HOW TO MAKE INVENTIONS;

OR,

INVENTING AS A SCIENCE AND AN ART.

A PRACTICAL GUIDE FOR INVENTORS.

BY

EDWARD P. THOMPSON, M.E.,

Member American Society of Mechanical Engineers; Member, an Examiner and an ex-Manager American Institute of Electrical Engineers; Member New York Electrical Society.

FIRST EDITION.

NEW YORK:
D. VAN NOSTRAND CO.,
23 MURRAY AND 27 WARREN STREETS.

TO

MY ALMA MATER,

THE

STEVENS INSTITUTE OF TECHNOLOGY,

THIS

BOOK IS DEDICATED.

PREFACE.

THE style adopted is that of a lecture, and, therefore, it is hoped that the use of personal pronouns may be overlooked.

The object in view is to make a mere beginning in the establishment of Inventing as a Science and an Art, but especially to present conclusions arrived at in the study of inventors and inventions in order that the capacity of inventors may be enlarged. If even a single useful invention results from the perusal of this book, I shall feel that the time has not been spent in vain.

Not knowing how a book with such a title would be accepted, preliminary notices were distributed soliciting subscriptions contingent upon publication. I am greatly indebted to those who so kindly sent in such subscriptions, and especially to those subscribers who wished me success. *The Electrical World* (New York) I also thank for inserting a series of paid articles on this subject, prepared and contributed by me during the year 1884.

Much encouragement for continuing the development of the subject-matter was given by Mr. T. Commerford Martin, editor of *The Electrical Engineer* (New York), and Mr. George H. Guy, editor of *Electricity* (Chicago), who so kindly invited me to deliver a lecture upon this subject before the New York Electrical Society in 1890.

As may be expected, the inventor will in no way be relieved of tedious labor by following any instructions contained in this book. I am inclined to believe that this will not be the basis of any criticism which may be rendered by any opponents or prejudiced minds ; because I have learned and am more and more impressed with what I believe to be a fact that a lazy inventor has never yet been born. No day laborer makes as many hours a day. The physician, missionary, and other philanthropists cannot show a better record for diligence of both the body and the mind. In writing this book I have borne this in mind, and have felt that there was no danger of making those suggestions and giving that instruction which would be rejected by the inventor simply because much work was involved. I have recognized, however, that humanity does not like things too dry and abstract, and, therefore, I have aimed in making the matter as easily understood as possible by means of illustrations and as few as possible of intricate and unusual technical words and phrases. It certainly is necessary for an inventor to have knowledge, but not to be a great literary scholar.

The work is particularly exceeding, when it is remembered that an inventor, according to Benjamin Franklin, must, in making a *great* invention pass through the three following stages, namely: 1. He starts to do that which others say is impossible. 2. When he claims to have succeeded, people believe him not. 3. When his invention comes into commercial use, hosts of inventors appear who claim to have done the same thing before.

One of the most important elements for ensuring success in any undertaking is *preparation.* At the present time, the World's Fair at Chicago is a "future event," but its success depends more upon what is done before, than after the day of opening. Committees are appointed for making preliminary arrangements. A site must be chosen first, as to location in the country and then as to the particular portion of the chosen city. An engineer is appointed for each department of industry. A business department with its managers and clerks must be established. The people must be informed and educated up to the idea of the benefits and attractions, or the attendance will be small. All this is *preparation.* The drift of this book is similar. It is intended as a means of preparation rather than as a collection of mathematical rules to be followed in order to make an invention. Napoleon is noted for the display of genius in many of his manœuvres, whereby he conquered nations under circumstances which depended upon instantaneously conjured plans developed mentally and carried out physically; but it must be remembered that if he had not spent preliminary hours in thought, made scores of maps of the proposed attacks, instructed his inferiors as to all the probable and improbable haps and mishaps, studied the lives of other successful and unsuccessful soldiers, and the histories of other nations, his genius would have counted for so little that there would probably have been no exhibition of the same.

NEW YORK. E. P. T.

CHAPTER I.

INVENTION, THE GREATEST SCIENCE IN THE WORLD.

TATHAM has said :—" Invention is the happiness of man." Edison has said that he is happiest while inventing. The Book of Truth says : " It is more blessed to give than to receive." Inventors may say :—" We give to the world more than we receive. We are happy in inventing. We have often become poor while the world has become rich by our inventions. Even when we have made our thousands, the world has netted its millions."

Of all the physical and mental sciences, which is the greatest in the world? Is it Chemistry, Natural Philosophy, Physiology, Mineralogy, Geology, Electricity, Mental Philosophy or Metaphysics? Most emphatically, No! The sun furnishes light, but of what value is the light if we use it not? The sciences just named furnish knowledge. Of what value is knowledge if it is not used? Invention is the greatest science, if measured by its usefulness to mankind, because it gives to the world the practical benefit of the other sciences. It is the science which applies knowledge to useful purposes. Without invention, Chemistry and Physics are practically worthless. Physics says:—" Heat expands." Invention applies this principle and builds a steam engine whose power is due to the expansion of water by heat. Chemistry and Mineralogy result in the discovery of phosphorus and sulphur. Invention makes the match, one of the most useful and wonderful and almost magic-like inventions ever made. Physics teaches that speaking vibrates the air and diaphragms, and that an electric current can be rapidly varied from zero to maximum and from maximum to zero. Invention applies these principles to the electrical transmission of speech. Geology exhibits the structure of the earth. Invention produces thousands of Green's driven wells.

CHAPTER II.

The Foundation of the Science of Invention.

Ever since the time of Bacon, any given science has been developed by classifying facts and establishing principles thereon. Before the time of Bacon, little progress was made in any science because principles were proclaimed and then facts sought to uphold the principles. The new process of Bacon is called the inductive system of developing a science; and the earlier process, the deductive system.

The development of a science by searching for and recording facts and establishing principles, does in itself assist the science to grow; thus, the science of Physiology, having been recorded in publications under classified principles, enables each future generation of physicians to acquire easily the principles, and to add, from time to time, valuable facts which either strengthen old principles or show their fallacy. The science of Chemistry forms the knowledge of the chemist, who, knowing it in its present condition, can make use of the experience of others, and add to its records, because he knows the record of the past. So, also, with the more abstract sciences, as those of Political Economy, the Sciences of Civilization, Religion and Psychology. Before the time of Bacon, any one who desired to add to the knowledge of the world worked in the dark. He knew little because the knowledge before him was not intelligently and conveniently collected and classified for his use.

Philosophical speculations occupied more time, and were considered more valuable than experiment. The Royal Society in olden times spent several meetings in discussing whether a pail of water, with a dead fish in it, weighed more or less than a pail of water containing a live fish. Finally, a member who was certainly ahead of his age, boldly and unexpectedly settled the question by actually weighing the pail of water under the two conditions.

An inventor, who expects the greatest success in conceiving and developing an invention, should be acquainted with principles of inventing, based upon facts evolved by the study of former inventions; or else he works in the dark; trusts to getting his ideas by accident; or leaves his inventions in such a crude state as to render them practically worthless. The science of Civilization deals with the greatest events of history; drawing therefrom the principles upon which the science is based. This book attempts similarly to establish the science of Invention upon the history of the greatest inventions and inventors.

CHAPTER III.

The Primary Power for Driving an Inventor.

In becoming a business man, a professor, an electrical engineer, or engaged in any occupation, the first requisite is to have a love for it. If a youth is to be a lawyer, he should first determine if he believes he would enjoy that profession. If he is to prepare for college, he must first determine if he prefers a profession to a business career. Having decided what he likes, let him proceed with a concentration of all his energies, and he is sure, nine times out of ten, to succeed. The very enjoyment of his work, and belief in his own power to succeed, will do more for him than any other one element, because all other elements are comparatively useless without well-directed and honest ambition.

Love of inventing may be natural or acquired. It grows with practice. The more one invents, the more he loves to continue. The natural love of cyling or playing games grows until it may be said to be acquired. The more one invents, the more he loves that employment.

CHAPTER IV.

How to Learn What to Invent.

Before the introduction of the telegraph system, the quickest communication of ideas between two points of considerable distance was by post, express or special messenger. Great inconvenience was the consequence and often ensued the loss of money and non-fulfillment of duties and obligations, in cases of death and important business transactions. Everything was done by the government and private corporations to provide means for lessening the time for transmitting messages. The public realized the importance of saving time. Probably thousands of people realized the inconvenience and injury done by slowness of transmission. Every one, substantially, may be said to have recognized the inconvenience, the trouble and the difficulty. They knew that it would take days and even months for their letters to reach certain parts of the world. They knew that in the case of death of one of the family the funeral would occur before those at a certain distance could receive the news. They knew that when a great event, such as a battle, was expected to take place in a foreign country, ten days or more would elapse before they could learn the result. They knew that during a journey of a colleague on important business through the country they could know his whereabouts and successes and failures with from one day to several weeks' delay. In short, they were strongly convinced of the existing difficulty. They had no doubt as to the usefulness of any means which would remove the difficulty. Some were resigned as if to a fate. Others hoped and even predicted wonderful improvements. But who was it that not only realized the difficulty, but had faith that the trouble could be removed? Who was it that not only talked with friends on his homeward ocean trip about the inconvenience of slow transmission of messages, and not only believed in a remedy, but expressed in words that he believed the difficulty could be removed? He talked with others more educated than himself in order to glean knowledge and make use of it for the public. This is a fact, therefore, based upon history, that Morse, the inventor of the telegraph, recognized the existence of a certain need in the world, and not only that, but also believed there was room for improvement; and on top of this knowledge and belief he had faith, and followed up his faith by diligence and actual work. This fact is apparent also in the study of other inventions. It is the public that realizes the existing difficulties, while it is the inventor who follows up his belief by his diligence. Take the case of the invention of the telephone. The public appreciated the value of the telegraph for communicating from one part of a country to another, but to telegraph from one part of a city to another amounted to little more than sending a special messenger. It was the inventor who not only recognized the difficulty, but also undertook a personal task of removing it.

The public realized the danger of boiler explosions. Inventors did also, but they went further and undertook to prove that they could remove the difficulty, and as a result invented the safety valve and improvements of construction and operation, whereby most boiler explosions of the present date—which are exceedingly scarce in proportion to the number of boilers—arise from sheer carelessness. Public opinion at one time, and only lately, denounced electric arc lighting, because it was dangerous. The cry against high tension currents aroused inventors to a belief in means for eliminating the danger, and they have already and almost perfectly succeeded, whereby the accidents are fewer in actual number, although the circuits have increased hundreds of miles. Among smaller, but very important inventions, may be mentioned the crank-and-gearing combination with shutters or blinds. People were aware of the danger of catching a cold, letting in flies and mosquitoes, and of other difficulties connected with shutting the blinds. The inventor also realized the difficulties, but in addition believed that he was the one to remedy it, the result being means for operating shutters by merely turning a small crank inside of the house. A study of the invention of the spring roller for window shades, from which fortunes have been made, exhibits the same fact. The principle derived may be stated thus :

Any given individual takes a step toward becoming, or improving himself as an inventor, who studies the need of the public ; learns the difficulties connected with that department of art or industry in which the need exists ; excites his mind with the belief that he can provide means to remove the difficulties ; and proceeds with diligence toward the solution of the problem.

The truth of this principle is strengthened by its negative aspects. Suppose the first step should be *not* to study the need of the public. The consequence would follow in many cases, in the production of useless inventions—*i. e.*, those which accomplish results not wanted. This often does occur. As an illustration, parlor skates may be mentioned. An inventor of an improved roller skate for to-day is an inventor of that which has no market, as skating rinks have gone out of fashion and lost their popularity. It is something which the public does not want at present, even though it did formerly pay a tribute of many thousand dollars to the early inventors and improvers of the parlor skate.

The second element of the principle before stated consists in learning the difficulties connected with that department of art or industry in which the need exists.

If there is any one difficulty in connection with any department of art, the would-be inventor may be sure of reward if he succeeds in overcoming the difficulty. How is he to become aware of the difficulty ? He is to make a business or study to this end. If he is engaged with a manufacturer he can daily become acquainted with difficulties which prevent the manufacturer from clearing as much profit as he should. At one time so much trouble was experienced at sea by the untimely jumping of the safety valve that steam navigation was well nigh abandoned. The engineer of the boiler manufacturer viewed the difficulty as something to be overcome, and solved the same by substituting a spring for the weight which controlled the valve. If he is a student or scholar of science, he can become acquainted with difficulties by studying any particular art. If he is a business man he can learn difficulties by the habit of observation of difficulties met with by himself, In connection with his own business, any man can learn some difficulty if he will only keep his wits about him and be on the lookout. He may meet it in traveling, in business, in his home, in his conversation with others, in the newspapers and in other directions. At the present moment exist problems well known to many, but yet unsolved, and of all degrees of magnitude, and in all departments of every art. Since the learning of difficulties is one of the elements of the first principle underlying the science of invention, it seems but proper that some should be given at least for the sake of illustrating what is meant by a "difficulty" for an inventor to solve. This matter is treated in the chapter on "Problems in Invention."

CHAPTER V.

Hindrances to the Progress of Invention.

Some are desirous of being inventors. They know they have a love for it. They admit that there is room for improvement and for original invention. They have studied the principles of science or of a particular art. They believe that others may and will invent. Ask them why they do not invent. The invariable reply is that they believe they possess no genius or inventive faculty. They imply that some have been born and gifted with what they have not. This is not true. Every man has more or less power of inventing. Every day every one busily occupied uses his power or faculty of inventing when he plans, in imagination, his business of the day, or whenever he thinks of the best way of carrying out an idea. Let one once believe that he does possess the power to invent and it will not be long before he will know that the field of invention is shut against none. From observation I conclude that the following principle is true: A belief of an individual that he himself does not possess genius or the power to invent is, in itself, a hindrance to the action of that power.

The corollary which follows is: An individual who will admit that he possesses a power of inventing, to a greater or less extent, may become an inventor by the proper use of his knowledge. Suppose that the inventor of the device for threading needles insisted previously upon the assumption that he had no genius. He did not so assume. Consequently he received an annual income of $10,000 from the sales of his patented needle-threader, which was at one time so popular a device. The inventor of the roller skate cleared nearly $1,000,000, although during only the last few years of the term of the patent.

Will any civilized white man assume he has no inventive faculty or genius when it is a fact that the Patent Office records show that colored men are inventors? I am personally acquainted with a colored man who has not only made electrical inventions and received letters patent of the United States, but has sold the same. His extreme confidence in his ability to invent is easily apparent to those who know him. Some of his inventions show a high type of invention; therefore it seems but proper that due honor should be given by mentioning his name. I refer to Granville T. Woods, formerly of Cincinati, Ohio.

CHAPTER VI.

Suggestive Ideas.

While I admit the plausibility of an inventor's working exclusively upon one subject, yet it is often true that he remains too long in one line of thought or channel. A certain inventor (Gatling) failed in protecting a successful screw propeller, after working upon that subject for a long time; but as soon as his attention was drawn to another line of work (guns) his enthusiasm revived and he soon made a commercial success. Frank J. Sprague stated at a meeting of the American Institute of Electrical Engineers, that upon his hearing of the great success of Brush, Thomson, Edison, and others in electrical inventing, he concluded there was room for him also, and therefore made valuable inventions, left the Army, and, as is well known, in a wonderfully short time succeeded both scientifically and financially. If success does not follow after a reasonable time in any given direction, try other departments.

It has often been stated that the way to invent is to think, and keep on thinking. It is almost impossible for one to think unless he has whereof to think. He must receive certain impressions from without before he has anything upon which to concentrate his mind. In short, as in all cases where good is to be obtained, inventing involves systematic and diligent mental and bodily work. The inventor must be given a suggestive idea. Probably an invention was never made except by receiving some kind of impression from outside of the mind. By studying past inventions and inventors it is found that certain suggestive ideas have prompted inventors over and over again, and continue to give to the world greater and greater reward.

The following-headed paragraphs contain some of those suggestions which have heretofore prompted inventors:

A device to do automatically that which has been done by hand.—An early example is that of the eccentric. A boy was obliged to turn a valve to let in the steam at each stroke of the piston. A later example is an automatic device which, exactly at the end of five minutes, in a long distance telephone system, cuts off the subscriber's line from use. The operators are apt to give subscribers too long. Such inventions are among the most valuable known. They save cost of manual labor, prevent injury and accident due to neglect of man, and often do the work much better. Progress of invention in this direction can be made by taking note of what is at present done by hand, and considering if it would not be advantageous to have a device which will accomplish the same thing automatically. The working out of a device to do it usually requires only ordinary intelligence. As soon as the boy wanted to go out to play ball and not let the steam engine stop, it occupied but a short time to rig up a string and lever between the valve and one of the moving parts of the engine and make the engine take care of itself. To make this class of invention, therefore, closely observe what is at present done by hand in the different departments of manufacture, electrical installations, commercial traffic, at home, on the street, railroad, and everywhere. Again, if three motions of the hand are necessary to operate an apparatus, try to make the device attend to some of those motions.

Preventing Loss of Life and Property.—When a serious catastrophe occurs on a railway system, in the street, or anywhere, it is the duty, or at least the function, of an inventor to study into the cause of the accident and discover, either by personal inspection, by official reports, or by the most reliable means at hand, the exact details of operation of the system before, during, and after the accident. An invention which will in principle prevent the same kind of accident in the future is that which is likely to become useful when fully developed and applied. This has been the manner in which valuable safety devices and systems have in the past been invented and introduced, and therefore it will be a safe rule to follow in the future.

Since the invention and introduction of the automatic brake system of George Westinghouse, Jr., and his associate inventors, loss of life and property has been enormously reduced. He and they provided means for stopping a train moving at a high speed within a distance several times less than could be done by hand, and therefore in the case of emergency the train could be stopped before an accident was possible. In many other ways, accidents have been prevented by this invention, which possesses utility in a very high degree. But there is a class of accidents impossible to prevent by the automatic brake system. Observation of records in the newspaper shows that two railway accidents per week occur on an average in the United States, with loss of life and property or both. It has been proposed through the press that these accidents be made a subject of legislation by appointing a committee to study into the cause of the accidents; to learn if there are or may be means in existence for preventing them; to determine if the railway companies shall be forced to adopt any invention or inventions adapted to prevent certain kinds of accidents; and to consider, in general, the best welfare of the public in this connection. In a similar manner, other departments of art could be considered in regard to means for preventing loss of life and property by navigation, chemical manufacture, and electric lighting and power. Some inventions in safety devices for railway systems are ludicrously interesting, but at the same time plausible. For example, there was an exhibition in this city of a system whereby, upon two trains approaching each other, the whistles on both locomotives are automatically operated so as to notify the engineers of danger. The whistle of either train is operated through electric circuits by the other train, and *vice versa*, when the trains approach within a predetermined distance of each other. It is appropriately called "The Tooting System."

How many hundreds of steam boilers would explode if equipped with only steam gauge and water signal, and not with a safety valve, which operates in case of danger, whether the engineer is asleep, intoxicated, careless, or entirely absent.

Reducing Cost of Manufacture, or of the Cost of the Products of Manufacture.—The now well-known wire hat-and-clothes hook costs only a small fraction of the former cast iron hook and is easier to place. The late embroidering machine does the work of dozens of factory girls at less cost and produces superior work. The first conception of a telegraph system before Morse's new alphabet system was by having a circuit closer on the main line for each letter and figure. The cost of a line of 36 wires from New York would be so great as to discourage capital.

It never even came into use. The first incandescent lamps were half as intricate as an arc lamp. The present machine for setting up type by striking keys like a typewriter, although practical, is no doubt as intricate in comparison to probable later improvements, as the first sewing machines were in relation to the present forms, which themselves are continually undergoing reduction in cost of manufacture. Aim, therefore, to so modify any given device that the same may be manufactured in larger quantities for the same money, or so that the products of that machine may be produced more rapidly. This is accomplished most probably by a radically different construction, whereby the cost of the castings for instance may be less; or whereby the number of moving parts, levers, wheels, &c., may be lessened; or whereby the result is obtained by the application or combination of different mechanical principles. Aluminium was first obtained chemically, and sold at from $3 to $6 per lb. The principle of making its oxide a conductor, by mixing carbon with it, and heating by an electric current, was applied, so that now it costs but $1 per lb. Every now and then we learn of these wonderful inventions for getting some old results at a much less cost. It is one of the most profitable and accessible fields for those who are willing to face the problems boldly.

By "less cost" or "cheaper" is evidently not meant "poorer material" or "careless work."

Fair Competition.—The fact that one inventor holds a monopoly is not necessarily a reason why a second inventor cannot share the profits. There is generally a chance of inventing that which will accomplish the same result without infringing the patent. Occasionally this is impossible, but oftener it is possible. It is better for the community that there should be two competing parties. It is probable that both parties will reap fortunes. The author does not encourage infringement, but fair competition among inventors, and therefore greater progress in the arts. The inventor who succeeds in "getting around" a certain patent, and avoids any doubt of infringement, does only right to the community—*i. e.*, to the majority—and breaks no laws. An example is that illustrated by the great monopoly once held by the telegraph company. Prof. Bell accomplishes even a better means of rapid transit of messages for moderate distances, as measured by the profits to the company; while the telegraph company to all appearances is not at all poor; neither are their numerous detail patents infringed, nor would the original, but expired, patents have been infringed had the telephone been invented at the beginning of telegraphy. The same general result was accomplished by non-infringing means. There are many illustrations of this principle; so that inventors need not stop from courtesy to other inventors, from fear of injuring their business. The community demands fair competition among inventors as well as among manufactures and dealers. Proceed, therefore, without fear to find out just how broadly a certain patented monoply is covered, and exert the utmost power to accomplish the same or better results by non-infringing means.

Slight Circumstances Lead to Invention.—For example, Prof. Short, of the Short Electric Railway Co., visited the Electrical Exhibition held several years ago at Chicago, and while there, became so interested in electric railways by observing a model of one, that from that moment he became, and has continued, an inventor of electric railway systems and devices.

Many years ago—*i. e.*, in 1688—a vessel containing melted glass broke, and a portion of the fused mass found its way beneath a large flag-stone, which, when removed, revealed a plate of glass. This accident suggested to Thévart the idea of casting plate glass. Crandall, who obtained fame through his toy building blocks, owned a large glass ball, which seemed possessed with life, always rolling where it was not wanted. This was the small circumstance which led to his invention of "Pigs in Clover" by which he cleared over $40,000.

From the foregoing facts a valuable principle is deduced, namely:

An observation of the ordinary circumstances of the day, with a view to invent, assists the desire and attempts to invent, and suggests finally the basis of a new and useful invention.

Experiment a Teacher.—Experimenting for the purpose of solving a certain problem often suggests the solution of an independent and unexpected problem.

Glauber searched long and diligently for the Philosopher's Stone, and by putting certain chemicals together for this purpose found that he obtained a substance radically different from either of the constituents. The compound thus produced is the medicine which bears his name. It is well to listen thus to the dictates of experiment, and not to become the least discouraged. Newton tried in every possible way to solve the theory he had as to the existence of gravitation. The natural experiment or operation of nature in the falling of an apple taught him in a manner entirely unexpected. While Edison was experimenting in telegraphy he saw some operation occur in an experiment which taught him a scientific principle he had not before fully realized, and at once concluded that if that principle were really what it appeared, he would make a talking machine. In the early days of printing, the type was carved upon wooden blocks;

but often breaking off, new letters had to be glued on to take their place. This taught an inventor, who was seeking for improvement in the art, to make our present movable type.

Different inventors follow different paths in the process of inventing. In some cases they perform experiments mentally upon their conceptions. One experiment leads in their mind to another, with new suggestions, until finally they are able to decide upon the fact of the invention as to whether it is operative or not. This is the most economical method. It, in itself, trains the mind to the power of intense imagination and of invention. Many preliminary experiments may often be dropped by studying books on the subject, to discover just what facts and principles exist that bear on the matter in hand. Many inventions have been made successful upon completion of the first device. A pencil and piece of paper will greatly aid the imagination, and will save much useless experimenting. I lately visited at his home an inventor of a "Put a Nickel in the Slot and Have Your Photograph Taken." The machine did all the work. It was automatic from the beginning to the end of the process. Although marvelous to behold, and apparantly intricate, it was the result of the very first experiment, and it did its work not only well, but every time. I found that it took but two months for him to reduce the mental invention to the physical; but to devise the complete mental invention and to experiment with all the movements *in the mind* assisted by pencil and paper, occupied the larger portion of a year.

Some begin to experiment upon the very first conception, and even build a full-sized machine at the first, and when the difficulties are found another device is built, and so on. This method is more expensive and requires more time, and does not in itself increase the power of imagination, which is one of the greatest aids to an inventor. A harmonious blending of these two methods makes the greatest inventor.

The style followed by the chemist and physicist in their experimenting for new principles is often copied by successful inventors. The former use small and almost minute quantities and apparatus, costing very little. Small experiments are as positive and often more so than large experiments. Planté experimented upon his secondary battery with small quantities of chemicals, costing but a few cents each. Distribute your time and money on numerous small experiments rather than upon a few large ones.

Reparation.—It is well known that tons of zinc have been wasted by the telegraph companies by throwing away the stubs of crow-foot zincs used in batteries. Georges d'Infreville has made an invention whereby this waste need not exist. Other important inventions could be quoted to illustrate the same teaching, namely :—When a part of a machine wears out, and must be thrown away, let the knowledge thereof be an incentive to prompt to a modified construction whereby the worn-out part may be replaceable by a new part, so that time and material shall not be wasted. In some old instances, a whole valuable device was thrown away until inventions were made whereby it was only necessary to throw away that part which was worn out.

Critical Inspection of Crude Devices.—Scarcely does an inventor see the invention of another but that it looks very crude, and that he makes valuable improvements, whereby both make more profit than either could have hoped to have made alone. The one has had practice perhaps in conceiving prolific ideas, but lacks practice in making mechanical inventions. He puts the crude device upon the market. It is about to fail. The second inventor, equipped with the broad ideas, applies his practice obtained in making mechanical inventions and improves so greatly upon the crude device as to reap benefit in conjunction with the first inventor.

A Device for doing by Electricity that which had previously been done by some other Agency.—Since the time of Cain and Abel welding has been accomplished by hammering. Only in modern times has a successful device been constructed whereby not only can ordinary welding be accomplished by the electric current, but the device will weld that which cannot be welded by the old process. Inventing is often like a horse-race. All the jockeys are endeavoring to reach the same goal first, and there is a theoretical possibility that all will get there at the same fraction of a second, but this scarcely ever happens. Possibly two arrive instantaneously apparently. In any event, the one who beats is the one who receives the prize. For the last decade inventors have been attempting to apply electric currents to welding. The one who first applied the electric converter principle where the maximum heating current is obtained from an electrical source was the first to succeed, but soon afterwards others made the same invention independently. Other results are being sought through the electric current, and inventors should be awake to this suggestive idea and attempt thereby to widen the usefulness of electricity.

The successful application of welding by electricity is somewhat similar to the introduction of the air brake. Others had attempted the solution of the problem, but fell short of success. Judges Walker and Swayne set forth in an important case (2

Bann and Ard., 55, 1875), that, although others had conceived the idea of air brakes before Westhinghouse, yet he is the first legal inventor and entitled to protection because the first to invent a practically operative air brake, which is so important to the safety of human life and property. An important principle is contained in the above illustrations. It is often more important to be the first to conceive broad ideas than to be first to produce the best.

Omission.—By omitting one or more of the elements which were at first thought to be necessary, but which one finds may be omitted and the same or even better results obtained by a new mode of operation, an invention is made. If by omitting an element the device is worse than before, then there is no invention. A certain party omitted the board foundation of a Nicholson pavement, but Judge Blodgett decided that these omissions constituted no invention ; but a reconstruction of a machine so that a less number of parts will perform all the functions of the greater is the invention of a high order. In a friction clutch for hoisting-machines the patentee dispensed with one of the friction cones and flanges found in the prior art, re-arranged the machine accordingly and put a spring where it was needed, and the patent was upheld by Judge Wheeler.

Transposition.—An inventor may often improve the manufacture by changing the relative positions of the parts of a device if at the same time he accomplishes the same or better results. Permutation locks have thus been improved; also watchman's time recorders. An inventor made a new location of a hinge and spring catch in a lantern and remedied a great difficulty in manufacture and use, and its advantages were immediately recognized and other manufacturers began to copy. The patent was upheld by Judge Wallace.

Change of Form.—Construct one or more of the parts of such a form or shape that an otherwise essential feature may be omitted. One by the name of Russell modified a water pump by constructing the inwardly projecting flange of such a form that it could be used wholly for the base of the pump, and thus do away with any frame-work. His patent for this improvement was upheld by Judge Colt.

By a mere change of form a new result is often obtainable. A patented baby-jumper differed from other jumpers in a backward curvature of the suspension rod to prevent contact with the child, and this improvement in mere form was held patentable by Judge Blodgett. The manufacture was as cheap as without the curvature, but as the result was improved with the change of form, more was obtained for the same money.

A similar case is that of a carbon filament for incandescent lamps being made with a curve like a horseshoe, instead of straight. They are equally cheap to make and they possess the improved result or advantage of having the leading-in wires enter the same end of the lamp bulb, and of exposing more illuminating surface per volume of vacuum space.

Combined Inventions.—An inventor may often obtain invention by combining the merits of two or more devices into one. If the result is an invention of equal convenience, cheaper than both elements and as meritorious as both, the single invention is a true invention according to Judge Lowell.

As an illustration, the preserving of meat may be taken. Enveloping meat in a covering of fibrous or woven material is old. Subjecting the meat to the action of a current of air of suitably low or regulated temperature is also old. Combining the two elements is pronounced new and patentable by Judge Nixon.

CHAPTER VII.

The Initial Step.

It is not enough to have a love for inventing. You may admire other inventors and inventions, and may think how satisfied and prosperous you might be if you could make a success, and you may even realize some problems which need solving, and yet not be an inventor. More is needed than mere desire. In order to get there, one step must be taken at a time. What, therefore, is the first step?

An inventor deals with positive results and absolute conditions, and not with chaos and creation. He proceeds in a manner peculiar to itself, and not in a common way with other workers. Mathematicians, physicists, chemists, carry out conditions, and obtain a result; and the fulfilment of the same conditions always produces the same result; $2 \times 3 \times 4$ always equals 24. There is positively no exception. The physicist follows the same law. If he wishes to transfer electricity from one point to another he must fulfil the proper conditions. An electric current of about two volts always decomposes water into hydrogen and oxygen gases. The result is sure to come, and there is but the same result.

With the inventor everything is just the opposite. His given quantity is the result, while the unknown quantities are the conditions. In the above arithmetical problem his known quantity corresponds to 24, and it is to find the conditions which, when obeyed, will give 24. It is evident that the result might be obtained in many independent ways ; thus

$$2\times 3\times 4 \text{ equals } 24$$
$$6\times 3+1+5 \text{ `` } 24$$
$$30-6 \text{ `` } 24$$
$$(2\times 6)+(6\times 2) \text{ `` } 24$$

and so on indefinitely, and limited only by the capacity and patience of the mathematican. Does it not follow, therefore, that an invention has different answers, and that a problem in arithmetic has only one answer? Yes! this is the general rule. The product 24 may be obtained by carrying out many conditions, or by few. $1+1+1+1$, etc., will eventually result in 24 as the answer, or simply $2\times 12=24$. The inventor should aim for the fewest conditions. The result should be obtained by as few steps as possible.

Analysis.—The result sought is usually compound, not elemental. There is scarcely an exception to this, although before the trouble is taken to analyze it the result seems elemental and not compound. The first essential step consists in analyzing the problem into two elements and if possible into more than two. Each element may itself be a compound. This analysis is exceedingly important, and will aid in systematic work. Nothing is more important in inventing than to have a target. He who has a definite aim is the one who conquers.

To illustrate the point, let an example be taken—*e. g.*, the typewriter—$20 on every Remington typewriter sold are said to go to the inventor. The claims cover only the particular construction of the machine, the elementary ideas being public property. Suppose it is desired to invent a radically different typewriter from the Remington or any other form found in practice. The initial step is to analyze the problem.

The following example will serve to illustrate how a result is divisible into its elements:

1. *The general result is* a machine which will write or print words and sentences when properly controlled by an operator.

The elementary results are (a) means for making the type to strike the paper at proper intervals of space; (b) means for moving the paper through the proper space after each letter is printed; (c) means for being able to see the printing during the operation, as in handwriting; (d) means for retracting the paper when a mistake is made; (e) means for making, simultaneously, multiple copies of the printed matter; (f) means for moving the paper at the end of each line; (g) means for giving a signal near the end of each line; (h) means for easily replacing a filled sheet by a new sheet; (i) means for adjusting the machine to print the lines at any approximately desired distance apart; (j) means for beginning the lines at a given margin; and (k) means for printing both capitals and small letters, figures, and punctuation marks, and possibly for printing French, German, or some other language besides English. By this analysis a complex problem is divided into eleven independent simple problems, which upon further consideration may be found divisible. The power of analyzing results comes by practice. Sometimes the inventor needs to obtain a new result—*i. e.*, doing something which no one ever thought of doing. Here, also, the first step is analysis. One who wishes to train to be an inventor or to improve his qualifications will find it profitable, just for the practice alone, to take a new or old result and try to divide it up into as many sub-results as possible.

The practice in analyzing should be:

1. *Gradual.*—Do not begin with intricate problems. What would be thought of an architect who tries to design a palace before he can design a cottage? Begin on the simplest problem and then pass to the greater and more complex problems.

2. *Continuous.*—Some men are very enthusiastic at intervals in any given undertaking and at alternate intervals lose their interest. They are early and late at work upon their scheme, and just as they are thoroughly saturated with the subject and probably near success they allow their mind to be transferred to some other subject, forgetting the former until it is too late. Recreation is good and should be practiced, but a loss of enthusiasm should not be allowed. Continually maintain the spirit of intense thought, stopping only for recreation and other matters of business, taking up the practice again with renewed enthusiasm.

3. *Special.*—The inventor should confine himself, not to a special device, but to that department of invention in which is to be employed his special knowledge and experience. Thus a mechanic can do better in analyzing problems bearing upon the particular mechanical device for carrying out a broad scientific invention than in conceiving a plan for multiplex telephony. When he understands the principles of the multiplex telephony he can then analyze the problem of obtaining the same results by less movements, or fewer parts, or in a radically different manner, leaving the system comparatively worthless

without the use of his improvements. On the other hand, scholars and professors, having a broad knowledge of all things, do not need to practice analysis on mechanical problems, but those relating to methods, chemicals, systems, and to the accomplishing of new results. The ordinary manufacturer, partly learned and partly a mechanic and partly a business man, may practice by analyzing medium problems, getting additional assistance from the mechanic, the professor, or books.

Varied.—There is a sense, though, where practice should be varied. One is apt to dwell upon improvements of the devices he daily meets with. This makes for him a very narrow field. He does not get a sufficiently varied practice. He should endeavor to broaden his knowledge through books and other sources of knowledge. A man occupied in business is apt to make inventions relating to stationery, ink bottles, blotting pads, fountain pens, &c., whereas his evenings and spare time could be occupied with the exhaustive study of some particular and newer department of science or industry than that which occupied the attention of the scribes in the year 1. Let the problem, therefore, relate to something special, but do not narrow it to the small number of devices you are apt to meet day after day and year after year in your routine of employment.

CHAPTER VIII.

Making and Developing Mechanical Inventions.

From a study of inventions I establish the proverb that a problem known is a problem half solved. The only exception is the case where natural laws prevent. An old problem, meaning the same thing by opposites, is that a double-minded man is unstable in all his ways. The problem must be *known.* It must not be simply a vision, an indefinite difficulty to be overcome, but it must be analyzed. The next step—the conception—is the mental doing of something in order to get one of the elemental results; and then doing something else to get the second elemental result; and so on, until each elemental result is accomplished in the mind. This will be found to be the easiest part of inventing. The invention will be very crude at first. It will be very impracticable, and perhaps so intricate and complex as to lead to discouragement. Do not expect to get at once the best way of obtaining the result. This has never been the rule with other inventors. The first form of mental device is crude. Out of ten men having sufficient knowledge, and working for the same solvable result, there will scarcely be one but will devise *some* mental invention for obtaining the result. In order to arrive quickest at the simplest solution one should travel by guide-boards, which themselves will not serve as horses to carry him to his destination and thereby relieve him of the tedious walk and work, but they will be so useful that if they were not there he would have to guess the way. What are the guides which will serve to make the simplest conception come the quickest? They are given in the case below regarding the arc lamp.

The developing process depends upon the class to which the proposed invention belongs. All inventions, fortunately, are found to be divisible into two classes, for purposes of development—Mechanical and Scientific, and each of these into—

KINETIC AND STATIC.—Samples of the former are the printing press, typewriter, cotton-gin, phonograph, annunciator, harvesting machine, and spinning jenny; and of the latter are cars, buildings, aqueducts, steam boilers, certain tools, etc.

The distinction is this: Kinetic—meaning, literally, relating to motion—describes all those inventions in which the elemental results or steps of the problem are carried out by elemental motions, and the whole problem by a combination of motions. Static—meaning the reverse of motory—is a term which includes all those inventions in which the results are accomplished by a combination of stationary elements, varying in form and number, and bearing certain fixed relations to each other. It includes all devices and products in which motion is not one of the essential elements.

KINETIC INVENTIONS.—Comprehension in the abstract is difficult; therefore let an example be considered. Among the best is the arc lamp. Let it be supposed that the arc lamp is capable of simplification, that it has not yet reached its simplest form. The initial step, as by the preceding chapter, is to analyze the result.

General Result.—The general result is to produce a combination of motions which will result in the production of an electric spark of constant length. Every problem in kinetic invention is to produce a combination of motions in order to obtain the final result. Knowledge, obtained by the experience of others, furnishes us with the fundamental and necessary information, that the heat of the arc burns the carbons away, so that the spark tends to grow longer.

First Elemental Result.—The first motion of the carbon or carbons, in order that the spark may exist, is that they should either be brought together and moved away; or, if already in contact normally, to be moved away from each other to such a distance as to produce the predetermined length of arc. Decide upon the simpler of the two. Let it be supposed that they are in contact normally. The first result to be obtained, therefore, is to produce such a motion that the distance between the carbons may quickly increase from zero to maximum, and remain at maximum or a little under maximum. The following questions present themselves: Shall the motion be rectilinear, curvilinear, vibratory, circular, or elliptical or a combination of two or more of the above? In the present problem this question is to be answered by the inventor.

