The number of vapors that exist at ordinary temperatures is very small. Of these, watery vapor is the most familiar, as well as the most important, on account of the part which it plays in many natural phenomena.

Liquids are divided into two classes, with respect to the readiness with which they pass from the liquid to the vaporous state, viz.: *volatile liquids* and *fixed liquids.*

VOLATILE LIQUIDS are those which have a natural tendency to pass into a state of vapor even at ordinary temperatures, such as ether, alcohol, and the like. If a vessel of water, alcohol, ether, or chloroform be left exposed to the air, the liquid is slowly converted into vapor, and disappears; in other words, it evaporates. To the class of volatile liquids belong essences, essential oils, volatile oils, amongst which may be mentioned spirits of turpentine, oil of lavender, attar of roses, oil of orange, and the like.

FIXED LIQUIDS are those which do not pass into vapor at any temperature, as, for example, fish oils, olive oils, and the like. At high temperatures they are decomposed, giving rise to various kinds of gases, but to no true vapors that can be condensed into the original form of the liquid. Some oils, like linseed oil, harden on exposure to the air, but it is not by evaporation, but by absorbing oxygen from the air, and thus passing to a solid state. Some solids are capable of passing directly to a state of vapor without first becoming liquid. To this class belong camphor, musk, and odorous bodies generally. Snow and ice may, under certain circumstances, evaporate without melting.

Evaporation under pressure.

222. The influence of evaporation by pressure may be illustrated

The most important vapor? What two classes of liquids have we? What are volatile liquids? Examples. Illustrate. What are fixed liquids? Examples. Effect of high temperatures upon them? Give examples of solids that vaporize?

by means of an apparatus shown in Fig. 145. It consists of a curved tube, the short branch of which is closed and filled with mercury; the mercury also fills a portion of the long branch. A small quantity of ether is introduced into the short branch, when it at once rises to the top, *B*, of this branch. At ordinary temperatures, the pressure of the external atmosphere exerted through the mercury, is sufficient to prevent the ether from forming vapor

If, however, the tube is plunged into a vessel of water heated to 112°, the ether will be converted into vapor and will occupy a certain portion, *AB*, of the tube, holding in equilibrium the pressure of the atmosphere, together with the weight of the mercurial column whose height is *AC*.

If the tube be withdrawn and allowed to cool, the vapor of ether will be condensed, and will appear as a liquid at *B*. If more heat be applied, it will again be converted into vapor, and the mercury will rise in the branch, *C*, as long as any ether remains to be evaporated. This shows that the tension of the vapor augments with the temperature. This principle holds true for all kinds of vapor.

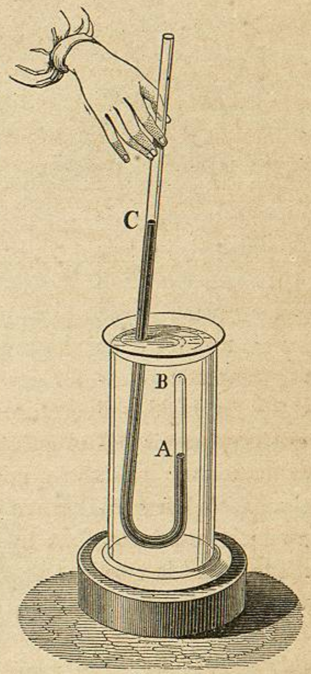

Fig. 145.

The tension acquired by the vapor of water, or *steam*, often becomes so great by being heated as to burst the strongest vessels, and thus is the cause of frightful accidents. The cause of wood snapping when burned in a fire-place, is the expansion of the water in the pores, giving rise at last to an explosion. When a chestnut is roasted in the ashes, the moisture within the shell expands into

(222.) *Explain the experiment showing the influence of pressure on vaporization. Why does wood snap when burned? Why does a chestnut snap when roasted?*

steam, and explodes with sufficient force to throw the nut from the fire. Hence it is that a small puncture is usually made in the shell, which permits the escape of the steam and prevents explosion.

Instantaneous Evaporation in a Vacuum.

223. Vapors formed upon the surface of a liquid escape by virtue of their tension. Under ordinary circumstances, the pressure of the air prevents a very rapid escape of vapor at ordinary temperatures, but when the atmospheric pressure is diminished in any way, evaporation takes place with great rapidity. If the pressure is entirely removed, the evaporation is instantaneous, like the flash of gunpowder, especially if the liquid is very volatile.

