Hugh Lee Pattinson.

SALTS OF SILVER.

1 NITRATE
2 CHLORIDE
3 IODIDE
4 IODIDE & FERROPRUSIATE
5 DARKENED SILVER & IODINE
6 DAGUERREOTYPE PLATE
7 BROMIDE
8 FLUORIDE
9 PHOSPHATE
10 TARTRATE
11 BENZOATE
12 FORMOBENZOATE
13 BENZOATE HYD. BENZULE

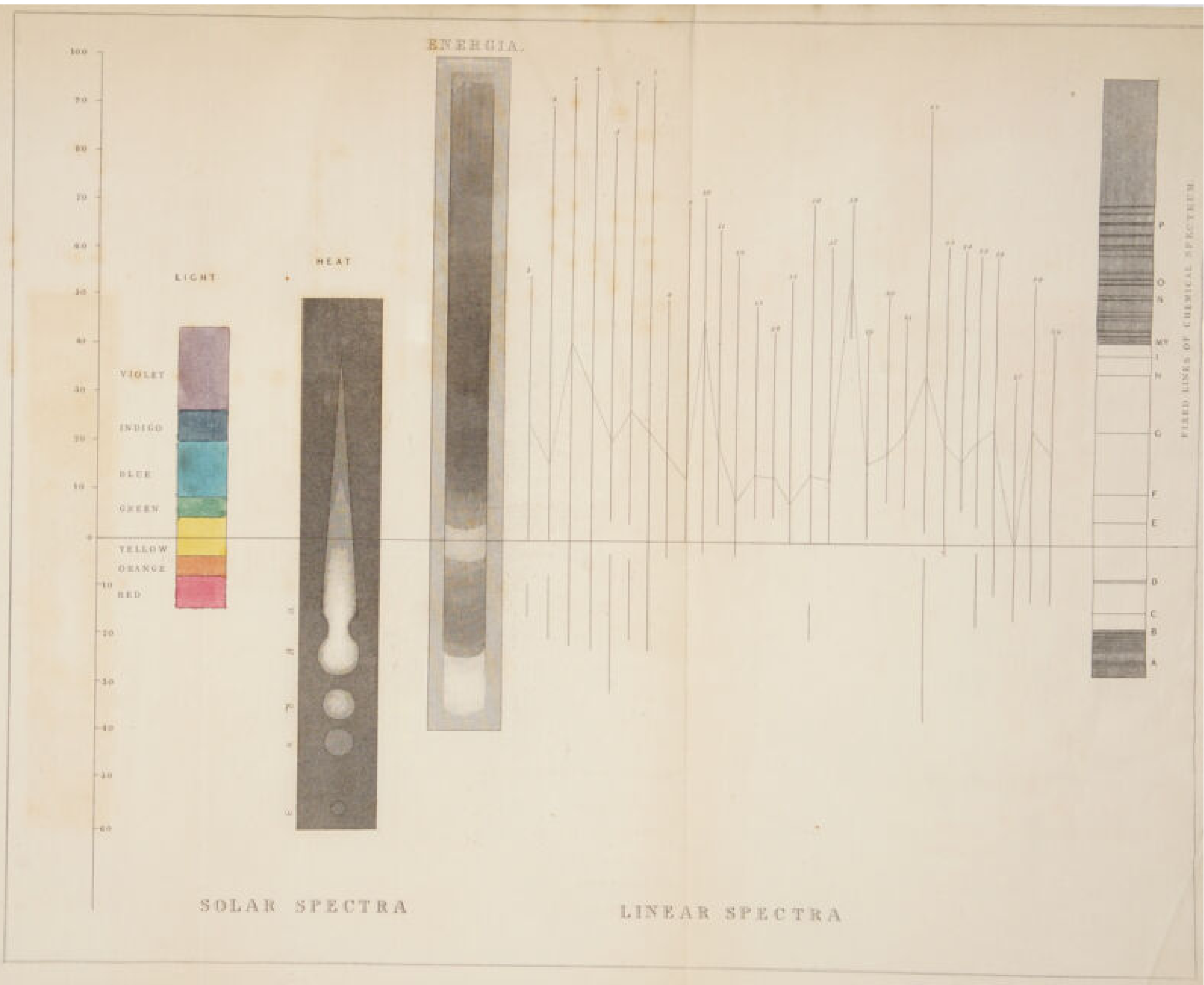
SALTS OF GOLD.

14 CHLORIDE
15 PROTOCYANIDE OF POTASSIUM
16 PROTOCYAN. & FORMOBENZOATE
17 DO. & AMMONIA
18 PERCYANIDE OF GOLD & AMMONIA

19 PLATINUM CHLORIDE
20 MERCURY CARBONATE
21 FERROCYANATE OF POTASH
22 DITTO & PERCHLOR IRON
23 CHROMATE OF COPPER
24 BICHROMATE OF POTASH

VEGETABLE COMPOUNDS.

25 GUM GUAIACUM
26 CORCHORUS JAPONICA
27 TEN WEEK STOCKS
28 WALLFLOWERS
29 GREEN OF LEAVES



RESEARCHES

ON

L I G H T:

AN EXAMINATION OF

ALL THE PHENOMENA CONNECTED WITH THE CHEMICAL AND MOLECULAR CHANGES

PRODUCED BY

THE INFLUENCE OF THE SOLAR RAYS;

EMBRACING

ALL THE KNOWN PHOTOGRAPHIC PROCESSES, AND NEW DISCOVERIES IN THE ART.

BY

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PREFACE.

The accumulation of facts in that department of science which immediately considers the chemical changes produced by the solar rays, has been so great, that the necessity of collecting and collating them, has been felt by all who were in the least degree interested in the progress of the inquiry. Whether I have executed this task satisfactorily or otherwise, is for the public to decide. I have endeavoured, as this is the first History of Photography which has been published, to give to every one his full share in these discoveries, which have accelerated the advancement of that art; and although in many cases my interpretation of phenomena may differ from that given by the observers themselves; in all, I have been most careful to adhere to their own expression of the facts.

I have, throughout the principal portion of this work, laboured under the difficulty of being obliged to speak of photographic phenomena as resulting from the agency of Light, being at the same time fully satisfied that they were to be referred to a principle which possessed none of the characters of Light or Heat, but which was intimately mixed with these elements in the solar rays. This subject is fully discussed in the third division of the volume; but I refer to it now, for the purpose of explaining, that the implied contradiction is only a submission to the generally received idea, for the purpose of rendering the inquiry intelligible to every reader.

It is due from me, that I acknowledge the kind and generous assistance which, through every stage of these experimental inquiries, I have received from Sir J. F. W. Herschel. The readiness with which that philosopher has communicated his discoveries, and the free and candid manner in which he has favoured me with his views, claims this expression of my feelings, as the only way in which I can sufficiently show, the value at which I estimate his liberal endeavours to assist a very humble experimentalist, in a path of inquiry in which, by his own laborious and ingenious researches, he has established his high pre-eminence. To Professor Wheatstone I am also indebted for some valuable matter connected with the early history of Photography.

ROBERT HUNT.

Falmouth, March 11. 1844.

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INTRODUCTORY CHAPTER.

PROGRESS OF THE INQUIRY UNTIL THE ANNOUNCEMENT OF THE DISCOVERIES OF M. DAGUERRE AND MR. HENRY FOX TALBOT.

(1.) INVOLVED in mystery as every thing is which is connected with the early history of our planet, I should be entangling my subject with useless and abortive speculations, did I venture to offer any on those passages of the Mosaic history which narrate the creation of Light, and of the orbs of the firmament. We there find Light the creation of the first day; and the Sun, which we are accustomed to regard as the source from which light emanates, or the exciting mover of the luminiferous ether, as the creation of the fourth period. Regarding this, our only record of the beginning, as the true expression of the sequence of events, it does not appear to me that we are required to interpret this revealed word to our finite apprehensions. The origin of things is lost in the sepulchral darkness of the antediluvian ages, into which the eye of the most gifted cannot penetrate. The Pentateuch declares in sublime conciseness, *And God said, Let there be Light, and there was Light;* which most distinguishingly marks the importance of this element in the great system of Nature. The grass, the herb yielding seed, and the fruit-tree yielding fruit, owe their growth, their glowing colours, and their serene beauty, to the influences of light. The moving creatures of the waters—the fowl that fly above the earth in the open firmament of heaven — the cattle — the creeping thing and the beast, are all of them directly dependant for healthful vigour, and almost for the continuance of life, on this mighty creation, which appears to have given form to the chaotic earth, as it chased the darkness from the face of the deep.

(2.) An agent influencing every form of animate and inanimate creation, would necessarily excite the attention of the earliest races. As it is by the agency of light, operating through the wonderful mechanism of the organ of vision, that a most extensive and important class of impressions are made upon the mind of man, he has, from the infancy of his days, regarded its source with feelings of wonder; and the Sun has been the object of his untutored adoration.

(3.) The uncultivated inhabitant of the wilds of nature has his moments of contemplation; and then his thoughts, travelling in the misty labyrinth of his ignorance and superstition, shadow out a great primary cause, to which he refers all the mysteries of that mighty universe of which he finds himself a proud inhabitant.

The nomadic tribes of the Caucassian valleys, clothed with a luxuriant vegetation, and teeming with life, could but observe the peculiar obedience of organised creation to the influences of the changing seasons. The pastoral state, was one peculiarly adapted to the nourishment of those powers of the mind, which elevate the individual or the mass; and in the shepherd-kings we may see the dawning brightness of the reign of reason, which in a later day gave to a small nation the sovereignty of the known world. Men in this condition could not long remain ignorant of the dependance of all the phenomena of vegetation upon Light. The growth of the plant, the unfolding of the leaf, the formation of the flower, of the fruit and of the seed, were soon found to be under the influence of the orb of day. In spring and summer nature was seen to grow into strength and beauty, and in autumn and winter it was seen to decline and indeed to die. Some connection between these phenomena, and the increasing and declining powers of the sun, must at an early period have been evident to man; and when the innate consciousness of a creative power was struggling, like the lustrous moon amidst the clouds of midnight, in their simplicity they gave to that orb the attributes of a god. The earliest religions of the Oriental races all bear evidence of this; and the mythology of the Greeks, rich with the poetry of Nature, places one deity at the head of their polytheistic system —the God of Heaven and of Light. In Baal and Astarte—in Zeus and Hera—in Apollo and Athena—we see alike, impersonations of Light the eternal renovator, and of Nature flourishing and decaying.

(4.) In those early days all the evident truths were viewed through a veil, which no one dared to draw aside, or dreamed of lifting up. A beautiful poetry overspread creation, and the spirit of life was seen and worshipped in the highest and the lowliest things.

At length a philosophic spirit grew in the mind of man, and young Science presumed to lift his daring hand. His early efforts were, however, "like the gropings of the blind Cyclops in his cavern;" and when searching for truth he too frequently wandered from it.

(5.) It does not appear that the phenomena of Light ever received much attention from the ancient philosophers. In their first attempts even to explain vision, they gave to the eye a power of projecting material rays, by which the forms and visible qualities of bodies were *felt out;* but they were at length induced to abandon this absurdity, and adopt the idea of Light as a peculiar medium, through which impressions were made on the eye, but in what manner was left quite undetermined. The heating power of the sun's rays could not escape notice; and the story of the mirrors of Archimedes sufficiently prove that some attention had been paid to this property.

The task of developing the progress of the beautiful science of Optics, is not the one to which I have to devote my attention, but to that very extraordinary property of the solar beam, by which chemical changes of the most singular kind are brought about, in living and in dead matter, in organic and inorganic bodies.

(6.) Although the most ordinary observer must through all time, have noticed that the sun's rays weakened and destroyed colours, yet this fact excited no attention; and it was reserved for the philosophers of our own time, to show that the attentive study of this peculiar property of Light, tends not merely to improve our perceptions of the beautiful, but leads to the discovery of some of the most important truths connected with the philosophy of the senses, and the secret operations of animal and of vegetable life.

(7.) At an early period the beauty of crystalline gems attracted attention; and the great demand there was for them, for the purpose of adorning the person, made the search after them a very lucrative employment. As many of these precious stones possess the property of shining in the dark, and of glowing with extraordinary brilliancy in certain positions, it became a matter of conjecture, if they shone with their own light, or if it was, that they again poured out light which they had the power of absorbing. Several Italian and other writers on this subject, particularly Boetius de Boot, say, "No man ever durst aver he had actually seen that stone that of itself afforded light."

That eccentric and extraordinary genius Benvenuto Cellini, however, affirms, in his Treatise on Jewelry, that he has seen the *carbuncle glowing like a coal with its own light.* The only advantage gained by this discussion was, that it led some to endeavour to prepare substances, which should possess the property of emitting light in the dark; and curiosity was at length gratified by the discovery of the *Phosphorus hermeticus*, of *Balduinus*, and of the *Bolonian Stone*, of which the peculiar properties will be mentioned under the proper head.

(8.) Amidst all the error and charlatanry of the alchymists, we find many important observations and really great discoveries. Amongst these empirical philosophers were men gifted with minds of a superior order, and the exceedingly careful experiments made by them, whilst they were endeavouring to torture the base metals into gold, and to distil the Elixir Vitæ, became the guiding lights to modern science. In 1556 it was noticed that horn silver was blackened by the sun's rays; and other peculiar influences which the alchymists observed, led them to fancy that the subtile element Light, was one of the most important agents in giving to Nature her infinite variety of form. Possessed with the idea, borrowed from the ancients, that all matter was compounded of three or four simple elements, many of these industrious experimentalists regarded Light as the great primary cause, which modified their salt, sulphur, and mercury, and transmuted them into the precious metals, or the myriad forms of organic matter. A notion, indeed, somewhat similar to this prevailed amongst the ancient philosophers, for Democritus speaks of minute atoms in swift motion, which, by their smallness and rapidity, were able to permeate the hardest bodies. "The sun's rays," says Homberg, "will insinuate themselves into bodies so as greatly to increase their weight;" and he seriously relates that four ounces of Regulus Martis, in powder, were augmented by $\frac{1}{10}$ in the balance, by being exposed for an hour at the distance of a foot and a half from the focus of the Duke of Orleans's burning-glass, notwithstanding much of it was dissipated in smoke: the absorption of oxygen was, of course, unknown to the ingenious Homberg. It will be interesting to review a few more of his assertions connected with this part of the subject. "A perfect metal," he says, "is nothing but very pure mercury, whose small particles are every way pierced and filled with sulphureous principle, or the matter of Light, which links and binds the whole mass together." "Gold," Homberg also says, "differs from silver in nothing but in having the globules of the mercury, whereof it consists, penetrated through and through, and being more fully saturated with the sulphureous principle, or the rays of Light." "The Light of the sun," he continues, "impinging against terrestrial bodies, modifies them according to their several textures; the luminous matter insinuates itself into the substance of bodies, to produce their sulphur, changes the arrangement of their parts; increases them, and consequently alters the substance of the body itself, after as many different manners as in different quantities it can be differently placed. So that, would we compare the variety of the materials which exist with those which might be brought into being, by all the combinations possible to be made, we must say that the universe, so far as we know of it, is but very small in comparison of what it might be; and that if there were several worlds, formed like this of ours, they might all be differently furnished with objects, without changing either the manner or the matter of the bodies whereof they should consist; which demonstrates an infinite contrivance and power in the Being who made the universe."*

(9.) The same idea was entertained by the illustrious Newton; but he lends to the speculation all that refinement which distinguishes his philosophical investigations. Sir Isaac Newton demands whether "gross bodies and Light are not convertible into one another; and may not bodies receive much of their activity from the particles of Light which enter into their composition? For all fixed bodies, being heated, emit Light so long as they remain sufficiently heated; and Light mutually stops in bodies as often as its rays strike upon their parts."

(10.) The errors which pervaded the chemical philosophy of this period, are too evident to the modern reader, to require any comment, beyond the simple remark in explanation, that the sulphur, salt, and mercury, mentioned by Homberg, are not the gross bodies to which these names are now applied, but certain subtile agents, supposed to be possessed of acid, alkaline, and metallic properties.

The hypothesis of Homberg, and the question of Newton, both exhibit striking proofs of remarkable penetration, and give evidence of minds which were

* French Memoirs, from 1700 to 1705.

struggling to burst through the materialities which a wretched empiricism had crowded around the philosophy of their times. They perceived agencies at work in the great laboratory of Nature, which could not be brought under the cognizance of the senses; and in the mighty struggle of their gigantic minds, a light, as it were of inspiration, appears to have been granted them. The hypothesis of the early chemist has become truth to one of the most eminent modern physicists: and let us restrain the railroad speed of the science of our day, gliding as it does too commonly over the easiest paths, and viewing in its rapid transit the surface merely, by the reflection that the question asked by Newton remains still unanswered.

A widely diffused and most ably supported theory is at variance with these doctrines; but until theory is indisputably established, we must not allow it to be forced upon us for fact.

(11.) I cannot quit this part of my subject without referring to some of the speculations of the talented, though credulous Boyle. I do this, not with any idea of supporting his views, which I regard as visionary to a certain extent, but for the purpose of showing, that long before inductive science had proved the chemical agencies of the different rays of the prismatic spectrum, the curiosity of gifted minds had led them very nearly to the truth. In the "Memoirs for a General History of the Air," we find the following very remarkable passages, which, although to a certain extent an apology for astrology, are full of suggestions; and, to use Boyle's own words, "wholly to neglect the physical use of the motion of these bodies (the planets), because superstition has crept in, is very extravagant, and ought not to pass uncensured in men of learning:"—

"Thus every planet," says the Honourable Robert Boyle, "has its own proper Light distinct from that of the others, which is either a bare quality, and then its utmost use and design is only to illuminate, or else all Light is attended with some peculiar power, virtue, or tincture; whence 'tis plain that every Light has its peculiar property, tincture, and colour—its own specific virtue and power, wherein the planets differ from each other; and consequently the celestial bodies are not to be considered as sluggish and unorganised matter, but as full of their proper motion, operation, and life. Thus the sun not only shines upon all the planets, but by his genial warmth calls forth, excites, and raises the motions, properties, and powers peculiar to them: whence, according to the angle they make with that grand luminary, and the degree wherein they are enlightened, either by its direct or oblique rays, in a near or remote situation in respect of the earth, must be more or less perceived by us. As for the manner wherein the planets transmit their powers, and thereby affect the remote bodies, 'tis not difficult to apprehend it; for we affirm no virtue or power to flow from the planets that comes not along with the Light as a property thereof.

* * * * * *

"As the other planets, so also our earth, is not only enlightened, warmed, cherished, and made fruitful by the power, virtue, and influence of the sun, but it hath, moreover, its proper, magnetical, planetary force awakened, fermented, excited, and agitated, which it sends back with the reflected Light of that luminary."*

I also find in the same Memoir some notices of the

* Boyle's Works, vol. iii. p. 39.

Oriental tradition, that the rays of the moon exert a baneful influence upon persons exposed to them. That timber trees, and many plants are materially influenced by the Light of the moon appears, from a very early period, to have been a generally-received notion.

(12.) Notwithstanding these remarkable agencies, which were supposed to be dependant upon some peculiar principle of Light itself, it does not appear that any experimental evidence of value was gained up to this period. It is clear that the early experimentalists above named, knew not how to distinguish the operations of Light, Heat, and Electricity from each other; nor indeed did they separate these from the simple phenomena of chemical attraction. They accumulated a large amount of curious facts,—effects depending on very diversified causes, all of which were attributed to that *element* which the author was inclined to regard as the most important and active in his scheme of creation, and the progression of life, to the rejection of any other power.

(13.) A more extensive record of observations now opens before us. In 1722 Petit showed that solutions of saltpetre (nitrate of potash) and sal ammoniac (muriate of ammonia) crystallised more readily in the Light than they did in darkness. Charles William Scheele of Stralsund, in Swedish Pomerania, one of the most brilliant geniuses of his, or of any age, was the first who analysed the action, and studied the influences, of the differently-coloured rays of Light. He discovered that the chloride of silver spread on paper was speedily darkened in the blue rays, whilst the red rays produced but very little or no change.* Senebier, who repeated the experiments of Scheele, states that he found the

* Scheele, Traité de l'Air et du Feu.

violet ray to darken the chloride of silver in fifteen minutes, while the red rays required twenty minutes, and the other colours various intermediate periods.*

(14.) Dr. Priestley was the first to call attention to the fact, that, under the influence of Light, plants emitted considerable quantities of oxygen gas, and absorbed carbonic acid: thus pointing out one of the most remarkable instances, of the beautiful order which is observed in all the works of Nature. Priestley's experiments were confirmed by those subsequently made by Percival, Henry, Ingenhousz, Senebier, and Saussure. Many of the experiments of these philosophers were not so strictly accurate as might have been desired; but the researches of those who have followed them in this path of inquiry, have all tended to confirm most of their results. A future chapter will be devoted to a survey of the very interesting phenomena connected with the respiration of plants, and the influence of the solar rays upon them during the various stages of their growth.

It became about this time, the latter part of the eighteenth century, a question, whether the observed chemical changes were produced by the Light, properly so called, of the solar rays, or by the heat which accompanied it.

(15.) Count Rumford, in a Memoir "*On the Propagation of Heat in Fluids*," published in the Philosophical Transactions, states, that he saw reason to doubt the existence of those chemical properties in Light which had been attributed to it; and, to conclude, that all those visible changes produced in bodies by the action of the sun's rays, were effected merely by the

* Senebier sur la Lumière, tom. iii. p. 199.

heat which is generated or excited by the Light which is absorbed by them. In 1798 this distinguished philosopher communicated to the Royal Society a Paper, entitled "*An Inquiry concerning the Chemical Properties that have been attributed to Light.*" The experimental investigations recorded in this memoir are important, and particularly interesting, as marking the progress of the inquiry.

Count Rumford found that gold or silver might be melted by the heat—invisible to sight—which exists in the air at the distance of more than an inch above the point of the flame of a wax candle. He then proceeded to examine what would be the effect of this heat on the oxides of these metals. Having wetted a piece of taffeta riband with a saturated solution of the chloride of gold, it was held, stretched horizontally, over the clear bright flame of a wax candle, the under side of the riband being kept at the distance of about an inch and a half above the point of the flame: that part of the riband which was directly over the point of the flame began almost immediately to emit steam in dense clouds; and, in about ten seconds, a circular spot, about three quarters of an inch in diameter, having become nearly dry, a spot of a very fine purple colour, approaching to crimson, suddenly made its appearance in the middle of it, and, spreading rapidly on all sides, became, in one or two seconds more, nearly an inch in diameter. The hue was not uniform, but varied from a light crimson to a very deep purple, approaching to a reddish brown. No traces of revived gold could be discovered, but the riband had all the appearance of being covered with a thin coating of the most beautiful purple enamel, which, in the sun, had a degree of brilliancy that was sometimes quite dazzling.

Whatever material was saturated with the solution of gold, the same stain was produced by the agency of a strong heat; and it was found that solutions of silver, under similar circumstances, imparted stains of a deep orange colour. It was ascertained by several trials that the *light* of the candle produced no change, the decomposition of the salts of gold and silver in these experiments being solely effected by the agency of *heat*.

(16.) Count Rumford next proceeded to examine what influence was exerted by the direct solar rays. Pieces of riband were wetted, and parcels of magnesia moistened, with a solution of gold: those which were exposed to the strong Light of the sun gradually changed colour, and in a few hours acquired a fine purple hue, whilst those preserved in darkness remained unchanged. It was also found, that the decomposition was more readily brought about, when the riband or the magnesia were exposed in a damp state, than if the solution was permitted to dry on them previous to exposure.

(17.) Arguing from the facility with which most of the metallic oxides are reduced, by means of charcoal when exposed to a high temperature, that gold might be revived from its solutions in the same manner, if the solution and the charcoal were equally exposed to a sufficient degree of heat, Count Rumford instituted some experiments to put this idea to the test. He found, by putting small pieces of charcoal into a glass tube filled with solutions of gold or of silver, and exposing it to a temperature of 210° Fahrenheit for two hours in the dark, that revived gold adhered to the surface of the charcoal. Similar tubes filled with solution of gold or of silver and fragments of charcoal were exposed to the direct rays of a very bright sun, and in less than half an hour small specks of revived gold, in all its metallic splendour, appeared on the surface of the charcoal. Etherial solutions of gold were found to be decomposed by the solar rays, and even by prolonged exposure to diffused Light. Spirits of turpentine and olive oil were mixed with aqueous solutions of gold and silver, and exposed to heat in a steam apparatus: both of them assisted in reviving the metals, but spirits of wine had no such influence, notwithstanding the presence of carbon, which enters nearly as largely into its composition as it does into the composition of the other two.

(18.) From these results Count Rumford concludes, that heat is generated by the absorption of the sun's rays; that at the moment of its generation it exists in almost infinitely small spaces; and consequently it is only in bodies that are inconceivably small that it can produce durable effects, in any degree indicative of its extreme intensity.

(19.) It must not be forgotten that Beckman found that, by exposing phosphorus in nitrogen and other gases, there was deposited upon the side of the glasses opposite to the Light a coloured powder, whilst no such effect was produced upon the parts in shadow. In 1801, Ritter, of Jena, repeated the experiments of Scheele, and demonstrated the existence of solar rays possessing very powerful properties in producing chemical change, which do not act sensibly upon the organs of vision, or which, in other words, are not Light-giving rays. Ritter found that the muriate of silver darkened rapidly beyond the violet extremity of the prismatic spectrum. In the violet ray it was less darkened; still less in the blue; below which ray the power of darkening diminished quickly. He also noticed that the red ray had the power of restoring darkened muriate of silver to its original colour; and hence concluded that there are two sets of invisible rays, one on the red side of the prismatic spectrum, which favours oxygenation, and the other on the violet side, which assist disoxygenation. Ritter also states, that he found phosphorus to emit white fumes in the invisible red rays, but that no such effect was produced by the invisible violet rays. Many of Ritter's experiments appear to have been illusive, although some of his conclusions are found to be correct.

(20.) In the same year, Labillardiere, in a Paper read before the Philomatic Society, brought forward some experiments to prove that Light was necessary for the development of pores in plants. He states, that blanched plants have no pores; that cresses which were grown in powerful artificial Light had not more than half the number which was found in those plants which had grown under the influence of daylight; and that the coats of bulbous roots have no pores on the parts which were below the ground, whilst they are found abundantly on the parts exposed to the sun. Victor Michellotti, of Turin, published a Paper on the Vitality of Germs, in which he showed that Light is injurious to young plants, and also to young animals. In 1806, Vogel exposed fat, carefully protected from the influence of the air to Light, and it became in a short time of a yellow colour: it acquired a rancid penetrating smell and a bitter taste, producing a burning sensation in the throat; whereas that which was open to the air, during exposure, always became acid. The same observer found that ammonia and phosphorus exposed to the sun's rays were rapidly converted into phosphuretted hydrogen and a black powder—phosphuret of ammonia. Vogel also noticed that the red rays of the prismatic spectrum produced no effect upon a solution of corrosive sublimate (bichloride of mercury) in ether, but that the blue rays rapidly decomposed it. He also observed that the decomposition of several metallic compounds was gradually brought on by the same class of rays.

(21.) It now becomes necessary that we should direct our attention to some most interesting and important discoveries of Sir William Herschel on the heating powers of the different rays of the prismatic spectrum. This is the more necessary, as it will be seen in the sequel, how difficult it is to determine the chemical powers of the different classes of rays, taking the common division of spectrum into chemical, luminous, and calorific rays.

In the Transactions of the Royal Society of London for 1800, Dr. Herschel's Memoirs on the heating power of the Solar Spectrum will be found. Previously to this time it was supposed that each ray contributed its proportional share to the intensity of the heat which is produced by the concentration of the sun's rays in the focus of a burning-glass. Dr. Herschel was, however, led to suspect that this was not the fact, from the following circumstances:—"In a variety of experiments," says this philosopher, "which I have occasionally made, relating to the method of viewing the sun with large telescopes to the best advantage, I used various combinations of differently coloured darkening-glasses. What appeared remarkable was, that when I used some of them, I felt a sensation of heat, though I had but little Light; while others gave me much Light, with scarce any sensation of heat. Now, as in these combinations, the sun's image was also differently coloured, it occurred to me that the prismatic rays might have the power of heating bodies very unequally distributed among them; and, as I judged it right in this respect to entertain a doubt, it appeared equally proper to admit the same with regard to Light. If certain colours should be more apt to occasion heat, others might, on the contrary, be more fit for vision, by possessing a superior illuminating power."

(22.) The experiments to determine the heating powers of the rays, consisted in passing each ray, through an opening in a piece of pasteboard, and placing delicate thermometers, with blackened balls, so that they could be irradiated with each particular colour. The result of these investigations proved, in the first place, that the red rays possessed a greater amount of heating power, than any other of the prismatic coloured rays; and, secondly, led to the discovery of "rays coming from the sun, which are less refrangible than any of those that affect the sight," and which have vested amongst them the maximum of the heating power.

"A beam of radiant heat, emanating from the sun," says Dr. Herschel, "consists of rays that are differently refrangible. The range of their extent, when dispersed by a prism, begins at violet-coloured Light, where they are most refracted, and have the least efficacy. We have traced these calorific rays throughout the whole extent of the prismatic spectrum, and found their power increasing, while their refrangibility was lessened, as far as to the confines of red-coloured Light. But their diminishing refrangibility, and increasing power, did not stop here; for we have pursued them a considerable way beyond the prismatic spectrum into an invisible state, still exerting their increasing energy, with a decrease of refrangibility, up to the maximum of their power; and have also traced them to that state, where, though still less refracted, their energy, on account we may suppose of their now failing density, decreased pretty fast; after which, the invisible *thermometrical spectrum*, if I may so call it, soon vanished."

Dr. Herschel determined that the invisible rays exerted a considerable heating power, at a point 1½ inch distant from the extreme red ray, even though the thermometer was placed at a distance of 52 inches from the prism.

(23.) These experiments were repeated by Sir Henry Englefield, with additional precautions against any source of error, and he found that the thermometer rose as follows:—

In the blue rays in 3′ from 55° to 56°, or 1°.
Green in 3′ from 54° to 58°, or 4°.
Yellow in 3′ from 56° to 62°, or 6°.
Full red in 2½′ from 56° to 72°, or 16°.
Confines of the red in 2½′ from 58° to 73½°, or 15½°.
Quite out of visible Light in 2½′ from 61° to 79°, or 18°.

(24.) M. Berard obtained similar results, excepting that he placed the maximum of heat at the very extremity of the red rays, instead of beyond them. These experiments were afterwards repeated by Sir Humphry Davy at Geneva, who confirmed the correctness of Dr. Herschel's experiments; and still more recently by M. Seebeck, who has shown that the place of maximum heat, varies with the substance of which the prism is made. Seebeck was assisted in his experiments by M. Wunsch; and they came to the following conclusions:—

Substance of the Prism.	Colour of Space in which the Heat is greatest.
Water - - - -	Yellow.
Alcohol - - - -	Yellow.
Oil of Turpentine - -	Yellow.

Substance of the Prism.	Colour of Space in which the Heat is greatest.
Sulphuric Acid	Orange.
Solution of Muriate of Ammonia	Orange.
Solution of Corrosive Sublimate	Orange.
Crown Glass	Middle of the red.
Plate Glass	Middle of the red.
Flint Glass	Beyond the red.

In the papers to which I have above referred, Dr. Herschel also describes his experiments to determine the illuminating powers of the different rays. He determined that the yellow and green rays afforded the greatest quantity of Light, and that the violet ray had the least. In conclusion Dr. Herschel asks, "May not the chemical properties of the prismatic colours be as different as those which relate to heat and Light?" How ably this question has been answered by his son, Sir John Herschel, will be hereafter seen.

(25.) Sir Henry Englefield, at the suggestion of Sir Humphry Davy, tried several experiments with respect to the power of the several coloured rays in rendering Canton's phosphorus luminous. It was found that the blue rays possessed that power in the highest degree, and there was reason to suspect that this power extended beyond the visible violet ray.

(26.) About this period Dr. Blackburne put forth a theory that Light was a compound of caloric and oxygen; but it does not appear to have found any supporters. In the consideration of the very remarkable phenomena connected with the changes produced by Light, it will be evident that the heat-giving rays, often very materially modify the results; hence the above sketch of the very interesting discoveries of Dr. Herschel will be found to be perfectly in place.

(27.) M. Seebeck repeated the experiments of Ritter, and he found that a *coloured* impression of the solar spectrum, was made upon paper spread with the muriate of silver. In and beyond the violet ray, it became a reddish brown; in the blue, it was blue or bluish grey; in the yellow, it was white or faintly tinged; and in and beyond the red, it was constantly red.

(28.) Dr. Wollaston, without knowing what had been done by Ritter, obtained the same results; and he also discovered some new effects, produced by Light upon gum guaiacum. Having made a tincture by dissolving this gum in spirits of wine, he spread some of it upon card-paper, slips of which were exposed to the differently coloured rays concentrated by a powerful lens. In the violet and blue rays the gum guaiacum acquired a *green* colour; in the yellow no effect was produced. In the red rays the gum already made *green* was restored to its original colour. The guaiacum card, when placed in carbonic acid gas, could not be rendered *green* by any of the rays, but was speedily restored from *green* to yellow by the red rays; which change Dr. Wollaston found, could be as readily produced by a heated silver spoon.

(29.) In June, 1802, Mr. Wedgwood, the celebrated porcelain manufacturer, published, in the Journals of the Royal Institution, " An Account of a Method of Copying Paintings upon Glass, and of making Profiles by the Agency of Light upon Nitrate of Silver; with Observations by H. Davy." This was certainly the first published account of any attempt to produce images by the decomposing powers of Light. It does indeed appear, that nearly about the same time M. Charles, in his lectures at Paris, proposed to make use of a prepared paper, to produce black profiles by the action of Light, but he died without disclosing the preparation which he employed.