First Elemental Invention.—Enumerate in the mind, or on paper, all the different ways in which the distance between two masses may be increased. It is true too often that the first device is crude because the inventor did not stop to consider several ways, and choose the best. The different sources of power are furnished by knowledge, and are to be enumerated in each elemental invention. These primary forces, with their modifications, are heat, light, magnetism, electricity, gravitation, chemical action, contraction, weights, wound-up springs, explosions, tides, waves, wind, earth's magnetism and currents, cohesion, adhesion, pressure, primary and secondary batteries, thermopiles, electric, steam, vapor, gas and other motors, and combinations of two or more of the above. In every elemental invention these sources of power should be considered and the best, single or combined, chosen. The means for communicating, or changing the direction, or varying the source of power, should also be chosen from an enumerated list. Together with their modifications, they are, in part, the lever, screw, wedge or inclined plane, pulley or wheel, smooth or toothed, belt, magnet and armature, compound lever, pawl and ratchet, crank, mediums, such as gas and liquid, cam, tackle, wheel and axle, worm gearing, bevel gearing, escapement, frictional gearing, idle-wheel gearing, pendulum, toggle joint, and parallel-motion device. The first elemental invention consists in combining one or more of the above sources of power with one or more of the above means for communicating and directing the power, until that combination is obtained which is the best in the opinion of the inventor. To be sure, this is a tedious and lengthy operation, but there is no short road for the inventor. He must follow the guides and be willing to plod his way. If there are ten means of communicating power the number of possible combinations is in the thousands. How improbable, therefore, is it for one to "hit" upon a thing? It is possible, but not probable.

Second Elemental Result.—If the lamp is for ordinary use, one carbon may remain stationary and the other fed. If for a focus lamp in locomotives or magic lanterns, both carbons should be fed. The questions which should be asked, as in similar kinetic inventions, are: Shall the carbons move simultaneously or alternately; in a linear or curvilinear direction; with uniform rates, continuously, or intermittently, or vibratingly; fast or slowly; by independent sources of power or jointly by the same power, or with a combination of two or more of those motions?

Second Elemental Invention.—In order to give both carbons the proper motion the same steps in combination should be followed as in the first elemental invention, remembering the fact that one of the carbons is consumed about twice as fast as the other.

Third Elemental Result.—The mechanism obtained by the former step is useless without means of regulation. In numerous devices in other departments of industry regulating mechanisms are required. The same principle of invention which applies to the one applies to the other. What is the exact meaning of regulation as being a result? What object must be accomplished? The mechanism obtained by the second elemental invention does not act uniformly with the consumption of the carbons. If the carbons burn away so fast that the arc distance increases, the mechanism should hasten the speed of the carbons, and vice versa.

Third Elemental Invention.—What force shall be used to regulate? The force which causes the irregularity. This is found to be true in other regulators. In the steam engine the load or power with which the mechanism moves is the regulating power for operating the governor. This is equivalent to saying that the steam pressure is the force which regulates the flow of the steam through the throttle. In the dynamo regulator the increase and decrease of current are the regulating power, and so in arc lamps, the regulating power is the variation of the current by the medium of a magnet. This rule is general, not absolute; therefore it is necessary to consider if the regulation can be effected by other sources of power. Having decided what source to employ, the point of application of the power should be considered. As many points as possible should be reviewed. In a clock it is sometimes applied to an escapement, while in an electric-clock system it is applied to a central clock once a minute or once an hour, and thereby all the clocks are regulated. In the same manner much tedious labor must be exercised in enumerating the various regulators in other departments of industry in order to suggest to the mind the possible and preferable point of application of the power.

The Last Elemental Result and Invention.—Before combining elemental inventions to form the general one sought, some new and additional result should be considered, whether this is a problem of the arc lamp or not. At a certain stage of the arc lamp industry it was necessary to switch off the lamp, and throw in the main line by a hand switch, and therefore the automatic cut-out was invented, which, however, is now expired as to the patent. In inventing there should be considered any additional results over the usual results. They may consist in certain attachments or in that portion of the invention relating to static invention.

Consideration of other devices in a similar manner will uphold the principle of invention that kinetic mechanical inventing consists in combining those elementary or compound motions which are adapted to produce the results sought. This is the secret, and it involves and necessitates preliminary practice and preparation before the inventor can expect to solve any very intricate problem.

Motions.—It is fortunate that the inventor is not obliged to discover motions. These are very old, although every inventor may not know them or cannot call them to mind at will. No new elementary motion has been discovered for many years; but the inventor has combined and re-combined them with such wonderful results as to make all the classes of machinery at present known. The number of combinations of the present known motions is in the thousands.

The inventor must know the known motions before he can expect to make any headway; further, he should know them by heart, and should experiment in their combination for the solution of problems, whether important or not, and he should analyze important kinetic mechanical inventions. The more important elementary and compound motions are given and explained below.

In the first place, all motion is relative—not absolute—because no absolutely stationary particle exists as far as known. All things on the earth move because the earth itself moves. Also, the molecules of a body are always in vibratory motion. For the purposes of the inventor, the earth may be assumed to be fixed, and that motion is to be considered relatively to the assumed stationary earth, or to movable or fixed points or objects upon the earth.

The shortest distance between two points is a straight line. A particle may move in that line, and in so doing has rectilinear motion, the simplest motion known, and, in short, the only elementary motion known. Another very simple motion is curvilinear motion, but when resolved is found to consist of two rectilinear motions occurring or at least tending to occur simultaneously at the same time. This principle of motion is beautifully illustrated by the writing telegraph, using two independent currents. The motion of the hand to make a horizontal rectilinear line gradually increases the strength of a distant magnet by means of a delicate rheostat. The motion of the hand to make a rectilinear line perpendicular to the first increases the strength of a second distant magnet near the first and perpendicular to the same. Each magnet's armature is pivoted to and moves a common pencil. Whatever the motion of the hand (rectilinear or curvilinear), the magnets cause the pencil to have the same motion, and yet the armature of each magnet can move in a rectilinear line only. The pencil partakes of the combined motion of the two armatures whenever a slanting or curved line is formed. If the hand moves in an ellipse, the pencil, moved by the magnets, moves in an ellipse, and so on for every motion. The pencil sometimes has rectilinear and sometimes curvilinear, but the armatures always have rectilinear motion. A curved motion is therefore a combination of rectilinear motions.

The simplest form of curvilinear motion occurs when a body has circular motion. The body, while in motion, remains equally distant from a fixed point. Parabolic motion is that in which the body moves simultaneously in two directions at right angles to each other, with velocities which are respectively accelerating and constant, the accelerating increasing as the square of the distance. Other forms of curvilinear motion are elliptical, sinusoidal, being in that curve assumed by a flexible cord suspended loosely and having its ends attached to two fixed horizontally located points; spiral, being in a curve, having the appearance of a snake coiled upon the ground or like the spring in a watch; helical, being in a curve represented by the ordinary helical spring; hyperbolical, to the eye apparently like the parabolical, the curve of the hyperbola being obtainable by the intersection of a conical surface by a plane parallel to the axis of the cone; epicycloidal, being the motion of any given particle in the circumference of a wheel when that wheel rolls either upon the outer or inner side of a circular line; cycloidal, being in that curve formed by a point in the circumference of a wheel rolling upon a straight line and remaining in a given plane; curtate-cycloidal, similar to above, except that the moving point is upon a projection extending externally to the circumference;

and prolate-cycloidal, being the same as in the above case, except that the moving point is attached to the wheel within its circumference.

Curved or rectilinear motions are divisible into intermittent, continuous, accelerating, diminishing, alternately accelerating and diminishing, rapid, slow, gradually accelerating or diminishing, reciprocating, *i. e.*, first in one direction and then in the other, and abruptly accelerating or diminishing, and periodical, being that motion in which the object moves for a while and then stops for a while, and then moves, &c., differing from intermittent motion in that the periods of motion are definitely durable and not apparently instantaneous. Parallel motion is that in which a point moves in a straight line parallel to a given straight line. Sun and planet motion is that in which one wheel rolls upon another which rotates upon a fixed axis.

Something should be said in regard to the nature of the combination of the motions for producing an invention. Is it like a chemical combination where the compound is different from any of its constitutents, or is it like a mixture where the elements of the mixture retain their individual properties? It is sometimes analogous to the compound and sometimes to the mixture. The curvilinear motion is similar to the compound, because the rectilinear motions in the curved line are infinitesimally small, and can practically be said not to exist. Practically the curvilinear motion is that in which its constitutents lose their indentity until analyzed, as in the case of a chemical compound. In the steam engine such a compound motion is found where the crank-pin moves with a circular motion. This circular motion is combined with the motion of the other parts of the engine, not as in a compound, but as in a mixture. Thus the eccentric, governor and slide valve have motions which taken together are essential parts of the invention, and yet they are as distinct as if each were a distinct device. The word "combined" therefore is a general word in the science of inventing, indicating either an intimate union or a mere mixture of motions.

Analysis of the Motions of Kinetic Mechanical Inventions.—Another analogy exists between invention and chemistry. The student in both cases becomes better prepared to solve problems of a certain class by analyzing existing combinations. By understanding the analyzing of chemical compounds of a certain class he is better prepared to obtain a new compound by combining chemicals; so also, by becoming expert in the analysis of an invention in the class of kinetic mechanical inventions, he is better able to solve a given problem in this class by combining the proper motions. A few examples are given, not only for such practice, but to illustrate the above-stated principles of inventing.

Sewing Machine.—One part of the thread must pass through the cloth in one direction, and a contiguous portion of the thread must return through the cloth in an opposite direction. The motion which is given therefore to the thread is reciprocating if it is desired to imitate sewing by hand. If the machine is to be operated by the foot, another motion—that of the treadle—is also reciprocating. After the thread is passed through the cloth some motion is necessary in order to prevent some of that portion which has passed through from returning, or else no stitch will be formed. This motion is different in different machines, and this feature admits of fertility of combinations. In general, the motion is such as to tie a knot in the thread, which serves the same purpose as a rivet head in the manufacture of sheet-iron articles. When the thread comes through sufficiently far a loop is formed. In one type of machine two peculiarly shaped prongs, somewhat like the fans of an electric motor, are mounted upon a rotating shaft, except that they are pointed. The prongs enter the loops and release them at such relative times as to be ready to form knots which are so artistic in appearance as to be used often for embroidering. It should be said that this rotary motion is coupled with a reciprocating finger, which acts at right angles to the motion of the prongs, and reciprocates at such relative times as to assist the prongs in forming the knots. It is well known that sailors can tie many different knots, and similarly the motions and relative motions for tying the knots in the thread may continue to change until all the kinds of knots are exhausted, and the motions may vary in different machines for producing the same knot. In another type of machine two threads are employed, and the motions are such as to intertwist or intertie the two. Another important motion is necessary in a sewing machine. It is a periodical motion of the cloth, which is moved the length of a stitch and which is held fixed for an instant at every stitch. This motion could be made by the hands of the sewer, but the motion would be defective; it should be automatic. Another motion is also periodical, being that which feeds the thread to the needle combined with a friction device for holding the thread at any desired tension. These motions are all derived from the reciprocating motion of the foot. This reciprocating motion is converted into rotary motion of a shaft, which corresponds therefore to the shaft of a machine shop, by means of which different machines, as the lathe, planing machine, drill, gear cutter, &c., may be operated. In the sewing machine each one of the motions desired is likewise obtained by mechanical connection with this shaft.

Clock.—The day is divided into 24 hours, each hour into 60 minutes, and each minute into 60 seconds. One hand indicates the hours; one the minutes, and one the seconds. The three hands have rotary motions, with different but uniform motions, sometimes about different axes and sometimes about the same. In some the source of motion is circular, as in the wound-up main-spring, and sometimes rectilinear, as in the wound-up weight. Again the primary motion may be reciprocating as in the case of a magnet and its armature. In all cases, the primary motion is generally immediately turned into rotary motion of a shaft or arbor from which the other motions are derived. This motion is true in a large class of kinetic mechanical inventions; the primary motion is first converted into a continuous rotary motion of a shaft. The motions of each hand of the clock must be so uniform as not to vary a second if possible during a year; but of course this is impossible. The primary motion is generally a very powerful motion and tends to feed itself out in a few seconds. Therefore it must be checked, and allowed to feed out intermittently; a little each instant, as is generally done by an escapement or balance wheel. The expansions and contractions of the pendulum by heat are periodical motions, which cause variations of velocity of the hands, whereby the wrong time would be indicated, except by automatic motions of contrary direction, which will neutralize those of expansion and contraction. The pendulum is maintained of the same actual length between the point of suspension and the center of the pendulum by such an arrangement that the expansions of certain parts of the pendulum cause them to shorten, while expansions of other parts cause them to lengthen, whereby the average is a non-variation of its length. Contractions by cold similarly have no actual effect upon its length. Since the hands must have different relative velocities, the wheels which gear with one another must be of proportionally different diameters, the rule being that when two circles of different diameters are geared together the smaller will make complete turns as much oftener as it is smaller in diameter.

Adding Machine.—In this, the figures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 are moved to distances proportional to the distances represented by the numbers themselves. A series of wheels will accordingly, by proper gearing or lever connections, move corresponding distances. In order that these wheels may not move back again with the figures (which must return to their original positions to be ready for a second, third, &c., movement), the ordinary pawl and ratchet are usually employed. The sum of the distances moved through by index hands on the wheels will be equal to the sum of the particular figures which were moved in the first place.

CHAPTER IX.

Making and Developing Scientific Inventions.

The following principle of the science of invention holds true in reference to a large class of past scientific inventions, and it may, therefore, be assumed to hold true for many future scientific inventions. It is formulated thus:—

An invention may be made by applying one or combining two or more principles of physical, electrical, or chemical sciences to a new and useful purpose. The corollary to this is: Any given problem of invention may be solved by becoming acquainted with the principles of physics, electricity, and chemistry, and then searching for principles which by their combination will produce the result sought.

Both of these principles prove the preference and almost the necessity of thorough scientific education on the part of the inventor. I believe it would be for the good of the industrial arts and the public to establish in our various scientific colleges a class for the development of the power of inventing. At present, students study science and store it away in their brains, as though the storage were to be permanent. By the time they undertake to use the knowledge they have forgotten most of it.

An exercise is needed whereby the student will be encouraged and assisted in making use of the scientific principles he learns. Let the professor of this department give the student a principle for application to some useful purpose. If the invention proves to be old the exercise is no less valuable. It will be original, even if not novel, and will thus serve to train the inventive faculty and assist in forever fixing the principle in the mind.

Suppose, for instance, that he should be asked to make practical use of the electrical principle, that the substance selenium is a conductor of electricity when exposed to light and a non-conductor when in the dark.

We can imagine one student proposing to solve the problem of rising with the sun. He would have an electric bell in circuit with an electric battery and with a piece of selenium, which would hang in the window. No current would pass in the night because the selenium is in the dark, but it would pass and ring the bell when exposed to the light of the rising sun. Another student would probably suggest the wonderful invention of the photophone, in which is employed this principle for transmitting sound. Another student might propose to make a meter for measuring the amount of energy consumed by an incandescent lamp during each month, by causing the selenium to be near the lamp. While the lamp was in, a local and small current would flow and operate the clock-work; when the lamp was out, the clock-work would stop. My readers may perhaps think of as many different applications of the principle as there are individuals, and some may result in a valuable and novel invention; but let me ask how many such applications of principles and facts can be made by a would-be inventor if he does not know the principles? Where can he find these principles? In books and periodicals on science; in miscellaneous readings and in the course of experiments. He can obtain them also by conversation with his acquaintances, and especially from those who have made a systematic study of science.

In order to make use of the principle of invention, set forth in the last corollary, the inventor should first decide what problem he wishes to solve and then search books; search his mind for any hidden principle he may have learned a long time since; converse with scientists if possible, and do everything which will acquaint him with the principles, and as each one appears think upon all of its bearings, to discover if it is possible to combine it with another principle in the solution of the problem. Suppose the problem is to transmit speech electrically—*i. e.*, the same problem that was solved by the first inventor of the telephone. We can imagine him seeking here and there for the principles and facts in the science of sound, electricity, and motion. He considers the same individually and collectively.

Or suppose we consider a problem which has not yet been commercially solved, the conversion of an alternating current into mechanical power; or, more briefly stated, the invention of a commercial alternating current motor, printing telegraph, electric meter, &c. In the same manner that other great inventions have been made and in accordance with the above stated corollary, the inventor must review the simple and complex principles and facts of science and mechanics with the object of applying the same to the solution of the problem, if the problem is capable of solution; that inventor who does this work most thoroughly and quickly will be the most successful.

One of the greatest difficulties in making this class of invention is that of finding or recalling the principles of science. In any given book they are often hidden, or it may be necessary to read several pages in order to obtain a single principle or fact. Truths of science are the most valuable tools one can possess for making scientific inventions. The inventor cares not how or when or by whom they were discovered. He cares for nothing except to *know* them and then to use them.

Note the two methods of procedure as set forth in the above principle and its corollary respectively at the beginning of this chapter. The principles are given in the following chapters. Scientific principles have another value to the inventor. They furnish him with that knowledge which will assist in making an invention, although the invention may not consist primarily of the combination of the principles used. They may sometimes enter in merely as elements of *construction*, not of *invention*.

Because a certain principle or principles have been applied to produce a given invention, is no reason that they cannot be applied in a subsequent invention. Take, for instance, the principle that light blackens certain compounds. This formed the basis of the invention of photographs. Only recently it has been employed by W. C. Patterson (the invention being owned by the Walker Electric Meter Co.). He allows a ray of light to pass through an eye in a galvanometer needle and strike a moving paper covered with a sensitive photographic film. In this way he photographs the movements of the needle. The area within the curve, by calculation, gives the amount of energy for a given time consumed by lamps, motors, etc.

In this book it would be useless to state absolutely every principle and fact of every department of science. Those of probable importance to the inventor are given. Those which have been applied once or twice, etc., are those which are most apt to be applied again, and certain old principles are known which have never been applied to any useful purpose. Out of all known electrical, physical, and chemical knowledge, those of maximum importance to the inventor have been formulated.

An inventor can make scientific inventions without necessarily making discoveries. The scientific principles combined can be old. How fortunate this is! The investigator studies the laws of nature and often spends a lifetime in adding only one or two new scientific facts or principles which may be appropriated by the inventor. This rule of invention is not generally recognized. The popular idea is that an invention is something radically new—new in every sense. Argument in the matter is useless, provided the rule can be established by the proper analysis of important inventions. Several examples are given in order to prove that the rule is applicable in nearly every case. It is very seldom that the inventor both discovers and invents. He makes use of the scientific knowledge obtained by others. He uses as his tools *old* principles and facts—those which are open to all.

The following analyses should be studied very carefully, and the inventor should analyze in a similar manner other inventions. The exercise is of great benefit as a preparation for solving problems. If he clearly comprehends any given problem solved by others and clearly understands that it has been solved by the combination of old scientific principles or facts, and follows the combination step by step in order to discern the order in which they are combined, he will be better prepared to undertake new problems, and will not be so apt to travel in the indefinite footpath laid out by the popular mind, which seems to think that the invention is something new in absolutely every sense; mysterious, due to inspiration, genius, or to some peculiar spirit which communicates the ideas without any preparation for, or attempts in, solving a given problem. In the analysis each problem is indicated by the name of the invention; and the principles which were chosen and combined by the inventors are stated as briefly as possible. It is easy to assume and can often be proved that the inventor in each case combined many principles by twos and threes, etc., before he obtained the right combination, and that he obtained the desired results with other combinations, but that the commercial type was the best of them all. In short, let the inventor notice the probable truths:

a. That the principles or facts combined were known in nearly every instance at the time the invention was made.

b. That the device was easy to design and construct after the right combination was found.

c. That the principles and facts are usually found not in one department of knowledge, but that a chemical fact is often combined with an electrical piece of knowledge, a heat principle with one or more acoustic, an acoustic with electrical, &c.

d. That it follows that if past inventions have been thus made, it is reasonable to believe that future inventions may be made in the same manner.

e. That the inventions would not have been made if the principles and facts had not been known.

f. And that in order to solve any given problem, the inventor need not expect to succeed until he has investigated scientific facts and principles with a view of obtaining the elemental and general results of a problem.

Or he may combine principles hap-hazard to learn if a useful result follows. This last method of procedure is the less to be recommended, because it is like a child writing promiscuously the characters of musical notes, flats, sharps, &c., upon five parallel lines with the hope that a new tune will be composed. The way recommended is, first, to have some problem to solve. If there is no problem, what is the use of trying to invent? It must be assumed of course by the author that the inventor has problems needing solution. Herein is a good place to distinguish the musician and poet from the inventor. I have seen them put on the same footing. They do not combine scientific facts and principles. They combine notes and words into bars and verses with no other object than to appeal to one or more of the senses or imagination. Instead of saying things in the ordinary way, the poet dresses up the words and sentences to appeal more forcibly to the longing one has of listening to the beauties of the particular language. A translated poem loses its charms, but an invention is useful independently of the nationality of the user. We hear of the musician and poet as being inspired, as having genius, and as being exceptional, and as succeeding not in proportion to anything except as to the amount of genius. It is held not to be similar with the inventor. He has a definite result he wishes to obtain; he must undergo the tedious and long work of seeking for and combining motions, principles and facts until he gets that combination which will solve the problem. With practice, this operation becomes very rapid. The reason of touching upon this comparison is to try to overcome an old popular notion that an inventor, like the poet, must wait for the inspiration. He who believes in waiting is more likely to become a poet than an inventor.

The analyses alluded to above are as follows:

Incandescent Lamp or Subdivision of the Electric Current for Lighting.—An electric current is converted into light by its passage through a conductor. The smaller the diameter, and the higher the specific resistance of the conductor, the greater the completeness of the conversion. Carbon has the highest specific resistance of all practical conductors, and is incombustible in a vacuum. Woody fibres, cotton and linen thread are carbonizable at a high heat, whereby pure carbon remains having the same cellular structure as the original material. High resistances in parallel subdivide a current, so that a small portion goes through each. Glass and platinum have the same rate, approximately, of expansion by heat, explaining why for so many years platinum has been used for making an electric connection from the exterior to the interior of a closed glass globe.

Screw Propeller for Ships.—The rotary motion of a screw in a medium produces longitudinal motion, as illustrated by the well-known cider press. Experiment showed that this medium could be water. This illustrates the case of the mere application of a single principle.

Thermometer.—Heat expands liquids proportionally to the temperature.

Thermostat.—A rod made of two strips of different kinds of metal riveted together bends through an angle proportional to the temperature.

Tesla's New Phosphorescent Light.—The higher the potential of an electric current and the greater the frequency of alternations of current, the greater the light during discharge.

Telegraph Relay.—A very weak current may be concentrated by passing the same through a very long coil of wire wound upon a core of iron. Mechanical motion may be produced upon a delicately movable armature within inductive relation to said core. A powerful current may be caused to flow by the mere closing of a circuit needing only a very small force.

Electrical Welding.—Heat is produced at loose contacts of metal in an electric circuit. The maximum heating power of an electric current is in a secondary coil of an induction coil. The coarser the coil in proportion to the fine primary coil, the greater the heating effects, assuming of course that the primary current is as great as practicable.

Air Brake.—Friction may be produced and a wheel prevented from rotating by means of a shoe pressed thereon by a spring. Air pressure, if sufficiently great, will overcome the force of the spring, reducing the friction to zero. Pressure of air may be diminished by allowing it to escape from its compressed condition into the open atmosphere. When air pressure is removed from a spring, the latter assumes its original pressure and produces friction upon the wheel.

Kinetograph.—The phenakistoscope, invented years and years ago, during operation, shows to the eye in rapid succession figures of an animal, a man, &c., in different relative attitudes, producing upon the eye the effect of one figure having motion, in view of the persistence of vision. In this instrument, the figures are not made by photography, which in the case of the kinetograph are true to life if made at a high rate during the motion of any given object.

Telephone.—Speaking vibrates the air and membranes in unison with the larynx in the throat. A vibrating membrane always produces the same sound for the same vibrations. A vibrating iron membrane (armature) vibrates an electric current. A vibratory current vibrates an iron membrane in unison with the vibrations of the current.

Siphon Recorder for Receiving Cable Dispatches.—A liquid charged with static electricity and located in an open capillary tube is expelled therefrom, overcoming the capillary attraction between the tube and the liquid. A paper surface moved past the stream of liquid, which may be ink, receives a line, whereas an ordinary pencil or pen would produce friction, which would take up more force to move the pencil than exists in the current which has traversed the sea.

Chlorine Bleaching.—Chlorine has such a strong attraction for hydrogen as to take it from other elements, forming a gas which escapes into the air, the action being increased by the light of the sun. The coloring matter in fabrics is due to the presence of hydrogen, which, if removed, leaves the fabrics white.

Direct Current Dynamo.—A closed conductor moved to and from a given current receives an induced alternating current. An alternating current is resolvable into a direct current by a pole changer acting in unison with the alternations. A direct current will energize a magnet.

Davy's Safety or Mining Lamp.—The temperature of a flame is, for any given oil, a certain degree. A metal introduced into the flame reduces the temperature immediately about the metal, where the flame becomes extinguished and unburnt carbon deposited, so that a fine wire gauze prevents a flame from passing through the same and appearing on the opposite side.

Gas Lighting.—Coal heated to redness out of contact with air generates carbonic mon-oxide $C\,O$, and carbureted hydrogen $C\,H_4$. These gases are combustible in air.

Water Gas Lighting.—Water vapor in contact with red hot material is decomposed into hydrogen and oxygen, which are combustible, relatively.

Forbe's Coulomb Meter.—A current heats a wire. A heated wire causes a rising flow of air. A mill is operated by moving air. Registering apparatus is operative by a windmill.

CHAPTER X.

Acoustic Principles as Tools for Making Scientific Inventions.

Speaking, singing, musical instruments and other sound producers vibrate the air, water or other medium.

That against which the vibrations strike vibrates synchronously with the particular medium, and in unison also with the membrane in the throat or with the vibrating element of the sound producer.

"Sound" (*i. e.*, air or other fluid vibrations) bounces away from a surface in the manner of a ball thrown against a house, except that the former moves in a straight line.

Sound does not pass through substances in the manner of a bullet through glass, but the vibrations given to the glass set the air on the other side into vibration, thereby equivalently passing through the glass or other substance considered.

Sound radiates in all directions from the sound producer.

Sound may be concentrated upon a point by producing the sound at the larger end of a funnel or directly in front of a concave surface.

When the smaller end of the funnel or a convex surface is employed the sound is scattered.

Sound is louder the nearer the sound producer. If the latter is moved double the distance away, the sound is only one-quarter as loud. If the amplitude of vibrations is increased, the sound is proportionally increased. The denser the air, liquid or solid, the louder the sound. In the direction of the wind the sound is louder than in the opposite direction. The presence of a violin box or similar resonant body increases the sound. Sound is loud according to the degree of elasticity of the medium.

A tube filled with air or water conducts sound so well that a sound can be multiplied several times. The larger the tube, the greater the length may be. If the tube is twice the diameter, the sound may be conducted twice the distance.

Any given vibration of sound, whether vocal or instrumental, or from another source, has a velocity of 1,100 feet per second, at the ordinary temperature, and at the ordinary atmospheric pressure. In water the velocity is 5,000 feet per second.

Metal conducts sound with a velocity of 16,000 feet per second.

A vibration of air consists of a condensation and a rarefaction. The air is first compressed and under abnormal pressure, and then it expands in the same manner as a solid rubber ball.

Sounds vary in pitch, *i. e.*, either high or low. The greater the number of vibrations, the higher the pitch, like a pendulum. The shorter the pendulum, the more rapid the vibrations.

Loud or soft sounds have respectively greater and less amplitude, corresponding respectively to a pendulum of a fixed length, having a greater or less swing. This property is called intensity.

Sounds also have quality, which varies according to the material which produces the sound. The sounds from violins, pianos, flutes and vocal organs come from different materials, and although of the same pitch, and intensity are of different quality.

Sound added to sound increases, and sound opposing sound diminishes it.

Air, while vibrated by sound, is as truly a form of mechanical power as a steam engine.

Sound may be recorded visually, by placing the sound producer in front of a diaphragm provided with a point resting upon a moving surface of wax, tin-foil or other yielding substance.

Sound cannot be bottled as water, but the records obtained as above will serve as a guide to the said point, so that by a repetition of movement of the surface the point will follow the record and cause the diaphragm to vibrate exactly as it did before, thereby causing the air to vibrate in unison and produce the sensation of the same sound upon the ear that was "stored" upon the surface.

Sound may be classified as musical, articulate (speech), and miscellaneous. Articulate sounds differ from the others in the same manner that a continuous but irregular current differs from intermittent currents.

An ivory ball dropped upon a stone bounces upward. A portion of the mechanical energy is converted into heat ; so also, in the case of sound, the condensations of air in vibrating produce heat, and the rarefactions, cold. The condensations and rarefactions are the result of the sound, and are but another name for vibrations.

The microphone does not magnify sound in the same sense that a microscope magnifies visible objects. The action is that a slight sound causes the carbon contacts to intermittently make and break a large electric current, which operates a telephone receiver, in the same manner that a relay opens and closes a local circuit, which furnishes the energy to transmit the message to double the distance first traveled by the message.

Neither does the microscope magnify light. It decreases it; because the magnified image is less bright than the object magnified.

The ticking of a watch at the end of a long metal or wooden rod is distinctly audible, while through air at the same distance the sound is scarcely heard. Likewise the earth conducts sound better than the air. If the ear is applied to the rails of a railroad, an approaching train is heard long before it can be heard in the air.

All kinds of sound at a short range apparently travel with equal rate, because the music from a brass band is not confused; but those of greater intensity move most rapidly. In battles, those at a distance can hear the report of a cannon before the command to fire.

The velocity of sound is the same whether traveling horizontally or vertically through the air; but it moves faster and faster from the source until a certain maximum is obtained.

A bell heard through a tube 3,000 feet long is heard twice at an interval of over two seconds. The air conducts one sound and the metal of the tube the other.

Wires are good conductors of sound. The scratching of a telegraph wire can be heard several miles, especially if the wire terminates in a membrane which terminates at the ear. Talking may be transmitted through a wire by stretching it from one membrane to another, and using them respectively as the mouth and ear piece.

Since sound is reflected, it is badly conducted by a substance formed in layers or separated masses. Poor conductors are substances like plaster, sand, porous earthenware, ashes and shavings.

Echoes are sometimes heard by speaking against houses from a distance of 100 feet or more ; but they may be produced at any time by means of a concave reflector whose radius terminates in the speaker at anything over 100 feet. At this distance a one-syllable word is heard reflected. At 500 feet five syllables can be heard by reflection.

Sound is reflected by clouds, also by the invisible aqueous vapor in the air.

Lenses made of membranes between which is a liquid or gas concentrate or scatter sound as truly as ordinary lenses refract the rays of heat and light.

The air may vibrate at any imaginable rate, but the ear cannot distinguish sound if the number exceeds 20,000 to 23,000 per second, or is less than 16 to 8 according to the person ; for it is true that some persons can hear a high rate of 23,000 vibrations per second, while another hears it not.

The louder the sounds, the higher the note which is audible. With weak sounds the ear cannot hear a note having over about 10,000 vibrations per second.

If several clocks are placed upon a shelf, their pendulums will soon vibrate in unison, although previously they were vibrating differently.

A tuning fork, scarcely audible, if placed upon a board, or a piano, is audible several feet away. The piano having a large surface, sets a large mass of air into vibration, and therefore the increased loudness.

If a tuning fork is operated in front of a small hole in a hollow body (resonator), the air inside will or will not loudly resound according to the volume of the enclosed air. If 1,000 tuning forks of different pitch are employed, the resonator will answer to only one fork.

The mouth is a resonator for the sounds produced by the larynx, and answers to all notes sung, because the shape and size are made to change by the different positions given to the lips, cheeks, teeth, tongue and jaws.

The longer the string in a piano, the lower the note. Men's voices are of lower pitch than those of women, because the vocal strings are longer in the former.

Sound produced by a tuning fork is simple—there is only one rate of vibration. That produced by strings is compound, and consist first, of one set, giving the note proper; secondly, the harmonics, which arise from vibrations of a different rate. The following analogies will explain: A rock dropped into quiet water is like a tuning fork, producing one large set of waves, but no small one. Immediately after the rock is thrown, cast in some smaller stones of different sizes. Little waves are visible upon the large waves, illustrating to the eye how vibrations of different rate and amplitude can coexist.

If vibrations of two sounds having vibrations of equal length are in the same phase, the sound is doubled; but if one vibration is half way behind the other, no sound is heard. If the vibrations are of different lengths, the sounds tremble, *i. e.*, are alternately loud and soft.

A gas flame sings when located within a tube open at both ends. Some of the air is consumed, making a rarefaction; then more air rushes in, causing a condensation, and so on in such rapid succession as to produce a note. The gas for the flame should issue from a finely drawn tube projecting upward from a gas pipe. This tube should extend into the first-named tube.

A plate fastened at its centre may be vibrated by a violin bow drawn across its edge. If sand is placed upon the plate it forms into fanciful figures, according to the point of application of the bow. The plate may be fixed at the edge and the bow drawn against the edge of a central hole. A membrane stretched and held by its edges and vibrated by blowing a whistle or by other sounds arranges sand, placed thereon, in regular figures.

Sounding bodies sometimes attract and sometimes repel other bodies. The sounding body is conveniently a violin. A balloon of carbonic acid gas is attracted toward the opening in the box; one of hydrogen is repelled.

Suspended and neighboring tuning forks attract each other. A piece of paper suspended by a silk thread and near a sound producer is attracted thereto; or a card may be fixed and a sounding tuning fork suspended near it. A flame is repelled by an adjoining sounding body.

Small resonotors, made for instance of small pasteboard boxes, containing each a small hole and mounted upon cross-arms pivoted at the centre, revolve about the pivot when a sounding box is located sufficiently near.

The graphophone differs from the phonograph in that in the latter the record on the wax occurs as indentations, while in the former curves are marked parallel with the surface of wax.

CHAPTER XI.

Principles in Heat and Light as Tools for Making Scientific Inventions.

Heat and light vibrate the molecules of a body;—sound vibrates the body as a mass.

Heat has the power of converting solids into liquids; liquids into gases; changing the color of metals, as by making them red hot, producing electric currents; effecting chemical reactions; producing sound; overcoming magnetism; and developing mechanical motion.

Light may be converted into heat, electricity, magnetism; and it will produce chemical decomposition and mechanical power.

Heat and light act in opposition to that of cohesion, as illustrated by its converting a solid into a gas; the volume of the gas being greater than that of the solid.

Heat, in vibrating the molecules of an animal's body produces a sensation which is also called heat; but science uses this term to indicate the vibration of the molecules of a body or of that of the medium between bodies, said medium having the property of communicating heat from one body to another.

When two bodies of different temperatures are brought together, the motions of the molecules of the one are communicated to those of the other, which becomes warmer; finally the molecular motions of both are communicated to surrounding objects, until reduced to the normal condition.

In a manner somewhat similar to sound being communicated from one body to a distant one by vibration of intermediate air, so heat and light are assumed to be communicated by an atmosphere so thin and light that it cannot be detected by any present known means.

Heat and light are not intercepted by a vacuum; but sound is cut off.

Solids, liquids and gases differ from one another because of the relative positions and motions of the molecules.

In gases, the heat has entirely overcome the force of cohesion; so that the distance between the molecules depends only upon the pressure of an external medium and upon gravitation. At a thousand miles above the earth the molecules of the air are probably many feet apart.

In solids, the molecules vibrate within fixed limits; and when moved beyond those limits by mechanical force the body is divided into separate masses.

In liquids, the forces of heat and cohesion are nearly balanced, and remain so between fixed temperatures under any given atmospheric pressure.

In solids, the distance between the molecules is less than in liquids, and less yet than in gases.

A vapor is an intermediate state between a liquid and gas. The forces of cohesion and heat are more nearly balanced in a vapor than in any other form. A slight reduction of temperature or increase of pressure causes liquefaction. A slight elevation of temperature or decrease of pressure causes gas.

Some solids have the property of vapors, in that they are convertible directly into a gas by heat without first becoming a liquid.

The molecules of an enclosed gas strike upon and rebound from the inner surface of the containing vessel; the resultant of all the forces being pressure which is increased by heat. If the gas is enclosed in a yielding vessel, as of rubber, the volume of the vessel increases by heating.

The volume of a solid or liquid likewise increases by heating and diminishes by cooling.

What is true of light is true of heat, because light is usually heat; but what is true of heat is not necessarily true of light, because heat exists without light.

The sum of the forces exerted upon a surface by the moleclues of a gas results in a *constant* resultant pressure.

In order to show the rapidity of vibrations of molecules, it has been proved that the number of impacts, in a second, of a molecule of gas upon a surface is 4,700 millions. The length of the path of the molecule at ordinary temperature and pressure is in length equal to .000000095 of a yard. The diameter of a molecule of hydrogen is approximately .0000000008 yard.

Heat produces three effects upon a body. 1. It increases the volume. In doing this, it overcomes the pressure of the atmosphere or other surrounding fluid. 2. It increases the rate of vibration, which is the cause of rise of temperature. Work is expended to do this in a manner similar to work being expended in increasing the number of vibrations per minute of a cannon ball or of the piston of a steam engine. 3. It increases the swing or amplitude of the vibration. Work is therefore expended, as in the case of a piston; the further it is moved, the more the energy expended.

Of solids, liquids and gases, the same are expansible by heat; gases, most; solids, least; and liquids, at a medium rate.

The expansion may be mostly in one direction, as with a rod; in two directions, as in a sheet; or in three directions, as in a cubical block.

The temperature of a body corresponds to the pressure of a liquid or to the electromotive force of an electric current. A thimbleful of water may have the same temperature as a barrelful.

The expansion of solids, liquids or gases is proportional to the temperature; *i. e.* to the rate of vibration of the molecules.

A globule of mercury or other liquid in a fine tube is moved considerably by heating the air in a bulb formed on the end of the tube. The air expands and drives the globule along the tube.

A fine evacuated capillary glass tube is acted upon gradually by the pressure, so that after a year or two the diameter of the tube is less.

Different kinds of substances have different degrees of expansion under the same amount of heat.

In a similar manner that a short magnet is more quickly magnetized and demagnetized by an electric current than a long magnet; so does a thermometer mercury column change more rapidly in length the smaller the bulb thereof.

Increase of density in any given substance increases the rate of expansion per unit of heat.

Among familiar substances, the following solids are more and more expansible by heat in the order named: Diamond, wood, graphite, compound minerals, glass, platinum, steel, iron, copper, lead, ice, gutta-percha.

The sources of cold and their degrees are:—mixed bisulphide of carbon and nitrous acid—140° C.; ether mixed with the vapor of carbonic acid when liberated from the confined liquefied carbonic acid—110°; Arctic regions—58°; liquefying of mercury from the solid state—40°; mixture of snow and salt—20°.

Red heat of metals is obtained at 550°. Fusion of silver, 1,000°; of cast iron, 1,530°; of platinum, 2,000°: blast furnance, 1,800°.

The heating of one side of a long rod causes that side to expand, while the other side remains cool for a while; consequently the rod bends. If the rod is made of different metals the rod will bend when heated, because one metal expands more than the other for any given amount of heat.

Heat may be made to break thick glass by heating one side and cooling the other.

Through the expansion of bodies heat becomes a form of mechanical energy.

Heat varies a current in expanding a rod pressing upon carbons touching one another while forming a part of an electric circuit. The more the rod is heated, the closer the carbons come in contact, and consequently the greater the current.

Non-crystalline substances expand by heat, equally in all directions. With certain crystals the expansion is not the same in all directions.

A substance besides that of type metal, which contracts upon heating and expands on cooling, is argentic iodide.

Independently of the kind of gas, whether air, hydrogen, chlorine, coal gas, or any other gas, the amount of expansion for the same amount of heat is approximately the same.