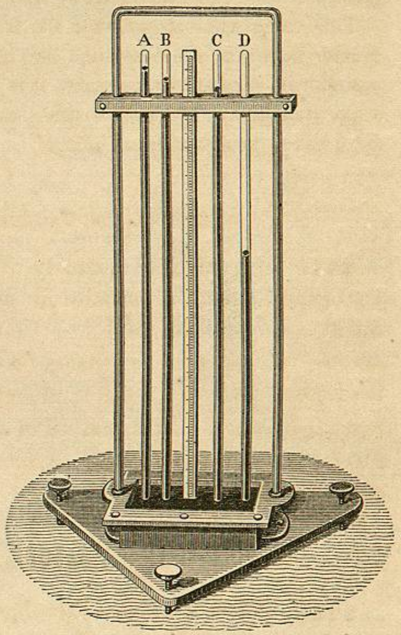

Fig 146.

This principle may be illustrated by means of the apparatus shown in Fig. 146. It consists of several barometer tubes, *A*, *B*, *C*, *D*, filled with mercury, and inverted in a common cistern of mercury, as shown in the figure. The whole apparatus is supported by a frame, to which is

How remedied? (**223.**) Why do vapors escape from the surfaces of liquids? When the pressure is removed, what happens? *How may the principle be illustrated? Explain the experiment in detail.*

attached a graduated scale. The mercury will stand at the same height in all of the tubes, at the height in *A*, for example.

If a few drops of water be introduced into the tube *B*, they will rise through the mercury in the tube, and on reaching the vacuum, will be instantly converted into vapor, as is shown by the depression that takes place in the column of mercury. If a little alcohol be introduced into the tube *C*, it will, in like manner, be converted into vapor, and will produce a still greater depression of the column. If a small quantity of ether be introduced into the tube *D*, a still greater depression of the mercury will be observed.

This experiment shows that the tension of the vapor of ether is greater than that of alcohol, and that of alcohol greater than that of water. By careful measurement, it is found that the tension of the vapor of ether is twenty-five times as great as that of water, and six times as great as that of alcohol.

Limit of the Tension of Vapors.

224. If a sufficient quantity of each of the liquids in the last experiment be introduced into the tubes, vapor will finally cease to form, and a portion will remain in the liquid state. In this case the tension of the vapor already formed is sufficient to balance the tendency of the liquid to pass into a state of vapor. In this state of affairs no more vapor can form without a change of temperature. This is the case supposed in the last article.

Saturation.

225. When a given space has taken all of the vapor that it can contain, it is said to be *saturated*. For example, if water be poured into a bottle filled with dry air, and the bottle be hermetically sealed, a slow evaporation will go on until the tension of the vapor given off is equal to the tendency of the remaining water to pass into vapor, when it

What does the experiment show? (**224.**) When does vapor cease to form? (**225.**) When is a space saturated with vapor? Example?

will cease. In this case, the space within the bottle is saturated.

It is a remarkable fact, established by numerous experiments, that for the same temperature, the quantity of watery vapor necessary to saturate a given space is always the same, whether that space is a vacuum, or whether it contain air or any other gas. The only point of difference in these cases is the rapidity with which the saturation takes place.

If the temperature varies, the amount of vapor required to saturate a given space will vary also. The higher the temperature, the greater will be the quantity of vapor required to saturate the given space, and the lower the temperature, the less the quantity required for saturation.

The quantity of watery vapor in the atmosphere is very variable, but notwithstanding the continued evaporation that is taking place from lakes, rivers, and oceans, the air in the lower regions of the atmosphere is never saturated. The reason is, that the vapor being less dense than the air at the surface, rises into the higher regions, where it is condensed by the greater cold existing there, and falls to the earth in the form of rain.

Causes that accelerate Evaporation.

226. The slow evaporation of water on the surface of our globe is accelerated by many causes, some of which are indicated below:

1. *Temperature.*—Increase of temperature also increases the tension of the vapor formed, and accelerates evaporation.

