the flame is observed directly, but which are clearly brought out when examined by the revolving mirror.

By employing a double mouthpiece, two sets of flame points of different lengths alternating with each other may be shown. Each vowel sound yields a characteristic series of flame points. A whistle will yield very fine points, while a very low bass note will produce scarcely more than a single point for each half revolution of the mirror.

CHAPTER X.

HEAT.

Heat is the manifestation of an extremely rapid vibratory motion of the molecules of a body. An increase in the velocity and amplitude of the vibrations increases the temperature of the body. A heated mass can impart vibratory motion to the ether which fills space and permeates all bodies, and these wave motions of the ether are able to reproduce in bodies motions similar to those by which they were caused.*

The more obvious effects of heat are expansion, fusion, and vaporization. All bodies increase in volume when heated; gases being the most expansible, liquids next, and solids the least. Heat may partially or wholly balance molecular attraction. Hence it is that, when heated, solids first expand, then (if no chemical action occurs) soften and become liquid, and finally vaporize.† Liquids are changed into vapors, and gases are rarefied.

EXPANSION.

Expansion takes place in all directions. To render this phenomenon apparent, an elongated and attenuated body, such, for example, as a fine wire, is chosen and its linear expansion only is noted. Fig. 180 shows an instrument for exhibiting the linear expansion of a long thin wire, 1 and 2 being respectively front and side views. The instrument is provided with two series of hard rubber pulleys mounted on studs projecting from a board. A fine brass wire (No. 32) attached to the board at one end passes around the successive pulleys of the upper and lower series in alternation, the last end being connected with one end of a spiral spring, which is strong enough to keep the wire taut without

* "Heat a Mode of Motion," by John Tyndall, is an interesting popular treatise on this subject.

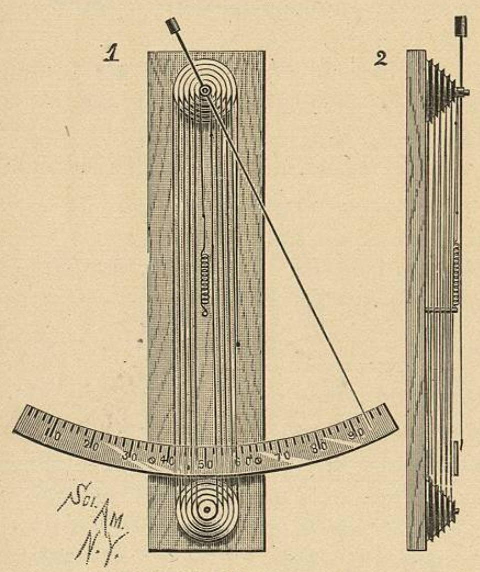
† Most organic bodies oxidize before the temperature of liquefaction is reached.

stretching it. The other end of the spring is attached to a stud projecting from the board. The pulleys are of different diameters, so that each series forms a cone. By this construction the wire of one convolution is prevented from covering the wire of the next.

The last pulley of the upper series is provided with a boss, to which is attached a counterbalanced index. A curved scale is supported behind the index by posts projecting from the board.

The series of pulleys are 12 inches apart, and there are

FIG. 180.



Metallic Thermometer.

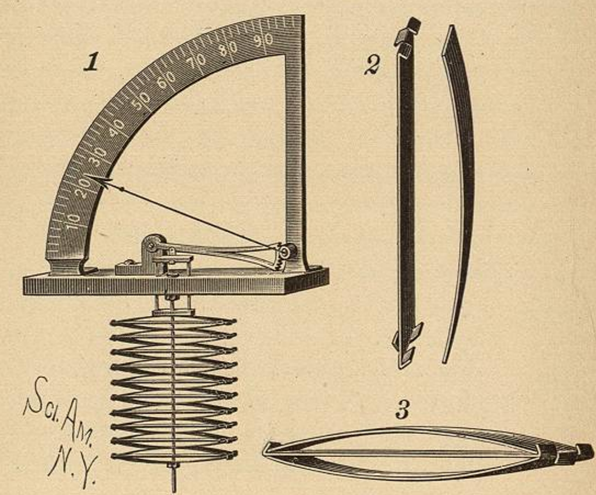
ten convolutions of wire, so that a small change of temperature produces sufficient expansion of the wire to cause a perceptible movement of the index. To increase the sensitiveness of the instrument, the wire is blackened by means of smoke or dead black varnish. An electric current passing through the wire heats it sufficiently to cause a deflection of the index; the amount of deflection depending, of course, upon the strength of the current.

