The Lactometer.

98. The LACTOMETER is entirely analagous in principle to BEAUMÉ's areometer, and is used to determine the purity of milk. The instrument, and the method of using it, are shown in Fig. 69.

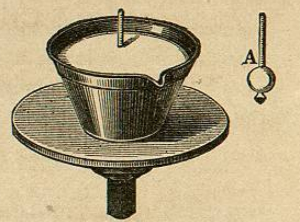

Fig. 69.

It is graduated by trial, using mixtures of milk and water. In the first trial pure water is used, then mixtures containing 10, 20, 30, 40, &c., per cent. of milk. The scale is therefore divided into 10 parts, between pure water and pure milk.

(**98.**) What is a Lactometer? How graduated and used?

CHAPTER III.

MECHANICS OF GASES AND VAPORS.

I.—THE ATMOSPHERE.

General Properties of Gases and Vapors.

99. GASES and VAPORS have been defined to be highly compressible fluids.

The distinction between a gas and a vapor, is not very clear. When a body in a gaseous form can, by moderate pressure, be reduced to a liquid form, it is usually called a vapor. For most of the purposes of Physics the distinction is unimportant.

Besides the property of compressibility, or rather as a consequence of it, gases and vapors continually tend to expand so as to occupy a greater space. The force which they exert in this way, is called their *Tension*, or their *Elastic Force.*

Thirty-four gases are known, thirty of which are compound, and four are simple. The four simple gases are, *oxygen*, *hydrogen*, *nitrogen*, and *chlorine*. Most of the gases are colorless, but some are not so.

Of the thirty-four gases, all but five have been liquefied by pressure, and the application of cold. The five that have thus far resisted are, *oxygen*, *hydrogen*, *nitrogen*, *deutoxyde of nitrogen*, and *carbonic oxyde.*

(**99.**) What are Gases and Vapors? *What is the difference between them?* What is meant by Tension? *How many known gases are there? Which are simple? Which have not been liquefied?*

Description of the Atmosphere.

100. The air we breathe is a mixture of *oxygen* and *nitrogen*, with a slight quantity of *carbonic acid*, *watery vapor*, and some accidental impurities. The oxygen and nitrogen are mixed in the proportion of 21 to 79.

The oxygen of the air supports life and combustion; without it, neither could long exist. The nitrogen serves to dilute it. Were the air composed entirely of oxygen, bodies would burn with too much rapidity, even many of the metals would be consumed. Animal life, too, would soon be exhausted by overaction in such an atmosphere.

The atmosphere is transparent, without odor, and colorless, except when seen in masses. In masses, it assumes a blue tint, and it is this which causes the sky to take a blue color.

Without an atmosphere, the celestial vault would appear perfectly black; in ascending high mountains, the sky gradually loses its blueness, and approaches a hue of black; this is because the mass of air above the observer rapidly diminishes as we ascend.

The air, by virtue of its elasticity, serves as a medium for the transmission of sound; it also serves as a means of transporting the vapors of oceans and lakes to fall upon the land in the form of rain, snow, and the like.

Expansive Force of Air.

101. Air, like simple gases, always tends to assume a greater volume.

To show this property, take a bladder fitted with a stop-cock, as shown in Fig. 70. Having moistened the bladder to make it more flexible, open the cock, squeeze out most of the air, and then close it.

(**100.**) Describe the composition of the atmosphere. *What is the use of the oxygen? Of the nitrogen?* What is the color of air? *What effect has the air on celestial appearances?* Mention some of the uses of the atmosphere. (**101.**) *How is the expansive force of air shown?*

Place the nearly empty bladder under the receiver of an air-pump, and exhaust the air. As the air becomes rarer in the receiver, the bladder will be seen to expand, showing that the air within it is expansible. In the same way, it may be shown that any gas is expansible.

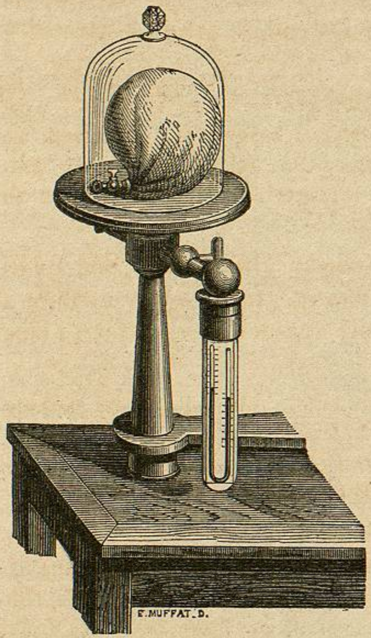

Fig. 70.