This property is utilized in the arts in the manufacture of extracts. The evaporation is carried on in chambers kept at temperatures of

What is the law of saturation at a given temperature? What effect has a change of temperature? Why is the amount of vapor in the atmosphere variable? (**226.**) What effect has increase of temperature on evaporation? *How is this property utilized?*

from 80° to 140° F., the air being continually renewed to carry off the vapor as fast as formed.

2. *Pressure.*—Diminution of pressure facilitates evaporation.

This principle has been utilized in the arts for the concentration of syrups. This application is illustrated by the method of concentrating syrups in sugar refining. The syrups are placed in large spherical boilers, from which the air is extracted by means of air-pumps worked by steam.

3. *Change of air.*—A continual change of the air in contact with the liquid facilitates evaporation, by carrying off the vapor which would otherwise saturate the layer in contact with the liquid, and effectually check the formation of additional vapor.

It is for this reason that the surface moisture of our fields and roads disappears more rapidly when there is a breeze than in calm weather. In the arts, the principle is applied by keeping a current of air playing across the surface of the liquid to be evaporated, by means of blowers, or otherwise.

4. *Extent of the liquid.*—A large surface is favorable to rapid evaporation, by affording a great number of points from which vapor may be formed.

This principle is utilized in the arts by employing shallow and broad evaporating pans. This application is illustrated by the process of making salt from sea-water. The water is spread out in large pans, which are very shallow, and then exposed to the influence of the sun's rays, when the water slowly evaporates, leaving the salt in the form of crystals.

Ebullition.

227. Ebullition, or boiling, is a rapid evaporation, in which the vapor escapes in the form of bubbles. The

What effect has pressure? *How is this utilized?* What effect has change of air? *Application of this principle?* What effect has the extent of liquid? *How utilized in the arts? Example.* (**227.**) What is Ebullition?

bubbles are formed in the interior of the liquid, and rising to the surface, they collapse, permitting the vapor to pass into the air.

In heating water, the first bubbles are due to the small quantities of air contained in the liquid, which expand and rise to the surface. Afterwards, as the heat is kept up, particles of water are converted into vapor and rise through the liquid, becoming condensed by the colder layers of water above them. When all of the layers become suitably heated, the bubbles are no longer condensed, but rise to the surface, and escape with a commotion that we call boiling, as shown in Fig. 147.

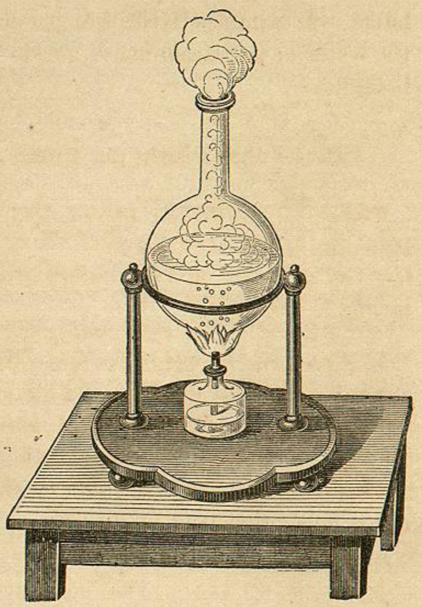

Fig. 147.

The following are the laws that govern the phenomena of ebullition:

1. *Under the same pressure, each liquid enters into ebullition at a fixed temperature.*

The temperature at which a liquid boils is called its *boiling point.* When the barometer stands at 30 inches, the boiling point of pure water is 212° F.; the boiling point of ether is 108° F.; the boiling point of alcohol is 174° F., and the boiling point of mercury is 660° F.

Explain the phenomena of boiling. What is the first law of ebullition? Illustrate.

2. *The pressure remaining the same, a liquid can not be heated higher than the boiling point.*

For example, if water be heated to 212°, it will begin to boil, and no matter how much heat may be applied, it will continue to boil, but will never become hotter than 212°; all the applied heat passes into the vapor and becomes latent. It becomes latent, because it does not heat either the water or the steam above 212°. This will be explained hereafter.

Causes that modify the boiling point of Liquids.

228. The principal causes that influence the boiling point of liquids, are: *the presence of foreign bodies, variations of pressure,* and *the nature of the vessels* in which the boiling is effected.

