above the mercury. The tubes are kept in place by a wooden frame, placed in a long glass cylinder filled with water. A thermometer, *t*, is plunged into the water for the purpose of determining its temperature. When heat is applied to the boiler, the temperature of the whole apparatus is raised, and the water in the tube, *B*, is converted into vapor, whose tension is made known by the difference of level of the mercury in the tubes, *A* and *B*. This difference is measured by a scale attached to the cylinder.

For example, if, when the thermometer stands at 158° F., the difference of level in the tubes is 9 inches, we say that the tension of vapor at 158° is 9 inches of mercury, or 4.5 lbs., that is, it presses each square inch of surface, with which it is in contact, with a force of 4.5 lbs.

Dalton increased the temperature from 32° to 212°, noting at each degree the difference of level between the mercury in the tubes, and thus was enabled to form a table showing the elastic force of vapor at all temperatures within these limits.

Dulong and Arago have more recently extended Dalton's table to temperatures above 212°. Their investigations show that the tension of watery vapor at 212° F. is 1 atmosphere; at 250° F. it is 2 atmospheres; at 273° F. it is 3 atmospheres; at 291° F. it is 4 atmospheres; at 306° F. it is 5 atmospheres.

From all of these results we infer that the tension increases very rapidly with the temperature.

Latent Heat of Vapors.

231. When a liquid begins to boil, all of the heat that is added enters into the vapor and becomes latent. The amount of heat that becomes latent, is different for different liquids. It is called the *latent heat of vaporization.*

It has been ascertained by experiment that the latent heat of watery vapor is about 990° F., that is, it takes $5\frac{1}{2}$ times as much

Example. *Between what limits does* Dalton's *table extend? What general inference may be drawn?* (**231.**) What is latent heat of vaporization? *What does it amount to for water?*

heat to convert any quantity of water into steam as is required to raise the same quantity of water from the freezing to the boiling point. This may be verified by mixing 1 lb. of steam at 212° with $5\frac{1}{2}$ lbs. of water at 32°. The latent heat becomes sensible by the condensation of the vapor, and there results $6\frac{1}{2}$ lbs. of water at 212°.

Examples of Cold produced by Heat becoming Latent.

232. If a few drops of ether be poured upon the hand and allowed to evaporate, a sensation of cold will be felt. The ether in evaporating extracts the heat from the hand, which becomes latent.

Damp linen feels cold when applied to the body, because the moisture in passing to a state of vapor extracts the animal heat, which entering the vapor, becomes latent.

The warm wind of summer is refreshing, because it causes a more rapid evaporation of the perspiration, which abstracts animal heat from the body to become latent in the vapor thus produced. The coolness that results from sprinkling the floor of an apartment in summer, arises from the passage of heat from a sensible to a latent state, in consequence of the evaporation of the water. For the like reason, a shower of rain is generally followed by a diminished temperature.

Water may be cooled by putting it in porous vessels. A small quantity escapes through the pores, and in evaporating abstracts a portion of heat from the remaining liquid, thus reducing its temperature. This is the process of cooling water employed in many tropical countries.

Congelation of Water and Mercury in a Vacuum.

233. When evaporation is rapidly increased, the absorption of heat is proportionally increased, and as it is taken from the surrounding objects, these are sometimes frozen. It has been stated that water may be frozen under

How is this shown? (**232.**) *Why does ether produce cold by evaporation? Why does damp linen feel cold? Why is warm wind refreshing in summer? Effect of sprinkling? Of a shower? How is water cooled in porous vessels?* (**233.**) Why does evaporation produce cold in surrounding objects?

the receiver of the air-pump by absorbing the vapor as rapidly as it is generated.

By operating with a liquid more volatile than water, a greater degree of cold is produced. By using sulphurous acid, which boils at 14° F., a sufficient degree of cold is produced to freeze mercury. This is effected by surrounding a thermometer bulb with cotton, saturated with sulphurous acid, and then placing it under a receiver and exhausting the air.