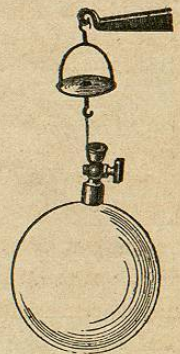
Fig. 71.

Weight of Air.

102. Air, like other bodies, has weight.

To show this, take a hollow globe of glass, fitted with a stop-cock, as shown in Fig. 71. Having attached it to one scale pan of a delicate balance, counterpoise it by weights placed in the other. Then by means of the air-pump exhaust the air from the globe; the opposite scale pan will descend, and some weights will have to be added

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(**102.**) *How is it shown that air has weight.*

to the first scale pan to restore the equilibrium. The weights added will indicate the weight of the exhausted air.

Composition of the Atmosphere.

103. It has been stated that our atmosphere is composed principally of oxygen and nitrogen, with small quantities of carbonic acid and watery vapor.

The amount of watery vapor depends upon the place, the season, the temperature, and the direction of the wind; under all circumstances it forms but a small per-centage of the entire atmosphere.

The carbonic acid in the atmosphere arises in a great measure from respiration and combustion. A continual supply of this gas is afforded by volcanoes. On the other hand, it is being continually taken up in the process of vegetation. Plants continually absorb it, appropriating the carbon, and giving off the oxygen which it contains. Another cause of diminution in the amount of carbonic acid in the air, is absorption by the water of our streams. Water absorbs large quantities of it, which thus becomes the means of dissolving earthy matters, and eventually of causing calcareous deposits.

It is the result of observation, that the supply and loss are very nearly balanced, so that the per-centage of carbonic acid in the atmosphere remains nearly constant. It amounts to about a thousandth part of the entire atmosphere.

Atmospheric Pressure.

104. The atmosphere, by virtue of its weight, exerts a force of pressure upon the surface of the earth as well as upon every object with which it is in contact. This force is called the *Atmospheric Pressure.*

(**103.**) Upon what circumstances does the watery vapor in the air depend? Whence is carbonic acid supplied? What becomes of the excess of carbonic acid? How do the supply and loss compare? What is the amount in the atmosphere? **104.**) What is the Atmospheric Pressure?

This pressure decreases as we ascend into the atmosphere.

If we suppose the atmosphere to be divided into layers parallel to the surface of the earth, it is evident that each layer is pressed down by the weight of all above it. Hence, the higher layers are less compressed than those below them. Being less compressed, they expand, or become *rarefied.* The existence of atmospheric pressure may be shown by a variety of experiments, some of which will be explained below.

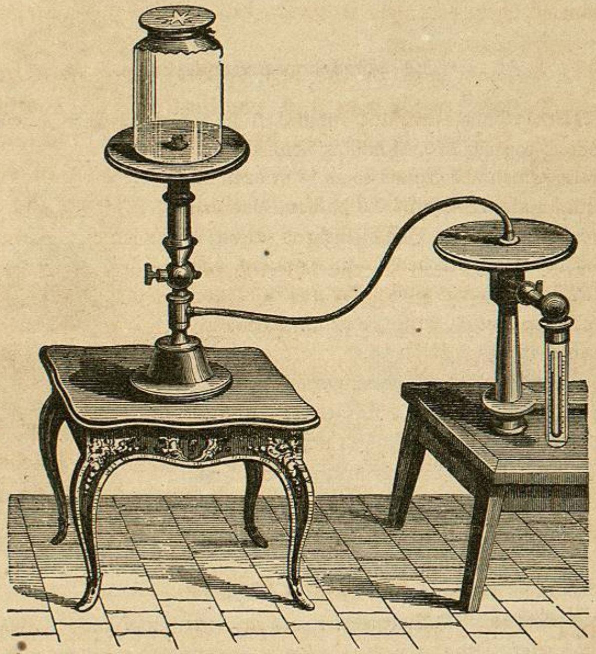

Fig. 72.

Bursting a Membrane.

105. A glass cylinder, open at both ends, has its upper end covered by a stretched membrane, such as is used by gold-beaters,

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How does it vary as we ascend? *How shown that the air becomes rarer in ascending?* (**105.**) *Explain the experiment of bursting a membrane.*

and its lower end is ground so as to fit the plate of an air-pump, as shown in Fig. 72.

In its natural condition, the membrane is pressed down by the weight of the atmosphere above it, and this pressure is resisted by the tension of the air within the cylinder. If now the air be exhausted from the cylinder, the membrane will no longer be pressed from within, and will finally burst with a loud report.