Metals become just visibly red at 525° C.; dull red, at 700°; cherry color, at 900°; orange, at 1,100; white, at 1,300°; brilliant white, at 1,500°.

A gas will pass through platinum at as high temperature as through porous earthenware, but not to such a degree.

When a solid is heated sufficiently to approximately overcome the force of cohesion, it becomes viscous or liquid, according to the nature of the substance.

The temperature for fusion is different with different substances. The following are some illustrations: Ice fuses at

0° C.; phosphorus, at 44°; wax, at 65°; fusible metal, at 68°; sodium, at 90°; sulphur, at 114°; lead, at 335°; aluminium, at 850°; and platinum, at 1,775°.

Heat applied to solids increases the temperature, but as soon as fusion begins the temperature remains constant until the whole solid has been converted into a liquid.

The same principle is true in regard to the conversion of a liquid into a gas.

Glass and iron are examples of those solids which pass through all the stages of viscosity before becoming a true and thin liquid. Of such substances the melting temperatures are all the temperatures between those at which viscosity begins and ends.

The melting point may be raised by increasing the atmospheric pressure upon the substance heated.

Generally, an alloy of metals fuses at a lower temperature than any of the metals composing it.

A mixture of a metal and non-metal usually fuses at a lower temperature than the metal. Steel (containing infusible carbon) melts at very much lower temperature than iron.

The principle is true generally for non-metals. Sodic and potassic chlorides, when mixed, fuse at a lower temperature than either when alone.

Heat may be stored by converting a solid into liquid or liquid into gas; when the gas becomes a liquid again or the liquid a solid, the same amount of heat is given out.

Equal quantities of ice and hot water intimately mixed are found to assume a temperature of 0° before the ice is all melted. This water at zero mixed with an equal quantity of water at a higher temperature results in water at an average of the two temperatures.

Most solids may become liquefied not only by fusion, but by solution. Common salt for instance fuses at a comparatively high temperature, but at any temperature above 0° it may become a liquid by solution in water. Some substances, practically infusible, are convertible into a liquid by solution. Solids which are opaque often become transparent by solution.

A liquid is limited in its capacity of dissolving solids. After a certain amount has been dissolved, any additional amount remains undissolved, unless the temperature is increased. The temperature of a liquid is decreased during the process of dissolving therein a solid,

If the solid and liquid enter into chemical combination, the temperature increases, decreases, or remains constant, according to the nature of the substances. With cold quick-lime and water (whereby the new substance, calcic hydrate, is formed) the mixture becomes very hot. The two substances combine to form a new compound. Where no chemical combination occurs the temperature lowers. Where the heat produced by chemical action is equal to the cold produced by conversion of a solid into a liquid, the temperature remains the same.

Heat is the force which determines crystallization, which may be obtained by solidifying bodies by slowly evaporating the liquid from their solution or by slowly solidifying from a state of fusion.

Water containing no air in solution freezes at 15° lower temperature than water in which air is absorbed. The water should be kept very quiet. Air may be removed from water by long boiling.

Violent agitation of a liquid at a freezing point prevents solidification.

When strong salt water freezes, the ice is practically pure.

Of solids and liquids of the same substance, the latter are greater in volume. Certain substances heretofore named are exceptions.

Water expanding on solidification is thought to be due to the fact that the crystals occupy more space than if it solidified without crystallization. When the crystals melt, the mobile liquid fills up the space formerly left between the crystals.

Certain substances, as gelatine and gum arabic, do not lower the temperature of water while dissolving.

Sodic iodide, at a slight additional pressure of atmosphere, boils while melting.

Any liquid at any temperature boils in a vacuum. To maintain the boiling, the vacuum must be maintained.

The vapors of liquids relatively insoluble produce double the pressure of either; those more or less soluble in each other exert less than double the pressure of either. Place water and benzole in an enclosed space. The pressure is double that which either the water vapor or benzole vapor would give alone.

Connect two vessels containing respectively ice water and hot water. The pressure of the vapor in each is the same as that which would exist in the cooler vessel if the other were absent. This principle holds true with all vapors.

The rate of evaporation varies with the temperature, the amount of vapor of the same liquid in the atmosphere, the surface of liquid exposed, and the changes in the nature of the surrounding atmosphere.

The following are the boiling points of some important liquids:—water, 100° C.; mercury, 358°; melted zinc, 940°; benzole, 80°; alcohol, 39°; liquefied nitrous oxide, 92°.

The boiling point is higher in case the liquid contains solid substances in solution. Concentrated salt water boils at 202° C. The boiling point is lowered if the liquid contains gaseous or volatile substances in solution.

Water covered with a film of sweet oil boils at a higher temperature than when not so covered. A slight explosion occurs when the temperature reaches 120° C., and then the liquid boils.

Water boils in glass vessels at 106° C., and in metal vessels at 100°. A piece of metal placed in the glass vessel makes the water boil at 100°.

Water boils at lower and lower temperatures, the further upward it is moved from the earth.

Water cannot be boiled in an enclosed vessel except at a very high temperature when it turns immediately into steam. Remove air from water by ordinary boiling. Place a little of the water in a thick sealed glass tube. Heat to 200° C. The water instantly disappears. The experiment is of course dangerous, as the pressure is 500 lbs. per sq. in.

In an enclosed space containing air a vapor will enter, in the same manner that sugar will enter water. In other words a gas will dissolve a vapor. The pressure within the vessel will be increased the same as if the vapor were entering a vacuum.

A liquid assumes a globular form when dropped upon a hot surface (above the boiling point). The globule rests upon a cushion of the vapor of the liquid. As soon as the temperature of the plate falls to that which allows the globule to be in actual contact with the plate, the globule bursts violently into steam. The temperature of the globule is below the boiling point. Upon the same principle, men have been able without injury, to plunge their wet hands into melted lead.

Water in a porous vessel grows colder. The evaporation at the surface produces the cold.

A liquid may be separated from another liquid, as ether from alcohol, by heating to the boiling point of the more volatile liquid (ether) which passes into a receiver, while the alcohol remains behind. Similarly, a gas may often be liberated from a solid, even if chemically combined therewith. Coal gas may thus be separated from coal.

By high pressure and low temperature, a gas, even air, carbonic acid, and ammonia, may be converted into a liquid. Oxygen in liquid form is colorless and transparent, and in evaporating has a temperature of—181° C.

Partially fill a metallic vessel with water. Add ice and a thermometer. The temperature falls. At a certain temperature dew will immediately form upon the vessel.

Some good absorbents of moisture from the air are phosphoric anhydride; quick-lime; strong sulphuric acid; calcic chloride and cobaltic chloride. Paper saturated with the latter, dried, and then put into damp air turns from blue to pink, and when taken to dry air becomes blue. Heat will also turn it blue.

If a thermometer bulb is wet with water, alcohol, ether, &c., the temperature falls in proportion to the dryness of the air.

Hair has the property of lengthening considerably by absorption of moisture. Twisted catgut strings untwist when moist and twist while drying. Similar actions occur with paper coated on opposite sides respectively with gelatine and varnish.

Radiated heat can be transmitted through a medium without appreciably increasing the temperature.

Light is not conducted by a substance, but heat is. If luminous paint is exposed in parts to light, the parts not exposed give no light in the dark. If light were conducted in the manner of heat, the paint would appear equally luminous in the dark. Many substances, as glass, will allow light to pass through the same, but the light is not conducted in the same sense as heat.

As with electricity, so with heat, substances have different conductivities. The best conductors of heat are usually the best conductors of electricity.

Different substances conduct heat at widely different velocities; and electricity is conducted by different substances at approximately the same velocity. There is a difference in the electrical velocities, but it is scarcely detectible for ordinary distances.

Heat is conducted in wood better in the direction of the fibre than transversely.

The mixed double mercuric and cupric iodide under the influence of heat turns from bright-red color to dark purple.

Copper is 100 times a better heat conductor than water.

Water becomes heated principally by circulation. One part becomes heated. It rises like a cork and the cold water takes its place, and so on until the whole mass is heated. For this reason the heat should be applied at the bottom. Alcohol may be burned on the top of water, and yet just below the surface the water is cold; showing that water is a very poor conductor of heat. Gases conduct heat even less than water, but they will allow heat and light to pass through. Liquids become hot by the process of circulation, as in the case of water.

Heat is communicated from one body to another with a rate dependent upon the number of points in contact. The maximum amount is conducted in any given time by having very smooth surfaces of contact.

Rays of heat and light are projected from a body equally in all directions, and lie in straight lines.

Rays of light and heat may be bent by allowing them to pass obliquely from any given medium, as air, into a denser medium, as glass, or a rarer medium, as rarefied air.

From any given mass heat and light are radiated in direct proportion to the amount of radiating surface; and according to the color. They are radiated best from a rough black surface, as made with lamp-black.

Both heat and light, like sound, are reflected from a substance. Not all is reflected; a portion is absorbed by the substance.

The angle at which the heat and light are reflected is equal to that at which they fall upon the surface. Echoes are reflected sound. The surface reflecting the sound seems to originate the sound; similarly, a white house seems to be the source of light; whereas the light coming from it is reflected light.

The rays of reflected light and heat are in the same plane as those which fall upon the surface.

Reflected heat and light may be reflected repeatedly and indefinitely, but a fraction disappears each time by absorption.

A bright concave surface brings the rays of light and heat to a focus; a convex surface scatters them.

In the highest attainable vacuum heat and light are reflected as well as in the open air; and in compressed air as well as in air at the ordinary atmospheric pressure.

The cold rays from ice or similar substance, when focused, reduce the temperature of that which is placed in the focus.

A flame radiates little heat in proportion to its high temperature; but an incombustible mass, as platinum, placed in the flame causes a large increase of radiated heat.

A ray of heat or light is a series of vibrations. In a ray of sound the vibrations travel about 1,100 ft. in a second; in the case of heat and light, the speed is such that only about eight seconds elapse in the transit of a vibration from the sun to the earth—93,000,000 miles.

Sound vibrates the mass; light and heat vibrate the molecules of the mass.

In the same sense in which the ear does not distinguish sound if the vibrations are above or below a certain rate, so the eye does not distinguish light below or above a certain rate of vibration. There are 3,000 nerves from the ear to the brain, all tuned to as many different sounds. The shortest respond to the highest notes; the lowest to the lowest notes; so also, in the case of the eye, there is a power of seeing only when the number of vibrations is within certain limits.

An electric crurent at the instant of rupture or closing, in circuit with one's head, causes the nerves of the eye to vibrate in unison with the vibrations of the current, so that in the dark a slight flash of light is produced, but no object becomes visible. Three Leclanché cells of ordinary size will not injure the eyes. The flash appears as if one were winking.

Let a body be heated from 0° C. to an indefinitely high temperature. The emitted heat vibrations are added to by more rapid vibrations as the temperature rises. The first vibrations visible occur at such a rate as to produce the sensation of red. Violet rays are due to the most rapid of those which produce sensation of light. Chemical effects are produced by rays which have a higher rate than those which produce violet and by violet rays also.

If a ray of light (which is accompanied by heat) falls upon a three-sided piece of transparent substance (called a prism) and strikes a surface in an otherwise dark room, the vibrations of the ray are separated from one another, occupying a long rectangular area, when projected upon a surface.

Violet is seen at one end and red at the other. Just beyond the violet, where no light is visible, exist chemical rays, because they will turn photographic paper black and produce other chemical actions. Just beyond the red, where no light is visible, a thermometer indicates heat. Throughout the limit between red and violet are heat, light and chemical rays. The strongest heat rays are at the red; the strongest chemical rays at the violet; and the strongest light rays at the yellow. The combination of all the color rays forms the original white sunlight.

The seven colors may be combined by reflecting each by a mirror, so as to strike all at the same spot. The spot appears white. Lenses may also be employed to combine the rays.

The seven colors, violet, indigo, blue, green, yellow, orange, red, are simple and cannot be analyzed; but two or more can be compounded to form other colors.

The above principles teach what is otherwise found to be a fact, that an incandescent body, as the sun, radiates simultaneously vibrations of different rates, and that they do not interefere with one another

A bright object is visible after it has been placed behind an opaque screen. This is due to the fact, that an image formed in the eye remains after the object is removed. Let a disc be painted with the colors of the rainbow arranged as the pieces of a pie when cut. If the disc is rotated rapidly it appears white. The colors mix in the eye. Before one color disappears from any given spot the others overlap.

If the red and green and yellow of the spectrum are reflected by mirrors upon a given spot, white light is produced. Compounded green, yellow and violet produce white; also orange and blue. Colored pigments cannot be used, as they are absorbents of colors. Mixed yellow and blue paints produce green, and so on with greatly different results from those obtained by mixing spectral colors.

Light produced by combustion is seldom simple. The yellow light of the gas flame contains blue, red, orange, &c. Common salt burned in alcohol gives nearly a pure yellow light. Roses have no color, because no red is present in such a flame. A man's face looks deadly pale in such a light.

Pure red is obtained by passing daylight through glass colored wlth cuprous oxide; pure blue by passing through a solution of cupric sulphate, and pure red by passing daylight through a solution of ferric sulpho-cyanide of iron.

Rock salt, 1 inch thick, transmits 92 per cent. of heat; smoking quartz, 67; glass, 39; alum, 12; ice, 6; and cupric sulphate, none.

Heat is largely "lost" in its passage through glass; but that which has passed through, passes through a second piece of glass with practically no loss. When alum and rock salt are superposed they are opaque to light and heat.

If 1 represents the amount of heat absorbed in its passage through air, 1,200 represents the amount absorbed by ammonia gas.

If a gas is allowed to rush into a vessel both become heated, because the molecules of the air strike against the side of the vessel, whereby the force of motion is partially converted into the force of heat.

When a gas is rapidly exhausted from a vessel, cold is produced, because the heat produced in the manner above stated is converted into motion.

The best absorbents of heat are the best radiators.

Elementary gases, as hydrogen, oxygen, &c., are worse absorbents of heat and light than compound gases, like carbonic acid, coal gas, &c.

White substances absorb the least and black the most light and heat. An exception is that of plumbic carbonate (white lead), which absorbs heat as fast as lamp-black.

Snow covered by some black substance melts faster than when bare.

Drops of water often cause the surface under the same to burn when both are exposed to sunlight. The drops absorb the heat and at the same time focus it upon the surface, because the drops have the shape of a lens.

Rock salt covered with lamp-black, or with iodine stops light, but transmits heat.

A hothouse becomes warm because the light reflected from objects within is reduced to polarized and heat rays to which glass is opaque.

Of any different substances absorbing heat one will increase in temperature faster than the other. They both are exposed to the same heat, but the temperature of the one rises faster than that of the other. Mercury rises in temperature much more rapidly than water. The former is said to have a higher specific heat than the latter.

The specific heat of any substance, when liquid, is higher than when solid. Water will get hot about twice as fast as ice.

The figure denoting the specific heat indicates how many times more heat is required to raise the temperature of the substance through 1° than to raise the temperature of water 1°. The atomic weight indicates how much heavier an element is than hydrogen. The product of the specific heat and atomic weight of any elementary substance is approximately a constant quantity, and equal to about 6.

Rubbing or pressing substances together produces not only static electricity, but also heat and sometimes light.

All substances, even ice, have heat, and it is believed that absolute cold has never been obtained; but that it would exist only when the molecules are so close together as to be incapable of motion.

Other sources of heat are the sun, electricity, chemical changes, those bodies which are warmer than the thing to be heated, percussion, terrestrial heat, absorption and animal heat.

Heat produced by friction is greater, the greater the relative motion and pressure.

Pieces of ice rubbed together in a vacuum melt.

Water shaken is increased in temperature about 1°.

Flint rubbed against steel detaches steel particles which are so hot as to burn with scintillation.

The movement of shooting stars through the air at their high velocity causes so much heat that they burn at a white heat, the same being invisible before reaching the earth's atmosphere.

H. T. Cory

A tube filled with water and rapidly rotated between two sticks may be made to boil.

The temperature of a body rises in a certain proportion to the increase of its density. Air compressed in a tube by a piston becomes heated.

Shot fired against an iron mass produces light visible at night; showing that mechanical motion is converted into heat and light. Iron when hammered becomes hot. In general, percussion, as well as friction and pressure, produces heat. Lead is not increased in density by, but becomes hot upon, hammering.

The amount of heat received by the earth from the sun in a year is capable of melting a coating of ice upon the surface of the earth 160 ft. in thickness; which is .0000000005 part of the total heat of the sun.

By descending into the earth 30 yards (more or less according to the location) the temperature remains constant during summer and winter. The heat is independent of the sun and is due to a source of heat within the earth.

Upon approaching toward the center beyond 30 yards the temperature increases; about 1° for every 90 feet. At a depth of 30 miles the temperature would be sufficient to melt all known substances. The amount of heat received at the earth's surface from the internal heat is .0001 that received from the sun.

Substances become warm while absorbing gases. Platinum becomes so hot by absorbing oxygen gas that a stream of hydrogen passed over the same ignites. While charcoal absorbs gases its temperature is increased.

If chemical actions are slow, heat is scarcely perceptible. The same chemical actions, when rapid, apparently generate a larger amount of heat. Wood, while decaying, gives off the same aggregate heat as the same quantity of wood burned in a fire.

All ordinary combustion is obtained from the union of the oxygen of the air with the substance burned.

Luminosity does not depend upon temperature.

Phosphorus when rubbed emits light. An alcohol flame, almost non-luminous, is of much greater temperature than that of a candle flame.

Hydrogen and oxygen when burning give no light, but give the hottest known flame.

Luminous paint, placed in sunlight and removed to a dark room, gives light for hours, but its temperature is not abnormal. Diamonds and a few other substances have this property of luminous paint.

Fire-flies give much light, but practically no heat.

The amount of *heat* produced by hydrogen burning in oxgyen is 17 times greater than that of wood in oxygen; while the *light* in the former is practically zero. In the Geissler tube light is produced without heat, but the luminosity is too little for commercial use.

Although charcoal, graphite and diamond are all pure carbon, yet the combustion of each gives a different quantity of heat; but the quantity is the same in the aggregate if the densities are taken into account.

In an animal the force of chemical affinity is converted into mechanical motion. The oxygen taken in at the lungs and the food at the mouth undergo chemical changes, which are reproduced in the forms of heat and motion.

Oxygen unites with carbon to form carbonic acid in animal life. In vegetable growth the carbon is taken from the carbon, liberating the oxygen. The oxygen which is consumed by animal life to form carbonic acid is liberated by plants which take the carbon only.

Oxidation of iron, wood, &c., produces heat. Oxidation of the muscles produces mostly contraction of the muscles, but little heat.

Plants store heat during growth and give it out during decay or combustion. An exception is at the time of blossoming. Oxidation then occurs and the temperature of the plant rises, as in animals.

The temperature of a flame is increased by increasing the rapidity of the supply of oxygen.

Highly compressed air allowed to exit into the air on a summer's day produces a shower of snow-flakes.

Compressed air escaping upon a thermopile in circuit with a galvanometer deflects the needle in one direction, while air from a bellows deflects the needle in the opposite direction.

A pin-hole in paper or other thin membrane acts as a lens in a camera. An image of an object in the light formed in the dark is inverted.

Light vibrations have an actual velocity about 185,000 miles per second.

The brightness of a surface exposed to light radiating from a luminous point is quartered when the distance is doubled. Heat, light and sound vary inversely as the square of the distance.

If a surface is inclined to a ray of light the brightness varies with the cosine of the angle. Cosines of angles are found explained in books on trigonometry.

A grease spot on paper practically disappears when equally illuminated from opposite sides, but grows darker and darker, the greater the difference of brightness on opposite sides.

The intensity of sunlight is 670,000 candle-power.

Light travels in a straight line, but may be bent by allowing it to pass obliquely to or from a denser or rarer medium, or to be reflected at an angle from a mirror.

A ray of light, as a whole, may be vibrated by rapidly interrupting the same by an opaque object, by vibrating a mirror; by varying the medium through which it passes; by vibrating a lens or prism which transmits the light; or by a combination of two or more of the above means.

A ray of light may be regulated as to intensity and quantity by any of the means named for vibrating it.

The image formed by one lens or reflector may be made larger by a second lens or reflector. Light is magnified by concentrating to a focus, as is the case with heat and sound.

The light from stars is bent and re-bent, and reflected by entering the denser atmosphere about the earth, and consequently the appearance of "twinkling."

A substance appears red because it absorbs all the other colors composing white light and reflects only red. In a similar manner substances appear blue, green, yellow, &c.

Red glass is red by transmitted light, because red passes through the glass while other colors are reflected or absorbed. So with glass of other colors.

Colorless glass is that which transmits all the colors.

A red object, as a rose, has no color in a room where only blue light exists, and so also with a green object in light of a different color. Although a gas, candle or oil flame has a yellow appearance, yet nearly all colors exist. The yellow is in excess. So also, some bodies appearing of a certain color reflect other colors, which are not visible, because overshadowed by the prominent color.

Place paper of one color upon paper of a different color. Fix the eyes upon the same, and jerk the top paper away. The remaining paper has a color different from either. The papers should be in daylight and the time of observation about one minute. The color of the top paper remains in the eye after removal and mixes with the color from the bottom paper, forming a color composed of the two colors.

The spectrum is the name given to the heat, light and chemical rays eminating from a source of heat and light, after analysis by a prism. The heat rays are slowest in vibration and the chemical most rapid, while light rays are medium.

Anything which will reduce the rate of vibration of chemical rays will convert them into light rays ; and similarly light rays would be converted into heat rays.

The sulphides of barium, calcium or strontium, commonly called luminous paint, give off blue light when placed in the chemical rays, which are otherwise invisible. The rate of vibration in the chemical rays is reduced to that of bluish light. The color varies with the temperature of the sulphide and whether the sulphide of barium, calcium or strontium is employed. The last named at 20° C. is violet; at 40°, blue; at 70°, yellow; at 100° (boiling point of water), orange; and at 200°, almost invisible. The light is emitted without extra heat. It may be called cold light.

The maximum time of luminosity of luminous paint is 30 hours.

For a few seconds or fraction of a second the following substances possess similar properties of luminious paint: Diamonds, amber, milk sugar, cane sugar, dry paper, silk, Iceland spar, uranium compounds. By means of a special instrument called a phosphoroscope the last-named substance is caused to become visible in a dark room .04 second after exposure to light. It has a higher candle-power than luminous paint, but lasts only the above fraction of a second. Many substances are not phosphorescent. For example, phosphorus, after which the property is named. Phosphorus appears light in the dark, simply because it unites with oxygen. It is not light in a vacuum, nor does exposure to light have any more effect than darkness. Other non-phosphorescent substances are liquids, metals, quartz and sulphur.

By heating diamonds, or the mineral chlorophane, to 300° C. (red heat of metals being 525°), the same become luminous and remain so for several days, although the temperature falls to the ordinary degree of the atmosphere.

Light stored by luminous paint is increased by heating ; but the luminosity lasts for a proportionally less time.

In the same manner that phosphorescent substances continue to vibrate in unison with light rays, so do many bodies continue to radiate heat when taken from a source of heat, and generally the molecules of all bodies are in continual vibration or else absolute cold would exist.

When a source of heat, light or sound rapidly approaches a person, the vibrations are more numerous per second ; and when moving away, less frequent. Illustration: An approaching whistling locomotive has the sound of a higher and higher pitch, and when receding the note descends in pitch.

Some substances have the property of appearing of different colors according to the angle at which they are looked at relatively to the source of light. They are, in part, tincture of night-shade or curcuma, extract of horse-chestnut, thin flakes of fuchsine, a solution of sulphate of quinine, aesculine, and canary glass (colored with compounds of uranium), a solution of chlorophyl in alcohol, and a decoction of madder in alum. The effects are best seen with the help of a lens, which concentrates the rays upon the substance.

Canary glass held in the light which comes into a dark room through blue cobalt glass is yellow ; because the high rate of vibration in blue rays is reduced by the yellow glass to that number of vibrations which produces yellow light.

Polished silver exposed to iodine vapor acquires a flim of argentic iodide, which will turn black upon exposure to light. The black substance is insoluble in sodic hyposulphite, while argentic iodide is soluble. Mercury vapor is condensed upon the black surface, but not upon argentic iodide. The black substance is mostly pure silver in a very finely divided state.

A photographic glass plate is glass which has been coated with collodion or gelatine containing potassic iodide and washed with an aqueous solution of argentic nitrate.

"Bromiodide emulsion" containing an aniline dye is not only the most sensitive to light, but is also highly sensitive to yellow light, so that yellow objects appear white in a positive photograph. With other ordinary photograph preparations the blackening in the negative is caused only by the violet and chemical rays, and not by yellow.

A negative in the development of which ferrous sulphate is used instead of sodic hyposulphate, a bath of potassic cyanide turns to a positive.

The eye of an animal is a camera. It is provided with a sensitive surface, which receives the image and connects with the brain by thousands of nerves. At the point where the nerves join the eye blindness exists, as may be proved by holding a white card, having two small black spots, at reading distance, the distance between the spots being equal to that between the eyes. Close the left eye and keep the other directed upon the left spot. The right spot is invisible because its image falls upon the spot where all the nerves join. The eye has its lens liquid for preventing the heat from injuring the eye; means for adjusting the focus according to the distance of the object viewed; and a variable opening for regulating the amount of light.

The image formed within the eye is inverted, as in a camera, but the brain, in some unknown manner, is so impressed that objects appear in their true position.

A cannon ball during transit past the eyes is invisible. If itself luminous, a streak of light appears. If non-luminous, but illuminated by a flash, the ball appears as though it were stationary. Also, the spokes of a rapidly rotating wheel appear to stand still during a flash of lightning at night, whereas, in daylight the spokes are not separately visible. The above facts show that an impression remains upon the eye only when the eye views an object an appreciable length of time. A lighted candle viewed for a minute appears again when extinguished, and then disappears and reappears, and varies in color, becoming orange, then red, then violet, and greenish blue, showing that some colors remain upon the retina or sensitive surface of the eye longer than others. White light remains longest, then, in order, yellow, red and blue.

White or bright objects against a black or dark background appear larger, and black against white, smaller than the real size. Illustration: A church steeple at a distance appears to lean over, due to unequal illumination of opposite sides. Objects of one color, surrounded by a different color, are accompanied in the eye by a fringe or edging of a color different from either.

In the same sense that all the different vibrations due to an orchestra reach the ear without confusion, so do all the colors in a picture produce no confusion in the eye. The different colors give different rates of vibration to different nerves. Violet light corresponds to a high note and red light to a low pitch. The length of a vibration or swing of an atom in producing the red is .000027 in., and in the case of violet, .000015 in.

Lenses of glass produce single images in a camera. Lenses of certain crystals, as Iceland spar, produce double images. Glass, when annealed or compressed, has this property of double refraction. Such doubly refracting substances cause objects to appear double when looked through. Besides Iceland spar, the following, among other, substances have the property of double refraction: Tourmaline, sapphire, ruby, sodic nitrate, quartz and ice.

Two rays of one color—*i. e.*, having one set of vibration (white light having as many sets of different rapidity of vibration as there are colors)—may be made to interfere and annihilate each other by reflecting them from slight angular surfaces upon a wall. Alternate black and white lines are visible, whereas the black lines disappear if one ray is removed. If white light is used, the black and bright lines are replaced by lines of different colors.

Place a coin in a vessel. Look into the vessel over its edge so that the coin is just out of sight, and add water. The coin comes into sight. The reflected light in coming from the denser fluid, water, is bent in coming to the rarer fluid, air.

Every object casts two shadows, a central or dark and a fringe or light shadow.

In a camera an image exists, even if there is no surface to receive it.

Pictures of a man running, each picture showing each succeeding position of the limbs, head, feet, &c., brought rapidly before the eye and rapidly removed so that the eye sees one figure at a time, and all the figures in rapid succession, make such an impression upon the eye as to form a single living picture. The instrument for doing this generally is called a phenakistoscope. When the different positions are taken by photography, it is called a kinetograph. They illustrate the principle that an image remains upon the retina of the eye an appreciable length of time.

When air vibrates to produce sound, the particles move to and fro, as if in a cylinder in front of a reciprocating piston. The air is alternately compressed and rarefied. In the case of heat and light, a medium is supposed to exist in which the heat and light travel as vibrations, but the particles have motions in straight lines perpendicular to the direction in which the light is moving. They have the same motion as particles in a wave of water. The wave travels along horizontally, but the particles of water move up and down. The waves of a rope illustrate the vibrations of light and heat. The particles of a rope move transversely thereto. All facts uphold the above statements in regard to the nature of heat, but it is still theoretical. As to sound, no doubt exists as to its consisting of condensations and rarefactions of a mass, whether solid, liquid, or gaseous.

Chemical rays of light—*i. e.*, those beyond the violet—may be stored by almost any substance. Illustration : Expose an engraving or drawing or any print to sunlight. Take it to a dark room and press it upon photographic paper. The engraving will be photographed. The chemical rays absorbed by the paper produce the reactions in the same manner as the sun, only much more slowly. In printing photographs, the process continues in a dark room after exposure to light. After a few hours the effect is noticeable.

CHAPTER XII.

Principles in Chemistry as Tools for Making Scientific Inventions.

Every compound body, as, for instance, water, is composed of elements, the smallest particle of a compound being a molecule, and the smallest part of an element an atom. This principle is the foundation of chemistry. Iron, for example, is composed of atoms of the same kind; therefore iron is an element. No one has ever been able to find that it is a compound. No known chemical action discovers anything but iron. The smallest particle which exists is therefore composed of iron and is called an atom. Now let the iron be caused to rust. By this means the iron combines with the atoms of another element called oxygen. The smallest particle of the compound rust or iron oxide is a molecule. If this molecule is analyzed it is found composed of iron and oxygen. The number of elements is comparatively few, but compounds are numbered by the hundred. Some compounds are natural, but most have been made artificially, and there is no reason known why others cannot be made. At long intervals a new element is discovered, but knowledge of chemistry shows that if others are found they will probably be rare and practically useless.

There are about sixty-three elements which may, as far as known, be composed of other elements. The composition of compounds may be known by analysis through the agency of burning them and studying the flame with a spectroscope, each substance giving its own peculiar visual signal.

The solvent power of water is greater in scope and magnitude than that of any other substance.

Substances which are merely mixed together are not compounds, and may be separated therefrom by mechanical filtration, by evaporation or distillation, or by hand.

Elements of a compound which have a stronger attraction for other elements than for each other will leave the former and unite with the latter, as illustrated by zinc in contact with sulphuric acid—it takes the oxygen and sulphur from the sulphuric acid and liberates the hydrogen.

Whenever two or more elements combine to form a compound the said compound differs from either element in one or all of the following respects: Conductivity of heat, sound and electricity, hardness, weight, color, and more or less in other physical properties.

The composition of bodies is generally made known by reacting upon them with other known compounds or elements. Thus, common salt looks like a thousand other substances and tastes like other compounds, and its other physical properties are much like those of other compounds. How shall its composition be known? React upon it with sulphuric acid and manganic oxide under the influence of heat. A green gas issues which will bleach vegetable colors. This gas, chlorine, could not have come from the sulphuric acid nor the manganic acid, therefore it must have come from the common salt; by reactions of other chemicals it is found that the common salt contains sodium. By means of chemical reactions compounds may be made as well as analyzed. If sodium is introduced into the green gas and heated, a bright fire is caused, resulting in a white smoke, which is found to be common salt, chemically called sodic chloride.

Compounds may also be analyzed by the electric current. If the terminals of a circuit are placed in an aqueous solution of cupric sulphate pure copper is separated from the sulphate and deposited upon one of the terminals. Scarcely a compound exists which is not decomposed by the passage of an electric current through its aqueous, acid or alkaline solution. Compounds may also be formed by the electric current. Thus, if the current in the above is closed upon itself the deposited copper on the terminal unites with one or more of the elements of the electrolyte and forms a compound therewith. A current passed from one lead terminal to another of the same substance in an electrolyte of sulphuric acid causes the compound known as plumbic peroxide to be formed upon one of the lead terminals. If the source of current be removed and the terminals closed upon themselves, the plumbic peroxide becomes analyzed to such an extent as to be reduced to a lower oxide, which is a new compound, differing widely in chemical and physical properties from the peroxide.

An electric current will, therefore, sometimes analyze compounds and sometimes combine elements into compounds. This is also true of heat and light.

Chemicals often combine or separate by reactions upon one another at the ordinary temperature.

It is by chemical actions that life is supported. Hold a glass tube in the mouth and breathe through the same while the other end dips in clear lime-water. Soon the water becomes milky, due to the formation of carbonate of lime. The oxygen which enters the lungs combines with carbon of the body, forming carbonic acid gas, which when exhaled unites with the lime and forms carbonate of lime. In a perfectly closed room, 10 feet on each side, death would ensue in a very few hours because the oxygen would be used up. The life-giving oxygen would be turned into the poisonous carbonic acid.

Vegetable life is supported by chemical action. Grains contain phosphorus ; therefore fertilizers for grains should contain phosphates. Ammonia occurs in manures, and it is from that gas that plants obtain their nitrogen. The leaves are the nostrils of the plants, whereby the carbonic acid of the atmosphere is inhaled so that the plants may possess carbon, which may subsequently be obtained by means of a kiln.

Metals, generally, are reduced from their ores by chemical reactions. The ores are mixed with those substances with which the non-metallic elements of the ores have stronger attraction than the metals. Those ores, which are oxides, may be mixed with carbon and heated to a high temperature. The oxygen leaves the metal and joins the carbon, forming carbonic acid, which escapes into the atmosphere, leaving the metal free. Carbonate ores are mixed with lime. The carbonic acid leaves the metal under high heat in presence of the lime and goes to the lime, forming carbonate of lime.

The metals which will decompose water without applying heat are calcium, strontium, barium, sodium and potassium—the same uniting with oxygen of the water and liberating hydrogen. The products formed are the oxides of the metals. Any metals decompose water if they form the terminal of an electric circuit and are dipped into the water. Decomposition is hastened by adding an acid to the water. Very intense heat will decompose steam. If iron or other easily oxidizable metal is in contact with the steam, the oxide of that metal is formed.

One of the most important characteristic differences between physical and chemical changes is that whereas in a chemical change the bodies subjected to the change have different chemical and physical properties after the change ; while before and after a physical change the bodies have the same physical and chemical properties except, sometimes, as to degree. Illustration : Chemically change iron by burning it until it is iron rust—*i. e.*, ferric oxide. Although the iron is still in the ferric oxide, yet the oxide has none of the characteristics of iron nor of oxygen ; for example, iron is magnetic, its rust is non-magnetic ; iron has a metallic lustre, its oxide has none. Iron is nearly eight times as heavy as water, while its oxide is only slightly heavier. Iron has a different color from its oxide. But suppose a physical change is produced in iron, it still remains iron. Suppose it undergoes the physical change of being melted, it is still iron, and has the important chemical and physical properties of iron. Chemical changes are thus distinguishable from physical changes.

Elements differ from compounds in being non-decomposable, and compounds from mixtures as having different chemical and physical properties from the elements of which it is made, while a mixture is made of elements or compounds which have no chemical union but still possess the properties of its constituents.

The metallic elements are aluminium, Al II; antimony, Sb III; arsenic, As III; barium, Ba II; bismuth, Bi III; cadmium, Ca II; caesium, Cs I; calcium, Ca II; cerium, Ce II; chromium, Cr II; cobalt, Co II; copper, Cu II; didymium, D II; erbium, E; glucinum, Gl; gold, Au III; indium, In II; uridium, Ir IV; iron, Fe II; lanthanum, La II; lead, Pb II; lithium, Li I; magnesium, Mg II; manganese, Mn II; mercury, Hg II; molybdenum, Mo VI; nickel, Ni II; niobium, Nb V; osmium, Os IV; palladium, Pd II; platinum, Pt II; potassium, K I; rhodium, Rh II; rubidium, Rb I; ruthenium, Ru I; silver, Ag I; sodium, Na I; strontium, Sr II; tantalum, Ta V; thallium, Tl I; thorium, Th IV; tin, Sn IV; titanium, Ti IV; tungsten, W VI; uranium, U III; vanadium, V III; yttrium, Y II; zinc, Zn II; zirconium, Zr IV.

The non-metallic elements are boron, B III; bromine, Br I; carbon, C IV; chlorine, Cl I; fluorine, F I; hydrogen, H I; iodine, I I; nitrogen, N III; oxygen O II; phosphorus, P III; selenium, Se II; silicon, Si IV; sulphur, S II; tellurium, Te II.

The meaning of the numerals and abbreviations is given later.

The general distinguishing characteristics of metals are their fusibility, hardness, ductility, comparatively heavy weight. They can be welded, they have an appearance always recognizable, and are good conductors of heat and electricity.

The composition of well-known alloys are explained thus: Copper and zinc make brass; lead and tin, solder and pewter; copper and tin, gun speculum and bell metal; twenty-two parts of gold to two parts of copper, standard gold; mercury and another metal, amalgam; bismuth and another metal, fusible metal; bismuth, five parts; tin, two parts; lead, three parts, an alloy fusible in boiling water; antimony and lead, type metal. Zinc, tin, lead and cadmium impart to their own alloys their own peculiar properties in proportion to the amounts contained in the alloys. Other metals do not impart their properties to their alloys in the proportion in which they exist in the alloys. The specific gravity and coefficient of expansion of the alloys containing two or more of the metals lead, tin, zinc and cadmium are the average of those of the metals forming the alloy. Other properties, as, for example, the fusing point, vary from those of the constituents of the alloy. The fusing points of tin, bismuth, cadmium and lead are respectively 235°, 270°, 315° and 334° C., while their alloy fuses at 65°. It is a peculiar coincidence that mixtures of certain salts melt at a lower temperature than the average of its constituents. Illustration: Potassic and sodic carbonates when mixed fuse at a much lower temperature than either would alone. The same is true of the chlorides of those metals. The alloys of the said metals, lead, tin, zinc and cadmium, with each other have electric and heat-conducting powers, which are directly proportional to the proportions in which they exist, but this is not true of the alloys of the other metals. Copper is soft, but with the addition of a little zinc it becomes hard. Sometimes an alloy is soluble in an acid, while one of its constituents is not. This is the case with an alloy of silver and platinum, which is soluble in boiling nitric acid, while platinum by itself is not acted upon at all. On the other hand, an alloy of gold and silver is not soluble in nitric acid, but silver by itself is soluble.

The combination of the elements with one another and in different proportions form hundreds of compounds.

An example of a mixture is that of wax and sand. Each retains its own properties. By mixing different elements or compounds together the result is a mixture or compound according to whether a substance has been formed which has different properties from any of its constituents.

Liquids and gases will gradually mix together, even if separated by a porous membrane, and a peculiar action is that the denser will pass through as much slower as it is denser.

Chemicals unite to form compounds because there exists a force of attraction among the elements. This attraction differs from cohesion or adhesion in that it does not exist between the atoms of the *same* element nor between the molecules of the *same* compound. Thus, a piece of lead has cohesion among its atoms, holding them together. It has also adhesion because another piece of lead is held by it, but it has no chemical attraction for its *own* atoms. Chemical attraction exists only between atoms or molecules of *different* kinds of substances. Thus, in paper, oxygen, hydrogen and carbon are so strongly and intimately held together that howsoever finely the paper may be subdivided by a knife or other mechanical means these elements do not separate.