Mr. Wedgwood made use of white paper, or white leather, moistened with a solution of nitrate of silver. Notwithstanding the imperfect character of his process, it is so very interesting, as the first attempt at producing pictures by Light, that I shall copy the author's description of it, and some of the remarks, from the Memoir:—

"White paper, or white leather, moistened with solution of nitrate of silver, undergoes no change when kept in a dark place, but on being exposed to the daylight it speedily changes colour, and after passing through different shades of grey and brown, becomes at length nearly black. The alterations of colour take place more speedily in proportion as the Light is more intense. In the direct beams of the sun, two or three minutes are sufficient to produce the full effect; in the shade several hours are required, and Light transmitted through different coloured glasses, acts upon it with different degrees of intensity. Thus it is found that red rays, or the common sunbeams, passed through red glass, have very little action upon it; yellow and green are more efficacious, but blue and violet Light produce the most decided and powerful effects. * * * * * * * * When the shadow of any figure is thrown upon the prepared surface, the part concealed by it remains white, and the other parts speedily become dark. For copying paintings on glass, the solution should be applied on leather, and in this case it is more readily acted on than when paper is used. After the colour has been once fixed on the leather or paper, it cannot be removed by the application of water, or water and soap, and it is in a high degree permanent. The copy of a painting or the profile, immediately after being taken, must be kept in an obscure place; it may, indeed, be examined in the shade, but in this case the exposure should be only for a few minutes; by the Light of candles or lamps, as commonly employed, it is not sensibly affected. No attempts that have been made, to prevent the uncoloured parts of the copy or profile, from being acted upon by Light, have as yet been successful. They have been covered with a thin coating of fine varnish, but this has not destroyed their susceptibility of becoming coloured; and even after repeated washings, sufficient of the active part of the saline matter, will still adhere to the white parts of the leather or paper, to cause them to become dark when exposed to the rays of the sun. Besides the applications of this method of copying that have just been mentioned, there are many others; and it will be useful for making delineations of all such objects as are possessed of a texture partly opaque and partly transparent. The woody fibres of leaves, and the wings of insects may be pretty accurately represented by means of it, and in this case it is only necessary to cause the direct solar Light to pass through them, and to receive the shadows upon prepared leather. * * * * * * The images formed by means of a camera obscura, have been found to be too faint to produce, in any moderate time, an effect upon the nitrate of silver. To copy these images was the first object of Mr. Wedgwood, in his researches on the subject, and for this purpose he first used the nitrate of silver, which was mentioned to him by a friend, as a substance very sensible to the influence of Light, but all his numerous experiments as to their primary end proved unsuccessful. In following these processes, I have found that the images of small objects, produced by means of the solar microscope, may be copied without difficulty on prepared paper. This will probably be a useful application of the method; that it may be employed successfully, however, it is necessary that the paper be placed at but a small distance from the lens. (*Davy.*) * * * In comparing the effects produced by Light upon muriate of silver with those produced upon the nitrate, it seemed evident that the muriate was the most susceptible, and both were more readily acted upon when moist than when dry, a fact long ago known. Even in the twilight, the colour of moist muriate of silver, spread upon paper, slowly changed from white to faint violet; though, under similar circumstances, no immediate alteration was produced upon the nitrate. * * * * * * * * * Nothing but a method of preventing the unshaded parts of the delineation from being coloured by exposure to the day, is wanting to render this process as useful as it is elegant."

The failure of two such eminent men as Wedgwood and Davy, in their attempts to produce Light-drawn pictures, appears to have discouraged any further experiments of this kind at that time in England.

(30.) In 1814, M. Niepcé, of Châlons on the Saône, turned his attention to the chemical agency of Light, his object being to fix the images of the camera obscura, and he appears to have discovered the peculiar property of Light in altering the solubility of many resinous substances. In 1824 M. Daguerre began a series of experiments with the same object in view. The first substances used by him, were, according to M. Arago, paper impregnated with a solution of the nitrate or chloride of silver, but his ill success induced him to abandon them. It is not, however, clear whether any other substances or materials were used by Daguerre previously to 1826, when, through a Parisian optician, he became acquainted with M. Niepcé. In 1827

M. Niepcé was in England, and in the December of that year he communicated* an account of his experiments to the Royal Society of London, together with

* Through the kindness of Professor Wheatstone, I am enabled to add the following letters, written to Mr. Bauer, which will serve to show the progress made by M. Niepcé at this date: —

No. 1.

Monsieur, Kew, le 19me Novembre, 1827.

Lorsque j'ai quitté la France pour me rendre ici, je m'occupais de recherches *sur la manière de fixer l'image des objets par l'action de la lumière.* J'avais obtenu quelques résultats que je me suis empressé de faire venir. Je désirerais qu'il pût vous être agréable de les voir. Votre suffrage, Monsieur, si toute fois j'en étais digne, me flatterait infiniment, et je me féliciterait d'avoir fait naître une circonstance qui devait me procurer l'honneur de vous connaître.

NICÉPHORE NIEPCÉ.

No. 2.

Monsieur, Kew, le 22me Novembre, 1827.

J'ai l'honneur de vous adresser une petite notice sur les recherches qui m'occupent. Elle n'aura pas l'inconvénient de fatiguer par sa longueur; mais je ne sais si elle remplira bien son objet. Il m'eût été pourtant difficile de m'expliquer d'une manière satisfaisante sur certains détails, sans compromettre mon secret. J'ai donc dû me borner à quelques considérations relatives aux perfectionnemens que réclament mes timides essais aux yeux de la critique, même la plus indulgente. Si cependant, Monsieur, vous en jugiez autrement, j'ose compter assez sur votre bienviellant intérêt pour vous prier de me faire connaître votre opinion à cet égard, et je m'y conformerai. Je désire vivement que ma découverte mérite de fixer l'attention de la Société Royale, et que dans ce cas, sa décision ne me soit pas défavorable, parceque alors je n'éprouverait probablement plus de difficulté pour faire parvenir mon hommage au pied du trône. C'est sous ce double rapport, Monsieur, que la recommandation et l'appui d'une person aussi influente que M. le Vice-Président de la Société, me seraient infiniment utile. Vous voudrez donc bien me several pictures on metal plates, in the state of advanced etchings, the etching being effected by acid, subsequent to that part of the process, in which Light assisted in

permettre de me rappeller aussi là-dessus à votre obligeant souvenir. Nous nous proposons d'avoir l'honneur de vous voir après demain, si toute fois notre visite ne vous dérange pas.

NICÉPHORE NIEPCÉ.

No. 3.

Monsieur, Kew, le 30me Novembre, 1827.

Je m'empresse de vous faire passer plus tôt que plus tard mes essais de dessin et de gravure d'après mes procedés *héliographiques*. Veuillez avoir la complaisance de me faire prévenir de l'arrivée de M. votre collègue; je serais, on ne peut plus, flatté de le voir, et de m'entretenir quelques instans avec lui. Mon intention ainsi que j'ai eu l'honneur de vous le dire hier, relativement à la présentation de mes essais, est simplement d'obtenir de la Société Royale un avis qui ne soit pas défavorable au résultat de ma démarche subséquente. Je pense, Monsieur, que cette démarche, c'est à dire, l'hommage de mon découverte à sa Majesté Britannique, ne m'empêcherait pas de m'adresser ensuite à la Société des Arts: je la désirerais puisque c'est là principalement où je pourrais trouver toutes les ressources qui me seraient nécessaires pour perfectionner et utiliser l'objet de mes recherches: je suis, en effet, bien décidé, dans ce cas, à leur donner suite ici plutôt qu'ailleurs. Pardonnez, je vous prie, mon importunité; elle a peut-être son excuse dans l'intérèt même que vous avez bien voulu de m'accorder.

NICÉPHORE NIEPCÉ.

No. 4.

Monsieur, Kew, le 28me Décembre, 1827.

En réfléchissant à l'obligeante attention que vous avez eu tout récemment, de faire donner communication de ma notice à Mr. le docteur Wollaston, et à un autre savant distingué, j'éprouve un vif regret de ne l'avoir pas su plutôt; mais les bonnes inspirations ne viennent jamais trop tard, lorsqu'il y a encore possibilité d'en profiter. Je désirerais donc savoir si, par votre médiation, Monsieur, je pourrais espérer d'obtenir une lettre de recommandation qui me laying bare portions of the resin-covered plate. These early productions prove, that the experimentalist of

mît en rapport avec ces savans. Je verrais du moins, dans le véritable intérêt qu'ils portent à la science, le gage certain de celui qu'ils pourraient prendre à ma découverte; et ce résultat seul, serait déjà quelque chose de très-flatteur pour moi. Mais peut-être seraient-ils eux-mêmes à portée de me procurer la connaissance de quelques unes de ces personnes vouées par goût au culte des arts, et plus dans le cas, par leur grande fortune, de les protéger utilement, que des artistes voués presque exclusivement à un autre culte. Cette réflexion, Monsieur, me ramène à la démarche qu'on vient de me faire faire, et dont je ne puis que fort mal augurer. Aussi serais-je charmé que vous voulussiez bien consentir à celle que j'ai l'honneur de vous proposer. Je me féliciterais d'autant plus qu'elle réussit, que je me plais à la regarder comme une heureuse inspiration du constant intérêt que vous avez daigné m'accorder jusqu'ici. Veuillez ne pas prendre la peine de m'écrire ; mais faites-moi dire seulement de passer chez vous, Monsieur, si vous le désirez, et je m'empresserai de m'y rendre. J'attends, au premier jour, une reponse décisive de Mr. Watkins ; et en cas qu'elle ne soit pas satisfaisante, ainsi que j'ai lieu de le presumer, je m'occuperais de suite de la nouvelle démarche, qui serait très-probablement la dernière.

N. Niepcé.

No. 5.

Le 17me Janvier, 1828.

J'ai écrit hier à Mr. le Docteur Wollaston : j'attends de réponse ce soir.

No. 6.

Châlons-sur-Saône, le 10me Mars, 1828.

[Refers wholly to private matters.] Nous sommes arrivés ici le 26 e Février.

No. 7.

Châlons-sur-Saône, le 4me Mai, 1828.

J'ai pris, durant notre séjour prolongé à Paris, mes mesures de précaution en me procurant tout ce qui pouvait m'être nécessaire

Châlons was acquainted with the method of making the shadows and lights of his pictures, correspond with

pour la continuation de mon travail. J'ai fait construire par l'opticien Vincent-Chevalier, un objectif achromatique qui donnera infailliblement dans la chambre noire, plus de champ et plus de netteté aux images représentées. Il m'a confectionné pareillement, pour le même objet, un verre périscopique d'après le système de Dr. Wollaston. Je serai ainsi à portée de comparer et de juger lequel des deux procédés est le plus avantageux. Je n'ai pas négligé de voir M. Lemaître, graveur, et M. Daguerre: j'ai eu avec eux plusieurs entrevues, et ils m'ont bien recommandé de profiter de la belle saison pour donner suite à mes recherches. M. Lemaître m'a dit obligeamment, que je pouvais disposer de son burin; il m'a même prié de lui envoyer quelques points de vue d'après nature, préparés sur cuivre, et il se chargera de les graver. J'ai reçu aussi de M. Daguerre beaucoup de témoignage d'obligeance, et surtout d'excellens conseils que je tâcherai de mettre à profit. Depuis mon retour ici, je n'ai plus eu de rapport avec eux; je ne me propose même de leur écrire que lorsque j'aurai obtenu un résultat décisif, si toute fois je puis m'en flatter. Quant à M. Daguerre, je ne sais d'ailleurs où le trouver; car il se disposait à faire quelques courses, ou plutôt quelques voyages, ce qui me porte à croire qu'il n'est pas à Paris dans ce moment. Quoique les nouveaux appareils auxquels je fais travailler ici ne soient pas encore disponibles, ça ne m'a point empêché, Monsieur, de reprendre mes expériences héliographiques d'après les moyens de perfectionnement indiqués dans ma notice. Je suis même déjà dans le cas de reconnaître que je ne m'étais point trompé dans l'appréciation de quelques uns de ces moyens appliqués, je ne dis pas à la gravure, mais au dessin d'objets vus dans la chambre noire. En parlant de ces dernières donnes, j'ai lieu de bien augurer de mes prochains essais de points de vue d'après nature, quoique ce genre de représentation soit sans doute ce qu'il y a de plus difficile, et que je ne prétende pas arriver ainsi d'emblée à la perfection. Voici le moment le plus favorable: la campagne est revêtue de tout l'éclat de sa parure; j'attends donc avec impatience que mes appareils soient prêt pour me mettre en mesure d'opérer. Si j'obtiens d'heureux résultats, j'aurai, Monsieur, le plaisir de vous en instruire, et de répondre même par là, j'en suis sûr, au vif intérêt que vous voulez bien prendre à l'objet de mes récherches. Dans ce cas, vous me permettrez aussi, je l'espère, those of nature, and of rendering his copies impervious to the erasing effects of the solar rays.

de vous offrir celui de mes nouveaux essais qu'on aura jugé plus de vous être présenté ; mais n'anticipons pas sur l'avenir : il y a souvent à celui du mécompte, et je sens que je me laisse trop entraîner par une illusion à laquelle le reconnaissance prête encore plus de charme.

N. Niepcé.

No. 8.

Monsieur, Châlons-sur-Saône, le 9me Janvier, 1829.

En continuant, comme je vous l'annonçais, mes recherches héliographiques, j'espérais toujours parvenir à un résultat décisif et digne, sous ce rapport, de vous être présenté. Cet espoir ne s'est point entièrement réalisé. Je dirai toute fois, avec la même franchise, que je suis aujourd'hui beaucoup plus rapproché du but qu'il me tarde d'atteindre. Vous vous rappellez peut-être, Monsieur, les moyens de perfectionnement indiqués dans ma *notice.* Je n'ai pas négligé d'en faire l'application ; et j'en augure trop bien jusqu'ici pour ne pas m'en occuper de nouveau, dès que le retour de la belle saison me permettra de reprendre mon travail. J'ai aussi reconnu, d'après quelques essais sur la verre, la possibilité d'imiter avec la plus grande vérité, et tout le prestige d'illusion, les effets du *diorama,* sauf pourtant la magic du coloris. Mais, Monsieur, autant je doutais, dans le principe, qu'il fût possible de représenter les objets avec leurs couleurs naturelles, comme je serais disposé à le croire maintenant. L'expérience m'a procuré là-dessus des données qui viendraient jusqu'à un certain point à l'appui de cette conjecture, et seraient en même tems une conséquence assez directe de la théorie de Newton *sur les anneaux colorés.* Malgré cela, il y aurait plus que de la témérité de ma part à donner à quelques résultats prématurés une importance qu'ils sont encore loin de mériter ; et si j'ose vous les communiquer, Monsieur, avec tout l'abandon de la confiance, c'est pour ne rien vous laissez ignorer de ce qui se rattache à des récherches auxquelles vous voulez bien prendre un si vif et si constant intérêt. Dans quelques mois d'ici je les poursuivrai, je l'espère, avec des nouvelles garanties de succès, pourvu que la saison me soit moins défavorable que l'an passé ; et je me bornerai d'abord à une seule application de

(31.) In a paper dated the 5th December, 1829, M. Niepcé communicated to M. Daguerre the parti-

mes procédés, à fin d'arriver plus promptement au but. Si j'ai ce bonheur là, Monsieur, vous pouvez compter sur mon empressement à vous le faire savoir.

N. Niepcé.

No. 9.

Monsieur, Paris, 3me Février, 1828.

Depuis votre départ j'ai fait deux tableaux, un pour le Diorama, et l'autre pour l'exposition du musée, ce qui m'a occupé toute l'espace du tems, ce qui fait que je n'ai pu donner aucune suite à mes recherches.

Quant à vous, Monsieur, je vois avec peine que vos occupations vous ont détournes de votre intéressante découverte, et que vous n'avez trouvé en quelque sort que découragement en Angleterre. Mais, consolez-vous: il n'est pas possible qu'il en soit de même ici; surtout, si vous arrivez au résultat que vous avez droit d'espérer, je puis vous assurer qu'on ne verra pas cela avec la même indifférence. Je me ferai un véritable plaisir, si cela peut vous être agréable, de vous indiquer les moyens d'en tirer de meilleure partie. Je ne puis vous dissimuler que je brûle du désir de voir vos essais d'après nature; car si ma découverte a pour base un principe plus incompréhensible, il n'en est pas moins que vous êtes bien plus avancé dans les résultats, ce qui doit nécessairement vous encourager.

Daguerre.

M. Niepcé.

Specimens of Heliography given by M. Niepcé to the late Francis Bauer, Esq., of Kew, and now in the possession of Dr. Robert Brown, of the British Museum.

1. A design $5\frac{1}{4}$ by 4 inches longways, on a pewter plate $6\frac{1}{2}$ by $5\frac{1}{2}$ inches; it is stated at the back to have been taken from a print about $2\frac{1}{2}$ feet long. The picture represents the ruins of an abbey: in a proper light it is very distinct.

culars of the process employed by him, and they entered into an agreement to pursue, for their mutual benefit, the researches which they had respectively begun. As many parts of this process of M. Niepcé's, and some of his remarks, are curious and interesting, I shall devote a brief space to a few extracts from this communication :*—

"The discovery which I have made," says M. Niepcé, "and to which I give the name of Heliography, consists in producing spontaneously, by the action of Light, with

2. A view 7½ inches by 6 inches longways, on a pewter plate 8 by 6½ inches; it is stated on the back to have been M. Niepcé's first successful experiment of fixing permanently the image from nature. The view is of a court-yard seen from an upper window. It is less distinct than the former; the outlines of the black portions are bordered by a white fringe, whiter than the adjacent parts. The surfaces on which the pictures appear are metallic, but are blacker, and reflect more light than the under pewter surfaces; the colour appears to be that of lead or platinum. No. 1. has experienced no injury. No. 2. is covered in some parts with minute brown spots.

3. A design 4½ by 5½ inches, upright, on a pewter plate 8 by 5½ inches, from a print, the subject "Christ bearing the Cross:" every line is beautifully distinct.

4. A copy from a print of a head 6½ by 5½ inches, upright, on a plate 7 by 5½ inches, etched by an after process, with two extremely good impressions of the plate.

5. An impression from a plate 8 by 7½ inches: the design is a landscape and ruin, 6¾ by 4½ longways. The lines are beautifully distinct in parts.

Besides the above, M. Niepcé presented a beautiful specimen to Mr. Cassells of Richmond, the subject of which appears to be the same as No. 5. It is also understood that M. Niepcé presented some plates to the late Sir Everard Home.

* See History and Practice of Photogenic Drawing, by M. Daguerre, translated from the original by T. S. Memes, LL.D. London, 1839.

gradations of tints from black to white, the images received by the camera obscura.

"Light, in its state of composition and decomposition, acts chemically upon bodies. It is absorbed, it combines with them, and communicates to them new properties. Thus it augments the natural consistency of some of these bodies: it solidifies them even, and renders them more or less insoluble, according to the duration or intensity of its action.

"The substance which has succeeded best with me, and which concurs most immediately to produce the effect, is asphaltum or bitumen of Judea, prepared in the following manner:—I about half fill a wine-glass with this pulverised bitumen. I pour upon it, drop by drop, the essential oil of lavender, till the bitumen can absorb no more. I afterwards add as much more of the essential oil, as will cause the whole to stand about three lines above the mixture, which is then covered and submitted to a gentle heat, until the essential oil is fully impregnated with the colouring matter of the bitumen. If this varnish is not of the required consistency, it is to be allowed to evaporate slowly, without heat, in a shallow dish, care being taken to protect it from moisture, by which it is injured, and at last decomposed. A tablet of plated silver is to be highly polished, on which a thin coating of the varnish is to be applied cold, with a light roll of very soft skin; this will impart to it a fine vermilion colour, and cover it with a very thin and equal coating. The plate is then placed upon heated iron, which is wrapped round with several folds of paper, from which, by this method, all moisture has been previously expelled. When the varnish has ceased to simmer, the plate is withdrawn from the heat, and left to cool and dry in a gentle temperature, and protected from a damp atmosphere.

"The plate thus prepared may be immediately submitted to the action of the luminous fluid, in the focus of the camera. But even, after having been thus exposed a length of time sufficient for receiving the impressions of external objects, nothing is apparent to show that these impressions exist. The forms of the future picture remain still invisible. The next operation then is to disengage the shrouded imagery, and this is accomplished by a solvent."

This solvent consists of a mixture of one part, by volume, of the essential oil of lavender, and ten of oil of white petroleum. A vessel being procured of a sufficient size, enough of this solvent to cover the plate is poured in. "Into this liquid the tablet is plunged, and the operator, observing it by reflected Light, begins to perceive the images of the objects to which it had been exposed, gradually unfolding their forms, though still veiled by the supernatant fluid, continually becoming darker from saturation with varnish. The plate is then lifted out, and held in a vertical position till as much as possible of the solvent has been allowed to drop away." The pictured tablet is now carefully washed by being placed upon an inclined plane, over which a stream of water is carefully poured.

It should be observed that the Light solidifies the varnish, and renders it less soluble than the parts upon which the shadows have fallen. In the same communication M. Niepcé says, "It were, however, to be desired that, by blackening the plate, we could obtain all the gradations of tones from black to white; I have therefore turned my attention to this subject, and employed at first liquid sulphate of potash (sulphuret of potassium ?) But when concentrated it attacks the varnish; and if reduced with water, it only reddens the metal. This twofold defect obliged me to give it up. The substance which I now employ *is iodine, which possesses the property of evaporating at the ordinary temperatures.*" It will be seen that the Daguerreotype process, which derives its name from its discoverer, consists in the application of iodine to silver plates, which is decomposed by the influence of Light.

(32.) It appears probable, that the discovery of the Daguerreotype was owing to some observations of Daguerre's, on the changes produced by Light on those silvered plates covered with films of iodine. M. Daguerre, however, appears to imply the contrary, in a note which he has appended to M. Niepcé's paper. This heliographic process was exceedingly tedious and uncertain. An exposure of two or three hours was necessary to produce an impression from an engraving, even under the influence of a bright sun; and in the camera obscura, the plate was left under the influence of strong Light for six or eight hours, and sometimes even longer, before a tolerable picture could be produced. M. Daguerre materially modified and improved this process. The resin of the essential oil of lavender, dissolved in alcohol, was found by him to be more susceptible of change than the bitumen; and instead of washing the plate with the solvent recommended by M. Niepcé, which often removed all the varnish from it, he exposed the tablet to the vapour of petroleum, by which a much more certain effect was produced.

(33.) A correspondence between M. Niepcé and M. Daguerre has been published, which sufficiently proves, that to the latter, the sole merit of the discovery of the process which bears his name is due. In 1831-2, M. Niepcé indeed regrets, that, at the recommendation of M. Daguerre, he had lost so much time in experiments on iodine. "I repeat it, Sir," he says, "I do not see that we can hope to derive any advantage from this process, more than from any other method which depends upon the use of metallic oxides," &c. &c. In another letter he speaks of a decoction of thlapsi* (shepherd's purse), fumes of phosphorus, and particularly of sulphur, as acting on silver in the same way as iodine, and that caloric produced the same effect by oxidising the metal, "*for from this cause proceeded in all these instances this extreme sensibility to light.*" We may perceive, from these remarks, that although M. Niepcé may not have been fortunate enough to discover the exquisitely sensitive method of M. Daguerre, he must have submitted to experiment, a great variety of substances in different states of combination. The philosopher of Châlons died in July, 1833, and a new agreement was entered into, between his son M. Isidore Niepcé and Daguerre.

(34.) In January, 1839, the discovery of M. Daguerre was reported, and specimens shown to the scientific world of Paris. The extreme fidelity, the beautiful gradations of light and shadow, the minuteness, and the extraordinary character of these pictured tablets, took all by surprise, and Europe and the New World were astonished at the fact, that Light could be made to delineate on solid bodies, delicately beautiful pictures, geometrically true, of those objects which it illuminated. In the July following, after a bill was passed, securing to M. Daguerre a pension for life of 6000 francs, and to

* Thlaspi Bursa-pastoris (Linn.), Capsélla Bursa-P. (De Candole).

M. Isidore Niepcé of 4000 francs, with one half in reversion to their widows, the process by which these pictures were produced was published. This process will be found particularly detailed in another part of this volume.

(35.) France declares that she purchased the secret of the process of the Daguerreotype for "*the glory of endowing the world of science and of art, with one of the most surprising discoveries that honour their native land.*" "This discovery," says M. Arago, in his place in the Chamber of Deputies, "France has adopted; from the first moment she has cherished a pride in liberally bestowing it—*a gift to the whole world.*" M. Duchatel, Minister Secretary of State, gives as the reason for rewarding the discoverer with a handsome pension, the argument that "*the invention did not admit of being secured by patent, for as soon as published, all might avail themselves of its advantages.*" In the face of this, "on or about the 15th of July, 1839, *a certain foreigner residing in France* instructed Mr. Miles Berry, patent agent in London, to petition her Majesty to grant her Royal Letters Patent for the exclusive use of the same within these kingdoms." This certainly needs no comment. It is unworthy the liberal spirit which should actuate the follower of science or of art. The patent cannot stand investigation, and it is to be desired that the necessary steps should be taken to set it aside.

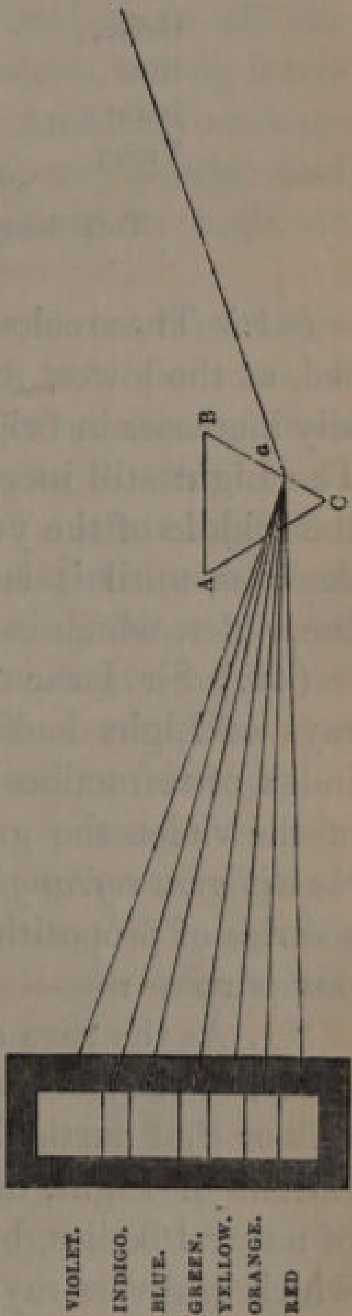
(36.) In 1834, Mr. Henry Fox Talbot, well known to the world as a natural philosopher, began some experiments with a view of rendering the images of the camera obscura permanent. On the 31st of January, 1839, six months prior to the publication of M. Daguerre's process, a paper giving an account of Mr. Talbot's labours, entitled, "Some Account of the Art of Photogenic Drawing, or the Process by which Natural

Objects may be made to delineate themselves without the aid of the Artist's Pencil," was read before the Royal Society; and in another communication on the 21st of February, 1839, the method of preparing the paper was given, and the process by which the design was fixed particularly described.

(37.) It will be evident to all, that the researches of the French artist and of the English philosopher were pursued, without any knowledge of each other's labours. The results in both cases were most satisfactory, and they equally rendered most important service; to science, in producing an instrument by which the mysterious phenomena of Light could be satisfactorily investigated, and to art, by giving her votaries tablets, upon which Nature impresses herself in all her delicacy and decision, in all her softness and her grandeur, and in all her richness of tone and breadth of effect. Colour alone is wanting, and there are sufficient reasons for believing, that in the progress of research we shall, before long, arrive at processes, by which the delightful pictures of the camera obscura, shall be rendered permanent in all the beauty of those glowing tints, which give to the fields of creation their exquisite charm and enchanting character.

(38.) During the period in which these interesting discoveries were made, philosophers had observed many other very remarkable phenomena, connected with the chemical properties of the solar beam, particularly the power it possessed of quickening, in an extraordinary degree, the combination of hydrogen and chlorine, which was first noticed by Gay Lussac and Thénard, and also the action of Light in determining the precipitation of platinate of lime, by Sir John F. W. Herschel. As these will be noticed under their respective heads, it will be unnecessary to do more than refer to them in this place. The magnetising power of the solar rays has for many years occupied the attention of the scientific world. The experiments of Dr. Morichini, Carpa, Ridolphi, and Mrs. Somerville, are much at variance with those of Berard, Configliachi, and others.

II. ON THE DECOMPOSITION OF LIGHT BY THE PRISM.



(39.) If a beam of white Light be admitted through a small hole in a window shutter, it will form a round white spot upon the place on which it falls. If we interpose a prism of glass, A B C, so that this beam of Light may fall upon one of its surfaces, as at *a*, the white beam not only suffers a change in its direction, but instead of the round spot of Light, we have an oblong image, composed of seven visible colours, viz. red, orange, yellow, green, blue, indigo, and violet. This lengthened image of the sun is called the *solar spectrum*, or sometimes the *prismatic spectrum*.

(40.) In 1666 Sir Isaac Newton was induced to examine this phenomenon, and by many trials he determined the lengths of the colours to be as follows, whilst the results obtained by Fraunhofer with flint glass prisms are slightly different: –

	Newton.	Fraunhofer.
Red	45	56
Orange	27	27
Yellow	40	27
Green	60	46
Blue	60	48
Indigo	48	47
Violet	80	109
Total length	360	360

(41.) These colours are not of equal brilliancy. The red, at the lowest extremity, is very faint, but it gradually increases in brightness, as it approaches the orange. The Light still increasing, arrives at its brightest about the middle of the yellow, from which point it gradually declines, until it is entirely lost in the upper edge of the violet, which is very faint.

(42.) Sir Isaac Newton showed, that the different rays of Light had different indices of refraction; the index of refraction for *red* light being the least, and that of the violet the greatest. His celebrated doctrine of *the different refrangibility of the rays of light* is given in a series of propositions, of which the two first will serve our purpose:

"1. As the rays of Light differ in degrees of refrangibility, so they also differ in their disposition to exhibit this or that particular colour. Colours are not qualifications of Light, derived from refractions or reflections of natural bodies, but original and connate properties, which in divers rays are divers," &c.

"2. To the same degree of refrangibility ever belongs the same colour, and to the same colour ever belongs the same degree of refrangibility. The least refrangible rays are all disposed to exhibit a red colour, and contrarily, those rays which are disposed to exhibit a red colour, are all the least refrangible; so the most refrangible rays are all disposed to exhibit a deep violet, and contrarily, those which are apt to exhibit such a violet colour, are all the most refrangible; and so to all the intermediate colours, in a continued series, belong intermediate degrees of refrangibility. And this analogy between colours and refrangibility is very precise and strict; the rays always agreeing exactly in both, or proportionally disagreeing in both."*

(43.) Sir David Brewster has shown some reasons for doubting the absolute correctness of this doctrine of Newton's. By examining the action of coloured glasses and coloured fluids, in absorbing light, he was led to conclude that *green* Light, consists of a mixture of the *blue and yellow* rays, and that *orange* Light is composed of *red and yellow* rays. "It consequently follows," says Sir D. Brewster, "that the orange and green rays of the spectrum, though they cannot be decomposed by prismatic refraction, can be decomposed by absorption, and actually consist of two different colours possessing the same degree of refrangibility. *Difference of colour is, therefore, not a test of difference of refrangibility*, and the conclusion deduced by Newton is no longer admissible as a general truth."†

Interesting and important as this inquiry is, it belongs rather to another branch of the science, and I have only introduced a notice of these doctrines in this place, to render intelligible, to those who may not be familiar

* Newton's Optics.

† Sir David Brewster's Optics (Lardner's Cabinet Cyclopædia).

with physical optics, much in the following pages, which might otherwise prove obscure.

(44.) It is for the same reason that I introduce a brief notice of the fixed lines in the spectrum. Dr. Wollaston first observed the existence of two fixed dark lines in the spectrum, one in the green and the other in the blue space. Fraunhofer, of Munich, by viewing through a telescope, the spectrum formed from a narrow line of solar Light, by some of his fine flint glass prisms, discovered that the surface of it was crossed throughout its whole length by dark lines of different breadths, none of which coincide with the boundaries of the coloured spaces. These lines are nearly 600 in number.

(45). Seven of these lines, B, C, D, E, F, G, H, from their distinctness, are particularly distinguished. These are represented in the figure in the Frontispiece. B lies near the outer end of the *red* space; C beyond the middle of the *red;* D in the *orange*, and is a strong double line; E is in the *green;* F in the *blue;* G in the *indigo;* and H in the *violet.* Besides these, there are other lines, which from their decision require notice. At A is a well-defined dark line, near the least refrangible edge of the red ray; half way between A and B is a group of seven lines, forming a black band; between B and C are nine lines, and *b* is a triple line in the green; between F and G are 185 lines, and between G and H are 190 of these dark spaces.

(46.) Fraunhofer has given the world, the first numerical estimate, on which any real dependence can be placed, of the illuminating power of the solar spectrum. He places the maximum at M, calling this 100; the Light at other parts will be as follows:—

Light at red end,	0·0	Light at E	48·0
— B	3·2	— F	17·0
— C	9·4	— G	3·1
— D	64·0	— H	0·56
Maximum at M	100·0	Violet extremity	0·00

(47.) The heating power of the solar spectrum was, as I have previously stated, examined by Sir William Herschel and by Sir H. Englefield: from their examinations it was found, that rays which had not the power of exciting vision gave the most sensible heat. These are situated below the red ray; but it must be distinctly borne in mind, that these heating rays are disseminated over the whole of the visible spectrum, but as they become mixed with the most refrangible rays, they rapidly decrease in energy.

(48.) It will be shown in the following pages, that the rays which are active in producing chemical change, are not, as was formerly imagined, confined to the most refrangible end of the prismatic spectrum, but that they are, under certain circumstances, equally active at the least refrangible end; therefore, although it will, when speaking of the different classes of rays, be convenient to retain the common expressions of chemical, calorific, and luminous rays, it must be understood, that no attempt will be made to define the limits of the calorific or chemical influence. I see reasons for believing that Light, or that agent which affects the organs of sight, is broadly distinguished from those rays which bring heat from its solar source, and both of these classes, from those, which produce those singular changes in the constitution of bodies, which are more particularly the objects of our study.

(49.) Sir John Herschel first called attention to a class of rays in the prismatic spectrum, situated below the ordinary red rays, and which are only seen when the eye is defended from the glare of the other rays, by a deep cobalt blue glass: these rays will be invariably termed the *extreme red rays*. These rays are situated so decidedly at the extremity of the visible spectrum, that if a dot be made in the centre of the well defined and round solar image to which it corresponds, and the glass be then laid aside, that dot is judged by the eye to be exactly at the end, or, if any thing, rather beyond than within the end of the visible spectrum. (*Herschel.*) It always appears to me as being some lines below the visible red; but I find by experiment, that my undefended eye is not sensible to the red ray so low in the spectrum as many friends have marked its limits. Sir John Herschel has also very satisfactorily shown, that there exists a class of *luminous* rays beyond the violet, which affect the eye with a sensation of lavender grey: these are called by him, in distinction, *lavender rays*, which name is also adopted in the present volume.

PART I.

THE INFLUENCE OF THE SOLAR RAYS ON COMPOUND BODIES, WITH ESPECIAL REFERENCE TO THEIR PHOTOGRAPHIC APPLICATION.

SECTION I.

ON METALLIC COMPOUNDS.

CHAPTER I.

PREPARATIONS OF SILVER.

(50.) Oxide of silver exposed for a few hours to good sunshine, passes into a more decided olive colour, than characterises it when first prepared by precipitation from the nitrate of silver, and consequently the covered portions are lighter than those exposed. Prolonged exposure to the sun's rays, for a week or more, renders this olive colour very much lighter, and the covered parts are found to be many times darker, than those on which the Light has acted directly. In some instances, where the oxide of silver has been spread on paper, I have noticed a very decided whitening process in some parts, after a few days' exposure; the cause of which, although diligently sought for, has not been detected. The oxide of silver dissolved in ammonia is a valuable photographic fluid. One application of a strong solution forms an exceedingly sensitive surface. The pictures on this paper are easily fixed by salt or weak ammonia.

(51.) NITRATE OF SILVER. — This salt in a state of purity, whether solid, or in solution in distilled water, does not appear to be sensibly affected by Light, but the presence of the smallest portion of organic matter renders it exceedingly liable to change under luminous influence. This property, induced Sir John Herschel, in his early photographic experiments, to combine organic matter with the solution of the nitrate of silver, previously to its being applied to paper, and afterwards to introduce into the pores of the paper organised salts of silver, but without any remarkable results. The organic combinations have, however, since that time, been found of exceeding value in quickening the change of the salts of silver under exposure to Light. We have already seen that Count Rumford found the nitrate of silver in contact with charcoal, or an earthy carbonate was soon reduced to the metallic state under the action of strong sunshine.

