which passes a metallic wire, terminating in a button. The wire is connected by a chain with the outer covering of a Leyden jar. When the circuit is completed by touching the button of the apparatus with that of the jar, a spark is given off, and heat enough developed to inflame the ether.

Fig. 277.

This experiment succeeds with a very small jar, or even a simple spark from the prime conductor. The experiment may be made more interesting by standing upon the electrical stool (Fig. 261), and inflaming the ether with the finger. The ether may be inflamed by a spark from a piece of ice held in the hand.

When an electrical battery is discharged through a fine metallic wire, it may be melted or even volatilized, according to the power of the battery.

In performing this experiment it will be best to use the *universal discharger*. This instrument and the manner of using it, are shown in Fig. 278. The discharger consists of two copper wires, *A* and *B*, mounted upon glass supports. The wires can slide freely through the rings that hold them, and can furthermore be turned about hinge

What variation may be made in it? How may a wire be melted? *Explain the construction and use of the universal discharger.*

joints, so as to bring their buttons as near as may be desired to any body that is placed upon the stand, *M*.

To melt a wire by electricity, we attach it to the two inner buttons at *i*, then connect one of the wires, *A*, for example, with the exterior coating of the battery, and complete the circuit by connecting *B* with the button of one of the jars of the battery. This is

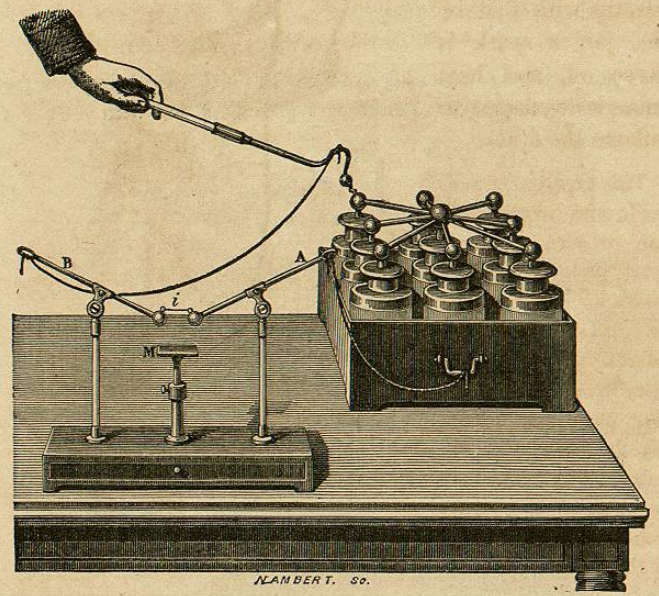

Fig. 278.

effected in the manner shown in the figure, the connecting chain being managed by means of a hook with a glass handle. At the instant of contact, the wire, if fine enough, is melted into globules, and even volatilized, that is, reduced to vapor, which disappears in the air.

When the wire is a little larger, it simply becomes red hot and gives forth a brilliant light; if still larger, it becomes heated without being luminous. Fine and short wires may be melted under

Explain the experiment of melting a wire in detail.

water in the same manner as in air, but the experiment is more difficult to make.

Mechanical Effects of Electricity.

396. The MECHANICAL EFFECTS OF ELECTRICITY are manifested when large charges of electricity are passed through imperfect conductors. They consist of violent expansions, with tearing, fracturing, and the like.

These effects are generally exhibited by placing the body upon the plate, *M*, of the universal discharger (Fig. 278), and then passing a

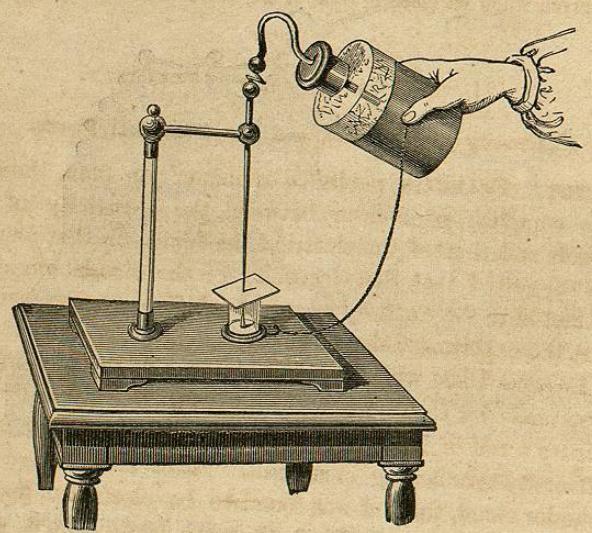

Fig. 279.

powerful charge from a battery through it. In this way a small block of wood may be torn to splinters in an instant.