The rapid vaporization abstracts so much heat from the mercury that it freezes in a few minutes. If we break the bulb, the mercury is found in a solid mass like a leaden bullet. In this form mercury can be drawn out into sheets, or stamped like a coin, but it soon absorbs heat from neighboring bodies, and again passes to a liquid state

VIII.—CONDENSATION OF GASES AND VAPORS.—SPECIFIC HEAT.

Causes of Condensation.

234. The CONDENSATION of a vapor, is its change from a vaporous to a liquid state. This change of state may arise from *chemical action*, *pressure*, or *diminution of temperature.*

1. *Chemical action.*—The affinity of certain substances for the vapor of water is so strong that they absorb it from the air, even when the latter is not saturated; such, for example, are quick-lime, potash, sulphuric acid, and many others. When placed in a closed space, they in a short time abstract all of the moisture in it.

2. *Pressure.*—If a closed cylinder is filled with vapor, and

Explain the experiment with sulphurous acid. Can mercury be frozen? (**234**) What is condensation of a vapor? Causes? Effect of chemical action? Examples. Effect of pressure?

this be compressed by a piston, as soon as the space occupied by the vapor is saturated, it will begin to condense, and if the pressure be continued, all the vapor will be reduced to the liquid state. Until the space becomes saturated, the pressure must be continually increased, on account of the augmented tension of the vapor, but after liquefaction begins, no further augmentation of tension takes place, and the pressure required to complete the liquefaction remains uniform.

3. *Diminution of temperature.*—When the temperature of any space is diminished, the amount of vapor required for saturation is diminished. After the point of saturation is reached, any further diminution of temperature causes a deposit of the vapor in a liquid form.

Steam is colorless, but when allowed to escape into the cold air, condensation takes place in the form of drops, which become visible. For the same reason, the moisture contained in the breath becomes visible in cold weather.

In winter the glass of our windows often becomes coated with drops like dew. This arises from the fact that the glass is colder than the air of the room, and thus acts continually to produce condensation of the vapor in the air. If the difference of temperature is sufficient, the particles of vapor are frozen as they are deposited, producing beautiful crystallizations. When the external air is warmer than that within, the deposit takes place on the outside of the glass. If a vessel of cold water be placed in a warm room, a deposition of moisture takes place on its exterior surface.

The more nearly the air is to saturation, the more abundant is the deposit of dew. Hence, before a rain, the deposit is especially abundant. Stone walls, and the like, being cooler than the atmosphere, are often in summer covered with moisture, when they are said to sweat. The moisture in this case is condensed from the air,

Illustrate. How long must the pressure augment? Effect of diminution of temperature? *What is the color of steam? Why does it become visible? Explain the deposition of drops on glass. Explain frost-work crystals. Why is the deposition more abundant before rain? Deposition on stones and walls?*

and does not come from the stones. If the sweating of stones is indicative of rain, it is because the deposition is most abundant when the air is most nearly saturated.

Heat developed by Condensation.

235. When a liquid passes to a state of vapor, a great quantity of heat is absorbed from neighboring bodies, and becomes latent. When the vapor returns to a liquid state, an equal amount of heat is given out and becomes capable of affecting our senses; in other words, it becomes *sensible.*

Heating by Steam.

236. Buildings are heated by means of steam conveyed from a boiler in the lower story, through iron pipes in the walls. The steam, by its heat and by the heat given out on condensation, serves to warm the apartments through which it is made to pass. To this end, coils of pipes are placed in the rooms to be warmed.

Distillation.

237. Distillation is the process of separating liquids from each other by means of heat.

The most volatile of the liquids is most easily evaporated, and its vapor is then condensed. The heat should be kept above the boiling point of the liquid that we wish to obtain, but below that which we wish to leave behind. The boiling point of alcohol being 174° F., and that of water 212°, if a mixture of alcohol and water be heated up to some temperature between these limits, the alcohol will all be vaporized, whilst most of the water will remain behind.