1. *Presence of foreign bodies.*—Matter in solution generally raises the boiling point of a liquid. Thus, a solution of salt does not boil so readily as pure water. If, however, the body dissolved is more volatile than water, then the boiling point is lowered. Fatty matters combined with water, raise its boiling point. Hence it is, that boiling soup is hotter than boiling water.

2. *Variations of pressure.*—Increase of pressure raises, and diminution of pressure depresses, the boiling point. When the pressure is great, the vapor, in order to escape, must have a high tension, and this requires a high temperature. When the pressure is small, the reverse is the case.

This principle may be illustrated by the apparatus shown in Fig. 148. It consists of a bell-glass, connected with an air-pump. Beneath the glass is a vessel of water. If the air be exhausted from

What is the second law? Illustrate. (**228.**) What are the principal causes that modify the boiling point? What is the effect of impurities? Illustrate by examples. What is the effect of pressure? *Illustrate. Explain the experiment.*

the bell-glass, the water enters into ebullition, even at ordinary temperatures. This is because the pressure is diminished.

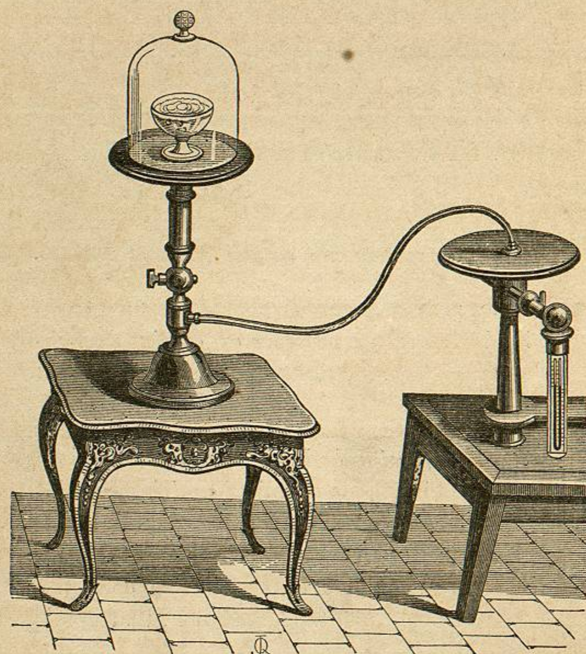

Fig. 148.

If it is desirable to continue the ebullition for some time, an arrangement must be made to remove the vapor as fast as formed. This can be effected by placing a dish of sulphuric acid under the bell-glass. The acid absorbs the vapor with great avidity. Furthermore, there is no increase of temperature in the water, but on the contrary the temperature continually falls, and the water may even be frozen.

The same principle may be further illustrated by a little instrument, shown in Fig. 149, called FRANKLIN'S *Pulse Glass*. It consists

How may water be frozen by evaporation? Explain FRANKLIN'S *Pulse Glass.*

of a glass tube, bent twice at right angles, and terminating at each extremity in a bulb, one of which is somewhat larger than the other. Before the larger bulb is sealed, a quantity of water is introduced,

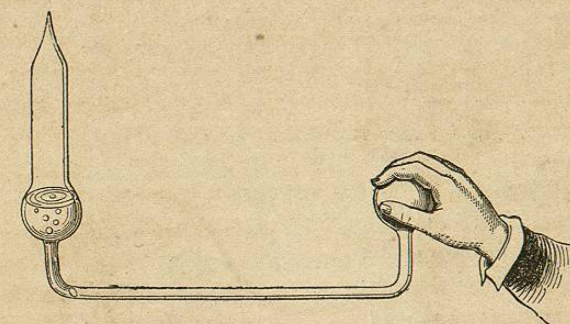

Fig. 149.

sufficient to fill the smaller one and a part of the larger one, and this is then made to boil over a spirit lamp until the air is driven out and the entire space is filled with steam. When this is effected, the large bulb is hermetically sealed by means of a jet of flame, directed across the open end of the tube. The space above the water is then filled with steam, which, as the instrument cools, is reduced to a low degree of tension. In this state of affairs the heat of the hand applied to the small bulb is sufficient to make the water boil, as indicated in the figure.