Fig. 279 represents an apparatus by means of which a hole may be torn in a card by using a single Leyden jar. A card is placed at the top of a glass cylinder, beneath which is a wire projecting from

(**396.**) What are some of the mechanical effects of electricity? *How exhibited? Explain the method of perforating a card by electricity.*

a metallic plate. The plate connects by a chain with the exterior coating of the jar. Above the card is a second wire which is insulated in the manner shown in the figure. When the circuit is completed, by touching the upper wire with the button of the jar, a shock follows, and the card is found to have been pierced as if run through by a needle or pin.

To pierce a plate of glass requires a large battery. The battery belonging to Harlem Museum (Art. 394), is capable of piercing a book of four hundred pages.

A partial account of the chemical effects of electricity has been given in speaking of the electrical cannon. More on this subject will be given when we come to treat of the effects of the Voltaic pile.

VI.—ATMOSPHERIC ELECTRICITY.

Identity of Lightning and the Electrical Spark.

397. FRANKLIN published a memoir in 1749, showing the complete parallelism between the electricity of the clouds and that of the electrical machine. In that memoir he suggested that the electricity of the clouds might be attracted to the earth by means of points, and recommended that the experiment should be made.

In accordance with that suggestion, the experiment was first made by DALIBARD, in May, 1752. He erected in his garden a rod of iron about forty feet high, having its upper extremity terminating in a point. After the passage of a thunder cloud, the rod was found to be electrified, and for the space of fifteen minutes sparks were drawn from it, which were used in charging several Leyden jars.

About a month later, FRANKLIN, without any knowledge of the discovery of DALIBARD, succeeded in attracting electricity from a cloud to the earth. He raised a silken kite, just before a coming thunder storm. The string of

Of piercing a plate of glass. (**397.**) Who first showed the identity of lightning and electricity? Explain DALIBARD'S experiments. Explain FRANKLIN'S experiments.

the kite was of hemp; attached to the lower end of it was a small key, and fastened to the key was a silken cord, by which the kite might be insulated. It was only after the string became damp from the falling rain that the key showed signs of being electrified. He was at last rewarded by obtaining an electric spark. So great was his joy that he could not refrain from bursting into tears.

The complete identity between lightning and the electric spark was thus established, and all, even DALIBARD himself, unite in attributing to FRANKLIN the honor of the discovery.

Atmospheric Electricity.

398. The existence of atmospheric electricity is not confined to clouds alone, for it often exists in the atmosphere when no trace of a cloud is visible. In this case the electricity is positive. It is most abundant in open spaces and at considerable elevations. In houses, in the streets, under trees, and in sheltered localities, no trace of free electricity is discoverable. During storms the electricity of the air is sometimes positive and sometimes negative. All clouds are supposed to be electrified, some positively and some negatively.

The electrical condition of clouds may be established by metallic rods, by kites, or by small balloons held by a string in the hand.

The electrical state of the atmosphere may be determined in a great variety of ways. M. BECQUEREL employed for this purpose the gold-leaf electrometer shown in Fig. 259. Instead of the button he used a stem of metal, attaching to its upper end a fine and flexible wire. To the second extremity of the wire he fastened an arrow,

(**398.**) What is the nature of the electricity of the air? Where is it most abundant? What is the state of the atmosphere during storms? How is the electrical condition of the clouds determined? *How is the electrical state of the atmosphere determined?*

which, being shot from a bow, ascended into the atmosphere, drawing the wire with it. When the arrow was shot directly upwards, the divergence of the gold leaves indicated the existence of free electricity, and the nature of this electricity was tested as already explained.

Lightning and Thunder.

399. LIGHTNING is nothing else than an elongated electrical spark, which passes between two differently electrified clouds when brought near each other. Sometimes a discharge takes place between a cloud and the earth; this is called a *thunderbolt.*

A flash of lightning is often of great length, and as it takes place along the line of least resistance, it generally follows a zig-zag path, as is often the case with the spark from a Leyden jar. When a flash of lightning is seen in the lower regions of the atmosphere, it has a brilliant white color; but in the higher regions, where the air is rarefied, it assumes a violet hue, similar to that of the electric egg (Art. 382).

THUNDER is the sound which follows a flash of lightning. It is due to vibrations caused by the passage of the spark through the air.