Why indicative of rain? (**235.**) Explain the development of heat by condensation? (**236.**) Explain the principle of heating buildings by steam? (**237.**) What is distillation? What degree of heat is required for distillation?

The Alembic.

238. An Alembic, or Still, is an apparatus for distillation.

The most usual form of an alembic is represented in Fig. 152. It is composed of a boiler, *A*, with a cover, *B*,

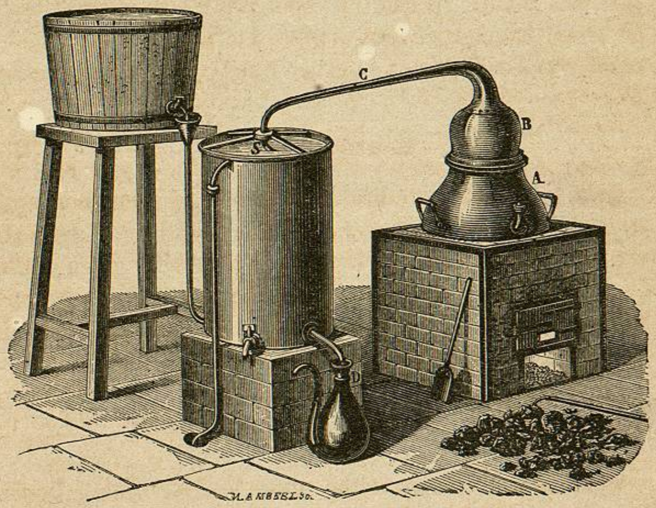

Fig. 152.

called the *dome;* from the top of the dome a metallic tube, *C*, passes into a vessel, *S*, called the condenser, and is then bent into a spiral form. This tube is called the *worm*, and after passing through the condenser, *S*, it leads to a *receiver*, *D*. The condenser, *S*, is kept full of cold water by an arrangement shown in the figure.

The substance to be distilled is placed in *A*, and a suitable heat is then applied. The more volatile portion is converted

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(**238.**) What is an Alembic? Describe the most usual form? How is distillation effected?

into vapor, rises into the dome, and passing through the worm, is condensed, and escapes in a liquid form into the receiver, *D*.

Wine is composed of water, alcohol, and a coloring matter. If this liquid be placed in the alembic and heated to any temperature between 174° and 212°, the alcohol is separated from the other ingredients. As a portion of water is evaporated, the alcohol thus obtained is not pure, and will require to be distilled again. At each distillation, the strength is increased, but no amount of distillation can render it absolutely pure.

By distillation, pure water may be obtained from the brine of the ocean, or from the impure water of our wells and springs.

Liquefaction of Gases.

239. Most of the gases have been liquefied, either by pressure alone, or by a combination of pressure with a diminution of temperature. An immense pressure may be had by utilizing the tension of the gases themselves, by generating large quantities in confined spaces.

One of the most interesting examples of the liquefaction of a gas is that of carbonic acid.

Carbonic acid is not only capable of liquefaction, but also of congelation. For this purpose, two immensely strong cylinders are fitted together, both being hermetically sealed, and communicating by a pipe. One of these cylinders is the *generator*, and the other the *receiver*. In the generator are placed the ingredients necessary to generate carbonic acid, usually carbonate of soda and sulphuric acid. After the opening is carefully closed, these materials are brought into contact, when an immense volume of carbonic acid is developed, and, being unable to expand, its tension becomes so great that a portion is condensed into a liquid form. The tension, at the temperature of 60° F., is equal to 50 atmospheres, or 750 lbs. on each square inch.