(52.) A remarkable analogy between the effects of heat and Light deserves notice, and it is also of some practical importance in the preparation of the papers. If a piece of nitrated paper is placed upon hot iron, or held near a good fire, it will be found that at a heat just below that, at which the paper chars, the salt is decomposed. Where the heat is greatest, the silver is revived, and immediately around it, the paper becomes a deep blue, beyond this a pretty decided green colour results, and beyond the green, a yellow or a yellow brown stain is made.

(53.) PRISMATIC ANALYSIS. — The first published accounts of the effects produced by the spectrum on chemical preparations in general, were those of Sir John

Herschel, to whom we are greatly indebted, for a very large amount of the most valuable information on this branch of the inquiry. I feel it a duty which I owe to this distinguished philosopher, to use his own words in describing these phenomena, as far as is practical, under the plan I have adopted, and to distinguish them from my own remarks, I shall in every case affix his name. The colour of the impressed spectrum, on paper washed with the nitrate of silver, is, at first, a pale brown, which passes slowly into a deeper shade; that portion corresponding with the blue rays, becoming a blue brown; and under the violet of a peculiar pinky shade, I have sometimes observed a very decided green tint on the point which corresponds with the least refrangible blue rays. The total length of the spectrum impressed on white paper, as well as the insensible gradations of its most refracted end will admit of measure, is about eighty-five parts. (*Herschel.*) Its limit of action is very nearly the centre of the yellow ray, and its maximum appears about the centre of the blue, although the action up to the edge of the violet ray is continued with very little diminution of effect: beyond this point the action is very feeble.

(54.) When the spectrum is made to act on paper which has been previously darkened, by exposure to sunshine under cupro-sulphate of ammonia, the phenomena are materially different. The photographic spectrum is lengthened out on the red or negative side by a faint but very visible red portion, which extends fully up to the end of the red rays, as seen by the naked eye. The tint of the general spectrum, too, instead of brown is dark grey, passing, however, at its most refracted or positive end into a ruddy brown. (*Herschel.*)

(55.) Photographic Application.—Nitrate of silver, although the most valuable of the salts of that metal to the photographer, as from it most of the other argentine compounds can be prepared, is not of itself sufficiently sensible to Light to render it of much use. It may, however, in some few cases, be advantageously employed. If well-sized paper is washed over, with a solution of 120 grains of the salt, in a fluid ounce of water, and dried at a little distance from a warm fire, we form a paper, which, for copying lace-work, feathers, and articles of which a perfect outline merely is required, answers very well. By soaking the paper previously to applying the wash of nitrate of silver, in isinglass, parchment size, a solution of gum-arabic, or by rubbing it over with the white of egg, it darkens much more readily, and eventually acquires a much deeper colour. A pleasing variety of grounds for the pictures, may be produced by varying these organic combinations, and a still more interesting series, by precipitating organic liquids with solutions of lead, applying them in the state of cream on paper, and drying, before the nitrate is applied, as was recommended by Sir John Herschel. The influence of lead in exalting the oxidation of the silver salts under the action of Light, will be further described in the section on lead. Pictures formed on the nitrated papers are rendered permanent by simply washing, first, in cold, and afterwards soaking, in warm water.

(56.) Chloride of Silver. — This salt of silver, whether in its precipitated state, or when fused — horn silver — changes its colour to a fine bluish grey by a very short exposure to the sun's rays, or even with prolonged exposure in diffused Light. If it is combined with a small quantity of the nitrate, the change is much more rapid, and the darkening process goes on to a deep brown, which slowly passes into a fine olive, and eventually, after a few weeks, the metallic silver is seen to be revived on the surface of the salt. It is somewhat remarkable, that great differences are observed in the colour produced on chlorides of silver precipitate by different muriates. Nearly every variety in combination with the nitrate, becomes *at last* of the same olive colour, it must therefore be understood that the following notices apply to the colour produced by an exposure of a few minutes only to good sunshine, and it must also be recollected that the chloride of silver in these cases is contaminated with the precipitant.

(57.) Muriate of ammonia inclines the precipitated chloride to darken to a fine chocolate brown, whilst muriate of lime operates to the production of a brick-red colour. Muriates of potash and soda afford a precipitate, which darkens speedily to a pure bark brown, and muriatic acid or aqueous chlorine, do not appear to increase the darkening power, beyond the lilac to which the *pure* chloride of silver changes by exposure. As far as my experiments have gone, it appears, that this difference of colour is owing to the admixture of the earth or alkali used with the silver salt, and not to the presence of organic matter, although it does, as in the case of the nitrate, produce similar varieties of colour. The muriates of baryta and of strontia have some very peculiar colorific properties when in combination with the chloride and some other salts of silver, which will deserve our particular attention; however, as these peculiarities are more strikingly exhibited in some of the positive photographic processes, which will be shortly described, it will be more in place to reserve a description of them for a future section.

(58.) Prismatic Analysis.—The spectrum impressed upon a paper, spread with the chloride of silver, is often very beautifully tinted, the intensity of the colours varying very considerably with the kind of muriate used. (56.) Papers prepared with the muriate of ammonia or of baryta, and then with two successive washes of the nitrate of silver, have given me, when the sunshine has been favourable, a range of colours very nearly corresponding with the natural hues of the prismatic spectrum. Under favourable circumstances, the mean red ray, leaves a red impression on the paper, which passes into green over the space occupied by the yellow rays. Above this a leaden blue is discovered, and about the mean blue ray, where the action is greatest, it rapidly passes through brown into black, and through the most refrangible rays it gradually declines into a bluish brown, which tint is continued through the invisible rays. At the least refrangible end of the spectrum, the very remarkable phenomenon has been observed, in the first instance, by Sir John Herschel, of the extreme red rays exerting a protecting influence, and preserving the paper from that change, which it would otherwise undergo, under the influence of the dispersed light which always surrounds the spectrum. Although this is very evident, when the spectrum concentrated by a good achromatic lens, is received on the muriated paper, it is still more strikingly shown, if we receive the spectrum directly from the prism, without the interposition of the lens. It indeed appears to me, from many experiments made in this manner, that not only the extreme red ray exerts this very peculiar property, but the ordinary red ray, through nearly its whole length. Including this whitened portion, the whole extent of chemical action exerted is " considerably more than double the total length of the ordinary luminous spectrum. (*Herschel.*)

(59.) Photographic Application. — It has been already stated, that the chloride of silver was used as a photographic agent by Wedgwood, Davy, and Daguerre, their success being but very limited. This salt became, however, in the hands of Mr. Fox Talbot, of the utmost importance. As it is to this talented experimentalist that we are indebted, for the first successful application of any chemical preparation on paper, as a tablet on which Light should impress, with unerring fidelity, the objects it rendered visible, it is right that his process, which is indeed a very valuable one, should take precedence of any other.

"I select," says Mr. Talbot, "in the first place, paper of a good firm quality and smooth surface. I do not know that any answers better than superfine writing paper. I dip it into a weak solution of common salt, and wipe it dry, by which the salt is uniformly distributed throughout its substance. I then spread a solution of nitrate of silver on one surface only, and dry it at a fire. The solution should not be saturated, but six or eight times diluted with water. When dry the paper is fit for use.

"I have found by experiment, that there is a certain proportion between the quantity of salt, and that of the solution of silver which answers best, and gives the maximum effect. If the strength of the salt is augmented beyond this point, the effect diminishes, and in certain cases becomes exceedingly small.

"This paper, if properly made, is very useful for all ordinary photographic purposes. For example, nothing can be more perfect than the images it gives of leaves and flowers, especially with a summer sun: the light passing through the leaves delineates every ramification of their nerves.

"Now, suppose we take a sheet thus prepared, and wash it with a *saturated* solution of salt, and then dry it. We shall find (especially if the paper has been kept some weeks before the trial is made) that its sensibility is greatly diminished, and in some cases seems quite extinct. But if it is again washed with a liberal quantity of the solution of silver, it becomes again sensible to Light, and even more so than it was at first. In this way, by alternately washing the paper with salt and silver, and drying it between times, I have succeeded in increasing its sensibility, to the degree that is requisite for receiving the images of the camera obscura.

"In conducting this operation, it will be found that the results are sometimes more and sometimes less satisfactory, in consequence of small and accidental variations in the proportions employed. It happens sometimes that the chloride of silver is disposed to darken of itself, without any exposure to Light: this shows that the attempt to give it sensibility has been carried too far. The object is to *approach* to this condition as near as possible, without *reaching* it, so that the substance may be in a state ready to yield to the slightest extraneous force, such as the feeble impact of the violet rays when much attenuated. Having therefore prepared a number of sheets of paper, with chemical proportions slightly different from one another, let a piece be cut from each, and having been duly marked or numbered, let them be placed side by side in a very weak diffused light for a quarter of an hour. Then if any one of them, as frequently happens, exhibits a marked advantage over its competitors, I select the paper which bears the corresponding number to be placed in the camera obscura."*

(60.) This variable sensibility of paper, prepared with the same ingredients, differing but very slightly in their proportions, admits of an easy explanation by a simple experiment. Precipitate upon a clean piece of glass a film of chloride of silver, which is best done in the manner recommended by Sir John Herschel: — A solution of salt of extreme dilution, is mixed with nitrate of silver, so dilute as to form a liquid only slightly milky, and into this, at the bottom of a deep vessel, is placed horizontally a glass plate, upon which the chloride is slowly deposited; the liquid being carefully drawn off with a siphon, and the last portions by fibres of hemp. When this is dry, we have a uniform film of the chloride of silver, chemically pure. If we take this plate, and having placed it at a very small inclination, expose it to Light, and drop upon its upper edge a small portion of the nitrate of silver, we shall see, that, as the nitrate solution slowly combines, as it descends, with the chloride, it darkens very unequally; the edges of the descending liquid, giving the most rapid indications of sensibility to sunshine. From this we learn that to produce the most sensitive chloridated photographic paper, it is necessary to have only an exceedingly slight excess of the nitrate of silver, beyond that which is necessary to effect the entire decomposition of the salt used; but, as I have stated before, this excess is absolutely essential.

(61.) The following are the best proportions, with which my practice has made me acquainted, for pro-

* London and Edinburgh Philosophical Magazine, March, 1839, vol. xiv. p. 209.

ducing papers sufficiently sensitive for use in the camera obscura:—

Muriate of soda, fifty grains to one ounce of water; in which solution the paper is washed, and then carefully wiped over with a clean cotton cloth, and dried.

A solution of the nitrate of silver, in the proportions of 120 grains to an ounce of distilled water, is then carefully applied twice over one side of the sheet, drying the sheet between each wash at a little distance from the fire.

Instead of the muriate of soda, it will often be found advantageous to use the muriate of ammonia (sal-ammoniac), in the proportions of thirty grains to an ounce of water; or the muriate of baryta, about forty grains, dissolved in an ounce of water.

(62.) For the less sensitive varieties of this kind of paper, the silver salt may be used in more economical proportions. No particular directions are necessary beyond those already given. Great care is of course required in all photographic manipulation, and the want of attention to the purity of the materials used, their correct proportions by weight and measure, and the absolute cleanness of brushes, cloths, &c. will constantly lead to the most perplexing failures. It may be well to observe in this place, once for all, that the selection of paper for photographic purposes requires to be made with care. The thing to be aimed at is, to obtain as great a transparency as possible, combined with such a thickness as shall ensure perfect opacity in the dark parts of the drawings. It is also to be desired that the sensitive preparations should be retained as much on the surface as possible, for experiment will show, the most striking difference between the same preparation spread on a paper of a firm texture and on an absorptive variety. The best kinds of paper, which are those known to the trade as hand-made and calendered papers, differ considerably on their two surfaces, one being much less absorbent than the other, which is the side that must be chosen as the one for spreading the sensitive washes over.

(63.) It was noticed by Mr. Talbot, in the very outset of his photographic experiments, that however carefully a paper might be prepared with the above materials, and the same applies to all others, it would sometimes turn out to be nearly, if not quite, insensible to Light in some parts of its surface. He thus describes this singular quality:—"Exposed to sunshine, this paper will exhibit large white spots of a very definite outline, where the preparing process has failed; the rest of the paper where it has succeeded turning black as rapidly as possible. Sometimes the spots are of a pale tint of cerulean blue, and are surrounded by exceedingly definite outlines of perfect whiteness, contrasting very much with the blackness of the part immediately succeeding." There can be but one opinion as to the cause of this very annoying peculiarity. The chemical compound used, exists in two definite and different states in the light and dark parts of the paper. We shall find, if we carefully examine the matter, that the same sheet of paper will absorb more moisture in some parts, than it will do in others, consequently we shall have (to cite the present case) a larger quantity of salt in some places than in others: and when we apply the nitrate of silver, portions of the paper will become covered with the chloride of silver, having the required excess of the nitrate of silver, while others will consist of the pure chloride, or a double salt, the muriate of soda and silver. Sir John Herschel proposes to remedy this "by saturating the saline washes used, previous to their application, with chloride of silver. By attending to this precaution, and by dividing the last wash of the nitrate into two of half the strength, applied one after the other, drying the paper between them, their occurrence may be almost entirely obviated." In my own experience I have found this method generally answer the desired object, but it appears to be somewhat injurious to the sensibility of the paper. If the saline wash is applied with a sponge, and rubbed over, care being taken not to remove the pile of the paper, it will be found that we are less liable to these spots, than when the paper is soaked in the solution.

(64.) A very pretty modification of these processes has been recommended by Sir John Herschel, which resulted from his experiments to ascertain how far organic matter was necessary to produce the change in the chloride and other salts of silver. A film of the chloride is precipitated on a glass plate, in the manner previously described (60.), and carefully dried in the dark. This pure chloride of silver is scarcely sensible to the influence of ordinary day-light, unless by a very prolonged exposure; but if it is washed over with a solution of the nitrate of silver, it becomes exceedingly sensitive, and may be used for receiving pictures in the camera obscura. These are very interesting and well defined negative pictures, which are direct or reversed according as looked at on the side which was exposed to Light, or the opposite. By pouring over these pictures a solution of hyposulphite of soda, they disappear, but on washing them with pure water, and drying, they are restored, and assume much the air of a Daguerreotype, when laid on a black ground, and still more so when smoked at the back; so that its character is in fact changed from a negative to a positive picture. (*Herschel.*) It is necessary that the plate should be exposed wet, and when withdrawn plunged instantly into water.

(65.) The action of Light having produced the required impression, it becomes necessary, to render these pictures permanent, that they should be subjected to some process, which should prevent the white parts from undergoing any change. Several plans have been recommended. Mr. Fox Talbot uses, and it appears with much success, a strong solution of common salt. This unites with the unchanged chloride of silver, and forms the double muriate of silver and soda, a salt which is not readily changed by exposure. Pictures so fixed, however, acquire, after some time, a peculiar dead blue tint, which interferes with the sharpness of the images very considerably. It does, indeed, appear that some slow bleaching action often goes on in the dark, upon the blackened portions themselves, and certainly the first application of a strong brine removes many of the most delicate and beautiful details of the drawing. Iodide of potassium has also been used; but this salt, under the combined influence of Light and moisture, acts more powerfully on the dark parts than the muriate of soda, and it has the unfortunate property of changing the white chloride of silver into the yellow iodide, which is fatal, where it is wished to take positive copies from the original negative pictures, as a yellow medium obstructs most powerfully, the free passage of those rays which darken the salts of silver. It is more desirable, if possible, to remove the unchanged chloride entirely from the paper; but there is some difficulty in ensuring this, as most of those preparations which dissolve the chloride of silver act with energy on the oxide. This is particularly the case with ammonia, which has sometimes been spoken of as a good fixing agent. The best solvent for the chloride is certainly the hyposulphite of soda, as recommended by Sir John Herschel. Some care is required in this fixing process, but with attention this salt will be found to be much more useful than any other agent. The drawing being produced, should be first soaked in clean water, to dissolve out as much as possible of the nitrate of silver. It is then to be immersed for a few minutes in water, to which a few grains only of common salt has been added, the object of which is to convert any portion of the nitrate that may remain in the paper into a chloride, as when any nitrate of silver is present the hyposulphite changes it to a sulphuret, the brown colour of which is destructive to the beauty of the picture, and to its use for multiplying originals. When dry, it is to be brushed over, first on the face, and then on the back, with the solution of the hyposulphite of soda, and immediately immersed in clean water. Having been allowed to soak for a few minutes, it should be placed on a porcelain slab, and gently washed with a soft sponge and clean water, until the fluid flows off without any sweetness of taste; the combination of the chloride of silver and the hyposulphite producing a sensation of intense sweetness over the mouth. It is a peculiarity of this method of fixing, that nearly all the delicate parts which may appear to have suffered in the process, develop themselves again with considerable sharpness on drying.

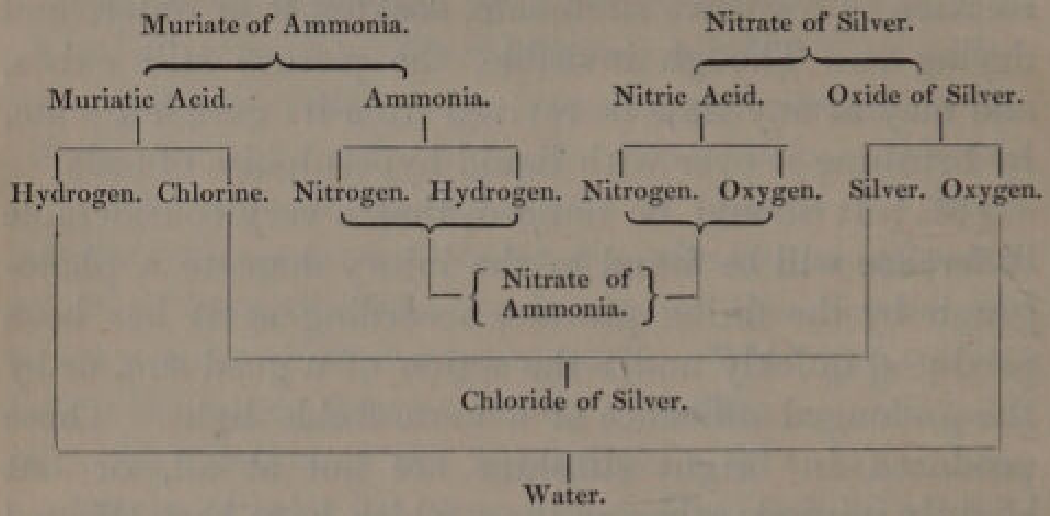
(66.) A very curious process of fixing, was first noticed by Sir John Herschel, and nearly about the same time dropped upon by the author, while endeavouring to fix some pictures produced by a positive process, to be described under the Iodides. It has the peculiarity of completely obliterating the picture, "reducing it to a state of perfectly *white paper*, on which the nicest examination (if the process be perfectly executed) can detect no trace, and in which it may be used for any other purpose, as drawing, writing, &c., being completely insensible to Light."—(*Herschel.*) Where iodine is present, the paper becomes a deep yellow. This obliteration is effected by washing the picture with a solution of corrosive sublimate, soaking it in water, and drying it. Though invisible, the picture still exists, and may at any time be revived from its dormant state, by brushing it over with liquid hyposulphite of soda.

(67.) It should be noticed, that a very considerable difference will be found in the injury done to a photograph by the fixing process, according as it has been produced quickly under the action of a good sun, or by the prolonged influence of a more feeble light. Those produced in bright sunshine are not at all, or but slightly injured; whereas those which have been effected by a weak daylight, lose much of their sharpness, and indeed many parts are often destroyed.

(68.) We have now to consider the nature of the change produced on the chloride of silver by luminous influence, about which it appears some misconception has existed. The following experiments will set the question in a clearer light. A piece of paper, which had been prepared with the muriate of ammonia and the nitrate of silver, was placed in a perfectly dry tube with some potassium, and then hermetically closed and left in the dark for twenty-four hours, that the oxygen present might be absorbed by the alkaloid. The paper in the glass was then exposed to good sunshine for several hours, during which time it darkened considerably, but not nearly so much as a piece of the same paper, which was exposed openly for ten minutes only.

The glass tube was opened in a solution of ammonia, but there was no indication of free chlorine. However, on dissolving the salt formed on the potassium, it was found to be a muriate of potash. This experiment distinctly proves the liberation from the paper of either chlorine or muriatic acid.

(69.) The change which takes place through the process will be best explained by a diagram.



In this state the materials exist in the paper, except that, as has been already stated, a little free nitrate of silver is also present. Under the influence of the Light the chloride of silver is decomposed, and the liberated chlorine, combining probably with the hydrogen of some decomposed water, combines with the potassium to form the muriate of potash; while the silver is oxidised at the expence of the oxygen of the free acid and the water. Some suppose the darkened salt to be a subchloride of silver.

(70.) The absorption of oxygen, or rather its combination with the decomposing chloride, is proved by another very easy experiment. Some pure chloride of silver was arranged in a bent tube closed at one end, and the other end immersed in a bottle of distilled water. In this state the chloride was exposed for many days to the action of Light, during which time it was frequently shaken, for the purpose of exposing the whole of the powder to its influence. As the chloride darkened the water rose into the tube, and it gave a precipitate of chloride of silver on the addition of the nitrate, thus distinctly proving the substitution of oxygen for chlorine under the agency of solar radiation. This explanation will also serve for the iodide and bromide, and some other salts of this metal, and it will not therefore be necessary to recur again to this matter, except in a few especial instances.

(71.) IODIDE OF SILVER.—Perfectly pure iodide of silver may be exposed for a long period to Light without undergoing any visible change, except perhaps in some cases a more decided yellow colour that is usual to it comes on; and this appears to depend on the influence of the calorific rays, as the same effect is produced by exposing it to a very moderate degree of heat. If, however, a very slight excess of the nitrate of silver is present, it becomes infinitely more sensitive than the chloride.

(72.) PRISMATIC ANALYSIS.—The spectrum impressed upon a paper prepared with a weak solution of the hydriodate of potash presents some very remarkable peculiarities. The maximum of intensity is found at the edge of the most refrangible violet rays, or a little beyond it. Sir John Herschel places it at five parts beyond. I have found that it varies slightly according to the kind of paper used, and also with the quantity of free nitrate of silver present. The action commences at a point nearly coincident with the mean red of the luminous spectrum, where it gives a dull ash or lead colour, while the most refrangible rays impress a ruddy snuff-brown, the change of tint coming on rather suddenly about the end of the blue or the beginning of the violet rays of the luminous spectrum. (*Herschel.*) Beyond the extreme violet ray, or rather beyond the maximum point, the action rapidly diminishes; but the darkening produced by these invisible rays, extends a very small space beyond the point at which they cease to act on the chloride of silver.

(73.) Photographic Application.—The use of papers prepared with the iodide of silver alone can only be recommended as affording a very pleasing variety of pictures, having a primrose instead of a white ground. The best proportions in which the respective salts of iodine and of silver can be used, according to my own experience, are the following:—Twenty grains of nitrate of silver should be dissolved in half an ounce of distilled water, and this, with a very soft brush, carefully applied over the paper, and allowed to dry. Ten grains of the iodide of potassium dissolved in the same quantity of water, is next to be applied, and the paper quickly dried near the fire, care being taken, not to warm it too much, as heat changes it from its delicate primrose colour to a pink or rosy brown, which, although still sensitive, is not so much so as the parts which are not so altered.

(74.) In combination with other reagents, the iodide of silver becomes exquisitely sensitive, and from two such combinations, gallic acid and the ferrocyanate of potash, result two of the most sensitive photographic processes on paper with which we are acquainted. To these we must now direct our particular attention; and I shall give in the first place, Mr. Talbot's description of the very beautiful process, which he has named the Calotype, and then proceed to offer some remarks on the peculiar chemical action of the sensitive combination used.

(75.) The Calotype Process.—*Preparation of the*

Paper. Take a sheet of the best writing-paper, having a smooth surface, and a close and even texture. The watermark, if any, should be cut off lest it should injure the appearance of the picture. Dissolve 100 grains of crystallized nitrate of silver in six ounces of distilled water. Wash the paper with this solution with a soft brush on one side, and put a mark on that side whereby to know it again. Dry the paper cautiously at a distant fire, or else let it dry spontaneously in a dark room. When dry, or nearly so, dip it into a solution of iodide of potassium, containing 500 grains of that salt dissolved in one pint of water, and let it stay two or three minutes in the solution. Then dip it into a vessel of water, dry it lightly with blotting-paper, and finish drying it at a fire, which will not injure it even if held pretty near; or else it may be left to dry spontaneously. All this is best done in the evening by candlelight. The paper so far prepared Mr. Talbot calls *iodized paper*, because it has a uniform pale yellow coating of iodide of silver. It is scarcely sensitive to Light, but nevertheless it ought to be kept in a portfolio or a drawer until wanted for use. It may be kept for any length of time without spoiling or undergoing any change if protected from the Light. When the paper is required for use, take a sheet of it, and wash it with a liquid prepared in the following manner: —

Dissolve 100 grains of crystallized nitrate of silver in two ounces of distilled water; add to this solution one-sixth of its volume of strong acetic acid. Let this mixture be called A.

Make a saturated solution of crystallized gallic acid in cold distilled water. The quantity dissolved is very small. Call this solution B.

Mix together the liquids A and B in equal volumes, but only mix a small quantity of them at a time, because the mixture does not keep long without spoiling. Mr. Talbot calls this mixture the gallo-nitrate of silver. This solution must be washed over the iodized paper on the side marked, and, being allowed to remain upon it for half a minute, it must be dipped into water, and then dried lightly with blotting paper. This operation in particular requires the total exclusion of daylight; and although the paper thus prepared has been found to keep for two or three months, it is advisable to use it within a few hours, as it is often rendered useless by spontaneous change, in the dark.

Paper thus prepared is exquisitely sensitive to Light, exposure of less than a second to diffused daylight being quite sufficient to set up the process of change. If a piece of this paper is partly covered, and the other part exposed to daylight for the briefest possible period of time, a very decided impression will be made. This impression is latent and invisible. If, however, the paper be placed aside in the dark, it will gradually develop itself; or it may be brought out immediately by being again washed over with the gallo-nitrate of silver, and held at a short distance from the fire, by which the exposed portions become brown, the covered parts remaining of their original colour.

The pictures being thus procured, are to be fixed by washing in clean water, and lightly drying between blotting paper, after which they are to be washed over with a solution of bromide of potassium, containing 100 grains of that salt dissolved in eight or ten ounces of water: after a minute or two, it is to be again dipped into water, and then finally dried. Where the bromide of potassium is not at hand, these pictures may be fixed with a strong solution of common salt.

(76.) The discovery of the extraordinary property of the gallic acid, in increasing the sensibility of the iodide of silver, was the most valuable of the numerous contributions which Mr. Talbot has made to the photographic art. The calotype process, as described and practised by Mr. Fox Talbot, yields pictures of exquisite beauty, which preserve with the utmost fidelity, not only the bold outline of the object, but its minute and delicate details. The charm of colour alone is wanting, and this is compensated by the harmony of the whole. The gradation of shadow is often given in a really wonderful manner, the lights of the picture decaying in soft and almost invisible tints into the deepest shades; the middle lights being preserved in a manner, which renders these pictures the most truthful studies for the artist who desires to fix the charms of Nature on his canvass, rather than those, so called, artistic effects, which are the bane of modern art, and destructive alike to truth and good taste.

(77.) The calotype picture is a negative one, having the shadows represented by lights, and lights by shadows; also reverse, as it regards right and left; but when fixed by the above process, a great number of positive copies, correct in all respects, may be taken from it. To do this, it is only necessary that the drawing be placed with its face against the sensitive side of a piece of ordinary photographic paper (61.), and being pressed into close contact by a board below, and a glass above, exposed for a short time to good sunshine. This period, of course, varies with the transparency of the original calotype, and the brilliancy of the sunshine. It must be remembered that the Light has to permeate a piece of paper, the yellow tint of which, offers considerable interruption to the free passage of those rays which are active in producing chemical change; we must therefore, be exceedingly careful to preserve the prepared sheet of as pale and uniform a tint as possible. All processes on paper, which require the production of the positive from the negative drawing, are, in one particular, alike defective. The irregularities of the paper itself are copied with the picture. This is only to be remedied by substituting some more transparent material, or getting a paper manufactured superior to any which is at present in the market, uniting transparency with firmness of texture and evenness of surface.

(78.) The part which the gallic acid plays in this process is sufficiently obvious. The chemical action of this acid on most of the metallic salts is well known, separating the metallic oxides very readily from the powerful acids. Since the attention of chemists has been more forcibly directed to the several phenomena connected with alterations produced in chemical compounds by luminous agency, numerous very curious instances have been discovered, of the continuation in the dark, of that change which Light has begun to produce. If we unite a solution of gallic acid and nitrate of silver, even in weak diffused Light, it will be found that a precipitate is almost immediately formed, whereas the same solution will often remain clear for many hours in the dark. If we apply this mixture whilst clear to any preparation of silver on paper, which is sufficiently sensitive, or has been exposed to Light for a sufficient time for a change to have commenced, the formation of the gallate of the oxide of silver, is carried on over those parts on which the solar rays have exerted their influence, with an energy equal to the intensity of the Light which has acted on the several parts, or, in other words, to the degree of change which the preparation has undergone; while, for some time, the parts in shadow, exerting no extraordinary power, remain clear and unchanged. To preserve these parts quite transparent, it is therefore advantageous to accelerate the decomposition over the other parts by the aid of caloric; and hence it is, that the talented discoverer advises the drawing to be held, for a few seconds, at a short distance from the fire. The gradual development of the calotype photographic picture, is, to a person who witnesses it for the first time, a phenomenon of a remarkable, indeed almost magical character. Some experience is required to check the action of the gallo-nitrate of silver at the proper time: if it has not remained on the paper long enough, the opacity of the dark parts is not sufficient to ensure good positive copies; and if it remains too long, the light portions begin to darken, and, as this darkening proceeds with rapidity, the picture is soon rendered useless as an original from which copies can be taken.

(79.) The calotype process may, for many purposes, be most advantageously simplified; but before we proceed to this, it will be interesting to know, the particular action of pure gallic acid, upon several varieties of argentiferous preparations which have been acted on by Light. Paper simply washed over with the *nitrate of silver*, and exposed for two minutes in the camera obscura, which was the time allowed in all cases, unless it is stated to be otherwise, gave, when washed over in the dark, a very faint image. The *chloride of silver* on paper gave, under the same treatment, a good picture; but it wanted clearness and depth of colour. The *bromide of silver* on paper gave, by an exposure of only one minute, a very beautiful picture. *Tartrate of silver*, even when the paper upon which it was spread was exposed for eight minutes, appeared insensible to the exciting power of the gallic acid. *Oxalate of silver*, exposed in the camera for ten minutes, gave an exceedingly faint representation. *Phosphate of silver* yielded a well-marked picture. *Carbonate of silver* in five minutes afforded a tolerably good result. Several of the compounds of benzoine, as formo-benzoate of silver, the benzoate of silver, and others, gave exceedingly pleasing pictures; and one, in particular, the *formo-benzoate of ammonia*, and the nitrate of silver, a photograph quite equal to those produced by Mr. Talbot's process; and I venture to recommend it for all purposes in which extreme sensibility, as for portraiture, is not required. Neither the pure *cyanate of silver*, nor the *ferrocyanate*, gave any sign of change after an exposure of five minutes, whether washed with pure gallic acid or with the gallo-nitrate of silver.* A great many other preparations of silver have been tried, and, as far as my researches have gone, it appears that whenever the salt used is sufficiently under the influence of Light to undergo a change, however slight it may be, the gallic acid will carry on the action in the dark and without heat, although the change is considerably accelerated by caloric. Gallic acid is therefore a most delicate test for any change produced, either by luminous or calorific radiation.

(80.) Mr. Channing of Boston appears to have been the first to publish any method by which the calotype

* Mr. Channing of Boston, in a paper on Photographic Manipulation, in the American Journal of Arts and Sciences, July, 1842, gives the following series as being capable of being brought out by gallic acid:—"Iodide with chloride, iodide, iodide with bromide, bromide, bromide with chloride, fluoride, nitrate, ferrocyanide, sulphocyanide, cyanide."

process could be simplified. This gentleman directs that the paper be washed over with sixty grains of crystalized nitrate of silver in one ounce of water, and when dry, with a solution of ten grains of the iodide of potassium in one ounce of water. It is then to be washed with water, and dried between blotting paper: it is now fit for use. A paper of a more sensitive kind is stated by the same authority, to be prepared by using a mixed solution of five grains of the iodide of potassium and five grains of the chloride of sodium in an ounce of water. My own experience enables me to say that but little, if any, improvement can be made upon these proportions. A much weaker solution of the nitrate may be used, and this, on the score of economy, is important. The most satisfactory preparations which I have yet employed are the bromide of silver, formed by washing paper first with a solution of silver, as above, and then with a solution of twenty grains of the bromide of potassium in one ounce of water; and, as I have before stated, the formobenzoate of ammonia and silver, formed by washing the paper first with the formobenzoate, in the proportion of fifteen grains of the salt to one ounce of water, and then with the nitrate of silver, as above. In good sunshine an edifice may be beautifully copied by either of the two last processes in a minute, and by the others in about two minutes. To preserve these pictures of a clear white, it is advisable that they should be soaked in water for a minute, previously to the application of the gallic acid.

(81.) Dr. Ryan has shown the necessity of some care in the use of the iodide of potassium, into a solution of which, Mr. Talbot recommends the nitrated paper to be placed for a few minutes. If the paper is left too long in such a solution, the iodide of silver will be dissolved, that salt being soluble in an excess of iodide of potassium. Simply passing the paper through the solution appears to answer every purpose effectually. Mr. Collen has modified Mr. Talbot's process, by brushing over the paper with a weak solution of the ammonio-nitrate of silver, and in using the same solution in combination with the gallic acid, instead of the nitrate of silver. It does not, however, appear to me that any advantage is gained by this mode of proceeding. A careful adjustment of the best proportions of the ingredients recommended by Mr. Fox Talbot, will be found to afford better results in a shorter time.

(82.) This calotype paper is capable of being used for the production of positive photographs by one process. Mr. Talbot, in his specification, thus describes his method:—" A sheet of sensitive calotype paper is exposed to the daylight for a few seconds, or until a visible discoloration or browning of its surface takes place; then it is to be dipped into a solution of iodide of potassium, consisting of 500 grains to one pint of water. The visible discoloration is apparently removed by this immersion; such, however, is not really the case, for if the paper were dipped into a solution of gallo-nitrate of silver, it would speedily blacken all over. When the paper is removed from the iodide of potassium, it is washed in water, and dried with blotting paper. It is then placed in the camera obscura, and, after five or ten minutes, it is removed therefrom, and washed with gallo-nitrate of silver, and warmed, as before directed. Engravings may be copied in the same way, and positive copies of them produced, but reversed from right to left. For this purpose a sheet of calotype paper is exposed to the daylight to darken it, as before mentioned; but it should be darkened rather more than when intended to be acted upon in the camera. The engraving and the calotype paper must be pressed into contact by screws or otherwise, and placed in the sunshine, and the copy will be produced in a few minutes. If the copy is not sufficiently distinct, it must be strengthened by means of gallo-nitrate of silver.*

(83.) No other paper, which has yet been discovered, is sufficiently sensitive to luminous agency to admit of its being used for taking portraits from the life. Portraits of exceeding beauty and fidelity, may be procured without difficulty, by paying strict attention to Mr. Talbot's directions for preparing the calotype paper. The inventor prefers for this purpose, a camera the focal length of whose lens, is not more than three or four times the size of the aperture; and the head of the person whose portrait is to be taken, must be kept as steady as possible; and, upon pointing the camera at it, an image is received on the sensitive calotype paper. No very good result can be expected, unless the paper is sufficiently sensitive to give a good image in twenty or thirty seconds. Mr. Talbot thinks he gains considerable advantage by carrying on the process in the open air, under a serene sky, without sunshine; or if sunshine is employed, a screen of blue glass should be used to defend the eyes from too much glare, and thus prevent that distortion of feature which would otherwise arise.