Thunder is not heard till an appreciable time after the flash is perceived. This arises from the fact that light travels with immense velocity, reaching the eye instantaneously, whilst sound travels more slowly, and only reaches the ear after a sensible interval of time. The distance of a clap of thunder may be ascertained by counting the number of seconds between the flash and the report, and allowing five seconds to a mile.

The intensity of the sound diminishes as the distance becomes greater: near by, it is sharp and rattling, like boards falling one

(**399.**) What is Lightning? What is a thunderbolt? *Why is the flash often zig-zag in its shape? What is the color of the flash?* What is Thunder? *Why is the thunder only heard after an appreciable time? How may the distance of the flash be determined? What effect has distance on the sound of thunder?*

upon the other; at a greater distance, it is dull and prolonged in a low rumble of varying intensity.

The rattling or rolling of thunder is differently explained. By some it is said to be due to a succession of echoes from the clouds and the earth. Others regard lightning, not as a single spark, but as a succession of sparks, each giving rise to separate explosions that succeed each other so rapidly as to produce a continuous rumbling sound. Others again attribute the rolling of thunder to the zig-zag course of the lightning, the sound from different points of the zig-zag path reaching the ear in times proportional to their distances. In this way the sounds from different points are superposed irregularly, giving rise to irregularity in the resulting sound.

The Thunderbolt.

400. A THUNDERBOLT is a discharge of electricity between a cloud and the earth.

When an electrified cloud passes near the earth, it acts upon it by induction, repelling the fluid of the same name and attracting that of an opposite name. As soon as the tension of the two electricities becomes greater than the resistance of the intervening air, a spark or flash passes, and the thunderbolt is said *to fall*, or the lightning *to strike*. The flash generally passes from the cloud to the earth, but sometimes the reverse is the case. The attraction between the two electricities increases as the distance diminishes. Hence it is that elevated objects are most likely to be struck, such as spires, high trees, lofty buildings, and the like. Good conductors, like metals, moist bodies, trees, and the like, are more likely to be struck than bad conductors. Hence the danger of taking refuge under a tree in a thunder storm.

Effects of the Thunderbolt.

401. The effects of the thunderbolt are extremely various and wonderful. It crushes or fractures bad conductors, inflames combustible bodies, melts metals, reverses the poles of magnets, and often kills men and animals. Sometimes it falls slowly in the form of a globe of fire, and then explodes with a noise like a battery of cannon. It is this form of lightning that is most likely to inflame the edifices which it chances to strike.

How is the rattle or roll of thunder accounted for? (**400.**) What is a Thunderbolt? *Why does lightning strike? Explain the phenomenon. What bodies are most likely to be struck? What least likely?* (**401.**) *Describe the effects of the thunderbolt.*

It is said that a ball of electrical fire fell, in 1718, near Brest, striking a house with such force that the roof sprung up as if a mine had been exploded beneath it, and the stones of the walls were scattered in all directions, some being carried to the distance of a hundred and fifty feet.

The thunderbolt is often accompanied by a peculiar sulphurous odor, which is due to the oxygen of the air becoming electrified, forming a product called *ozone*.

Considering the fearful character of the thunderbolt, but few individuals perish from it. It is estimated that no more than twenty deaths a year occur from this cause throughout the whole of France, which is only one out of two millions of inhabitants.

Means of Safety.

402. It is recommended to those who are fearful of the effects of lightning, that they should wear clothing of silk, or still better, that they should sit in chairs insulated by glass legs or upon a thick plate of this material. They should also keep as far as possible from conductors, particularly the metals. When thus insulated, even if struck, they can only experience a slight shock, which can hardly prove fatal.

In some of the French villages it is customary to ring bells during a storm, with the idea of driving away the cloud, and avoiding the hail which so frequently accompanies thunder storms. This does no good, but simply exposes the bell ringer to additional danger, for high edifices, like church spires, are by far the most likely to be struck, and as the bell ropes are conductors of electricity, the danger to those who hold them is much increased.

Example. What is the cause of the peculiar odor that accompanies lightning? (**402.**) What are some of the methods of protection from lightning?

The Return Shock.

403. The RETURN SHOCK is a violent, and often fatal shock, felt by men and animals at a great distance from the place where the lightning strikes. (See Fig. 280.)

This phenomenon is due to the inductive influence exerted by an electrified cloud upon bodies beneath it, which are all strongly charged with electricity contrary to that of the cloud. Now if a discharge takes place at any point, the cloud returns to its neutral state, induction ceases instantly, and all of the bodies electrified by induction instantly return to a neutral state. The suddenness of this return is what constitutes the return shock.