SIMPLE THERMOSTAT.

Fig. 181 shows a simple thermostat which is capable of many useful applications. It is represented with an index and scale, but these are not essential for most purposes.

The instrument depends for its operation on the difference between the expansion of brass and steel. The linear expansion of brass is nearly double that of steel, so that when a curved bar of brass is confined at the ends by a straight bar of steel, the brass bar will elongate more than

FIG. 181.



Thermostat.

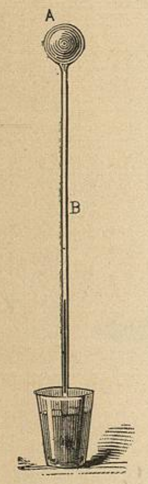
the steel bar when both are heated, and will in consequence become more convex.

At 2 are shown two bars, the straight one being of steel, the curved one of brass. The steel bar is slit for a short distance in two places at each end, and the ears thus formed are bent in opposite directions to form abutments for the ends of the curved brass bars, two brass bars being held by a single steel bar, thus forming a compound bar, as shown at 3. Each compound bar is drilled through at the center. Ten or more such compound bars are strung together loosely upon a rod, which is secured to a fixed support. A stirrup formed of two rods and two cross pieces rests upon the upper compound bar and passes upward through the support. Above the support it is connected by a link with a sector lever which engages a pinion on the pivot of the index. The use to which the thermostat is to be applied will determine its size and construction. It may be used in connection with kilns and ovens and for operating dampers, valves, and electric switches.

AIR THERMOMETER.

The air thermometer, consisting of an air bulb, A, and capillary tube, B, plunged in a colored liquid, shows changes in the volume of air due to expansion and contraction under changes of temperature by the rising or falling of the column of the colored liquid in the capillary tube. It is a sensitive thermometer, but of little practical value, on account of the variability of the volume of air by changes of pressure.

Fig. 182.

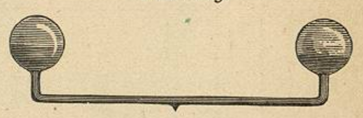


Air Thermometer.

PULSE GLASS.

The pulse glass (Fig. 183) is due to Franklin. It consists of two glass bulbs, formed on opposite ends of a tube bent twice at right angles, the system being partly filled with water, the air having been expelled by boiling the water before sealing the tube. When the bulb which contains the water is held in the hand, and the tube is placed in horizontal position, the rapid evaporation of the water by the warmth of the hand creates a pressure which causes the transfer of the water to the cooler bulb. The quick evaporation of the thin film of water adhering to the sides of the otherwise empty bulb increases the pressure, and causes a rapid ebullition of the water in the other bulb,

Fig. 183.

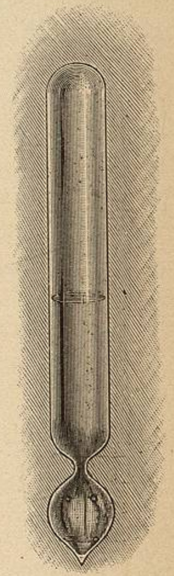


Pulse Glass.

and at the same time carries off the heat to such an extent as to produce a very decided sensation of cold.*

When the bulb is held at an inclination of about 40°, the water pulsates from one bulb to the other. The interior of the cool bulb becomes quickly dry, and evaporation in it therefore ceases. The water from the other bulb at once flows back into the lower one, to be again expelled by renewed expansion and evaporation.

Fig. 184.



The instrument operates continuously and very regularly when placed in a horizontal position upon a table, with one of the bulbs in the vicinity of a lamp, that is, within eight or ten inches of the flame, the other bulb being placed as far as possible away from the flame and shaded.

The straight form of pulse glass, shown in Fig. 184, exhibits the vaporization of water *in vacuo* to better advantage than the bent form.

