"Truble is hard to bear"

governor-valve; *S*, the shaft by which the power is conveyed to the machinery. The cross-head, *a*, slides to and fro in a groove, and is fastened to the rod which works the piston in the cylinder *A*. The expansive force of the steam is thus communicated to *a*, thence to *I*, by which the crank is turned. The heavy fly-wheel renders the motion uniform (p. 23).

V. METEOROLOGY.

1. General Principles.—(1.) The air always contains moisture. The amount it can receive depends upon the temperature; warm air absorbing more, and cold air less. At 100° F., a cubic foot of air can hold nearly 20 grains of invisible water vapor; a reduction of 70° will cause nine tenths of that quantity to be condensed into visible droplets. When the air at any temperature contains all the vapor it can hold in an invisible state, it is said to be saturated; *any fall of temperature will then condense a part of the vapor.*

(2.) When air expands against pressure (*i.e.*, doing work in the expansion), its energy, being thus expended, ceases to be manifested as temperature. The warm air from the earth ascending into the upper regions, is thus rarefied and cooled. Its vapor is then condensed into clouds, and often falls as rain. Owing to this expansion of the atmosphere and the greater radiation of heat in the dry air of

the upper regions, there is a gradual diminution of the temperature as the altitude increases, the mean rate in the north temperate zone being about 1° for 300 feet.

2. Dew.[*]—The grass at night, becoming cooled by radiation, condenses the vapor of the adjacent air upon its surface. Dew will gather most freely upon the best radiators, as they will the soonest become cool. Thus grass, leaves, etc., receive the largest deposits. It will not form on windy nights, nor when there are clouds in the sky to reflect the heat radiated from the ground. In tropical regions the nocturnal radiation on clear nights is often so great as to render the formation of ice possible. In Bengal, water is exposed for this purpose in shallow earthen dishes resting on rice straw In parts of Chili, Arabia, etc., by its abundance, dew feebly supplies the place of rain. When the temperature of plants falls below 32°, the vapor is frozen upon them directly, and is called *white*, or *hoar-frost.*

3. Fogs are formed when the temperature of the air falls below the *dew-point*, *i. e.*, the temperature at which dew is deposited for a given degree of humidity. They are characteristic of low lands, rivers, etc., where the air is saturated with moisture.

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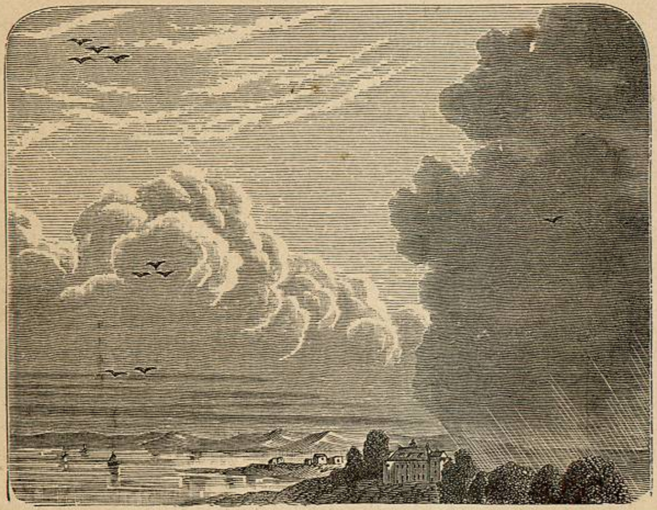
[*] Dew was anciently thought to possess wonderful properties. Baths in this precious liquid were said greatly to conduce to beauty. It was collected for this purpose, and for the use of the alchemists in their weird experiments, by spreading fleeces of wool upon the ground. Laurens, a philosopher of the middle ages, claimed that dew is ethereal, so that if we should fill a lark's egg with it and lay it out in the sun, immediately on the rising of that luminary, the egg would fly off into the air!

4. Clouds differ from fogs only in their elevation in the atmosphere. They are produced chiefly by the cooling due to expansion as currents of warm moist air rise high above the surface of the ground. In tropical regions they float only at great heights; in arctic regions, near the ground.

Fig. 189.



Different kinds of Clouds—one bird indicates the Nimbus, two birds the Stratus, three birds the Cumulus, and four birds the Cirrus cloud.