3. *Nature of the vessel.*—When the interior of the vessel is rough, the projecting points form centres for developing vapor, and the boiling point is lower than when the surface is smooth. Water boils at a lower temperature in an iron than in a glass vessel. In fixing the boiling point of thermometers, a metallic vessel should always be employed to boil the water in, on account of the fact just mentioned.

What effect has the nature of the vessel on ebullition? Illustrate.

Papin's Digester.

229. When water is heated in open vessels, its temperature can not be raised beyond a certain limit, but in closed vessels both the water and its vapor may be raised to very high temperatures, so that the tension of the vapor may reach several atmospheres. The instrument employed to show this fact is called PAPIN'S *Digester*, so called because PAPIN invented it for extracting the nutriment from bones.

It is represented in Fig 150, and consists of a thick bronze vessel, *M*, whose cover is held in place by a screw passing through a strong frame. To avoid danger of explosion, the instrument is provided with a safety-valve, similar to that used in steam-engine boilers. The safety-valve consists of a valve, *u*, fitting closely over an opening in the cover. This valve is held in place by a lever, *ab*, and a movable weight, *p*. One end of the lever is fastened at *a* by a hinge-joint. By moving the weight *p*, along the lever, we may vary the force with which the valve, *u*, is kept in place.

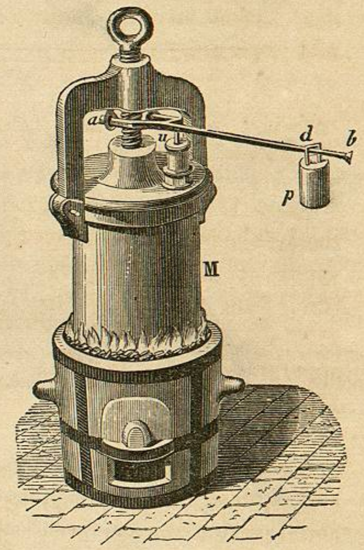

Fig. 150

Suppose the weight, *p*, to be 30 lbs., or 1 atmosphere, then if the distance *ad*, is made equal to four times the distance *au*, from the principle of the lever the pressure upon the valve will be that of the atmosphere increased by 120 lbs., that is, it will be equal to 5 atmospheres, and whenever the tension of the vapor within the

(**229.**) *What is* PAPIN'S *Digester? What principle does it illustrate? Explain its construction.*

digester exceeds this, the valve will be forced open, and a portion of the steam will escape with a whistling sound that indicates great compression.

If the valve be left open, the temperature can only be raised to 212°, and we have the phenomena of simple boiling. If water be heated in a well corked bottle, the tension of the vapor will finally cause the cork to spring from its place with a loud explosion.

It is the high tension of confined vapors that gives rise to the explosion of steam-boilers. Hence the necessity of constructing them of strong materials, and of providing them with proper safety-valves.

Measure of the Elastic Force of Vapor.

230. DALTON measured the elastic force of watery vapor at every temperature, from 32° F., up to 212° F., by means of the apparatus shown in Fig. 151.

This apparatus consists of two barometer tubes, *A* and *B*, filled with mercury, and inverted in an iron boiler, also filled with the same liquid. The tube, *A*, contains mercury alone, whilst the tube, *B*, contains a small quantity of water

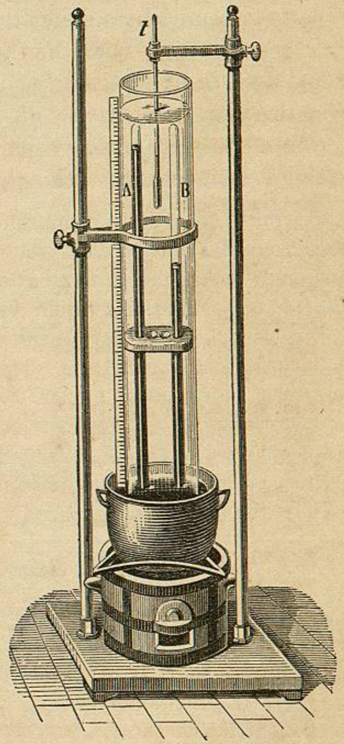

Fig. 151

Illustrate its use by an example. What causes explosions of steam-boilers? Precautions to be taken. (**230.**) Explain DALTON'S apparatus for measuring the tension of vapors, and the method of using it.