Explain the method of distilling alcohol? Water? (**239.**) How may gases be liquefied? *Example. Explain the apparatus for liquefying carbonic acid? The process of liquefaction?*

After liquefaction has ceased, if a stop-cock be turned so as to allow a part of the confined gas to escape, a portion of the liquid acid passes to a state of vapor with immense rapidity, and in doing so, absorbs so much heat from the remaining portion as to freeze it. The frozen acid is thrown out by the gaseous jet in flakes like snow. It is very white, and so cold as to freeze mercury instantly. It evaporates very slowly, and when tested with a spirit thermometer, its temperature is found to be 112° below the 0 of FAHRENHEIT'S thermometer. By using this solid with other substances for which it has an affinity, the greatest degree of artificial cold may be obtained.

Specific Heat of Solids and Liquids.

240. Experiment shows that different bodies require different amounts of heat to elevate their temperatures through the same number of degrees. The amount of heat required to heat any body a certain number of degrees, is called its *specific* heat.

If equal weights of water, iron, and mercury have the same amount of heat communicated to them, the mercury will be most heated, the iron next, and the water least of all. When heated to a certain temperature, water absorbs ten times as much heat as iron, and thirty-three times as much as water.

In order to compare bodies with respect to their specific heat, we take as a unit the amount of heat necessary to raise a given weight, say 1 lb., of water through 1° F. Two principal methods have been employed to ascertain the relative specific heat of bodies.

In the *first* method, the body to be experimented upon is brought to a standard temperature, say 212° F., and is then brought into contact with ice. The amount of ice melted makes known the quantity of heat given off by the body in

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How may a portion be solidified? Describe the solid gas. How may intense cold be produced? What degree of Fahrenheit? (**240.**) What is specific heat? Illustrate. How do we compare bodies with respect to specific heat? Explain the first method of determining the specific heat of a body.

passing from 212° to 32°, from which the relative specific heat may be determined.

In the *second* method, the body to be experimented upon is heated to a certain temperature, and then plunged into water at a lower temperature. The two bodies interchange heat and come to a common temperature. Then, from a knowledge of the weights of the two bodies mixed, their original temperatures, and their common resulting temperature, their relative specific heats may be determined.

The following table shows the specific heat of a few of the most important substances:

TABLE.

SUBSTANCE.	SPECIFIC HEAT.	SUBSTANCE.	SPECIFIC HEAT.
Water	1.000	Copper	0.095
Glass	0.198	Silver	0.057
Iron	0.114	Mercury	0.033
Zinc	0.096	Platinum	0.032

Of all these bodies water has the greatest specific heat, and consequently it requires more heat to raise its temperature through any given number of degrees.

Water heats slowly, and mercury very rapidly. Of course mercury cools rapidly and water slowly.

The specific heats of gases have been determined with respect to air as a standard, but the results need not be given in this treatise.

The second method. What body has the greatest specific heat? What bodies heat fastest? Cool fastest? Examples.

IX.—HYGROMETRY.—RAIN.—DEW.—WINDS.

Hygrometry.

241. HYGROMETRY is the process of measuring the amount of moisture in the air with respect to the amount necessary to saturate it.

The object of hygrometry is not to determine the absolute amount of moisture in the atmosphere, but simply to find out its degree of saturation. The absolute amount of moisture remaining the same, the atmosphere might at one temperature be saturated, whilst at some other temperature it would be far from saturation.

In winter the air is generally damper than in summer, though in the latter season it generally contains a greater absolute amount of vapor than in the former. This is due to difference of temperature. For the same reason the air is damper at night than in the day time. A cold room is damper than a warm one for the same reason.

Moisture in the Air, and its Effects.

242. The quantity of moisture in the air varies with *the seasons*, with *the temperature*, with *the climate*, and with *different local causes.*

When the air is too dry, the exhalation by the pores of the skin, called insensible perspiration, is too abundant, the skin cracks, and exfoliates, and much suffering results. When the air is too moist, the insensible perspiration is retarded and often entirely stopped, resulting in many painful diseases.