The *stratus* cloud is composed of broad, widely-extended cloud-belts, sometimes spread over the whole sky. It is the lowest cloud, and often rests on the earth, where it forms a fog. It is the night-cloud.

The *cumulus* cloud is made up of large cloud-masses looking like snow-capped mountains piled up along the horizon. It forms the summits of pillars of vapor, which, streaming up from the earth, are condensed in the upper air. It is the day-cloud. When of small size and seen near midday, it is a sign of fair weather.

The *cirrus* (curl) cloud consists of light, fleecy clouds floating high in air. It is composed of little needles of ice or flakes of snow.

The *cirro-cumulus* is formed by small rounded portions of cirrus cloud, having a clear sky between. Sailors call this a "mackerel sky." It accompanies warm, dry weather.

The *cirro-stratus* is produced when the cirrus cloud spreads into long, slender strata. It forebodes rain or snow.

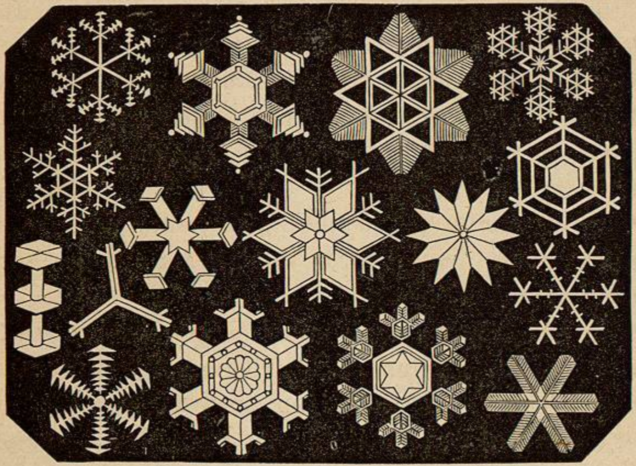
The *cumulo-stratus* is due to increase in thickness of the cumulus clouds, becoming denser and darker below, while the upper parts flatten out and thus appear like the stratus clouds. They often precede thunder-storms.

The *nimbus* cloud is that from which rain falls. It may be produced by the thickening of any of the forms just described.

5. Rain is the product of rapid condensation of vapor in the upper regions. At a low temperature the vapor is frozen directly into *snow*. This may melt before it reaches the earth, and fall as rain or sleet. A sudden draught of cold air into a heated ball-room has produced a miniature snow-storm. The wonderful variety and beauty of snow-crystals are illustrated in the figure.

Rain always warms the air. Vapor can not condense without giving out as temperature the energy which had kept its molecules apart in the vaporous state.* It has been estimated that the heat given to the west coast of Ireland by rain-fall is equivalent

FIG. 190.



Snow-crystals.

to half of that derived from the sun. At Cherrapoonjee, in India, the annual rain-fall is four times as great as on the coast of Ireland.

6. Winds are produced by variations in the tem-

perature of the air. The atmosphere at some point is heated and expanded; it rises and colder air flows in to supply its place. This produces currents. The *land and sea breezes* of tropical islands are caused by the unequal specific heat of land and water. During the day the land becomes more highly heated than the water, and hence toward noon a sea-breeze sets in from the ocean, and is strongest in the afternoon. At night the land cools faster than the water, and so a land-breeze sets out from the land, and is strongest after midnight.

Trade-winds are so named because by their regularity they favor commerce. A vessel on the Atlantic Ocean will sometimes, without shifting a sail, set steadily before this wind from Cape Verde to the American coast. The air about the equator is highly heated, and, rising to the upper regions, flows off north and south. The cold air near the poles sets toward the equator to fill its place. If the earth were at rest this would make an upper current flowing from the equator, and a lower current flowing toward it. As the earth is rotating on its axis from west to east, the under current starting from the poles is constantly coming to a part moving faster than itself. It therefore lags behind. When it reaches the north equatorial regions, it lags so much that it becomes a current from the north-east, and in the south equatorial regions a current from the south-east.

