with moisture, and the point at which the needle stands is marked 100. The intervening space is divided into 100 equal parts, and these are numbered from 0 up to 100. The temperature is noted by a thermometer attached to the frame of the instrument.

To use the instrument, we note the reading of the needle and of the thermometer, and from these the exact amount of moisture in the air may be computed.

Hygrometric state of the Atmosphere.

245. By the HYGROMETRIC STATE of the atmosphere, we mean its relative degree of saturation. If we denote complete saturation by 1, and the air contains half the amount of vapor necessary to saturate it, its hygrometric state will be denoted by 0.5.

GAY LUSSAC has constructed a table, by means of which the hygrometric state of the air may be found when we know the reading of the hygrometer already described. together with that of the attached thermometer.

Formation of Fogs and Clouds.

246. FOGS and CLOUDS are masses of vapor condensed into drops, or vesicles, by coming in contact with colder strata of the atmosphere. The term fog, applies when these masses are in contact with the earth, and the term cloud, when they are suspended in the air.

The air at all times contains a greater or less quantity of invisible vapor, and if at any time the air becomes cooled below a certain limit, a portion is condensed and becomes visible; the result is either a fog or a cloud.

One of the most common causes of clouds is the cold generated by an ascending current of air. When the air becomes heated, it expands and ascends, and being continually subjected to a diminishing pressure, it expands rapidly, and a large amount of heat must become latent. This absorption of heat produces cold enough to condense the vapor into clouds. When a cloud floats into a warmer stratum of the atmosphere, it is often converted into invisible vapor and disappears. It is *dissolved*.

Mountains arrest the winds blowing from the plains, and force them to ascend their sloping sides. Coming in contact with the colder strata of the atmosphere, the moisture is converted into clouds and fogs. Hence we often see the mountain tops covered with fogs and clouds, when the other portions of the sky are clear. The condensation of water on the flanks of mountains is the most fruitful source of our streams. When a cold wind meets with a warm and moist current of air, the cooling process is so great as to generate clouds.

Two theories have been advanced to explain the reason why clouds remain suspended in the air. According to the *first* theory, the particles of moisture are hollow spheres of water like soap-bubbles, filled with air less dense than that without. Consequently the little vesicles float in the air like so many minute balloons. According to the *second*, and favorite theory, the particles are extremely small, and float in the air in the same way that particles of dust and other small bodies are seen to be borne along by the atmosphere.

Fogs form over bodies of water and moist grounds, when the air above them is cooler than the water or earth.

Fogs are frequent along the course of rivers and upon inland lakes. The cause of the dense fogs that prevail in the neighborhood of Newfoundland, is the Gulf Stream. The water brought by the Gulf Stream is warmer than that of the surrounding ocean, and as the vapor rises from it, it is converted by the cold air from the neighboring regions into fog.

How is it used? (**245.**) What is meant by the hygrometric state of the atmosphere? (**246.**) What are Fogs? Clouds? How are fogs and clouds formed? *What is a common cause of a cloud?*

When does a cloud dissolve? Effect of mountains on clouds? Utility of mountain condensation? Explain the two theories of the formation of clouds. *Where are fogs most frequent? Why so many fogs on the banks of Newfoundland?*

Rain.

247. RAIN is a fall of drops of water from the atmosphere. When several particles of a cloud unite, the weight becomes too great to be supported by the air, and the drop thus formed falls to the ground.

When a cloud floats into a colder stratum of the atmosphere, it becomes more condensed, and we have a fall of rain. When it floats into a warmer stratum it dissolves. Hence we often see the clouds of the morning dissolve under the influence of the sun, which acts to heat the upper regions of the atmosphere.

The quantity of rain that falls in any country depends upon its neighborhood to the ocean or other bodies of water, upon the season, upon the temperature, and upon the prevailing direction of the winds. More rain falls near the coasts than in the interior; more rain falls in summer than in winter; more rain falls in tropical climates than in temperate and polar climates; and finally, more rain falls in those countries where the prevailing winds are from the ocean than where they are from the continents.

The following table indicates the number of inches of rain that fall during the year at the places named:

At Copenhagen	18	inches.
" Paris	22	"
" Havana	90	"
" Calcutta	81	"
" Grenada	126	"

From this we see that the quantity of rain increases rapidly as we approach the equatorial regions.