The less the cohesion the greater the effects of chemical attraction. Thus, in liquids the cohesion is least and molecular repulsion is least, and in the liquid condition compounds generally are most easily formed, as illustrated by solid calcic chloride and ammonic fluoride, which do not combine in the solid state, but they do if first dissolved in water. A powder separates from the water and is found to be calcic fluoride. The fluoride leaves the ammonia and combines with the calcium.

The chemical attraction is sometimes so strong that solids combine directly, being so powerful that the atoms of either body overcome the cohesion in the other body. Thus, sal ammoniac (ammonic chloride) and lime are both solid and have no odor. Let them be mixed together, immediately the smell of ammonia is very strong. The atoms of the lime unite with some of those of the chloride, liberating the ammonia gas, which gives the odor. Again, a bright fire is obtained by simply touching together solid iodine and solid phosphorus. The smoke consists of phosphoric iodide. The atoms of the phosphorus and iodine separate from each other in each solid and come together again in such a manner that each atom of phosphorus takes three atoms of iodine, making one molecule of phosphoric iodide.

It is a curious principle that if substances are soluble in water or acids they will combine if the compounds are such as to be insoluble in the liquid. Dissolve aluminic sulphate in water. Add a solution of ammonia in water. A white powder is formed, which does not dissolve, and which is found to be a new compound, consisting of aluminic oxide, which is called a precipitate, because it falls to the bottom of the vessel.

Sometimes two solutions of two compounds when mixed result in two insoluble compounds, with nothing remaining in solution. Mix together solutions of argentic sulphate and baric chloride. The precipitates are baric sulphate and argentic chloride. When filtered, the solution contains nothing, unless an excess of one compound exists. Any given free element unites with one or more free elements at fixed temperatures, differing according to the particular elements.

Illustration : Hydrogen and oxygen unite at about the temperature of 1,000° F. in the case where each is isolated from other elements. Above that temperature they will not unite. The heat causes the repulsion between the atoms to be stronger than the chemical attraction. Below that temperature they will not separate, because the chemical attraction is greater than the repulsion due to heat. About the only exception is that of chlorine and hydrogen, which have two temperatures or kindling points. In the dark a very high temperature is required to cause them to unite, while in diffused daylight they are kindled at approximately the ordinary atmospheric temperature. There is no reason to believe that the same amount of work is not done; for with a high temperature the union is instantaneous, while with diffused daylight (not in the sun) a long time is consumed—the action is slow but long. If the oxygen and hydrogen are associated with other compounds, they often unite at approximately the ordinary temperature. Thus in the decay of wood, oxygen and hydrogen leave the carbon and form water. Again, when sulphuric acid acts upon sugar, the hydrogen and oxygen leave the sugar at about 120° F. in the proportion to form water and unite with the sulphuric acid, which becomes more dilute. The principles are, therefore: (*a*) That isolated elements unite at a fixed temperature, which depends upon what the elements are. The temperatures vary all the way from the ordinary temperature to many hundred degrees. (*b*) Elements already combined leave one another to join foreign elements alone or compound at a lower temperature than that at which they would combine if isolated. How many hundreds of compounds are formed by this principle!

Howsoever finely substances are mechanically pulverized, chemical action is not generally facilitated, as it is when the substances are dissolved. An exception is that of sulphur and potassic chlorate. Pulverize them finely and mix intimately. Suddenly they combine with a dangerous explosion.

Hydrogen and oxygen always combine in fixed proportions by volume to form water. One gallon of oxygen combines with two gallons of hydrogen. With different proportions, a residue of one of the gases is found. Hydrogen and chlorine combine in the proportion of one volume of each to form hydric chloride. Any given compound is always and only formed by the combination of the elements in a fixed proportion. However, elements often combine in different proportions, but the compounds are different. Thus nitrogen and oxygen combine in five different proportions by volume. One volume of hydrogen can unite with one or two or three, etc., volumes of many other elements and compounds.

What is true of combining volumes is true of combining weights; elements or compounds combine in different proportions by weight; but the same proportional weights always produce the same compound. A few important exceptions exist. Starch and dextrine have equal weights of each of its elements. Each has 6 parts of carbon, 10 of hydrogen and 5 of oxygen.

Although having exactly the same chemical composition, starch and dextrine have different physical properties.

A few exceptions exist also as to atoms of the same substance combining with each other. One atom of oxygen can be made to combine with another atom of oxygen, whereby ozone is formed. The difference between the element and its compound is that whatever property oxygen has, ozone has the same magnified. Thus oxygen bleaches very slowly; ozone bleaches rapidly.

Elements which are free may combine to form compounds. It is also true that the elements of one compound will often depart and combine with the elements of another compound, or with other free elements. Potassium will combine with free oxygen, or it will take oxygen from water. In both cases potassic oxide is formed.

How is it known that a chemical change occurs? By change of color, of form, of temperature or production of electricity. Gunpowder when exploded changes from the solid to the gaseous form. Sulphuric acid added to copper produces a blue substance—cupric sulphate Silver and copper placed on the tongue and brought in contact with the terminals of a delicate galvanometer are found to deflect the needle. Sulphuric acid added to syrup produces heat. In all these cases new compounds are formed.

Compounds which at the same time are sour to the taste, which turn blue litmus paper red, which are composed of non-metals, and which contain hydrogen, are acids; those acids which contain hydrogen only are called hydracids. Those which contain hydrogen and oxygen are oxacids. An acid is in nearly every case a combination of either oxygen and hydrogen or hydrogen alone with a non-metal. When an acid is named, therefore, the above rule enables one to name its constituents. Thus, bromic acid contains oxygen, hydrogen and bromine. *Hydro* fluoric acid contains hydrogen and fluorine.

Non-acids, called hydrates, and formerly called alkalis, have opposite properties from those of acids, since they turn red litmus paper blue; have a caustic taste; and are composed of hydrogen, oxygen and a *metal*, while acids do not contain a metal.

Hydrates are named in such a manner that their compositions are apparent. Thus, baric hydrate is the combination of hydrogen and oxygen with the metal barium; ferric hydrate has hydrogen, oxygen and iron, and calcic hydrate has hydrogen, oxygen and calcium.

There are two hydrates of iron, the ferr*ic* and the ferr*ous*, the latter containing less oxygen, and so with some other metals.

Instead of speaking of silver hydrate, iron hydrate, &c., the Latin words are used for the sake of euphony and system, but in many the English is adhered to, as in cobaltic hydrate, meaning that hydrate which contains cobalt.

If calcic hydrate is heated, all the hydrogen and enough oxygen escape to form water (*i. e.*, one part of oxygen to every two of hydrogen.) The remainder is calcic oxide. So with other hydrates. They may be reduced similarly to oxides, not necessarily by heat; but that product which is left by removing all the hydrogen and enough oxygen to form water is the oxide of the metal. The oxides are so named that their constituents are apparent. Thus, chromic oxide is composed of the metal chromium and oxygen. Auric oxide has gold and oxygen. Zincic oxide has zinc and oxygen. When two oxides of the same metal occur, the suffixes *ic* and *ous* are used as before, but sometimes there are three oxides of the same metal. Recourse is then had to the prefixes *mon*, meaning one part of oxygen; *di*, meaning two parts, and *tri*, meaning three parts. Chromic trioxide has three parts of oxygen, while chromic monoxide has one part.

Metallic oxides need not always be made by removing hydrogen and some of the oxygen from hydrates. Thus, potassic oxide may be formed by burning potassium in dry air, but the result as far as the proportions of the elements in the oxide are concerned is the same as if formed from hydrates in the manner set forth.

Acids turn blue litmus paper red. Hydrates turn red litmus blue. There is a third class of compounds which will neither turn red litmus blue, nor blue litmus red, nor will it have any coloring effect upon litmus; neither does it have any acid or burning taste. They are called neutral compounds. The combination of a metal with a non-metal forms a neutral compound. The name distinguishes the constitutents. Thus, manganic chloride has manganese and chlorine. *Ide* is the suffix. *Ide* is used to indicate a neutral binary compound.

Exceptions: Some oxides of non-metals are neutral. Example: Water, carbonic oxide, nitric oxide, and a very few others.

The hydrogen in an acid may be replaced in part or wholly by a metal. Thus, in sulphuric acid (an oxacid) the hydrogen can be replaced by zinc, whereby the compound is changed to zincic sulphate. The name given to a compound thus obtained is called a salt. Common salt (sodic chloride) may be formed by adding sodium to the hydracid, called hydric chloride. The sodium expels the hydrogen and unites with the chlorine. Where the oxacid is used the word ends in *ate* or *ite*, according as to whether there is more or less oxygen. If made from a hydracid, the word ends in *ide*, as in the formation of the names of neutral binary compounds. Examples of the formation of salts: Silver added to the oxacid nitric acid results in argentic nitrate; iron added to the oxacid sulphuric acid forms ferric sulphate. Lead added to the hydracid, hydric chloride, forms plumbic chloride.

Some substances in chemistry have unsystematic names and greatly hinder the growth of the science, as system and regularity are prevented. Some are named after men, as Glauber salts. The proper name is sodic sulphate, which by its very name shows its own composition. Oil of vitriol is sulphuric acid. Saltpeter is potassic nitrate. Soda is sodic oxide. Potash is potassic hydrate. Sulphuretted hydrogen is hydric sulphide.

Oxacids, hydracids, anhydrides, hydrates, neutral binary compounds, and salts are indicated not only as to their composition by their names, but also by symbols containing figures which indicate the propotional amounts of the elements in the compound. For the sake of brevity, initials of the names of the elements are employed. Sometimes the initial of the Latin word is used, so that the same letter for different elements may be avoided. Thus, H_2SO_4 is an oxacid, called sulphuric acid. The figures 2 and 4 show that there are two parts by weight and volume of hydrogen and four of oxygen. S has no number, but one part of sulphur is understood. These symbols are very useful in showing the reactioms between compounds. Thus $Zn + H_2SO_4 = H_2 + ZnSO_4$.

The metal zinc replaces hydrogen in the oxacid and changes it to the salt, zincic sulphate. To show the composition of water, the equation is thus:

$$H_2 + O = H_2O.$$

To show how an oxacid is turned into an anhydride, this equation is an example:

$$H_2SO_4 - H_2O = SO_3 \text{ (sulphuric anhydride.)}$$

The following equation shows how a hydrate is changed to a metallic oxide:

$$2KHO \text{ (Potassic hydrate)} - H_2O = K_2O.$$

Some elementary atoms have the power of combining with 1 atom of hydrogen, some with 2, some with 3, and some with 4, 5 or 6. Illustration: In HCl (hydric chloride) 1 atom of chlorine is combined with 1 of hydrogen. In H_2O (water,) 1 atom of oxygen is combined with 2 of hydrogen. In H_3, N (ammonia) 1 atom of nitrogen is combined with 3 of hydrogen.

In H_4C (marsh gas) 1 atom of carbon is combined with 4 of hydrogen.

That elementary substance whose 1 atom combines with 1 of hydrogen is termed a monad, from the Greek for unity. Similarly those which take up 2, 3, 4 atoms of hydrogen are called dyads, triads and tetrads respectively.

It is a principle that 1 atom of a monad will combine with 1 atom of another monad; that 2 atoms of a monad will combine with 1 atom of a dyad, or 2 atoms of another monad; that 3 atoms of a monad will combine with 1 atom of a triad, or with 1 atom of a dyad and 1 of a monad, or with 3 atoms of a monad, and so on in the arithemtical manner. So also with dyads. One atom takes 2 monads, or 1 dyad. Two atoms of a dyad take 4 of a monad, or 1 monad and 1 triad, &c. In this manner it is only necessary to know whether an atom is a monad, dyad, triad, &c., in order to know the *proportional* amounts of elements in any given compound whose elements are known, and to be able to write the symbols of compounds and to foreknow the new compounds which will be formed in any chemical changes.

The monad, dyad, triad, &c., elements are indicated by the Roman numerals found after the names of the elements heretofore given.

A dyad may replace 2 monads, a triad, 3 monads, or 1 monad and 1 dyad, &c. Thus, in H_2O the dyad oxygen may be replaced by 2 atoms of the monad chlorine, making the compound which is equal to $2H\,Cl$.—*i. e.*, two molecules of hydric chloride. CH_4 is one of the important constituents of coal gas. The tetrad C (carbon) may unite with 2 atoms of the dyad oxygen, which will replace 4 atoms of the monad hydrogen. The 4 atoms of the monad hydrogen will also unite with 2 atoms of the dyad oxygen, forming water. The following equation shows the reactions, assuming that the supply of oxygen is plentiful:

$$CH_4 + O_4 = CO_2 + 2\,H_2O.$$

This is just what happens when marsh gas (CH_4) is burned in air. Carbonic di-oxide, CO_2, and water, H_2O, are formed. Similarly any reactions can be predicted. Suppose that zinc is added to hydric chloride. Zinc is a dyad, therefore the equation is:

$$Zn + 2\,HCl = Zn\,Cl_2 + H_2.$$

It is known that there should be 2 molecules of H Cl, because Zn must have 2 atoms of the monad Cl in order to be satisfied.

Sometimes compounds exist which are not "satisfied"; but they are unstable; they become satisfied when opportunity offers. Thus, if carbon is burned in a limited supply of oxygen the lower oxide, CO, is formed. Since C is a tetrad and O is a dyad, the compound is not satisfied. The carbon can take up another atom of oxygen, and experiment shows that it does so when the CO is burned in air, whereby carbon di-oxide, CO_2, is formed. CO is one of the constituents of coal gas, being combustible, while CO_2 is one of the gases escaping from a gas flame.

Some reactions are given below employing the above principles.

Na (Sodium, monad) + H_2O = H Na O + H.

The above is the reaction when metallic sodium is placed upon water. The products are sodic hydrate and hydrogen.

Fe (iron) + $H_2S\,O_4$ = Fe S O_4 + 2H.

In the above, the dyad Fe takes the place of 2 atoms of the monad H in the compound H_2SO_4.

Ca CO_3 (calcic carbonate) + Na_2S (sodic sulphide). =
Na 2 CO_3 (sodic ") + Ca S (calcic ").

Two atoms of the monad sodium change places with 1 atom of the dyad Ca.

The following compounds of metals are more or less soluble in water:

Acetates, except that of calcium; chlorates; chlorides, except those of mercurosum and silver; formates; iodides, except that of silver; nitrates; sulphates, except those of antimony, barium lead and strontium; fluoride, except those of barium, calcium, copper, lead, magnesium, manganese and strontium; benzoate, except those of copper, tetrad, iron, lead, mercurosum; bromide, except those of mercurosum and silver; citrate, except those of barium, cadmium, lead, manganese, mercurosum, silver and strontium; ferrocyanide, except those of cobalt, dyad, iron, manganese, nickel, silver and zinc; malate, except that of mercurosum; succinate, except those of lead, mercurosum, silver and tetrad tin; tartrate, except those of antimony, barium, bismuth, calcium, lead, mercuricum, nickel, silver, strontium, dyad, tin and zinc; arseniate of ammonium, of potassium and sodium; arsenite of ammonium, of potassium and of sodium; borate of ammonium, of cadmium, of magnesium, of potassium and of sodium; carbonate of ammonium, of potassium and of sodium; chromate of ammonium, of calcium, of copper, of tetrad iron, of magnesium, of mercuricum, of nickel, of potassium, of sodium and of zinc; cyanide of ammonium, of barium, of calcium, of magnesium, of mercuricum, of potassium, of sodium, of strontium; ferrocyanide of ammonium, of barium, of calcium, of magnesium, of potassium, of sodium and of strontium; hydroxide of ammonium, of barium, of calcium, of potassium, of sodium and of strontium; oxalate of ammonium, of chromium, of manganese of potassium, of sodium and of tetrad tin; oxide of barium, of calcium, of potassium, of sodium and of strontium; phosphate of ammonium, of antimony, of barium, of calcium, of potassium, of sodium; silicate of potassium and of sodium; sulphite of ammonium, of barium, of calcium, of potassium, of sodium and of strontium; aluminium ammonium sulphate; aluminium potassium sulphate; ammonium arsenic chloride; ammonium sodium phosphate; ammonium ferrous sulphate; ammonium cupric sulphate; ammonium potassium tartrate; antimony posassium tartrate; chromic potassium sulphate; iron (ferric) potassium tartrate; platinic bromide, chloride and cyanide, nitrate, oxalate and sulphate.

The following compounds of metals are more or less soluble in one or more of the acids, nitric (HNO_3), sulphuric (H_2SO_4), and hydrochloric ($H\ Cl$):

Arzeniates, except those of ammonium, potassium and sodium; arsenites, except those of ammonium, potassium and sodium; borates, except those of ammonium, potassium and sodium; carbonates, except those of potassium and sodium; chromates, except those of ammonium, copper, tetrad iron, magnesium, nickel, potassium and sodium; cyanides, except those of ammonium, calcium, magnesium, mercuricum, potassium, sodium and strontium; hydroxides, except those of ammonium, barium, potassium, sodium and strontium; oxalates, except those of ammonium, potassium, sodium and tetrad tin; oxides, except those of barium, potassium, sodium and strontium; silicates, except those of potassium and sodium; sulphides, except those of ammonium, barium, potassium, sodium and strontium; tartrates, except those of aluminium, ammonium, chromium, cobalt, copper, tetrad iron, potassium and sodium; phosphates, except those of ammonium, potassium, sodium; acetate of calcium and of mercurosum; benzoates of copper, tetrad iron, lead, of mercurosum, mercuricum, silver; bromides antimony, bismuth, mercurosum, silver; chlorides of antimony, bismuth, mercurosum; citrates of barium, cadmium, calcium, lead, manganese, mercurosum, mercuricum, silver, strontium, zinc; cyanides of barium, cadmium, chromium, cobalt, copper, dyad iron, lead, manganese, nickel, zinc; ferrocyanides of lead, zinc; ferrocyanides of barium, lead, manganese, and of zinc; fluorides of barium, cadmium, cobalt, copper, dyad iron, lead, magnesium, manganese, mercuricum, nickel, strontium, and of zinc; formates of lead; iodides of antimony, bismuth, lead, mercurosum, mercuricum; malates of barium, calcium, lead, mercurosum, mercuricum, and silver; succinates of aluminium, barium, calcium, cobalt, of copper, of lead, of mercurosum, of silver, of strontium, tetrad tin, and zinc; ammonium magnesium phosphate; antimony oxychloride; bismuth oxychloride; bismuth basic nitrate; calcic sulphantimonate; mercurius solubilis Hahnemanni; mercurammonium chloride; mercuric sulphate, basic; potassium platinic chloride.

The following compunds of metals are among those which are insoluble in the acids above named:

Chloride of silver; cyanide of silver; ferricyanide of cobalt, of dyad iron, of manganese, of nickel and of silver; ferrocyanide of cobalt, of copper, of dyad iron, of tetrad iron, of nickel, of silver; iodide of silver; sulphate of strontium.

It is a very peculiar phase of combination that certain atoms of different elements change place from one compound to another and have a fixed proportion for combining. The principal compounds of this class are stated thus, with the proper word, monad, dyad, &c., to indicate their power of combining with other monads, dyads, &c.:

NH_4, monad, is a root of ammonia compounds. Example: $(NH_4)Cl$ (ammonic chloride).

NO_3, monad, is a root of nitrates. Example: $Ca(NO_3)_2$ (calcic nitrate).

CO_3, dyad, is a root of carbonates. Example: $Ba(CO_3)$.

SO_4, dyad, is a root of sulphates. Example: $CuSO_4$ (cupric sulphate).

HO, monad, is a root of hydrates. Example: KHO (potassic hydrate).

CN, monad, forms the root of cyanides.

PO_4, a triad, forms the root of phosphates. Example: $Hg_3(PO_4)_2$ (mercuric phosphate).

Any one of these roots will go from one compound to another in certain reactions without themselves appearing to undergo any decomposition. Example: $Cu + H_2(SO_4) = H_2 + Cu(SO_4)$.

The operation is that when copper is dissolved in sulphuric acid (H_2SO_4), the root (SO_4) goes from the zinc to the copper and the hydrogen is set free. It is another wonderful freak, that these roots never exist by themselves, unless that infinitesimal time taken in passing from one compound to another be considered ; but by losing or gaining another atom of one of the elements, they exist alone. Example:

Taking H from NH_4 leaves NH_3 (ammonia).

" O " SO_4 " SO_3 (sulphurous acid).

" O " CO_3 " CO_2 (carbonic di-oxide).

Adding H to HO gives H_2O (water).

The gist of practical chemistry is that relating to an accurate and extended knowledge of the reactions which occur among chemical compounds. One should follow the equations below, taking notice of the exact composition of each chemical, and how the foregoing principles have been applied. In order to make the equations easily intelligible, the name of the compound often accompanies the symbol. The compounds on the left undergo an exchange of some of their elements, and two or more new compounds are formed, according to the rules already stated. One of the new compounds is generally a precipitate —*i. e.*, one of the new compounds is insoluble and falls as a powder to the bottom of the vessel and may be obtained free by filtration. An assistance in this respect will be the list of soluble and insoluble compounds already given. Sometimes the new compound or liberated element is a gas and escapes into the air or into a vessel provided for the purpose. Sometimes heat is necessary in order to make the reaction take place. Sometimes both compounds remain in solution. The equations are as follows :

Cu (copper) + O = Cu O (cupric oxide).

$C + O_2 = CO_2$ (carbonic di-oxide).

Cu + $H_2\ SO_4$ (sulphuric acid) = Cu O_4 (cupric sulphate) + 2H.

Zn + $H_2\ SO_4$ = Zn SO_4 (zinc sulphate) + 2H.

Fe + $H_2\ SO_4$ = Fe SO_4 (ferric sulphate) + 2H.

2 Na (sodium) + 2 (H_2O) = 2(Na HO) (sodic hydrate) + 2H.

2 K (potassium) + $2(H_2O) = 2(KHO) + 2H$.

$Fe_3 + 4\ H_2O = Fe_3\ O_4$ (ferric oxide) + 8H.

Cu O (cupric oxide) + $2H = Cu + H_2O$.

Na_2O (sodic oxide) + $H_2O = 2(Na\ HO)$ (sodic hydrate).

Ca O (calcic oxide) + H_2O (water) = Ca $(HO)_2$ (calcic hydrate).

$P_2O_5 + 3\ (H_2O) = 2(H_3\ PO_4)$.

2 (HCl) (hydrochloric acid) + Ba $H_2\ O_3$ (baric hydrate) = Ba Cl_2 (baric chloride) + $H_2\ O_2$ (peroxide of water) + H_2O (water).

$Ag_2\ SO_4$ (argentic sulphate) + Ba Cl_2 = 2 Ag Cl (argentic cloride) + Ba SO_4 (baric sulphate).

Ba Cl_2 (baric chloride) + $H_2\ SO_4$ (sulphuric acid) + Ba SO_4 (baric sulphate) + 2(HCl) (hydrochloric acid).

$H_2\ O + Cl_2 = Cl\ HO$ (chloric acid) + HCl (hydrochloric acid) $NH_4\ (NO_2)$ (ammonia nitrate + slight heat = N_2 + $2\ H_2O$).

KNO_2 (potassic nitrite) + $NH_4\ Cl$ (ammonic chloride) + H_2O $= KCl + NO_2\ NH_4$ (ammonic nitrate) + H_2O.

$H_2\ SO_4 + KNO_3 = HKSO_4$ (double sulphate of potassium and hydrogen) + HNO_3 (hydric nitrate, commonly called nitric acid).

$Cu_3 + 8(HNO_3 = 3(Cu\ (NO_3)_2)$ (cupric nitrate) + 2(NO) (nitric oxide).

$HNO_3 + KHO = KNO_3 + H_2O$.

Pb $(NO_3)_2$ (plumbic nitrate) + heat = PbO (plumbic oxide) + N_2O_4 (nitric peroxide) + O.

NO (nitric oxide) + 5H + heat = NH_3 (ammonia) + H_2O.

$H_2 SO_4$ (hydric sulphate, called also sulphuric acid) + $2KNO_3$ = $K_2 SO_4 + 2HNO_3$.

2 ($NH_4 Cl$) (ammonic chloride) + Ca H_2O (calcic hydrate) = $2NH_3 + Ca Cl_2 + 2 (H_2O)$.

(NH_4) HO (ammonic hydrate) + $HNO_3 = (NH_4)NO_3 + H_2O$.

$HNO_3 + KHO = KNO_3 + H_2O$.

Pb $(NO_3)_2$ + 2 $(NH_4)HO$) = 2($(NH_4)NO_3$) (ammonic nitrate) + Pb $(HO)_2$.

HNa CO_3 (double carbonate of sodium and hydrogen) + $H_2SO_4 = H Na SO_4 + H_2O + CO_2$.

CH_4 (carburetted hydrogen or carbonic hydride) + $2O_2$ + heat = $CO_2 + 2H_2O$.

Mn O_2 (manganic oxide) + 4(HCl) + heat = Mn $Cl_2 + Cl_2$ + 2 H_2O.

$Cl_2 + 2(KHO) = KCl + KCl O + H_2O$.

Ba $(Cl O_3)_2$ (baric chlorate) + H_2SO_4 = 2(HCl O_3) (hydric chlorate) + Ba SO_4.

$Cl_2 + H_2O + AgNO_3$ (argentic nitrate) = Ag Cl + HClO + HNO_3.

$HCl + HCl O = Cl_2 + H_2O$.

H_2SO_4 + Na Cl = Na HSO_4 + HCl.

Na HSO_4 + Na Cl = Na_2SO_4 + HCl.

$KHO + HCl = KCl + H_2O$.

$Hg_2 (NO_3)_2 + 2(HCl) = 2Hg Cl$ (mercuric chloride) + $2(HNO_3)$.

$(NH_4)_2 CO_3$ + Ca Cl_2 = 2(NH_4 Cl) + Ca CO_3.

$CA\ SO_4 + Ba\ 2(NO_3) = Ca\ 2\ (NO_3) + Ba\ SO_4$.

$2\ (Ag\ NO_3) + Ca\ Cl_2 = 2\ (Ag\ Cl)$ (argentic chloride) $+ Ca\ (NO_3)_2$.

$Pb\ (NO_3)_2 + H_2\ S$ (hydric sulphide) $= 2\ (HNO_3) + Pb\ S$.

$2\ (HNO_3) + Ba\ H_2O = Ba\ (NO_3)_2 + 2\ (H_2O)$.

$2\ (As\ Cl_3)$ (arsenic chloride) $+ 3\ (H_2S) = 6\ HCl + As_2\ S_3$ (arsenic sulphide).

$Bi\ Cl_3$ (bismuth chloride) $+ 3\ KI$ (potassic iodide) $= Bi\ I_3 + 3\ (KCl)$.

$2\ HCl + Pb\ (NO_3)_2 = 2\ (HNO_3) + Pb\ Cl_2$.

$Se\ O_2$ (selenious acid) $+ H_2S$ (hydric sulphide) $= Se\ S_2 + 2\ (H_2O)$.

$Ba\ Se\ O_4$ (baric seleniate) $+ 4\ HCl = Se\ O_2 + Ba\ Cl_2 + 2\ (H_2O) + Cl_2$.

$Te\ O_2$ (tellurous acid) $+ 2\ H_2S = Te\ S_2 + 2\ (H_2O)$.

$Pb\ (NO_3)_2 + 2\ (Na\ HO)$ (sodic hydrate) $= Pb\ (HO)_2 + 2\ Na\ NO_3$.

$Pb\ (NO_3)_2 + H_2\ SO_4 = H_2\ (NO_3)_2 + Pb\ SO_4$.

$PCl_3 + 3\ H_2O = P\ (HO)_3 + 3\ HCl$.

BCl_3 (boric chloride) $+ 3\ (H_2O) = B\ (HO)_3 + 3\ (HCl)$.

$Cu\ SO_4 + 2\ (KHO) = Cu\ (HO)_2 + K_2\ SO_4$.

$3\ (Si\ F_4)$ (silicic fluoride) $+ 2\ (H_2O) = 2\ (H_2\ Si\ F_6) + SiO_2$.

$Mn\ SO_4$ (manganic sulphate) $+ 2\ Na\ HO) = Mn\ (HO)2$ (manganic hydrate) $+ Na_2\ SO_4$.

Sb_2 (antimony) $+ 6\ (H_2\ SO_4) = Sb_2\ (SO_4)\ 3 + 6\ H2O + 3\ (SO_2)$.

$Zn\,SO_4 + 2\,(KHO) = Zn\,(HO)_2 + K_2\,SO_4$.

$Sb_2\,S_3 + Fe_3 = Sb_2 + 3\,(Fe\,S)$.

$Sb_2\,S_3 + 6\,(HCl) = 2\,(Sb\,Cl)_3) + 3\,(H_2S)$.

$Co\,(NO_3)_2 + 2\,(Na\,HO) = Co\,(HO)_2$ (cobaltic hydrate) $+ 2\,(Na\,NO_3)$.

$Mn\,SO_4 + (NH_4)_2\,Co_3$ (ammonic carbonate) $= Mn\,CO_3 + (NH_4)\,2\,SO_4$.

$2\,HCl + Sn = Sn\,Cl_2$ (stannous chloride) $+ H_2$.

$3\,Fe\,SO_4 + Au\,Cl_3$ (auric chloride) $= Fe\,Cl_3 + Fe_3\,(SO_4)\,3 + Au$.

$Ba\,(NO_3)_2 + (NH_4)_2\,CO_3 = Ba\,CO_3 + 2\,(NH_4)\,(NO_3)$ (ammonic nitrate).

$HNa_2\,PO_4$ (hydro di-sodic phosphate) $+ 3\,(Ag\,NO_3) = Ag_3\,PO_4$ (argentic phosphate) $+ 2\,Na\,NO_3$ (sodic nitrate) $+ H\,NO_3)$.

Hg_2O (mercuric oxide) $+ 2\,HCl = 2\,(Hg\,Cl) + H_2O$.

$2\,H\,(CN)$ (hydric cyanide) $+ 2\,(Hg\,(NO_3)_2 =$ (mercuric cyanide) $2\,Hg + 2\,H\,(NO_3)$.

$Ca\,SO_4 + (NH_4)_2\,CO_3 = Ca\,SO_4 + (NH_4)_2\,(SO_4)$.

$Hg\,SO_4 + Hg + 2\,Na\,Cl = 2\,(Hg\,Cl) + Na_2\,SO_4$.

$Sr\,(NO_3)_2 + Ca\,SO_4 = Sr\,SO_4 + Ca\,(NO_3)_2$.

$Al\,SO_4 + 2\,(NH_4)\,(HO) = Al\,(HO_2) + (NH_4)\,2SO_4$ (ammonic sulphate).

$HCl + Ag\,NO_3 = HNO_3 + Ag\,Cl$.

$H_2S + 2\,(Hg\,NO_3)$ (mercurous nitrate) $= Hg_2\,S + 2\,(H\,(NO_3).)$

$H_2S + Pb\,(NO_3)_2 = 2\,(H\,(NO_3)\,) + Pb\,S$.

$HCl + Hg(NO_3) = H NO_3) + Hg Cl$ (mercurous chloride).

$2 (Na Cl) + Hg SO_4 = Hg Cl_2 + Na_2 SO_4$.

$Hg Cl_2 + 2 (NH_3) = Hg NH_2$ (double chloride of mercury and hydrogen) $+ (NH_4) Cl$.

$2 KI + Pb (NO_3)_2 = 2 KNO_3 + Pb I_2$.

$2 (Na Cl) + Hg SO_4 = Hg Cl_2 + Na_2 SO_4$.

$2 Sn Cl$ (stannous chloride) $+ H_2 S = Sn S + 2 (HCl)$.

$Sn Cl_2$ (stannic chloride) $+ H_2S = Sn S + 2 (HCl)$.

$Sn Cl_2 + 2 KHO = Sn (HO)_2 + 2 (KCl.)$

$Hg Cl_2 + Cu = Hg + Cu Cl_2$.

$2 Ag NO_3 + H_2SO_4 = Ag_2 SO_4 + 2 HNO_3$.

$Ag NO_3 + (NH_4) (HO) = Ag HO + NH_4 NO_3$.

$Sr Cl_2 + Ca SO_4 = Sr SO_4 + Ca Cl_2$.

$Ba Cl_2 + 2 Na HO = Ba (HO)_2 + 2 (Na Cl)$.

$Ca Cl_2 + (NH_4)_2 CO_3 Ca CO_3 + (NH_4)_2 CO_3$.

$Al Cl_2 + 2 (NH_4) HO = Al (HO)_2 + 2 (NH_4) Cl$.

$Cu SO_4 + 2 KI = Cu I + K_2 SO_4$.

$Hg Cl_2 + 2 KI = Hg I_2 + 2 KCl$.

$Cu SO_4 + H_2S = Cu S + H_2 SO_4$.

$Au Cl_3 + 3 KI = Au I_3 + 3 KCl$.

$Pt Cl_4 + 4 KI = Pt I_4 + 4 KCl$.

$Hg Cl_2 + H_2S = Hg S + 2 HCl$.

$2 Au Cl_3 + 3 H_2S = Au_2 S_3 + 6 HCl$.

$Sn\ Cl_2$ (stannic chloride) $+ H_2S = Sn\ S + 2\ HCl$.

$Sb_2\ S_3 + 6\ HCl = 2\ Sb\ Cl_3 + 3\ H_2S$.

$2\ HCl + Sn = Sn\ Cl_2 + H_2$.

$(Ag\ NO_3) + Cl\ Na = Cl\ Ag + NO_3\ Na$.

$PO_4\ Na\ H + 3\ Ag\ NO_3 = PO_4\ Ag_3 + 2\ Na\ PO_4 + HNO_3$.

$Hg_2\ O = Hg + Hg\ O$.

$Hg_2\ O + 2\ HCl = Hg_2\ Cl_2 + H_2O$.

$Hg\ (NO_3)_2\ (H_2O)_3 + nH_2O = Hg_2\ NO_3HO + NO_3H + (n + 2)\ H_2O$.

$2\ H\ (CN) + Hg_2\ (NO_3)_2 = Hg\ (CN)_2 + Hg + 2\ HNO_3$.

$Hg_2\ (NO_3)_2 + 2\ Na\ Cl = Hg_2\ Cl_2 + 2\ Na\ NO_3$.

$2\ Hg\ (NO_3) + H_2SO_4 + 2\ Na\ Cl + H_2O = Hg_2\ Cl_2 + Na_2\ SO_4 + 4\ HNO_3$.

$3\ Al_2\ O_3 + 3\ Si\ F_4 = Al_2\ O_3\ (Si\ O_2)_3 + 2\ Al_2\ F_6$.

$5\ Si\ O_2 + 2\ Al_2\ F_6 = 2\ (Al_2\ O_3\ Si\ O_2) + 3\ Si\ F_4$.

$3\ Si\ F_4 + 2\ H_2O = 2\ H_2\ Si\ F_6 + Si\ O_2$.

$2\ HSi\ F_5 + 2\ KHO = 2\ K\ Si\ F_5 + 2\ H_2O$.

$2\ HSi\ F_5 + 6\ KHO = 6\ KF + 4\ H_2O + Si\ O_2$.

$3\ Ca\ F_2 + B_2O_3 = 3\ Ca\ O + 2\ BF_3$.

$2\ BF_3 + 3\ H_2O = B_2\ O_3H_6F_6$.

$4\ (B_2O_3H_6F_6) = B_2O_3 + 9\ H_2O + 6\ (HBF_4)$.

$Fe\ S + H_2SO_4 = H_2S + Fe\ SO_4$.

$Sb_2 S_3 + 6 HCl = 3 H_2S + 2 Sb Cl_3.$

$H_2S + O_3 = H_2O + SO_2.$

$N_2O_3 + 6 H_2S = 2 NH_3 + 3 H_2O + S_6.$

$Sn + H_2S = H_2 + Sn S.$

$2 Fe S + O_3 = Fe_2 O_3 + S_2.$

$3 Ca O + S_6 = Ca S_2O_3 + 3 Ca S_2.$

$Ca S_2 + 2 HCl = Ca Cl_2 + H_2S + S.$

$2 (Fe SO_4) + O = Fe O_3 (SO_3)_2.$

$Fe S_2 + H_2 O + O_7 = Fe SO_4 + H_2 SO_4.$

$3 SO_2 + H_2 (NO_3)_2 + 2 H_2O = 3 (H_2SO_4) + 2 NO_3.$

$NO_2 + SO_2 + H_2O = NO + H_2SO_4.$

$2 NO_2 + 2 SO_2 + H_2O = 2 (NSO_4) H_2O.$

$2 (NSO_4) H_2O + H_2O = 2 NO + 2 (H_2SO_4).$

$3 SO_2 + H_2(NO_3)_2 + 2 H_2O = 2 NO + 3 (H_2SO_4).$

$2 SO_2 + 2 NO_2 + 2 H_2O = 2 (H_2SO_4) + 2 NO.$

$2 Ag + 2 (H_2SO_4) = Ag_2 SO_4 + 2 H_2O + SO_2.$

$Mn O_2 + H_2SO_4 = Mn SO_4 + O + H_2O.$

$2 Cr O_3 + 3 (H_2SO_4) = Cr_2 O_3 (SO_3)_3 + O_3 + 3 H_2O.$

$2 (Fe SO_4) + heat = Fe_2 O_3 + SO_2 + SO_3.$

$K_2 SO_4 + C_4 = K_2S + 4 CO.$

$2 Ca S + O_4 = Ca S_2O_3 + Ca O.$

$Ca S_2O_3 + Na_2 CO_3 = Ca CO_3 + Na_2 S_2O_3.$

$2\ AgCl + Na_2S_2O_3 = 2\ NaCl + Ag_2S_2O_3.$

$3\ SO_2 + Zn_2 = Zn\ OSO_2 + Zn\ S_2O_3 + ZO_3.$

$4\ (Na_2S_2O_3\ 5\ H_2O) = 20\ H_2O + 3\ (Na_2SO_4) + Na_2S_5.$

$3\ (K_2O)\ (H_2O)\ (SO_2)_2 + S = 2\ (K_2S_3O_6) + K_2OSO_2 + 3\ H_2O.$

$H_2S_3O_6 = H_2SO_4 + SO_2 + S.$

$Fe_2Cl_6 + 2\ (Na_2S_2O_3) = Na_2S_4O_6 + 2\ FeCl_2 + 2\ NaCl.$

$5\ H_2S + 5\ SO_2 = H_2S_5O_6 + 4\ H_2O + S_5.$

$2\ CS_2 + 2\ H_2S + Cu_6 = 6\ CuS + C_2H_4.$

$CS_2 + 2\ NH_3 = H_2S + NH_3\ HCNS.$

$K_2CS_3 + 2\ HCl = H_2CS_3 + 2\ KCl.$

$K_2CS_3 + 3\ H_2O = K_2CO_3 + 3\ H_2S.$

$2\ S_2Cl_2 + 2\ H_2O = 4\ HCl + SO_2 + S_3.$

$H_2SO_3 + H_2O + 2\ SO_2 = 2\ (H_2SO_4) + S.$

$Pb\ S_2O_4 + H_2S = H_2S_2O_4 + PbS.$

$2\ HPO_3 + C_6 = 6\ CO + H_2 + P_2.$

$3\ Ca\ (PO_3)_2 + 2\ (H_2SO_4) = Ca\ (H_2\ (PO_3)_2)_2 + 2\ (Ca\ SO_4).$

$3\ Ca\ (PO_3)_2 + C_{10} = 3\ Ca\ (PO_3)_2 + 10\ CO + P_4.$

$3\ Ca\ (PO_3)_2 + 6\ HCl + C_8 = 3\ Ca\ Cl_2 + 8\ CO + H_6 + P_2.$

$3\ H_2\ (PO_3)_2 + 3\ (Ag_2\ (NO_3)_2 + 3\ NH_3 = 3\ Ag_2\ (PO_3)_2 + 3\ NH_3H_2\ (NO_3)_2.$

$2\ Na_2\ OH_2\ (PO_3)_2 + 3\ (Ag_2\ (NO_3)_2) = 3\ Ag_2\ (PO_3)_2 + 2\ (Na_2\ (NO_3)_2) + H_2\ (NO_3)_2.$

$2\ Na_2\ (PO_3)_2 + 2\ (Ag_2\ (NO_3)_2) = 2\ Ag_2\ (PO_3)_2 + 2\ (Na_2\ (NO_3)_2)$.