7. Ocean Currents are produced in a similar manner. The water heated by the vertical sun of

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* "A gallon of water weighs ten pounds, and if spread out so as to form a layer an inch thick, it would cover about two square feet of space. To cover a square mile an inch in depth, 60,000 tons of rain are required, or 12,000,000 gallons. In the condensation of the vapor needed to produce a single gallon, heat enough is given out to melt 75 pounds of ice, or to make 45 pounds of cast-iron white-hot. An inch of rain-fall on each square mile hence implies an evolution of heat sufficient to melt a layer of ice spread over the ground 8 inches thick, or to liquefy a globe of iron 130 feet in diameter, or a rod of it a foot in thickness and 260 miles in length."

the tropics rises and flows toward the poles. The Gulf Stream carries the heat of the Caribbean Sea across the Northern Atlantic to the shores of Scotland and Norway. This great stream of warm water, flowing steadily through the cold water of the ocean, rescues England from the snows of Labrador. Were it not for the barrier of a chain of mountains connecting North and South America, Great Britain would be condemned to arctic glaciers.

8. Adaptations of Water.—The great specific heat of water exercises a marked influence on climate. It tends to prevent sudden changes of weather. In the summer it absorbs vast quantities of heat, which it gives off in the fall, and thus moderates the approach of winter. In the spring the melting ice and snow drink in the warmth of the sunbeam. Since so much heat is required to melt the ice and snow, they dissolve very slowly, and thus ward off the disastrous floods which would follow, if they passed quickly into the liquid state.

Water contains air, which is necessary for the support of animal life. This air not only makes it available as a home for fish and other creatures that inhabit the water, but also makes the change from water to steam more gradual. Much of it is driven off when the water is heated. When water has been carefully deprived of the air usually held in solution, it is liable to violent commotion at any moment when it is heated above 212° F. With such water every stove-boiler would need a thermometer. A tea-kettle would require as careful watching as a

steam-engine, and our kitchens would witness frequent and perhaps disastrous explosions.

Water, like other liquids, expands with heat and contracts, on cooling, down to 39° F. At this temperature it has its greatest density. On cooling it further, there is slight expansion until 32° F. is reached, when it rapidly expands about one tenth in freezing.* This expansion is due to the formation of crystals. These, on account of their angular form, require more space than liquids do. It is thought that between 39° and 32° crystallization is going on among the molecules. As soon as a few crystals are definitely formed, each serves as a nucleus around which others gather, and the process becomes then far more rapid. Certain metals, such as bismuth and iron, act like water in this respect, and are hence well fitted for making sharp castings, filling every crevice of the mold as they expand in crystallizing.† This crystallization of water is of great importance in connection with the freezing of our lakes and rivers. Were it not crystalline when

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* Since ice when it melts contracts, pressure aids in liquefaction and so lowers the melting-point. In descending over the rough surface of a mountain slope, glacier ice is subjected to alternate pressure and extension. The pressure melts it and makes the mass slide farther down. Passing over some ledge it snaps, producing great fissures. When the walls of these come into contact they freeze together again, but only to be re-melted.

† Fit a small flask with a cork, through which passes an upright glass tube. Fill with colored water. Apply heat to the flask until the liquid runs over the top of the tube. This shows the expansion by heat. Now apply a freezing mixture to the flask, and at first the liquid in the tube falls, but soon begins to rise. When it runs over as before, apply heat and it shrinks back again. Thus *cold will expand and heat contract it.* When water is at its maximum density (about 39°) expansion sets in alike, whether you heat or cool it.

frozen, the water at the surface during severe weather, radiating its heat and becoming chilled, would contract and fall to the bottom, while the warm water below would rise to the top. This process would continue until the freezing-point was reached, when the whole mass would solidify into ice. Our lakes and rivers would freeze solid every winter. This would be fatal to all animal life in it, at least of the higher orders, such as fish. In the spring the ice would not, as now, buoyant and light, float and melt in the direct sunbeam, but, lying at the bottom, would be protected by the non-conducting water above. The longest summer would not be sufficient to thaw the deeper bodies of water. As it is, the ice is formed at the surface, and there it floats, protecting the water beneath from further reduction of temperature.*

Water, in freezing, has a tendency to free itself from salts and other substances dissolved in it. Thus, melting ice furnishes a means of obtaining fresh water in Arctic regions. If a barrel of vinegar freeze, we shall find much of the acid collected in a mass about the center of the ice.

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* Water distills from the ocean and land as vapor, at one time cooling and refreshing the air, at another moderating its wintry rigor. It condenses into clouds, which shield the earth from the direct rays of the sun, and protect against excessive radiation. It falls as rain, cleansing the air and quickening vegetation with renewed life. It descends as snow, and, like a coverlet, wraps the grass and tender buds in its protecting embrace. It bubbles up in springs, invigorating us with cooling, healing draughts in the sickly heat of summer. It purifies our system, dissolves our food, and keeps our joints supple. It flows to the ocean, fertilizing the soil, and floating the products of industry and toil to the markets of the world. (See "Chemistry," p. 56-63.)

