emitting a light of dazzling brightness. If the points are slightly separated, the current still continues to pass between them, and the light takes the form of a luminous arch, called the *voltaic arch*. In this experiment the point connected with the positive pole wastes away, whilst the other increases in size; hence we conclude, that particles of carbon are transported from the former to the latter; this explains how the current continues to pass in spite of the interval which separates them.

The intensity of the *electrical light* is very great. A battery of 48 small couples furnishes a light equal to that of 572 wax candles; with 100 couples a light is produced so intense as to dazzle the eyes, and with 600 couples the intensity is such as to render it as impossible to look at it, as it is to look at the sun.

In 1844, Foucault first made use of the electrical light instead of that of the sun, to illuminate the solar microscope. Since then, many attempts have been made, and with some success, to apply it to purposes of general illumination. Fig. 287 represents an apparatus employed for the purpose of illumination. The battery is contained in the interior of a cast-iron pedestal, upon which is erected a column of the same material. At the top of the column are two carbon points, one connected with each pole of the battery by copper wires, insulated by gutta percha coverings.

Chemical Effects.

420. The most important chemical effects produced by galvanic electricity, are the decomposition of bodies traversed by it, and the transportation of their elements.

In order to understand the chemical effects, we must explain the meaning of certain terms employed in chemistry.

Oxydes are *generally* compounds of oxygen with the metals. Thus, iron rust is an oxyde of iron, that is, it is a compound of oxygen and iron; vermilion is an oxyde of lead; potash is an oxyde of potassium, and so on.

What is the voltaic arch? *Illustrate by example. Describe* Foucault's *experiment. Describe the apparatus for illumination.* (**420.**) What are the most important chemical effects? *What are oxydes?*

Acids are *generally* compounds of oxygen with some non-metallic body. Thus, sulphuric acid is a compound of oxygen and sulphur; nitric acid is a compound of oxygen and nitrogen; carbonic acid is a compound of oxygen and carbon, and so on.

Salts are *generally* compounds of an acid with an oxyde. Thus, sulphate of potash is a compound of sulphuric acid and potash; nitrate of copper is a compound of nitric acid with an oxyde of copper, and so on.

In these definitions, we say *generally*, because the definitions given are only intended for illustration, and it is not thought best to enter into a detailed account of the various substances described. That belongs to Chemistry.

Decomposition of Water.

421. A galvanic current was first employed to decompose water in the year 1800, by Carlisle and Nicholson.

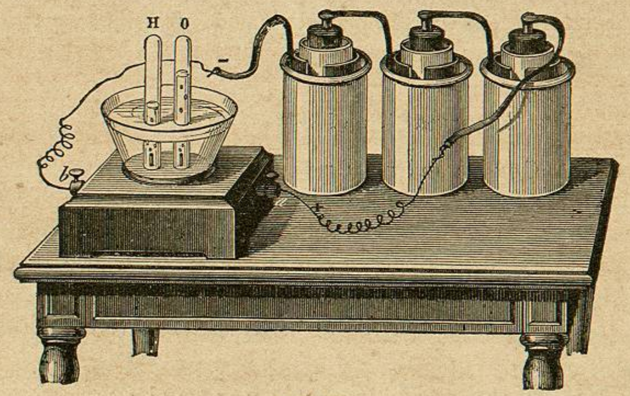

Fig. 288.

To repeat the experiment, we may employ the apparatus shown in Fig. 288. It consists of a glass dish with a wooden bottom. Rising from the bottom are two platinum wires,

Acids? Salts? (**421.**) When was water first decomposed? How may the experiment be repeated?

which pass through the wooden stand and terminate in the tubes, *a* and *b*. These wires serve as electrodes.

The glass vessel is partially filled with water, to which a small quantity of sulphuric acid is added to improve its conducting power. Two narrow bell-glasses, *H* and *O*, are filled with water and inverted over the two platinum wires. The tube, *a*, is then connected with the positive pole of the battery, and the tube, *b*, with the negative pole. A current is set up from one wire to the other through the water, and decomposition begins, as is shown by bubbles of gas rising in the two bell-glasses.