$(Na\ O)_2\ (NH_4)_2\ H_2\ (PO_3)_2 + 3\ (Ag\ (NO_3)_2) = Na_2\ (NO_3)_2 + (NH_4)_2\ (NO_3)_2 + H_2\ (NO_3)_2$.

$Na_2\ (PO_3)_2 + Ag_2\ (NO_3)_2 = Ag_2\ (PO_3)_2 + Na_2\ (NO_3)_2$.

$3\ (Cu\ SO_4) + 2\ PH_3 = 3\ (H_2SO_4) + P_2Cu_3$.

$PCl_5 + H_2O = PCl_3\ O + 2\ HCl$.

$3\ PCl_5 + 3\ H_2B_2O_4 = 3\ PCl_3\ O + 6\ HCl + B_2O_3$.

$PCl_5 + H_2S = PCl_3\ S + 2\ HCl$.

$2\ PC_3S + 6\ Na_2\ O = 6\ Na\ Cl + 3\ Na_2\ P_2O_4S_2$.

$2\ PCl_3 + 3\ H_2S = P_2S_3 + 6\ HCl$.

$2\ NH_3 + P_2O_5 = H_2O + N_2\ (HO)_4$.

$PCl_3\ O + 3\ NH_3 = 3\ HCl + N_3H_6PO$.

$PCl_3\ S + 3\ NH_3 = 3\ HCl + (NH_3)_2PS$.

$PCl_5 + 2\ NH_3 = 2\ HCl + N_2H_4PCl_3$.

$N_2H_4PCl_3 + H_2O = N_2H_3PO + 3\ HCl$.

N_2H_3PO + heat = $NH_3 + NPO$.

$As_2\ O_3 + C_3 = As_2 + 3\ CO$.

$As_2\ O_3 + H_2ON_2O_5 + 2\ H_2O = N_2O_3 + 3\ H_2OAs_2\ O_5$.

$Zn_3\ As_2 + 3\ (H_2SO_4) = 2\ As\ H_3 + 3\ (Zn\ SO_4)$.

$2\ As\ H_3 + O6 = As_2\ O_3 + 3\ H_2O$.

$As_2\ O_3 + Zn6 + 6\ (H_2SO_4) = 2\ As\ H_3 + 6(Zn\ SO_4) + 3\ H_2O$.

$2\ As_2O_3 + S_7 = 2\ As_2S_2 + 3\ SO_2.$

$FeS_2FeAs_2 + 2\ FeS_2 = 4\ FeS + As_2S_2.$

$3\ As_2O_3 + 2\ HCl = 2\ (As_3ClO_4) + H_2O.$

$S_9 + 2\ As_2O_3 = 2\ As_2S_3 + 3\ SO_2.$

$2\ Na_2H_2OAsO_6 + 7\ H_2S = 8\ H_2O + 2\ Na_2As_2S_6.$

$2\ Na_2As_2S_6 + 4\ HCl = 4\ NaCl + 2\ H_2S + 2\ As_2S_5.$

$CaCO_3 + 2\ NH_4Cl = CaCl_2 + CO_3(NH_4)_2.$

Heat $+ 3\ CaCl_2O_2 = Ca(ClO_3)_2 + 2\ CaCl_2.$

$2\ CaS + 2\ H_2O = CaO_2H_2 + CaO_2H_2 + CaS_2H_2$

$3\ CaO_2H_2 + 6\ S_2 = 2\ CaS_5 + CaS_2O_3 + 3\ H_2O.$

$2\ PO_4MgNH_4(H_2O)_6 +$ heat $= Mg_2P_2O_7 + 2\ NH_3 + 13\ H_2O.$

$HKO + K = K_2O + H.$

$K_2CO_3 + CaH_2O_2 = 2\ KHO + CaCO_3.$

$SO_4K_2 + Ba(HO)_2 = SO_4Ba + 2\ KHO.$

$NO_3Na + ClK = NO_3K + ClNa.$

$NH_3 + K = NH_2K + H.$

Heat $+ 3\ NH_2K = NK_3 + 2\ NH_3$

$(CN)_6FeK_4 + CO_3K_2 = 5\ KCN + CNKO + Fe + CO_2.$

$KOCN + 2\ H_2O = CO_3HK + NH_3.$

Heat $+ 3\ KClO = 2\ KCl + ClO_3K.$

$(ClO_3)_2Ca + 2\ KCl = 2\ KClO_3 + Cl_2Ca.$

$3\ Br_2 + 6\ KHO = 5\ KBr + KBrO_3 + 3\ H_2O.$

$S_2K_2 + 2\ HCl = SH_2 + 2\ KCl + S.$

$SO_4K_2 + HCl = SO_4KH + Cl\ K.$

$SO_4H_2 + Cl\ Na = SO_4Na\ H + HCl.$

$Na\ HSO_4 + Na\ Cl = SO_4Na_2 + HCl.$

$Heat + 2\ SO_4Na\ H = S_2O_7Na_2 + H_2O.$

$Na_2\ HPO_4 + NO_3H = NO_3Na + PO_4Na\ H_2.$

$Na_2\ HPO_4 + HONa = PO_4Na_3 + H_2O.$

$Na_2\ HPO_4 + Cl\ NH_4 = PO_4Na\ (NH_4)\ H + Cl\ Na.$

$Ca\ CO_3 + 2\ HCl = Ca\ Cl_2 + H_2O + CO_2.$

$4\ H_2O + C_3 = CO_2 + 2\ CO + H8.$

$Si_3\ H_4O_5 + 12\ KHO = 3\ (2\ K_2Si\ O_2) + H6 + 5\ H_2O.$

$2\ (NH_3HCl) + Ca\ O = Ca\ Cl_2 + H_2O + 2\ NH_3.$

$2\ NH_3 + CaO + O8 = Ca\ ON_2O_5 + 3\ H_2O.$

$KNO_3 + H_2SO_4 = HNO_3 + KHSO_4.$

$4\ (H_2(NO_3)_2) + Cu_3 = 3\ (Cu(NO_3)_2) + 2\ NO + 4\ H_2O$

$3\ N_2O3 + H_2O = H_2\ (NO_3)_2 + 4\ NO.$

$2\ NH_3 + N_2O_3 = N_4 + 3\ H_2O.$

$2\ (NH_3HCl) + K_2ON_2O_3 = N_4 + 2\ KCl + 4\ H_2O.$

$H_2\ (NO_3)_2 + As_2\ O_3 = H_2OAs_2\ O6 + N_2O_3.$

$3\ NO_2 + H_2O = NO + 2\ HNO_3.$

$NO + 2\ (HNO_3) = 3\ NO_2 + H_2O.$

$2\ N_2O_2 + 4\ (KHO) = 2\ K + K_2\ (NO_3)_2 + 2\ H_2O.$

$2\ H_2\ (NO_3)_2 + Sn = 2\ H_2O + 4\ NO_2 + Sn\ O_2.$

$3\ (H_2\ (NO_3)_2) + Ag_4 = 3\ H_2O + N_2O_3 + 2\ (Ag_2\ (NO_3)_2).$

$4\ (H_2\ (NO_3)_2) + Cu_3 = 4\ H_2O + 2\ NO + 3\ (Cu\ (NO_3)_2).$

$5\ (H_2\ (NO_3)_2) + Zn_4 = 5\ H_2O + N_2O + 4\ (Zn\ ON_2O_5).$

$2\ Na\ Cl + Mn\ O_2 + 2\ (H_2SO_4) = Na_2\ SO_4 + Mn\ SO_4 + 2\ H_2O + Cl_2.$

$Mn\ O_2 + 4\ HCl = Mn\ Cl_2 + 2\ H_2O + Cl_2.$

$4\ (Ca\ (HO)_2) + Cl_4 = (Ca\ OCl_2\ O + Ca\ Cl_2 + 2\ Ca\ O) + 4\ H_2O.$

$(Ca\ OCl_2O + Ca\ Cl_2) + 2\ (H_2SO_4) = 2\ (Ca\ SO_4) + 2\ H_2O + Cl_4.$

$2\ Na\ Cl + H_2OSO_3 = 2\ HCl + Na_2\ OSO_3.$

$Fe + 2\ HCl = Fe\ Cl_2 + H_2.$

$Na + HCl = Na\ Cl + H.$

$Ag_2\ O + 2\ HCl = H_2O + 2\ Ag\ Cl.$

$Cu_2\ O + 2\ HCl = H_2O + Cu_2\ Cl_2.$

$Sb_2\ O_3 + 6\ HCl = 3\ H_2O + 2\ Sb\ Cl_3.$

$Mn_2\ O_3 + 6\ HCl = 3\ H_2O + 2\ Mn\ Cl_2 + Cl_2.$

$Mn\ O_2 + 4\ HCl = 2\ H_2O + Mn\ Cl_2 + Cl_2.$

$Hg\ O + Cl_4 = Hg\ Cl_2 + Cl_2O.$

$Cl_2\ O + 2\ HCl = H_2O + Cl_4.$

$HNO_3 + 3\ HCl = 2\ H_2O + NOCl_2 + Cl.$

$NOCl_2 + H_2O = 2\ HCl + NO_2.$

$6\ KHO + Br_6 = 5\ KBr + KBr\ O_3 + 3\ H_2O.$

$2\ KBr + Mn\ O_2 + 2\ (H_2SO_4) = K_2SO_4 + Mn\ SO_4 + 2\ H_2 O + Br_2.$

$6\ H_2O + Br6 + P3 = 3\ H_2PO_4 + 6\ HBr.$

$2\ Na\ I + Mn\ O_2 + 2\ (H_2SO_4) = Na_2\ SO_4 + Mn\ SO_4 + 2\ H_2O + I_2.$

$6\ KHO + I6 = 5\ KI + KIO_3 + 3\ H_2O.$

$5\ KI + KIO_3 + 6\ HCl = 6\ KCl + 3\ H_2O + I6.$

$Na_2\ (IO_3)_2 + 2\ Na_2\ O + Cl4 = Na_2\ (IO_4)_2 + 4\ Na\ Cl.$

$2\ Na_2\ (IO_4)_2 + 4\ (Ag\ NO_3) = 2\ Ag_2\ (IO_4)_2 + 4\ (Na\ NO_3).$

$2\ Ag\ (IO_4)_2 + H_2\ (NO_3)_2 = Ag_2\ OI_2O_7 + Ag_2\ (NO_3)_2 + H_2O.$

$2\ (Ag_2\ (IO_4)_2) + H_2O = O_7\ 2\ Ag_2\ (IO_4)_2 + H_2IO8O_7.$

$8\ H_2O + I_{10} + P_2 = 10\ HI + 3\ H_2\ (PO_3)_2.$

$4\ KI + 3\ H_2\ (PO_3)_2 = 4\ HI + 2\ K_2H_2\ (PO_3)_2.$

$NHI_2 = N + HI + I.$

$Fe\ I_2 + Fe_2\ I6 + 4\ (K_2CO_3) = 8\ KI + Fe\ OFe_2\ O_3 + 4\ CO_2.$

$Ca\ F_2 + H_2SO_4 = Ca\ SO_4 + 2\ HF.$

$2\ Ca\ F_2 + Si\ O_2 + 2\ (H_2OSO_3) = 2\ (Ca\ OSO_3) + SI_4 + 2\ H_2O.$

$Si\ F_4 + 2\ H_2O = Si\ O_2 + 4\ HF.$

$Hg\ SO_4 + Hg + 2\ Na\ Cl = Hg_2\ Cl_2 + SO_4Na_2.$

$Hg_2\ Cl_2 + 2\ NH_3 = Hg_2\ Cl\ NH_2 + NH_4\ Cl.$

$2\ Na\ Cl + Hg\ SO_4 = Cl_2\ Hg + SO_4\ Na_2.$

$Hg\ Cl_2 + 2\ NH_3 = Hg\ NH_2Cl + NH_4Cl.$

$HgCl_2 + Cu = Hg + CuCl_2$.

$3\ HgSO_4 + 2\ H_2O = Hg_3SO_6 + 2\ H_2SO_4$.

$PbS + 3\ O = PbO + SO_2$.

$PbS + 2\ O_2 = PbSO_4$.

$Pb_3O_4 + 4\ HNO_3 = 2\ Pb(NO_3)_2 + PbO_2 + 2\ H_2O$.

$PbO_2 + 4\ HCl = PbCl_2 + Cl_2 + 2\ H_2O$.

$3\ BiCl_3 + 4\ H_2O = Bi_3O_2Cl_3(HO)_2 + 6\ HCl$.

$2\ CuO + Cu_2S = 2\ Cu_2 + SO_2$.

$Fe + SO_4Cu = SO_4Fe + Cu$.

$Cu_2H_2 + 2\ HCl = Cu_2Cl_2 + 2\ H_2$.

$2\ CuSO_4 + 4\ KI = Cu_2I_2 + I_2 + 2\ K_2SO_4$.

$2\ HNa_2PO_4 + 3\ CuSO_4 = Cu_3(PO_4)_2 + 2\ Na_2SO_4 + H_2O_2SO_4$.

$C + CO_2 = 2\ CO_2$.

$C + H_2O = CO + H_2$.

$2\ Fe_2H_6O_6 - 3\ H_2O = Fe_4O_9H_6$.

$3\ BaCO_3 + Fe_2Cl_6 = 3\ CO_2 + Fe_2O_3 + 3\ BaCl_2$.

$Fe_7Cy_{18} + 12\ KHO = 3\ FeCy_6K_4 + 2\ Fe_2O_3 + 6\ H_2O$.

$Fe_2Cy_{12} + 3\ FeCl_2 = Fe_5Cy_{12} + 6\ KCl$.

$Fe_5Cy_{12} + 8\ KHO = 2\ FeCy_6K_4 + Fe_2H_6O_6 + FeH_2O_2$.

$Fe_2Cl_6 + 6\ KI = 2\ FeI_2 + I_2 + 6\ KCl$.

$FeS + 2\ HCl = FeCl_2 + H_2S$.

$Fe_2 Cl_6 + H_2S = 2 Fe Cl_2 + 2 HCl + S.$

$2 Fe SO_4 = SO_2 + Fe_2 O_2SO_4.$

$Al_2 O_3 + 3 C + 3 Cl_2 = Al_2 Cl_6 + 3 CO.$

$Al_2 Cl_6 + ((NH_4)_2 S)_3 + 6 H_2O = Al_2 O_6H_6 + 3 H_2S + 6 NH_4Cl.$

$Cr (SO_4)_3 + 3 (NH_4)_2S + 6 H_2O = Cr_2 H_6O_6 + 3 (NH_4)_2 SO_4 + 3 H_2S.$

$2 Cr O_3 + 12 HCl = Cr_2 Cl_6 + 6 Cl + 6 H_2O.$

$2 Cr O_3 + 6 HCl + 3 H_2S = Cr_2 Cl_6 + 3 S + 6 H_2O.$

$Cr O_4K_2 + 2 Na Cl + 2 H_2O_4Cr O_2Cl_2 + SO_4K_2 + SO_4Na_2 + 2 H_2O.$

$2 Cr O_3 + 3 H_2SO_4 = Cr_2 (SO_4)_3 + 3 O + 3 H_2O.$

$K_2Cr_2 O_7 + 12 NH_4F + 7 H_2SO_4 = 2 Cr F_6 + K_2SO_4 + 6 (NH_4)_2SO_4 + 7 H_2O.$

$Co_2Cl_6 + 3 Ba CO_3 = Co_2 O_3 + 3 CO_2 + 3 Ba Cl_2.$

$Mn S + Co Cl_2 = Mn Cl_2 + Co S.$

$3 K_2Mn O_4 + 2 H_2O = K_2Mn_2 O_8 + Mn O_2 + 4 KHO$

$Ba S + 2 HNO_3 = (NO_3)_2Ba + H_2S.$

$SO_4Ba + 2 C_2 = SBa + 4 CO.$

$6 Ba H_2O_2 + 6 I_2 = Ba (IO_3)_2 + 5 Ba I_2 + 6 H_2O.$

Miscellaneous principles and facts are as follows :—

Quick-lime, phosphoric anhydride, and sulphuric acid (concentrated) absorb with avidity moisture from the air.

Hydrogen is the lighest substance known, being a rare gas; while platinum is the heaviest, except one or two rare metals.

Sodium and potassium, and not aluminium, are the lightest metals, being light enough to float upon water.

Hydrogen gas has not been liquefied by pressure, but carbonic acid gas and ammonia gas have been, and can be without difficulty, with the proper apparatus. Hydrogen gas has the property of passing through hot, but not cold, iron, palladium, and platinum. Hydrogen is combustible with oxygen, chlorine, and a few other elements by the action of heat; or, indirectly, by placing certain compounds in contact with one another. Hydrogen and chlorine, when mixed and exposed to sunlight, explode violently with formation of hydrochloric acid. Colored textile materials are bleached by the action of chlorine or by ozone; because these two elements have a strong affinity for hydrogen, and because all aniline and vegetable colors are due to the presence of hydrogen. Chlorine, when absorbed by water, and placed in the sun, will decompose a portion of the water uniting with the hydrogen and liberating the oxygen. If hydrogen and iodine are passed over platinum, heated to redness, they combine, forming hydriodic acid; whereas water is decomposed into hydrogen and oxygen gases, if passed through red-hot iron tubes. About the only chemical which acts upon glass is hydrofluoric acid, and the action is so great that in a few minutes a surface of polished glass looks like ground glass. Although all water, in nature, is composed of oxygen and hydrogen, it also contains free oxygen absorbed, which may be expelled by heat, or a vacuum pump, or absorption by some chemical with which it has a strong affinity.

The temperature of a flame remains at that at which combustion occurs, so that a very slight lowering of the temperature will extinguish it; therefore a piece of metal gauze, put through a gas flame, will prevent the flame from coming through the gauze, the gauze being made of any metal.

At the ordinary temperature, phosphorus will unite gradually with oxygen, becoming white; and if rubbed, will burst into a flame, and be converted into a cloud of white fumes of the oxide of phosphorus; and similarly all metals can be made to combine with oxygen, upon condition that the temperature is sufficiently high.

One-thousandth of a pound of coal gas, when exploded with the proper proportion of air, is equivalent to a force which will raise a weight of 48 pounds through the space of one foot, showing that the explosion of coal gas, by an electric spark, for instance, produces great power.

Water, although apparently incompressible, is compressible to the extent that were the atmospheric pressure of 15 pounds to the square inch doubled, 1,000,000 volumes would become less by 50 volumes. It is a very bad conductor of heat and of electricity; and is not known to conduct the latter unless by it decomposed more or less into hydrogen and oxygen gases. Above 4° C. it expands by heat, and it is a remarkable fact that below that temperature it also expands, but it always resumes the same density at any given pressure and temperature.

Certain solids are not only soluble in water, but also certain liquids, as alcohol, ether and acetic acid; and also gases, as ammonia and hydrochloric acid and nitric acids; the rate and degree of solubility depending upon the nature of the gas, the temperature of the water, and the pressure upon the surface of the water.

An atmosphere or ocean of air surrounds the earth, and varies in pressure from the top to the bottom, being greatest at the latter limit, and equal to 15 pounds per square inch.

The atmosphere contains intimately *mixed* nitrogen and oxygen, principally, and traces of water vapor and carbonic acid gas.

The atmosphere has the property of a lens, in that after the sun has actually "set" it may still be seen, because the air refracts or bends the rays downward.

Carbon occurs in three distinct physical states—as animal or vegetable charcoal or coke; as representing one state properly called charcoal; as graphite and as diamond; so that when any one is burned, in presence of pure oxygen, carbonic di-oxide alone is formed.

Rain-water, when passing through the air, absorbs such impurities as carbonic acid gas, gases from chemical works, factories, &c.

In addition to phosphorus having the property of lighting at the ordinary temperature, especially if rubbed slightly, phosphoretted hydrogen, in escaping from a tube, will ignite immediately and continue to burn as long as the supply lasts.

Litmus is a liquid having the property of turning red when mixed with an acid; of turning blue when mixed with an alkali; and being changed from neither red nor blue when treated with any other known substance.

The combustion of magnesium metal in air produces intensity of light equal to that of the arc lamp or "calcium" light, the product being the infusible oxide of magnesium, called magnesia.

Zinc becomes brittle at the temperature of about 205° F.

Certain chemical elements can be combined or separated by the force of heat, electrolytic action, light, or by contact with other elements or compounds, or by the combination of those forces.

Although mercury is the only liquid elemental metal, viscous or soft metallic substances may be obtained, as amalgams, by mixing certain other metals with mercury.

Sodium has such a strong attraction for mercury as to combine therewith, to form an amalgam, with a brilliant light and hissing sound.

The most abundant element in the world, except oxygen, is aluminium, and exists in combination with oxygen as an oxide, together occasionally with small quantities of potassium, iron, calcium and magnesium. Aluminium is only about two and one-half times as heavy as water; while iron is eight times as heavy as water, and platinum is twenty-one times as heavy as water.

Although ordinary iron has the property of receiving a deposit of copper when immersed in a solution of a copper salt, yet it loses this property if first mometarily dipped in strong nitric acid and then washed.

Wrought iron, cast iron and steel differ from one another according to the amount of carbon they contain ; wrought iron containing the least and cast iron the most ; while the temper of steel depends upon the degree of heat from which it is suddenly cooled. The electric conductivity of steel increases with its temper.

These different iron mixtures with carbon have different electrical and heat conductivities and powers of magnetic reception.

Nickel, like iron, is more easily fusible when containing a small quantity of carbon, and will also, like iron, at a red heat, decompose water into hydrogen and oxygen.

Cotton, linen and wood are rendered practically incombustible when treated (in the manner of starching) with tungstate of soda, which will also serve as a mordant in dyeing.

A bar of pure tin, when bent, emits a peculiar, soft, crackling sound.

When gold is rolled sufficiently thin, it will transmit light, and will have a color dependent upon the thinness of the foil.

Gold-leaf, which is green by transmitted light, becomes ruby red when heated to 316° F.

Platinum has such a power of concentrating oxygen on its surface, that when a coil thereof is heated in an alcohol flame, and the flame extinguished, the red-hot platinum will continue to be red hot, even in the absence of the flame. The platinum must remain over the wick.

"Platinum black" absorbs more than 800 times its volume of oxygen.

There are no two substances having exactly the same degree of hardness; and of two substances, that one which leaves a mark upon the other, by friction, is the harder. Among the hardest substances are diamond and steel, and among the softest solids are soapstone, potassium, graphite and lead.

A weak solution of chloride of cobalt is pink. A concentrated solution is blue. Paper saturated therewith is light pink and turns blue when heated.

Sulphur, at the ordinary temperature, is hard, like a stone. When first heated, it is very thin, and when heated higher it is viscous or very thick. At a still higher temperature, the fused sulphur becomes again thin, and in cooling, the same change takes place.

If oxygen 1 volume, and hydrogen 2 volumes, are mixed in a vessel and exploded—for instance, by a spark—water vapor is produced which has a volume of only $\frac{2}{3}$ the gases when not combined, *i. e.*, the volume is only 2. If 1 volume of chlorine and 1 of hydrogen are combined, the result is 2 volumes. In general, the volume after combination is 2, even if the volume of the elements before chemically combining, as in N_2O_3 (nitrogen peroxide), is 5.

CHAPTER XIII.

Principles in Electricity as Tools for Making Scientific Inventions.

Electricity is a form of force. What it is further than this no one knows, any more than one knows what gravitation is.

Two general classes of electricity are generally named static and dynamic, often called galvanic. Similarly, we could speak about gravitation. The words explain the difference. Static electricity is the condition where a charge tends to flow, but cannot because the circuit is not complete. It is electricity at rest. If a weight rests upon the floor, there is static gravitation. The weight tends to move, but cannot. Make a hole in the floor and it moves. The floor acts as a resistance. So with static electricity; it does not move because there is too great a resistance; there is no proper conductor upon which it can move. As soon as a conductor is provided, the current flows. This current is called dynamic. Static electricity is often spoken of as frictional; but dynamic electricity may also be frictional. However, for the inventor, he cares not for names, and therefore each principle and fact will be stated by the words which convey the information in as simple a manner as possible. Gravitation will not travel along a wire and back again to the generating point, but an electric current will, and the wire may be tapped at any point and the electric energy converted by the proper means into mechanical, chemical, magnetic and light energy. If the wire is completely broken, the generator of the electricity maintains the wires charged, but performs no work.

Electricity is generated in the following different ways: By friction or when two substances are rubbed together; compression of substances; variation of temperature upon tourmaline; fracture of substances; solidification of a substance from a state of fusion or gas; chemical action in a primary or secondary battery; combustion of carbon, the same being electrified negatively, and the resulting carbonic acid, negatively; by evaporation of a liquid. Fog, snow and rain are found to be charged. The clouds are most always electrically charged. It is generated by the relative motion of electro or permanent magnets; by induction from any other neighboring circuit; by certain animals and fish; by heat, as when two different metals are touched together in a flame; and by friction of clouds, producing lightning.

Light is claimed to be converted into electricity by coating opposite sides of a plate of glass with sheets of tin-foil (bright on one side and dull on the other) and exposing the dull side to the direct rays of the sun and dipping in alcohol. The electromotive force or pressure is about .06 volt. The dull side of one sheet of foil should face a bright side of the other sheet. The current passes through a wire connecting the sheets of tin-foil.

Coat two silver plates with silver salts or aniline dyes, and immerse in a conducting liquid, and it is found that a small current is generated, if electrically connected, while one plate is exposed to light and the other placed in the dark.

Slight electric currents may be obtained from the earth by connecting a well-insulated and long-distance telegraph line to ground at both ends, *omitting* all electric generators. A delicate galvanometer needle is deflected, but resumes its original position when the line is interrupted. The amount of current depends upon the condition of the tides; upon the relative temperatures of the two points of the earth at which the line is grounded; and upon the condition of the sun's spots. The direction of the current is easterly, and the maximum is in the direction from N. W. to S. E.; but this rule is found to be general and not without exception.

The generation of electricity by chemical action consists in a transferring of the atoms from one compound or element to other elements or compounds. When this change takes place, an electric current is produced. The chemical force is changed into electrical force. This current may then be changed again into chemical force by passing it through a solution of any given compound, whose atoms either separate or rearrange themselves into other compounds, or unite with the atoms of one or more other compounds. These are principles, but no one knows whether the chemical and electrical forces are one and the same thing disguised to human eyes.

Electrical conductors are as follows, being approximately less and less in the order named: Metals, pure graphite, acids, aqueous solutions of acids, salts or hydrates; animals, vegetables, water, snow, linen and cotton. The non-conductors are principally: Metallic oxides; ice at the lowest possible temperature; caoutchouc, dry gases or mixture of gases; dried paper; silk, precious stones; glass, wax, sulphur, resins, amber and shellac; alcohol, flour of sulphur and powdered glass.

Carbon being of high resistance, its mixture with a non-conductor increases the resistance of the former and lowers that of the latter as far as the final result is concerned. Similarly, fine metallic particles mixed with carbon result in a substance of different resistance from either; in general, substances of different resistance (or conductivity) may be obtained of any desired degree by mixing different substances in the same or different proportions. The result will always be a resistance differing from that of either constitutent. An illustration of the application of this principle is found in the invention of the present cheap commercial reduction of aluminium from its cheap oxide, which is a non-conductor, but mixed with carbon is practically a conductor. The passage of a heavy current heats the same to such a high a temperature that the oxygen leaves the aluminium and goes to the carbon, forming carbonic acid gas, which escapes, leaving the aluminium free.

The relative conductivity of conductors is as follows : Silver being taken as the best and represented in value by 100. Copper is nearly as good a conductor, being represented by 99.9; gold by 80; sodium, 37; aluminium, 34; zinc, 29; cadmium, 24; brass, 22; potassium, 21; platinum, 18; iron, 17; tin, 13; lead, 8; German silver, 8; antimony, 5; mercury, 2; bismuth, 1; graphite, 0.

The relative conductivity of some liquids is indicated by calling that of silver 100,000,000,000,000. Cupric nitrate saturated solution in water would be represented by 8,900; cupric sulphate, saturated, by 5,420; sodic chloride, saturated, by 31,-520; zinc sulphate, saturated, by 5,770; sulphuric acid, diluted so as to be 1.24 times as heavy as water, by 132,750; commercial nitric acid, by 88,680; and perfectly pure water, as obtained by distillation, by 7.

Reference has been made to the action of light on the conductivity of selenium. Its conductivity is doubled in direct sunlight. Even gas light increases its conductivity.

In the following principles relating to the electro-chemical generator and decomposition it is assumed that it is known that a device for carrying the above principles into effect consists of a vessel containing a liquid called conveniently the electrolyte and two pieces of solid material dipping therein, called the electrodes. A wire joining the electrodes and including or not including electric lamps, or bells, or motors, &c., is called a circuit.

The electrolyte may be a single conducting acid, dilute or concentrated; or an aqueous or acid solution of a decomposable salt, oxide or hydrate. Usually, it cannot be a vegetable or animal substance. If of the same metal, a current is not produced theoretically; but in practice, it is impossible to get two pieces which have the same molecular structure, temperature, chemical constitution, &c., so that a very slight current may often be detected. Not only should the metals be different in order to obtain large currents, but the electromotive force (pressure) and current are dependent upon the particular metals joined in the same cell. If zinc and carbon are used as the electrodes in dilute sulphuric acid, for instance, there is more electromotive force than if iron is used in the place of zinc; again, the electromotive force is still less with lead. In the place of solid conductors, gases or even liquids may be employed, or the electrodes may be provided with a coating of a salt, oxide or similar decomposable compound. As far as the elements are concerned, the electromotive force is higher and higher according to the distance apart of any two of the following-named elements: Oxygen, sulphur, nitrogen, fluorine, chlorine, bromine, iodine, phosphorus, arsenicum, chromium, boron, carbon, antimony, silicon, hydrogen, gold, platinum, mercury, silver, copper, bismuth, tin, lead, cobalt, nickel, iron, zinc, manganese, aluminium, magnesium, calcium, barium, lithium, sodium, potassium. Example: If one electrode is oxygen (made for instance by using carbon which is exposed to air) the electromotive force is much greater with a second electrode of lead than of silver. The electromotive force is the least with electrodes made of elements which are next to each other in the above list. The electromotive force is greatest between the first and last, namely, oxygen and potassium. In the above series dilute sulphuric acid is the electrolyte. The series varies a little with other electrolytes.

The fact that the electromotive force increases under certain conditions is not necessarily a proof that more energy is obtained from certain amounts of chemical actions in a cell any more than that a locomotive necessarily does more work in going from New York to Philadelphia in two hours than in three. More work is done in the former case in a given interval, but not more total work.

The principles upon which a cell in general produces a current may be explained thus: The structure in the first place is a conducting and decomposable liquid which serves as an electrolyte. The liquid if not decomposable is not operative. Thus, mercury is a conducting liquid, but does not serve as an electrolyte. Again, the liquid should be not only a compound, but a conducting compound. Oil is a compound, but no electrolyte. It is not a conductor. The electrolyte may consist of several liquids.

The chemical actions which occur in a cell take place at the surfaces and often within the mass of the electrodes; but not much beyond the surfaces. The maximum action takes place on those surfaces nearest together. The larger the amounts of surface exposed to the action of the electrolyte, the greater the current, but the electromotive force remains constant, which, however, may be increased by connecting two or more cells in series, *i. e.*, by connecting electrically the negative electrode of one cell with the positive of the next cell, and so on. Illustration: If each cell contains electrodes of carbon and zinc, the zinc of one cell is connected to the carbon of the next, which is connected to the zinc of the next, and so on, the final carbon and zinc being the terminals of the battery, which if connected by a conductor instantly allows the chemical actions to take place and a current to flow. If like electrodes are joined in sets a current is found by joining the sets. The electromotive force is not increased, but the current is. The product of the current by the electromotive force is equal to the amount of electrical energy, just the same that the product of the height of a column of falling water by the amount of water which falls equals the amount of work which the falling water performs.

Sometimes cells may be electrically connected in a closed circuit without giving a current by connecting *all* the zincs and all the carbons into one set or closed circuit. Various combinations of the above elementary methods of connecting up cells may be made. Thus some cells of a given set may be joined in series and others in parallel, and still others in opposition, the resulting current being due to the nature of the combination.

The current produced by the chemical action in a battery will produce chemical action in another battery, but only on the condition that the energy of the former current is greater than that of the latter. Illustration: Let the terminals of a sulphuric acid battery be dipped in dilute sulphuric acid. Hydrogen and oxygen are given off at the respective terminals, which will escape into the air or combine with the electrodes according to their chemical nature. If the terminals are platinum, the oxygen and hydrogen both escape, except that a small amount at the beginning will be mechanically absorbed by the platinum. If the oxygen and hydrogen unite with the electrodes in such a manner as to form insoluble compounds thereon, as will be the case with lead terminals, the same will act as a good cell itself after the said battery is taken away. Similarly, any secondary conducting terminals and any conducting decomposable electrolyte form more or less of a secondary cell after the primary charging battery is removed and the cell closed upon itself.

Some cells give a constant current and some give a weaker and weaker current until the final is very weak. The latter generally are formed with one electrolyte; the former with two, separated in such a manner that they can mix only very slowly, as may be done, for example, by means of a porous earthenware jar. When two electrolytes are employed, an electrode is placed in each. The reason why a single electrolyte cell forms a decreasing current is that bubbles of gas collect upon the surfaces of the electrodes. As gases are bad conductors, the internal resistance increases, thereby decreasing the current. The current becomes strong again upon removing the gases either mechanically or chemically. The greatest collection of bubbles is at that pole which in sulphuric acid or other decomposable compound of hydrogen is where the hydrogen is liberated. By means of the double electrolyte cell a chemical is furnished with which the hydrogen unites as soon as liberated, thereby preventing the formation of bubbles. Those liquids which can furnish oxygen, chlorine or similar substance with which hydrogen will unite are suitable for the second electrolyte. Some such compounds are: Nitric acid, HNO_3; aqueous or acid solutions of salts, such as potassic bichromate, potassic chlorate, sodic chloride, ammonic chloride, &c.

Almost any chemical reactions known in chemistry for producing either oxygen or chlorine are applicable in the cell for the chemical removal of hydrogen bubbles. The name given to the bad action of the bubbles is polarization, because it corresponds to electrically connecting the poles of a weaker cell in opposition. Two currents are tending to flow in opposite directions, the differences between the two being the resultant or useful current.

Another chemical way of preventing the bubbles is by using as the second electrolyte those particular salts which liberate a pure metal instead of hydrogen. The metal forms a coating which is a good conductor; therefore the resistance is not increased.

The following list of metals serves to predict upon which electrode the hydrogen is given off in a primary cell. If any two are employed in the order named, the first one of the pair is the hydrogen electrode: Silver, copper, antimony, bismuth, nickel, iron, lead, tin, cadmium, zinc.

Some of the ways in single electrolyte cells of removing the bubbles mechanically are by agitating the electrolyte; by rubbing the electrode, or by covering it with platinum black or similar substance, which will absorb the hydrogen, and by having a greatly enlarged electrode, especially as to the amount of surface exposed to the electrolyte in proportion to that of the other electrode.

Electrodes placed in the ocean form a good cell, because the motion of the salt water washes off the bubbles as soon as formed.

Sometimes the polarization is so great with cells in series that it causes the poles of some of the cells to be reversed; but the poles of a single cell never become reversed. Short-circuiting is one of the principal causes of reversal. The polarization then becomes the maximum, causing the greatest counter-current. When the cells are not duplicates in size or chemical nature, &c., reversal occasionally occurs.

When common moist earth is mixed with ammonic chloride (sal ammoniac) and electrodes of copper and zinc are immersed therein, a cell is formed having but little polarization. The hydrogen bubbles are thought to be absorbed in the porous earth. Powdered carbon in large quantity serves as a partial depolarizer in view of the comparatively large amount of pores for absorbing the hydrogen, and because the oxygen absorbed from the air unites with the hydrogen.

The forcing of air into a liquid through a tube, whereby the electrolyte is effectually agitated, assists greatly in depolarizing. The quiet addition of oxygen to the electrolyte by mixing without any chemical combination with the electrolyte does not assist in depolarizing.

The generation of electricity by the use of oxygen in the air is obtained by using carbon as one of the electrodes and a metal as the other electrode. The oxygen is absorbed in the pores of the carbon and there unites with the hydrogen, which is liberated at the carbon electrode. The oxygen continually feeds itself from the air into the carbon. When the carbon is under such a condition as to receive no air, the weakness of the cell is very noticeable.

Electrodes may be of the same conducting solid, if immersed in different liquids which are so arranged as to gradually mix. Example: Divide a vessel into two parts by an earthenware partition, and place potassic hydrate and sulphuric acid in the respective compartments. Place platinum electrodes therein, and a cell is obtained.

Different gases may also be employed in place of the liquids, but a liquid must also be used between the gases, and the electrodes must be in contact with both the liquid and the gases. Example: Invert tubes of hydrogen and oxygen respectively over and in dilute sulphuric acid, and use platinum electrodes which pass up through the electrolyte into the gases. A cell is obtained, as may be known by connecting the electrodes electrically through a galvanometer.

Zinc is soluble in sulphuric acid, but when coated with a layer of mercury, as may be done by dipping it in mercury for a few minutes after having dipped it into some sulphuric acid, it becomes practically insoluble in the acid; but it may then be caused to dissolve in the acid if connected electrically with some other metal or carbon also in the acid.