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21 F. 70 − 32 = 38 ÷ 1$\frac{8}{10}$

F 1 = 1$\frac{8}{10}$ 1 : 1$\frac{8}{10}$ :: 38 ::

PRACTICAL QUESTIONS.

1. Why will one's hand, on a frosty morning, freeze to a metallic door-knob sooner than to one of porcelain? porcelan is no better [illegible]

2. Why does a piece of bread toasting curl up on the side exposed to the fire? the vapor escapes from the side.

3. Why do double windows protect better than single ones from the cold? Glass is a non conductor

4. Why do furnace-men wear flannel shirts in summer to keep cool, and in winter to keep warm? what keeps out heat, keeps out [illegible]

5. Why do we blow our hands to make them warm, and our soup to make it cool? Hands colder than breath, soup is warmer

6. Why does snow protect the grass in winter? keeps out warm than

7. Why does water "boil away" more rapidly on some days than on others? [illegible] temperature of atmosphere

8. What causes the crackling sound of a stove when a fire is lighted?

9. Why is the tone of a piano higher in a cold room than in a warm one? Because cold expands [illegible] heat contracts

10. Ought an inkstand to have a large or a small mouth? a small one

11. Why is there a space left between the ends of the rails on a railroad track? to allow the ~~ex~~ expansion of the metal

12. Why is a person liable to take cold when his clothes are damp? the absorption of the heat body

13. What is the theory of corn-popping? heat expands the air inside and make it break it

14. Could vacuum-pans be employed in cooking? no,

15. Why does the air feel so chilly in the spring, when snow and ice are melting? because it absorves the energy

16. Why, in freezing ice-cream, do we put the ice in a wooden vessel and the cream in a tin one?

17. Why does the temperature generally moderate when snow falls?

18. What causes the singing of a tea-kettle? *Ans.* The escaping steam is thrown into vibration by friction against the spout.

19. Why does sprinkling a floor with water cool the air? absorbs the heat

20. How low a degree of temperature can be marked by a mercurial thermometer? 39° degrees.

70 − 32 = 38 ÷ 1$\frac{8}{10}$ = 1

21. If the temperature is 70° F., what is it C.? 21$\frac{1}{10}$

22. Will dew form on an iron bridge? yes On a plank walk? not so much

23. Why will not corn pop when very dry?

24. When the interior of the earth is so hot, why do we get the coldest water from a deep well? well not deep enough, from

25. Ought the bottom of a tea-kettle to be polished? no

26. Which boils the sooner, milk or water? milk

27. Is it economy to keep our stoves highly polished? polish not save

28. If a thermometer be held in a running stream, will it indicate the same temperature that it would in a pailful of the same water?