By testing the gases thus obtained, we find that in the glass, *O*, corresponding to the positive pole of the battery, is pure oxygen, whilst that in the glass, *H*, corresponding to the negative pole, is pure hydrogen. We see also that the volume of hydrogen is twice that of the oxygen. This experiment shows that water is composed of oxygen and hydrogen, mixed in the proportion of one volume of the former to two of the latter.

Decomposition of Oxydes and Salts.

422. Oxydes and salts may in like manner be decomposed by a current of electricity. In decomposing oxydes, the oxygen is transported to the positive electrode, and the metal to the negative electrode. In the decomposition of acids there is a like transfer of elements, the oxygen going to the positive, and the other component to the negative electrode.

In decomposing salts, there may be several cases. Sometimes there is a simple resolution of the salt into an acid and an oxyde, in which case the acid goes to the positive and the oxyde to the negative electrode. Sometimes, besides the separation into acid and oxyde, the latter is decomposed;

Explain in detail. (**422**.) How may oxydes and salts be decomposed? Explain the different cases of decomposition of salts.

in this case the oxygen and the free acid go to the positive, and the metal alone goes to the negative electrode. This action is utilized in the process of electrotyping.

DAVY, at the beginning of the present century, used the battery to decompose potash, soda, lime, baryta, magnesia, alumina, &c., and thus demonstrated that all of these substances, previously regarded as simple bodies, were in reality compound. They consist of oxygen united with metals, which are called respectively, potassium, sodium, calcium, barium, magnesium, aluminium, &c.

Application of Electricity to Galvanoplasty.

423. GALVANOPLASTY, or ELECTROTYPING, is the operation of copying medals, statues, and the like, in metal, by the aid of galvanic electricity.

Such copies were formerly made by the process of casting; now they are in many cases more elegantly produced by galvanoplasty. This process was discovered simultaneously by SPENCER, of London, and JACOBI, of St. Petersburg, in 1838, the year preceding the discovery of the daguerreotype process.

Method of Electrotyping.

424. The first step is the preparation of a mould of the object, upon the accuracy of which depends the success of the entire operation. Wax, plaster, or gutta percha may be used, but the latter material is now considered the best. At ordinary temperatures, gutta percha is hard, but on being heated, it becomes soft and ductile. To form the mould, the gutta percha is warmed by putting it into a vessel of warm water and allowing it to remain till it is of the proper softness; it is then placed upon the object to be

Explain DAVY's experiments. (**423**.) What is Galvanoplasty? When discovered? By whom? (**424**.) Explain the operation of electrotyping, in detail.

copied, and pressed with the fingers till it touches every point of the surface of the object, when it is left to harden by cooling. After hardening, it is removed and is ready for use. As gutta percha is apt to adhere to certain bodies, precaution should be taken to cover them with a thin layer of powdered plumbago or graphite. This may be laid on with a soft brush, and if properly applied, it effectually prevents the adhesion of the mould.

The second step is to deposit the metal in the mould. As gutta percha

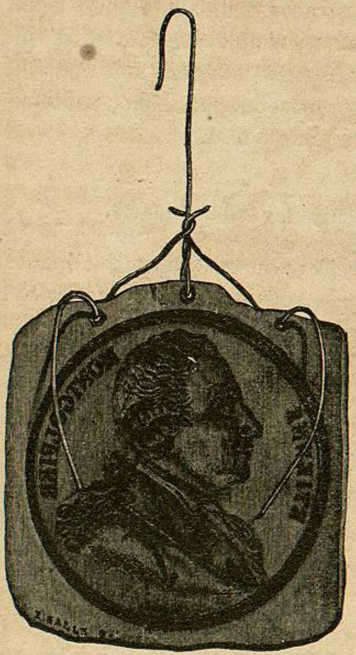
Fig. 289.