(**247.**) What is Rain? *Explain the cause of rain.* Upon what does the amount of rain in any place depend? *Give examples of the amount of rain in different places. Inference.*

Dew and Frost.

248. DEW is a deposition of watery particles, that takes place upon the soil and plants during the calm nights of summer.

The true theory of dew was first established by WELLS. According to his theory, dew results from the earth and plants becoming cooled by radiation, thus producing a deposit of moisture from the neighboring strata of air. Good radiators are soonest covered with dew, whilst bad radiators have little or no dew formed upon them.

The state of the atmosphere influences the amount of dew. When the air is clear, the dew is abundant, when cloudy, little or no dew is formed. In this case the clouds radiate heat to the earth, and this prevents the latter from cooling so rapidly. A strong breeze prevents the formation of dew, by removing the strata of air next the earth before they have time to be cooled down to the point of saturation, or the *dew point.* A gentle breeze may facilitate the formation of dew, by replacing the layer of air from which the water has been deposited, by another which contains more moisture.

WHITE FROST is nothing more than frozen dew. It is often seen in autumn, and arises under the same circumstances as are favorable to the formation of dew. In order that frost may occur, the earth must be cooled below 32° F.

Snow and Hail.

249. SNOW is a collection of frozen particles of water, formed in the upper regions of the atmosphere, whence it falls to the ground in flakes.

(**248.**) What is Dew? What is WELLS' theory of dew? What bodies are soonest covered with dew? What ones have little dew upon them? What effect has the state of the atmosphere on dew? Why is there much dew on clear nights? Little on cloudy nights? What is the dew point? Effect of a gentle breeze? What is White Frost? (**249.**) What is Snow?

Snow flakes are made up of crystals, arranged in star-like forms with three or six branches, differently arranged, but always remarkable for their regularity and beauty. When snow falls, the temperature of the air is near 32° F. If the temperature is much lower, the snow is less abundant, because the amount of vapor in the air is less.

The quantity of snow that falls in any place is generally the greater as the place is nearer the pole, or as it is higher above the level of the ocean. At the poles, and on the summits of high mountains in all latitudes, snow remains through the entire year. As we approach the equator, the region of perpetual snow rises higher and higher above the level of the ocean. In the Andes, under the equator, the limit of perpetual snow is between 15,000 and 16,000 feet above the level of the ocean; in the Alps it is only 10,500 feet above the level of the ocean; towards the northern extremity of Norway it is but 3,000 feet above the ocean level.

HAIL is composed of layers of compact ice, arranged concentrically about nuclei of snow. Its formation is undoubtedly of electrical origin, and will be again treated of under the head of electricity.

Winds.

250. WINDS are currents of air, moving with greater or less rapidity. They are generally named from the quarter whence they blow; thus a wind that blows from the east is called an east wind, and so for other winds. Winds are sometimes named from some local peculiarity. Thus we have *trade winds*, *monsoons*, *siroccos*, and the like. The prevailing directions of the wind are different in different countries, for reasons that will be explained hereafter.

Causes of Winds.

251. Winds are caused by variations of temperature in the atmosphere; these variations produce expansions and

Describe a snow flake. *What law governs the fall of snow?* What is Hail? (**250.**) What are Winds? How named? (**251.**) What are the causes of winds?

contractions, thus disturbing the equilibrium of the atmosphere, causing currents. These currents are winds. For example, if the air is more heated over one country than over the neighboring countries, it dilates and rises, its place being supplied by the colder air which flows in from the surrounding regions. The surplus of air thus brought in flows over at the top of the ascending column. Hence there is a current near the earth in one direction, whilst at a higher elevation there is a current flowing in a contrary direction.

Regular, Periodic, and Variable Winds.

252. Winds are divided into three classes: REGULAR WINDS, PERIODIC WINDS, and VARIABLE WINDS.

1. *Regular winds.*—Regular winds are those which blow throughout the year in the same direction. They occur in the neighborhood of the equator, extending on each side about 30 degrees. From their advantage to commerce they are called *trade winds*. On the north side of the equator they blow from the north-east, on the south side they blow from the south-east.

The trade winds arise from currents of air flowing from the polar regions towards the equator; the velocity of the earth about its axis being greater as we approach the equator, these winds lay behind as it were, and become inclined to the westward, giving north-east winds on the north side, and south-east ones on the south side of the equator.