29. Which makes the better holder when one wishes to protect his hands from a hot dish, woolen or cotton? woolen

30. Which will give out the more heat, a plain stove or one with ornamental designs?

31. Does dew fall? yes

32. What causes the "sweating" of a pitcher?

33. Why is evaporation hastened in a vacuum?

34. Does stirring the ground around plants aid in the deposition of dew?

35. Why does the snow at the foot of a tree melt sooner than that in the open field?

36. Why is the opening in a chimney made to decrease in size from bottom to top?

37. Will tea keep hot longer in a bright or a dull tea-pot?

38. What causes the snapping of wood when laid on the fire? *Ans.* The expansion of the air in the cells of the wood.

39. Why is one's breath visible on a cold day?

40. What gives the blue color to air? *Ans.* The particles floating in it reflect the blue light of the sunbeam.

41. How does the heat at two feet from the fire compare with that at four feet?

42. Why does the frost remain later in the morning upon some objects than upon others?

43. Is it economy to use green wood?

44. Why does not green wood snap?

45. Why will a piece of metal dropped into a glass or porcelain dish of boiling water increase the ebullition?

46. Which can be ignited the more quickly with a burning-glass, lampblack or white paper?

47. Why does the air feel colder on a windy day?

48. Could a burning-lens be made of ice?

49. Why is an iceberg frequently enveloped by a fog?

50. Would dew gather more freely on a rusty stove than on a bright kettle?

51. Why is a clear night colder than a cloudy one during the same season?

52. Why is no dew formed on cloudy nights?

53. Why will "fanning" cool the face?

54. How are safes made fire-proof?

55. Why can you heat water more quickly in a tin than a china cup?

56. Why will a woolen blanket keep ice from melting?

57. Does dew form under trees?

58. What is the principle of heating by steam?

59. What is the cause of "cloud-capped" mountains?

60. Show how the glass in a hot-house acts as a trap to catch the sunbeam.

61. Does the heat of the sun come in through our windows?

62. Does the heat of our stoves pass out in the same way?

63. The top of a mountain is nearer the sun, why is it not warmer?

64. What is hoar-frost? *Ans.* Frozen dew.

65. Why will a slight covering protect plants from frost? *Ans.* Because it prevents radiation.

66. Why is there no frost on cloudy nights? *Ans.* The clouds act like a blanket, to prevent radiation and keep the earth warm.

67. Can we find frost on the windows and on the stone flagging the same morning?

68. Why will not snow "pack" into balls except in mild weather?

69. Why is the sheet of zinc under a stove so apt to become puckered? Heat

70. Why does a mist gather in the receiver of the air-pump as the air becomes rarefied?

71. Why are the tops of high mountains in the tropics covered with perpetual snow?

SUMMARY.

Heat is produced by longer and less refrangible waves and slower vibrations of ether than those which cause light. Solar energy may be radiated, reflected, refracted, absorbed, and polarized, whether manifested as light or heat. If we elevate the temperature of a body sufficiently, such as a piece of platinum, we can cause it to emit rays of both heat and light. A body which allows the radiant heat to pass through it easily is styled *diathermanous*; rock-salt is such a body, being to heat-rays what glass is to light-rays. The sun is the principal source of heat. But heat can be obtained by chemical and mechanical means. In burning coal we secure it by the former method. Mechanical energy may be changed directly into heat, as in striking fire with flint and steel, and in hammering a bullet on an anvil until it is hot. According to Joule's law, 772 feet fall of a given weight corresponds to 1° of rise of temperature in the same weight of water.

Among the physical effects of heat are a change of temperature, expansion, liquefaction, vaporization, and evaporation. The heat-force increases the kinetic energy of the molecules, thus elevating the temperature; and the increased vibration of the molecules causes an expansion of the body. The latter is so uniform in certain substances, such as mercury, that it is used to indicate changes of temperature, as in the thermometer. The expansion of the metals by heat is turned to account in many art processes. The walls of a gallery in the Conservatoire des Arts et Metiers in Paris, had begun to bulge. To remedy this, iron rods were passed across the building and screwed into plates on the outside of the walls. By heating the bars, they were expanded, when they were screwed up tightly. Being then allowed to cool, they contracted, thus drawing the walls back toward a perpendicular. The same has been done for weakened walls in many other places.

Heat is the great antagonist of cohesion. The liquid and gaseous states of bodies depend on its relative presence or absence (absolute cold is as yet only a theoretical condition, all bodies with which we are familiar being relatively warm). When the heat-force nearly balances that of cohesion, the body breaks down into a liquid, and when the repellent fairly triumphs, the particles fly off as a gas. Immediately before and after each of these marked changes, viz., of a solid to a liquid and of a liquid to a gas, the thermometer indicates a constant temperature. Thus water from melting ice affects the thermometer just as the ice does, and steam is no hotter than the boiling water. The heat which, in these processes, becomes hidden from the thermometer is called latent, though we now know that, having been occupied in doing internal work, it has merely become potential, and can be readily turned again into kinetic energy. The so-called latent heat of water is only the potential heat-energy of the separated molecules, which will reappear the instant the molecules collapse and come once more within the grasp of cohesion. On this principle is based the method of heating by steam. Evaporation is a slow change to vapor that takes place at all temperatures, but may be greatly increased by a diminution of pressure, as in a vacuum. It is a cooling process, and is practically applied to the manufacture of ice.

By the subtraction of heat, *i. e.*, by cold, and by the addition of pressure, which antagonizes the repellent heat-force, gases may be liquefied and even congealed, the transparent carbonic-acid gas thus becoming a snowy solid. What were formerly called the "permanent gases" (oxygen, hydrogen, etc.), have been liquefied by means of the cold produced by their rarefaction when they were suddenly released from a pressure of two or three hundred atmospheres.