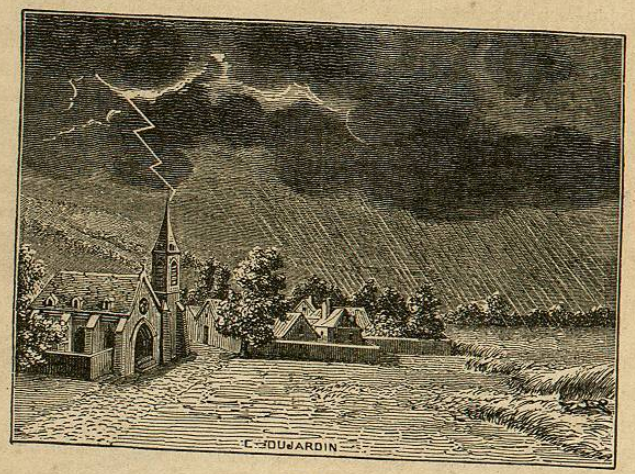

Fig. 280.

The return shock may be illustrated on a small scale, by placing a living frog near an electrical machine in motion. Every time that the machine is discharged by placing the finger upon it, the frog experiences a shock, which is nothing else than the return shock above described.

(**403**.) What is the Return Shock? *Explain its cause. How illustrated?*

Lightning-rods.

404. A LIGHTNING-ROD is a rod of metal, placed upon a building or ship, to preserve it from the effect of lightning, as shown in Fig. 281.

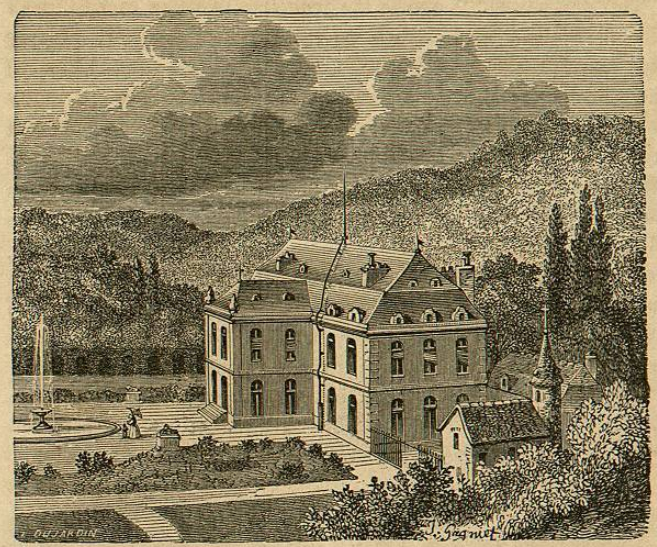

Fig. 281.

A lightning-rod should fulfill the following conditions:

1. It should be of sufficient size.

A copper rod of a half inch in diameter, or an iron one of three fourths of an inch in diameter, is large enough to protect any building.

2. If made of more than one piece, the parts should be screwed or welded together, to avoid defective joints.

(**404**.) What is a Lightning-rod? What is the first condition that a lightning-rod should fulfill? *Illustrate.* Second condition?

3. It should terminate above in a single platinum point. The point should be of platinum that it may not be fused. It also prevents the point from rusting.

4. The rod should be carried down into the earth till it meets with a good conducting medium, such as a layer of wet or moist earth.

When no such medium can be reached, a pit should be dug, and after the lower end of the rod has been carried to the bottom, it should be nearly filled with some good conductor, as coke.

The lightning-rod was invented by FRANKLIN, who thought that its protective action consisted in drawing off the electricity from the cloud, and conducting it to the earth. The real explanation of its utility is just the reverse. The cloud acts by induction upon the earth, repelling the electricity of the same name as that in the cloud, and attracting that of an opposite name, which accumulates upon the bodies under the cloud. Now, by arming a body with metallic points communicating with the earth, we permit a flow of electricity from the earth to the cloud. This flow not only prevents the accumulation of electricity upon the body, but it tends gradually to neutralize the electricity of the cloud itself, and thus the rod acts in a double way to prevent the body from being struck.

Electrical Meteors.

405. A METEOR is any atmospheric phenomenon; thus, wind, rain, snow, hail, thunder, and lightning are meteors. Besides thunder and lightning, three other meteors are attributable either wholly or in part to electricity; these are: *hail*, *tornados*, and the *aurora borealis*.