Fig. 290.

is a non-conductor of electricity, it is necessary to cover it with a conducting substance. This is done by laying on a coating of plumbago in the same manner as in forming the mould. The mould thus prepared is then made ready for the bath by attaching to it the proper suspending wires, as shown in Fig. 289.

Fig. 290 represents one face of a medal to be copied, and Fig. 289 represents the gutta percha mould prepared for receiving the metallic deposit. For making the deposit,

which we shall suppose to be of copper, a DANIEL'S battery of two or three couples is usually employed.

A couple of DANIEL'S battery differs from one of BUNSEN'S in the following particulars. The carbon cylinder is replaced by one of zinc, denoted by *Z*, in Fig. 291, and the zinc cylinder is replaced by one of copper, denoted by *C*, in the same figure. The outer vessel is of glass, and is filled with a solution of sulphate of copper (blue vitriol), which is kept saturated by some crystals of the sulphate

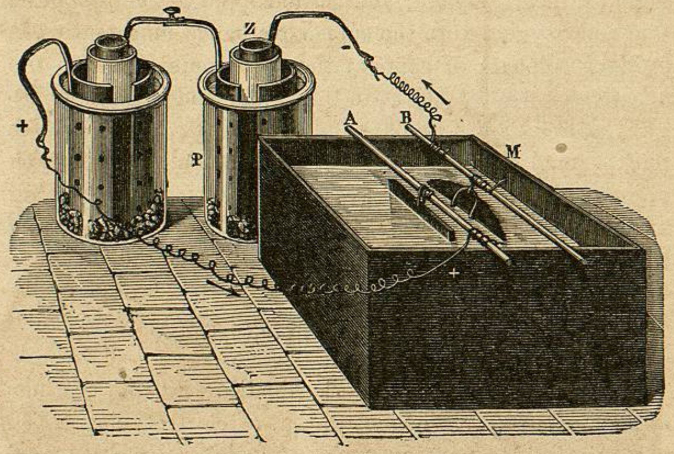

Fig. 291.

placed at the bottom of the vessel. The porous vessel is filled with dilute sulphuric acid. When this battery is in action, water is decomposed; the oxygen goes to the zinc, forming oxyde of zinc, which is dissolved by the sulphuric acid, giving sulphate of zinc. The hydrogen of the water goes to the sulphate of copper in *P*, and decomposes it. The result of these decompositions and recompositions is to keep up a current of electricity, as shown by the arrows, which will continue as long as the vessel, *P*, is kept full of the saturated solution of sulphate of zinc.

Fig. 291 shows the method of depositing the metal upon

What kind of a battery is used for depositing copper? *Explain one of* DANIEL'S *couples*. Explain Fig. 291.

the mould. *M* is a vessel filled with a solution of sulphate of copper; *A* and *B* are metallic rods communicating with the two poles of the battery; the mould is suspended from the rod, *B*, and facing it is a plate of pure copper suspended from the rod, *A*; these constitute the electrodes, the mould being the negative one.

The current which is set up through the solution of copper between the electrodes, decomposes the sulphate into sulphuric acid, oxygen, and pure copper. The sulphuric acid and oxygen go to the copper plate, and uniting with it, produce sulphate of copper; the pure copper goes to the negative electrode, that is, to the mould, and is there deposited. After about two days the coating of copper becomes thick enough to be removed from the mould, and it then presents a fac-simile of the object to be copied. In copying medals, each face is copied separately, and the two are united by means of some fusible metal placed between them

Electro-gilding and Electro-plating.

425. The process of covering bodies with thin coatings of gold or silver is analogous to that of electrotyping. The perfection of the process consists in making the coating of gold or silver, not only of uniform thickness, but also closely adherent.

