indicate as far as analogy goes the fact of a violent evolution of heat from the interior to the surface; the revelations of the most powerful telescopes show the sun's surface as full of small holes called pores. These pores are probably small sun spots, or it is stated that the larger sun spots have been observed to begin at one of the small black spots or pores. It has also been observed that the chromosphere appears depressed at and near these spots or pores; it therefore becomes reasonably apparent that they are at the surface of the photosphere, and are the nuclei of descending currents, while the faculæ are the apices of ascending currents, carrying the highly heated, dissociated elements of the sun, such as silicium, magnesium, calcium, and other metals, to the surface, where it is partially cooled by radiation to a point of intense luminosity, and from which by its increasing gravity tends to move off toward points of depression, of which the pores and darker spaces between the faculæ are the natural courses, thus keeping a constant circulation from the interior to the surface condensation, luminosity, a return to the interior, dissociation by absorption of heat, and again sent upon the outward round of circulation. There seems to be a limit to the amount of heat that could possibly be produced or added to the sun's energy by the concentration of cosmical matter, other than by contraction, which must unite with a heat-producing medium for development; and also of the impact of meteoric matter, which may contribute a small amount of heat as well as volume to the sun's mass, and to which may possibly be attributed the origin of the sun spots whose ragged and irregular contour seem better to conform to this mode of origin in many instances than to cyclonic action. Perhaps cyclonic action is normal to the sun's surface circulation, and meteoric projectiles only generative in their effects. The highly attenuated interplanetary zone which we term the zodiacal light may also add heat or fuel to the sun by its gradual contraction and condensation, as well also to absorb a part of its intense radiation. If the theory of La Place, vivid as it is in beauty and vastness of conception, be accepted, the condensation of cosmical matter should still be going on, and not cease until the sun itself becomes a solid mass, and the solar system enshrouded in darkness. The condensation of interplanetary matter, the corona, and the impingement of meteoric matter, contributing as they probably do a portion to the heat and energy of the sun, yet we can conceive of no equivalent in these elements to compensate for the volume of heat and light radiating into space. Again, if there exists an ethereal substance in space sufficient to maintain a combustion in the sun equivalent to its immense radiation, it would be dense enough to influence and retard the motions of the planets, and still further, to interfere with the periodicity of comets. The extraordinary coincidence of the agreement of the orbits of the great comet of 1843 and that of comet A of 1880, seems to leave but little doubt in the minds of leading astronomers as to their identity. If it should be proved so by a third coincident return, it will no doubt set aside the arguments for a resistive medium worthy of computation, although, near the sun and extending beyond the point of perihelion passage of many comets, there is no doubt an as yet uncondensed resisting medium that lends its retarding influence to passing bodies, and, for as much as we yet know, may be the real and principal cause of the erratic course of many comets after their perihelion passage. Again, the evidences furnished by geological research are becoming more convincing that the earth is receiving from the sunless heat now than it did ages ago, or during the middle geological periods, when its surface ceased to be influenced by its internal heat. The rate of decrease is so small that it cannot be measured by the record of man; it can only be made evident by the comparative changes in the flora and fauna of the earth, from the abundance and magnitude of its fossil exhibit, to the scantiness of its present existence. The amount might not be a fraction of a degree in a thousand years. The sun's apparent constancy of radiation may be partially if not wholly accounted for by the decreased absorption of the interplanetary matter constituting the zodiacal light, and the more dense mass in immense proximity to the sun, the existence of which was so fully shown in the observations of the eclipses in 1878 and 1880, and beautifully illustrated in the late publication from the National Observatory. Their illuminated aspect seems to indicate that light and heat are absorbed in their passage to the planets, and therefore, if a condition of constant contraction has been and is going on, the sun's effect will appear to be constant, or nearly so, although really losing heat and decreasing in temperature. There remains another element which seems to be a part of, and to have a strong interplanetary relation, being one of a mysterious triad, whose functions appear so interwoven and unchangeable that they are yet an enigma to mankind. Its sphere of greatest activity is upon the verge of vacuity; it exists as an almost unknown and pervading element of all matter, and, for all we know, of all space. In its dual nature we recognize a latent and active principle. It is developed by interchange of chemical elements, and by its power the strongest bound elements are reduced to their simple terms. Certain functions of each of the triad are common terms, while others are widely different or antagonistic. This element, electricity, together with its magnetic brother, seems to possess energies scarcely yet understood; these may be, so far as we know, only derivative functions of each other. Heat and light being strongly developed by electric energy while passing in contact with natural elements where these elements are disrupted or transposed, as in the carbon light and atmospheric discharges, as well also in the mysterious incandescent or vacuum light in which there is no disturbance of any material element, but a development of heat and light by its mere passage through or over an element of slight resistance, showing visibly that its sphere of light and heat-giving activity lies upon the verge of vacuity. From the well-known conditions of light, heat, electricity, and magnetism, in their generative and inductive relations to each other, and the admitted powerful and almost simultaneous magnetic relation between the sun and the earth, it is inferred that all interplanetary space has no bar to its instantaneous and coincident effect.