(84.) Iodide of Silver and Ferrocyanate of Potash. — At the meeting of the British Association in 1841, at Plymouth, the author communicated to the Chemical Section, a method which he had discovered of

* Repertory of Patent Inventions.

preparing a highly-sensitive paper, with the iodide of silver and the ferrocyanate of potash. It will be found that paper prepared with the iodide of silver, and then washed with a solution of the ferrocyanate of potash, will blacken almost instantly on being exposed to the sun's rays. This effect will take place with the greatest rapidity, when the iodide of silver on the paper is as free from admixture as possible. Perfectly pure iodide of silver does not appear to undergo any change when exposed to Light. Under the prismatic spectrum, the space covered by the red rays is rendered very yellow, an effect due to the heat of those rays alone. Gallic acid gives evidence of some disturbance beyond this, having taken place, over that part on which the more refrangible rays fell, by producing in the dark various shades of darkness. If, however, upon some pure iodide of silver, spread out on glass, and exposed to Light, we drop a little of a solution of the ferrocyanate of potash, an instantaneous darkening will take place and extend, in different degrees, over the whole space moistened by that salt.

Although this effect is produced, when the iodide of silver is formed on paper, with the respective salts, in almost any proportion, provided the alkaline salt is not in excess, the best effect is produced when paper is prepared in the following manner:—

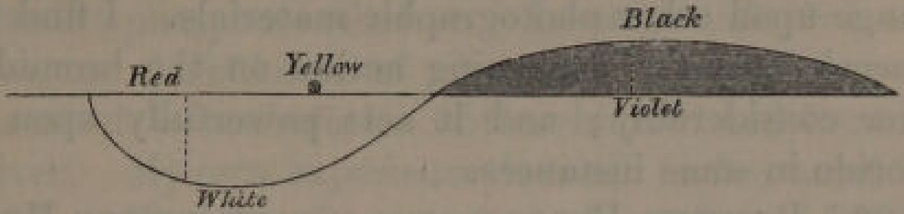
(85.) A piece of well-glazed letter-paper is washed over on one side with a solution of nitrate of silver—two drachms to one ounce of distilled water. It is then dried at a little distance from a warm fire, as speedily as possible. It is next washed over with a solution of the iodide of potassium—one drachm to one ounce of water—and being placed upon a smooth board, or a porcelain slab, pure water is poured slowly and uniformly over the paper to wash away any soluble salts. It may be used immediately, or dried, and kept for future use. To use this paper, it is washed over with a saturated solution of the ferrocyanate of potash (*yellow prussiate*), lightly dried with blotting paper, and placed in the camera. A few minutes are quite sufficient to give a very beautiful negative picture. Leaves of plants, or engravings, are copied with very great sharpness of outline, by the exposure of a moment to sunshine.

I stated in my first announcement of this process, that if the paper when washed with the solution of the ferrocyanate was dried, it was insensible to solar agency. If, by high drying, all the hygrometric moisture is removed from the paper, this is pretty nearly true; but under the ordinary conditions, the paper will change with tolerable rapidity, but not so rapidly as when moist, nor does it eventually arrive at such a degree of blackness.

(86.) Extremely rapid as the change which takes place is, it may be very much quickened by first bringing on a degree of oxidation on the iodide of silver, either by heat or Light. If the paper is allowed to brown under the influence of either of these elements, and then washed with the solution of the ferrocyanate, the change is almost instantaneous. It is, however, unfortunate that this previous darkening, interferes with the transparency of the paper so much, that positive copies cannot be obtained from these negative photographs.

(87.) The fixing of these photographs appears to be a matter of some uncertainty. It frequently happens that different specimens, all fixed by the same process, have different degrees of permanence, some of them fading very rapidly, and others enduring for a long time, without the slightest appearance of change. This arises from the obstinate retention of a portion of the ferrocyanate in the paper, the presence of the smallest quantity being eventually fatal to the picture. This action of the ferrocyanate of potash was first pointed out by Sir John Herschel, who used this salt as a fixing agent; but he soon abandoned it on this account. The most successful mode is to soak the photograph for some time in warm water, which should be frequently changed, after which it should be brushed over on both sides with a weak solution of the iodide of potassium, and then again soaked in cold water for five or ten minutes, and dried.

(88.) Prismatic Analysis.—The spectrum produced upon the iodide of silver has been already described (72.). After the application of the ferrocyanate of potash, the paper blackens with extreme rapidity, the darkening process commencing in the violet rays, and extending over the whole space, occupied by the invisible chemical rays, and all the visible spectrum down to the extreme red rays. If removed as soon as the first darkening is seen to take place, a coloured spectrum will be found impressed, the red rays impressing a red colour, and the blue ones blue. In a short time a bleaching action comes on under the red rays, and extends upwards to the green. In the first action there is no evidence of any protecting influence in the extreme red ray; but when the bleaching effect is set up, the space occupied by the extreme red ray is maintained perfectly dark. I have been very kindly favoured with a prismatic analysis from Sir John Herschel, which quite confirms my own results,—the spectrum this distinguished philosopher obtained being of this character:



(89.) Advantage has been taken of this bleaching property, for the production of positive photographs by the first process. The plan pursued, is essentially, to darken the paper after the application of the ferrocyanate, and then to throw the balance in favour of the whitening effect, by washing over the paper with a tolerably strong solution of the iodide of potassium. Some processes, which are much more certain, and which give more permanent pictures, will presently be described.

(90.) The increased sensibility of this paper, appears to depend on the united decomposition of the ferrocyanate of potash and the iodide of silver. It is well known that the ferrocyanate of potash is decomposed by prolonged exposure to the sun's rays, and a portion of prussian blue formed. It will be found that this decomposition is brought about with much greater rapidity, if iodide of potassium is mixed with the ferrocyanate; and this appears to be the case with most of the metallic iodides: with the iodide of silver this is very decided. Chemical philosophy affords us numerous examples, of the power which one body possesses of setting up an action similar to its own, in bodies brought into contact with it. Here we have two bodies in, what appears to be, almost chemical union, each one subject to change under solar power, exerting this *catalytic* influence, as it has been called, upon each other.

(91.) The ferrocyanate of potash will, in all probability, be found equally useful in quickening the change upon other photographic materials. I find that it accelerates the darkening action on the bromide of silver considerably; and it acts powerfully upon the chloride in some instances.

(92.) Positive Photographs formed by the Hydriodic Salts. — If photographic paper, which has been darkened by exposure to Light, is washed over with the hydriodate of potash, it is speedily whitened by the same agent. This property was observed by Herschel, Talbot, Lassaigne, Fyfe, and the author, about the same time. The interesting character of the photographic processes founded upon this peculiarity, led me to pay considerable attention to them. The results of my inquiries were published at the time in the "Philosophical Magazine*," since which but little has been added to our knowledge of the subject.

(93.) To avoid unnecessarily complicating this part of my treatise, I shall refrain from entering into that very minute detail, which is given in the paper above referred to, and confine myself to an explanation of the best mode of preparing a good photographic paper, on which, by the united agency of the hydriodates and the solar rays, perfect pictures may be produced in the camera or otherwise, having their lights and shadows correct as in nature. It is necessary to remark, that more exact attention is required in the preparation of this kind of paper, than in almost any other; very trifling differences in the proportions of the ingredients used, and in the time occupied in the first darkening process, completely changing the result, as will be hereafter explained.

* Philosophical Magazine, Vol. xvii. No. 109., September, 1840.

(94.) In preparing this kind of paper, almost any of the sensitive salts of silver may be used. Dr. Fyfe prefers the phosphate of silver. Lassaigne, Bayard, and Talbot, use the chloride of silver. Verignon, however, recommends a combination of the chloride and bromide of silver. My own experience is much in favour of the chloride. Muriate of ammonia and muriate of baryta produce much better effects than any other muriates, the bleaching action being more easily excited, and the resulting pictures being of a more beautiful character.

Good letter paper is soaked for five or ten minutes in solutions of either of the above salts — forty grains of the salt to four ounces of water. Each sheet is then carefully removed, and being laid on a porcelain or marble slab, gently wiped over with very clean linen. It is then dried. When dry, the paper being pinned out upon a board, it is washed over with the following solution: —

Take of crystallized nitrate of silver 120 grains, and dissolve it in twelve fluid drachms of distilled water; to this solution add four fluid drachms of alcohol, which will render the mixture opake. After a few hours, a minute quantity of a dark precipitate falls, which must be separated by the filter.

This solution must be applied with a very soft sponge brush, boldly but lightly, over one surface, and the paper carried directly into the sunshine. It is instantly changed, but usually it darkens very unequally, owing to the irregular absorption of the fluid by the paper (63.). After it has been exposed for a few minutes, it is removed, and being again washed over with the argentine solution, it is a second time exposed, and kept in the sunshine, until a very regular fine chocolate brown colour is produced. It is then dried in the dark and preserved for use.

(95.) It is necessary that great attention should be paid to the quantity of Light to which, in this part of the process, these papers are submitted. The morning sun should be chosen, and a perfectly cloudless sky, if possible. It may appear unlikely, but nothing is really more true, than, that these papers indicate to the practised eye in the bleaching operation, the effects of every cloud which has obscured the sun's disc during the darkening process. A peculiar film, as if the washes had been applied with a dirty brush, is produced by every such check.

(96.) To use the papers thus prepared, it is required that they should be washed over with an hydriodate, and exposed to the sun's influence wet. The iodide of potassium being the salt which is most easily obtained will be generally preferred. It is very difficult to decide on the best proportions in which this salt should be used, the difference of a few grains only, wonderfully altering the result: in general about 30 grains of a pure salt to one ounce of water, will be found to produce the best effect. In some experiments instituted to settle this important point, it was found that papers washed with a solution containing 100 grains to the ounce, required twelve minutes to bleach in the direct rays of the sun; whereas papers washed in a solution of the strength above recommended, took but four minutes. For the camera obscura I would recommend the use of the hydriodate of baryta over every other preparation; and if by throwing down some of the baryta by a drop or two of dilute sulphuric acid, we set free a little hydriodic acid, it acts much more energetically on the darkened paper, giving in the camera, provided a good clear image is formed, and a due portion of Light admitted, a very beautiful positive picture in half an hour. When engravings are required to be copied, which they may be most beautifully, by this process, they should be soaked in water, and superimposed on the photographic paper quite wet. The object of this is two-fold — to insure transparency, and the closest possible contact; the interposition of a film of air interfering with the result. Although it may appear, that there is much which is perplexing in this process, a little attention will soon render any one perfect in the manipulatory details, and then the results are certain. Pictures taken from nature with the camera in this manner possess extreme beauty. The fine contrast of the shadows with the lights, give them the character of finished sæpia drawings; and the gradations of tint, corresponding with the amount of Light radiated from different objects, are very pleasing.

(97.) These drawings may be most perfectly fixed, provided they are kept in a portfolio, and only exposed to the sunshine *occasionally*, by washing them in clean water, which removes all the hydriodate that has not been decomposed. If, however, these drawings are exposed continually to Light, and to the influence of atmospheric changes, they slowly fade out, and in a month or two no trace of a picture remains. This may be thus explained. If a darkened paper is washed over with an hydriodate, and exposed to sunshine, it is at first bleached, becoming yellow; then, if long exposed, it again darkens. If in this state, it is put aside in the dark, it will in a few days, be completely bleached; by exposure to Light it may be again darkened, but not so readily as at first, and the yellow colour is again restored in the dark.

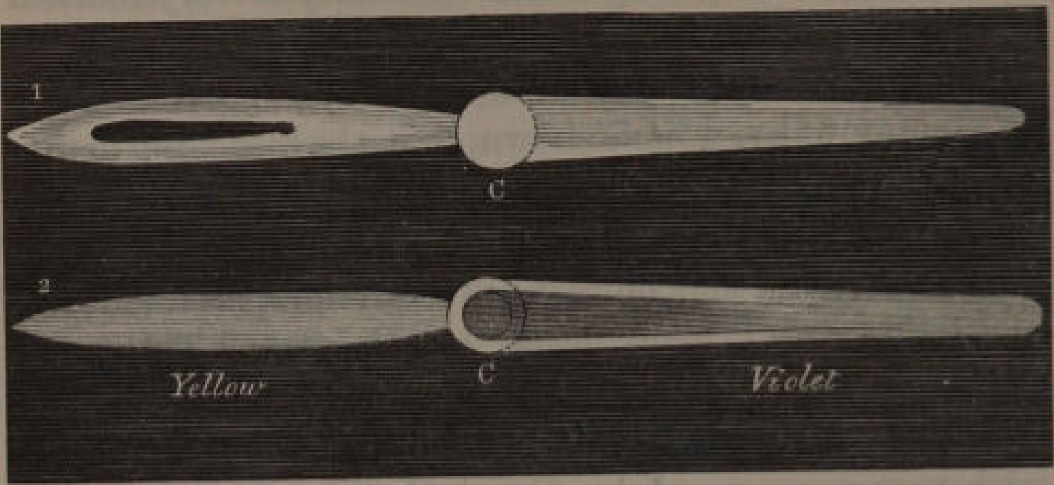
(98.) If a dark paper, bleached by an hydriodate and Light, be darkened, and then placed in a bottle of water, the yellow colour is much more quickly restored, and bubbles of gas will escape freely, which will be found on examination to be oxygen. If placed in an exhausted vessel and hermetically sealed, the drawings thus formed are quite permanent, however much they may be exposed to sunshine. From this it is evident that the gradual fading arises from the influence of atmospheric moisture. The water is slowly decomposed under luminous influence, the hydrogen unites with the iodine to form hydriodic acid, which converts the darkened portion again into the yellow iodide.

(99.) A few interesting experiments will place this question in a much clearer light. Precipitate with any hydriodate, iodide of silver from a solution of the nitrate, and expose the vessel containing it, liquid and all, to sunshine. The exposed surfaces of the iodide will blacken; remove the vessel into the dark, and after a few hours all the blackness will disappear; we may thus continually restore and remove the blackness at pleasure. The next experiment not only illustrates the phenomenon we are considering, but it further shows, in a very marked manner, the influence of Light in producing chemical change. In one watch-glass was placed a solution of the nitrate of silver; in another, a solution of the iodide of potassium. The two glasses were connected by a filament of cotton, and a circuit made up with a piece of platina wire. This little arrangement was exposed to Light, and in a very short time iodine was liberated in one glass, and the yellow iodide of silver formed in the other, which blackened as quickly as it formed. A similar arrangement was placed in the dark. Iodine was slowly liberated; *no iodide of silver formed*, but around the wire in the glass containing the silver solution, a beautiful crystalization of metallic silver. If the glasses in which the processes of decomposition have taken place, be placed in the dark, it will be found, in a few hours, that the solution which has become brown, from the liberation of iodine, again gets gradually clear, and the darkened precipitate is converted into the yellow iodide of silver. The power of the sun's rays in influencing or disposing chemical affinity is very marked in these experiments.

(100.) Prismatic Analysis.—In my popular Treatise on Photography, I have shown, that the bleaching action is carried on by the influence of the blue, and the more refrangible rays; also, that the least refrangible portion of the spectrum acts powerfully on the prepared surface, and induces an *extreme degree of blackness.* This peculiar and complex action has been much more fully examined by Sir John Herschel, who repeated the analysis with papers prepared by the author.* When a paper prepared as above was exposed to the spectrum, and washed with a solution too weak fully to excite it, two contrary actions were produced by the rays above and below the zero point or mean yellow. By the former the paper was bleached, the action beginning in the least refrangible violet, and extending upwards a considerable distance, and downwards to the circumference of a semicircle, having the point at which the action commenced for a centre. By the latter the paper was darkened, the blackness spreading upwards and downwards; upwards till it passed the zero point, and nearly or quite attained the semicircle above-mentioned, and downwards to a space beyond the extreme red ray. By repeatedly washing the paper with the hydriodic solution, both actions grew more intense, but the bleaching

* Sir John Herschel on the Action of the Rays of the Solar Spectrum (Philosophical Transactions).

action the most so. At length, by repeated washings, the darkness produced at the lower part of the spectrum began to give way, and was slowly replaced by a very feeble bleaching, which at length extended very far indeed below the extreme red rays, and upwards to join the semicircle C. Within this semicircle and its



train, a somewhat dark, perfectly circular and well-defined solar image arose, its diameter being somewhat less than that of the semicircular terminations, so as to leave a perfectly clear and distinct white border all around it, as represented in No. 2. This circle gradually extended itself into an oval or tailed form, but preserving its circular shape below, and maintaining the white border inviolate. Finally, after long-continued action, the interior browned oval above-mentioned, was found to have been prolonged into a figure of the annexed form,

of which the termination by a narrow neck and circular enlargement, indicates the definite action of a ray much further removed along the axis of the spectrum.

We shall perceive from this, that four distinct actions are exerted on these papers—1st, Bleaching by the most refrangible rays. 2dly, Blackening by the least refrangible. 3dly, Darkening by the most refracted portion of the spectrum; and, 4thly, Bleaching by the rays of least refraction. The two last actions may be imitated to a considerable extent by radiant heat, and I have but little doubt that the bleaching by the red rays is due to thermic influence. The two first actions, it will be evident, are, first, the formation of the iodide of silver, and, secondly, the re-oxidation of this iodide. The definite spaces to which the rays are confined, on which these actions depend, are very remarkable, and appear to point to an involved system of solar emanations, which we are not in a situation at present to explain.

(101.) These very peculiar influences, may be most prettily illustrated, by placing a piece of the prepared hydriodic paper, with an engraving superposed, behind four pieces of coloured glass. Beneath a blue glass the engraving will be very perfectly copied with correct light and shadow. If a deep green glass is used, a negative picture will result, from the blackening of the paper, and the same takes place under a yellow glass; but under a glass stained red with oxide of gold, a negative picture is formed, not by the darkening of the oxide of silver, but by the eating out of *strong lights* on all the lines which correspond with the *dark parts* of the engraving, these parts having the most calorific influence.

(102.) Experience has convinced me, that the use of coloured glasses, in any experiment which has for its object, the elucidation of any of the phenomena connected with the chemical power of the sun's rays, is to be avoided, as leading to error in many cases, and giving uncertain results in all. No correct conclusions can be arrived at in any way, but by prismatic analysis. The above, and some other experiments, which are to be found in these pages, are only given, as an easy way of showing some of the very peculiar and beautiful phenomena, with which the art of photography has made us acquainted. I shall, in a future page, make some remarks on the influence of coloured media, when I shall endeavour to show, the numerous sources of error to which we are liable, when we trust *solely* to their use, however carefully they may have been analysed by the prism.

(103.) Ioduret of Silver.—If upon a plate of polished silver we place a small piece of iodine, and apply the heat of a spirit lamp or candle beneath the plate for a moment, a system of rings is speedily formed, which is somewhat remarkable. To these rings Mr. Fox Talbot first called attention. The first ring, and which spreading constantly, forms the exterior of the circle, is of a bright yellow colour; within this, there arise successively, rings of green, red, and blue colours, and then again a fine yellow circle, centred by a greyish spot on the place occupied by the iodine. On exposing these to the Light, it will be found that the outer yellow circle almost instantly changes colour, and that the others slowly change, in the order of their positions, whilst the interior yellow circle resists for a long time the solar influence.* These rings must be regarded as films of the ioduret of silver, varying, not only in thickness,

* Mr. Fox Talbot informs us, that in 1838 he discovered the method of rendering a silver plate sensitive to light, by exposing it to iodine vapours. Daguerre did not publish his process until August, 1839. It is curious to observe, how very near the English experimentalist, approached to the discovery, which has given universal fame to the French artist.

but in the more or less perfect states of combination in which the iodine and the metal are. The exterior circle is an ioduret, in an exceedingly loose state of chemical agregation: the attractive forces increase as we proceed towards the centre; where a well formed ioduret, or probably a true iodide of silver, is formed, which is acted upon by sunlight with difficulty. The exterior and most sensitive film constitutes the surface of the Daguerreotype plates, which process, with its improvements, must now be described. The changes which these colóured rings undergo are remarkable; by a few minutes' exposure to sunlight, an inversion nearly of all the colours takes place, the two first rings becoming a deep olive green, and a deep blue inclining to black. It is a very pleasing experiment, to form those beautiful rings, by placing a small piece of iodine on a little silver leaf, and then, covering one half of them with an opaque body, expose them to the solar rays.

(104.) THE DAGUERREOTYPE.—The material used as the tablet, upon which the solar radiations are made to impress external nature, is copper plated with silver. The copper serves principally to support the silver foil, but it has been stated, with some degree of correctness, that the combination of the two metals tends to the improvement of the effect. It is essential to success that the silver should be brought up to the most perfect polish. This is best done by polishing with cotton dipped in sweet oil, and finely levigated Tripoli powder, or rotten stone.* The cotton is to be frequently changed, and great care must be taken that the plate is not touched with the fingers. Dry cotton and very fine Tripoli dust must be used to complete this part of the

* Polishing with spirits of wine has been recommended in preference to the use of oil.

process. The plate is then subjected to the heat of a spirit lamp, or a charcoal fire, for a few minutes, and cooled as speedily as possible, by placing it on a mass of metal or a stone floor: the object of this is to remove the organic film which the oil has left on the plate. Daguerre has recently stated it as the result of his experience, that any organic or atmospheric film, interferes with the rapidity of the operation; hence, after having polished the plate, he floats it with pure water, and heats it to a high degree over a spirit lamp, and afterwards pours off this layer of water in such a manner, that its surface, on which the film, or any sediment removed, may float, shall not touch the plate; after this, the plate is not again polished. This film has been stated by some to assist in the formation of the images, but experience has shown, that too much attention cannot be bestowed on its removal. The plate, when cold, should be finished off with cotton dipped in a solution of one part of nitric acid to sixteen of water, and then with dry and clean cotton.

(105.) The next operation is to form on the surface of the silver the sensitive film. On the success or otherwise of this operation every thing depends. The plate, when viewed by a very weak artificial light, should present a perfectly yellow and brilliant surface. Several plans have been suggested, by which the iodine may be made to attack the plate equally; but all of them requires, on the part of the operator, the closest care and attention. The most easy, and, at the same time, the most certain, appears to be the following. Some cotton wool being placed very evenly on a board the size of the silver plate, is saturated with an alcoholic solution of iodine, and allowed to dry in the dark, in a cool place. This board is laid in a box, and the silver plate placed about two inches above it, being supported at the four corners. The cover of the box being closed, all is allowed to remain in this state for two or three minutes, when, on removing the plate, it will generally be found that the required fine yellow surface is produced.

(106.) The ioduretted plate is now placed in the dark chamber of the camera, and the focus being properly adjusted, it is exposed to the agency which is to impress upon it the required images. The length of time, necessary for the production of the best effect, varies with the state of the Light, the kind of image to be copied, the condition of the plate, and other things, which can only be arrived at by experience. In general, where the plate is prepared, as directed by Daguerre, with the iodine alone, about five minutes is required, in ordinary sunshine, to copy any architectural pile; but a much less time is often sufficient.

(107.) The plate being removed from the camera in the dark, no image should be visible upon it. A change has taken place; but as the colour of the plate is not altered, that change cannot be seen. If the plate in any part is browned by too long an exposure, the lights of the picture are injured. To develop the hidden picture, the plate is placed in a box, at the bottom of which is a little mercury, so arranged, that the heat of a spirit lamp may be applied, until the temperature of the mercury is about 167° Fahr. The lamp is then removed; and the plate, which is watched through a glass in the side of the box, by the light of a taper, allowed to remain until the picture, in all the beauty of its minute details, is perfectly brought out. It is then removed, and it has to be subjected to the operation of fixing, or of rendering the plate of metal insensible to any further solar agency.

(108.) In forming a Daguerreotype image, it is not absolutely necessary to heat the mercury. Faraday proved that mercury was volatilised at common temperatures; and Moser has pointed out, that if the Daguerreotype plate, after it is taken from the camera, is placed over a vessel of cold mercury for some hours, the image will be brought out in the same manner as if the mercury had been warmed. Moser has likewise shown that if the mercurial vapour is raised to a temperature between 250° and 300° Fahr., the Daguerreotype picture becomes fixed, and may be strongly rubbed. "It loses a little of its intensity at first, but not afterwards. The images, however, cannot generally resist rubbing with moist materials, as with polishing substances." It is not necessary to have recourse to the ordinary methods for removing the iodine from these fixed pictures, as it can be rubbed off.

(109.) Fixing may be effected in several ways, all of which depend upon the removal of the iodine from the plate. A strong solution of common salt will do this; but if the plate is placed in such a solution, and then touched with a rod of zinc, the removal is much more rapidly and effectually accomplished. By far the best plan, however, appears to be that recommended by Daguerre, in the first instance. The plate is first placed in clean cold water, and then into a solution of the hyposulphite of soda, in which it is moved to and fro, until all the yellow colour is completely gone. It is then removed, placed in an inclined position, and boiled rain water, cooled so as to be just warm, poured over the plate in a continuous stream. Any drops of water which may remain on the plate must be removed by forcibly blowing over it. The process is now completed, as far as preventing the further action of Light is concerned. The picture is formed of the fine dust of mercury deposited over those parts on which the Light has acted, the thickness of the vapour agreeing exactly with the intensity of the Light which has fallen on the different parts of the picture: the shadows being represented by the high black polished face of the silver.

(110.) This picture can of course be immediately destroyed by a touch, it is therefore necessary to protect it at once, by a glass or some other means. Berard, Fizeau, and others, have recommended the use of the chloride of gold, for the purpose of giving adhesion to the mercurial deposit. It is thus applied, according to the method recommended by M. Fizeau, and which appears to have been the most successful of any of the plans which have been adopted. A double salt of hyposulphite of soda and gold is formed, by mixing very dilute solutions of the respective salts. After the iodine has been removed, as before directed, the plate is placed in an iron frame, and a sufficient quantity of the salt of gold to cover the plate, poured over it. It is then heated by a spirit lamp for a minute, or until the impression acquires the greatest strength. The liquid is then poured off, the plate well washed and dried. Gold is deposited over the plate, and thus the picture rendered less liable to injury.

Dr. Berres of Vienna states that considerable success has attended his plan, which consists in exposing the plate for a few minutes to nitric-acid vapour, and then placing it in nitric acid, at $61\frac{1}{4}°$ Fahrenheit, in which a considerable quantity of silver and copper is dissolved. Shortly after being placed therein, a precipitate of metal is formed over the photograph. It is then removed, and the plate polished with chalk or magnesia, until the picture can be clearly seen.

(111.) The power of multiplying these very beautiful productions is much to be desired. Several plans have been proposed, and used by the inventors, with certain degrees of success, particularly Professor Groves' method of etching by electrical agency. All of them, however, are of great uncertainty; and even with the most careful manipulation, a successful result cannot be depended on. It does not form a part of the plan of the present work to embrace these matters, though they are of the highest interest to every one who is concerned in the success of photographic publication. It must, however, be acknowledged, that the only successful method of multiplying original photographic designs, appears to be the use of processes on paper, or some more transparent material, which giving negative pictures in the first instance, will afford positive copies.

(112.) The Daguerreotype process has been greatly improved; and in the hands of Claudet, and others in England and America, a degree of sensibility secured, upon the silver surface, which it appears almost impossible to surpass. This is effected by exposing the plate, after the process of iodization, to the influence of chlorine or bromine, very much diluted with common air, or by using either the chloride of iodine or the bromide of iodine. The unstable character of these compounds is well known; and on the facility with which these agents are decomposed, depends the increased sensibility of the Daguerreotype plates prepared with them.

Fizeau has recommended the use of bromine water for the purpose of improving the sensitiveness of the iodized plates. This is prepared by shaking together in a bottle some bromine and water, care being taken that the bromine appears in excess. One part of this bromine liquor is united with thirty or forty parts of water, and being poured into a square shallow vessel covered with a glass, the iodized plate is exposed to its action for a few seconds, during which it passes from its yellow colour into a rose hue, which is the most sensitive coating yet discovered. A preparation, known by the name of the Hungarian mixture, has been rather extensively sold in Paris, for the purpose of giving sensitiveness to the plates, which it does with a considerable degree of certainty.

(113.) As long back as 1841, it was announced that M. Daguerre had discovered a process by which an instantaneous effect was produced; and in a communication with which the author was favoured from Daguerre himself he states, "*By means of that new process it shall be possible to fix the images of objects in motion, such as public ceremonies, market-places covered with people, cattle,*" &c. But, up to the present time, some great obstacle appears to have interfered with the successful practical use of this new and important discovery. It has been stated, and apparently on satisfactory evidence, that electricity is the agent employed to assist the operations of Light in bringing about the required change.

(114.) The expense of metallic plates and their inconvenience, particularly to travellers, renders it very desirable that some material, such as paper, might be employed instead of them. Some very tolerable effects have been produced upon silvered paper; but the pictures thus formed, want the fine black surface, which is to contrast with the mercurial vapour, and which forms the chief charm of a good Daguerreotype. In the Philosophical Transactions, Part II., for 1840, is a paper, by the author, "*On the Influence of Iodine in rendering several Argentine Compounds spread on Paper sensitive to Light.*" As many of the results are of considerable importance, particularly as they bear upon some of the opinions which we shall have to examine, I shall briefly mention such facts as appear necessary to the complete elucidation of this very interesting subject.

(115.) Any of the ordinary photographic papers, will darken by exposure to a brown or dark olive colour. Exposed to the vapour of iodine, the paper becomes of a steel blue or violet colour. If subjected to solar influence in this state, mercurial vapour attacks all the parts on which the Light has acted, in the same manner as it does the iodized metallic plate, giving a tolerable picture. I also found, that perfectly pure oxide of silver, spread on paper and iodized, was similarly disposed to receive the mercurial vapour, after it had been submitted to the sun's rays. The yellow-brown phosphate of silver, was also found to acquire additional sensitiveness under the influence of iodine, and to yield a tolerable picture when exposed to the mercurial fumes.

(116.) Papers which were prepared, by first saturating them, with strong solutions of the nitrate of silver, and then exposure to phosphuretted hydrogen gas, until there was a complete revival of the silver over the surface of the paper, were found to be acted upon by iodine, in a similar way to the silver plates themselves, and for most purposes are capable of being substituted for them. The pictures, when the papers are well prepared, are formed as readily as upon the iodized plates, and are not at all wanting in the beauty of their general effect, or in the delicacy of their minute detail. It unfortunately happens that a considerable degree of risk attends the preparation of the paper by this spontaneously inflammable gas.

(117.) Papers prepared in a similar way, substituting the sulphuretted for the phosphuretted hydrogen, are in nearly all respects equal to them. Some difficulties attend the preparation, but, by observing the following directions, papers of a very uniform dark grey surface may be prepared. The paper is first soaked in a solution of the muriate of ammonia, carefully wiped with cotton cloths, and then dried. It is next dipped in a solution of nitrate of silver, dried in the dark, and then carried into a vessel in which sulphuretted hydrogen is slowly forming. When it has darkened to an iron brown, the paper must be passed through water slightly impregnated with chlorine or muriatic acid, and again dried. It is once more dipped into an argentine solution, and when dry, subjected a second time to sulphuration. These papers are best iodized by drawing them slowly over a saturated solution of any hydriodic salt, in which is dissolved a considerable quantity of iodine: care must be taken that one side only of the paper is wetted. It is then dried near the fire, and subjected in the camera to the solar agency. After mercurialization, the picture is fixed most effectually by a strong solution of common salt used moderately warm.

(118.) If when these drawings are finished, they are placed in a solution of corrosive sublimate, the images entirely disappear, but after a few minutes they are seen, as if by magic, unfolding themselves, and gradually becoming far more beautiful than before—delicate lines, at first invisible or barely seen, are now distinctly marked, and a rare and singular perfection of detail is given to the photograph. A similar obliteration is described before (66.); but in this case the results are very different, the picture being again restored by the agent which caused it to disappear. It would appear that the mercury on the paper, is slowly converted into a protochloride; the *modus operandi* is not, however, quite evident.

(119.) From the great interest which attaches to the discovery of Daguerre, we must now endeavour to examine, some of the most remarkable points in the phenomena, which are afforded in pursuing his photographic practice. If we expose a prepared plate for a considerable time, to the action of Light in the camera, it is darkened, and a *negative* picture results. The discovery of Daguerre, is, that, before the negative image is formed so as to be visible, the ioduret of silver has undergone a change, which has given it the property of condensing over well-defined spaces the vapours of mercury. It has been shown by M. E. Becquérel, that if the plate be removed from the influence of Light in the camera, before it has been exposed sufficiently long to afford, with the mercurial vapour, any picture, or at least any thing beyond the faintest outline of a design, the process may be carried on, by exposing the plate to Light under a *red glass*, until it is fitted for the production of a perfect positive picture by the vapours of mercury, or until by prolonged exposure a decided negative photograph comes up. E. Becquérel assumes, from these results, that there exists two orders of rays, which have not been previously described, and which he calls

Rayons excitateurs, and
Rayons continuators.

(120.) These conclusions, it appears to me, have been come to by Becquérel, and discussed by Moser, without that philosophic deliberation which should always distinguish such inquiries. It will be found that the process, supposed to be carried on by the *rayons continuators*, considering them as a new class, is due to the calorific rays, and it will be found that very nearly the same effect is produced, by the application of artificial heat to the under surface of the plate. But it is not entirely to the calorific rays that the effect is due. We know, as will presently be seen, that the least refrangible rays of the prismatic spectrum are not without some chemical power, and that is a power quite independent of their heating effect; and it will be found, with nearly all the sensitive preparations, that the action, under any circumstances of Light, is carried on much more rapidly upon those parts over which, either by Light or heat, a chemical disturbance has been already begun, than over the other parts. Moser, indeed, admits that some blue and violet rays penetrated the red glasses he used in his experiments, therefore the only effect which, as I conceive it, the red medium produced, was to retard the change, over the undisturbed parts of the plate, whilst a sufficient quantity of the most refrangible, and extra spectral chemical rays, had passed the glass, to continue the change which had been already begun. Yellow glasses were found by Moser to produce, first negative and then positive images; but "*these positive images have always a blackish covering.*" Now this is as easily explained as the action of the red glass. The change is carried on "*by the large quantity of white light*" which these yellow glasses allowed to pass, with much greater rapidity over the parts on which the Light has already acted, than on the others; but even these were gradually changed. Any one conversant with the ordinary photographic processes, must have observed, that when the maximum point of darkening has been arrived at, a peculiar olive tinge, gradually comes on *, and the picture being now a fine brown colour on an olive ground may be considered a positive one.