When the bulb is held in the hand, the rapid evaporation, by the warmth of the hand, of the water flowing through the narrow neck of the tube and down the inner surface of the bulb creates a pressure of vapor, which finds exit through the neck of the tube, and bubbling up through the main body of the water, is condensed either in the water or above it. Sometimes the tube, when designed for use as a toy, contains the figure of an imp, which the ebullition of the water agitates violently.

THERMOSCOPIC BALANCE.

The action of the thermoscopic balance, shown in Fig. 185, is due to the facility with which liquids evaporate in a vacuum. A small amount of heat is sufficient to vaporize the liquid to the extent required to secure the desired action. The instrument is provided with a glass tube bent twice at right angles, and having a bulb blown on each end. The

* This phenomenon is one of latent heat, a subject omitted here, but treated at length in text-books on physics.

tube and the bulbs, like the pulse glass, are partly filled with water, and a vacuum is secured by boiling the water in the bulbs before sealing them. The center of the tube is furnished with V-pivots, which rest in bearings in the top of the forked column. The column also supports a metal screen, which is bright one side and black on the other. Two pins project from the screen to limit the movements of the glass tube and bulbs.

When the instrument is in use, the screen is placed toward the source of heat, and when radiant heat strikes the bulb which is unshielded by the screen, the water in that bulb is vaporized, and sufficient pressure is produced to drive the water upward into the bulb behind the screen. When a little more than half of the water has been in this manner forced from the lower to the higher bulb, the upper bulb preponderates. The tube and bulbs are supported on their pivot so as to secure unstable equilibrium, so that, when the upper bulb begins to descend, it completes its excursion at once, and exposes the full bulb to the radiant heat, at the same time carrying its empty bulb behind the screen, where it cools. The transfer of the water from the full bulb to the empty one now occurs as before. This operation is repeated so long as the bulbs are exposed to the action of radiant heat. The oscillations may be quickened by smoking the sides of the bulbs remote from the screen, and still greater rapidity of action may be secured by concentrating the heat on the bulbs by means of condensers or reflectors.

The principle of the thermoscopic balance has been utilized in the construction of an electric meter. To render it available for this purpose, a coil is inserted in each bulb above the water line and electric connections are provided, by which the current is sent through the coils in alternation as the bulbs tilt. The current thus commuted heats first one coil and then the other, causing the transfer of the water from one bulb to the other in the manner already described. Registering mechanism is provided which records the number of oscillations of the tube. The rapidity of the operation of the instrument is proportional to the strength of the current.

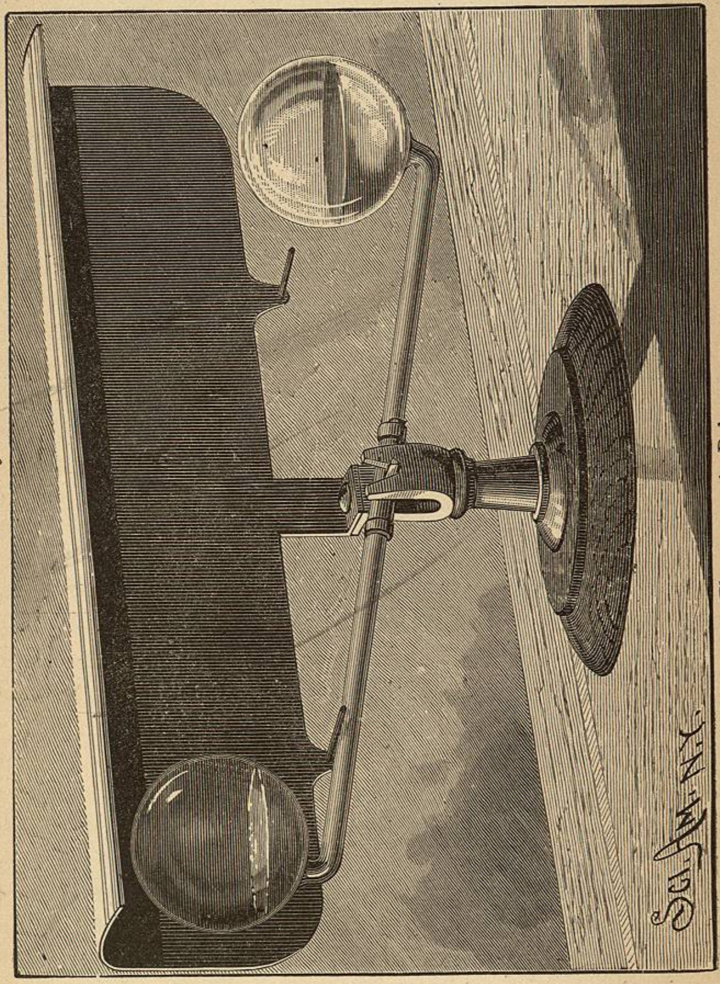


Fig. 185.