The bursting of the membrane shows the pressure of the air. The report arises from the sudden rush of air to fill up the exhausted cylinder.

The Magdebourg Hemispheres.

106. This apparatus, named from the city where it was invented, consists of two hollow hemispheres of brass, which are ground so as to fit each other with an air-tight joint. The hemispheres are shown in Fig. 73. One of them is so prepared that it can be attached to an air-pump, and is provided with a stop-cock, by means of which a communication with the external air can be opened or closed at pleasure.

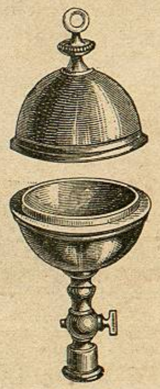

Fig 73.

The two hemispheres being placed one upon the other, the pressure of the external air is exactly counterbalanced by the tension of that within, and no obstacle prevents them from being drawn apart. If, however, the air be exhausted from within, the external pressure is no longer counteracted by an expansive force from within, and it requires a considerable effort to effect their separation, as shown in Fig. 74. We shall see hereafter that the hemispheres are pressed together by a force equal to 15 lbs., multiplied by the number of square inches in their common cross section.

What causes the bursting? The report? (**106.**) *What are the Magdebourg Hemispheres? Describe the experiment, and explain it.*

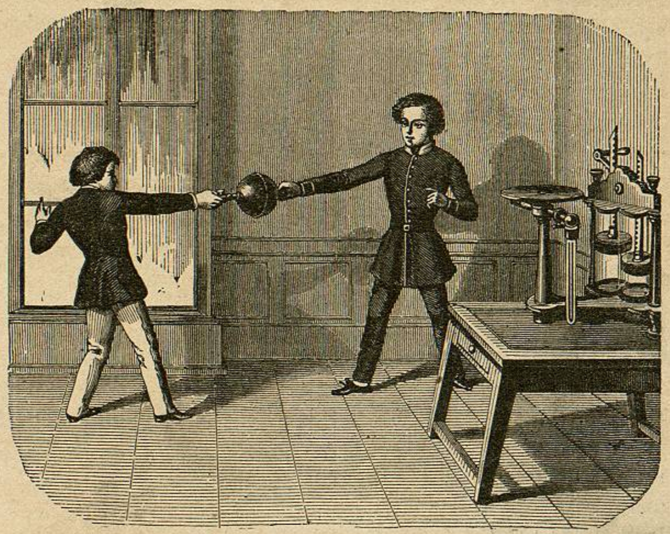

Fig. 74.

The experiment was devised by Otto de Guericke, of Magdebourg. He constructed two hemispheres more than two feet in diameter, and after having exhausted the air, it is reported that it required several horses to draw them asunder.

Torricellian Tube.—Measure of the Atmospheric Pressure.

107. The preceding experiments show that the atmosphere exerts a force of pressure; the intensity of that force may be measured by other means.

Torricelli, a pupil of Galileo, showed in 1643, that this pressure amounts to about 15 lbs. on each square inch of surface, at the level of the sea.

What experiment was made by Otto de Guéricke? (**107.**) What is the pressure of the atmosphere on a square inch?

In order to repeat TORRICELLI'S experiment, take a glass tube about three feet in length, closed at one end and open at the other. Turning the closed end downwards, let it be filled with mercury. Then holding the finger over the open end, let it be inverted in a vessel of mercury, as shown in Fig. 75. On removing the finger, the mercury sinks in the tube until the column, *AB*, is about 30 inches high, when it comes to a state of equilibrium.

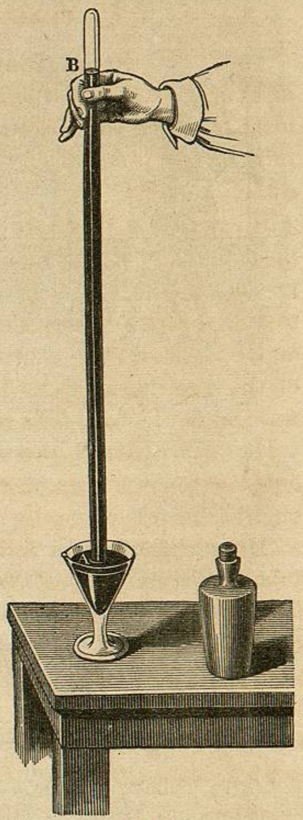

Fig. 75.

In this condition, the mercury is sustained by the pressure of the air upon the surface of the free mercury in the vessel, transmitted according to the law explained in Article 70. At the level of the sea, the height of the column *AB*, is on an average not far from 30 inches, or 2½ feet.