From the progress that has latterly been made by Mr. Crooke in the study of the molecular physics of electricity in high vacua, it is hoped a long stride forward will be made in the knowledge of the probable influence this mysterious element may bear in the heat and light-giving power of the sun. The ideal of the existence of subtile fluids and molecular vibrations with their interchangeable tensions and intensities, as representing the elements of sound, heat, light, electricity, magnetism, and gravitation, are as yet a ladder in the mystery of creation in which every step forward in the investigation of ultimate elements is one round higher to a knowledge of the infinite.

METEORS.

By R. J. McCarty.

History records many instances of the fall of masses of stone, iron, and other substances from the higher regions of the atmosphere. Until the beginning of the present century these records were regarded by many as either entirely mythical, or based upon some events entirely susceptible of explanation from local causes, so that there was hardly sufficient faith in the fact to stimulate the philosopher to search for the cause. But when on April 26, 1803, near L'Aigle, in Normandy, a shower of stones followed the explosion of a fiery globe which rushed with great velocity over that region, and when this fact was officially verified by a commission of the French Government, there was left no room for doubt that meteoric light is often followed by the precipitation of matter to the earth.

From observations made of the instants of appearance and disappearance of the light and of the position of its path with respect to the stars, astronomers have been able to calculate that the source of meteoric light lies always within the limits of the atmosphere, and that the velocity of the meteor varies from seventeen to thirty-six miles per second.

It is, therefore, impossible to doubt that meteors are masses of matter rushing with tremendous velocity through the air.

But this amounts to little more than a definition and does not explain the physical causes of the phenomena, and the questions arise: Whence the light by which we know the meteor, and whence the matter of which it is composed?

Now it is known that resistance to motion will always generate heat, and that great heat is always accompanied by light. For instance, an axle or journal, if not properly lubricated, while rapidly rotating under great pressure, will become red hot, and the reason it does not become red hot when lubricated is that the oil reduces to a great extent the resistance due to friction, and at the same time absorbs the heat generated by the resistance which it is not able to destroy.

Moreover, we know that the atmosphere offers resistance to the passage of bodies, proportioned to the square of their velocities.

Experiments in gunnery show that a fifteen-inch shot moving with a velocity of 1.500 feet per second encounters an atmospheric resistance of about one and one-half tons If such a shot could be given a meteoric velocity of thirty miles per second, equal in round numbers to 150,000 feet per second, the resistance would be increased to about 15,000 tons. The quantity of heat generated by such a resistance under such circumstances is unknown, but reasoning by analogy from the above instance of the red hot axle, it seems perfectly reasonable to conclude that sufficient heat would be evolved to ignite and perhaps dissipate many rigid and practically incombustible substances. It is therefore generally conceded that meteoric light is caused by heat developed by the atmospheric resistance incident to the great velocity with which such bodies are known to move. If the meteor is composed of matter sufficiently fixed, a portion of it often survives the great heat and falls to the ground in a highly heated state. If it is composed of more inflammable material, it is consumed and dissipated in the air, which explains why we may not expect a meteorite from every meteor.