2. *Periodic winds.*—Periodic winds are those which at regular intervals of time blow from opposite directions. Such are the *monsoons* that prevail in the Indian ocean,

(**252.**) How are winds divided? What are regular winds? Where do they occur? What are they called? What is their direction on the north side of the equator? On the south side? Explain the causes of the trade winds? What are periodic winds?

blowing one half of the year from north-east to south-west, and the other half in the opposite direction. When the sun is on the north of the equator, the southern portion of the Asiatic continent is warmer than the southern part of Africa, and the winds blow from south-west to north-east; when the sun is on the south side of the equator, the reverse is the case.

3. *Variable winds.*—Variable winds are those which blow sometimes in one direction and sometimes in another, without any apparent law of change. The further we recede from the equatorial regions, the more variable are the winds in their character.

The Simoon.—The Sirocco.

253. The SIMOON is a hot wind that blows from the deserts of Africa. It is felt in the northern and north-eastern parts of the African continent. During its prevalence the thermometer often rises to 120° F. In the desert this wind becomes suffocating from its heat and dryness. Travellers exposed to it cover their faces with thick cloths, and their camels turn their backs to escape its injurious effects.

The SIROCCO is a hot wind that sometimes is felt in Italy. When it blows, people remain in their houses, taking care to close every door and window. Some suppose this to be a continuation of the simoon from the African desert, others think that it has its origin in Sicily.

Velocity of Winds.

254. The velocity of winds is very variable. The velocity is measured by instruments called *anemometers.*

Explain the cause of the monsoons. What are variable winds? When are they most variable? (**253.**) What is the Simoon? Explain. What is the Sirocco? Explain. (**254.**) What is an anemometer?

These consist of a species of windmill attached to a train of wheel-work, by means of which the number of revolutions per minute can be registered. From the number of revolutions the velocity can be computed.

The velocity of the gentlest breeze, or zephyr, is not more than one mile per hour; a moderate wind travels at the rate of 4½ to 5 miles per hour, a brisk wind 20 miles per hour, a tempest 40 to 50 miles per hour, and a hurricane from 90 to 100 miles per hour.

X.—SOURCES OF HEAT AND COLD.

Sources of Heat.

255. The principal sources of heat, are: *the sun, electricity, chemical combination and combustion, pressure and percussion,* and *friction.*

1. *The sun.*—The sun is the most abundant source of heat. We are ignorant of the cause of heat in the sun's rays.

It has been computed that the heat received from the sun by the earth in a year is sufficient to melt a layer of ice extending over the entire globe, and 100 feet in thickness. Yet on account of the great distance of the earth from the sun, and its comparatively small size, it can only receive the minutest portion of the heat which the sun radiates in all directions.

2. *Electricity.*—The subject of heat due to electricity will be treated of under the head of Electricity.

3. *Chemical combination and combustion.*—Chemical combinations are generally accompanied by a disengagement of heat. When they take place slowly, the heat is inappre-

Describe it. *What are the velocities of some of the winds?* (**285.**) What are the principal sources of heat? What is the most abundant source? *What is the amount of heat received by the earth from the sun in a year?* Explain chemical combination as a source of heat.

ciable, but when they take place rapidly, there is often produced an intense heat, and sometimes a development of light.

Combustion is one form of chemical combination. The forms of combustion exhibited in our fire-places and our lamps, is a combination of the carbon and hydrogen of the wood and oil with the oxygen of the air. The products of such forms of combustion are watery vapor, carbonic acid, with gases and volatile products that appear under the form of smoke. Combustion is a decomposition of certain substances, accompanied by a composition of new products. In this change, no element is lost, simply a change of form takes place.

The flame produced in combustion, is a mixture of gaseous and volatile matters, heated red hot by the heat disengaged in the process of combustion.

The process of respiration is a species of slow combustion, in which the carbon and other matter of the blood unites with the oxygen of the air. This species of combustion gives rise to the heat of the body of men and animals. This heat is called *animal heat.*

Fermentation is a chemical process that gives rise to heat.