If we suppose the cross-section of the tube to be one square inch, the atmospheric pressure upon that surface must be sufficient to balance the weight of 30 cubic inches of mercury. Now the weight of 30 cubic inches of mercury is a little less than 15 lbs.; hence, we say the measure of the atmospheric pressure is 15 lbs. on each square inch.

A pressure of 15 lbs. on each square inch, is often called *an atmosphere*, and this becomes a unit for expressing the pressures of gases and vapors. Thus, when we say, in any given case, that the pressure of steam in a boiler is four

Describe TORRICELLI'S *experiment. How shown that the pressure is* 15 *lbs. on an inch?* What unit of pressure is adopted for all gases and vapors? Example.

atmospheres, we mean that it exerts a pressure of 60 lbs. on each square inch of surface.

Pascal's Experiments.

108. As soon as TORRICELLI'S experiment was known in France, BLAISE PASCAL undertook to ascertain by experiment whether the mercury was actually retained in the tube by the pressure of the atmosphere, or by some other cause.

He caused a friend to repeat TORRICELLI'S experiment upon the top of the mountain of Puy-de-Dome, correctly reasoning, that if the height of the mercurial column was due to atmospheric pressure alone, it ought not to be so great on the mountain top as at the level of the sea. The result of the experiment showed that the height of the column was less on the top of the mountain than at its base.

He next reasoned, that if the tube were filled with any liquid less dense than mercury, the height of the column ought to be proportionally greater. Consequently, he made at Rouen, in 1646, the following experiment. He took a tube, similar to that of TORRICELLI, but nearly 50 feet in length, and after filling it with wine, inverted it in a vessel of the same liquid. PASCAL observed that the column fell, until it was about 35 feet high, when it came to rest. In this case, the column was fourteen times as high as when mercury was used, and as mercury is fourteen times as dense as wine, he concluded that the sole cause of the phenomenon in question was the pressure of the atmosphere.

The Barometer.

109. A BAROMETER is an instrument for measuring the pressure of the air. If, to TORRICELLI'S tube, were fitted a

(**108.**) Describe PASCAL'S experiments in detail, and his mode of reasoning. What conclusion is derived from PASCAL'S experiments? (**109.**) What is a Barometer? What is its principle?

scale for measuring the exact altitude of the mercurial column, it would be a barometer.

Several forms have been given to the barometer, some of which will be described in the following articles.

The Cistern Barometer.

110. Fig. 76 represents a Cistern Barometer, such as is in common use in France and in this country.

It consists of a glass tube, *ai*, about 34 inches long, closed at the top and open at the bottom. This tube has a diameter of about four-tenths of an inch. It is filled with mercury and inverted in a cistern, *A*, which is partially filled with the same liquid, as explained in Article 107. The mercury settles in the tube till the height of the column is about 30 inches at the level of the sea.

The cistern *A*, is 3 or 4 inches in diameter, and it is so adapted to the tube *ai*, as to permit the air to penetrate to the cistern at the joint *i*. Only a part of the cistern is seen in the figure, the remainder being let into the frame which supports the whole instrument. At the top of the

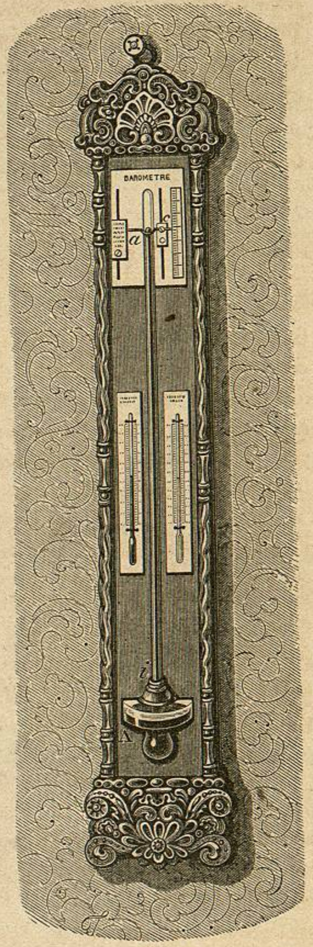

Fig. 76.

(**110.**) Describe the Cistern barometer. The tube. The cistern.

frame is a scale, *C*, having its 0 point at the level of the mercury in the cistern; or on the opposite side, is a scale on which are marked certain weather indications.