Respecting the origin of meteoric matter, many theories have from time to time been advanced. For instance, it was supposed by some to be formed by the condensation of vapors of various substances in the air in a manner similar to that by which hailstones are produced from the vapor of water. The absurdity of this is manifest. La Place, with more reason, supposed that such matter was cast from the moon by volcanic action with such force as to be brought within the limits of terrestrial gravitation, and, indeed, considering the absence of atmospheric resistance on the moon (for that luminary has little or no atmosphere), and considering that the force of gravitation at the lunar surface is but one-fourth what it is on the earth, it is not impossible that the tremendous volcanic action peculiar to the moon might accomplish such a result; but, as will appear further on, such a supposition is incompatible with the general facts attendant upon meteoric phenomena.

It happens that mechanical science is able to demonstrate that meteoric matter is entirely foreign to the earth or moon, thus:

The greatest velocity with which a body, moving under the action of terrestrial gravitation alone, could possibly strike the earth, would evidently be attained by letting the body fall from an infinite distance—and it is demonstrated by a well known theorem in dynamics, that under such circumstances a body would strike the earth with a velocity of about seven miles per second; but we have seen that meteors move with velocities varying from seventeen to thirty-six miles per second, so that they must have a velocity not due to the earth; which is but another way of stating that they must have a planetary motion.

Therefore meteors are cosmical bodies; that is, bodies having their origin in the same general cause which produced the sun, moon, and stars, so that they may be regarded as minute planets or comets moving around the sun, obeying the same laws and controlled by the same forces which order the motions of the most gigantic planet of our system.

When we consider that between the orbits of Mars and Jupiter there are more than two hundred small planets, varying in size from two hundred and fifty to sixteen miles in diameter, and that others are being discovered every year, it seems entirely reasonable to conclude, even without reference to meteoric phenomena, that there are myriads of such bodies belonging to the solar system so very small that they can never be detected.

And meteoric phenomena show that the orbital motions and positions of these small bodies are such as occasionally to bring them within the dominion of terrestrial gravitation, whereupon they are drawn from their orbits toward the earth with increasing velocity, and striking the atmosphere burst into flame from the causes given above.

However satisfactory it may seem in explaining the ordinary meteor, which may be seen on almost any clear night, to flash like a rocket across the sky, it would be spreading the above reasoning over too much surface to extend it to those periodical phenomena, called meteoric showers, which make it appear as if all the stars in the heavens were being precipitated upon us.

It having been observed that all planets revolve around the sun in the same direction and nearly in the same plane, and that the sun himself rotates in the same direction about an axis near perpendicular to the mean position of the planes of the planetary orbits, the suspicion arose that this could not be the result of chance, and that therefore the mechanism of the solar system must derive its motions from a single physical cause—and indeed it has been demonstrated that the probability for a single cause for 228 planets moving in the same direction around the sun is 1—½·228 in which 1 represents certainty. The fraction ½·228 when developed would be represented by 1 divided by a number of sixty-nine figures, so that the valve of the fraction would be almost nothing, which shows it to be a practical certainty that such motions are the result of law and not chance.

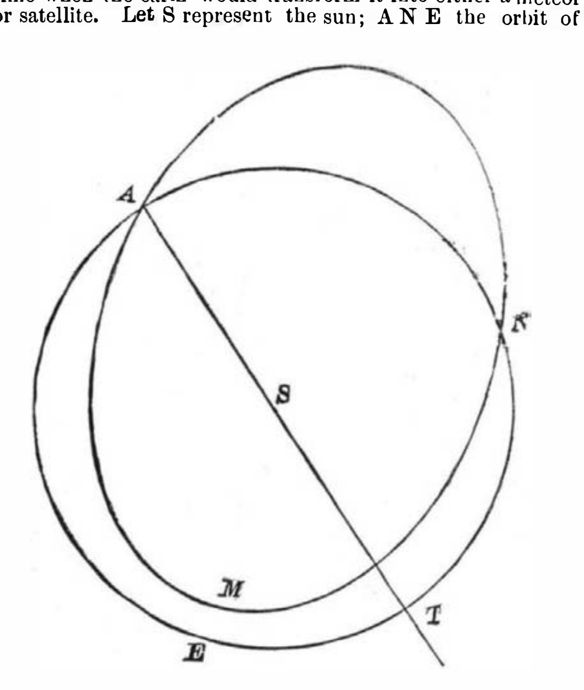
The attempts to discover this law, directed somewhat by the suspected existence of gaseous nebulæ, culminated in the nebular hypothesis, which resting as it does upon such a high degree of probability, conforming so entirely to natural law, and explaining so many phenomena entirely inexplicable on any other theory, may be regarded as established as fully as any speculative principle can be without becoming a fact or truth.