The object to be gilded or silvered is first heated upon a charcoal fire to remove all fatty matter; it is next plunged into dilute sulphuric acid, and then rubbed with a hard brush to remove any oxyde that may exist upon the surface; it is next plunged into common nitric acid, and then into nitric acid into which a small quantity of salt and soot has been thrown; it is then washed in pure water and carefully dried in sawdust, and is ready for use.

Explain the chemical changes which take place. (**425.**) What is the process of electro-silvering and electro-gilding? How is the object cleaned?

The method of silvering, or electro-plating, is shown in Fig. 292. The object to be silvered is suspended in a bath of a silver solution by a metallic rod which connects with the negative pole of a BUNSEN'S battery. Immediately below it is a plate of pure silver, which is connected with the positive pole of the battery. The object to be silvered and the silver plate, *a*, constitute the electrodes, *a* being the positive one. The explanation of the process is analogous to that in the preceding article.

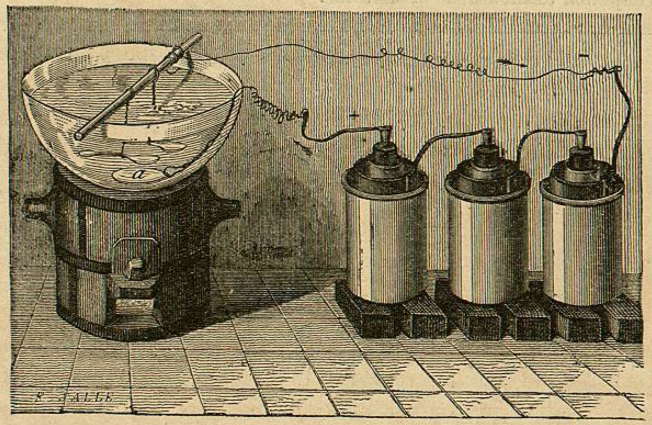

Fig. 292.

The salt of silver generally employed is a double cyanuret of silver and potassium. The thickness of the coating deposited will depend upon the power of the battery and upon the time of immersion.

The process of gilding is the same as that of silvering, except that we use a cyanuret of gold and potassium, and a plate of gold at *a*, instead of a silver one.

Explain the process of silvering as shown in Fig. 292. *What salt of silver is employed?* What is the process of gilding? What salt of gold is used?

The history of electro-plating and electro-gilding is briefly as follows: In 1803, BRUGNATELLI first gilded a silver medal by suspending it in a solution of gold from the negative pole of a battery, but proceeded no further. In 1840, DE LA RIVE, of Geneva, discovered a process of gilding metals with a battery, but by his process much gold was wasted, and the work was unsatisfactory. In the same year, ELKINGTON, an Englishman, discovered the process of gilding by means of the cyanuret of gold and potassium. A few months later, RUOLZ succeeded in silvering and platinizing metals by the methods now in general use. The arts of electro-plating, electro-gilding, and electrotyping are now of general application, and afford occupation to thousands of artisans.

Give an outline of the history of electro-plating and electro-gilding.

CHAPTER X.

ELECTRO-MAGNETISM.

I.—FUNDAMENTAL PRINCIPLES.

Relation between Magnetism and Electricity.

426. IT was observed at an early period that the magnetic and electrical fluids had many analogous properties. In each case fluids of the same name repel, whilst those of an opposite name attract. It was also observed that a stroke of lightning often reversed the poles of a magnetic needle, and sometimes completely destroyed its magnetism. The two have also points of dissimilarity. Magnetic fluids are not transmitted like electrical fluids through conductors. A magnet does not, like an electrified body, return to a neutral state when brought into communication with the earth. Magnetism can only be developed in a few, whereas electricity may be developed in all bodies.

Between these analogies and dissimilarities nothing positive could be affirmed with respect to the identity of magnetism and electricity, until, in 1819, ERSTED made a discovery which showed that these physical agents are most intimately allied, if not identical.

(**426.**) What early observations were made on the relation of the phenomena of electricity and magnetism? What dissimilarities were noticed?