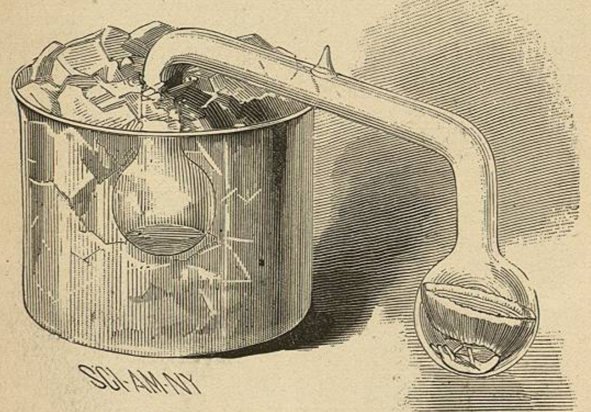
Thermoscopic Balance.

CRYOPHORUS.

Wollaston's cryophorus is similar in form and principle to the pulse glass, the only difference being that the tube connecting the two bulbs is made much larger, to avoid choking by ice—a thing sure to occur when the tube is of small diameter—the water vapor which is drawn toward the empty bulb (in a manner presently to be described) being condensed and frozen on the walls of the tube to such an extent as to entirely close it.

The cryophorus in process of construction is partly filled with water, which is boiled in the bulbs before sealing,

Fig. 186.



Wollaston's Cryophorus

to drive out the air. When the empty bulb of the apparatus is placed in a freezing mixture of ice and salt, for example, the evaporation of the water in the filled bulb, due to the cooling and condensation of vapor in the empty bulb, is rapid enough to carry off the heat to such an extent as to cause the water to freeze. Instead of employing the freezing mixture, a spray of ether or bisulphide of carbon may be projected upon the empty bulb with the same results.

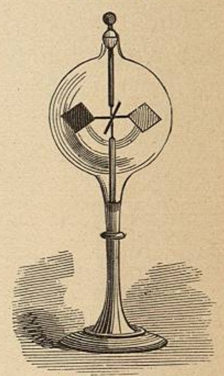
This is a very interesting experiment, illustrating the principle of freezing by rapid evaporation. It also exhibits the change of state of water from gaseous through liquid to solid condition.

RADIOMETER.

The radiometer is a heat engine of remarkable delicacy as well as great simplicity. It illustrates a class of phenomena discovered by Crookes, which are difficult to explain in a brief and popular way.*

The instrument consists of a very slight spider of aluminum supporting on the end of each of its four arms a very thin mica plate blackened on one side and silvered on the other side.

Fig. 187.



Radiometer.

The aluminum spider is provided with a jewel, which rests upon a delicate needle point supported at the center of the glass globe.

The spider is retained on its pivot by a small tube extending downward from the top of the globe. When placed in sunlight or near a gas or lamp flame, the vanes revolve rapidly.

An alum cell interposed between the radiometer and the source of light and heat allows the light to pass, but intercepts the heat rays. Under these conditions the vane will not rotate. An iodine cell, which is opaque to light, when arranged in the same way allows the heat rays to go through, and these cause the rotation of the vane.

TYNDALL'S EXPERIMENT ON RADIANT HEAT.

It often happens that students who desire to test for themselves the experiments of distinguished investigators are prevented from such instructive pleasures by the notion that, for delicate experiments, fine and expensive apparatus is required. Such apparatus is undoubtedly desirable and pleasant to work with, but where it is not to be had, a little courage and ingenuity may provide cheap substitutes which will perfectly answer the student's purpose. The crude apparatus herewith figured illustrates this fact.

* "The Principles of Physics," by Alfred Daniel, contains a clear explanation of the radiometer.