Hence the importance, in a sanitary point of view, of regulating the amount of moisture in our dwellings so as to avoid both of these extremes. On this account it is that *evaporators* are attached to our

(**241.**) What is Hygrometry? *Illustrate.* Explain the difference between the hygrometrical state of the air in winter and summer. (**242.**) Under what circumstances does the quantity of moisture in the air vary? *Explain the effect of dryness and moisture on the system. Important sanitary precaution.*

furnaces, which, when properly regulated, keep up a suitable degree of moisture in the heated air, furnished to warm our apartments.

The Hygroscope.

243. A Hygroscope is an instrument for showing the amount of moisture in the air.

Any hygrometric substance, that is, any substance capable of absorbing moisture, may be employed as a hygroscope. A great number of animal and vegetable substances, such as paper, parchment, hair, catgut, are elongated by absorbing moisture, and are shortened when dried, and are therefore adapted to the construction of a hygroscope. We shall explain the construction of a single instrument of this class in illustration of the principle employed in all.

It consists, as shown in Fig. 153, of a piece of wood cut out in the shape of a monk, having a cowl of pasteboard turning about an axis, *a*. The axis, *a*, passes through the neck of the figure, and connects with an apparatus shown in the section *AB*, on the left of the figure. The axis, *a*, is connected with a piece of twisted catgut kept tense by a spring. When the weather is dry, the catgut twists tighter, carrying with it the axis *a*, and the monk lays off his cowl, as shown in the figure. When the weather is damp, the catgut untwists, and the monk puts on his cowl. In adjusting the instrument, care should be taken to have the cowl on the head when the catgut is damp.

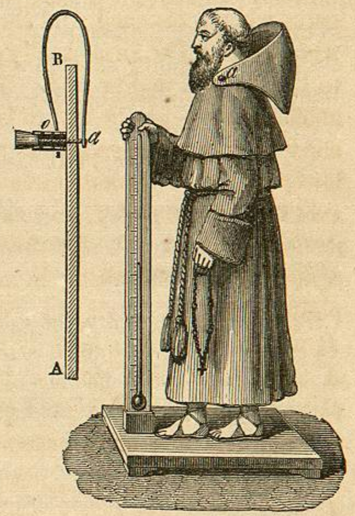

Fig. 153.

(**243.**) What is a Hygroscope? What substances may be used in the construction of a hygroscope? Examples. Explain the hygroscope shown in Fig. 153.

Instruments of this kind are very uncertain in their action, and are therefore used as matters of curiosity rather than for any scientific value they may possess.

The Hair Hygrometer.

244. A Hygrometer is an instrument for measuring the amount of moisture in the air. Several kinds have been invented, but the hair hygrometer is the most used.

This instrument is constructed from the principle that a hair elongates when moistened, and shortens when dried. The form usually given to it is shown in Fig. 154. A hair about eight inches in length is fastened at its upper end, and at its lower end it is wound around the axis of a small pulley, and then is made fast to it. A silk thread is wound around the pulley in an opposite direction, having a weight, *P*, attached to it to keep it tense. A needle attached to the pulley plays in front of a graduated arc, as the hair elongates and contracts.

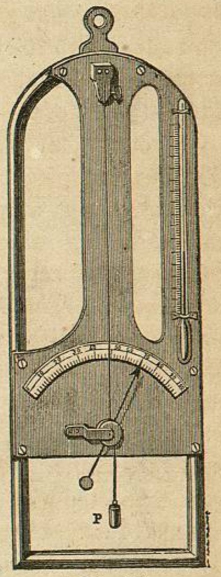

Fig. 154.

To graduate the instrument, it is placed under a bell-glass, and the air is thoroughly dried by some substance, such as quick-lime, which is capable of absorbing the moisture of the air. The point at which the needle then stands is marked 0. The air is then saturated

(**244.**) What is a Hygrometer? Explain the construction and use of the hair hygrometer. *How is it graduated?*