(121.) What is the nature of the change which the ioduret of silver undergoes on these Daguerreotype plates? This question has been often asked, and answered in various ways. Draper †, from an experiment in which he placed a paper saturated with starch, on an iodureted plate, and which, after exposure, gave no evidence of the formation of the iodide of starch, from the liberation of the iodine, infers that no decomposition of the sensitive surface has taken place. Moser contends, that " the action of Light does not necessarily consist in the separation of two chemically combined bodies." He appears to attribute the alteration of colour, to an isomeric change in the iodide of silver. In a paper published in the Philosophical Magazine, April, 1840, I stated it as my opinion that there were two iodides of silver, one speedily darkening, and the other unalterable by Light. The results of my observations, since that period, lead me to view the matter differently, and I regard the action of Light on this salt, as a very evident case of decomposition. (98.) I have, in a more recent paper in the same journal ‡, drawn attention to some instances of decomposition, apparently similar to those produced by Light, and indeed regarded by Moser as the effects of " *invisible light*," but which can be very clearly traced, to the disturbance of the caloric, latent in the bodies operated on. I refer to this, only in proof of

* Moser says, " I exposed iodized plates to daylight, and, whenever possible, to strong sunlight. *The plates became first black, then lighter, and lastly greenish.*"

† Philos. Mag., Sept. 1841.

‡ On the Changes which Bodies are capable of undergoing in Darkness, &c., April, 1843.

the position, that the *blackened iodide* is indeed silver, from which the iodine has been set free, in a state of very fine division, and partial oxidation. As these phenomena will form the subject of a separate chapter, I shall not do more than refer to them in this place.

(122.) It will be found, if we allow one part of a sensitive plate to blacken, whilst the other portion is protected from the Light, that the dark part is very easily removed by rubbing with the hand, whilst the unchanged division, resists any such mechanical means of removal. In the very fine powder thus rubbed from the silver, I have never been enabled to detect any iodine, but it comports itself, in all respects, like the oxide of silver and the finely divided metal. A fact mentioned by Moser — viz. that he has been enabled to remove film after film of the sensitive surface, and yet had a surface which was still sensitive to Light, which he considers conclusive in favour of his argument, that the combination of silver and iodine is not decomposed—appears to me to prove nothing. The iodine may attack the plate to a considerably greater depth than we imagine; and hence, although we may remove eight surfaces, we may still have a sensitive surface left, or, as I am inclined to believe, the iodine being liberated, from the most superficial film, attacks immediately the one below it. The powerful affinity of this element for the metals, will countenance this opinion, and it will account for the failure of Dr. Draper to produce the iodide of starch in his experiment. It has been shown by M. Lerebour, that the presence of the smallest quantity of iodine vapour in the camera is quite sufficient to prevent the formation of any image; and he distinctly states that he has failed to produce a picture, during the whole of a long summer day, owing to his having kept his iodizing box and camera together, by which the latter received a little of the vapour of this subtle elementary body. Ammonia dissolves off from the plate the darkened portion, whilst a solution of the muriate of soda, or of the hyposulphite of soda, removes the unchanged ioduret. These facts certainly support the view, that decomposition has taken place on the sensitive surface, that the iodine has been liberated by the action of the solar rays, and that this change fits parts of the plate for the condensation of the mercurial vapour. There are some facts, however, curiously connected with this action of vapours, which will hereafter claim our attention.

(123.) PRISMATIC ANALYSIS. — In the Philosophical Magazine for April, 1840, the author published an account of the effects produced by the spectrum on a Daguerreotype plate. The experiment has been repeatedly tried, and the results have been the same, if we except a little shifting of the point of maximum action — a subject on which more will be said hereafter. The most refrangible portion of the spectrum, appears, after the plate has been exposed to the vapour of mercury, to have impressed its colour; the light and delicate film of mercury which covers that portion, assuming a fine blue tint about the central parts, which are gradually shaded off into a pale grey; and this is again surrounded by a very delicate rose hue, which is lost in a band of a pure white. Beyond this, a protecting influence is powerfully exerted; and, notwithstanding the action of the dispersed light, which is very evident over the plate, a line is left, perfectly free from mercurial vapour, and which, consequently, when viewed by a side light, appears quite dark. The green rays are represented by a line of a corresponding tint, considerably less in size than the luminous green rays. The yellow rays appear to be without action, or to act negatively, the space upon which they fell being protected from the mercurial vapour; and it consequently is seen as a dark band. A white line of vapour, marks the place of the orange rays. The red rays affect the sensitive surface in a peculiar manner; and we have the mercurial vapour, assuming a molecular arrangement which gives to it a fine rose hue; this tint is surrounded by a line of white vapour, shaded at the lowest extremity with a very soft green. Over the space occupied by the extreme red rays, a protecting influence is again exerted; the space is retained free from mercurial vapour, and the band is found to surround the whole of the least refrangible rays, and to unite itself with the band which surrounds the rays of greatest refrangibility. This band is not equally well defined throughout its whole extent. It is most evident from the extreme red to the green; it fades in passing through the blue, and increases again, as it leaves the indigo, until beyond the invisible chemical rays it is nearly as strong, as it is at the calorific end of the spectrum. By lightly rubbing a Daguerreotype picture of the prismatic rays, it is obliterated, except over the spaces corresponding with the yellow and red rays. In November, 1842, Dr. Draper forwarded to Sir John Herschel, a specimen of a Daguerreotyped impression of the solar spectrum, obtained by him in the south of Virginia; and in the Philosophical Magazine for February, 1843, Sir John Herschel published an account of his examination of it. In its principal features, this spectrum corresponds with those I have obtained; and I am inclined to attribute the variations which do exist, not merely to a difference in the Light of the sun, but also to some peculiarities in the prisms employed. I am quite inclined, with Dr. Draper, to believe that spectra obtained near to, or at a distance from the equator, will be found to vary considerably; and it is only on the strength of this opinion, that I am at all enabled to reconcile, the somewhat contradictory results of our experiments. The principal difference which is to be observed between Dr. Draper's spectrum on the Daguerreotype plate, and that which I have described, consists in the remarkable distinctness of the compartments, which are found between the space occupied by the yellow ray and the most refrangible portion of the spectrum. The same protected spaces are observed at the top and bottom of the spectrum; but there is no appearance of the same influence at the sides of the spectral image. Sir John Herschel has shown that the tints observed on this spectral image, are the Newtonian series of colours of the first order of the reflected rings; modified, however, in its first stages, by a cause which seems to have shifted the initial black of that series, to a higher point in the scale of thicknesses of the producing film, or to have displaced the whole series by the intrusion of a white commencement. For the Newtonian reflected tints of the first order are black; very feeble and hardly perceptible blue; brilliant white; yellow; orange, at which point the series breaks off. (*Herschel.*)

(124.) It will not be improper to mention here, that when copper, plated with silver cannot be procured, very tolerable results may be obtained, by using plates of copper silvered, with the ordinary silvering compound of chloride of silver, common salt, and cream of tartar. The copper being brought to a perfect polish, is well washed with salt and water; a little of the silvering compound is briskly rubbed over the plate, until it presents a uniform coating of white silver; the plate is immediately washed in clean salt and water, and dried near the fire, by carefully rubbing it with very clean cloths. I have found that the polish of this silvering is much improved, by passing the plate through a very weak solution of iodine in water. A thin film of ioduret of silver is thus formed. It is then exposed to sunshine, and afterwards rubbed with a clean leather and a little fine prepared chalk, by which the iodized surface is removed, and a beautifully polished face left to operate on. It is then iodized, and used in the same manner as the plated copper tablets.

(125.) Some very curious results have been obtained by operating on silvered plates, with iodine in various ways. A silvered plate, with some leaves placed upon it and pressed close with a glass, was immersed in a solution of iodine in water, and in this state exposed to the Light. An ioduret of silver was rapidly formed, and blackened; this blackened coating was dissolved off, and another formed. Thus successive layers of the salt were formed and removed, until at the expiration of an hour, all the silver was gone from the exposed parts of the plate. Upon removing the leaves, it was found that a most beautiful impression of them was made on the copper, and they were of a rich green colour.

(126.) A piece of glass was covered with silver leaf, and treated in the same way as the silvered copper. The metal was dissolved from the exposed parts, and a very perfect silver leaf left upon the glass.

(127.) It may be worthy of observation, that the image on the Daguerreotype plates may be completely obliterated by rubbing, but it may be again restored, by placing it in a tolerably strong solution of iodine in water. I have often found, that the parts over which the mercury has not been deposited, are deeply etched by the solution of iodine, and it does appear that with some attention, a very important practical advantage may be taken of this remarkable peculiarity. The great difficulty lies in overcoming the spots which are formed by definite spaces in the metal, which are in different electrical conditions, from the other parts. These form so many points of action, and give rise to circles, which rapidly spread and obliterate the design. I have not much doubt but we might, by adopting Mr. Groves's method of etching these plates by the influence of an acid and a powerful voltaic current, produce some very pleasing results.

(128.) After exposure to Light, a well-prepared Daguerreotype plate, was placed in a vessel, in which chlorine was very slowly forming, from manganese and muriatic acid. In a short time the iodized surface, which had not been exposed sufficiently long to undergo any change of colour, became perfectly black. In this state it was subjected to Light; the effect of which was to whiten the plate with much rapidity. The author's engagements have not allowed of his following out this discovery; but it has in two or three trials which he has made, produced very tolerable positive pictures by the first process, without mercurialization.

(129.) Bromide of Silver. — This salt, like the iodide, does not appear to be very readily changed by the solar rays, when it is perfectly pure. The slightest admixture of the nitrate of silver, renders it very susceptible of change, and under certain conditions it becomes the most sensitive of the photographic preparations. M. Biot has expressed it as his opinion, that it is not possible to find any substance more sensitive to

Light than the bromide of silver. This opinion must, however, be qualified by the above conditions. Sir John Herschel has used films of this salt precipitated upon glass plates, which, when dry, are washed over with a solution of the nitrate, with the greatest advantage, in the camera obscura. It must, however, be observed, with regard to this, and other salts, which are stated to be unchanged in their pure state, that this applies only to a visible change. We have distinct evidence that a moment's exposure of the pure bromide of silver to the sun's rays is quite sufficient to produce a change, which may be rendered visible by subsequent applications.

(130.) Prismatic Analysis. — As soon as the prismatic spectrum falls upon paper, prepared with this salt, it blackens over the whole extent of action with nearly equal intensity. As far as I have been able to detect it, which it is difficult to do, from the rapidity of the action, the maximum effect is produced somewhere about the indigo ray. My own results correspond exactly with those obtained by Sir John Herschel, who says, "But the most characteristic peculiarity of the spectrum is its extravagant length. Instead of terminating at the fiducial point (the mean yellow ray) or thereabouts, the darkened portion extends down to the very extremity of the visible red rays. In tint it is pretty uniform (a grey black, not by any means intense) over the whole length, except that a slight fringe of redness (but no green or blue) is perceptible at the least refracted end." The author has, however, found that the grey-black may be very much darkened by allowing the nitrate of silver to be pretty much in excess; and by using a very faint spectrum he has sometimes got decided evidences of natural colouration. Below the red ray an extended space is protected from the agency of the dispersed light, and its whiteness maintained; thus confirming the evidence of some chemical power in action, over a space beyond the luminous spectrum, which corresponds with the rays of the least refrangibility.

(131.) Photographic Application. — If a paper is first washed with a solution of the nitrate of silver (100 grains to an ounce of water), and when dry with a solution of 20 grains of the bromide of potassium in four drachms of water, and the silver solution again applied, a paper of exquisite sensibility results, and it may be used with advantage in the camera obscura. These papers turn brown in the dark, by which their susceptibility to change by Light is much lessened.

(132.) In 1841, I published a process, which I then considered as quite new, by which pictures were produced on bromidated papers, after an exposure of an exceedingly short duration. This process had, I have since found, been previously pointed out by M. Bayard: of this I was, until long after, quite ignorant. Although there are some objections to the process, it is so very interesting, as giving evidence of the rapidity with which a faint gleam of Light will effect a change of state, that it cannot be well omitted in this place.

(133.) Paper is prepared with bromide of potassium and nitrate of silver, in such proportions that the nitrate is in very slight excess. When used, it is washed over with a solution of 120 grains of nitrate of silver, and placed wet in the camera. After being exposed for a second or two, the Light must be shut off, the camera carried into a dark room, and the paper allowed to dry in the dark. When dry it is placed in the mercurial vapour box; and heat being applied, the mercury is very slowly vaporised. The picture now begins to develop itself, and gradually a most intense negative photograph results. It often happens that the picture appears at first clouded; but if the paper is carefully placed in the dark, it generally, in the course of a few hours, gets clear. I have often procured most beautiful pictures by this method, after an exposure to solar influence during a second; and moving objects have been well defined, showing the action to be almost instantaneous. Photographs thus procured are best fixed, by soaking the paper in a weak solution of salt in water, and then by brushing the paper over with the hyposulphite of soda. The great difficulty to be overcome in this process, is the annoyance continually arising, from the perfect blackness produced over every part of the paper by the mercurial vapour. Often, when the best result appears to have been attained, in an instant the delightful picture vanishes away, and a sheet of blank blackness takes its place. It is not quite clear, to what this can be attributed; some kinds of paper are more liable to it than others, from which it would appear that it arises from the condition of the surface. I have, indeed, on some occasions been enabled to trace this blackening, from a little downy pile standing out more prominently from one part than from another. My attention has been carried away by the scientific interest which attaches to the inquiry, and I have not allowed myself to be detained, by the intricacies which I have found connected with those manipulatory details, necessary for the perfection of many of the processes described, and, amongst others, the one now mentioned. I have no doubt, however, that very beautiful effects might be relied on, if a little attention was given to a preliminary process, by which a perfectly uniform surface might be ensured. Certainly this process promises a degree of susceptibility, which no other, with which we are acquainted, seems likely to realize.

(134.) I have already mentioned, that the bromide of silver may be used very advantageously with the gallic acid for the production of pictures. I am inclined, under all circumstances, to regard the bromide as preferable to the iodide of silver. Certain it is that if we use these salts alone, or in a pure state, the bromide has an advantage over the iodide. It will be found that papers prepared with a single wash of each of the following solutions—

Bromide of potassium	50 grains,	water 1 oz.
Nitrate of silver	100 grains,	ditto—

may be used most advantageously for copying any fixed objects. They require but a few minutes' exposure, and at any time, the picture may be brought out, by washing with the solution of gallic acid. These photographs, which possess all the requisites of good negative ones, may be well fixed, by washing with a weak solution of the bromide of potassium, or with the hyposulphite of soda.

(135.) If a paper is covered with a perfectly pure bromide of silver, it will, when washed over with a solution of the ferrocyanate of potash, exhibit an increased degree of sensitiveness to solar agency; but the resulting picture, falls very short of that blackness which we get by using the iodide of silver, the darkest parts never becoming deeper, than a full grey or lead colour.

(136.) Prismatic Analysis.—If a bromidated paper, whilst under the influence of the spectrum, is washed with the ferrocyanate of potash, it begins to darken instantly over the violet rays, which darkening action extends down to the end of the visible red ray, some slight interference being observable about the region occupied by the yellow and orange rays. Then a bleaching action begins, over the space on which the red rays fall, which slowly extends up to the green: by a long-continued action, an oval spot begins again to darken, about the centre of the bleached space. In this case, as in that with the iodide of silver, if a second wash of the hydriodate of potash is applied, the bleaching action is extended over the region of the most refrangible rays, and considerably beyond them. We observe again in this instance, the negative action of the extreme red rays, which has been previously described.

(137.) Fluoride of Silver.—The combinations of fluoric acid and silver have not been previously examined. Sir John Herschel, indeed, suggested some experiments on glass plates of a very interesting description, but I am not acquainted with any published account of the results. Paper washed with fluate of soda, and then with nitrate of silver, is not more sensitive to Light than the nitrate itself, but it eventually becomes much darker.

(138.) Prismatic Analysis.—A paper was washed first with nitrate of silver, and then with the fluate of soda. Under the spectrum the action commenced at the centre of the yellow ray, and rapidly proceeded upwards, arriving at its maximum in the blue ray. To the end of the indigo the action was pretty uniform; it then appeared to be very suddenly checked, and a brown tint was produced under the violet rays, all action ceasing a few lines beyond the luminous spectrum. Some faint indications of change were evident to the lowest edge of the yellow, but none whatever below that point. The colours of this spectrum are not a little remarkable. I have now before me a spectrum impressed two months since, and the colours are still beautifully clear and distinct. The paper is slightly browned by diffused light, upon which appears the following order of colours. A yellow line distinctly marks the space occupied by the yellow ray, and a green band the space of the green: through the blue and indigo region the colour is an intense blue, and over the violet a ruddy brown.

(139.) The fluates of soda and of potash have been used in many different manners, and variously combined. It has been found that the fluate of soda has the property of quickening the sensibility of bromidated papers to a very remarkable extent; and from this quality a new process, which I would distinguish by the name of the Fluorotype, results.

(140.) The Fluorotype.—This process, which is characterised by its easy manipulation, and by the sensibility of the papers when carefully prepared, consists in the formation of a salt of silver, which I suppose must be considered as a fluo-bromide of silver. It is at present somewhat difficult to say, which is the most efficacious manner of proceeding; but the difference, as it regards the sensibility of papers, is so very trifling that this is not of much consequence. The paper may be washed first, with the bromide of potassium, and then with the fluate of soda; or, which will be found on the whole the best plan, the two salts may be united. The strength of the solutions should be as follows:—

{ Bromide of potassium	20 grains.
{ Distilled water	1 fluid ounce.
{ Fluate of soda	5 grains.
{ Distilled water	1 fluid ounce.

Mix a small quantity of these solutions together when the papers are to be prepared, and wash the paper once over with the mixture, and when dry, apply nitrate of silver, in solution, 60 grains to an ounce of water. These papers appear to keep for some weeks without injury, and they become impressed with good images in half a minute in the camera. This impression is not sufficiently strong to serve, in the state in which it is taken from the camera, for producing positive pictures, but it may be rendered so, by a secondary process.

(141.) The photograph is first soaked in water for a few minutes; it is then placed upon a slab of porcelain or stone, and a weak solution of the protosulphate of iron applied, which very readily darkens, all the parts on which the light has acted, to a deep brown, and every object is brought out with great sharpness. When the best effect is produced the process must be stopped, or the lights suffer. All that is necessary is to soak the paper in water, and then fix the drawing with hyposulphite of soda. This process admits of numerous modifications.

(142.) Phosphate of Silver was first suggested as a good photographic material by Dr. Fyfe, who recommends that the paper should be soaked in a solution of phosphate of soda, and then dried; after which the nitrate of silver is spread over one side of the paper by a brush; the paper is again dried; and afterwards put through the phosphate, by which any excess of nitrate of silver, is converted into a phosphate. Although papers thus prepared answer exceedingly well, for copying by application, they do not change so readily as to render them of any use in the camera obscura. One advantage possessed by these phosphated papers, is the readiness with which they are fixed by the application of a weak solution of ammonia. The yellow phosphate of silver is quite soluble in ammonia, and we are thus enabled to remove it very readily, without doing much injury to the darkened parts of the paper. Dr. Fyfe recommended the application of the precipitated phosphate to paper, glass, or metal, in the form of a paint; and if this is carefully done, some very pleasing effects are to be produced. After the phosphate has been darkened by exposure to sunshine, it is very readily bleached by the joint agency of the solar rays and the hydriodate of potash. This was the process published by Dr. Fyfe, for producing positive photographs by one application, at a very early period; other processes were found, however, to give much more satisfactory results, and it is now but seldom used.

(143.) Prismatic Analysis. — The spectral image formed on the phosphate, does not present any thing very remarkable. The maximum point is situated in the mean blue ray; the chemical disturbance is carried on actively over the indigo, and with some energy in the violet rays, and to a considerable distance beyond the visible spectrum. It extends downwards, nearly to the centre of the yellow ray: about this region the image has a decided green shade. A space without any visible change here presents itself, but over the region occupied by the red rays, the phosphate assumes a brick-red colour. A precipitate consisting of phosphate of lime, combined with organic matter, common salt, and nitrate of silver, was used by Sir John Herschel, and the spectral image formed, appears very nearly to have resembled that just described. Some very trifling differences are observed; but these are merely the shifting of the points of maximum effect which are constantly varying with the dose of the ingredients.

(144.) Tartrate of Silver. — This salt, whether prepared from pure tartaric acid, from the tartrate of potash, cream of tartar (bitartrate), or from Rochelle salt (tartrate of potash and soda), appears at first to change, but very slowly, under the influence of solar emanations; but after a short period the darkening process is very much accelerated, and the paper prepared with this salt, assumes a much higher degree of blackness, than almost any other of the argentine preparations. For copying engravings, or botanical specimens, it possesses some advantages; but I have never found any combination of the tartrates and the salts of silver, sufficiently sensitive for use in the camera obscura.

(145.) Prismatic Analysis.—The rěsults obtained by Sir John Herschel are so very curious, that I shall take the liberty of transcribing nearly his own words. The kind of paper employed by this distinguished philosopher was thus prepared: — "1st, Nitrate of silver, S.G. 1·132; 2d, Saturated solution of Rochelle salt; 3d, Nitrate of silver, 1·132; which proving but little sensitive, a third wash of the nitrate was added, by which its sensibility was materially increased, its other qualities remaining unaffected. The spectrum impressed upon this paper commenced at, or a very little below, the mean yellow ray, of a delicate lead colour, but faint and dilute; and when the action was arrested soon after the first impression was made, such was the character of the whole photographic spectrum. But if the Light was allowed to continue its action, there was observed to come on suddenly, a new and much more intense impression of darkness, confined in length to the blue and violet rays; and, what is more remarkable, confined also in breadth to the middle of the sun's image, so far, at least, as to leave a border of the lead-coloured spectrum traceable, not only round the clear and well-defined convexity of the dark interior spectrum at the least refrangible end, but also laterally along both its edges. And this border was the more easily traced, and the less liable to be mistaken, by reason of its singular contrast of colour with the interior spectrum. That of the former, as was observed above, was lead grey: of the latter, an extremely rich, deep, velvety brown. The less refrangible end of this interior brown spectrum, presented a sharply terminated and regular elliptic contour, the more refrangible a less decided one." Sir John Herschel discovers three points of maximum intensity in this spectrum, situated about the least refrangible blue, the most refrangible indigo, and beyond the visible rays. In my note-book I have marked but two maximum points — one situated in the indigo ray, and the other at the edge of the most refrangible violet rays. Having attempted to explain some effects which I observed upon Daguerreotype plates (76.), nearly corresponding with those just described, by a speculation similar in its general character, to that of this distinguished experimentalist, whose ideas on this subject I was not at all aware of until after the publication of my own, I shall again copy into my pages Sir John Herschel's own words: —

(146.) "It may seem too hazardous to look for the cause of this very singular phenomenon, in a real difference between the chemical agencies of those rays which issue from the central portion of the sun's disc, and those which, emanating from its borders, have undergone the absorptive action of a much greater depth of its atmosphere; and yet I confess myself somewhat at a loss what other cause to assign for it. It must suffice, however, to have thrown out the hint; remarking only, that I have other, and, I am disposed to think, decisive evidence, of the existence of an absorptive solar atmosphere, extending beyond the luminous one. The breadth of the border, I should observe, is small, not exceeding 0·5 or $\frac{1}{7}$th part of the sun's radius; and this, from the circumstance of the experiment, must necessarily err in excess."

(147.) If paper prepared with tartrate of silver is allowed to darken slightly, and then washed over with a weak solution of the iodide of potassium, the darkening process proceeds with great rapidity, and a most intense blackness results.

(148.) If a paper prepared with the tartrate of silver as above is washed over, before exposure even, with a solution of the iodide of potassium, its sensibility is very much increased; and we find, by exposing such a paper to the prismatic spectrum, that a very different image is impressed. The impression does not descend below the green ray of the spectrum, but at that point a delicate blue or grey colour is impressed; it rapidly darkens, and throughout the whole of the most refrangible rays a very intense blackness is produced, which penetrates very deeply into the paper. The darkening process is carried for a very considerable space beyond the last visible violet ray, but with a very diminished intensity. The least refrangible rays do not appear to act at all; or if at all, they assist in converting the whole of the tartrate into iodide of silver. We do not find any of those protected spaces in this spectrum which are observed in the photographic image received on the pure tartrate.

(149.) If the same paper is washed with the ferrocyanate of potash, its sensibility is also improved. The impressed spectrum in this instance, exhibits the maximum effect about the blue and indigo rays; but it is prolonged through the mean yellow, down to even below the least refrangible red ray, though it is not extended so far beyond the visible violet.

(150.) It would only be unnecessarily complicating the subject, and swelling the size of this volume, if I particularised the effects produced upon all the salts of silver. Those already described may be regarded as types of all the others. The carbonate, sulphate, acetate, citrate, and oxalate of silver, all of them undergo a considerable, and a tolerably rapid, change under the influence of Light. In some proportions the oxalate exhibits a very high degree of susceptibility; and with this salt, the citrate, and the acetate, the same double and triple maxima of intensity occur, when they are subjected to prismatic influence, as we have seen occurs with the tartrate.

(151.) Although I have passed over many of the salts of silver, without particularising the effects produced, I cannot refrain from calling attention to some few of the organic combinations. BENZOATE OF THE OXIDE OF SILVER dissolves pretty freely in warm water. A single wash of this renders paper tolerably sensitive. The pictures thus procured are fixed most readily by washing in warm water.

(152.) Benzoate of silver precipitated from the nitrate of silver by benzoate of ammonia, redissolved in boiling water, and washed over good writing-paper, renders it moderately sensitive. The first action is far from being energetic, under the greatest intensity of Light; but after a short time the grey tint which is at first formed passes very rapidly into a beautiful deep brown. The benzoate of ammonia and the nitrate of silver in successive washes, has been repeatedly tried, but without having obtained any improvement in the result. Under this section I may place papers prepared with hydrobenzoinamide and nitrate of silver; with formobenzoate of silver, and the benzoate of hydruret of benzule and nitrate of silver, the results being very similar. It will be interesting, however, to describe the results of prismatic analysis upon two or three of these preparations.

(153.) Prismatic Analyses. — Benzoate of oxide of silver. The action of the prismatic spectrum is first evident in the mean blue ray, from which it slowly extends upwards in nearly uniform force to the upper edge of the indigo ray, beyond which it rapidly diminishes in intensity. *The space occupied by the invisible chemical rays is maintained, even during prolonged exposure, much whiter than those parts of the paper under the influence of the diffused light.* This is the first instance in which the most refrangible rays have been observed to exercise the same kind of influence, as the least refrangible rays have been described as doing. Below the blue ray, the action extends to the lowest edge of the green ray, beneath which no evidence of change can be detected. Hence we have a spectral image, which is confined to a space but little more than one half the length of the luminous spectrum, if we except the portion occupied by the extra spectral violet rays.

(154.) Formobenzoate of silver. — The action of the spectrum in this instance is also seen to begin about the region of the mean blue ray. It goes on with apparently equal energy down to the yellow ray, and is tolerably active to the upper edge of the orange rays. Washing with the hyposulphite of soda, however, shows a well-defined line of maximum intensity, which exactly corresponds with the least refrangible blue rays. Above the blue, the action is powerfully exerted through the indigo rays, after which it declines in energy, but it is continued beyond the visible violet, over a space quite equal in extent to that of the visible violet rays.

(155.) Benzoate of Hydruret of Benzule and Nitrate of Silver.—The chemical change on this preparation commences at the limits of the green, and reaches its maximum at a point corresponding with the mean blue ray, after which it gradually diminishes, and any visible effect ceases just beyond the most refrangible violet rays. The rays below the green appear to be quite inactive. This spectral impression is scarcely more than one half the length of the visible spectrum.

(156.) It has been before stated, that Gallic acid had the power of calling forth the dormant images from these combinations of benzoine. I merely recur to it to state, that it will be found, on washing over any of these papers with this acid, after they have been exposed to the spectrum, that evidences of decided action will be observed over the whole of the space covered by the prismatic image. These facts are, in the present state of our knowledge, exceedingly enigmatical; but it appears to me, that by recording them, we advance step by step towards the development of some important truth.

(157.) It might appear, from the very unstable character of the combinations of cyanogen, that combined with the salts of silver these would produce very susceptible photographic compounds. Such, however, is not generally the case. The pure cyanate of silver undergoes but very little change during an exposure of many days. The amazing sensitiveness imparted to the iodide of silver by the ferro-cyanate of potash has been already spoken of (84.). A weak solution of hydrocyanic acid produces the same effect, but in a much slighter degree.

(158.) If a solution of the red prussiate of potash is washed over nitrate of silver, we have a photographic compound of some interest. In about half an hour a very beautiful copy of a print may be taken. Over all the parts which correspond with the lights of the picture, Prussian blue is formed, which appears green when contrasted with the yellow of the paper. If a small portion of the protosulphate of iron is added, the blue produced is much more intense. This chemical change is, I find, brought about entirely by the blue and violet rays of the spectrum.

(159.) If chloride of silver is allowed to darken by exposure to sunshine, and is then washed over with a solution of the ferro-cyanate of potash, no very evident action is visible. If, however, this paper is exposed under a deep green glass, it will be found to bleach with some degree of rapidity. If exposed to a very concentrated spectrum, this bleaching power appears to be exerted by the yellow and green rays, whereas over the other parts, symptoms of darkening are sufficiently evident.

(160.) If by washing a paper, which has been saturated with nitrate of silver, with a solution of caustic potash, we cover it with an oxide of silver, or, still better, if, instead of potash, we use ammonia, and then wash it with hydrocyanic acid, the paper is, of course, bleached in the dark, and the resulting cyanide of the oxide is readily blackened by exposure to the solar rays. This shows how very slight a difference in the manipulatory processes will change the character of a compound in its relations to light.

(161.) Chromate of silver, arseniate of silver, and some other salts, have been described as absolutely unchangeable by Light. Experience has, however, shown that this is not the case, as a very sensible change takes place, either after a short or long exposure, upon all the salts of silver yet examined. The chromate of silver does not change much in colour, even after an exposure to good sunshine for many days, but it eventually assumes a very metallic brown shade, and revived silver is readily detected. Under certain circumstances, the arseniate becomes really a very good photographic agent, and I find that paper washed with the *liquor arsenicalis* of the Pharmacopœia (a solution of arsenic in water, assisted by the presence of some potash), and then with nitrate of silver, changes with tolerable readiness, and darkens to a perfectly jet black. The photographs resulting from this process are really the most decided in their contrasts of light and shadow, of any procured with the argentine preparations.

(162.) I have now to consider, which I shall do very briefly, the effects of other metallic preparations in combination with the silver salts. Sir John Herschel was the first who examined this matter, and he found the combinations of some of the salts of lead and silver produced papers more sensitive than the silver alone. The use of lead was however abandoned, owing to the discoloration which went on in the dark, with greater or less rapidity, over the papers impregnated with its salts. Both gold and platinum, I have found, interferes with the change set up by luminous agency on the salts of silver; and where, even by using a large excess of the silver salt, a good photograph is procured, the gold or platinum still continues to exert a decomposing power in the dark, and eventually destroys the picture. At one period I was inclined to think the presence of copper with the silver was detrimental; a rather extensive series of experiments, have, however, shown me that a small quantity of any of the soluble salts of this metal, rather quickens than retards the change in the argentine salts. A large portion of copper certainly lessens the sensitiveness of the silver preparations, and have a tendency to destroy the paper. Iron has a decided property of accelerating the process of change; but it unfortunately keeps up the darkening influence when once set agoing, even when preserved from the light, and consequently it cannot be used with any advantage practically. When we come to the consideration of the effects produced upon these metals and others, I shall have to point out some very striking properties of the salts of silver, which do not properly find a place here.

CHAP. II.

PREPARATIONS OF GOLD.

(163.) It has been long known, that an etherous solution of gold, decomposes by exposure to the sun's rays, metallic gold being deposited on the side of the vessel nearest the light. Charcoal saturated with a solution of the chloride of gold, and exposed to the sun's rays, is speedily covered with a very fine film of the revived metal. Ivory may also be gilded by washing it with the same solution and exposure. Most of the salts of gold, indeed, are reduced by solar agency.

(164.) Sir John Herschel, in the Philosophical Transactions, Part I. for 1840, has given some very interesting particulars respecting some aurated preparations:—

Papers washed with CHLORIDE OF GOLD, freed from an excess of acid, are slowly changed under the influence of the solar beams, a regularly increasing darkness takes place, and the paper at length becomes purple (*Herschel*). I have observed that the first action of the Light is to whiten the paper, which has been rendered a pale yellow by the chloride. If papers are removed from the light when thus bleached, it will be found that a darkening action will gradually come on, and eventually develop the picture, which may be impressed on the paper. This process is much quickened by placing the paper in cold water.

(165.) Chloride of gold with nitrate of silver gives a precipitate of a yellow brown colour, possibly metallic double salts, in which the gold as well as the silver is in the state of chloride. On glass this precipitate is but very slightly sensitive, on paper it is blackened somewhat more speedily (*Herschel*).

(166.) If paper impregnated with oxalate of ammonia be washed with chloride of gold, it becomes, if certain proportions be hit, pretty sensitive to Light, passing rather rapidly to a violet purple in the sun (*Herschel*). I have found it exceedingly difficult to arrive at the best proportions: generally speaking, thirty grains of the oxalate of ammonia, and a saturated solution of the chloride of gold, has been the most successful in practice. These papers must be dried in the dark without heat. After the picture has been obtained, I have succeeded in fixing it, by soaking it in cold water, and then washing it over with the ferrocyanate of potash.

(167.) Paper impregnated with the acetate of lead, when washed with perfectly neutral chloride of gold, acquires a brownish-yellow hue, and a sensibility to Light which, though not great, is attended with some peculiarities highly worthy of notice. The first impression of the Light seems rather to whiten than to darken the paper, by discharging the original colour, and substituting for it a pale greyish tint, which by slow degrees increases to a dark slate colour; but if arrested, while yet, not more than a moderate ash grey, and held in a current of *steam*, the colour of the part acted on by Light (and of that only) darkens immediately to a deep purple: the same effect is produced by immersing it in boiling distilled water. If plunged into cold water, the same change comes on more slowly, and is not completed till the paper is dried by heat. A *dry heat*, however, does not operate this singular change (*Herschel*).

(168.) PRISMATIC ANALYSIS.—*Chloride of Gold.* The maximum effect is produced by the mean blue ray, and the influence is exerted but a little way below the green; indeed, it is doubtful if it can be said, that any visible effect is produced below the green itself. Above the blue, the action is carried on, but with declining energy, through the indigo and violet rays, beyond the most refrangible edge, of which no action can be detected.

To distinguish the following processes from the Chrysotype, which will be described in another section, I propose to designate them as *Aurotypes*.

(169.) AUROTYPES. — Protocyanide of potassium and gold, prepared according to Himly's method*, was washed over paper and dried; then it was washed with a solution of nitrate of silver, and again dried. This paper darkens with considerable rapidity, and this blackening proceeds steadily in the dark. Good photo-

* Appendix, No. I.

graphs result from this preparation. The pictures are best fixed by soaking in a little salt and water, and then washing with a weak solution of the hyposulphite of soda.