Broadly stated, it is as follows: At one time all the members of the solar system were united in a single mass of blazing matter rotating about an axis nearly coincident with the present axis of the sun, and, by reason of the expansion due to excessive heat and the operation of centrifugal force, extending its lenticular form far beyond the orbit of the outermost planet. By the process of cooling, the action of centrifugal force, and the law of gravitation, the outer portions of, this chaotic mass became detached from the main body and broken into small fragments, thus forming an immense annulus, each member of which revolved around the original mass, just as planets revolve around the sun. Some of these fragments afterward became united by gravity and collision, and the result was a larger mass continually increasing in size by absorbing its smaller neighbors, just as the earth now absorbs meteoric matter, and still revolving around the original mass. By a repetition of this process at the different stages at which the centrifugal force, increasing with the increase of velocity due to the gravitation of the denser portions of the nebula toward its center, would balance gravity, the solar system as it now stands was formed, the sun being the remnant of the original chaotic mass—all of which, judging from the behavior of matter under somewhat analogous conditions here on the earth, is in perfect conformity with physical law.

Now, unless we are prepared to combat the nebular theory we must admit that at certain epochs of its development the solar system was swarming with millions of small meteor-planets; that these have either all been since consolidated into the masses of the few larger planets, or that there are some still remaining, which, owing to their peculiar situations and motions, have escaped the clutches of their more powerful neighbors.

The latter is by far the most reasonable, since it is difficult to conceive how all these small bodies, moving as they do, could be absorbed by the larger in any finite time—and here it may be well to remark that it must be owing to the great distance between the orbits of Mars and Jupiter that the asteroids have not been appropriated by one or the other of those planets, and to the peculiar positions of their orbits that they have not been united in a single mass. The nebular hypothesis therefore permits us to assume, if it does not force us to believe, that not only are there many small isolated bodies revolving around the sun as planets, but also that these bodies revolve in groups and even in continuous rings.

Suppose that one of these small bodies should revolve in an orbit of exactly the same period as the earth. It is evident that so long as this was kept up the small body would preserve its identity, but should its period be changed in even the smallest degree, it would become a question of time when the earth would transform it into either a meteor or satellite. Let S represent the sun; A N E the orbit of



the earth; A N M the orbit of meteor planets; A S T the line of intersection of the planes of the two orbits. Suppose a group of meteors to revolve in A N M with a period differing from the period of the earth. It is evident that this group of meteors and the earth would at some time reach the point, A, at the same instant, and the result would be a meteoric shower.

Such meteoric masses as were not absorbed by the earth in this *rencontre* would pursue their course, and after a certain period some of them would again be caused to contribute to a similar meteoric display.

It is easy to see that this display would happen about the same time of the year, and at regular intervals determined by the relation between the periodic times of the earth and group of meteors.

Suppose now that A N M should represent the orbit of a continuous stream of meteors moving around the sun like an immense ring. Every year when the earth arrived at A there would be a meteoric shower. This is what happens each year about August 10th.

Thus far we have kept within the limits of the solar system entirely, in order to show that all meteoric phenomena could be accounted for within those limits.

But there are certain meteoric displays, notably those which appeared in 1799, 1833, and 1866, which cannot be considered as coming within the limits of the above reasoning, because it is known that the group from which these meteors emanate has a retrograde motion, and moves in a cometary orbit. But this fact no more militates against our previous reasoning than do retrograde comets against the nebular theory. It only enlarges the scope of the inquiry, and shows that while many meteoric masses are proper to our system, they may also wander to us from the remote depths of space.