It becomes of importance to study into the molecular actions which are thought to take place in the decomposition of a liquid by passing an electric current through it. Let sodic chloride (common salt) in solution in water be considered. It is supposed that the atoms of sodium and chlorine while in solution are not all permanently combined, but are continually uniting and separating, so that during any given minute there exists not only sodic chloride, but also the separated elements. When, however, the salt is dried so as to become a solid, the chlorine and sodium unite permanently until again dissolved in water or other liquid. Again, the atoms of hydrogen and oxygen of liquid water are continually combining and separating, but in ice the atoms are permanently combined. So with all conducting compound liquids it is supposed that different atoms composing the same are both combined and separated, but all the time substantially as close together; *i. e.*, the atoms do not escape as a gas. This supposition is necessary or else it is difficult to grasp the reason why an electric current decomposes liquids. By the use of the supposition the phenomenon of electrolysis is easily explained. When the current passes through water, the atoms of hydrogen and oxygen being relatively electro positive and negative, become charged so that they go to the respective electrodes and remain separated as long as charged. They will go together again upon cutting off the current and allowing them to generate a current as in the ordinary oxy-hydrogen voltmeter. The supposition or hypothesis explains also why a liquid becomes a better conductor when heated. The heat increases what might be called the liquidity of the liquid. It makes the force of cohesion less, so that the hydrogen and oxygen (in case of water) will more easily separate. It is thought from the above considerations that the atoms separate from one another under the influence of a current as a result of mechanical motion produced by the current. The theory explains all the phenomena of electrolysis. Solid compounds are not decomposable by the passage of a current because the atoms are permanently combined; they do not, as in liquids, alternately combine and separate. The force of cohesion between them is greater and greater the lower the temperature; but with liquids the forces of cohesion and chemical attraction are more nearly balanced than in any other form, as pointed out in the chapter on heat. The force due to electrical molecular repulsion overcomes gradually the force of cohesion. It might properly be called heat without rise of temperature; because heat also causes decomposition of water. The electric current decomposes the water or other conducting compound liquids with practically no rise of temperature in comparison with that of over 1,000° required by heat. As far as total effects are concerned, however, heat and electric separation are similar. As soon as a compound arrives at a certain high temperature the decomposition takes place in the whole mass; but with the electric current the decomposition is very, very slow, gradual and local. Deposition of metal from a solution of its salt may not only be effected by passage of a current through two electrodes separated from each other in the solution, but by the mere immersion of certain metals in the solution. When a rod of zinc is placed in an acid solution of stannous chloride, the tin leaves the chloride and forms in crystals upon the surface of the zinc. Mercury separates silver in large quantities and quite rapidly from a solution of argentic nitrate. Zinc in plumbic acetate soon looks like a beautiful tree of lead scales. The principle underlying the action is that the metal placed in the solution of a second metallic salt takes the place of said second metal. Thus, if iron is placed in cupric sulphate the equation is as follows: Fe (iron) plus $CuSO_4$ (cupric sulphate) equals (copper) plus $FeSO_4$ (ferric sulphate). Consequently, in order to get out the copper from the solution, iron must be put in the place of the copper.

An electric cell in which the electrolyte is an aqueous solution of chromic chloride, and the electrodes, tin and platinum, gives no current at the ordinary temperature; but if heated considerably, a current is produced in a closed circuit. The chemical action consists in the conversion of the tin into stannic chloride. When the cell is cooled, it returns to its original chemical condition, and when heated a current is again given off; and the operation may be repeated indefinitely without loss of material, provided the cell is made air-tight, so that no chlorine shall escape. When the tin is each time liberated from the stannic chloride it falls to the bottom as a metallic precipitate. The bottom of the cell should therefore be employed from the beginning as the support for the tin. This is an example of the conversion of heat into electricity. Another example is as follows : The electrolyte is melted potassic nitrate; the electrodes, carbon and iron. The carbon unites with the oxygen from the nitrate, forming a carbon di-oxide. The heated nitrate causes the conversion of heat into electricity.

The obtaining of electricity by the consumption of carbon without heat is illustrated by the cell in which sulphuric acid is one electrolyte, and graphite and platinum the electrodes; the acid containing also a small proportion of potassic chlorate, as the second electrolyte. The potassic chlorate may be replaced by peroxide of chlorine. The graphite may be replaced by ordinary battery carbon. The carbon gradually disappears.

It is a singular phenomenon that with continuous and uniform currrents, the nerves in a human body are not as sensitively affected as if the same current is interrupted. A shock is felt if the current is rapidly alternated, closed and opened, or undulated or vibrated in any manner. An irritation of the nerves of the tongue by an electric current produces a sensation of taste, and so also the exciting of other organs produces their peculiar sensations. Even after death the nerves may be contracted. Certain cases are reported in which life was restored by exciting the respiratory muscles.

Of all chemical elements, carbon is the only one which has not been melted by means of the electric current, but it has been heated to such a high temperature by the current as to weld two pieces together, the carbon becoming soft while hot, like wrought iron. With ordinary commercial electric lighting currents wire of any metal may be melted, and even volatilized, in which condition they burn by uniting with the oxygen of the air, forming oxides. Differently colored flames are produced according to the metal burned. Platinum and iron, tin and zinc give approximately white light. A metallic sheet held in front of an alternating or intermittent current magnet becomes hot in proportion to the strength of the current, while the magnet remains comparatively cool. The eddy or Foucault currents induced in the plate are the cause of its being heated. A metallic core put within a vibratory current magnet also becomes hot.

Two plates of the same metal which have just served to conduct a current into and out of a conducting compound liquid, can of themselves furnish a current through an electric conductor, connecting the two plates.

If the two plates are lead, and the liquid, dilute sulphuric acid, the electricity thus stored is due to the electrolytic formation upon the respective plates of the peroxide of lead and the pure reduced lead. After the passage or exit of the stored current, the lead has united with oxygen and become a lower oxide of lead, while the peroxide of lead parts with its oxygen and becomes the lower oxide of lead also. Local actions convert lead into the objectionable sulphate of lead.

The storage, so-called, of electricity by the ordinary storage battery is not a correct statement. The electricity in passing from one lead plate to another forms new chemical compounds. The subsequent chemical affinity during discharge causes new compounds to be formed with accompanying electricity. In brief, the electrical force is converted into chemical force, which remains as long as desirable. Subsequently, the chemical force is converted into electrical force.

Any chemical compound of a metal attached to one electrode and capable of uniting with oxygen, when coupled electrically with a second electrode provided with a chemical compound of the same metal capable of uniting with hydrogen, will, in an electrolyte containing hydrogen and oxygen (for example, water containing a solution of the salt of said metal), generate an electric current, whether these chemicals have been produced as in storing electricity or by any other manner known or unknown.

To store electricity consists, therefore, in producing chemical changes in given compounds and using the new compounds in such a manner as to produce an electric current, or else it consists, as in the case of the Leyden jar, in charging a metallic mass with electricity while separated from a second metallic mass by glass or similar insulator. When the two are electrically or metallically joined, the stored electricity is obtained for use.

The metals and alloys which have been electrically welded to themselves are: Gold, silver, silicon, phosphor and aluminium-bronze; brass, bismuth, copper, zinc, platinum, malleable wrought and cast iron; antimony, magnesium, lead, manganese, alloy of aluminium and iron; gun metal, German silver, fusible metal, crescent, Bessemer, stub, chrome, musshet and cast steel, and tin. Example: Lead has been electrically welded to lead; gold to gold, &c. Different metals which have been welded together are: Copper to either gold, silver, German silver, iron and brass; brass to either soft steel, tin, German silver, cast iron; wrought iron to either soft or cast steel, tool steel, crescent steel, cast brass, German silver; gold to either platinum, silver, German silver and silver to platinum.

Electric welding may not only be effected by the alternating current, but also by continuous currents.

When an electric conductor is heated by an electric current, the center of the same is the hottest, the temperature being less and less toward the outer surface.

If two small bars of different metals—best for the purpose being antimony and bismuth—be laid upon each other and crosswise and soldered together, an instrument is obtained by which a *small* electric current may be converted into "cold;" *i. e.*, if the current is in one direction the temperature of the joint is lowered about 4°. When the current is reversed, the temperature of the joint is increased an equal amount. The reverse of the above principle is true. If the joint is heated while the ends of the bars are connected by a conductor, a current of one direction is generated. A current of the opposite direction is produced if the joint is cooled. With a very delicate galvanometer a current is found to be produced, however small the amount of heat added to or subtracted from the joint. Why the cold is produced is no better known than why heat is produced by the passage of currents of opposite direction through the joint; but if the theory of heat is right, the matter is explained by a consideration of the motion of the molecules. In the one case the motions of the molecules are accelerated, producing heat; in the other case they are retarded, resulting in cold. Another way in which the temperature of a conductor is affected is illustrated by the following statement: When a metallic bar is heated at one end and cooled at the other, the temperature of the bar is raised to different amounts according to the direction of the current. The variation is so slight that it can be detected only by very sensitive means. The two ends may be respectively heated and cooled to fixed temperatures by boiling water and ice. A differential arrangement will best show the difference. Use two parallel bars, for example, of iron. Connect one pair of ends by a wire in boiling water and the other leave separate in ice water. Pass a current through the bars by connecting the unjoined ends to an electric generator. Corresponding parts of the two bars will be found to have very slightly different temperatures. The current should be strong enough to heat both bars. It will be noticed by this arrangement that the current passes through one bar from its cool end to the hot, and through the other from its hot end to the cold.

With the same current, a wire in a vacuum becomes much hotter than if the wire is surrounded by a gas, liquid or solid. The surrounding material conducts the heat away rapidly, while in a vacuum, the heat is conducted away only slowly by the conductors leading to the wire. In both cases, of course, substantially equal amounts of heat are given away by radiation. A given current will heat a round wire more than a flat one of the same cross-section, because the latter has a greater radiating surface.

Heat is produced by an electric spark. The electromotive force for an arc lamp must be comparatively high on account of the high counter-electromotive force. This counter-pressure is similar to the counter-electromotive force produced by polarization in an electric battery. In both instances it depends largely upon the nature of the electrodes. In an arc lamp with carbon electrodes it is 36 volts; with iron and copper, 24; with zinc, 19; and cadmium, 10. The temperatures of the ends of the two electrodes are widely different, although heated by the same spark; that of the positive being between 2,500° and 3,500° C., and that of the negative, between 2,000° and 2,500°. The minimum resistance of the heated air and gases between the electrodes is found to be 1 ohm, increasing to 15 sometimes. Let two wires of different metals touch each other. A current in one direction cools the joint, while a current in the opposite direction heats the joint.

Mechanical motion is directly convertible into electricity by friction. The electricity thus produced is exactly the same as if obtained by chemical action, but the pressure is always thousands of times greater and the total energy is very small in comparison to the amount of power producing the friction.

In the science of electricity often appear the terms positive and negative electricity. This arises from the introduction of a theory that electricity consists of two fluids capable of motion. When both together the motion is zero. When separated so far as not to have sufficient power to overcome any existing resistance between them, they are at rest. During the operation of their joining each other a current is produced. Similarly are heard the terms positive and negative poles of a generator. One electricity comes from one and the other from the other pole. When separated, the two electric fluids stand still. This theory does not agree with all facts; but it has taken strong hold upon the science, and serves at least as a convenient way of explaining most electrical effects.

The substances named as follows are in such an order that each becomes negatively electrified when rubbed with any of the bodies following, and positively electrified when rubbed with any of the bodies preceding it: Gutta-percha, sulphur, resin, sealing-wax, caoutchouc, metals, wood, silk, cotton, glass, rock crystal, ivory and flannel. Illustration: If shellac is rubbed with flannel, the former will attract a small pith-ball suspended by a silk thread, and is therefore said to be negatively charged. The flannel will repel the pith-ball and is said to be charged positively. Glass is positively electrified when rubbed with silk, while the silk is negatively electrified.

A bird cage containing a bird may be charged with such a heavy charge of static electricity as would kill the same bird outside of the cage; illustrating that static electricity distributes itself on the outer surface of objects. A hollow sphere having a small hole and charged shows no charge inside the sphere. This rule has its modifications. An object within an object is capable of electrification. Again, if two charges of positive and negative electricity are passed through a metallic conductor, the whole mass becomes charged.

Let a large mass such as a piece of metal mounted upon a dry glass rod be charged. Electricity may be taken from it in small quantities, as water from a pail, by touching it with a small piece of metal mounted upon glass. The small piece will be found to be charged with electricity. If touched to another large discharged metallic mass, as to a gas pipe, it becomes discharged, when it will take another small amount from the first-named mass as before.

The rate with which a mass may be discharged depends, among other things, upon its shape; if angular, its discharge is quicker than if continuously curved like a ball. If provided with numerous sharp points, the discharge occurs most rapidly.

When a highly charged body has a film of oil or water upon its outer surface, a shower is formed in consequence of the repulsion occurring among the particles of the liquid. Similarly, a candle flame brought near the body is repelled as if by blowing upon it with a current of air. A light wheel having tangential sharp wire points rotates when delicately pivoted and charged. The charges should be strong, such as are produced, for example, by a Holtz electrical machine, or lightning, or Leyden jar.

Particles of dust in the air serve to discharge a body of its electricity. Each particle becomes charged, floats away; other particles do the same, and so a circulation is maintained until the particles have distributed the electric charge to distant objects and the earth. Illustration: Fill a glass jar with a fine powder, preferably smoke, such as may be made from burning a little turpentine. Charge these particles electrically, as by a wire connected with the electrical machine. The particles keep carrying off the electric charge until they are all repelled and rest upon the sides of the jar, leaving the atmosphere therein very soon comparatively clear.

A fine powder is transferred from one plate to another analogously to electroplated metal by charging the two plates respectively with positive and negative static electricity. The particles become charged with the same kind of electricity as the plate upon which they rest, and are therefore repelled, and at the same time attracted by the opposite kind of electricity of the other plate.

The difference between the ordinary chemical storage battery and a condenser, both of which are electrical accumulators, is that in the former the electricity is transformed temporarily into chemical force, while in the latter the electricity remains electricity, and is accumulated in the sense that a great deal exists on a comparatively small surface.

The simplest form of condenser is probably that which consists of a large plate of glass having pieces of tin-foil pasted upon opposite sides, with a blank margin of at least an inch. Connect the tin-foils with the electric machine and earth respectively. Soon the accumulation is so great that the condenser, even after a few moments, will give a longer spark than the machine. Any device is a condenser which consists of conductors separated slightly by a non-conductor. The layer of insulation serves as a resistance which makes it more difficult for the electricity to escape to the earth. It is analogous to storing water by carrying it from the ocean to the top of a mountain. Work is thus stored up, which will be given out again when the water is allowed to fall upon a water-wheel.

A condenser is kept charged by supporting the same on an insulator. It is discharged by electrically connecting the two sheets of tin-foil.

The thinner the insulating plate between the tin-foils, the greater the capacity, which is also greater, the larger the surfaces of tin-foil and insulating plate; but with any given condenser, its capacity is limited to a fixed amount, howsoever large the charging electrical machine.

Let the condenser be so constructed that the glass and tin-foils may be taken apart while charged. The tin-foils are found to be substantially void of electricity, and yet when put together again, a shock is received by touching, simultaneously, both pieces of tin-foil. The action of the tin-foil results in the distribution and accumulation of the electricity upon a large surface on each side of the glass.

Experiment shows that after discharge of a condenser a residue reappears after a few minutes. Let the residue be discharged. After a few minutes a second residue comes, and so on for four or five times. The residues are very slight, but they show that the glass has the power of absorbing some of the electricity. Exactly what happens to the glass as a mass, or as to its molecules, is not fully known. Other insulating plates between the tin-foils or between other thin metallic plates exhibit the same property of absorption. The amount of residues depends upon the amount of charge, upon the nearness of contact of the elements, upon the material of which they are made and upon the thinness of the insulator. If the foil is replaced by a liquid conductor, such as dilute sulphuric acid, as may be done by a change in the mechanical construction of the condenser, the residual charge is found to exist after a few moments; but if the liquid is given a shock right after the first discharge, the residual charge may be detected within a few seconds instead of minutes. The device may be made of two concentric glass vessels of slightly different sizes placed one within the other, and containing sulphuric acid.

If two pieces of gold-leaf are held together at one end, they spread apart when electrified. They become thereby charged with the same same kind of electricity and repel each other. Motion is therefore one of the effects of frictional electricity.

When large amounts of static electricity are desired, the Leyden battery is used, which consists of several condensers connected in series.

If a condenser is discharged through a conductor, as may be done by connecting the pieces of tin-foil with a wire, the current which passes is continuous, but not uniform. It is vibratory. It is similar to releasing a spring from tension; it has a continuous but oscillatory motion until it comes to rest.

If a condenser is discharged through the air by using two conductors each touching a tin-foil, but not quite touching each other, the discharge is abrupt, and the current formed is intermittent, consisting of a rapid succession of small impulses.

Electricity has an effect upon the human body and upon animals in general. Beginning with small and taking gradually greater and greater shocks, the elbows feel it first most strongly, then the chest, and finally the stomach. An army of 1,500 men once took a shock by joining hands. They felt it strongly. Those at and nearest the center get the least shock, which is explained that some leaks to earth before the central men receive it. The discharge of a large battery may be retarded by passage through a wet rope.

The spark which is formed by the disruptive discharge has different colors according to the nature of the terminals, and some of the material is volatilized and passes from one pole to the other. Thus, with gold and silver, some of the silver is deposited upon the gold, and some of the gold upon the silver. Carbon terminals give a yellow spark; ivory, a beautiful red, and copper, green, especially if the copper is first covered with a coating of silver. The color varies also with the nature of the gas in which the sparking occurs. In a vacuum it is violet; in hydrogen, red; in the ordinary atmosphere, white; in a partial vacuum, red; in oxygen, white; and in mercury vapor, green. When the spark is produced, a sound occurs, whose intensity depends upon the magnitude of the cause of the spark. As is well known, in the case of lightning, the noise is very great. Even with slight sparks the noise is quite striking and peculiar when made in nitrogen gas. The sound in all cases is due to vibrations communicated to the air. When the spark occurs, the gas is momentarily intensely heated, causing a rarefaction. On suddenly cooling, condensation of the air occurs, and both taken together produce the sound. In addition, the sound is also thought to be caused by the spark making a hole through the air, *i. e.*, a vacuum; when the spark ceases, the air rushes into the hole, causing a condensation. This hole-formation idea is not at all unreasonable, because a powerful spark will pass through glass or carboard and other insulators placed between two pointed terminals, and a very fine hole is formed, which is so small as to be invisible. Make the hole near the bottom of a glass tube closed at one end. Hold the closed end under water and blow into the tube. Very small bubbles will be seen passing up through the water from the hole.

With any given spark it has the most light-giving power, the greater the intensity of the discharge. When the discharge takes place between sharp points, the spark has the appearance of a brush; when between ball-shaped terminals, the spark is linear, and often zig-zag, as in lightning, the earth and the clouds being the balls.

A line of sparks may be formed by letting the discharge take place through successive conductors all but touching each other. Thus, let the pieces be in a straight, curved or zig-zag line, and at about .01 inch apart. Let the first and last pieces be connected to the pieces of tin-foil upon the condenser. At the ends of each piece a spark is visible, so that the effect is that of a line of light. In this manner pictures of light may be made.

The spark is accompanied by heat, as illustrated by producing a spark upon a gas burner. The gas becomes lighted. Ether may also be lighted, and alcohol, if first warmed.

Let the discharge be made through a very fine platinum wire. The wire is slightly heated. If the spark first passes through cardboard, the heating of the wire is less.

Egg shells become faintly luminous in the dark by first passing sparks through them. So do also fruits, sugar, fluor-spar, and heavy spar.

Gold-leaf may be turned into vapor by pressing the same between two glass plates and sending a charge through the gold-leaf. The particles of the gold condense into a violet-colored powder, visible through the glass.

Magnetize and demagnetize iron rapidly, it becomes heated; or repeatedly hammer a metal, it becomes heated; or rub a substance, it becomes heated. Also charge and discharge a condenser rapidly, the glass becomes heated. In all, the molecules are certainly set into vibration.

Independently of any heating of the air or perforation, enclosed air is expanded by sparks. If the terminals are balls, the expansion is only instantaneous; if pointed, the air only slowly expands.

The oxygen and nitrogen of the air may be caused to unite in small quantities by repeated sparks in a vessel of moist air. Blue litmus paper is turned red after the sparks have been passed, and the density is slightly diminished. The sparks will ignite a mixture of oxygen and hydrogen with the formation of water vapor. Coal gas and oxygen are also set on fire by the spark. This spark of frictional or static electricity will also decompose substances as water, ammonic hydrate (ammonia), hydric sulphide, and solutions of oxides and metallic salts; but the chemical actions of galvanic electricity (from the dynamo or galvanic battery) are much greater than those of static electricity.

The duration of an electric spark in air is .004 second; in water, .018 second.

The velocity of electricity is not accurately known, but it is about the same as that of light. The velocity depends upon the nature of the conductor and also the medium around the conductor. With an insulated wire in water the velocity is less than with such a wire in air. The velocity is independent of the electromotive force or diameter of the wire.

Carbon cannot be electroplated successfully upon itself or another substance, but an equivalent result is obtained by decomposition of a hydrocarbon at a high temperature, the carbon forming a hard coating upon the incandescent surface.

The thickness of the deposit varies in any given period with the temperature of the receiving substance.

In any given electric circuit of sufficient energy heat may be obtained by sufficiently reducing the cross-section of the conductor, or by breaking the circuit and maintaining an arc between the two parts; or if the current is alternating, pulsatory or intermittent, by placing a second conductor closed upon itself (like a ring) as close as possible (without touching) to the circuit named.

Amber attracts only when rubbed, but a lodestone always attracts.

What is true of amber is true of all substances, which, if metallic, must be supported by good insulation.

Substances attracted by the magnet are iron and steel greatly, and nickel, cobalt, chromium, manganese, bismuth, antimony and zinc very slightly.

Steel retains its magnetism almost perfectly when removed from the magnet, and becomes a second magnet, while the remaining substances (nickel, &c.) retain a mere trace of residual magnetism.

The laws of magnetic attraction are the same as those of gravitation. The force varies inversely as the square of the distance. Example: At twice the distance the force is only $\frac{1}{4}$ as great.

A lodestone is always a magnet, but an electromagnet becomes non-magnetic upon interrupting the current which flows in the coils of the magnet.

If the coils surround an iron core, the total magnetism is no greater than without iron; but the force is directed in the same direction as that of the pole-pieces formed upon the core.

The force of gravitation exists not only between the earth and all substances, but between and among any and all bodies, and is always in the form of attraction; but magnetism and electrical force may be made to exhibit themselves either as repulsion or attraction.

Of two magnets, the unlike poles thereof attract—the like repel each other.

Between two pieces of rubbed substances, as amber, if the rubbing is done with the same material, repulsion occurs.

Pieces of different materials rubbed together, while properly insulated from the hands or earth, attract one another with a force sufficient to overcome that of gravitation.

The amount of repelling or attracting force is greatest in a dry atmosphere or vacuum and increases with the force of rubbing and with the efficiency of the insulation employed, but is limited according to the nature of the material and the amount of surface.

The force of magnetism may be steered in any dirction by motion of the whole magnet or of the pole-pieces only.

In electric currents of low potential, such as those generated by a dynamo or galvanic battery, the amount of energy carried by a conductor is greater, the greater the cross-sectional area, while with frictional electricity, or that produced by rubbing, the larger the exterior surface of the conductor, the better the electricity is conducted.

The electrical conductivity of a metal decreases with rise of temperature and that of carbon increases.

Every metal has a different degree of conductivity at the same temperature, among the best being silver, copper, gold and zinc, and among the worst being platinum and German silver.

An electric current may be set into vibration by alternately increasing and diminishing the resistance at one or more points; by similarly varying the electromotive force or pressure of the current; by varying the self-induction or "inductance;" by varying the induction between two or more conductors; by varying the temperature of a conductor in the current; by alternating the current; by alternately interrupting and closing the circuit; by varying the electric generation of the current; by varying the length or cross-section of a conductor (which may be solid or fluid) included in the circuit; by varying the pressure upon carbons or similar semi-conductors in loose contact and in the electric circuit; by alternately cutting in and cutting out resistances from the circuit; by varying the degree of perfection of contact between two or more terminals of an electric circuit; by the rising and falling of a liquid conductor surrounding a solid conductor partly immersed in the liquid, both the solid conductor and liquid conductor being in the electric circuit; by sliding backward and forward two electric terminals while in contact; by alternately heating and cooling a conductor whether liquid or solid; by alternately depositing and removing a conducting coating; by varying the action of light upon the conductor, provided the same is made of selenium, which becomes a fairly good conductor in the light and loses this property immediately in the dark; or by the action of light or heat upon those substances which will undergo a chemical change when exposed to light or heat; by varying the distance between an electromagnet in the circuit, and a piece of iron, steel or nickel, or another electromagnet in the same or different circuit; by varying the distance between a permanent magnet wound with a coil closed upon itself and a second piece of steel or iron or nickel; by varying the distance beween two parallel conductors carrying currents from the same or different generators; by alternately increasing and decreasing the length of a coil of wire; by varying the length of a spark between two electrodes or electric terminals; by variation of chemical action; by varying the amount of surface acted upon by a liquid or electrolyte in a galvanic battery; by varying the chemical nature of the electrolyte or electrodes; by heating and cooling the liquid or electrodes; by varying the distance between the electrodes; by agitating the liquid; by varying the opposing action of a second battery in the same current; by the action of a varying quantity or intensity of heat upon a conductor forming a part of the circuit; by the variations of temperature upon a thermopile; by the variation of pressure of an atmosphere upon a thermopile; and by alternately heating and cooling the mineral kaoline, while included in an electric circuit (this mineral having the property of conducting electricity when heated and losing its conductivity when cooled).

A pivoted polarized armature (*i. e.*, a permanent steel magnet) having one pole located between the opposite poles of an electromagnet included in a circuit carrying an alternating electric current, is set into vibration in unison with the alternations.

An alternating electric current may be converted into mechanical motion not only as above, but a magnet in circuit therewith will repel a mass of metal, which should for best effects be in the form of a ring, or it may be an ordinary solenoid having its terminals electrically connected. The coil, for maximum power, should be of large wire.

An alternating, intermittent or undulatory current may be communicated from one circuit to another circuit or coil by placing the two close to each other without touching. The secondary current is the induced current, and the primary is the inducing current. The amount of energy represented in the secondary circuit is dependent upon the length of wire exposed to the influence of the primary and upon the cross-sectional area of the wire of the secondary. The secondary will induce a tertiary current in a third wire, and so on indefinitely.

By having a very long, fine primary wire, in the form of a coil, and a large but short secondary wound upon or within the first coil, the induced current will be of low pressure and great quantity. An opposite effect may be obtained by opposite conditions.

The motion of one coil carrying a continuous or uniform current to or from another closed coil will induce or increase a current in the latter, according to the relative directions of winding.

A great variety of effects in vibrations of current may be obtained in a closed secondary coil by vibrating before it a coil carrying an alternating, intermittent or undulatory current.

Secondary, tertiary, &c., currents have exactly the same properties as the primary

When a circuit is broken a spark is formed at the point of rupture, and its length or light-giving power for any given current is increased, the longer the wire forming the circuit and more yet if the wire is coiled into numerous convolutions, and provided also the diameter is as small as practicable. With a large wire of short length the spark is short, but has the maximum heating but minimum lighting power. These properties of forming sparks of different magnitudes as to light and heat are likewise true in regard to secondary, tertiary, &c., currents.

When the electromotive force or pressure is sufficiently great a spark will occur upon bringing electric terminals toward each other to a distance dependent upon the electromotive force.

A spark may be maintained between two incombustible terminals or electrodes by bringing them together and then separating them and maintaining them at a fixed distance from each other; or a substantially continuous sparking may be obtained by rapidly vibrating the electrodes to and from each other, the spark being formed each time they break the circuit.

The electric spark in air is intensely violet, but if the electrodes are combustible the color is partly changed to a mixture of other colors; when formed beneath the surface of oils, it is green; in turpentine and the sulphide of carbon, it is white; while it is red when formed in alcohol, and in general of a different color for almost every liquid.

The pressure of enclosed air is increased by the transmission through it of an electric spark.

A mixture of oxygen and hydrogen, or of hydrogen and chlorine gases, or of air and coal gas, or of any two or more gases capable of ignition by a flame, is ignited with explosive powers by an electric spark.

Sparks of greatest length and of maximum chemical power are best obtained either by electricity from the frictional electric machine or induction coil or lightning, while sparks of the greatest heat and light power are best obtained from the dynamo or large galvanic batteries.

Iceland spar has the peculiar property that when forcibly and quickly compressed of becoming charged with electricity, as may be shown in the dark by its exhibiting a spark when touched, or by its attracting pith-balls and other light particles, all illustrating the principle that compressure produces static electricity.

Tourmaline while heating or cooling has a charge of electricity, and so do some other substances to a less degree, namely: Axenite, cane sugar, potassic tartrate, Pasteur's salt, topaz, phrenite, scolezite, zinc silicate and boracite.

Sulphur when melted in a glass vessel becomes charged with electricity, as may be proved in the dark by seeing a slight spark between it and a pith-ball loosely in contact therewith. Light will produce static electricity. Thus, place fluor-spar in the sunlight or electric light. Heat electrifies it also.

The first Leyden jar ever made consisted of a corked bottle containing water and a wire passing through the cork into the water. After charging, it could be discharged by holding the bottle in one hand and touching the wire with the other, thereby illustrating the principle that electricity can be stored in a bottle.

Frictional electricity may be converted into magnetism by twisting a fine platinum wire into a coil, inserting a fine steel needle wound with silk thread, and passing a succession of electric sparks through the coil. The needle becomes a weak permanent magnet.

Upon exposing a mixture of chlorine and hydrogen to the light of an arc lamp they combine with the formation of hydrochloric acid. Also the chemical effect of the light from the spark is illustrated by its power to turn chloride of silver black.

The spark produced by statical as well as galvanic electricity produces chemical action, as illustrated by the fact that electrodes when immersed in a conducting compound liquid cause decomposition. In the case of galvanic electricity it is not necessary that the electrodes be so close to each other as to produce a spark.

While it is true that upon rarefaction of enclosed air the luminosity thereof becomes increased, it has been lately shown that with a maximum obtainable vacuum the light becomes extinct, electrodes being supposed to extend into the enclosed air and charged with frictional electricity.

The spark or arc and therefore, also, the resistance of the circuit may be varied by varying the material of the electrodes; the distance between the electrodes; the homogeneity of the structure; the chemical composition of the fluid in which the arc is formed; the motion of the fluid or the temperature of the electrodes.

In any given arc lamp in a primary the positive electrode becomes of a higher temperature than the negative, while if in a secondary current the opposite is true.

The following are the leading types of alternating electric current motors: (*a*) An ordinary direct current series motor will operate with an alternating current. (*b*) An alternating electric current generator acts as a motor when in circuit with a second similar generator driven by mechanical power; but the motor is not self-starting. (*c*) A motor will operate in which provision is made for passing the impulses of opposite direction through different field magnets so as to get continuous north and south poles. (*d*) The combination of an ordinary alternate and direct current motor. (*e*) A motor in which the magnetic poles of either the armature or field magnet are not stationary, but are progressively shifted. (*f*) A motor in which a closed coil is repelled and then opened; another closed coil is repelled and then opened, and so on, whereby an armature is rotated. (*g*) Gutmann's various types of motor. (*h*) A motor in which the coils of the field magnet are closed upon themselves, and in which the armature coils are in circuit with a primary or secondary circuit.

It is important to remember the distinction of causes of repulsion and attraction. Like magnetic poles repel, but currents of like direction attract each other. Unlike magnetic poles attract, but currents of unlike direction repel. Again, in the case usually met in static electricity, like charges repel each other, while unlike charges attract; thus, two pith-balls both charged with either positive or negative repel each other, but when one is charged with positive and the other with negative electricity they attract each other. Upon the principle of currents being attracted or repelled, liquids may be set into motion by so arranging them to be the carrier of one or both of the currents. The liquids may be caused to circulate. Of course, the liquid should be an electric conductor.

If a copper disc is rotated, a magnetic needle, even at a comparatively great distance from the disc, is rotated. If a copper disc is strongly rotated between the poles of a powerful magnet it becomes hot. The plane of the disc should be parallel to the axes of the pole-pieces, which should be quite close together.

An alternating current is transformed into a substantially continuous current in a shunt to an arc formed between the terminals of a secondary coil, the respective terminals being a sharp point and a ball. The electromotive force should be sufficient to form a spark discharge. The arc is accompanied by a singing note or sound. An ordinary Ruhmkorff coil and platinum terminals may be employed.

Magnetization of iron may be produced by successive discharges of a Leyden jar battery. The best form for a temporary magnet is that of glass tube filled with iron filings.

An increase of temperature or "heat" decreases the magnetism—whether in iron or steel.

A line of light is seen to pass from one pole to the other located in a vacuum. A magnet applied to the side of the vacuum chamber attracts the line of light the same as if it were an iron wire. On reversing the current through the magnet (*i. e.*, applying the opposite magnetic pole) the line of light is repelled.

The continuous line of light between the poles may be intermitted or stratified by increasing the so-called vacuum.

Electricity may be converted into light and heat by the use of a condenser made by placing mica between sheets of tin-foil, ozone being formed during the heating and formation of a luminous layer between the foil and mica.

The spark between the terminals of a secondary coil of very low resistance (the primary being of high resistance, and both being of a good conductor, carries so much heat that when the spark is infinitesimally small, *i. e.*, when the terminals are in bad contact, the same soon become fused together, forming as strong a joint as by ordinary welding.

The impulses of one direction in an electric current may be sifted from those of the other direction, and at the same time doubled, by passing the said alternating current through a battery or dynamo of the same electromotive force as that of the alternating generator.

An alternating current is converted into a direct current by a pole-changer, acting synchronously with the alternations.

A globule of mercury changes its length during the passage of an electric current.

A varying impulse of current may be retarded by transmission over a circuit of many miles—the longer, the greater the retardation.

It is against the principles of mechanics for an intermittent current to transmit articulate speech, but such a current can transmit musical sounds.

The rapid breaking and closing of a current produce an intermittent current.

The regular and rapid varying of a current from approximately zero to maximum produces a pulsatory current.

The current which varies in exact proportion to any force which is the cause of variation is an undulalory current.

A very peculiar manner of generating a vibratory current consists in vibrating a wire made of different metals. Such a vibrating wire acts as an electric generator of minute currents. When the vibrations stop, the current stops.

Reeds of different lengths produce different musical notes when struck; and each reed will give but one note. Therefore, if of iron, and vibrated in front of an electromagnet, a musical telephone transmitter is obtained, and will operate a receiver constructed in the same manner.

Instead of acting by variation of magnetism, as above, the current may be intermitted by the vibrating reeds in so far as the transmitter is concerned. In both cases, the vibration of any particular reed in the receiver will result in the vibration of the reed of the same length in the receiver; but no other reed of the latter will vibrate.

Among the semi-conductors which convert sound into electric vibrations when employed as loose contacts in an electric circuit, as in the carbon telephone transmitter, are: Platinum black; paper, whose pores are filled with metallic particles; metallic sulphides; cork coverd with plumbago; cupric iodide; charcoal containing in its pores platinic perchloride; amorphous phosphorus; paper moistened with a conducting liquid; manganic oxide and plumbic hyperoxide; white silver powder; shot in a glass tube; carbon saturated with mercury.

The best substance over any of the above is lamp-black mixed with some adhesive substance, such as syrup, and pressed into buttons under enormous pressure and carbonized.

A glass tube filled with a mixture of finely divided tin and zinc (white silver powder) and corked at the ends with carbon terminals, sealed with wax, and included in an electric circuit, is a sensitive rheostat for minute currents. When pulled or compressed a galvanometer or telephone receiver will indicate the fluctuation of current produced.

Paper moistened with a mixture of potassic iodide with a small amount of starch paste, or if moistened with potassic ferricyanide, is sensitive to an electric current. If touched with electric terminals upon opposite sides of the paper, the same becomes colored blue at the point touched. By moistening the same with cupric sulphate the result is a blackening of the paper at the point touched. The substances thus sensitive are those which are electrolytically decomposable into new compounds or elements which have a different color from the original.

A diaphragm, pressing upon parallel carbonized silk or linen threads, is thrown into vibration by a vibratory current. The parallel currents in the filaments variably attract or repel one another.

Of two pieces of selenium included in an electric circuit, that one which is annealed is the more sensitive to light for the purpose of increasing its electrical conductivity by the action of light.

Sparking may be partially eliminated by providing an electric condenser or choking magnet of high self-induction in a shunt around the terminals at which the sparking tends to occur. A choking magnet is a long coil of fine wire upon an iron core. The magnet may have a closed secondary coil wound upon it.

Variation of a beam of heat upon a thermopile does not produce immediate and proportional variation of current on account of sluggishness of heat; but variation of a beam of light upon selenium in an electric circuit produces immediate and proportional variation of current.

A musical note, or at least a humming, is produced at the arc of an alternating current lamp; being produced by the rapid extinction and re-establishment of the current, the effect being similar to that of "singing flames."

A peculiar manner in which a vibratory current may vibrate a diaphragm is that in which the latter has a metallic projection resting upon a moving surface moistened with a conducting solution, as chalk, containing caustic potash mixed with mercuric acetate in the pores of the chalk. Or hydrogen disodic phosphate may be used. The moistened surface forms the remaining terminal. Variations of current produce variations of friction, and variations of friction produce variations of motion of the diaphragm.

When the plates of an electric condenser are vibrated to and from each other, the electric charge thereon is varied in intensity.

Let one circuit contain a generator, a carbon transmitter and two coils. Let another circuit contain a telephone receiver and two coils of the same electrical dimensions as the first two and placed respectively opposite them. Sounds at the transmitter are not heard in the receiver. Place a metal between two of the coils; the sound will be heard. The two coils in either circuit should be wound in opposite directions.

The closing of a circuit induces a momentary extra current. The opening of a circuit induces a momentary extra opposition current; both being the greater, the greater the length of wire, and especially if the wire is coiled.

The amount and duration of the extra currents vary with different metals, different molecular structure, and the form of cross-section. With iron the duration is greatest, and increases with the diameter of the wire. With carbon the duration is practically zero The duration is not varied by changing the electromotive force.

If the wire is bent back upon itself, so that the outgoing and return wires are as close together as possible without touching, the extra currents are nearly cancelled.

With any given conductor of considerable length, that in any given portion of cross-section reacts upon that in the remaining portion, illustrating that the current may be considered as constructed of an infinite number of parallel elementary currents.

Self-induction and extra currents are reduced about 80 per cent. in iron, and 35 per cent. in copper, by employing thin, flat ribbon instead of circular wire.

The extra currents in a steel wire are greater and of much greater duration than in a flat tape, where the duration is scarcely perceptible,

Copper-plated iron wire has less self-induction than the iron wire itself.

In two parallel iron and copper wires joined at the ends the extra currents in the copper wire are reduced over 60 per cent.

An iron telegraph wire having a circular section with rapid currents, has more than three times the virtual resistance during its actual work than that supposed to be its true resistance.

The self-induction of iron diminishes by heating the iron or by putting it under strain, or both. A moderate longitudinal strain decreases its self-induction capacity about 40 per cent. Pass a constant current and heat an iron wire to red heat, allowing it to cool with the current on, or in place of heat magnetize the wire, or in place of magnetism give the wire mechanical vibrations; the result of either step is a strong internal circular magnetism, so that a wire thus treated has no longer its former amount of self-induction, which has fallen 60 per cent.

A bar of steel having north and south magnetic-poles may be magnetized so that there will be a weak north pole at the south pole and a weak south pole at the north pole. This is called superimposed magnetization.

The number of alternations per second of an electric current so far obtained is claimed to be 30,000.

A horizontally pivoted steel magnet or needle swings in a horizontal plane until it points north; and a vertically pivoted magnetic needle dips and points north, the earth itself being a magnet.