(170.) It will be found that several of the combinations of the oxide of gold with cyanogen yield very interesting pictures, which promise to be of some importance in the photographic art. A few of these may be briefly mentioned.

(*a*) Protocyanide of potassium and gold, with a weak wash of nitrate of silver, changes with tolerable quickness, and presents a good contrast of light and shadow.

(*b*) Protocyanide of gold, formobenzoic acid, and nitrate of silver, give very beautiful results, and are tolerably quick in changing, although as yet no paper has been prepared, sufficiently sensitive for use in the camera obscura. The darkened portions are exceedingly intense, the impression being made nearly through the entire substance of the paper; hence affording very perfect photographs, from which copies of exceeding sharpness may be procured.

(*c*) Protocyanide of gold, formobenzoate of ammonia, and nitrate of silver, give results of an exceedingly pleasing kind. Papers thus prepared do not appear to be quite so sensitive as those which are prepared with the formobenzoic acid, but they are sufficiently so for copying engravings in good sunshine.

(*d*) Nitrate of silver, protocyanide of potassium, and gold. A very delicate picture results from a short exposure to sunshine, which continues to darken without the aid of Light as long as any portion of gold remains undecomposed. It is a peculiar property of all the salts of gold, that the darkening process once set on foot is carried on in the dark as long as any gold remains.

(171.) Prismatic Analyses.—The following results, obtained upon several different preparations, will serve to exhibit most of the peculiarities which mark the influence of the solar beam or auriferous preparations.

On paper prepared as above (170. *a*). The maximum of action is far down in the blue rays, nearly on the verge of the green. After a few minutes the action is extended, through the green ray to the very centre of the yellow ray. Towards the most refrangible end, the action is tolerably uniform through the whole of the blue and indigo rays; it slowly declines through the violet; but it extends with some considerable power over a space beyond the visible spectrum, equal to a third of its entire length.

(172.) A paper washed with the protocyanide of potassium and gold, between two washes of the nitrate of silver, exhibited the maximum of intensity on the very edge of the least refrangible blue ray. The darkening process was carried on, down to the edge of the orange ray, below which no action could be detected. Above the blue rays the influence became gradually weaker, and faded away entirely, at a point beyond the violet rays, distant from the visible ray about the width of the violet rays themselves. No action could be detected at the least refrangible end of the spectrum.

(173.) A paper prepared as described (170. *b*) was acted upon with much energy. The maximum of action was in the mean blue ray, and a well-defined line marked the least refrangible edge of the rays. The influence was, however, extended to the centre of the yellow ray, the action over the space occupied by the green ray being exceedingly well defined. At the most refrangible end the action was exerted with great energy up to the extreme edge of the visible violet rays, from which point it gradually declined until the darkening entirely ceased at the extremity of a space beyond the violet, quite equal to half the length of the luminous spectrum. This paper had browned a little by keeping. This browning was entirely removed by the influence of the red rays, and to some extent bleached by all the rays along their lateral edges, presenting a similar phenomenon, to that already described, as observed by Sir John Herschel on the tartrate of silver, and by myself on the Daguerreotype plates.

(174.) A paper prepared with a neutral solution of the chloride of gold, ammonia, and nitrate of silver, still exhibited the maximum effect in the mean blue ray, the darkening extending, however, with tolerable strength to the lower edge of the green rays, which impresses a decided green colour on the paper. The influence proceeds pretty equally through the blue and indigo rays; it diminishes through the violet, and ceases to act at the end of a space beyond the violet rays equal to three-eighths of the length of the visible spectrum.

(175.) A paper with protocyanide of gold, nitrate of silver, and ammonia, gave no evidence of any darkening action *within the luminous spectrum.* At the most refrangible edge of the violet rays, chemical action begins, and it rapidly reaches its maximum at a very short distance from it. A faint darkening goes on over a space equal to one half of the visible rays.

(176.) Papers prepared with the percyanide of potassium and gold, then formobenzoic acid and nitrate of silver, darken very rapidly over the whole extent of the most refrangible rays, the darkening commencing in the blue ray, and apparently going on through the whole period of exposure with greater energy about the mean ray of that colour, than in any other part. The influence is exerted with much power down to the red rays, and a second wash of the nitrate of silver carries the action below them. Over the violet end of the spectrum a very beautiful purple-brown colour is brought out, which fades into a lilac in the invisible rays, which exert their power with some energy over a considerable space.

(177.) If papers are carefully prepared with the percyanide of potassium and gold, &c. as the last named, they will be found to be exceedingly useful. If the preparations are pure, and the proportions in good adjustment, the results are most satisfactory, and the photographs are amongst the most beautiful that can be imagined. My own results do not enable me to fix with certainty the best proportions in which these agents should be united. It however appears, that a saturated solution of the percyanide of potassium and gold, with formobenzoic acid, spec. grav. 1·12, and a solution of 100 grains of the nitrate of silver to an ounce of distilled water, are tolerably near the proportions required for the production of the most sensitive papers. I have, however, sometimes obtained very beautiful photographs with these agents united in different proportions from the above.

(178.) The action of oxalic acid on solutions of the salts of gold has been long known to chemists. When a neutral oxalate is heated with a neutral solution of gold, metallic gold is precipitated. Light acts the same part as heat. If a neutral chloride of gold and oxalate of potash be washed over paper and exposed to the sunshine, a slight change is immediately produced, which, however, goes on darkening until it at last assumes a very deep hue. Sir John Herschel remarks on this peculiarity: "A stain is produced, which however feeble at first, under a certain dosage of the chloride, oxalate, and free acid, goes on increasing from day to day, and from week to week, when laid by in the dark, and especially in a damp atmosphere, till it acquires almost the blackness of ink, the unsunned portion of the paper remaining unaffected, or so slightly, as to render it almost certain, that what little action of this kind exists, is due to the effect of casual dispersed Light incident in the preparation of the paper. I have before me a specimen of paper so treated, in which the effect of thirty seconds' exposure to sunshine was quite invisible at first, and which is now of so intense a purple as may well be called a black, while the unsunned portion has acquired comparatively but a very slight brown. And (which is not a little remarkable, and indicates that in the time of exposure mentioned the *maximum* of effect was attained) other portions of the same paper exposed in graduated progression for longer times, viz. 1^m, 2^m, and 3^m, are not in the least perceptible degree, darker than the portion on which the light had acted during thirty seconds only."

(179.) Gold is not only thus effected when in combination with other salts, but any of the preparations of gold having been exposed to solar influence go on "darkening spontaneously and very slowly, apparently without limit, so long as the least vestige of unreduced salt of gold remains in the paper." I find that on paper, after this decomposition of the chloride has been entirely effected, a change still goes on, and eventually a beautiful revival of gold gives a metallic appearance to the surface.

(180.) It has been stated, on the authority of Mr. Goddard, that a plate of gold is rendered very nearly as sensitive to luminous agency by the action of iodine vapour, as are the plates of silver used in the Daguerreotype process. I have not yet succeeded in rendering gold as sensitive as silver by either iodine or bromine; but it has been shown by Moser that all metallic plates are rendered to a certain degree photographically sensitive by being exposed to these vapours. On this subject some further remarks will be made in this volume.

CHAP. III.

PLATINUM.

(181.) In 1832 Sir John Herschel communicated to the British Association at Oxford the curious fact, that when a solution of platinum in nitro-muriatic acid has been neutralised by the addition of lime, and which has been well cleared by filtration, is mixed with lime-water in the dark, no precipitation to any considerable extent takes place—for a long while, indeed, none whatever; though after long standing, a slight flocky sediment is formed, after which the action is arrested entirely. But if the mixture, either freshly made, or when cleared by subsidence of this sediment, is exposed to sunshine, it instantly becomes milky, and a copious formation of a white precipitate (or a pale yellow one if the platinic solution be in excess) takes place, which subsides quickly, and is easily collected. The same takes place more slowly in cloudy daylight.

(182.) By exposing this mixture to Light which had permeated different coloured fluids, it was found that the action was confined entirely to the violet end of the spectrum. Sulphuric tincture of red-rose leaves protected the fluid entirely: an exposure of many days to full sunshine behind this fluid occasioned no precipitation, but it takes place instantly if exposed to full daylight, as copiously as if it had been all the time kept in total darkness. Yellow fluids, particularly a solution of the bichromate of potash, also serve to defend it.

(183.) When a solution of the chloride of platinum, as neutral as possible, is mixed with a saturated solution of the cyanate of potassium also boiling, a percyanate of potassium and platinum results. If paper is washed with this solution, and exposed to sunshine, a very faint change only is apparent, even after prolonged exposure. If, however, after a short time, the paper is taken into the dark, and washed with a solution of the protonitrate of mercury, a very pretty, though delicate positive picture results. The only mode by which any thing like permanence can be given to these pictures when formed, is by washing them in a dilute warm solution of carbonate of soda. Nearly all the PLATINOTYPES, however, slowly fade in the dark.

(184.) On allowing the above solution to cool, a great number of minute crystals of a yellow colour are formed. By dissolving these in water a solution is made which imparts to paper a much higher sensibility than the last named preparation.

(185.) If either of these two papers, after they are taken from the Light, be washed over with a solution of the nitrate of silver, a positive picture is brought out, but it is, although perfect, exceedingly faint. If in this state, the paper is exposed to sunshine, it blackens over the portions which were uncovered, whilst the covered parts remain light, the result being a good negative picture.

(186.) If the solution of the percyanate of potassium and platinum is washed over paper, and after it is dried a solution of the protonitrate of mercury is applied, the paper becomes of a yellowish-brown tint. Exposed to sunshine, it gives a very peculiar picture, which will be either negative or positive, according to the depth of colour that comes on, which is exceedingly capricious. The exposed portions often pass into a beautiful vermilion colour, which, however, fades with some rapidity, leaving the ground of the paper a buff or ruddy brown.

(187.) Prismatic Analysis. — The action appears to commence at the same time, or nearly so, in the yellow ray and in the blue. Commencing in the blue ray, the change of colour, or reddening, goes on through the violet ray; but it is confined, or very nearly so, to the visible spectrum. In the yellow ray a very positive blackening at first comes on; but this gradually passes away, and a bleaching action results. This bleaching is evident in copying of plants on this kind of paper, the parts covered by the green leaves becoming pale as the other parts darken.

(188.) Percyanate of potassium and platinum, with one washing of nitrate of silver, affords a very pleasing result. The pictures procured on this kind of paper being of a well-defined deep lilac tint. A great many combinations of these two salts have been tried, and some of them give very pleasing photographs. If the nitrate of silver is in slight excess, and particularly if the silver is applied to the paper first, the impression is quite as strong on the wrong side of the paper as it is upon the right one. The iodide of potassium promises to be the most successful fixing agent for these kinds of platinotypes; but after a few months, although carefully preserved in a portfolio, little more than a blank sheet of white paper is left.

(189.) If, in addition to the nitrate of silver, we unite some corrosive sublimate, on the paper, with the platinum salt, an exposure of fifteen minutes produces but little apparent effect. If, however, on removing it from the Light, the paper is washed over with strong ammonia, a picture of intense blackness, on an iron-grey ground, is immediately produced. Heat brings the whole of the paper to one uniform iron-grey tinge. If the picture is placed in a solution of corrosive sublimate, a negative picture is very speedily produced by the dissolving out of the shadows.

(190.) Chloride of platinum spread on paper undergoes some change very speedily, although this is not often evident until it is afterwards washed over with the protonitrate of mercury. A great variety of combinations have been made the subjects of experiment. The chloride of platinum has been united with oxalic acid, tartaric acid, formic acid, and a great many of these compounds in which cyanogen plays an important part. The results have been pretty much the same in all: in some cases, the action of the solar rays is to deepen the yellow colour of the paper, in others, to bleach it; and hence when the subsequent washing with the mercurial solution is given, sometimes a positive and sometimes a negative image results. All the combinations with the ferroprussiates have exhibited, by a decomposition of these salts, very pleasing blue grounds.

(191.) Iodide of Platinum.—Sir John Herschel was the first to call my attention to the sensibility of paper prepared with the iodide of platinum. In a few minutes a very decided image is formed upon it; but this very rapidly fades out, the sensibility of the paper not being at all impaired, even after repeated exposures to Light.

(192.) *Bromide of Platinum* exhibits the same peculiarities as the iodide. I have tried upon these preparations a great many fixing agents, without being quite successful with any. It appears, indeed, to be a distinguishing characteristic of the salts of this metal, that, in the dark, they have the power of overcoming the change which has been produced by the solar rays, and of restoring themselves to their original state. The kind of change brought about by exposure to Light is not very evident: in some cases the yellow platinum salts are darkened, in others bleached; in either case, if these papers are put aside, the original yellow is restored. It appears to me, that to a greater or less extent, this occurs with all the platinotypes, and I am inclined to regard the change as a de-oxidisation of the metal, which is again enabled during darkness to recover its lost portion of oxygen: but this is by no means certain.

(193.) In Sir John Herschel's Memoir on the Chemical Action of the Rays of the Solar Spectrum, some peculiar phenomena exhibited by the chloride and iodide of this metal are named, which it is important I should transfer to my pages, corroborating in a striking manner the capricious nature, under the influence of the solar rays, of the salts of this singular metal:—

"A solution of chloride of platinum in ether being washed over a bibulous paper impregnated with hydriodate of potash, in certain degrees of strength and copiousness, browns pretty rapidly in the dark, but much more rapidly, and to a much deeper tint, in sunshine. A paper so washed and partly shaded, on exposure, produced a well-defined figure of the shading body, which, on the addition of a fresh wash of the hydriodate, *out of* *the Light*, became much more strongly contrasted with the surrounding ground."

(194.) "Paper washed with acetate of lead, and then with chloride of platina, is absolutely insensible, and only becomes very feebly so, when thoroughly impregnated with nitrate of silver. But if in place of the nitrate of silver, a wash of hydriodate of potash be superadded, the effect is remarkable. If the hydriodic solution be strong and plentiful, the paper is immediately coloured dark brown, whether in Light or darkness. If very weak, no effect; but if applied of a certain intermediate strength, though not *immediately* affected in the shade, yet, if held (while wet) in the sun, it darkens with extraordinary rapidity to the same deep brown hue, *and presently after, the exposure to the sun continuing whitens again.* A fresh dose of the hydriodate being applied it again darkens, but is no longer capable of restoration, and the darkness goes on increasing to a fine deep chocolate brown."

(195.) From the powerful influence exerted by the oxalate of the protoxide of iron on the salts of platinum, I was led to hope that this combination might be brought under the agency of the sun's rays, to some extent. Experiment has proved to me that this is the case; but the action is not so much accelerated by the sun as to render its use of any photographic value. If a paper prepared with a tolerably strong solution of the oxalate, and a solution of the chloride of platinum, made neutral by carbonate of soda, is exposed, with one portion carefully screened, for only a few minutes, it will be found that the uncovered portion, is by far the darkest, and for a certain period this darkening goes on, even out of the Light; but after a time a bleaching action commences and, unless an additional quantity of the oxalate is applied, all evidence of solar influence is erased.

(196.) Having placed a number of photographs prepared with salts of platinum in a portfolio with others which had been taken on papers spread with silver salts, I was somewhat surprised to find, that although the pictures on the platinum papers were faded out, very good images of these pictures, dark upon a light ground, were left upon the argentine papers. This curious action would appear to point to a method by which these evanescent pictures, may be made to leave very good positive images behind, by being placed in juxtaposition with other photographic papers.

CHAP. IV.

MERCURY.

(197.) It has long been known to chemists that the protoxide of mercury is very liable to resolve itself into the peroxide and metallic mercury, under the influence of the direct solar rays, or even of daylight. The peroxide also, it has been stated by Guibourt, is converted into metallic mercury and oxygen by long exposure. This I find may be effected with some degree of rapidity, and the peroxide used for the production of really interesting photographic drawings. If red precipitate is ground to a very fine powder, and well incorporated with gum water, it may be applied upon paper very evenly with a camel's hair brush, and it dries, forming a fine red surface. If paper thus prepared is exposed, with an engraving upon it, to good sunshine, for ten or twelve hours, all the exposed parts are deeply blackened, and those under the white parts of the engraving changed to a deep olive, thus giving a negative photograph, which is somewhat singular in its appearance and colours, which are red, olive, and black. If these papers are, after having been thus darkened, washed with water, the peroxide of mercury is removed, and a faint brown stain only, left upon the paper, over the parts which were covered with the darkened oxide. I have observed that the peroxide of mercury kept in a bottle, near a window into which the sun shines during the greater portion of the day, slowly changes to a deep yellow colour, and is, on the side next the Light, reduced to a fine powder, which adheres with tolerable firmness to the glass.

(198.) CARBONATE OF MERCURY, it is well known, parts with carbonic acid in contact with the air, and becomes brown, even in the dark. If, when recently prepared, it is exposed to Light, a very rapid darkening is brought on, which, it appears probable, may be advantageously employed in varying our photographic specimens. The best mode of preparing this kind of mercurial paper with which I am acquainted, is to wash good writing paper, with a saturated solution of the protonitrate of mercury. It must then be dried as quickly as possible, without bringing it too near the fire, which very rapidly, if hot, decomposes the salt, when in contact with organic matter. A moderately strong solution of the carbonate of potash is then applied. If exposed whilst wet, provided there is good sunshine, this preparation darkens to a good black in a few minutes. If carefully dried between folds of blotting paper, and exposed in a dry state, the darkening is still more rapid.

(199.) Prismatic Analysis. — The action of the spectrum, appears to be limited to a space, between the lower edge of the blue and the extreme limits of the violet rays, over which the darkening is very rapid; the other rays appear to be nearly without action, although by carefully heating the paper after exposure up to the point at which decomposition is effected, it becomes evident that some influence has been exerted beyond the visible violet, and also about the region of the yellow rays, as these parts are the first which exhibit any symptoms of change by calorific agency.

(200.) "Protonitrate of mercury, simply washed over paper, is slowly and feebly blackened by exposure to sunshine." This was first observed by Sir John Herschel, who, by taking adyantage of the properties of some of the protosalts of iron, produced some very curious photographic results, which must now be described. If paper is impregnated with the ammonia-citrate of iron, and one portion of it being covered, the other part is exposed to the sun, and then washed with the protonitrate, this salt is slowly reduced over the sunned portion.

(201.) If the protonitrate of mercury is mixed with either the ammonia-citrate or tartrate of iron, a precipitate is produced. Sir John Herschel recommends one measure of a solution of ammonia-citrate, and one of a solution of ammonia-tartrate of iron, containing, each, one tenth of its weight of the respective salts; tartaric acid, a saturated solution, one eighth of the joint volumes of the other solutions. Form a cream, by pouring in rapidly, one measure of a saturated solution of the protonitrate, and well mixing with a brush. This cream should be spread very quickly over the whole paper, well worked in, cleared off as much as possible, and finished with a brush nearly dry, spread out broad, and pressed to a straight thin edge, which must be drawn as lightly and evenly as possible over every part of the paper, until the surface appears free from every streak, and barely moist. The talented discoverer of this process goes on to remark that, "about half an hour, or an hour, according to the sun, affords pictures of such force and depth of colour, such velvety richness of material, and such perfection of detail and preservation of the relative intensities of the Light, as infinitely to surpass any photographic production I have yet seen, and which indeed, it seems impossible to go beyond. Most unfortunately they cannot be preserved. Every attempt to fix them, has resulted in the destruction of their beauty and force; and even when kept from Light, they fade with more or less rapidity, some disappearing almost entirely in three or four days, while others have resisted tolerably well for a fortnight, or even a month. It is to an overdose of the tartaric acid that their more rapid deterioration seems to be due; and of course it is important to keep down the proportion of this ingredient as low as possible; but without it I have never succeeded in producing that peculiar velvety aspect, on which the charm of these pictures chiefly depends, nor anything like the same intensity of colour without oversunning."

(202.) Sir John Herschel gives yet another very interesting combination:—"Let a paper be washed over with a weak solution of periodide of iron, and, when dry, with a solution of protonitrate of mercury. A bright yellow paper is produced, which (if the right strength of the liquids be hit) is exceedingly sensitive while wet, darkening to a brown colour in a very few seconds in the sunshine. Withdrawn, the impression fades rapidly, and the paper in a few hours recovers its original colour. In operating this change of colour the whole spectrum is effective, with the exception of the thermic rays beyond the red."

(When we come to notice the iron salts, many other applications of mercurial preparations by this distinguished philosopher will be given.)

(203.) Deutiodide of Mercury—formed with a persalt and the iodide of potassium. During good sunshine this preparation darkened very distinctly in fifteen minutes: an hour's exposure brought on a full brown colour. If, after exposure to the sun, paper on which it may have been spread, is gently warmed by the fire, the brown colour fades quite away, leaving the paper of a bright red.

(204.) The protonitrate of mercury has been combined with a great number of the organic acids and their salts. Some change is very evident upon all that have yet been tried, the sun, in spaces of time varying from five minutes to as many hours, producing very marked evidences of its decomposing power. The formates, benzoates, and gallates, are the most decided in their action; and if, after a short exposure, papers prepared with these salts are washed over with the oxalate of iron, tolerably good pictures are produced.

(205.) The pernitrate of mercury and the yellow subsalt which is formed when the nitrate is put into hot water, have both been made the subjects of experiment. They have, when used alone on paper, and when united with other metallic and alkaline salts, given decided evidence of change under the sun's rays, but not to such an extent, as appears to warrant any hope of their being of any photographic value.

(206.) Subnitrate of mercury and the benzoate of the hydruret of benzule, were united on paper, and in half an hour of good sunshine a very fair picture was formed, the darkened parts, being of a deep buff colour. The picture rapidly faded out, but it could at any time be restored by washing it over with the hyposulphite of soda, or the protosulphate of iron.

(207.) NITRATE OF MERCURY and ferroprussiate of potash.—Even in the dark the latter salt is slowly decomposed, and the paper discoloured by the formation of prussian blue. In the sunshine this is very rapidly produced, after which a bleaching action comes on. If after the bleaching process has been carried on, until the paper is nearly white, it is removed from the Light, and washed over with a saturated solution of nitrate of silver, a positive image is produced. The protonitrate of mercury, and the red prussiate of potash undergo nearly the same changes as the above. The cyanates are not so marked in the changes which they undergo; but even those combinations which appear to be the least sensitive show, by the subsequent application of the proto-salts of iron, or the nitrate of silver, that definite action has been set up by the solar rays.

(208.) Chromate of mercury, formed from a solution of the nitrate of mercury and the bichromate of potash, is rapidly darkened under the first impulse of the solar action; it then bleaches, but somewhat more slowly. If papers thus prepared are now removed from the Light, and washed over with a solution of nitrate of silver, very beautiful pictures of a fine red colour are produced: these are rendered permanent by washing with a very weak solution of a mercurial salt; at least as it regards Light. They still change under the influence of time, and some of the transformations which they undergo are exceedingly curious. They usually fade out entirely over the side of the paper which has been exposed, and on which the picture was at first formed; but as the picture vanishes from the front of the paper, it slowly developes itself on the back, not of the same red colour, but the metal is revived, and we have a semi-metallic picture of much interest. I have not yet procured any of these pictures in an entirely perfect state, although many have approached very nearly to it. Could we depend upon the change taking place in a regular manner, we should have the means of producing very beautiful and curious photographs. (See *Chromate of Copper — Chromatypes.*)

(209.) Many other mercurial salts spread upon paper, and precipitated upon glass, have been experimented with; and although no results sufficiently certain to warrant the publication of them have been obtained, yet most decided evidences have been afforded that all these salts are liable to decomposition under the influence of the solar rays. On many of them the invisible radiations from hot iron have a very powerful effect; and these are not, as might have been expected, much influenced by the calorific rays of the spectrum. This seems to point to some difference between the solar and terrestrial radiations.

CHAP. V.

IRON.

(210.) For nearly the whole of the facts contained in this chapter we are indebted to the labours of Sir John Herschel. In his hands the salts of iron have become valuable photographic agents; and two or three processes which have been devised by this indefatigable experimentalist, in which the iron salts, play an important, if not the chief part, are among the most interesting within the range of the photographic art, whether we regard the beauties of the pictures which are formed, or the singular changes, which take place during exposure and fixation. I have, for my own pleasure, repeated all Sir John Herschel's published experiments with much care, but I believe I have but very little to add to what he has already observed and published. I shall therefore extract largely from Sir John Herschel's Memoir, and add such remarks of my own as may appear to explain any of the processes more fully.

(211.) THE CHRYSOTYPE.—"Paper is washed with a moderately concentrated solution of ammonia-citrate of iron, and dried; the strength of the solution being such as to dry into a good yellow colour, and not at all brown. In this state it is ready to receive a photographic image, which may be impressed on it, either from nature in the camera obscura, or from an engraving on a frame in sunshine. The image so impressed, however, is faint, and sometimes hardly perceptible. The moment it is removed from the frame or camera, it must be washed over with a neutral solution of gold, of such strength as to have the colour of sherry wine. Instantly the picture appears, not indeed at once of its full intensity, but darkening with great rapidity up to a certain point, depending on the strength of the solutions used, &c. At this point nothing can surpass the sharpness and perfection of detail of the resulting photograph. To arrest this process, and to fix the picture (so far at least as the agency of *Light* is concerned), it is to be thrown into water slightly acidulated with sulphuric acid, and well soaked, dried, washed with hydrobromate of potash, rinsed, and dried again."

(212.) Subsequently the talented discoverer of this process recommended the hydriodate of potash as superior to the hydrobromate as a fixing agent. "As soon as the picture is satisfactorily brought out by the auriferous fluid, it is to be rinsed in spring water, which must be three times renewed. It is then blotted off and dried, after which it is to be washed on both sides with a somewhat weak solution of hydriodate of potash. If there be any free chloride of gold present in the pores of the paper it will be discoloured, the lights passing to a ruddy brown; but they speedily whiten again spontaneously, or at all events on throwing it (after lying a minute or two) into fresh water, in which being again rinsed and dried, it is now perfectly fixed."

(213.) If instead of a solution of gold the nitrate of silver is used, the picture is brought out somewhat more slowly, and, as far as my own experience goes, with much less beauty, whether we consider colour or detail.

(214.) Cyanotype.—This name has been applied by Sir John Herschel to the whole class of processes in which cyanogen in its combinations with iron form a leading part. The following constitute the most interesting of this class which Sir John Herschel has yet published.

1. A paper is prepared as above (211.) with the ammonia citrate of iron, and a latent picture is impressed upon it. If the action of Light has been carried on to the darkening of the paper, the picture is negative. Over this picture a solution of the ferroprussiate of potash, in which is dissolved a little gum arabic, is

very sparingly but equally applied. As soon as this is done, the negative image vanishes, and by slow degrees is replaced by a positive one of a violet blue colour on a greenish yellow ground. If when *dry* the picture is not so distinct as could be desired, a second wash is applied; and when the image is fully developed, which it is with exceeding beauty if the operation has been carefully performed, the paper must be dried as speedily as possible. No fixing is required; the picture becomes pale in a very strong light, but it recovers its original colour in the dark.

(215.) 2. Mix together ammonia citrate of iron and sulphocyanate of potash in solution, and to the mixture add a small quantity of nitric acid. If only a certain portion of acid be added, the resulting red liquid spread on paper, whitens spontaneously. This is not the case if more acid is added; but paper washed with the superacidulated solution, retains when dry a considerable degree of colour, and receives a positive image with great rapidity, which appears more distinctly at the back of the paper than on its face. These impressions have not yet been successfully fixed.

(216.) 3. With a mixture which may contain equal proportions of ammonia-citrate of iron and ferrosesquicyanate of potash prepare a paper, and impress it with a picture, after which throw it into water, and dry it; a *negative blue* picture will be produced. If this picture is washed with a solution of the protonitrate of mercury, it is in a little time discharged. The mercurial salt being thoroughly washed out, and the paper dried, the picture is susceptible of restoration. If a smooth iron is passed over it somewhat hotter than is used for ironing linen, but not sufficiently so to scorch the paper, the obliterated picture immediately reappears, not blue, *but brown.* However carefully kept, these photographs fade after a few weeks and disappear. A fresh application of heat restores them to full intensity.

(217.) 4. This use of a mercurial salt led Sir John Herschel to devise an improvement on the cyanotype process, No. 1., which affords much more certain results and more decided pictures. One part by weight of the ammonia-citrate of iron is dissolved in eleven parts of water, and this is mixed with an equal quantity of a saturated cold solution of corrosive sublimate (bichloride of mercury). Before a precipitate has had time to form, the solution is washed over paper (which should have rather a yellowish than a bluish cast) and dried. This paper appears to keep well. It is exposed to Light till a faint, but perfectly visible picture is impressed. It is then washed over as rapidly as possible with a broad flat brush, dipped in a saturated solution of prussiate of potash, diluted with three times its bulk of gum water, so strong as just to flow freely without adhesion to the lip of the vessel. Care is required to spread this wash with one application, evenly, over every part of the paper. Beautiful pictures are thus produced, which will immediately bear exposure to Light tolerably well, but which after a few days will bear strong sunshine uninjured. By long keeping, details which were barely seen at first, come out with continually increasing intensity.

(218.) 5. Wash a paper with a solution of the ammonia-citrate of iron and dry it; then wash it over with a solution of the ferrocyanate of potash; there is no immediate formation of true prussian blue, but the paper rapidly acquires a deep purple colour. If in this state these papers are exposed to Light, they give positive pictures of great sharpness; but they possess this peculiarity — they darken again spontaneously on exposure to the air in darkness, and are soon obliterated. The paper, however, remains susceptible to Light, and capable of receiving other pictures, which fade in their turn. If these pictures are washed with ammonia or its carbonate, they are for a few moments obliterated, but they presently reappear, with *reversed lights and shades*. "In this state they are fixed, and the ammonia, with all that it will dissolve, being removed by washing in water, their colour becomes a pure prussian blue, which deepens much by keeping. If the solutions be mixed, there results a very dark violet-coloured ink, which may be kept uninjured in an opaque bottle, and will readily furnish by a single wash, at a moment's notice, the positive paper in question, which is most sensitive when wet."

(219.) 6. Paper simply washed with the ferrosesquicyanuret of potassium, is highly sensitive to Light. Exposed to sunshine for about an hour, with an engraving upon it, a beautiful negative photograph is the result. These are fixed by soaking in water in which a little sulphate of soda is dissolved, to ensure the fixity of the prussian blue deposited. While dry this cyanotype is dove-colour on a greenish yellow ground; after washing, it becomes bright blue on a white ground.

(220.) 7. Prepare a paper by washing, first, with a weak solution of ammonia-citrate of iron, one part by weight of the salt to twenty parts of water, and, when dry, with a saturated solution of the protonitrate of mercury. When nearly dry expose it for twenty minutes or half an hour to the Light, and a faint photograph will result. If it is now wetted with water and held for a few minutes in the sun, every part of the picture becomes visible, each line assuming an inky blackness. Instead of water, the solution of the nitrate of mercury may be used, and it possesses the advantage of giving greater permanence to the picture than when it was excited by water only.

(221.) The rationale of these processes has been well explained by their talented discoverer. In nearly all cases the action of the sun's rays is a deoxidising one. In the case of the ferrosesquicyanuret of potassium, No. 6., oxygen is parted with, which combines with hydrogen to form water. Prussian blue is deposited, the base being supplied by the destruction of one portion of the ferrocyanic acid, and the acid by the destruction of another. The change which takes place in the other cyanotype processes is somewhat more complicated.

(222.) To make this clear, however, I shall again quote from Sir John Herschel's Memoir: —

"It seems at first sight natural to refer these curious and complex changes to the instability of the cyanic compounds; and that this opinion is to a certain extent correct is proved by the photographic impressions received on papers, which have no iron but what exists in the ferrocyanic salts themselves. Nevertheless, the following experiments abundantly prove that in several of the changes above described, the *immediate action* of the solar rays is not exerted on these salts, but on the iron contained in the ferruginous solutions, added to them, which it deoxidises or otherwise alters, thereby presenting it to the ferrocyanic salts in such a form as to precipitate the acids in combination with the peroxide or protoxide of iron, as the case may be. To make this evident, all that is necessary is simply to *leave out the ferrocyanate* in the preparation of the paper, which thus becomes reduced to a simple washing over with the ammoniacitric solution. * * * If a slip of this paper be held for only four or five seconds in the sun (the effect of which is quite imperceptible to the eye), and when withdrawn into the shade be washed over with the ferrosesquicyanate of potash, a considerable deposit of prussian blue, takes place on the sunned part, and none whatever on the rest, so that on washing the whole with water, a pretty strong blue impression is left, demonstrating the reduction of iron in that portion of the paper to the state of protoxide. The effect in question is not, it should be observed, peculiar to the ammonia-citrate of iron. The ammonia- and potasso-tartrate fully possess, and the perchloride, *exactly neutralised*, partakes of the same property: but the experiment is far more neatly made, and succeeds better, with the other salts."

I have found that nearly all the salts of iron, under the influence of the sun's rays, for a longer or shorter period, undergo the same kind of decomposition, and to a certain extent, exhibit the same phenomena when washed with the ferrocyanates.

(223.) Prismatic Analysis. — (*Herschel.*) Papers washed with the ferrosesquicyanuret of potassium exposed to the prismatic spectrum, prove that the decomposition of the salt, and deposit of prussian blue, is due to the action of the blue and violet rays, the rays below the blue, having absolutely no influence. The greatest activity appears to exist about the region of the indigo rays.

(224.) If this salt is mixed with perchloride of iron, and washed over paper, whilst it is exposed to the spectrum, the action is continued down to the very end of the thermic spectrum. (See *Frontispiece.*) The formation of the deposited colour in this region is accompanied with phenomena of a novel character, referable to the heat developed by the thermic spectrum. Oval brown spots are formed, which correspond with the heat spots referred to, and which are evidently due to calorific agency. If ammonia-citrate of iron is used instead of the perchloride, "a copious and richly-coloured deposit of Prussian blue is formed over the whole of the blue, violet, and extra spectral rays in that direction, extending downward (with rapid graduation) almost to the yellow." If the action of Light is continued, the blue and violet rays in a very strange way destroy their own work: "a *white* oval makes its appearance in the most intense part of the blue, which extends rapidly upwards and downwards. At a certain point of the action, the upper or more refrangible extremity of the white impression exhibits a semicircular termination, beyond which is a distinct and tolerably well-defined *conjugate image*, or insulated circular white spot, whose centre is situated far beyond the extreme visible violet."

225. Sir John Herschel has also examined the action of the prismatic rays on the ordinary ferrocyanuret of potash, which it is well known undergoes a change slowly in the sunshine, depositing prussian blue. Paper washed with a fresh solution of this salt, slowly deposits when exposed to the spectrum, prussian blue over the region of the blue, violet, and lavender rays, whilst the formation of a violet-coloured streak takes place, where the violet ray is most intense. The action of the calorific rays is very strongly marked, when the decomposition of the salt is assisted by a wash of very dilute sulphuric acid. The impression is at first greenish, but as it blends with the upper portions of the spectrum, it passes into blue; the ground upon which this

streak is impressed being a brown, which appears to form, as it were, a narrow border around it.

(226.) We are indebted to Sir John Herschel also, for a very remarkable process, in which the dormant pictures are developed by the breath or a damp atmosphere. This process was announced at the Cork Meeting of the British Association in August, 1843, and was published immediately in the *Athenæum* of September the 16th, from which publication the particulars of the process are extracted.