From what has been said we conclude that meteoric phenomena are but the continuation of that process by which the solar system has for infinite ages been collecting the scattered matter from outer space, and by which the planets have grown to their present size; that this process now retains but the shadow of its ancient vigor, and will probably slowly fade and finally vanish in the great end toward which all creation tends.—*Kansas City Review.*

THE ZINC MINES OF SUSSEX COUNTY, NEW JERSEY.

By NELSON H. DARTON.

AT Ogdensburg and Franklin Furnace, about sixty miles northwest of New York city, on the New York, Susquehanna, and Western R. R., are several veins of zinc minerals which are, without question, the most interesting formations of their character in the United States. They have been worked for a number of years, but are as yet apparently inexhaustible. They were discovered by Dr. Fowler, a large property holder and mineralogist of the vicinity, in 1815–16, who drew attention to the wonderful variety and association of minerals in the outcrops of the veins, and also to the great purity and immense quantity of the ore in sight. It was not long before the attention of some capitalists was directed to the district, and they leased from Dr. Fowler the privilege of working certain of the mineral veins. Since that time these veins have been extensively developed, and have long formed a mining center at Franklin Furnace. Formerly, many men were employed in their development, but now a less number is required, as the mining facilities have been increased.

At Franklin, on Mine Hill, within a hundred feet are the veins of magnetic iron ore, graphite, Franklinite, forty feet or more in thickness, and lying upon beds of pyroxene and garnet rock; and in the limestone, then the vein of zinc ore—besides which at Ogdensburg there are two other zinc ore veins, and thus there are three, which are included between walls of granular limestone, which a few feet beyond are adjacent to walls of gneiss, or in some instances syenite or granite. The localities are two in number: First, the two veins known as the West and Main vein at Ogdensburg, in Sparta township, and the vein two miles north at Mine Hill, in Franklin. The former veins are divided into three mines known as the Manganese, New Jersey, and Passaic—the later mine being at present the only one worked. The Ogdensburg veins are very peculiarly arranged, and it is not until lately that their true configuration has become known, as pointed out by me in a paper read before the New York Academy of Sciences in November, 1882. On the geological map of the veins, published with the survey report in 1868, they were mapped as being one, and that similar in arrangement to the vein at Mine Hill, with a crook toward the northwest, the latter having a crook to the northeast; both form the southern ends of the veins. The juncture of this crook was represented as a sharp point, and diverging at an angle of about 35° from the main vein. This is true at the Mine Hill vein, but at Ogdensburg the relations are quite different, as there are two distinct veins essentially parallel and at several hundred feet apart at their southern terminations. But entirely separate from them are two high basins, two hundred feet in diameter, and about 80 feet in depth. The main vein is two thousand feet in length, and twenty-two feet in thickness at the surface and decreasing very gradually as it descends. It is surrounded by complete walls of dolomite, at least to a depth of eighty feet. The ores that occur in it are the following: Zincite, a red oxide of zinc containing about 80 per cent. of zinc, the red color being caused by the presence of scales of red oxide of iron disseminated through it. This ore is a much valued one, and constitutes a large percentage of the average ore. It is used directly for the production of either spelter or white oxide of zinc. It is mixed in all proportions with the mineral Franklinite in small black grains, or modified octahedrons containing iron, zinc, and manganese. This mineral is separated from the zincite by mechanical or magnetic means, and used for the production of compounds of iron and manganese, known as spiegeleisen or ferromanganese. It was formerly rejected as worthless, not being of use in manufacturing zinc or iron, but is now a valuable production. Besides, there are several impurities: Rodonite or bisilicate of manganese and tephroite; its unisilicate; rhodochrosite, its carbonate. Small amounts of silicate of zinc, willemite, also occur, besides carbonates, of zinc and magnesia and very appreciable amounts of silicate of copper. The arrangement of these minerals in the vein is very peculiar, and I will detail them. The foot wall of dolomite, as before mentioned, is more or less impregnated, for about a foot in depth, with masses of zincite, holding a little franklinite and some tephroite, generally in large defined crystals. Above this is a bed of zincite, six feet in thickness, containing a small proportion of granules of franklinite and at times considerable silicious matter. Above this is a hanging wall, not continuous, however, impregnated with rhodonite, franklinite, zincite, tephroite, and rhodochrosite, and in a few places blend. Above this is the main vein, about twelve feet in thickness, of zincite, holding much franklinite and some small portion of the other minerals. Above this is a thickness of about one foot of a mixture of franklinite, zincite, rhodonite, and rhodochrosite, quite separated from each other, and above this some pure zincite, which joins the veins to the hanging wall, which is also more or less permeated with the zincite.