4. *Pressure and percussion.*—Whenever a body is compressed so as to reduce its volume, heat is developed. The greater the compression, the greater the amount of heat developed. If gas be suddenly and violently compressed, the heat generated is sufficient to set fire to inflammable bodies. This subject was referred to in the article on Compressibility, in which the instrument used for inflaming tinder is figured. (See Fig. 4.)

Percussion is a source of heat. If a body, like a piece of metal, for example, be hammered, it soon becomes hot. It is percussion that causes the heat when a flint is struck against a piece of steel. In this case there is a piece of the steel detached and rendered red hot by the collision.

Explain the phenomena of combustion. What is flame? What is respiration? What kind of heat comes from respiration? What is fermentation? Explain compression as a source of heat. Illustrate. Explain percussion as a cause of heat.

5. *Friction.*—Friction is the resistance which one body offers to another when they are rubbed together. This resistance is accompanied with a great development of heat. In many cases, the friction is so great that the rubbing bodies are set on fire. In this way many savage tribes procure fire. Pieces of ice when rubbed together, generate heat enough to melt them. In machinery, the friction on axles often sets them on fire, especially when lubrication has been neglected.

Sources of Cold.

256. The principal sources of cold are: *fusion, vaporization, expansion of gases,* and *radiation of heat.*

1. *Fusion.*—When a body melts, it absorbs heat from the surrounding bodies, which becomes latent in the melted body.

2. *Vaporization.*—When a liquid passes to a state of vapor, it absorbs heat, which becomes latent in the vapor. Both of these causes of cold have been considered already.

3. *Expansion of gases.*—When a gas is compressed, it gives out heat, and conversely, when it expands it absorbs heat. This heat, it is, that acts to keep the particles asunder, and the further apart the particles are kept, the greater the amount of heat required.

Heat is the repulsive force that keeps a body in a gaseous state at all, or even in a liquid state.

If air be compressed in a condenser and then allowed to escape into the atmosphere, a slight cloud will be formed; this is due to the cold generated by the expanding air, which condenses the vapor in the air. This experiment illustrates the manner in which clouds are formed in the upper regions of the atmosphere.

Explain friction as a source of heat. (**256.**) What are the principal sources of cold? Explain fusion as a source of cold? Vaporization. Expansion of gases. *Explain the formation of a cloud when compressed air expands.*

4. *Radiation.*—Radiation produces cold, because radiation is nothing else than giving off heat.

The earth, and all bodies on its surface, are continually radiating heat. This is compensated during the day by the heat received from the sun; in fact, the amount received is greater than that given off. But at night the reverse holds true, and a greater amount is radiated than is received. This cooling of the earth's surface is, as has been stated, the cause of dew and frost.

It is often said that it freezes harder when the moon shines than when it is concealed by clouds. This is the case, but the moon has nothing to do with the freezing. The true explanation of the phenomenon is this: When the moon shines, it is generally cloudless, and the radiation goes on more rapidly, and of course a greater degree of cold is produced. On the contrary, when the moon is obscured, it is generally cloudy; now the clouds are good radiators of heat, and the heat that they send back to the earth is nearly or quite enough to compensate for that radiated from the earth; hence the process of freezing is either retarded or entirely prevented.

Plants are good radiators, hence they are more likely to be affected by frost than other objects. To protect them from frost, we cover them with mats, which prevent radiation, or rather radiate back the heat that the plants throw off.

Explain radiation as a cause of cold. *Illustrate. What effect has the moon on freezing? Why is it colder when the moon shines than when cloudy? Why are plants likely to be affected by frost? How are they protected?*

CHAPTER VI.

OPTICS.

I.—GENERAL PRINCIPLES.

Definition of Optics.

257. Optics is that branch of Physics which treats of the phenomena of light.

Definition of Light.

258. Light is that physical agent which, acting upon the eye, produces the sensation of sight.

Two Theories of Light.

259. Two theories have been advanced to account for the phenomena of light: *the Emission Theory*, and *the Wave Theory.*

According to the *emission theory*, light consists of infinitely small particles of matter, shot forth from luminous bodies with immense velocity, which, falling upon the retina of the eye, produce the sensation of sight. This is the theory of Newton and Laplace.

According to the *wave theory*, light consists of *waves*, or vibrations, transmitted through an impalpable medium

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(**257.**) What is Optics? (**258.**) What is Light? (**259.**) What two theories of light have been advanced? Explain the emission theory. Explain the wave theory.