Hail.

406. HAIL consists of globules of ice which fall from the clouds. The globules consist of a coating of ice, disposed

Third condition? Fourth condition? *Who invented the lightning-rod? Explain its mode of action.* (**405.**) What is a Meteor? Mention some of them. (**406.**) What is Hail?

about a central nucleus of compact snow. They are called *hailstones*. Hailstones sometimes are very large, being not infrequently as large as a pigeon's egg, and it is said they sometimes weigh several ounces.

A fall of hail is often preceded by a noise like that of rattling nuts in a bag. This noise is attributed to collisions between the hailstones. A hailstorm is always accompanied by electrical phenomena, and thunder generally precedes or accompanies the fall of hail. From this circumstance it is inferred that hailstorms are in some way due to electrical action. As yet no satisfactory theory has been advanced to account for the formation of hailstones, and especially those enormous ones that are sometimes seen.

VOLTA supposed them to be formed between two clouds oppositely electrified, and that they were alternately repelled from one to the other, like electrical puppets, during which time they were continually increasing in size by congealing the moisture of the clouds upon their surface, till at last they became heavy enough to break through the lower cloud and descend to the earth. This theory is now rejected.

The Tornado.

407. A TORNADO is a violent whirlwind, attended with rain, thunder, and lightning. Tornados often travel considerable distances, overturning buildings and uprooting trees; they are accompanied with a noise like that of heavily-loaded carts driven over a stony road. The flashes of lightning and balls of electrical fire that accompany tornados, indicate their electrical origin.

Two species of tornado are recognized: *terrestrial* and *marine*, according as they take place on land or on water. The latter class present remarkable phenomena. The rotary force of the wind raises the water in the form of a cone, whilst a second cone forms in the cloud, having its apex downwards. These cones move to meet each other, forming a column of water reaching from the ocean to the

Describe a hailstone. *Explain the rattling sound preceding a hailstorm. What was* VOLTA'S *theory of the formation of hail?* (**407.**) What is a Tornado? Why is it regarded as of electrical origin? *How many species of tornados?*

cloud. In this form the column of fluid is called a *water-spout*. When a water-spout strikes a ship, it does immense damage.

The Aurora Borealis.

408. The AURORA is a luminous phenomenon, which appears most frequently about the poles of the earth, and more particularly about the *boreal* or northern pole, whence its name.

At the close of twilight, a vague and dim light appears in the horizon in the direction of the magnetic meridian. This light gradually assumes the form of an arch of a pale yellowish color, having its concave side turned towards the earth. From this arch streams of light shoot forth, passing from yellow to pale green, and then to the most brilliant violet purple. These rays or streams of light generally converge to that point of the heavens which is indicated by the dipping needle, and they then appear to form a fragment of an immense cupola, as shown in Fig. 282.

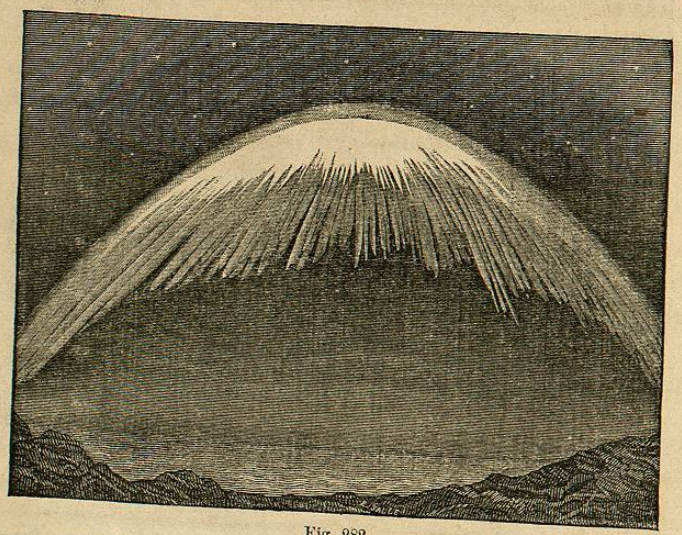

Fig. 282.

What is a water-spout? (408.) What is the Aurora? *Describe it.*

Since the aurora is always accompanied by a disturbance of the magnetic needle, and is generally arranged in the direction of the dip, and because the chemical action of electricity is accompanied by precisely analogous phenomena, it is inferred that it is due to electrical action. Such is at present the generally received belief.

Why is it regarded as of electrical origin?