The west vein is not of the even, regular dimension of the main vein, but of very crooked outline and variable widths and depths—from sixteen feet to four in width, about 150 feet in length, and about one hundred feet in depth. Nearly all the ore has been removed from it. Its character was similar to that of the main vain, but its constituents quite homogeneously mixed together. A tunnel connects this vein with the main one. The first basin is between the southern ends of the veins, the other just south of them; both were half filled with dirt when found, but under this was a thick bed of franklinite; and under this the calamine, a silicate of zinc containing water. It was much mixed with dirt, but this is readily washed out, and is one of the most valuable outputs of the mines. When it is mixed with lime and distilled, white oxide of zinc is obtained. Its color proper is pure white, and many specimens in this condition have been found. One a cylinder forty feet long, two to three feet in diameter, and with walls about two to four inches in thickness of a pure white color, lying upon an incline up the basin, evidently at one time a water course. Many other specimens of various minerals have been found in this basin, especially some crystals of jeffersonite fully a foot long and perfect in every angle.

The Passaic Company, the only one at present at work, have developed mines for some time. The principal mine is in the main vein, from which 50 tons per day are taken, and the basin where the silicate or calamine is taken out. A large engine house is erected nearly over the mouth of the main vein, which has a shaft 240 feet in depth and works two drills. Two forty horse power boilers are in the engine house, working an 8 inch mining pump with 5 foot stroke, an air compressor, a No. 5 Blake pump in the level, and a No. 1 Worthington double action pump in the bottom of the shaft, besides some smaller machinery in the shop, the hoisting engine, etc.

At the calamine mine a few hundred yards away a small portable hoisting engine is used, and at the mills for washing it at the bottom of the hill, a six horse power Hoadly engine for running the stamps, washers, and a No. 3 Knowles pump, 10 inch cylinder, 16 inch stroke. The washed silicate is dried in heaps and shipped direct to their works, or in some instances sold to other companies. The able superintendent is Mr. T. M. Mitchel, who, assisted by about sixty men, attends entirely to the work, and it is since he has been with the company that the true width of the vein—22 feet—was ascertained. The vein of lean ore hiding the rich layer of zincite six feet in thickness was formerly considered the foot wall of the vein until explored by Mr. Mitchel.

At Mine Hill in Franklin the zinc is again found in nearly a direct line northwest; the Ogdensburg deposits in a vein of nearly the same length, but in many places forty feet in thickness, of quite homogeneous composition, and apparently inexhaustible. It has been much mined, but now only one opening is worked to any extent, which is the Buckwheat Field mine on the crook of the vein. Here is a monstrous opening, several hundred feet in length, forty in width, and seventy in depth, approached by a tunnel from the valley of the Walkill River a distance of a thousand feet, and by ladders up its side. There is a shaft about a hundred feet deep in the opening and ramifies out into the vein. Opening from the north is a huge grotto where they are now taking out ore. The entrance to this part of the vein was barred by a huge dike, apparently the end of the vein, it being forty-five feet in thickness, and at right angles to the vein. Behind it the continuation of the vein was found; the grotto having assumed large dimensions by the removal of the ore, which is composed of zincite, franklinite, and willemite, or green anhydrous silicate of zinc, besides some minor constituents. When mixed with lime and distilled, the oxide of zinc distills off, the silica of the willemite combines with the zinc, and the oxide of zinc, thus freed from its silica distills also, and thus this otherwise useless product is valuable. The mining is very simple here; compressed air drills are used; the ore blasted out with giant powder, placed on cars, and drawn by donkeys through the tunnel to a small platform, where it is weighed and dumped directly on the cars for shipment to the company's works at Newark or to Jersey City. An engine for hauling ore from the mine below the opening to the donkey cars and for compressing the air for the drills is the only machinery employed besides a small mine pump below the opening.