A bar of iron becomes magnetic when pointed north, but not when pointed east or vertically; the magnetism being, however, very slight.

The north pole of a magnet continually tends to attract its south pole. The center of the magnet neither attracts nor repels, being similar in this respect to the center of the earth.

Some mineral compounds of iron are magnetic and some not. Iron pyrites is non-magnetic, while black oxide of iron is attracted to a magnet. In both cases the iron is chemically combined with a non-metal, and yet they possess opposite properties; again, although a magnet attracts a magnetic substance or another magnet, magnetic substances will not attract each other.

A compass needle points at a slightly different angle from year to year; and it has very slight daily variations. It is influenced to one or two degrees by the *aurora borealis.* In the polar regions this action is greatest, and occurs also before the appearance of the light.

The needle generally points away from the true geographical pole to what is called the magnetic-pole. It would be found to point toward the geographical pole if carried on the following tour: Commence at Philadelphia, go north to Hudson's Bay; then go along the eastern coast of the White Sea and across the Caspian; then along the eastern shore of Arabia, through Australia, to the South Pole; along the eastern part of South America; returning to Philadelphia.

All compass needles are acted upon by the earth's magnetism; but by attaching two parallel needles at opposite ends of a stick in such a manner that they point in exactly opposite directions, the action of the earth is neutralized. The action of the earth may be neutralized also by a large permanent magnet at such a distance from the needle as to exactly counteract the earth's magnetism. In either of the above cases the compass will be acted upon by other magnets and currents the same as if no earth's magnetism existed. Disturbances in the sun produce fluctuations of the needle. The greatest variation ever known was noticed a few hours after a large luminous mass was seen to pass over a sun's spot. A picture of the magnetic lines of force of a magnet may be made by sprinkling fine iron filings on a card held upon the poles of a horseshoe magnet. The lines are all curved except those in line with both pole centers. Each filing becomes a minute magnet. The curves are closest together at the poles, spreading as they radiate therefrom. The picture is made permanent by first waxing the paper and melting the wax after the lines are formed. While forming, the paper should be slightly shaken to assist in neutralizing the friction. A compass needle at any position lies parallel to the lines of force represented by the filings. The lines of force are similar to the rays of light, in that the more lines cut by a surface the greater their intensity upon that surface, while an important distinction is that the magnetic lines act only upon iron and slightly on only a few other substances. A bar of soft iron which has become a feeble magnet by holding it north and south (and dipped properly) becomes more and more non-magnetic the more it is pointed east and west. Its magnetism thus obtained may be made permanent by twisting or hammering. Steel is permanently magnetized by peculiar movements upon a second magnet, either steel or electromagnetic. The magnetism is much stronger and more permanent if heated to 212° F., then again magnetized, and then heated as before, and so on for six times. The manner of magnetizing is to move one pole of the magnetizing magnet back and forth over the steel bar to be magnetized. A better way is to move different poles of two strong magnets repeatedly each from the center to the opposite ends of the steel bar which is to be magnetized. If this steel bar joins the opposite poles of a third and fourth permanent magnet, the said bar will be much more strongly magnetized. The higher the temper of steel, the more difficult it is to be magnetized, but the more durable is its magnetism. This rule is true only for steel containing equal amounts of carbon. For pieces having variable amounts, the greatest magnetic permanency is obtained at different degrees of temper. It is a peculiar phenomenon that perfectly pure iron obtained by electroplating has the property of becoming slightly permanently magnetized, showing that this property is not absolutely due to the carbon in steel; especially does it not appear to be due to the carbon when it is remembered that cast iron contains more carbon than steel and yet is practically non-susceptible to being permanently magnetized. Incandescent and even red-hot iron are not attracted by a magnet; and a permanent steel magnet loses its magnetism at bright red and is not attracted by a magnet. A steel magnet which has been heated is weaker when cooled than before. When cooled from red heat, its magnetic force is substantially zero. If, at the same time a bar of steel is being magnetized, it is hammered or twisted, it will acquire a higher degree of magnetism. The falling of a steel magnet after magnetization weakens it. In short, twisting or hammering *after* magnetization weakens the magnet. Twisting repeatedly in the same direction does not repeat the weakening, but subsequent twisting in an opposite direction diminishes the magnetic force. Magnetization of iron wires diminishes the twisting power thereof. Pass sewing needles through very small corks and float them on water. Bring a magnet near the same. The corks arrange themselves in geometrical figures, whose shape depends upon the number of corks. A slight motion of the water will often cause the corks to rearrange themselves in differently relative positions. Finally, a figure will be obtained which will be staple.

Generally it may be said that magnets act only upon iron, nickel considerably, and two or three other metals very slightly; but there are exceptions, or rather magnets act upon nearly all substances, but in a different manner. A gas may be repelled by a magnet; thus let a candle-flame be used as it is visible gas; place the candle so that its flame is between the poles of a powerful magnet. The flame is repelled. Other illustrations in the case of gas are as follows: Place a small piece of iodine on a plate between the poles and apply heat. The colored vapor is seen to be deflected by the magnet as if by a breeze. The gas which is acted upon most powerfully is oxygen gas, but being colorless, the fact is difficult of exhibition. One of the best ways is to make soap bubbles with any given gas and place the bubbles near the poles. Liquids are also acted upon. Fill closed tubes, each with a different liquid, and suspend in a horizontal position by a silk thread. The tubes will assume a fixed position. With ether, alcohol, milk, water or blood the tube will stand at right angles to the axes of the pole-pieces; if of solutions of the compounds of iron or cobalt, the tubes will stand parallel to said axes. As to solids, a piece of copper suspended by a silk thread between the poles and rotated is stopped almost instantly by the magnetism. Other substances acted upon, especially if in the form of rods or bars, are bread, sugar, sulphur, alum, iodine, phosphorus, glass and rock crystal. It is thought that all substances are either repelled or attracted by magnets, provided the same are sufficiently powerful.

A most remarkable phenomenon is that accompanying a spark formed between the poles of a powerful magnet. Let the terminals of the circuit of the magnet touch at a point between the two poles. A sound like that of a pistol is produced. When a fine wire of tin, zinc, bismuth or iron under tension conducts an intermittent current, the wire produces a sound at each break of the circuit.

Magnets are generally rigid and the poles at fixed distances from each other. If the magnet is straight, the poles are at a maximum distance and have the maximum power. When the distance is zero, the magnetism is not zero, but is at its minimum; as is illustrated by connecting the poles of a horseshoe magnet by a piece of soft iron. Other pieces will still be attracted, but not with such force as when the poles are not connected by iron. If connected by other metal, except nickel, the magnetism is not appreciably diminished. If the magnet is flexible, torsional, compressible or extensible, and the poles are within the proper distance, they will move one way or another, the movement being due to an attractive force between the poles. A magnet for any given strength must be wound accordingly. If for a current having a high electromotive force, the coil should be made of a long, fine wire; if the current is one of low pressure, the wire should be of large diameter and comparatively short. When sugar is added to water it dissolves; but soon the degree of saturation is reached at which no more sugar will dissolve. So also with a magnet. Begin with a small current and increase it. The magnet becomes stronger and stronger, but soon becomes no stronger, although the current continues to increase. A magnetic force is the most steady for any given fluctuating current, when the convolutions of wire are more and more numerous from the ends toward the center. There are different ways in which water may be made to dissolve a solid above its normal degree of saturation; for example, the water may be heated. In the case of a magnet more effective magnetism per unit of current is obtained if the iron core is made of insulated iron plates or wires. Again, the magnet will reach its point of saturation quicker with a solid than with a porous iron core. Below the point of saturation the magnetism varies with the current in the most economical proportion if the core is from three to four times the diameter. Since the breaking of a current causes a sound in the iron of a magnet (the iron being suitably suspended and resting against a sounding-board and the iron being alternately expanded and contracted), it is natural to infer that if iron is alternately expanded and contracted (*e. g.*, by heat and cold) by any suitable means, it will become magnetic. Such is the case, but the magnetism is very slight. When a stone is lifted from the ground mechanical energy is stored; because the stone in falling can perform the same work (as in driving a clock) as was required to lift it. So also is it the case with a small piece of iron pulled away from a magnet. It requires a force to pull it away. Work is done. Of two pieces of iron and steel of the same weight, the one is more attracted than the other by a given magnet. The shorter a magnet, the more quickly it is magnetized when the circuit is closed, and the more quickly it is demagnetized when the circuit is interrupted. Let a magnet be a long magnet. A piece of iron is attracted with greater force in the direction of the major than of the minor axis. A piece of iron which has never been magnetized is more sensitive than one of the same weight and size which has been magnetized; but its original condition may be obtained by reversing the current. An armature may be removed from a magnet by external force; but also by heating the magnet or armature or both. There is no difference in the natures of a permanent magnet and electromagnet; but there are certain characteristic differences. The former cannot be demagnetized and magnetized simply by respectively closing and opening an electric circuit, or varied in strength simply by varying the strength of the current. If a piece of steel is employed as the core of a magnet, the magnetism cannot be varied from zero to maximum, as can be approximately done with soft iron as a core. The friction of iron sliding upon iron may be varied by variation of a current, carried by a wire wound upon the iron.

By varying the length of a magnet its magnetism is varied. If two magnets are in branch circuits, an increase of resistance in either branch will increase the magnetism of the magnet in the other branch. It is like two rivers branching away from each other and meeting again. Dam or partially dam up one branch and more water will flow through the other branch. Magnetism is diminished and almost extinguished by joining the ends of the coil by a wire of large size. The degree of saturation of a piece of steel is increased by adding to it in the process of manufacture about 4 per cent. of the element tungsten. The magnetism is also more permanent. If any given movement of a bar of steel before a magnet magnetizes the steel, the reverse movements will almost demagnetize it.

Motion between two magnets may be obtained with an alternating current by placing the magnets in series with each other. When either pole changes its polarity, the other does also, and consequently the force exerted by one magnet upon the other is constant as far as the senses are concerned; but analytically considered, the force is rapidly intermittent.

When an alternating current is passed through an ordinary magnet, especially if having a great many windings, the current is greatly diminished; but not with the same results as obtained when passed through a rheostat or similar resistance. In the latter case the current is lost in the form of heat; but in the former only a very small portion of that which disappears is lost. This is why a magnet so used is called a choking magnet. It serves to stop a part of the current by stopping partially the generation. A choking magnet may be more or less deprived of this property by placing it inside of a ring of metal of considerable mass. The current is then hindered but very slightly. It is found that it is difficult to move the magnet through the ring, and also that if the magnet is fixed, the ring will be repelled from the center of the magnet.

If a copper disc is delicately suspended or balanced horizontally above the end of a vertical magnet, it is repelled by an intermittent current. Currents are induced in the disc which is consequently repelled. An alternating current may be substituted for the intermittent with similar effects. It is found that an induced current in a secondary conductor is a little behind time with respect to an inducing current. Consequently, when any given induced impluse is just about to cease, an inducing impluse is beginning. Consequently, replusion takes place.

The disc and ring are equivalents in that the latter may be considered as composed of concentric rings. If the disc is placed between the magnet and the ring, the latter is not repelled, although it is strongly repelled more and more while the disc is being removed. If the ring is replaced by a coil in circuit with an incandescent lamp, the same is extinguished or lighted according as to whether the disc is or is not between the coil and the magnet.

If the coil and lamp are balanced above the magnet, the primary current may fluctuate between considerable limits and yet the intensity of the light will remain constant.

If two rings are placed over the alternating current magnet, it will be found difficult to slide one ring from the other, and when let go, they will attract each other until they are concentric rings.

If the disc is pivoted at its center eccentrically to the magnet, it will rotate when the ring is held parallel to the disc. It is due to the attractive action between the disc and ring.

The action of repulsion between the magnet and ring or disc is called by different names—hysteresis, magnetic friction and magnetic lag. Whatever the name, the principle is the same, being the motion due to the primary impluses of one direction upon the retarded induced impulses of the opposite direction. When two rings are used as described, they have induced currents both obtained from the magnet, and consequently the induced currents are both alike in the same direction, and consequently attraction takes place.

A copper ball rotates if placed upon the disc which rests horizontally upon the end of the alternating current magnet.

In general, an alternating current magnet acting upon a closed conductor produces repulsive motion, which may by proper mechanism or relative disposition be rotary, reciprocating, &c.

A bar made of two strips of different metals bends when heated by atmospheric changes of temperature or by an electric current or other source of heat. A bar of two strips of the same metal, and having different amounts of radiating surfaces and different resistances, and electrically insulated from each other, does not bend by changes of atmospheric temperature, but does bend by the heat developed during the passage of an electric current, whether continuous, intermittent or alternating.

The space immediately surrounding a wire carrying a continuous and uniform current contains what may be termed static or, better, stored-up energy. A second wire parallel to the first will receive no current during the existence of the continuous uniform current, because the field of force, or the space containing the stored electric energy, corresponds to air held under pressure by an excessive weight. Take the weight away, and the air will expand and produce work. Similarly interrupt the uniform continuous current. This corresponds to removing the weight. Immediately a current is found in the second wire, lasting until the first current has diminished to zero. If the weight is partially lifted, the expanding air will perform work; so also will a current appear in the second wire during the time that a resistance is introduced into the first wire circuit. Similarly, as any decrease or increase of the weight will vary momentarily the amount of work done by the compressed air, so will any variation of the current in the first wire produce a current in the second wire. Again, as long as the current in the first wire is constant, no current will appear in the second wire. In the above cases the second wire is supposed to be closed upon itself like a ring. If it is an open circuit, it will receive a static charge in the place of a current at each variation of the current in the first wire. The effects of the field of force around the first wire depends upon the medium which surrounds it. If iron is used, the currents in the second wire are greater than without it; not that there is any force generated, but less becomes useless by dissipation. The iron surrounding the wire acts as a concentrator of the field of force. The iron should for best effects consist of laminæ insulated from one another and lying in planes perpendicular to the axis of the wire, or else should be an insulated iron wire wound helically about the wires. The presence and effect of the iron about the wires may be compared to substituting the good conductor copper for carbon in an electric circuit. The iron is the best conductor of the magnetic currents forming the field of force around the conductors. These magnetic currents are in concentric circles around the axis of the first conductor. The reason of laminating an iron core may now be apparent. If not laminated, a static charge occurs upon the iron in a longitudinal direction, which is discharged as a current at each variation of primary current. This current in the iron circulates longitudinally from one part of the iron to another. This can be more easily appreciated by considering that the iron which surrounds the wires is a tube slipped over the same, and several feet thick. Or more forcibly by supposing the wires are rings and the iron is a tube whose ends are in contact. The iron would then act not only as a conductor of the currents in the field of force, but also as a secondary conductor. Practice shows this to be so, because such a tubular core becomes very hot on account of the currents which are called Foucault currents. By laminating the core no longitudinal currents can be conducted by the iron to a greater distance than the thickness of each lamina.

A converter for intermittent currents should have an open magnetic core; while for alternating currents the core should be closed upon itself, unless the alternations are unusually slow. It is peculiar, though not difficult to understand, that, while the impulses of an intermittent current are all of one direction, yet the induced impulses of current formed in an adjacent closed secondary conductor are alternating in direction. The analysis of the action is thus: When an impluse of the intermittent current begins it must increase from zero to maximum, thereby inducing a current having a different direction from that which will be produced when the said impulse stops, *i. e.*, decreases from maximum to zero; all depending upon the principle that increasing and decreasing currents induce currents of opposite direction in a secondary conductor.

A current of electricity in a wire has often been compared to a current of water in a tube; but in the one case the water is confined within the tube while in the other the electric current is not only in the wire, but also in the space surrounding the wire. Practically, this space is comparatively slight, being possible of detection for only a few feet with the highest electromotive force currents, but theoretically it extends to an infinite distance.

If a wire carrying a current is wound upon glass, the molecules of the latter undergo a new motion from that due to the ordinary heat vibrations. The new motions are detectible by polarized light.

The greater the rate of vibration, alternation, intermission, undulation or other oscillation of a current in a wire, the larger the proportion of current found upon the surface and in the space surrounding the wire. In electric lighting systems the same are much more efficient if the single conductor is replaced by several small conductors, or by a single tape conductor, so as to obtain more surface per mass.

When a continuous-current circuit is closed or broken, some substance in space surrounding the conductor is set into vibration. These vibrations stop as soon as the current is uniformly continuous, but the assumed unknown substance (thought to be the same which propagates light vibrations) continues to be held in an altered condition from that before the circuit is broken or closed respectively.

A proof of the latter part of the statement above becomes apparent by holding a compass needle over the conductor. It is deflected until it stands at right angles to the wire.

Electricity is generally converted into mechanical motion by a magnet; but this is not the only way. Take a horizontal tube, whose ends are bent upwards. Fill with a conducting liquid like salt water or dilute sulphuric acid. Drop in a globule of mercury. Pass a current through the liquid. The mercury travels from one end of the tube to the other in a direction dependent upon that of the current. It moves with sufficient force to make it travel up hill, and moves with greater and greater force as the current is greater and greater. A liquid may be raised above its natural level by the direct action of the current. Divide a porous jar into two compartments by a porous partition and introduce a decomposable liquid, conveniently, cupric sulphate dissolved in water. Introduce electrodes and pass a current from one liquid to the other. A difference in the heights of the liquids occurs. The converse of the above phenomenon is also true. If a liquid is forced through a diaphragm from an enclosed compartment, a current in the direction of the motion of the liquid is produced, and the electromotive force increases with the pressure. Whenever a liquid in a vessel is stirred, a current is produced. The liquid in the interior of the earth is always in motion and the earth currents may probably be explained on this principle. Molecules are set into motion by the current. This is illustrated by the arc lamp in which particles of carbon are carried from the positive electrode to the negative. A piece of iron gives forth a sound when magnetized by a vibrating current, being due to the mechanical motions, compressions and expansions, which are communicated to the air. A vibratory motion may be communicated to a globule of mercury in substantially the following manner: Take a vessel of dilute sulphuric acid containing a very small proportion of chromic acid, and place therein a globule of mercury. Immerse an iron wire until it just touches the mercury. The globule of mercury will vibrate and will continue to do so indefinitely. The mercury vibrates in a very regular manner. By close observation, the vibrations are seen to consist of elongations and contractions. It is first spherical, and then egg-shaped, and so on.

An English electrical paper contains the following novel article by Dr. Mengarini :

"If a platinum and acidulated water voltameter is traversed by an alternating current, which, by means of an adjustable resistance, can be kept at a constant value whilst the surface of one of the electrodes is gradually diminished, a point is reached at which the current density at the movable electrode becomes so great that large bubbles of gas are evolved which for a moment insulate a portion of the electrode from the liquid. The metallic surface is then capable of igniting the bubbles of gas, producing small explosions and flashes of light in the liquid. With care it is possible to render the electrode incandescent along its whole length, so that it is covered with a sheet of flame from which dart flashes of bluish light with little explosions. At the same time on the first electrode, where the current density has remained constant, appears a copious evolution of gas, without comparison greater than it was at first when the other electrode did not exhibit this phenomenon of recombination. This gas is found to be a mixture very rich in hydrogen. If it is a salt that is being decomposed, a considerable deposit of metal takes place on the second electrode, which is seen by simple inspection, without the necessity of weighing, to be very much greater than that which would have taken place under ordinary conditions. If on the electrode whose surface has been kept constant, the current density is so small that no trace of decomposition appears on it; still, as soon as the first electrode commences to be incandescent, the products of decomposition immediately appear on the second, which, in the case of solid ions, at once becomes covered with a metallic deposit, just as if it formedthe negative electrode of a voltameter traversed by a direct current. A similar result occurs if one of the electrodes, without being covered by a sheet of gas from which starts a continuous series of explosions, is surrounded by liquid in a state of strong ebullition, so that, without any luminous phenomena, the electrode gives out a feeble sound, resembling the hum of a gnat. In order to carry out this experiment, it is sufficient to enclose the electrode in a porous cell immersed in the liquid. After starting the current, as soon as the density reaches a suitable value, the liquid enters into ebullition. If a third electrode of platinum is placed in the voltameter containing the two electrodes when the above experiments are being made and a wire carried from it to one terminal of a galvanometer, the other terminal of which can be connected by means of a key to either of the two original electrodes, it is found, on suddenly breaking the alternating circuit, that, whilst the electrode that became incandescent is either not polarized at all, or only very feebly so, that with the larger surface shows strong polarization, the direction of the current being the same as that from the copper pole of a volta couple. On inserting other voltameters containing sulphate of copper, nitrate of silver, etc., in series with the first and placing therein electrodes of such an area that decomposition does not occur when the alternating current passes through them, as soon as the above phenomenon takes place, the current remaining constant, an active electrolytic decomposition commences with deposition of copper, silver, etc., in each of the other voltameters."

Hurmuzescu states in the *Electrical Review* (London) the following:

"A fine wire stretched between two supports, one of which is provided with a strainer or spring, for regulating the tension, on being traversed by a large continuous current begins to vibrate. . . . . The explanation of this fact seems to me to lie in the interchange of heat between the wire and the surrounding atmosphere; this constitutes really a thermic motor, in which the energy expended is supplied by the current."

CHAPTER XIV.

"I've Got an Idea."

This is the exclamation which usually heralds the embryo of an invention. It has been uttered so often as to become a familiar expression. As soon as such an announcement is made the inventor knows that it is only a matter of intelligence, knowledge, work and practice to develop the idea into a clear conception, and the conception into a complete invention. When he arrives at the stage of being able to say: "I've got an idea," he has, substantially, the invention. He has obtained that which he has sought. He seems enthusiastic. He makes sketches mentally and on paper of a device which will carry out his idea. He obtains all the knowledge he possibly can which will assist him in developing the invention. He realizes the importance of practice in development and of knowing how earlier inventors made the quickest progress in development. He feels that the import of the conception is so great that he cannot know too much of that which he feels every inventor is supposed to know. He is like a man who starts a new business with which he is not acquainted; each day shows him his ignorance of what he ought to have known. He realizes the importance of preliminary preparation.

What great benefits and wealth have resulted from such ideas! How many luxuries and conveniences have grown therefrom! Such ideas have singly been the foundation of a fortune. What physical objects of property have outweighed in value mental acts called an idea? Therefore, is it not important to investigate the causes of ideas, learn if an idea is simple or compound, and if compound, to discover its element by a process of analysis? If this can be done, how important it will be to a would-be inventor? If an idea is something which is obtainable by money, work, knowledge, or any other form of acquirable property, the inventor may be assumed to be anxious to know the fact. The popular mind apparently seems to look upon an idea as something which has been bestowed upon a person by some power independent of any action on his part further than the passive action of reception of an idea. The very expression forming the title of this chapter contradicts such a notion. The inventor says: "I've got an idea," or "Eureka," meaning "I've found it." To *get* a thing implies action. To *find* a thing implies action. Again, it will probably be found by investigation that an idea is not a myth, but it is something. Chemical compounds are made by putting two or more elements together. If ideas are compound, much light will be obtained and much assistance arrived at if the compound idea can be analyzed. The problem before us is evidently a great one; it is of so much importance that an attempt to solve it cannot be spent in vain, even if only one ray of light is caused to enlighten the beginning of the road leading to its solution.

The problem is resolved into parts represented by the following questions: Is an idea single or compound? If compound, what are its elements? How can an idea be obtained? What other useful data can be obtained by investigation? The answers are most probably found hidden in examples of the past. The astronomer can predict eclipses because he studies the causes of former eclipses. The geologist can give information of the existence of certain substances under the surface of any given portion of the earth without seeing those substances, because he knows general principles and laws pertaining to the fixed relations of the visible to the invisible constituents of the earth at other portions of its surface. Similarly, it may become possible to learn how to get an idea as a basis of an important invention, if past ideas be carefully studied, and, if compound, analyzed. The invention of printing is taken first as a basis for study.

Coster was the first to conceive the idea of replacing handwriting by printing. He had often thought what a blessing it would be to the people at large to be able to own books, which at that time were very expensive because multiplication was done by hand. Only rich people owned them. When he became old, he was in the habit of strolling into the woods, and upon one occasion found the initials of his fiancée, which he had carved upon the bark of a tree when a young man. This led him to cut off bark and cut it into letters, which he naturally took home, and finding that his grandchildren liked to play with them, he carved many letters and used the same as means for teaching the children to read. On one occasion he brought home the letters wrapped up snugly in a piece of parchment. Some of them remained stuck to the parchment, and after removal by one of the children, imprints were left upon the surface and attracted the attention of one of the boys, who showed them to his grandfather. The latter was struck with the incident as a wonderful phenomenon, and studied into the cause in a severely critical and analytical manner. He found that the pressure upon the letters had squeezed out some of the colored sap, which stuck to the parchment at all points of contact of the same with the letters. Was this an invention ? No. He no more had an invention than the boy who first saw the prints. He had already done more than the boy. The latter saw the prints, enjoyed the phenomenon. Coster did more. He sought the cause. When he knew the cause, he learned something he never knew before. He learned a fact that a bark letter containing moist sap pressed upon a surface of parchment paper left an imprint. This was knowledge, not an invention. He had been for a long time trying to solve the problem of multiplication of letters and words upon parchment. His idea consisted in putting this and that together. His idea was compound. It consisted of two elementary constituents, by whatever name the constituents may be called. The two constituents were two facts, namely: (*a*) A moist letter leaves an imprint upon parchment as often as it is pressed thereon. (*b*) Duplicating books by hand is a very slow and expensive process. He put these two facts together and was able to say: I've got an idea. He might have continued to leave either fact by itself for the rest of his life without making an invention. He had as a very prominent part of his knowledge the fact that books were made by a very slow and expensive process, and had been seeking for that knowledge by which he could remove the difficulty. When he obtained the other fact or element, it is easier to comprehend the naturalness of his putting the two facts together than of leaving them alone and separated. This principle of the action of the mind is illustrated by other examples If a person is intensely striving to solve a given problem, it is natural for him to apply knowledge almost as soon as it becomes a part of his education. I admit that it is useless to try to explain the nature of the power which prompted him to put the two facts together; just as it is impossible at present for physicists to explain the inherent nature of that wonderful force which at a distance of millions of miles holds the planets and stars in their places; or that force by which hydrogen and oxygen unite and form water, which differs in every respect from the hydrogen and oxygen when simply mixed; or that force which holds a pith-ball to a piece of amber which has been rubbed; or that force which lights up the world day after day for years and years. Although the nature of these forces cannot be understood, yet they are just as useful to mankind. The inventor and engineer make as much use of them, probably, as if they knew their true nature. The forces are employed in the same manner that a carpenter employs his tools. He does not know necessarily how they were made or of what chemical elements they consist; but he makes the same use, and no more or less use, of the tools because of this lack of knowledge as to their inherent nature. So, also, the nature of the power which prompted Coster to combine the two facts is not known; but experience and examples indicate that this power exists and acts whenever a person becomes acquainted with such elementary facts. The duty of the future inventor is to be awake to problems needing solution and to push forward to the attainment of all the knowledge he can reach; and he may continually feel that the power to combine exists and that it will operate as soon as those particular facts are clearly comprehended, which are such as to form, when combined, an idea.

One or all of the facts may come by accident, or by effort, or by a combination of circumstances. In the particular case under consideration the fact of the imprints by pressure came accidentally. The fact came by experimenting in the case of Humphrey Davy's conception of the safety lamp, by which he became titled "Sir," and received in the first few months of its use $12,000 collected for him by the miners of the country, who thus expressed their gratefulness. As in the case of Coster, Davy longed to make an invention whereby the fearful and repeated loss of life by mine explosions would be prevented. He was especially spurred on by a particular explosion in which one hundred men were killed in a single mine within one minute. This made him the more eager to solve the problem. In accordance with the principle already pretty well established by other successful inventors, he becomes thoroughly acquainted with the problem. He studies the causes of the explosion. He looks into the exact chemical and physical actions which take place. This knowledge, to be sure, was free to all; but he becomes acquainted with it, not simply from curiosity or for the mere sake of being well read or highly educated. He sets before himself the knowledge in an analytical and in a systematic manner. He at last arrives at the sum and substance of the whole matter by formulating his knowledge as a fact. The "firedamp," *i. e.*, combustible gas escaping within the mine, mixes with the air entering the mine. When the proportion of firedamp and air arrives at a certain relation the same becomes ignited by the miner's lamp and explodes with great power, burning men, clothes, mules and all else combustible. This was one fact which, coupled with another, should, according to the lessons learned from Coster, produced the "idea" whereby the mine could be lighted without danger of igniting the mixture. Having exhausted all book knowledge, he being a great student, he experimented with the flame of a miner's lamp and with explosive mixtures. Systematic and logical experimenting based upon previous knowledge of chemical and physical principles developed, among others, two facts, namely: (*a*) When two compartments are connected by an open metal tube, and filled with explosive mixtures, the one may be lighted and exploded; but the flame will not pass through the tube and set fire to the mixture in the other compartment. (*b*) The flame of an oil lamp will not pass through a fine wire gauze.

To know these facts, and to know the fact underlying the cause of the explosion in mines, did not constitute invention as long as no power of the mind acted to combine them. As we may expect, the power did act, he got the idea, and immediately planned a lamp which was a device for carrying out the idea. The device has been modified in different ways, but the idea still remains the same. The mind combined them as soon as the right constitutent facts were presented. With Coster the final wanting fact came by accident. With Davy the final wanting facts came by systematic and logical experiment.

In the following illustrations the wanting fact was obtained by a search of the old scientific principles and facts. Most modern scientific inventions have been thus made, as, for instance, the telephone, kinetograph, incandescent electric lamp, air-brake, telegraph, mechanical telephone, steam, air and gas-engines, artificial ice machine, bleaching, dyeing, thermostat, electric meter, telescope, microscope, photography, &c.

Many ideas forming the foundation of purely kinetic mechanical inventions are compounded in a similar sense. Lee was a fellow or professor at a college. He loved study more than anything else. As time passed, he soon loved a maiden more than his studies; but upon being married, which was against the rules of the college, he was left without employment, so that his wife was obliged to take up her former employment of knitting stockings. After vain attempts in getting employment, and after often watching the process of knitting, he recognized how slowly the knitting was performed, and wondered if it might be possible to make a machine to do the work. One fact he had to start with was the movement of the fingers. He studied the exact motions given to the yarn. He became perfectly familiar with the stitches, so that he soon knew how to knit by hand. This knowledge constituted one fact; but he felt his lack of the knowledge of the remaining fact necessary to give him the complete idea. He did not know anything about machinery, although he felt the importance of such knowledge as indicated by his looking up books on the subject, and especially by his visiting machine-shops and factories and conversing with mechanics. At last the power of combing facts acted, because he had the two which were necessary. Learning that by means of machinery any and all motions could be produced, he conceived the idea of building a stocking frame in which the motion of his fingers would be performed by a mechanical device. As soon as this idea occurred to him the embryo of the knitting machine was created. To know how knitting was done by hand did not exercise the power of inventing. To know that by mechanics any combination of motions could be produced did not exercise the power, but as soon as he knew both the power acted apparently as promptly and surely as that of magnetism when a piece of iron is held near a magnet. The first machine was very crude; but its faulty operation indicated where improvements were needed. Soon Lee was making a large income, and would undoubtedly have continued to increase it except for competitors, there being no patent law at that time. He next set up his machinery in France, where he received a warm welcome from Henry the Fourth, during whose reign Lee and his family lived in luxury from the profits of this business in manufacturing his stocking frame.

CHAPTER XV.

Failure and Success.

If you invent that which proves to have been invented before, do not lose courage; but rather let it be the means of showing you that you are an inventor, and that the more inventions you make, the more likely you will be to obtain novelty, as well as usefulness. This principle is substantiated by the case of Gatling, the inventor of the improved gun. He first invented the propeller wheel, in the form in which it is now used, but in applying for a patent found that Ericcson had forestalled him. The disappointment and mortification of this failure were severe, because he foresaw the importance of the new method of propulsion; but with youth and energy he overcame its depressing effect. During the next few years he made inventions, which became introduced into practice, and finally, invented and patented the gun, which now bears his name.

This is a good principle upon which to act. If anticipated, give in, and concede priority, as you have nothing else you *can* do, unless you can prove priority by proper evidence. Again, do not spend years upon one subject, exclusively of others. Perhaps your problem belongs to the same class, practically, as those of the Philosopher's Stone; Quadrature of the Circle; The Fourth Dimension; The Precise Solution of Equations of the Fifth Degree; or Perpetual Motion.

Over a century ago, Hartman became so discouraged, because he could not solve the problem of Perpetual Motion, that he went and hanged himself, and only lately a believer in the same problem committed suicide in the city of my residence, leaving evidence, that his reason for so doing, was his disappointment in life, because he could not produce perpetual motion. I do not intimate that any one of my readers is undertaking impossibilities; but they may be wasting time in a path in which others, for scores of years, have failed. I mention, as an example, thermo-electricity, by contact of different metals. Give it up! but if you wish to work on this subject, in general, try the solution of conversion of heat into electricity, in some other line than by the contact of different metals. Clamond spent thirty-five years on thermo-electricity with scarcely any improvement over his predecessors.

CHAPTER XVI.

Simultaneous Inventions.

The preceding chapter illustrates that Gatling would have been credited, both by honor and money, through his method of boat propulsion, if Ericcson had never been born. The element of time, alone, lost him his right to a patent. The system of duplex, and multiplex telegraphy was invented almost simultaneously, and independently, by four individuals, in different countries. I know of a certain inventor whose six, out of fifty applications, have come into interference with pending applications in the Patent Office. A count of the number of interference cases in the U. S. Patent Office, would amount probably to several hundred per year.

These facts establish the following principles :—

Important inventions are often made by independent inventors, at approximately the same time.

I do not as a rule enter into argument upon the principles I state, as I undertake to establish them upon facts; but this is such a curious principle, that I cannot refrain from theorizing, slightly. As soon as a large, influential, electric company introduces the alternating electric current into commerce, inventors naturally, and simultaneously, turn their attention to electric converters, alternating current meters, and motors, and to various other devices peculiar to an alternating current. When any generic invention is introduced, it is easy to see that inventors undertake, simultaneously, to get a patent upon the best specific way of carrying out the generic invention. Such inventions have profited enormous fortunes.

In view of the last principle, inventors cannot be too careful and quick in having their inventions properly described and attested, even if they do not apply for a patent immediately. The drawings and description of the first mental invention should be signed, witnessed, and executed before a notary public, if possible, on the day of conception.

A study of Camille A. Faure's wonderful, but simple, improvement upon Planté's electrical storage system establishes a valuable principle. The latter experimented several years upon the storage battery, his object being the determination of the best metals to be employed as electrodes. He did not proceed as an inventor. He worked more as an investigator. He tried silver, gold, platinum, and other metals in the same manner that an engineer would test samples of wire, in order to pronounce which is the best. Planté learned that lead was superior to all other metals. To form a battery, he would pass a current through the plates immersed in dilute sulphuric acid, continuing the current for several days. Then the battery would be discharged, by allowing the current to escape through a resistance. The operation would be repeated until a sufficient layer of active material was formed upon the surface of the lead plates. The manufacture of a large battery would occupy about three months, and would consume nearly as much electrical energy as the device would yield during its lifetime. These experiments were made thirty years ago. Only comparatively lately, Camille A. Faure, whose name is now so familiar, considered, analytically, the question of secondary currents, for the purpose of putting the storage system on a commercial basis. He recognized the importance of understanding the exact chemical nature of the secondary battery. He considered carefully just what chemicals existed, when charged, and when discharged. Faure learned that this material consisted of a mixture of the lower oxides of lead, as common red lead and litharge. Consequently, when he found after discharge, that the substances were red lead and litharge, how easy it was for him to go to a paint store and get these materials, and apply them to the lead plates in the course of a few minutes, and at the same time have a thickness of active material, sufficient to store as much electricity as would, by the Planté process, occupy perhaps six months. If Faure had not taken the trouble to find out the exact chemical composition of the materials existing, at different stages, in the Planté battery, it is safe to say that he would not have made the wonderful improvement he did. The converse is also apparently true. He made the invention, principally, because he took the pains and trouble to find out, by ordinary means, the exact composition and chemical reactions in the Planté battery. Before formulating a principle upon this single example, let another case be considered, in order to obtain a second fact for establishing the principle.

The invention considered is that of the first dynamo. Dr. Pacinotti, of Florence, constructed an electric motor, which antedated the dynamo. He studied the motor from the standpoint of an inventor. He analyzed the electrical changes which took place in the motor, in view of improving the same, and then constructed a greatly improved form. To show how well he knew the scientific principles, he suggested in a publication, that if a certain minute change were made in his motor, and, instead of passing a current through the same and obtaining power, he believed that he could apply power, and obtain an electric current. Gramme acted upon this suggestion and thus was born the first dynamo.

Do not trust to accident, nor to inspiration, nor to any mythical spirit or genius to make your invention for you. Do not expect the invention to come to you, without any exertion on your part. For thirty years the electric motor was known, but was not operated by power to obtain a current. For thirty years the red lead and litharge occurred on the lead plates, after discharge. Obtaining, with a view to invention, an accurate knowledge of the scientific nature of the electric motor, and of the early secondary battery, was the factor which suggested the respective inventions.

The rules based upon the above principle may be formulated thus :—

As soon as any one, either by investigation, alone, or with the assistance of a chemist or physicist; or as soon as a scientist, or any individual, announces a scientific fact, or principle not known before; embrace the opportunity of being the first to apply the fact, or principle, to a useful purpose. In reading periodicals, or scientific papers, have this rule of invention in view. Look out for the results of scientific investigation, not as a student, who simply reads as a matter of obtaining knowledge; nor as a critic; nor as a pastime; but for the single, and concentrated purpose of being the pioneer in the application. As soon as Faure made his invention, there were scores of immediate, and independent, inventors, who conceived the improvement of compressing the active material into small cells, or perforations, in the lead plate, for the two-fold advantage of obtaining more metallic surface, and of retaining the active material in its proper place; since, if applied to a flat lead surface, it is apt to fall off gradually but surely.

The question is sometimes asked by the thoughtless, of what use is it to spend a fee to belong to an electrical society; or to be a subscriber to a scientific paper? The man who wishes to be a successful inventor cannot afford to despise such things.

The history of the invention of the carbon transmitter strengthens the above rule of invention. In 1873 Edison discovered the scientific principle that all semi-conductors have the property of varying the current, according to the pressure upon two pieces in loose contact and in an electric circuit. Four years later, when inventing in the subjects of telephones, he recalled the new knowledge, and by introducing semi-conductors into a circuit, and talking against them, he thereby applied the new knowledge to a useful purpose.

CHAPTER XVII.

Simplicity the Result of Specific Invention.

It is a principle that the final type is simpler in construction than the generic invention.

The first telephone transmitter was more cumbersome and costly than the present; while the first envelope-machine was as confusing in appearance as the wisps of hay in a haystack. Many men wonder why they could not have invented the telephone. They should be reminded of two things: they either did not try, or else they think that the first unsuccessful telephones were as simple as the present one.

Nearly every physical invention is at first of low efficiency, complex and intricate in construction, and tending very much to drive the inventor into despair. If he has evidence that he is on the right track, he should not stop for such difficulties, by abandoning the invention and finding afterwards that others commenced where he left off and succeeded. It is far better, as a last resort, to get the assistance of another inventor at the expense of a portion of the interest in the patent, and act thereby in accordance with the old proverb that "two heads are better than one."