If nitrate of silver, specific gravity 1.200, be added to ferro-tartaric acid, specific gravity 1.023, a precipitate falls, which is in a great measure re-dissolved by a gentle heat, leaving a black sediment, which being cleared by subsidence, a liquid of a pale yellow colour is obtained, in which a further addition of the nitrate causes no turbidness. When the total quantity of the nitrated solution added amounts to about half the bulk of the ferro-tartaric acid, it is enough. The liquid so prepared does not alter by keeping in the dark. Spread on paper and exposed *wet* to sunshine (partly shaded) for a few seconds, no impression seems to have been made, but by degrees, although withdrawn from the light, it developes itself spontaneously, and at length becomes very intense. But if the paper be thoroughly dried in the dark (in which state it is of a very pale greenish yellow colour), it possesses the singular property, of receiving a dormant or invisible picture, to produce which (if it be, for instance, an engraving that is to be copied), from thirty seconds to a minute's exposure in the sunshine is requisite. It should not be continued too long, as not only is the ultimate effect less striking, but a picture begins to be *visibly* produced, which darkens spontaneously after it is withdrawn. But if the exposure be discontinued before this effect comes on, an invisible impression is the result, to develope which, all that is necessary is to breathe upon it, when it immediately appears, and very speedily acquires an extraordinary intensity and sharpness, as if by magic. Instead of the breath, it may be subjected to the regulated action of aqueous vapour, by laying it in a blotting-paper book, of which some of the outer leaves on both sides have been damped, or by holding it over warm water. Sir John Herschel remarks, that many preparations of gold and silver possess a similar property in an inferior degree.

(227.) So extensive have been the researches of the distinguished philosopher, whose labours I have so frequently quoted, particularly into the action of the sun's rays on the salts of iron, that little can be added to his published information. It may not, however, be uninteresting to add a few brief remarks on some of the salts of iron, to which Sir John Herschel has not extended his observations, or at least which have not been recommended by him as photographic agents. OXALATE OF IRON in solution, to which an excess of oxalic acid has been added, affords, after a few minutes' exposure, when washed with nitrate of silver, a very intense black picture, which slowly fades into a dingy grey. If the oxalate of iron and silver be combined in the paper, and exposed, so powerful a picture results, that it is difficult to tell the right from the wrong side, the impression penetrating quite through the paper.

(228.) Oxalate of iron, with an excess of acid, washed over paper, and then a wash of ferrocyanate of potash, gives a very faint blue paper, which blue colour is entirely discharged if the acid is in large excess; if, however, the proportions are so adjusted that a little blue is still left on the paper, it is exceedingly sensitive to the sun's rays, the colour being very rapidly discharged. If after exposure, the paper is washed over with nitrate of silver, chloride of mercury, or a neutral solution of gold, a blue picture of much intensity results, which may be rendered tolerably permanent either by a wash of the ferrocyanate itself, or by a solution of the iodide of potassium.

(229.) Iodide of iron loses colour in the sunshine, and on paper, gives a positive picture; the subsequent application of the nitrate of silver has not been, with me, in any way successful in improving the faint picture it gives.

(230.) Chromate of iron changes but very slightly in colour by exposure; but if spread on glass or paper, and exposed, one part being shaded, and afterwards it is washed over with the nitrate of silver, the chromate of silver is formed over one portion, but not over the other. It is necessary that the chromate of iron should be newly formed.

(231.) As far as my researches have gone, all the persalts of iron are converted into protosalts by exposure to sunshine, when in combination with organic matter. And I have reasons for believing that all the protosalts undergo some change, it being very evident that exposed and unexposed portions of papers washed with solutions of the protosalts act very differently upon solutions of gold and silver. What this change may be it is impossible to say in the present stage of our inquiry, but it will be seen that scarcely any of the metallic salts resist the agency of the sun's rays, as will be still further proved. The absorption of oxygen, or deoxidation, will not account for many of the results which we obtain.

CHAP. VI.

COPPER.

(232.) It has been long known to me that plates of copper could be rendered sensitive to solar influence, by being submitted to iodine vapour. In a very early stage of my experiments with the Daguerreotype, I operated with pure copper plates; and some results obtained at that time were of considerable promise. The publication of any account of a process, by which photographs might be taken upon copper, was first made by Mr. Fox Talbot, who has included it amongst those embraced by his patent for "improvements in obtaining pictures or representations of objects by the action of Light." Mr. Talbot's process is as follows:— A polished copper plate is exposed to the vapour of iodine or bromine, or the two substances combined, or either of them in combination with chlorine. Or the copper plate may be immersed in a solution made by dissolving one of the above-mentioned substances in alcohol or some other solvent. The plate is now placed in the camera, and after it has remained in it for a period varying, according to my own experiments, from twenty minutes to two hours, it is exposed to sulphuretted hydrogen, or one of the liquid hydrosulphurets. By these, various colours are produced upon the plate, according to the intensity with which Light has acted on the different parts.*

It must not be imagined, that the colours produced on the plate of copper are the natural colours of the object

* See Repertory of Patent Inventions, October, 1841.

delineated. This colouration arises, merely from the formation of films, of greater or less thickness, of sulphuret upon those parts of the ioduret of copper, which have been decomposed by the sun's influence.

(233.) THE CHROMATYPE. — The first announcement of this process, was made by the author, at the meeting of the British Association, August, 1843. The process is so exceedingly simple, and the resulting pictures of so very pleasing a character, that, although it is not sufficiently sensitive for use in the camera obscura, it will be found of the greatest value for copying botanical specimens, engravings, or the like.

Good writing-paper is washed over with sulphate of copper in solution, the strength of which is not of much importance. About one drachm to an ounce of water is preferred; when dry it is washed over with a moderately strong, but not a saturated, solution of the bichromate of potash. The paper, when dry, is fit for use, and it may be, I believe, kept for any length of time in a portfolio, without its sensibility being in the least impaired.

When exposed to the sunshine, the first change is to a dull brown; and if checked in this stage of the process, we have a *negative* picture; but if the action of Light is continued, the browning gives way, and we have a *positive* yellow picture on a white ground. In either case, if the paper, when removed from the sunshine, is washed over with a solution of nitrate of silver, a very beautiful positive picture results. In practice it will be found advantageous to allow the bleaching action to go on to some extent: the picture resulting from this, will be clearer and more defined, than that which is procured when the action is checked at the brown stage. To fix these pictures, it is necessary to remove the excess of nitrate of silver, which is done by washing in pure water. If the water contains any muriates, the picture suffers; and long soaking in such water entirely destroys it: or if a few grains of common salt are added to the water, the apparent destruction is very rapid. The picture is, however, capable of restoration; all that is necessary being to expose it to the sunshine for ten minutes or a quarter of an hour, when it revives; but instead of being of a red colour, it becomes lilac, the shades of colour depending upon the quantity of salt used to decompose the chromate of silver. After this exposure, no fixing is required, the continued action of Light only still further improving the pictures.

(234.) Sir John Herschel has given some instances in which the chemical rays, as they are called, appear to destroy their own work. I am enabled to add another to the list. If a piece of the chromatype paper is exposed to the prismatic spectrum, it darkens instantly over the region of the blue ray. This darkening extends to a point beyond the violet ray equal to the width of that ray, and downwards to the extreme edge of the green, proceeding, by long exposure, into the yellow. After a short time, this darkening is followed by a bleaching action, which commences at the upper edge of the violet, and proceeds slowly downwards to the edge of the most refrangible green. The brown over the green space gives way but very slowly; and it is only after very long-continued exposure to a good sun, that this portion is entirely whitened.

(235.) If we mix together a solution of sulphate of copper and of the bichromate of potash, the mixture will, in the dark, remain perfectly clear for a considerable time; but if exposed to sunshine, in a few minutes a rapid effervescence ensues, and a greenish yellow precipitate falls. This, and the precipitate produced in like manner in neutralised platina solutions, deserves the attention of chemists.

(236.) MODIFICATION OF THE CHROMATYPE. — If to a solution of the sulphate of copper we add a solution of the chromate of potash — the neutral salt — a brown precipitate falls very copiously, which is a true chromate of copper. If this precipitate, after being well washed, is added to water rendered tolerably acid by sulphuric acid, it is dissolved, and a dichromatic solution is formed, which is, when spread upon paper, of a pure yellow. A very short exposure of the papers, washed with this solution, is quite sufficient to discharge all the yellow from the paper, and give to it a perfect whiteness. If an engraving is to be copied, we proceed in the usual manner; and we may either bring out the picture by placing the paper in a solution of carbonate of soda or potash, by which all the shadows are represented by the chromate of copper; or by washing the paper with the nitrate of silver. It may sometimes happen that, owing to deficient Light, the engraving is darkened all over when the silver is applied; this colour, by keeping, is gradually removed, and the Lights come out clear and sharp. The little excess of acid in the paper, acts upon the chromate, which has been partially changed, and a pale yellow, instead of a red salt, is formed.

(237.) If the chromate of copper is dissolved in ammonia, a beautiful green solution results. If papers are prepared with this solution, they act similarly to those last mentioned. If the pictures prepared as above (233.) are washed with ammonia, they are nearly obliterated; but upon exposing them to the air and Light, negative pictures of a pale blue colour result.

(238.) Iodide of copper, by long exposure, does not appear to undergo any change; if, however, it is washed over with nitrate of silver, it becomes unequally black upon the exposed and covered parts. If, previously to exposure, freshly made iodide of copper is washed over with nitrate of silver, an intense black paper results. This paper has some remarkable properties; if it is exposed wet to the prismatic spectrum, a bleaching action comes on with rapidity under the red and orange rays, particularly over the space occupied by the "parathermic" rays of Herschel. Little or no action is seen to take place over any other part; but upon removing the paper from the Light, and washing it with hyposulphite of soda, it becomes evident that a deep browning, penetrating quite through the paper, has been effected by the blue rays.

If we place leaves of tolerable transparency upon such a paper, the bleaching action is carried on beneath them, whilst the exposed parts remain of a jet black colour.

(239.) All the salts of copper, undergo some change under the influence of the solar radiations. The change is not in many cases apparent, but in some it is so. If, however, a solution of any salt of copper is laid over paper, and it be exposed to the sunshine, a change is brought about; and if after it is removed from the Light, it is washed with nitrate of silver, the covered portion remains of its original colour, whilst the exposed parts darken very considerably. The following salts afford really interesting pictures:—Sulphate, muriate, nitrate, carbonate, acetate, oxalate, ammonia-oxalate, tartrate, malate, chloride, bromide, and arseniate. I do not doubt but by attention and experiment, some of these may afford very valuable photographic preparations. At all events these results, to which I was the first to call attention, show the immense field of inquiry which is opening before us.

CHAP. VII.

MANGANESE.

(240.) The instability of some of the salts of manganese, led to the hope that this metal might be made available for photographic processes. Although this has not yet been effected, a sufficient amount of evidence of its compounds being, like those of other metals, susceptible of change under solar influence, has been obtained.

(241.) If two bottles are filled with a solution of mineral chamelion (manganesiate of potash), and one of them be placed in the sunshine, whilst the other is carefully preserved in darkness, it will be found that the one exposed to the sun, will very rapidly throw down a deep brown precipitate, whereas the one in the dark, remains for some time quite clear. This experiment, if carefully made in weak diffused day-light, will exhibit, although more slowly, the same change, showing in a very remarkable manner the influence of Light in determining the tendency to precipitation.

(242.) If a solution of the manganesiate of potash is washed over paper, it imparts to it a brown colour. The sun's rays have a tendency to discharge this colour, and thus give a positive image. The addition of a small quantity of the nitrate of silver to paper prepared with this salt of manganese, renders it brown, but upon exposure to Light it assumes a very intense blackness.

(243.) If the deutoxide of manganese is dissolved in a solution of the cyanuret of potassium, and paper washed with this solution, it will be found that an exposure to sunshine for half an hour, will produce no visible change over the surface; but on looking through the paper, it becomes evident that a considerable deposition of a brown precipitate has taken place within its pores over the spaces which were not protected from the action of the Light.

(244.) Many of the salts of manganese spread upon paper, exhibit some evidence of change under solar action. The muriate in particular undergoes decomposition, and some oxide of manganese is deposited. It is, however, to be remarked, that in those cases in which no apparent change is produced even by prolonged exposure to the sun's rays—that is, no change of colour—we are not to conclude that no disturbance has taken place. In nearly all cases, it will be found that a sufficient amount of change has been effected, to be rendered evident by the application of some reagent, after it is removed from the Light. In particular, in the instances of the manganesic salts, as in those of copper, the subsequent application of the nitrate of silver produces very decided evidences of change. The chloride of gold in some cases, appears to be reduced by these salts which have undergone solarization, in a manner strikingly different from the effect produced by salts which have not been exposed to the sun. It has also been noticed, that the balance of affinity has been so much disturbed by the solar agency, that ammonia, the hydrosulphurets, and the ferroprussiates, produce different effects upon the exposed and covered parts. May not these very curious phenomena be dependent upon the absorption of the active principle which is found to exist in the sun's rays, and every radiant source?

CHAP. VIII.

LEAD.

(245.) The pure coloured oxide of lead, in a moist state, under the influence of the sun's rays, parts with oxygen, and is converted into the deutoxide. It has been found, that this is more decidedly the case, with the oxide prepared by chlorine from the acetate of lead, than with that which is prepared by the action of nitric acid on minium or red lead; from which it would appear that the oxygen is in looser combination in the one case than in the other. It was observed by Sir H. Davy, that this change was effected by the least refrangible rays; hence we may suppose it to depend on the calorific power of these rays.

(246.) In a very early stage of his photographic inquiries, Sir John Herschel was led to employ mordant washes of lead, and of organic matter precipitated by lead. These were found to have a very decided effect, in quickening the change which takes place upon the nitrate of silver when exposed to Light, and in some cases it was found that a sensibility quite equal to the processes proposed by Mr. Talbot (59.) was produced. Papers, unfortunately, which are prepared with lead, have a tendency to darken spontaneously, or at least to turn very yellow, or sometimes grey, in the dark.

(247.) Combinations of lead, with the organic acids, have been repeatedly tried; but, except in a few instances, no very marked effect has resulted. Oxalate of lead does indeed appear to be susceptible of change of colour under prolonged exposure; and the formate and benzoate of lead, show that the solar rays produce some effect with tolerable quickness, which is rendered evident by subsequent washing with gallic acid, with nitrate of silver, or one of the hydrosulphurets.

(248.) If red lead is boiled with cyanuret of potash, and paper washed with this solution is exposed to the Light, it undergoes some change, which is rendered evident by nitrate of silver. If gallic acid is washed over paper saturated with this solution, it becomes, at first, pink, and then brown. Upon exposing this to the Light, it loses colour; but although this change is produced with some rapidity, it is not found to proceed on to the point of whiteness, however long the paper may be exposed to sunshine.

(249.) If acetate of lead is washed over a paper, and then a weak solution of gallic acid, it will be found that no change of colour is produced for some time in perfect darkness; but a very short exposure to Light brings on a very decided darkening, which goes on even without the continuance of the solar influence.

(250.) Numerous combinations of lead and other metals have been examined, with a view to detect, if possible, some of those cases of unstable affinity which yield the most interesting photographic results. Nothing very remarkable has been discovered. Lead certainly has the power of increasing the sensibility of gold and platinum to the action of Light, and of carrying on the degree of darkness ultimately produced, much further than when these metals are used alone; and hence it is very probable that lead may in some processes be of considerable use, where the object is to produce originals, from which a great number of transfers may be taken.

CHAP. IX.

NICKEL.

(251.) Nitrate of nickel spread upon paper passes, with some degree of rapidity, into a fine light brown, giving tolerably good negative pictures.

(252.) Nitrate of nickel spread upon paper, and then ammonia, promises to afford some very interesting photographic results. It is somewhat difficult to decide upon the exact proportion in which the ammonia should be used. It appears that a sufficient quantity should be applied to effect the precipitation of the oxide of nickel, but not enough to re-dissolve it. If an excess of ammonia is used, the paper appears absolutely insensible, but if the proportions are well adjusted, a preparation which darkens quite as readily as the nitrate of silver, results. The subsequent application of the nitrate of silver considerably darkens the parts which have been already changed by Light.

(253.) Upon submitting paper thus prepared to the prismatic spectrum, it was found that the change was entirely dependent upon the influence of the rays of greatest refrangibility, the prolonged action of the other rays producing no apparent effect.

(254.) Iodide of nickel, prepared with nitrate of nickle and iodide of potassium, changes with some degree of quickness; but if the iodide of ammonia is used, no change takes place.

(255.) Nitrate of nickel and ferroprussiate of potash changes, after an exposure to sunshine of from fifteen minutes to half an hour, from a delicate light blue to a pea green.

Many other salts of this metal have been found to afford similar results.

CHAP. X.

SUNDRY METALLIC COMPOUNDS.

(256.) TIN.—It has been found that chloride of tin, carefully neutralised, will, when in contact with any organic matter, undergo a considerable change in the sunshine; a dirty appearance being given to it in half an hour, so as to contrast very decidedly with the original whiteness. Its oxide, washed, after exposure to the sun, with nitrate of silver or chloride of gold, exhibits very decided evidences of change.

The purple of cassius changes in the sunshine to a steel grey. If the dyers' muriate of tin is applied to paper, and then dried without much heat, it may be used to produce results of some interest. If, after exposure for half an hour to good sunshine, the paper is washed with very dilute chloride of gold, the purple of cassius will be formed with much greater readiness over the shaded than the exposed parts, giving thus positive images. If the solution of gold is applied too copiously, the darkening is carried on with great rapidity over the whole of the sheet; but although at first it appears that the sheet is of one uniform colour, it will, by keeping, show distinctly the covered spaces.

(257.) COBALT.—The changes which some of the salts of this metal undergo when exposed to heat are well known. These appear to depend entirely upon the abstraction of moisture. Under the influence of the prismatic spectrum, these changes of colour take place, but only under the red rays, by long exposure. Another kind of change is apparent under the spaces on which the blue rays fall, and which, very different from that produced by the heat rays, is a permanent change. On paper the nitrate, muriate, and carbonates of cobalt, have been found to deepen in colour very considerably under exposure. In a few instances, when the sun has been very fervent, the pale blue of these salts changed to a good violet; but when removed from the light, this colour passes into a deeper blue. Washed with nitrate of silver, the blue passes into a brown; and if again exposed, positive images are produced.

(258.) The very intense and beautiful brown which is given to the ordinary argentine preparations, by the presence of cobalt, may possibly be of some advantage in practice. If paper is washed with muriate of cobalt, and then nitrate of silver, in proper proportions to allow the silver to be in excess, it will be found to be superior to the ordinary muriated papers; and it is so far economical, that a very much weaker solution of the nitrate of silver may be used, and as deeply coloured an impression made, as when a larger dose of the silver has been applied. Nitrate of silver does not darken very readily when spread on paper; but if mixed with nitrate of cobalt, it will be found to change more easily, and give a deeper colour than the silver salt alone would do.

(259.) Some of the arsenical combinations will be found to be influenced by the solar rays, and particularly the arseniate of potash. If a paper washed with this salt is exposed for an hour or two, the subsequent application of nitrate of silver brings out a decided image of any body used to obstruct the Light.

(260.) Tartrate of antimony is also found to be affected by the agent we are considering, and pictures may be produced by washing it with the nitrate of silver, as in other instances. (239, &c.)

(261.) Bismuth, Cadmium, Rhodium, and some other metals, have been found, under certain conditions, to afford evidence of the same kind of changes as we have seen takes place in so many other bodies. The attentive study of the peculiarities of the rarer metallic compounds will, it appears, probably afford many curious results. As far as the researches have been carried, they afford good presumptive evidence that every chemical combination undergoes some peculiar modification under the power of the solar rays.

CHAP. XI.

CHROMIUM AND FERROCYANOGEN.

(262.) The bichromate of potash is particularly distinguished by its photographic properties. These were first pointed out by Mr. Mungo Ponton, who proposed the following interesting process:—Well-sized paper is to be immersed in a solution of bichromate of potash, and dried by the fire; by this it assumes a fine yellow colour, and it may be kept for any length of time without injury, and is always ready for use. When an engraving is laid on this paper, and it is exposed to the sunshine, it passes rapidly, over all the parts through which the Light can act, into a light brown; consequently the first result is a yellow picture upon a brown ground. In this state the photograph cannot be exposed to the Light, as all the yellow parts would become brown. If, however, the paper is soaked in water, all the unchanged salt is dissolved out, but that which is browned is not disturbed. We have thus a delicate negative picture, from which positive copies may be taken. If the paper is exposed too long to sunshine, it loses colour. A pleasing variety may be made by mixing sulphate of indigo, with the bichromate of potash, the colour of the object and of the ground being different shades of green.

(263.) The change which the solar rays produce upon this salt is one of deoxidation. Chromic acid is liberated, and it combines with the organic matter of the size of the paper. Mr. Ponton states that the neutral chromate exhibits no such change; it has, however, been since discovered, that even the chromate of potash on paper will darken; but it is only by long exposure that much effect can be produced; and the ultimate degree of darkness falls very far short of that given by the bichromate. This change is effected by the blue rays of the spectrum, and their action appears to be confined within rather narrow limits.

(264.) M. E. Becquerel has investigated, with considerable care, the action of chromic acid on organic bodies under the influence of Light; and he has shown that the darkening is dependent upon the nature of the size used on the paper. Perceiving this, it occurred to him that the application of starch as a size to the paper, pleasing effects might be produced, by the agency of iodine, and the result was satisfactory.

According to Becquerel's method, a sizing of starch is applied very evenly over the paper; it is then steeped in a concentrated solution of the bichromate of potash, and dried. Pictures are taken in the usual way, and the paper is washed and dried. When dry, it is immersed in a weak alcoholic solution of iodine, and afterwards, when it has remained in it for some time, it is rinsed in water, and carefully dried between folds of blotting paper. If the drawing is not considered to be sufficiently distinct, the immersion may be repeated, until it becomes so. The effect is not improved by using a more concentrated solution of iodine. When the paper is wet, the shades of the picture are of a very fine blue, but when it is dry, they become of a deep violet. If while the photograph is still wet, it be covered with a layer of gum-arabic, the colour of the drawing is greatly preserved, and it is more beautiful when dry.

(265.) The metallic chromates have been thought to be compounds of too permanent a character to change under solar influence. Many of them, however, it will be found deepen in colour by exposure; and the chromate of mercury has been found to undergo a very remarkable change. Paper was prepared with the bichloride of mercury (corrosive sublimate) and the chromate of potash, and exposed with an engraving upon it for some hours. There was evidently some change of colour, but it was very slight, over the exposed parts. This was placed aside, and remained in a dark drawer for two or three months without being noticed. It was then found to have become through its substance semi-metallic, and both on the front and back of the paper, a tolerably good impression of the engraving was visible.*

* Whilst these pages have been going through the press, the author has discovered a very beautiful variation of the chromatype. A neutral solution of the chloride of gold is mixed with an equal quantity of the bichromate of potash. Paper is washed with this solution, and dried

(266.) FERROCYANATES. The photographic uses of these salts have already been the subject of consideration (84. 218, &c.); and it only remains to state, in this place, that a solution of the ferroprussiate of potash mixed with a solution of the iodide of potassium, applied to paper, speedily changes in the sunshine, and may be used for the production of a very pretty variety of negative photographs. M. Fischer pointed out that a solution of ferrocyanate of potash precipitated by alcohol, and rapidly dissolved in water, when exposed to Light passes into a green and then a blue colour, depositing prussian blue, and giving a strong smell of hydrocyanic acid.

near the fire. On exposing this paper to light, it speedily changes, first to a deep brown, and ultimately to bluish black. If an engraving is superposed, we have a negative copy, blue or brown, upon a yellow ground. If this photograph is placed in clean water, and allowed to remain in it for some hours, very singular changes take place. The yellow salt is all dissolved out, and those parts of the paper left beautifully white. All the dark portions of the paper become more decided in their character, and accordingly as the solarization has been prolonged, or otherwise, or the light has been more or less intense, we have either *crimson, blue, brown, or deep black negative photographs* of a most beautiful character.— Feb. 22. 1844.

SECTION II.

ON THE ACTION OF THE SOLAR RAYS ON VEGETABLE SUBSTANCES.

CHAPTER I.

RESINS.

(267.) Heliography.—By this name M. Niepcé distinguished, in 1827, the first process by which the images of the camera obscura were rendered permanent, after having impressed themselves upon prepared tablets. Although the process of the philosopher of Chalons is not likely to attract much attention from the photographer, who is now in possession of processes which infinitely surpass it in sensitiveness, yet, as it was the germ of every thing which has been done in the art since that period, and as it develops some important operations of the solar rays, it could not be allowed to pass without especial notice. M. Niepcé has given directions, which are essentially as follows—the process is given more in detail in the introduction. (31.)

(268.) Into a glass is put a small portion of asphaltum, upon which is dropped essential oil of lavender till the asphaltum is impregnated with it, and as much additional oil is added as will cover it to a slight depth. The mixture is then submitted to a gentle heat, until the whole of the essential oil is saturated with the colouring matter of the bitumen. A highly polished plate of silver is procured, and with a soft roll of skin some of this varnish is applied, in a very thin and equal coating; the plate is then placed upon heated iron, and when the varnish has ceased to simmer, it is withdrawn, and left to cool and dry in a gentle temperature, secured against any moisture. The plate thus prepared is placed in the camera, and in bright summer sunshine, a period of four or six hours is necessary to produce any thing like the proper effect. The images are exceedingly faint at first, but they are brought out by the action of a solvent which removes from the plate, or renders perfectly transparent, those parts upon which the solar rays have not acted. This solvent consisted of one part, by volume, of essential oil of lavender, poured upon ten parts, by measure also, of oil of white petroleum. The varnished tablet is placed in a proper vessel, which has been filled with the solvent, and the operator, by reflected Light, watches the development of the images, and removes the plate when the proper effect is produced.

The process is then completed, by placing the plate upon an inclined plane, and washing it with very clean water, to remove all the softened parts of the varnish which may still adhere to it. This varnish may be spread upon metal, glass, or stone. Engravings are more easily copied by this method, than pictures from nature can be procured.*

(269.) Niepcé appears to have advanced this process considerably; but his partner in this inquiry, M. Daguerre, suggested the use of materials by which the operation was greatly improved, as it regards sensitiveness and general effect. These improvements consisted in applying the residuum obtained by the evaporation of the

* See previous note, page 29, where some of the subjects obtained on these plates by M. Niepcé himself are described.

essential oil of lavender to the plates, instead of the asphaltum; and instead of dipping the plate, after exposure, into a solvent, it is so placed that the *vapour* of petroleum acts upon it, by which the portions of the varnish that have been acted on by the Light is rendered transparent.

(270.) Daguerre remarks that all bitumens, all resins, and all residua of essential oils, are decomposable by Light in a very sensible degree. To exhibit this action, very thin coatings of them should be spread over fitting surfaces; and it is a curious fact, and well worthy the inquiry of chemists, that different solvents act differently upon these resinous plates after they have undergone the action of solarization. If alcohol is used, the parts on which the Light acted are dissolved off; but if an essential oil is employed, the parts in shadow are those effected by the solvent.

(271.) I have tried nearly all the gum resins in general found in the shops of druggists, &c. and these are, I find, acted upon in the same way as the pure resins, and indeed the gums give some indications of losing solubility by exposure to sunshine.

(272.) Guaiacum.—The colour of this peculiar resin is yellowish brown, but upon exposure to the sun's rays it becomes green. Dr. Wollaston first pointed out, that this change was brought on by the violet rays; that the original colour was restored if it was exposed to the red rays, and that the same change was effected by the application of artificial heat.

Dr. Wollaston did not observe any change on exposing pieces of card, covered with an alcoholic solution of this gum, in the prismatic spectrum. But, taking a lens of seven inches in diameter, and having covered the central part of it, so that a ring of one tenth of an inch only was left at its circumference, he could collect the rays of any colour in a focus—the focus for yellow Light being 24½ inches. By this arrangement it was found, as above stated, that the violet and blue rays changed it to green; that the yellow rays produced no effect, and that in the red rays the *green colour* was destroyed. When the guaiacum was placed in carbonic acid, it could not be rendered green at any distance from the lens, but was rapidly restored from green to yellow by the red rays. Thence he inferred that the rays of greatest refrangibility favour disoxygenation, but that the least refrangible ones favour oxygenation. These changes have been recently investigated by Sir John Herschel, the results of whose inquiries I shall now give.

(273.) This resin dissolved in alcohol, spread evenly upon paper, gives nearly a colourless ground. Exposed to the spectrum a blue colour is impressed upon the paper, over the spaces between the least refrangible green rays, and a point situated upon the invisible rays a few lines beyond the violet rays. The action of dispersed Light changes the paper to a pale green, but over the region of the red rays the original pale colour of the paper is preserved.

(274.) If a paper thus prepared is exposed to the action of Light, which has permeated a deep blue fluid, until it assumes a uniform pale blue tint, it will be found, that under the influence of the prismatic spectrum a restoration of the original yellow colour takes place over the region of the green, yellow, orange, and red rays, the blue colour being entirely removed by the orange ray. It will be remembered that Dr. Wollaston attributed this restoration of colour to the action of heat. Had this been the true interpretation, we might expect to find the change most evident in that part of the spectrum where the heat was greatest, which we see is not the case.

(275.) Sir John Herschel exposed a portion of this paper to the action of chlorine considerably diluted with common air, by which it acquired a pale, dirty, greenish-yellow hue. Transferred immediately to the spectrum, it was impressed with faint tints nearly corresponding to the natural ones—the red was evident—the yellow dilute, and nearly white—the blue, a fine sky blue, while beyond the violet succeeded a train of somewhat greenish darkness.

(276.) If a paper prepared with the alcoholic solution of guaiacum, is placed in an aqueous solution of chlorine, it acquires a beautiful and pure celestial blue colour. "This paper is very sensitive, and may be used for copying engravings, which it does with this singularity, that the picture penetrates the paper, and appears on the back with nearly the same intensity as on the face." Under the influence of the less refrangible rays the blue colour is changed into a pale reddish yellow, but simply whitened over the more refrangible region of the spectrum. Photographs or spectra received on this paper speedily fade. (*Herschel.*)

(277.) Several experiments were tried, with a view of determining if the conclusions arrived at by Dr. Wollaston, as to the influence of artificial heat in producing these changes of colour were correct, and if they explained the restoration produced by the least refrangible rays of the solar spectrum. It has already been noticed that the rays of greatest calorific power produce no change upon the paper, whereas the decoloration is brought about by the rays in the region of the red, orange, yellow, and green spaces. It was found by

Sir John Herschel that an artificial heat between the limits of 180° and 280° soon changed guaiacum from a green to a yellow state if moist, but that no such change was produced if absolutely dry. It was thought desirable to try the effect of the spectrum upon papers prepared as above, whilst, at the same time, they were subjected to a temperature sufficiently high to produce this effect had the paper been moist; this artificial heat being meant to assist the power of the calorific rays: this was done by holding a hot iron at the back of the paper. It was found, however, that, although it quickened the action over the luminous spaces, which were not at all changed in their character, that no perceptible effect was produced by those rays which possess the greatest heating power. From these researches of Sir John Herschel it would appear, that this restoration of guaiacum to its original colour is not dependent upon the heating power of the sun's rays, but upon some influence strictly analogous to that exerted by the "chemical rays," but modified by the combined influences of Light and heat.

CHAP. II.

COLOURS OF FLOWERS.

(278.) The action of Light on the juices of plants has been carefully studied by M. Chevreul; but as his experiments were made with reference only to their permanence as dying materials, and with white Light as it proceeds from the sun, they afford no information as to the influence of the separated rays. This subject has alone engaged the attention of Sir John Herschel. The author has indeed tried a few experiments with the colouring matter of leaves; but for nearly the whole of the information contained in this chapter we are indebted to that distinguished philosopher.

(279.) Certain precautions are necessary in extracting the colouring matter of flowers. The petals of fresh flowers, carefully selected, are crushed to a pulp in a marble mortar, either alone or with the addition of a little alcohol, and the juice expressed by squeezing the pulp in a clean linen or cotton cloth. It is then to be spread on paper with a flat brush, and dried in the air without artificial heat. If alcohol be not added, the application on paper must be performed immediately, as the air (even in a few minutes) irrecoverably changes or destroys their colour. If alcohol be present, this change is much retarded, and in some cases is entirely prevented.

(280.) Most flowers give out their colouring matter to alcohol or water. Some, however, as the Escholzias and Calceolarias, refuse to do so, and require the addition of alkalies, others of acids, &c. Alcohol has, however, been found to enfeeble, and, in many cases, to discharge altogether these colours; but they are, in most cases, restored upon drying, when spread over paper. The juice of the *Viola tricolor*, extracted by alcohol, is a striking example of this temporary destruction of colour. Papers tinged with vegetable colours must be kept perfectly dry and in darkness.

(281.) The colour of a flower is by no means always, or usually, that which its expressed juice imparts to white paper. The red damask rose, called by florists the black rose, gives a dark slate blue, as do also the clove carnation and the black holyoak; and the common red poppy (*Papaver Rhœas*) imparts to paper a rich and most beautiful blue colour. Sir John Herschel attributes these changes to the escape of carbonic acid in some cases; to a chemical alteration, depending on the absorption of oxygen, in others; and again in others, especially where the expressed juice coagulates on standing, to a loss of vitality, or disorganisation of the molecules. To secure an evenness of tint on paper, the following manipulation is recommended:—"The paper should be moistened at the back by sponging and blotting off. It should then be pinned on a board, the moist side downwards, so that two of its edges (suppose the right-hand and lower ones) shall project a little beyond those of the board. The board then being inclined twenty or thirty degrees to the horizon, the alcoholic tincture (mixed with a very little water, if the petals themselves be not very juicy) is to be applied with a brush in strokes from left to right, taking care *not to go* over the edges which rest on the board, but *to* pass clearly over those that project; and observing also to carry the tint from below upwards by quick sweeping strokes, leaving no dry spaces between them, but keeping up a continuity of wet spaces. When all is wet, cross them by another set of strokes from above downwards, so managing the brush as to leave no floating liquid on the paper. It must then be dried as quickly as possible over a stove, or in a current of warm air, avoiding, however, such heat as may injure the tint."

(282.) Before I proceed to give Sir J. Herschel's remarks on the results of his inquiries, or offer any of my own, I shall mention, as briefly as is consistent with a correct understanding of the matter, several of the most remarkable results obtained by him upon vegetable juices, referring all those who may desire more detailed information to his memoir itself.*

(283.) CORCHORUS JAPONICA.—The flowers of this plant impart a fine yellow colour to paper. Sir John Herschel says he has met with no vegetable colour so sensitive. If the flowers are gathered in the height of their season, paper coloured with them begins to discolour in ten or twelve minutes in clear sunshine, and in half an hour is completely whitened. The colour seems to resist the first impression of the Light, as if by some remains of vitality, which being overcome, the tint gives way at once, and the discoloration, when commenced, goes on rapidly. *It does not even cease in the dark when once begun;* hence photographic images received upon papers prepared with this juice slowly fade out.