THE BEST METHODS OF ESTIMATING THE FOREIGN CONSTITUENTS OF IRON.

A. TAMM contributes the following paper on analytical method to the *Jernt. Kont. Annaller:*

Carbon.—In England and Germany the carbon is usually estimated by dissolving the iron in ammonio-chloride of copper, collecting the insoluble residue on an asbestos filter, drying and burning it in a combustion tube. The carbonic acid formed is collected by absorption in caustic potash, and then weighed. In Freiberg the carbon is oxidized with chromic acid instead of oxygen, which requires more practice. In France the iron is dissolved in mercuric chloride, according to Boussingault's method.

By the English method 300 grammes of ammonic chloride of copper is dissolved in 1 liter of water, and 50 c. c. of this solution is taken for every gramme of iron. In the analysis of cast iron, at least 2 grammes must be dissolved, and in wrought iron 5 grammes. The solution takes place in half an hour if gently warmed and stirred, a few drops of hydrochloric acid being added. The total carbon remains. In most cases an estimation of graphite is unnecessary; but for this purpose the iron is generally dissolved in nitric acid, and the silica and graphite which are left are burned to carbonic acid. For exact estimations of graphite the Swedish iodine method is preferable.

Silicon.—It is estimated in England and America by dissolving in aqua regia or nitric acid, and evaporating it down with sulphuric acid, especially if there is much silica. In Creuzot and Terrenoire the pulverized iron is oxidized by moistening with nitric acid and igniting in a muffle, then heating in a current of oxygen and subsequently in dry hydrochloric acid gas, so as to convert it into perchloride of iron, which can be sublimed, leaving the silica behind to be subsequently purified.

Phosphorus.—Most of the methods of estimating phosphorus convert it into the yellow molybdate compound. From 1 to 3 grammes of iron are dissolved, either in nitric acid to which hydrochloric acid is then added, or in a mixture of both acids, more rarely in nitric acid alone. The first is the best and most common. In England equal parts of nitric acid (spec. grav. 1·4) and hydrochloric acid (spec. grav. 1·19) are employed. For precipitating phosphoric acid the ammonium molybdate solution may be acid, alkaline, or neutral; yet an acid solution is preferable, as it better prevents the separation of molybdic acid. [The presence of an excess of ammonium nitrate is an advantage.—*Ed.*] The magnesia method is not to be recommended, on account of the large quantity required and its circumstantiality.

Sulphur.—For the estimation of sulphur, aqua regia is used to dissolve the iron, and this converts the sulphur into sulphuric acid, which is precipitated by barium chloride. Some chemists convert the sulphur into sulphureted hydrogen. In Freiberg the gases are passed into hydrochloric acid containing bromine, and then precipitated with barium chloride. Pattinson leads the gases into ammoniacal chloride of cadmium, the precipitated sulphide of cadmium is oxidized to sulphate by means of bromine acidified with hydrochloric acid, and then precipitated with barium chloride. The gases may also be passed into acetate of lead, sulphate of copper, or nitrate of silver. Rollet, in Creuzot, passes a current of purified hydrogen mixed with one-third its volume of carbonic acid through the pulverized iron heated to redness. When there is a large quantity of sulphur, he passes the gases into nitrate of silver and precipitates sulphide of silver. If there is but little sulphur, he passes it through a row of bottles, each of which contains 2 c. c. of a nitrate of silver solution of such strength that the silver corresponds to 0·0004 gramme of sulphur, or exactly 0·01 per cent. of the 4 grammes taken for analysis. The number of bottles precipitated gives the percentage in hundredths.

Manganese and Iron.—For the estimation of manganese and its separation from iron, ammonium acetate is commonly employed in England and Belgium, while sodium acetate is used in Germany, France, and Sweden. In England the percentage of iron is generally found by titrating with bichromate of potash, but in Germany, France, and Belgium (and America) the permanganate is used. In the presence of perceptible quantities of titanic acid, sodium sulphide can be used to reduce the iron, as it has no action on the titanium. In Sweden the crucible test is still in use, as it also gives much other valuable information. It gives the percentage of cast iron, not of pure iron, but this is rarely required except in ores very rich in manganese.

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TABLE OF CONTENTS.