CHAPTER XVIII.

The Age of Invention.—A Cause of Invention.

The world has had its age of national wars; its age of geographical discovery, as at the time of Columbus when the whole of the Eastern Continent seemed to give up everything and try to claim America; its age of scientific discovery, right after the time of Bacon, when physical and chemical sciences grew faster than ever before; its age of religious war which seems now to be passing away, and being replaced by a tone of greater toleration; its age of the gold-mining panic; and now its age of invention. Each invention is the embryo of another invention. Electric lighting begets hundreds of detail inventions and improvements, and so with other new arts and industries.

Sometimes, and especially in the early days of the age of invention, several generations were occupied in the perfection of an invention. In one generation the mental invention is made. In the second, the crude generic invention; and in the third, the perfected, specific form. Thus it was with the screw propeller. The steam engine inventor, Watt, wrote to Dr. Small in 1770, "Have you ever considered a spiral oar for that purpose?" (of propelling boats). In 1834, Francis Pettit Smith constructed a boat propelled by a wooden screw, driven by a wound-up spring. Later he built a large boat and exhibited it on a canal, using steam power. A few years later Ericcson constructed, and patented, and introduced the specific form in use at present.

From the time that Harrison began to invent and perfect the chronometer, for use at sea, and obtained his reward of $50-000 from the English Government, forty-five years elapsed. He should have received $100,000, as that was the reward offered. The good King of Sardinia, however, bought four of his chronometers, paying voluntarily $20,000 for them, stating that it was a small recompense for the time spent by him for the general good of mankind. As contrasted with the above almost ancient inventions, it is very striking to note the rapidity with which our present inventors complete the commercial specific invention and reap the fruits of their labors.

CHAPTER XIX.

The Government Favorable to Inventors.

The Government not only protects an invention by a patent, but also by requiring duty paid upon certain articles manufactured in a foreign country. Six years ago I ordered an Ayrton and Perry voltmeter from England and paid $20 duty, which now goes as profit to the American inventor, since the American style has become so popular; consequently the inventor is benefited very directly. The new duty on tin is so high that capitalists have incorporated companies for mining tin in the United States, where its ore occurs abundantly. This opens a new field for the inventor to experiment and produce the best process for the particular kind of ore found in this country. No wonder the people, through the Government, favor the inventor. Two-thirds of the wealth of this country are due to invention. The wonderful invention of the telephone is a self-evident proof of the value of Government protection and encouragement to inventors. Howe made one million dollars from his invention relating to sewing machines. Many of my acquaintances have made fortunes from patented inventions. Smaller inventions also have a remarkable record. The rubber mat, with projections for receiving coins, netted a handsome income to the inventor and large profits to those who promoted its interest; while its convenience to storekeepers was a great benefit to the public.

Certain detail improvements in primary batteries, electric switches, telegraph relays, telephonic apparatus, electric door openers, insulators, dynamos, motors, electric lamps, &c., have handsomely rewarded the inventor through royalties, stock, or cash. Even such small inventions as toys are of much benefit to children, not only in amusing them but in the relief they bring to mothers and guardians; also in the instruction they quietly but forcibly bestow upon children. The ball and elastic, which cost but one-quarter of a cent to manufacture, netted a fortune to the patentee and manufacturer. The lead pencil, with rubber tip, brought $100,000 to the inventor. Copper tips for shoes netted millions, and such an apparently valueless device as the dancing jim-crow paid yearly $75,000. Large fortunes were also made from Pharaoh's serpents; the Wheel of Life; the pencil sharpener; the gimlet screw; powdered emery on cloth; and the rivet and eyelet for clothing.

At the end of the next seventeen years, especially in the electrical industry, larger profits than ever can probably be named as coming to inventors from their inventions, judging from the speed with which so many are even now reaping the benefits of their brain. In view of the vast benefits directly to inventors and also to the people, I advise favoring all bills and laws for the protection of inventions and industries. To be sure the people are taxed. A person pays more, on the average, for a patented article than after the patent expires; but they can afford it on account of the superiority of the patented device; and they should pay extra for the sake of encouragement to inventors. It is argued that inventors invent for the love of inventing; but why do they have the love. Many love their business; but why? Many love to be engaged in writing novels or other books. Many love to be Senators and Presidents. Their love depends upon several elements, but an important one, when honestly stated, is a substantial reward. Acting on this principle, foreign countries and societies have offered rewards to the inventor first solving successfully a given problem. Dr. Vander Weyde has stated, in a conversation on this subject, that France offered $100,000 to him who would make a commercially successful motor. That was at the time when the electric motor was in its infancy. Societies and corporations have made similar offers at various times and in various countries; it is an admirable plan, but the inventor should consider himself fortunate that he is not dependent upon that kind of reward. The experience of all countries has shown that the inventor is most effectually encouraged by rewarding him a patent which he can negotiate as a piece of personal property, at his own terms, in his own name, and at such a time best suited to his interests, all according to the value of the invention which is covered by the patent.

CHAPTER XX.

Invention and Capital.

Inventors continue to invent! Capitalists continue to invest! I am personally acquainted with an individual who, in the early days of the telephone, was offered one-quarter interest in the patent for $1,500. To another party, it is reported, the rights for the whole of New Jersey were offered for a mere nominal sum.

Inventors and capitalists should be more willing to cooperate. It is too often the case that the former must pay for his own experiments and patent costs before a capitalist will even take the trouble to look into the merits of the alleged invention. On the other hand, it is too often true that the capitalist seeks to join with the inventor, but the latter wants too high a price at the beginning.

Referring to the beginning of this paper, you remember I stated the necessity of "confidence in success." This principle applies equally well to capitalists. Let them join with and encourage the inventor. Let them take an interest, by assignment, and pay for expenses in the premises. Brains and knowledge are valuable and necessary and are the primary cause of invention, but the inventor cannot obtain protection and try his invention practically without money. I say to inventors and capitalists join hands, not merely as a trial, but with a determination to succeed. Put up a few hundred dollars on scientific books and electrical, chemical and physical apparatus for some promising inventor. If you wait until he shows the value of his invention, you will find the price for an interest is more than you care to pay. Successful inventors have almost universally had the assistance of capitalists; not after grant of patent and proof of success; not after the inventor acquired fame, but at the time of the embryo of the invention.

Men of capital have more confidence at present in proposed inventions than in the time of Murdock, the inventor of artificial lighting by gas. Sir Humphrey Davy asked Murdock if he expected to use the dome of St. Paul for the gas holder. Sir Walter Scott made many clever jokes about it. Wollaston declared that they might as well try to light London by a slice from the moon as to send the light through the streets in pipes. John Wilkenson prophesied of the proposed ship of iron, "It will be only a nine days' wonder, and afterwards a Columbus's egg."

CHAPTER XXI.

Accidental Inventing Exceptional.

Every invention, before the introduction into practical use, passes through two stages, namely, mental and physical.

An invention is mental when it exists as an imagination or conception in the mind of the inventor.

An invention is physical when the mental invention is put into bodily form by hand, or by hand with the assistance of a convenient tool.

A mental invention sometimes does not become a physical invention. The laws of nature may not permit its operative, physical construction. An example is that of perpetual motion. In the U. S. Patent Office are hundreds of applications for devices claimed to produce motion and force forever when once started. The simplest form of such an invention is a wheel mounted upon a shaft or axle. The same would rotate forever, when once started, if it were not for the retarding forces of friction, resistance of the air, and imperfections more or less due to mechanical construction. I know of a case where a certain business man, who had sufficient brains and education to obtain his wealth, was induced by one possessed of a mental perpetual motion invention to expend two thousand dollars in the construction of the physical invention. The wheel, upon which balls and chains and mercury were to operate, was so large that in one turn it would travel fifty feet. It was proposed to employ this device principally to propel railway trains.

A Canadian noticed that by means of a tackle a man, weighing one hundred and fifty pounds, raised a weight of six hundred pounds, and after he had induced some men to construct an alleged automatic force-creating machine at great expense, they came to the sorrowful conclusion that perpetual motion machines were not practical, however inviting the mental invention.

A mental invention sometimes does not become a physical invention because the inventor lacks money, technical knowledge, or diligence. Such a mental invention often becomes a physical invention by the assistance of a capitalist, an educated person, or a diligent companion.

A mental invention fails often to become a physical invention because it falls short of completeness. It is then more properly called an idea. It lacks some one or two elements to be supplied, perhaps, many years later either by the same inventor or by another.

The telephone, as a physical invention, was a conveyer of musical and vowel sounds before it could transmit articulate speech, and yet the mental invention included both, and particularly the latter.

A mental invention of one person often fails to become a physical invention because of anticipation by a prior inventor. The later inventor either abandons the case or proceeds to undertake to prove priority of invention.

Having shown that an invention may be either a mental invention or a physical invention, and that it must first be mental before it can be physical, it becomes necessary to state the exception to this principle. The exception, however, very seldom occurs. It is sometimes remarked that the inventor stumbled upon the invention while experimenting upon some independent invention; or, that he made it purely by accident—without thinking. Certain chemical compounds have been made without any prior idea on the part of the inventor as to the result of mixing the elements to produce the compound, and also without any idea as to its usefulness and novelty. In this manner Bunsen discovered that freshly precipitated oxyhydrate of iron is an excellent antidote for arsenic poison. This accidental or stumbling method of inventing is very exceptional, especially in modern inventing.

Professor Brackett of Princeton College recognizes this truth as based upon the experience of former inventors. He says, in regard to Volta's invention, "It was not the mere outcome of happy accident, but the result of severely logical reasoning upon the facts which he had observed while he was investigating the so-called 'animal electricity' of Galvani."

CHAPTER XXII.

Women Inventors.

The United States Official Gazette puplished the following: "The Patent Office has published, and has for sale, a volume containing a list of women inventors to whom patents have been granted, from 1790 to July 1, 1888."

Investigation shows the approximate number of women patentees in the United States to the present date, to be 2,400, and that the prevailing departments of art, in which they work, are kitchen utensils; articles of dress; fabrics; toys; hospital appliances; and educational devices, especially; but, scattered here and there we find nearly every department represented. By far the larger portion is domestic. The total number of men patentees in the United States in the rough is greater than the population of New York City.

The woman inventor of the fluting iron made a handsome fortune, while those interested with her were equally profited. This is only one case out of many similar successes of women inventors.

Some women, of course, are overworked, and some so busy with various matters that little time and strength are left for the task of inventing; but there are thousands of intelligent, educated, and especially wealthy women, who have more time to spare than men of the same standing, and these women wishing often for some employment, either for the sake of occupation or profit, waste their time waiting for something to turn up. The chance, in other directions, for women to gain fame or wealth is very limited in comparison to the opportunities for men. The former are confined mostly to literature, painting and music. In conversation with women on this subject they almost universally excuse themselves, or mourn their incapacity, on the ground that they have no genius or gift for inventing. They might as well wait for a piano to teach them to play, without practice, as to wait for an invention to come to them without action. They should have a certain amount of conceit, and try in every way, and especially by practice, and systematic thought, to invent something which will overcome an existing difficulty. Not only is there a prospect of reward, but the very act of developing a conception begets probably the highest type of earthly happiness.

One reason, as exhibited from the study of inventions, why women are not more prominent among inventors, is that upon finding a difficulty to be overcome, and abandoning conceiving the possibility of success, she immediately explains it to her husband, or son, who dwells upon the subject until developed into a complete invention, showing again the want of confidence in herself. Do not be surprised if the invention is not developed and perfected in a day. It is said that inventor Bell's father tried to transmit speech, and that the son followed in his footsteps many years before success. It needs confidence and perseverance, more than luck or the indefinite quantity called genius. All women have the gift ; but they will never realize it, until they have confidence, and practice with great perseverance.

I think it will be admitted that some of the greatest difficulties with the natural laws, are met with in the kitchen. The domestics are probably not more to blame, than those who ought to invent devices, which would relieve some of the heavy responsibilities placed upon the employed, who usually lack intelligence, education, memory, &c., more than they do the moral virtues, such as obedience, &c. Servants formerly burned milk. Now they have the device where the milk is heated by boiling water, so that burning becomes impossible ; because it is a scientific fact that milk cannot be heated to 212° Fahrenheit in a vessel standing in water, and not hermetically sealed. The milk heater is therefore a great invention since it does not allow a servant to burn milk. The improved coffee pot, whereby the disagreeable and unwholesome elements of the coffee are removed, is likewise a remarkable invention. Some servants can make good bread, and others, equally competent in other things, cannot. This is a difficulty which I believe is not an impossibility to overcome. Some apparatus should be invented, so that any person, by obeying certain simple rules, can operate it, and produce bread of the best quality. While staying at a boarding house during college life, the bad bread was successively due, according to the landlady, " to a new barrel of flour," "new girl," "the dough stood too long, or too short a time," "potatoes were inadvertently omitted," "trying a new yeast cake," "the oven wasn't hot enough," etc.

CHAPTER XXIII.

Problems in Invention.

If inventors, and those who have a love for inventing, were more generally acquainted with the problems known only by a comparatively few, progress in inventing would be much more rapid and superior. One man may not be able to solve a problem, although he has worked at it for weeks; whereas another, having special experience in another department of industry, may start in a radically new direction and solve the problem successfully. The mere mention of a difficulty is such an assistance that the one who names the problem is often (but not rightfully) accredited as the inventor. An attempt was made at the Patent Centennial at Washington, in 1891, to prove that the widow of General Greene was the inventor of the cotton gin. She was merely the one who pointed out how important a machine would be which would clean cotton from its seed. The story of Whitney's invention illustrates how necessary it is that the multitude should be acquainted with existing problems. Mrs. Greene, herself, although recognizing the difficulty, was void of the knowledge of mechanics, and therefore did not possess the qualification for designing any machine whatever. The story is told thus by the son :

"Eli Whitney, the sole inventor of the cotton gin, was spendthe winter of 1793 in the family of Mrs. Greene, on her plantation, 'Mulberry Grove,' eleven miles from Savanah, Ga. On one occasion she had a number of officers who had served in the army under General Greene meet at her house to dine. They were Southern planters, and in the course of conversation at the table were lamenting the destitution of the South, saying that corn and indigo were the only crops—that the negroes ate up the corn, and that the price of indigo was so low that its culture did not pay, but if some machine could be devised for cleaning upland cotton from its seed, they could all improve their condition and make slave-labor profitable. The hostess, Mrs. Greene, referred them to her young friend Whitney, who was present, saying that he could make such a machine; that he could invent anything in the mechanical line—which Mr. Whitney modestly disclaimed. But this incident first called his attention to this great want, and its importance, if successful. He had recently graduated at Yale College, and was preparing to study law. However, he resolved to devote himself for a time to this invention, and in consequence went to Savannah, searching the warehouses there to find some cotton in the seed, which he had never seen. At length he found a small quantity, and devoted the rest of the winter to his invention, and produced the cotton gin, the same that is in general use to-day, virtually unimproved upon. He had invented the breast of the machine, with its toothed cylinder and hopper, and was thinking how he should dispose of the cotton when on the cylinder of saw-teeth, after it had been separated from the seed. Mrs. Greene, who was watching the progress of the invention with great interest, playfully took up a hearth-brush and said: 'I can get rid of the cotton on the cylinder,' and began to brush it off, probably not having the remotest idea of a revolving brush, but Whitney conceived the idea of a revolving brush and applied it. But the brush does not constitute a cotton gin nor separate the cotton from its seed. Lord Macauley said: 'What Peter the Great had done for the advancement of Russia, the inventor of the cotton gin has equaled, and more, in promoting the power and progress of the United States.'"

Miscellaneous Problems.

W. C. Barney, in the Electrical Engineer (New York), reminds the public that even after the expiration of Bell's patent for transmitting speech by the use of an undulatory current in a closed circuit the American Bell Telephone Co. will order a patent to issue upon the carbon transmitter, which now forms the subject-matter of two applications in interference and both owned by the Bell Co., which will then have protection for another seventeen years upon telephony broadly because the other form of transmitter (the magneto telephone) is not nearly as practical. The problem is to invent that which does not involve the principle of vibrating the current, by speaking against terminals, in loose contact in an electric circuit. After March 7, 1893, the use of an undulatory current for transmitting speech becomes public. The editorial of the above-named paper and the daily press are calling loudly for accomplishing the result of the carbon transmitter, or microphone, by a different device.

Under this head the inventor should be reminded of the fact that while the telegraph will operate between New York and

Chicago, Omaha, Denver and San Francisco, the telephone is a failure for distances further than Boston, and very imperfect for that distance.

In the trolley system for electric railways, the trolleys now in use jump the wire, the car stops, and the trolley must be replaced. This objection should be remedied.

Ferry-boats are seldom known to be injured in collisions. Why should not the problem be solved of constructing ocean steamers or providing attachments whereby they are not so often sunk? The compartment invention is a step in this direction.

Women are greatly annoyed by the absence of elevators for elevated railway stations. The problem is one for inventors, rather than for contractors.

An engineering periodical wonders why there is not in the market a ball-bearing for steam engine shafting. The bicycle ball-bearing will not do for large machinery.

The present locking nut, with steel spiral, for railways often fails. In fact, rusting the nut on is about as efficient.

If a house carries on business between New York and Denver, ten days elapse before important papers can be returned. I for one would pay $1 postage on many legal papers if they would go to any point in the West during about one night. Rapid transit for commercial and legal papers is next in importance to the telephone.

In manufacturing illuminating gas from steam, the product being called water gas, the steam is passed through white-hot coals. It is noticed that a large portion of the incandescent coal at the point where the steam enters is cooled down to such a temperature as to become useless for decomposing the water into oxygen and hydrogen.

That which is not known as physically impossible is worth consideration by the inventor. At the time of writing, there is a great drought over this section of the country, and yet within a mile above our heads have hung for several days enough clouds to form a deluge. It is difficult to support things in the thin air, and yet those clouds float there as if the air were mercury or iron. No engineer can give a reason why some water at least cannot be obtained from such clouds. It is the inventor's place to consider this problem with the help of all the knowledge he can possibly get.

Some of the difficulties in storage batteries are the buckling of the plates, whereby they bend toward each other, and neutralize the current by touching each other; falling off of the active material; formation of sulphate of lead, which increases the resistance, and which is formed at the loss of an equivalent amount of the active oxides of lead ; the great weight of a battery; the eating away of the terminals where they pass out of the electrolyte ; and partial polarization.

In the form of air-brake systems using the direct pressure of the air, the engineer too often uses too much pressure, thereby wearing the wheels oval by sliding. What is the prevention or tell-tale ?

At seashores, pumps driven by the waves are becoming common, but for driving machinery a difficulty still exists, arising from the varying amplitude of the waves.

The storage system is perfection, as far as the public are concerned, but death to the operating company, on account of over 50 per cent. of the current being lost, solely by the process of storing. The overhead system is highly economical, but the public reject it for streets having handsome residences. The surface or underground system embodies, in theory, the best elements of both the former ; but—can leakage and danger be prevented ?

Since hotels will insist in carrying out the law (requiring fire-escapes), by supplying in each room a combustible rope which only serves to burn and let the inexperienced circus actor drop, why cannot architects or others acquainted with building provide an internal fire-escape of a fireproof nature—or provide that which is a part of the building and not an attachment ? This seems easy enough, but the problem consists in getting that construction which will take well with the style of man who pays for the building.

A telegraphic relay depends upon a spring for its delicate adjustment, but the spring soon loses it elasticity. Can a relay be constructed so as not to be dependent upon the elasticity of a spring ?

A very common accident on cable railways is that where people are thrown off from the platform when the engineer puts the final grip upon the cable. A peculiar motion occurs, which has thrown some of the nimblest men.

In large buildings in New York, and other large cities, it occupies the letter carrier about ¾ hour to distribute the letters in each building. Is it possible to devise advantageous mechanical means for doing this ? It depends upon what the system is when invented.

Considerable trouble is experienced by steam boiler-makers because the tubes and shell separate, due to large contractions and expansions in cooling and heating. The cylindrical part of the shell has a different degree of expansion and contraction from that of the tubes. The problem is to provide the best means for preventing the tubes from becoming loose in the ends of the boiler.

To prolong the durability of taps for cutting internal screws, the difficulty is experienced, because the greater part of the tapping is done by the forward end of the tap, while the remainder remains practically unworn.

In the present fire extinguisher, operated by the melting of solder by the heat of the fire, to let water out of a vessel upon the fire, the solder becomes solidified by the cold water, thereby preventing the flow of water, at least only through the very small hole made at the beginning of the melting. Consequently, this easily fusible metal stopper seems to have its defects.

No subject is more inviting to inventors capable of designing complicated mechanisms than that of setting up type by a device like a typewriter. The latest is that in which the type metal is melted, while the keys are for feeding the fused metal into a proper matrix for each letter. After use, the type are upset and melted over again. This is certainly a novel idea, and it is being used by one or two large newspaper establishments, but it is not applicable to the ordinary printing-house. The principal cost of getting printing done is that for the setting up. Why should this not be capable of cheapness equal to that of typewriting where a copyist can operate 15,000 letters in an hour?

Chemists experience difficulty in keeping hydrofluoric acid, as it attacks glass, while platinum—very expensive—is about the only metal it does not attack. Earthenware is not suitable. Bottles have been made of wax, but the weakness is a defeat to its success. Rubber and lead are attacked, although slowly, making the acid impure, and experiencing leakage after standing any considerable length of time.

In electric welding, the larger part of the current passes, and is not converted into heat, as desired, at the point of welding—of course, the more heat there is the more current there is in the circuit, but still the principles of science do not teach that the proportion of heat to current cannot be increased. How can it be brought to an efficient maximum?

In view of more injury arising from stoves in railway accidents than from the accidents themselves, is it possible to apply electricity to heating the cars? It depends upon the results obtained by an analytical and synthetical consideration of this problem.

It is reported by butchers that artificial hatching of chickens is becoming a failure. The chickens are hatched all right and live a few months, but are very thin and most of them die. There seems an important difference between the natural and artificial. In the former the chickens are out of doors in the warm weather with absolutely pure air—in the latter, they are in a close place, with scarcely anything to breathe but carbonic acid gas, or other impurities, coming from the heating process. Does not the delicate health of the chickens arise from bad air? Remember that telephony was becoming a failure before the invention of the carbon transmitter, which produced such good results as to make a grand success.

The subject of electric railways connecting cities and supplying even greater rapid transit than by steam is being agitated. The armature would be mounted upon the car axle, thus eliminating entirely all the numerous mechanisms of the locomotive. There is one difficulty, however. The present trolley is well enough for slow speeds; but something radically different and superior must be invented for making continuous electric contact between a stationary conductor and a train going at, say, 90 miles per hour.

There is no apparent reason why the governing of a steam engine should not be accomplished efficiently by electric means for adjusting the throttle valve. This problem has been attacked, but in such a crude manner that the ordinary mechanical governors have not been abandoned.

Why do passengers on a railway train become worn out, when the pleasant ride through a beautiful country should be beneficial? It is due to the smoke and coal gas from the locomotive. To prevent production of these nuisances is substantially impossible; but how about a design of a car or a device whereby people may have the pure air to breathe?

Carbon depositied by heat is well known as superior to carbonized wood. The difficulty is to manufacture it in the form of carbon filaments for incandescent electric lamps.

Murders take place by pistol shots in hotels, and are not known until the escape of the criminal. Provide protected automatic means for giving a signal at the hotel office.

In the manufacture of carbon filaments, the same break in large proportion, from shrinking about 25 per cent. The problem is to carbonize with less breakage.

Prof. Nichols, of Cornell, has proposed obtaining incandescence for electric lamps by providing means whereby the incandescing substance is magnesia or similar infusible and incombustible substance, of a white color, instead of carbon. The incandescence is reached at a much lower temperature in the former, and therefore also follows greater economy.

In the manufacture of arc lamp carbons, the present difficulty is in baking them so that all the rods are at a uniform temperature. Some are found baked perfectly and others only partially, so that the operation must be repeated for a large per cent.

One of the most difficult problems known is to be able to renew carbon filaments without throwing away the bulbs.

Who is to be the first to provide an incandescent electric lamp which will not "blacken" by carbon depositing on the inside of the bulb, or who will produce equivalent means for removing this objection to the lamp?

Wanted, a good design for electric lamp bulbs, having a minimum interior space, to shorten time and expense for exhausting, which is the most expensive step in its manufacture.

Door bell hangers do not recommend, and some refuse jobs, in equipping buildings with electric bells, because repair is so often needed. The difficulty seems to lie in the sparking; evil results from sparking both at the bell and at the push button. Otherwise the electric bell is more advantageous than the mechanical.

Incandescent lamps, to be efficient, are limited to a maximum of 50 candle power, and arc lamps, to a minimum of 1,000 c. p. The problem is to furnish a lamp equally as practical, but of a candle power of about 100 to 200.

There is a continual call among housekeepers for means of "turning down" the incandescent lamp. Tell them that they may as well turn it out, as they need no match to light it with, and they will reply that it is not a question of economy, but of convenience for a night lamp, or as a means of showing as a signal where the lamp is in an otherwise dark room. The rheostat has been proposed, and one or two other schemes, but the commercially successful way still seems to be wanting. The result to be obtained is the production of an adjustable intensity of light, at the limits of one candle power and the maximum.

At high speeds, trains jump the track, and serious accidents occur. This generally may be looked upon by inventors as inevitable; but such a decision should never be conceded by an inventor until he has analyzed the causes of such accidents, and located the fault, whether with the wheels, the construction of the rails, or the speed relatively to the weight; consider also whether prevention or cure should be aimed at.

After the production of reading matter by the typewriter one must count the words. Where the matter is located irregularly much time is needed. A good and cheap device for counting the number of words made by a typewriting-machine would certainly have a market among typewriter copyists.

Reference is made among these problems to a substitute for the carbon telephone transmitter, in order to give another inventor a chance to benefit himself and others, after the monopoly has been so long held by another party. A similar case is found in time locks for safes. A time lock is of no value if it can be opened by any secret, before the time set. But suppose the clockwork stops before that time. There should be secret means for opening it under this condition. In the present system the time lock is combined in such a manner with a combination lock that if the clock should stop before the time set for opening the safe, the manufacturers can give the owners a combination which will open it; but this combination will not open it if the clock does not stop. It seems a possibility that inventors could provide means whereby the *owners* could open it under the sole condition that the clockwork stops before the proper time. It must be remembered that there must be no means whatever whereby the safe can be opened before the time set, while the clock is still working, or else the object of the time lock is a failure, being to prevent a thief from torturing the men with the secret to open the safe.

A problem needing much attention by inventors having considerable mechanical knowledge is the turn-out for trolleys, operative when the electric car passes upon a side track. Although the present form only fails a few times a week, it is quite a wonder it does not always fail.

The trolley support for holding the trolley upward, against the line, is at present made in such a variety of forms that this alone is evidence that there is probably no best trolley arm.

It is scarcely possible to obtain a glass of sweet milk in restaurants if a thunder-storm is occurring within a hundred miles or so. The cause of acidity is well known, but the problem of preventing it seems to be little considered. Lightning, *i. e.*, the electricity, changes oxygen into the allotropic state of ozone, which has a strong affinity for certain elements of the milk, causing an acid to form. This is a problem for chemists, although its solution in a simple, mechanical manner may perhaps be that which is conveniently applicable in the kitchen and restaurants by servants.

A periodical states that one of the difficulties attending the use of the telephone, on long lines, is in suppressing "overhearing" from other wires, due to induction or leakage. In using the instrument, it is often annoying to have your conversation heard by those other than the one you are supposed to be addressing. A present method is to have a return *wire* instead of using the *earth*, but the expense of a line is thereby nearly doubled.

To provide such means that the vibrations of air produced by wagons, trains, horse-cars, &c., can be changed in number per second to considerably below that rate which does not produce sound to the ear, or to increase to such a rate as to eliminate the sensation of sound, or in other directions of development, let the inventor try to turn sound into silence, as far as the ear is concerned. The scientist can go so far as to tell the inventor that there is known no reason why it cannot be done.

One of the difficulties in electric railway departments is that of repairing overhead lines, which are high in the air.

The same cause, "retardation," which prevents rapidity of telegraphic transmission at long distances, is an important cause in preventing telephonic transmission at long distances.

It is now apparently conceded that the last car on a train is the most dangerous. A friend facetiously remarked that the railway company ought not to have a last car.

Heat, light, and sound may be radiated, reflected and in some instances transmitted through substances, and concentrated into a focus. Can these properties be saïd to be true of electricity, and if so, what are their applications?

During the past two or three years the alternating electric current has become widely applied in connection with electric lighting. There is to-day no motor which can be operated commercially on a large scale by such a current. Consequently, a system of electric power cannot be combined with a system of alternating current lighting. Motors for alternating currents have been invented; but on account of their extremely low efficiency, are applicable only to small power, as for driving small ventilating fans. It has been reported that a large capitalist and manufacturer offered the sum of one million dollars for a patent on a successful alternating current motor for railways, and that electricians have agreed that a monument will be erected in honor of the inventor before he dies, and that in other ways he will be rewarded for solving one of the greatest difficulties in connection with electric power. The names of the present inventors of commercially successful alternating current motors, for very small power, should be mentioned in this connection. They are: Prof. Elihu Thomson, Nikola Tesla, Ludwig Gutmann, Lieut. F. Jarvis Patten, Chas. J. Van Depoele, and Prof. W. A. Anthony, with his two colleagues, Messrs. Jackson and Ryan. In the space of about only two or three years these inventors discovered valuable principles which are perhaps merely the beginning of further developments, either by themselves or others.

The best alternating motor at present is the synchronizing motor, combined with the improved small motor for starting.

Since the improvement of Faure, the electro-chemical storage battery has been introduced on a commerical scale; but if it were as economical for railways as the overhead system, the latter would become extinct. The storage system at present finds its way only where economy is not to be considered. The problem is one of the most difficult of the day, since the transmission of electrical energy, in storing and in recovering, involves a loss each time. Thus to convert electrical into chemical energy, and then chemical into electrical, necessitates a total loss, even in the laboratory, of about twenty-five per cent. and in practice more yet on account of mechanical difficulties. One more improvement equal in magnitude to that of Faure over Planté would make the storage system a grand success.

The wonderful invention of photography has not yet been superseded by that of photographing colors. The man with red hair has dark hair in his photograph, and for that he may be thankful; but the rosy-cheeked girl, with beautifully tinted ribbons, and adorned with variegated flowers, would greatly enlarge the sale of cameras if her picture would result in a reproduction of her colors. This subject was attacked in the early days of the art; but it may remain for electricians, especially electro-chemists, to combine an appropriate electrical principle with a chemical principle to solve the problem. Some substances assume different colors under the influence of light, and it is also true under the influence of electrolytic action.

Perpetual motion is impossible, but the forces of nature, as the wind, falling water, the heat and light of the sun, the rise and fall of tides, the ocean's billows, the earth's magnetism, evaporation, and lighting are intermittent, and therefore, although untrustworthy in their natural condition, are nevertheless forms of energy which cost nothing, and which are at the disposal of the future inventors for storage, and for sale in the shape of heat, light power, electricity, and chemical action. To prove that there is immense power in the chemical rays of the sun, it is only necessary to fill a vessel with a mixture of hydrogen and chlorine gas, close it hermetically and expose it to the sun. The vessel is blown to atoms, although the mixture is unaffected in the dark or when exposed to merely the heat of the sun. The actinic or chemical rays are a powerful agency on a cloudy day, sufficient actinic rays being present to cause the combination to take place gradually with the formation of a minute drop of hydrochloric acid.

Yes, there is enough power there. The power is cheap. If the day is cloudy, the time for storing need simply be lengthened. Even if every house has no yard where the device can be exposed to light, yet there is a roof to every dwelling exposed to the full daylight, and its size is proportional to the size of the house and therefore to the number of lamps therein.

At present, the commercial form of electricity is obtained from fuel, such as coal; but the heat is first changed into mechanical motion, which is then changed into electrical energy. Electricity may be changed directly into heat or light. The problem is to change the force of heat directly into electrical energy. A steam locomotive is more ecconomical by far than an electric railway system; but a heat electric engine would certainly be economical.

From the beginning of the electric age until the present striking improvements have been made in electric generation, and there is no reason for expecting them to stop.

One of the greatest difficulties with the present dynamo is apparent when it is realized that the only part needing attention is the commutator, which must be kept from sparking. Each dynamo could be left to take care of itself if it were not for this difficulty. In electric railways, the commutator is injured by dust, the sparking wears it out rapidly, and the machine on this account alone needs attention. There is needed an electric motor that can be locked up in a box and left there for weeks without attention, the current being conveyed to it by wires passing through the box. This is only one of the fields needing a commercial means of preventing sparking upon the rupture of reversal of a current.

At last the electric meter appears to have met with commercial success, one form being electro-chemical and the other electro-mechanical. But I would not be surprised if another meter were invented far outweighing all others in simplicity of construction, accuracy of measurement, durability and convenience.

One of the greatest difficulties in the manufacture of dynamos and electric motors is the apparent necessity of boring the pole-pieces in order that the same may be at the mininum inductive distance to the armature.

A. Reckenzaun, C. E., states in a paper before the American Institute of Electrical Engineers: "The problem of devising suitable gearing for street cars carrying their own motors has been and is still of the greatest importance. The conditions to be satisfied are by no means simple."

Nikola Tesla points out that the next necessary step in the further development of light by great frequency of alternations of current, combined with very high potential, is the production of an insulator which will not be injured by the charge and discharge. He finds great difficulty because no induction coil so far made is able to withstand the currents of high frequency and potential which are obtainable.

The last lines of the following clipping will indicate that the inventor's power is needed in a certain detail of marine machinery:

"*Another Ship Disabled.*

"NEW YORK, July 14.—The tramp ship Endymion is reported to have been met on July 10th with her crank broken, struggling to reach New York. She declined the assistance of passing ships and is expected off Fire Island to-day. Tugs are in readiness to meet her when sighted. The Endymion is from Banon, England. She is the fourth ship which has suffered in this manner in a month."

In 1881, Prof. Thurston presented the following problem before the Society of Mechanical Engineers. He says:

"The second of these greatest of inventors is he who will teach us the source of the beautiful, soft-beaming light of the fire-fly and the glow-worm, and will show us how to produce this singular illuminant, and to apply it with success practically and commercially. This wonderful light, free from heat and from consequent loss of energy, is nature's substitute for the crude and extravagantly wasteful lights of which we have, through so many years, been foolishly boasting. The dynamo-electrical engineer has nearly solved this problem. Let us hope that it may be soon fully solved, and by one of those among our own colleagues who are now so earnestly working in this field, and that we may all live to see him steal the glow-worm's light, and to see the approaching days of Vril predicted so long ago by Lord Lytton."

In telegraphy, condensers have been used with advantage in preventing the bad effects of self-induction, sparking, extra currents, &c. It has many times been pointed out that if a durable condenser for large currents, such as are used in electric light and power stations, could be invented, the efficiency of electric motors (especially the alternating) and dynamos could be greatly increased. The objection to all known condensers for large currents is that the insulation is easily punctured, burned or otherwise injured by the charges they receive, rendering the condenser useless.

At the time of writing, the decision of Judge Wallace has upheld the Edison filament patent. How easy it would be, therefore, to sell to an opposing party an invention by which the current can, without a filament, be subdivided for producing lights of from 10 to 20 candle power each in as economical and desirable a manner as by the use of the present incandescent electric lamp.

Since the introduction of the incandescent electric lamp attempts have been made whose object is to use the great heat of a gas flame for producing greater intensity of light. In the ordinary flame only about 8 per cent. is light energy, the remaining 92 per cent. being heat.

Some effective way of preventing "sweat spots" and "chill cracks" in cast car wheels is called for.

Recently, a telephone manager received such severe shocks as to be thrown down insensible, and the telephone wire was setting fire to the building. Others tried to get at the wire to cut it, but were treated likewise. They telephoned to six different electric light stations to turn off the lights before the remedy was effected. What is the best way to prevent such mishaps in the future, or how can any existing devices be made commercially valuable?

In feed cutters and similar machines great injury is often produced by unusual and sudden resistance coming upon the machine. How can the small pulley be so attached as to become loosened at a predetermined strain thereon and be subsequently adjustable?

How long shall explosions, fires, deaths, &c., continue from the use of oil lamps? Until a lamp is made which can be upset or tumbled around on the floor with no other injury than the breaking of the chimney, the inventor should feel somewhat responsible for damages.

In hunting, the tremendous noise and re-echoing of the gun frightens the game, so that it is usually necessary to walk about a mile to meet more game. In other ways the noise is objectionable. Cannot the inventor devise means whereby silent and effective hunting may be carried on. It would be a great boon to the sportsman.

Since the inception of photography it has doubtlessly occurred to many that it is probable that some inventor may be able to photograph, and especially to print photographs from negatives in the dark, by the use of substances sensitive to heat rays. The secret for the inventor to discover is that chemical or combination of chemicals which will be sensitive to heat rays. A difficulty he will meet, not found in the case of light, is that heat is conducted. This difficulty, however, may not be insurmountable. Photographers have plenty of time to spare and plenty of printing to do on rainy days and in the evenings.

George Gibbs, M. E., in a paper before the Western R. R. Club, proposed a problem as follows, relating to car lighting:

"A favorite scheme for obtaining electricity at a low cost seems to have been to connect the dynamo to a car axle; but the difficulties of obtaining regular motion and current, and providing light when the train stops, have necessitated the employment of accumulators as regulators and auxiliaries. In these plans automatic appliances are provided to cut off the current from the dynamo when the speed of the train falls below a certain rate, and to deliver the current to the batteries in the same direction, no matter which way the train may move. Many foreign railways have tried this plan, the most successful instance being of the "Pullman Limited" on the London, Brighton & South Coast Railway, where the system is still in use. The main *difficulty*, and one which the International Railway Congress states has not been solved satisfactorily, is the method of transmission of power from the axle to the dynamo."

CHAPTER XXIV.

CONCLUSION.

I HAVE spoken of pecuniary reward. Men have made fortunes, both as inventors and as capitalists investing in inventions. Whether wealth is obtained or not, one thing will result from the introduction of a useful invention, as surely as heat results from combustion, and that is, a name which will last forever, as an honor both to the inventor and to his descendants.

Napoleon's name also probably will last forever, but whereas he conquered nations, by producing certain blessings at great sacrifice of human life, benefit without sacrifice has been produced by Archimede's screw, Barker's mill, Watt's steam engine, Stephenson's locomotive, Galvani's electric battery, Faraday's electric motor, Davy's safety lamp, Bunsen's burner, Morse's telegraph, Gramme's dynamo, Prof. Thomson's electric welding process, Planté and Faure's storage of electricity, Edison's incandescent electric lamp, phonogragh and carbon transmitter, Bell's telephone, Westinghouse's air brake, and Pullman's vestibule cars.

The good which inventors do lives after them ('tis not "interred with their bones,") and their inventions are better memorials than monuments of gold.

People, at large, live and think in the Present; scholars or the learned are busy with the Past; astronomers predict Future positions of the heavenly bodies; but inventors apply the knowledge of the Past, look into the Future for new worlds to conquer, and supply the Present with the fruits of their labors.