273° C). Neat! This, of course, is ideal. In reality, all of the gases eventually liquefy and most solidify before they can reach 0 K. Still, the thought is very satisfying.

a sample from real data:

Data table	T °C	P_1 lb/in²	P_2 lb/in²	P_3 lb/in²
BOILING H_2O	100	20.6	28.0	1 atmos 15.1
ICE H_2O	0	1 atmos 15.0	20.5	11.1
DRY ICE & ALCOHOL	-72	11.2	1 atmos 15.0	8.2

Graph