Heat is *conducted* from molecule to molecule of a body, *radiated* in straight lines through air (or space), and *circulated* by the transference of heated masses through a change of specific gravity due to expansion. The first method is characteristic of solids, and the third of liquids and gases. The elastic force of steam increases when it is confined and a higher temperature is reached. The steam-engine utilizes this principle. There are two forms of this machine, the high-pressure and the low-pressure, according as the waste steam is ejected into the air or condensed in a separate chamber. The phenomena of dew, rain, etc., depend upon the fact that a change from a higher to a lower temperature causes the air to deposit its moisture.

HISTORICAL SKETCH.

Democritus, the originator of the Atomic Theory, held that heat consists of minute spherical particles radiated rapidly enough to penetrate every substance. Until very recently, heat and light were thus reckoned among the Imponderables, *i. e.*, matter which has no weight. Aristotle considered heat more a condition than a substance. Bacon, in his "Novum Organum," wrote: "Heat is a motion of expansion." Locke, half a century later, said: "Heat is a very brisk agitation of the insensible parts of an object, which produces in us the sensation from whence we denominate the object hot, so that what in our sensation is heat, in the object is motion."

The material view, however, held its ground. At the beginning of the 18th century, Stahl elaborated a theory that a buoyant substance called *phlogiston* is the principle of heat, and that when a body burns, its phlogiston escapes as fire. In 1760, Dr. Black investigated and made known the principles of what he termed *latent* heat, *i. e.*, heat which becomes hidden when ice is turned into water or water into steam. Priestley discovered, in 1774, and Lavoisier afterward developed, the modern view of combustion. But the latter philosopher then advanced the theory that heat (caloric) is an actual substance, which passes freely from one body to another and combines at

18[illegible] Grove [illegible]
Peripatetic [illegible]
[illegible] Classic
Aristotle [illegible]

pleasure. Toward the close of the 18th century, Benjamin Thompson, better known as Count Rumford, a native of Woburn, Mass., but in the employ of the Elector of Bavaria, proved the convertibility of force. "He first took the subject," as Professor Youmans well remarks, "out of the domain of metaphysics, where it had been speculated upon since the time of Aristotle, and placed it on the true basis of physical experiment."

Soon the scientific world seemed to be ripe for this discovery, and it appears to have sprung up spontaneously in men's thoughts every-where. Mayer, a physician of Germany, and Grove, of England, proved the mutual relation of the forces, the latter first using the term "Correlation of Forces," since changed to Conservation of Energy. Joule discovered the law of the "Mechanical Equivalent of Heat," about 1843. In his famous experiments, he used pound-weights made to fall through a measured distance. Cords were attached to them, so that, as they fell, they turned a paddle-wheel placed in a box of water. Other liquids were used instead of the water. The rise of temperature in the liquids was carefully marked. The loss by friction in the apparatus was estimated, and so, at last, the dynamical theory of heat was fully demonstrated. Names of philosophers well known to us, such as Henry, Helmholtz, Faraday, Thomson, Maxwell, Le Conte, Youmans, Stewart, and Tyndall, are associated with the final establishment of this theory.

Consult, on this interesting subject, Tait's "Recent Advances in Physical Science"; Stewart's "Treatise on Heat"; Tyndall's "Heat a Mode of Motion"; Maxwell's "Theory of Heat"; Thurston's "History of the Growth of the Steam-engine"; Buckley's "Short History of Natural Science"; Smiles' "Lives of Boulton and Watt"; Youmans' "Correlation of the Physical Forces"; "Read and the Steam-engine"; "American Cyclopedia," Art. "Steam-engine"; "Popular Science Monthly," Vol. XII., p. 616, Art. "Liquefaction of Gases"; Scott's "Meteorology," and Thomson's "Cruise of the Challenger."

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conetic
potential – the power

IX.

MAGNETISM.

> "Next in order I will proceed to discuss by what law of Nature it comes to pass that iron can be attracted by that stone which the Greeks call the Magnet, from the name of its native place, because it often produces a chain of [iron] rings hanging down from it. Thus you may see five and more suspended in succession and tossing about in the light airs, one always hanging from the other and attached to its lower side, and each in turn, one from the other, experiencing the binding power of the stone; with such a continued current, its force flies through all."