A curved piece of metal embraces the tube and carries an index, which, as the piece is raised or depressed to correspond to the top of the column, points out upon the scale *C*, the height of the column. Two thermometers, one of mercury and one of alcohol, are also attached to the frame, which serve to show the temperature of the instrument and of the mercury which it contains.

The 0 point, or beginning of the scale, is at the surface of the mercury in the cistern. When the pressure of the air increases, a portion of the mercury in the cistern is forced up into the tube, and the 0 point descends; when the pressure diminishes, the reverse takes place. But inasmuch as the surface of the mercury in the cistern is very great in comparison with that in the tube, this rise and fall is, for most purposes, quite unimportant. When great accuracy is required, the bottom of the cistern is made of leather, and can, by means of a screw, be raised or depressed until the surface of the mercury in the cistern just grazes the point of an ivory pin projecting from the top of the cistern. This improvement, devised by Fortin, is now in general use.

To determine the height of the barometer, the 0 point is first adjusted, then the curved piece is slid up or down till it coincides with the surface of the mercury in the tube, and the height is then read off on the scale *c*. The height of the thermometer should also be noted.

In the instrument described, the scale *c* does not extend throughout the whole length of the instrument, because, in ordinary cases, only a small part of the scale is needed. When a barometer is to be used in high altitudes, the scale is continued downwards as far as necessary.

Describe the scale. The index. The thermometers. *Where is the 0 point of the scale? How is the 0 point regulated in accurate barometers?* How is the height of the barometer determined?

The Siphon Barometer.

111. Fig. 77 represents a SIPHON BAROMETER. It consists of a curved tube, *ab*, having two unequal branches, the shorter one acting as a cistern. In the longer branch, there is a vacuum above the mercury, but the shorter one is supplied with air, which communicates with the external atmosphere through a small opening, *i*. There are two scales, one at the upper part of each branch, and in front of each is a movable index which may be raised or depressed until it comes to the free surface of the mercury in each branch. By means of these scales, the difference of level in the two branches may be measured. This difference is the height of the barometric column.

To prevent violent oscillations when the instrument is moved from place to place, the two branches communicate through a fine, almost capillary, tube. This arrangement also prevents the possibility of a bubble of air penetrating from the shorter to the longer branch, when the instrument is inclined.

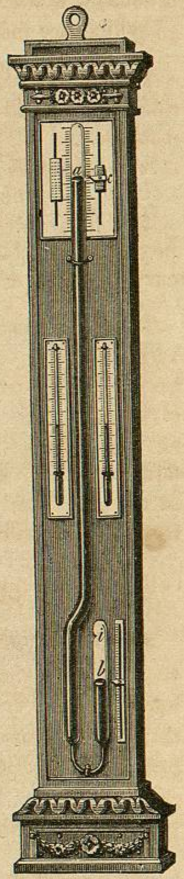
Fig. 77.

Properties of a good Barometer.

112. The space at the top of the tube should be per-

(**111.**) Describe the Siphon barometer. What takes the place of a cistern? How many scales are needed, and how are they arranged? How is the difference of level determined? *How are oscillations obviated?* (**112.**) What are the qualifications of a good barometer?

fectly free from air or moisture, otherwise they would, by their elastic force, prevent the mercurial column from rising to its proper height.

The elastic force of vapor of water is, as will be shown, very considerable, even at ordinary temperatures. To expel both air and moisture, the mercury should be boiled in the tube before the latter is inverted into the cistern.

The mercury should be pure, the bore of the tube should be sufficiently large, and the scale should be accurate. Mercury may be purified by distillation.

Thus far, mercury has been preferred to all other liquids for filling barometers. It is true, other liquids might be used, but in such case, the tube would become unwieldly from its length. In the case of water, a tube of about 35 feet would be required. There is another objection to using water, which arises from its tendency to form vapor even at ordinary temperatures. The formation of vapor at the top of the tube, would, as we have just seen, prove highly injurious to the working of the instrument.

Mean Height of the Barometer.

113. The height of the barometer is constantly fluctuating. The difference between the greatest and least heights observed at Paris, amounts to as much as one-thirteenth part of the greatest. The fluctuations become greater as we approach the poles, and less as we approach the equator.

The mean or average height can only be found at any place from a great number of observations. If we take hourly observations for one day and divide the sum of the heights by 24, the result is called *the mean height for that day*. This does not differ much from the height observed at midnight. If we take the sum of the mean daily heights for a year, and divide by 365, the result is *the mean height*

What liquid is best for filling barometers? Objections to other liquids? (**113.**) Where are the fluctuations of the barometer greatest? Least? Amount at Paris? *How is the mean height for a day determined? For a year?*