(284.) PRISMATIC ANALYSIS.—Exposed to the spectrum, in about fifteen or twenty minutes the colour is totally destroyed, and the paper whitened in the whole region of the green, blue, and violet rays, to which, therefore, the most energetic action is confined. If the action of the spectrum be prolonged, a much feebler whitening becomes sensible in the red, and a trace of it also beyond the violet into the "lavender" rays. By keeping papers thus impressed, terminal spots were detected beyond the red extremity, and also beyond the violet, they having gradually developed themselves.

(285.) COMMON TEN-WEEKS' STOCKS. — *Mathiola annua.* — The colour imparted to alcohol by the double variety of this flower, in the height of its flowering, is a rich and florid rose red; when fresh prepared, papers stained with it are sensibly discoloured in a few hours,

* On the Action of the Rays of the Solar Spectrum on Vegetable Colours, &c. "Philosophical Transactions, Part II. for 1842."

and completely whitened in two or three days. Exposed to the spectrum, the rays chiefly active in operating the discoloration, are found to be those extending from the yellow to the less refrangible red, beyond which rays the action terminates abruptly. Above the yellow, it degrades rapidly to a minimum in the blue, beyond which it recovers somewhat, and attains a second but much feebler maximum in the violet rays.

(286.) Sulphurous acid whitens this paper, but it resumes its original colour after a little time, which is materially quickened by the aid of Light. Papers thus completely discoloured, when exposed to the spectrum, were restored to their original colour, *by rays complementary to those which destroy it in the natural state of the paper;* the violet rays being chiefly active, the blue almost equally so, the green little, and the yellow, orange, and most refrangible red not at all. Sir John Herschel attributes, and I think rightly so, the power of the sulphurous acid in inducing a dormant state of the colorific principle to a partial deoxidisement, unaccompanied, however, with disorganisation of its molecules.

(287.) It has been noticed that alcohol in many cases weakens the colours of vegetable juices, and in some entirely masks them. With the *Papaver orientale* this is very strikingly shown. The colour of the flower is a brilliant orange, " the colouring matter of which is only extractable by alcohol, and then only in a state so completely masked, as to impart no more than a faint yellowish or pinkish hue to paper, which it retains when thoroughly dry, and apparently during any length of time, without perceptible increase of tint." This paper is immediately rendered a vivid scarlet colour when an acid is applied to it. If paper covered with this alcoholic extraction is exposed for a long period to the influence of the Light, it undergoes some disorganisation, so that, on being exposed to the vapours of muriatic acid, a dormant picture — supposing it to have been covered with an engraving — is gradually developed in a soft and pleasing style. The time required to produce these pictures extends over from twenty to thirty days.

(288.) Papers covered with an alcoholic tincture of *turmeric* are slowly acted upon. It is whitened by the blue and violet rays. If it is browned by carbonate of soda it is somewhat more sensitive, especially when wet, and an abruptly terminated action is perceptible in the red region. (*Herschel.*)

(289.) *Bulbine bisulcata* and two other species from the Cape of Good Hope were found by Sir John Herschel to yield from the green epidermis of their leaves and flower stalks a bright yellow juice, which darkens rapidly on exposure to Light, changing at the same time to a ruddy brown. Exposed to the spectrum, the less refrangible rays are found inoperative either in inducing a change of tint, or in preserving that portion of the paper on which they fall from the influence of dispersed Light. A darkening commences about the mean yellow ray, but it continues very feeble through the green ray, above which it darkens more strongly, arriving at its maximum in the blue, but extending to a considerable distance beyond the violet with some degree of intensity.

(290.) *Cheiranthus cheiri, Wallflower.*—" A cultivated double variety of the flower, remarkable for the purity of its bright yellow tint, and the abundance and duration of its flowers, yields a juice, when expressed with alcohol, from which subsides, on standing, a bright yellow finely divided fæcula, leaving a greenish-yellow transparent liquid, only slightly coloured supernatant. The fæcula spreads well on paper, and is very sensitive to the action of Light, but appears at the same time to undergo a sort of chromatic analysis, and to comport itself as if composed of two very distinct colouring principles, very differently affected. The one on which the intensity and sub-orange tint of the colour depends, is speedily destroyed, but the paper is not thereby fully whitened. A paler yellow remains as a residual tint, and this on continued exposure to Light, so far from diminishing in tone, slowly darkens to brown. Exposed to the spectrum, the paper is first speedily reduced nearly to whiteness in the region of the blue and violet rays. More slowly, an insulated solar image is whitened in the less refrangible portion of the red. The exposure continuing, a brown impression begins to be perceived in the midst of the white streak, which darkens very slowly over the region between the lower blue and the extreme violet rays. It never attains any great intensity, but presents a singular appearance in the midst of the white train previously eaten out."

291. The common *Marigold* yields an insoluble fæcula, which appears identical with that produced by the wallflower and that of the *Corchorus japonica*, and it is found to be quite as sensitive to Light; but photographs procured upon it cannot be preserved, the colour is so fugitive. The juice of the *Mimulus Smithii* affords a yellow die, which is similarly affected. " The *Ferrarea undulata*, a dark-brown flower, yields, when expressed, a dull green juice, which, spread on paper and dried, turns very speedily blue, under the influence of the blue and violet rays of the spectrum, owing to the destruction of this yellow principle, which, mingling with the sub-

stratum of blue (itself a much more indestructible tint), gives its natural tinge of green. The brown colour of the French marigold, *Tagetes patula*, passes rapidly in sunshine from brown to green, probably from the destruction of the same yellow principle. And bees' wax, it is well known, is bleached by Light, from the presence of a similar fugitive principle. (*Herschel.*)

(292.) The *Viola odorata* yields to alcohol a rich blue colour, which it imparts in high perfection to paper. Exposed to sunshine it fades pretty rapidly, but a residual blue tint remains, which resists the action of Light for a long time, even for weeks. When carbonate of soda is added to this solution it becomes green, and a slip of paper stained with this fluid, exposed to the spectrum, is changed yellow under the orange and red rays; a slight discoloration is perceived in the indigo-blue rays, but not the slightest alteration under the *green* rays. The colouring matter of the purple iris shows this in a still more marked manner. In these instances the blue constituent of the green is destroyed by the solar rays. (*Herschel.*)

(293.) A variety of *Sparaxis* from the Cape of Good Hope gave to paper a dark olive-green colour, which was nearly insensible to Light. The addition of carbonate of soda changes this colour to a good green, which is tolerably sensitive to solar influence. A photograph impressed on a paper prepared with it is reddened by muriatic acid fumes. If then transferred to an atmosphere of ammonia, and when supersaturated, the excess of alkali allowed to exhale, it is fixed, and of a dark-green colour. (*Herschel.*)

(294.) The Red Poppy.—*Papaver Rhœas* yields a very beautiful red colour, which is entirely destroyed by Light. When perfectly dried on paper the colour becomes blue. This blue colour is speedily discharged by exposure to the sun's rays, and papers prepared with it afford very interesting photograghs. The purple juice of the *Senecio splendens*, the double purple groundsel, imparts a beautiful colour to paper. It requires, however, an exposure of some weeks to daylight before the original whiteness is restored, which it at length is in the most perfect manner. (*Herschel.*)

(295.) The juices of the leaves of a great number of plants have been examined by the author; and the juices from leaves of the laurel, the vine, the common cabbage, and the grasses, have been found to be sufficiently sensitive, when spread upon paper, to give very good copies of engravings in an hour, provided the atmosphere was clear and the sun bright. The action of the prismatic spectrum upon those I have examined, agrees very nearly with results published by Sir John Herschel, as obtained upon the juice of the elder leaf. The red rays have a decided action, and give a ruddy yellow impression. It appears to me, this change is dependent upon the calorific agency merely, as similar changes are brought about by artificial heat. On the upper edge of the yellow ray, the space between the red and it being unaffected, a very faint image begins to be formed; this action goes on increasing up to the mean blue rays; it then declines, and ceases altogether within the limits of the visible violet ray.

(296.) From an examination of these admirable researches by Sir John Herschel on the colouring matters of plants, it will be seen that the action of the sun's rays is to destroy the colour, effecting "a sort of chromatic analysis, in which two distinct elements of colour are separated, by destroying the one and leaving the other outstanding." The action is confined within the visible spectrum, and thus a broad distinction is exhibited between the action of the sun's rays on vegetable juices and on argentine compounds, the latter being most sensibly affected by the "invisible rays" beyond the violet.

(297.) "It may also be observed, that the rays effective in destroying a given tint are in a great many cases, those whose union produces a colour complementary to the tint destroyed, or, at least, one belonging to that class of colours to which such complementary tint may be referred. For example, yellows tending towards orange are destroyed with more energy by the blue rays; blues by the red, orange, and yellow rays; purples and pinks by yellow and green rays."

(298.) I may here mention, that some very remarkable changes take place in the colours of many vegetable powders, in which we might least expect such alterations to occur. Experience has shown to the pharmacopolist the necessity of preserving the powdered leaves of the foxglove, the hemlock, the henbane, the aconite, and other green vegetable powders, of active medicinal powers, in the dark. It is found that these powders do not merely lose colour, passing slowly from a green into a slaty grey, and ultimately into a dirty yellow, but they undergo some decomposition, by which, at the same time, they lose much of their medicinal activity, and indeed after a season they become nearly inert.

Few pharmaceutical articles suffer more in this respect than the powder of the jalap root; the ipecacuanha also loses much of its emetic power by exposure to Light. This is entirely independent of any action of the air or moisture. I have observed these deteriorating influences on those powders, which have been kept in the most carefully closed bottles.

The powders of Cascarilla bark, of the Valerian root, and some others, particularly some of the varieties of rhubarb and the ginger root, are found to adhere with considerable firmness to the sides of the bottles next the Light, whereas the sides in shadow are left clear. I have also observed that a deposit will take in a similar manner on the sides of bottles containing some of the vegetable tinctures. This of course depends upon the same function which occasions camphor to be deposited in crystals upon the side of the glass next the Light, and maintains them there; whereas if that side is turned from the Light, the crystals will be gradually removed and again deposited on those parts upon which the rays of Light first impinge. These phenomena must have been long and often observed, yet we have not any satisfactory explanation of them. It does, however, appear, that we are advancing gradually towards the elucidation of these and many other matters, which have often excited the wonder of observers without leading to any particular inquiry.

(299.) In bringing the first part of these researches to a conclusion, I cannot resist the temptation of calling attention to the great number of instances now adduced, in which we have distinct evidence of *chemical change* under the influence of the sun's rays. Those already mentioned appear quite sufficient to support me in the position I have long maintained, that the solar rays are continually acting upon matter—it signifies little in what form it may be presented to its influence. Although for photographic purposes we can only select those compounds which exist in a state of "tottering equilibrium," at least in the present state of our knowledge, yet we have distinct evidence, that a sunbeam cannot fall upon any solid body, without leaving permanent traces of its action. In the second part, these phenomena will be still further examined.

PART II.

THE INFLUENCE OF THE SOLAR RAYS UPON VITAL ORGANISATION, AND UPON SIMPLE INORGANIC BODIES.

SECTION I.

ON THE VEGETABLE KINGDOM.

CHAPTER I.

THE GERMINATION OF SEEDS, AND THE GROWTH OF PLANTS.

(300.) The surface of our earth is rendered beautiful, by the almost countless forms of vegetable life which adorn it. On the bare surface of the wind-beaten rock, the mysterious lichen finds a sufficient amount of those elements which assimilate and form its structure, to support it through all the stages of its growth; and at length, having lived its season, it perishes, and in its decay forms a soil for the germination of plants, which stand a little higher in the scale of vegetable life. These again have their periods of growth, of maturity, and of dissolution; and their disintegrated portions become the habitat of others, which pass through the same changes, until at length the once naked rock is covered with a garden, and the flowering shrub and the enduring tree wave in loveliness above it.

(301.) In a short time we find the almost microscopic seed, placed in a few grains of earth, springing into life, developing its branches, unfolding its leaves, and producing flowers and fruit ; and although it has become a stately plant, we shall not discover much diminution of the soil from which it grew, and from which it would at first appear it derived all those solid matters of which its structure is composed. Experiments have been made in the most satisfactory manner, and it has been proved, that a very small amount only, of the soluble constituents of a soil are taken up by the roots of a plant; we have then to look to other sources for the origin of the woody matter, of the acid and saccharine juices, of the gums and of the resins, yielded by the vegetable world. These are all, it will be found, formed by some mysterious modifications of a few elementary bodies, acted upon by the solar rays ; and these are the phenomena which it is the business of this section to examine.

(302.) The conditions necessary to germination are, moisture, a moderate temperature, and the presence of oxygen gas. The experiments of Ray, Boyle, Scheele, Achard, and Humboldt, all show that the presence of atmospheric air is necessary. Germination cannot take place at the freezing point of water, and at 212° all vitality is destroyed. If seeds are kept quite dry, they will not germinate, although the other conditions are fulfilled. All seeds do not germinate at the same seasons, some requiring a more elevated temperature than others, which fact explains the cause of the different periods at which we find the plants springing from the soil.

(303.) It has already been remarked, that Michellotti proved Light to be injurious to germination, and Ingenhouz and Sennebier found that seeds germinated more rapidly in the shade than in sunshine. This fact has been more recently established, beyond all doubt, by the author.

(304.) My investigations were first published in the Philosophical Magazine for April, 1840, and they have, since that, been continued, grants having been made to the author by the British Association; and a report of the progress of the inquiry will be found in the report of the Association for 1842. It is necessary for a correct understanding of the results obtained, that all the conditions under which the experiments have been made should be distinctly stated.

(305.) Six boxes were so prepared, that air was freely admitted to the plants within them, without permitting the passage of any Light, except that which passed through the coloured glasses with which they were covered.

These glasses permitted the permeation of the rays of Light in the following order: —

1. A Ruby Glass, *coloured with Oxide of Gold.*—This glass permits the permeation of the ordinary red, and the extreme red rays only.

2. A Brown-Red Glass. — The extreme red ray appears shortened; the ordinary red ray, and the orange ray pass freely, above which the spectrum is sharply cut off.

3. Orange Glass.—The spectrum is shortened by the cutting off of the violet, indigo, and a considerable portion of the blue rays. The green ray is nearly absorbed in the yellow, which is considerably elongated. The whole of the least refrangible portion of the spectrum permeates this glass freely.

4. Yellow Glass, *somewhat Opalescent.*—This glass shortens the spectrum by cutting off the extreme red ray, and the whole of the most refrangible rays beyond the blue ray.

5. Cobalt Blue Glass. — The spectrum obtained under this glass is perfect from the extreme limits of

the most refrangible rays down to the yellow, which is wanting. The green ray is diminished, forming merely a well-defined line between the blue and the yellow rays. The orange and red rays are partially interrupted.

6. Deep-Green Glass.—The spectrum is cut off below the orange and above the blue rays. Although the space on which the most luminous portion of the spectrum falls, appears as large as when it is not subjected to the absorptive influence of the glass, there is a great deficiency of Light, and on close examination with a powerful lens, a dark line is seen to occupy the space usually marked by the green ray.

(306.) A case was also prepared, containing five flat vessels filled with different-coloured fluids.

A. Red. *Solution of Carmine in Supersulphate of Ammonia.*—This gives a spectrum nearly in all respects similar to that given by the ruby glass (1.); all the rays above a line drawn through the centre of the space occupied by the orange being cut off.

B. Yellow. *A saturated Solution of Bichromate of Potash.*—This beautifully transparent solution admits the permeation of the red and yellow rays, which are extended over the space occupied by the orange ray in the unabsorbed spectrum. The green rays are scarcely evident.

From the absorptive powers of the sulphurets of lime and potash in solution, I was very desirous of using them, but they were found to be so liable to decomposition when exposed to the sun's rays as to be quite useless for my purposes, sulphuretted hydrogen being liberated in such quantities as to burst the bottles with great violence.

C. Green. *Muriate of Iron and Copper.*—This medium is remarkably transparent; the blue, green, yellow, and orange rays pass freely, all the others being absorbed.

D. Blue. *Cupro-sulphate of Ammonia.* — This fluid obliterates all the rays below the green ray, those above it permeating it freely.

E. White. — This is merely water rendered acid by nitric acid, for the purpose of securing its continued transparency. It should be noted that spaces in the boxes have been left open to the full influence of the Light, that a fair comparison might be made between those plants growing under ordinary circumstances, and the others under the dissevered rays.

(307.) It will be seen from the above, that the following combinations of rays have been obtained to operate with.

1. and A. The calorific rays well-insulated.

2. A smaller portion of these rays mixed with a small amount of those having peculiar illuminating powers.

3. The central portion of the solar spectrum well-defined, and all the rays of least refrangibility, thus combining the luminous and calorific rays.

4. The luminous rays mixed with a small portion of those having a calorific influence.

5. The most refrangible rays with a considerable portion of the least so; thus combining the two extremes of chemical action, and affording a good example of the influence of the calorific blended with the chemical spectrum.

6. Some portion of those rays having much illuminating power, with those in which the chemical influence is the weakest under ordinary circumstances.

B. The luminous rays in a tolerably unmixed state.

C. The luminous rays combined with the least actively chemical ones, as in 6.; but in this case the luminous rays exert their whole influence.

D. The most refrangible or chemical rays well-insulated.

E. White Light.

(308.) From these arrangements it will be evident, that, although we do not secure the complete isolation of the rays, as we should do with a prism, we procure Light in which the great preponderance of one influence over others, suffices to insure, to a certain extent, the decided action of that one. I am well aware that we only arrive at approximations to the truth by the system adopted, but I am also unacquainted with any method by which these experiments could be tried for any time, otherwise than with absorptive media.

(309.) When we look on a spectrum which has been subjected to the influence of some absorptive medium, we must not conclude, from the coloured rays which we *see*, that we have cut off all other influences than those which are supposed to belong to those particular colours. Although a blue glass or fluid may appear to absorb all the rays except the most refrangible ones, which have usually been considered as the least calorific of the solar rays; yet it is certain that some principle has permeated the glass or fluid, which has a very decided and thermic influence, and so with regard to media of other colours.

The relative temperatures indicated by good thermometers placed behind the glasses and fluid cells, which I have used, will place this in a clear light. The following results present a fair average series, and distinctly mark the relative degrees in which these media are permeable by the heating rays:—

GLASSES.

Colour.	Rays not absorbed.	Temperature.
1. Ruby.	Ordinary red, and the extreme red - -	87°
2. Red.	Ordinary red, and orange, portion of extreme red - - - - -	83°
3. Orange.	Little blue, green, yellow, orange, red, and extreme red - - - -	104°
4. Yellow.	Red, orange, green, and blue - -	88°
5. Blue.	Violet, indigo, blue, little green, and some red	94°
6. Green.	Orange, yellow, green, and blue - -	74°

FLUIDS.

A. Red.	Ordinary and extreme red - - -	78°
B. Yellow.	Ordinary red, and yellow - - -	80°
C. Green.	Blue, green, yellow, orange - - -	69°
D. Blue.	Green, blue, indigo, violet, and trace of red	73°
E. White.	All the rays - - - - -	89°

Here we see, that, contrary to what we might have supposed at first, the highest temperature is not obtained behind the red media, but behind those which have a yellow or orange tint. Indeed, a higher temperature is found behind the colourless fluid than any of the others ; and when we consider, that the thermic influence is not confined to the red spaces of spectrum, but that it extends over all the visible rays, and to a great extent below them, we see at once that a larger quantity of radiant caloric must permeate the least coloured media. It will also be shown in a future chapter, that red glasses and fluids absorb a larger quantity of the heat rays than any others except black ones, and consequently indicate a higher temperature themselves, although a lower one is observed behind them.

(310.) With these arrangements it was distinctly proved, that under the influence of the luminous and calorific rays, germination was, in many cases, entirely prevented, and in all, the growth of the young plant was checked, and the development of leaves and buds prevented. The following results have been obtained with carefully selected roots of tulips and ranunculuses.

The first appearance of germination took place with the tulips under the orange glass (3.), which was followed in three days by those under the red glass (2.), then by those under the ruby glass (1.), and next by those under the influence of the yellow (4.), blue (5.), and green glasses (6.). The roots under the orange glass developed the cotyledons a week earlier than those under the yellow, blue, and green glasses. But that the ranunculuses observed the same relative order in germinating, I should have suspected that some peculiarity in the bulbs had influenced the result, although these had been selected with the most scrupulous care. At first the greatest progress was made by the tulips under the yellow (4.) and orange glasses (3.); but the leaves under each of these were by no means healthy, particularly under the yellow glass (4.), which had a singularly delicate appearance, being of a very light green, and covered with a most delicate white bloom.

(311.) The leaf-stalks of the tulips shot up remarkably long, and were in both cases white; at length an exceedingly small flower-bud appeared on the plant under the orange glass (3.), which perished almost as soon as it appeared, and the death of the plant immediately followed. The tulips under the yellow glass (4.) never showed any buds, and their vitality soon failed them. The condition of the ranunculuses was in most respects similar to that of the tulips; they exhibited the same exuberant length of stalk, but the leaves were of a more healthful appearance. These plants, however, never showed any flower-buds, and they died nearly about the same time with the tulips.

(312.) It may be proper to mention that the garden-pots in which these roots were planted, were filled with a mixture of fine earth, sand, and well-rotted manure from a hot-bed. A few days after their exposure, those under the orange and yellow glasses threw up several fungi, and continued for some days to do so, which was not the case with any of the others.

(313.) Under the ruby (1.) and red glasses (2.), the tulips shot up a *single lobe*, which maintained a little life for three or four weeks, but never rose more than two inches above the soil. There was a marked redness upon this stunted formation, which I often fancied was in some respects characteristic of the kind of medium under which they were placed. The tuberous roots perished in the soil; sufficient moisture and warmth had called into action the latent principle of germination, but being unable to maintain it against the destructive influence of the Light, they rotted.

Beneath the green glass (6.) the plants all of them grew slowly, but tolerably strong. They were, however, marked by a more extraordinary length of stem than those before mentioned; some of the stems of the ranunculuses being above ten inches in length, having a small leaf at the end not more than two thirds of an inch in diameter. These plants all showed flower-buds, but none of them could be made to flower, notwithstanding the greatest care and attention was bestowed upon them; the effort of throwing up the buds appeared to exhaust their powers, and the whole of these plants soon died.

The results under the blue glass (5.) were very different; the roots germinated, I think, a little less quickly than they did in the open ground, forming compact and healthy plants, developing their flower-buds strongly, and flowering in perfection.

(314.) Numerous experiments have been tried with the seeds of mignionette, many varieties of the flowering pea, the common parsley, and cresses; with all of them the results have been similar to those already described. The seeds have germinated, in general, the most rapidly under the red glass (2.), in the spring of the year, but when the heat of summer has advanced, the temperature of the red Light has been too great, and germination has been prevented. Except under the blue glass, these plants have all been marked by the extraordinary length to which the stems of the cotyledons have grown, and by the *entire absence of the plumula*. No true leaves forming, the cotyledons soon perish, and the plant dies. Under the green glass (6.) the process of germination has been exceedingly slow, and the plants, particularly the cresses and mignionette, have speedily died.

Under the blue glass (5.) alone has the process gone on healthfully to the end; and although I have found a few instances of a perfect plant under the yellow glass (4.), it has not on any occasion yet endured to the formation of a flower; excepting the plants under the yellow and blue glasses (4. and 5.), all have been more or less etiolated.

(315.) The results, in those cases where fluid media have been used, from the more perfect isolation of the rays which have been thus obtained, have been much more decided. Under the influence of the Light which has been subjected to the absorptive powers of the yellow fluid (B.), *germination has been entirely prevented*. Under the red fluid (A.), in some cases, germination has commenced, but the young plant has speedily perished. Under the green (C.), the plant has been developed, but in a very weak state, with pale leaves and nearly colourless stalks; but under the in fluence of the blue (D.), the most perfect plants have been produced, and through all their stages maintained in the most luxuriant state. These experiments sufficiently prove, that the process of germination is obstructed by the influence of LIGHT on the surface of the soil, although the bulbs and seeds have been buried some depth beneath it. The effects of HEAT, as exhibited by the red rays, are not, I think, to be regarded as destructive in themselves, as plants have been found to grow under the influence of these rays when they have been supplied with an extraordinary quantity of water, to supply that drawn off by continued evaporation; whereas, although the evaporation, which has been equally rapid under the yellow media, has been met in the same manner as under the red, it has produced no beneficial results.

(316.) One very remarkable result must be noticed. Under all ordinary circumstances plants bend in a very decided manner *towards the Light.* In all my experiments with red fluid media *they have as decidedly bent from it.* I do not know how to explain this as the effect of mere heat; it would appear that some property resides in the red rays which acts in opposition to the general law. Further investigations are required on this point.

(317.) It has been stated by Dr. Draper that he has found, under the influence of the bright sun of Virginia, that plants have grown well in Light which has been made to permeate a considerable thickness of an intense yellow solution. I am not certain if the germination of seeds has been effected under the same circumstances; but even if they have been made to germinate, it admits of explanation. The fervent rays of southern climes would permeate media, by which the subdued rays of our latitudes would be obstructed. In proof of this I may remark that, during the height of the splendid summer of 1842, I was myself successful in procuring the germination of a few seeds in the box (B.), or under the influence of the yellow Light. At the same time some very remarkable photographic results were obtained, which distinctly proved the atmosphere to have been in such a condition, that a larger quantity of the sun's rays were enabled to penetrate it and reach the earth. It was also observed that the foliage of all trees was of a much darker green, and that many flowers, particularly those of a pink or pale red colour, generally assumed a particular and decided blue or lilac tint.

(318.) The soil in which the plants grew, was the same in each of the boxes used, but it was several times observed that, under the yellow glasses and fluids, fungi made their appearance. From the occurrence of these vegetables under the same circumstances on several occasions, I was naturally led to observe their production with greater care. I could not, with the utmost attention, make the *Agaricus muscarius* grow behind any other absorbent media than the yellow, under which it grew luxuriantly. This appears, in some measure, to explain the popular notion, that mushrooms and plants of that variety, grow most abundantly under the influence of bright moonlight. It has never yet been found that any heat comes with the rays of the moon, and the amount of chemical action which has been detected is exceedingly small ; we must therefore regard the moonbeams as consisting almost entirely of the luminous rays, the other active rays being in all probability absorbed by the moon's surface.

(319.) It is not at present in our power to explain, in any thing like a satisfactory manner, the way in which the luminous rays act in preventing germination. The changes which take place in the seed during the process have been investigated by Saussure : oxygen gas is consumed, and carbonic acid is evolved; and the volume of the latter is exactly equal to the volume of the former. The grain weighs less after germination than it did before ; the loss of weight varying from one third to one fifth. This loss of course depends on the combination of its carbon with the oxygen absorbed, which is evolved as carbonic acid. According to Proust, malted and unmalted barley differs in the following respects:—

	Unmalted.	Malted.
Resin	1	1
Gum	4	15
Sugar	5	15
Gluten	3	1
Starch	32	56
Hordein	55	12

This shows that the insoluble principle hordein is, in the process of germination, converted into the soluble and nutritive principles starch, gum, and sugar. We are therefore at present left in considerable doubt; we can only suppose that the luminous solar rays act, as indeed we find them to do on many of the argentine preparations, in preventing those chemical changes which depend upon the absorption of oxygen. A like interference has been observed by Sir John Herschel to be exerted by the extreme red rays of the spectrum; and, from the manner in which germination is impeded in the seeds covered by a deep red media (58.), we may trace a somewhat similar influence.

(320.) I have endeavoured, but as yet without being successful, to ascertain the real use of the cotyledon. Mrs. Ibbetson attempts to show that it is of no use for the purpose of nourishment, but that its office is merely to screen the first leaves from Light and air. I am rather inclined to regard them as the lungs or gills of the young plant, in which, under the influence of the solar rays, the decomposition of air and water is effected. I shall not, however, in the present stage of the inquiry, venture on any further speculations on this matter.

CHAP. II.

THE AERATION OF PLANTS.

(321.) For the discovery that oxygen gas is exhaled from the leaves of plants during the day-time, we are indebted to Dr. Priestley; and Sennebier first pointed out that carbonic acid is required for the disengagement of the oxygen in this process. M. Théodore de Saussure and De Candolle fully established this fact.

(322.) The following experiments, which are but modifications of those of De Candolle, will place the matter in the clearest light:—A bell glass was filled with distilled water and inverted in a plate of oil; fresh gathered leaves and young sprigs were previously placed in the water; another similar glass was filled with water strongly impregnated with carbonic acid gas, in which the same kinds of leaves, &c. were placed, and this was likewise inverted in oil; a sprig of mint was placed in a bottle filled with carbonic acid, a bent tube was inserted through the cork, and this tube carried into a vessel also filled with carbonic acid; the bottle was inverted in a vessel filled with mercury. These arrangements were exposed to bright sunshine. In the glass filled with distilled water no oxygen gas was discovered; but in the other, pure oxygen gas was speedily set free; and in the bottle containing carbonic acid, which was exposed for many days, under the most favourable circumstances, a considerable quantity was collected. Now it is very evident that the oxygen must have been produced by the decomposition of the carbonic acid, effected by the leaves, under the influence of the solar beam.

(323.) The woody fibre of plants, and all the carbon which is found as an elementary constituent of the resins, gums, juices &c., of the vegetable world, is derived exclusively from the atmosphere, to which it is supplied by the respiration of animals, and all those processes of combustion which are continually going on.

(324.) By some peculiar function, the leaves of plants during every moment of their lives are absorbing carbonic acid. It has been stated that the reverse of this takes place during the hours of darkness, and that at night the leaves absorb oxygen, and exhale carbonic acid. It appears to me that this statement has been made without sufficient consideration, or the requisite experimental evidence. "This reversal at night," says a most talented philosopher, "of what was done in the day, may, at first sight, appear at variance with the unity of plan which we should expect to find preserved in the vegetable economy; but a more attentive examination of the process will show that the whole is in perfect harmony, and that these contrary processes are both of them necessary in order to produce the result intended." He then, evidently feeling the difficulty of the question, proceeds to explain this harmony as follows. "The water which is absorbed by the roots, generally carries with it a certain quantity of soluble animal or vegetable materials, which contain carbon. This carbon is transmitted to the leaves, where, during the night, it is made to combine with the oxygen they absorb. It is thus converted into carbonic acid, which when daylight prevails is decomposed; the oxygen being dissipated, and the carbon retained. It is evident that the object of the whole process is to obtain carbon in that precise state of disintegration, to which it is reduced at the moment of its separation from carbonic acid, by the action of solar light on the green substance of the leaves; for it is in this state alone that it is available in promoting the nourishment of plants, and not in the crude condition in which it exists when it is pumped up from the earth, along with the water which conveys it into the interior of the plant. Hence the necessity of its having to undergo this double operation of first combining with oxygen, and then being precipitated from its combination in the manner above described." These passages are selected, not with any view of reflecting upon their accomplished author, but because they afford the best expression of the views which have been generally entertained on the strength of the experiments of Saussure and Grischow, which admit of another explanation.

(325.) It is only the green parts of plants which absorb carbonic acid; the flowers absorb oxygen gas. Plants grow in soils composed of divers materials, and they derive from these, by the soluble powers of water which is taken up by the roots, and by mechanical forces carried over every part, carbonic acid, carbonates, and *organic matters containing carbon* (?). Evaporation is continually going on, and this water escapes freely from the leaves during the night, when the functions of the vegetable, like those of the animal world, are at rest, and carries with it carbonic acid. "A cotton wick," says another experimental philosopher, "inclosed in a lamp which contains a liquid saturated with carbonic acid, acts exactly in the same manner as a living plant in the night. Water and carbonic acid are sucked up by capillary attraction, and both evaporate from the exterior part of the wick." And this is the true exposition of the matter.

(326.) A plant placed in a vessel containing water impregnated with carbonic acid, and carefully closed, so that no water could escape by evaporation except through the plant, was placed under the receiver of an air-pump in which was put some pure potash, and a good exhaustion effected. The potash was found to have absorbed carbonic acid. The same arrangement was made, only that the water now used was *distilled*. Under the same circumstances in every respect, a like quantity of moisture was found to be absorbed by the caustic potash, but of course no carbonic acid.

(327.) Precisely similar arrangements were placed under bell glasses filled with atmospheric air, which was dried and freed from carbonic acid, by exposure to potash for some time. In neither case could any diminution of the quantity of oxygen be detected, but carbonic acid was found in the air in which the plant in the carbonated water was placed, but not a trace in that which surrounded the plant in distilled water. I need not say that these experiments were made in the dark.

(328.) There is no reversion of the processes which are necessary to support the life of a plant; the same functions are operating in the same way by day and by night, but differing greatly in degree. During the hours of sunshine, the whole of the carbonic acid absorbed by the leaves, or taken up with water by the roots, is decomposed, all the functions of the plant are excited, the processes of inhalation and of exhalation are quickened, and the plant pours out to the atmosphere streams of pure oxygen, at the same time as it removes a large quantity of deleterious carbonic acid from it. In the shade, the exciting power being lessened, these operations are slower, and in the dark they are very nearly, but certainly not quite, suspended.

(329.) The experiments of Sennebier show that the most refrangible of the solar rays are the most active in determining the decomposition of carbonic acid by plants. The views of this philosopher have been generally adopted. A few years since, however, Dr. Daubeny published in the Transactions of the Royal Society the results of some experiments which appeared to show that to the luminous or yellow rays, and not to the violet, must this influence be referred; and more recently, at the meeting of the British Association at Cork, Dr. Draper communicated a paper, in which he states that, having tried the effects of the solar spectrum upon tubes filled with water saturated with carbonic acid, and in which leaves were placed, he found that the greatest quantity of gas was set free from the fluid placed in the yellow ray, thus apparently confirming the statement of Dr. Daubeny.

(330.) Since this announcement, the very gloomy and uncertain state of the weather, has almost entirely prevented my testing the correctness, or otherwise, of Dr. Draper's results. During a few faint gleams of sunshine I have repeated the experiments in Draper's own method, and I have found that *bubbles of air* have been liberated in the tubes under the influence of the yellow and red rays, but they have been *carbonic acid.* In the tubes which were placed in the blue and violet rays alone, a perfect decomposition had taken place, and the bubbles which were collected were *pure oxygen gas.*

(331.) Experiments have been made with absorbent media, the Light which has been carefully analysed, permeating under the influence of the blue Light: in every instance oxygen gas has been collected, but not any under the energetic action of yellow and red Light.

(332.) However, from the first development of leaves, until the perfect maturity of the plant, these processes which we have been considering are continually carried on; and not these only, for it is evident that the same agent is active in producing the decomposition of water, and I also believe of ammonia, from which the plant derives the hydrogen and the nitrogen it requires for the formation of its several principles.

(333.) We have now certain knowledge. We know that all the carbon which forms the masses of the magnificent trees of the forests, and of the herbs of the fields, has been supplied from the atmosphere, to which it has been given by the functions of animal life, and the necessities of animal existence. Man and the whole of the animal kingdom require, and take from the atmosphere, its oxygen for their support. It is this which maintains the spark of life, and the product of this combustion is carbonic acid, which is thrown off as the waste material, and which deteriorates the air. The vegetable kingdom, however, drinks this noxious air; it appropriates one of the elements of this gas — carbon — and the other — oxygen — is liberated again to perform its services to the animal world. It is not possible to conceive a more perfect, a more beautiful system of harmonious arrangement than this, making the animal and the vegetable kingdoms mutually dependent. The existence of the one ceases when the other is destroyed. If the vegetable world was swept away, animal life would soon become extinct; and if all animal existence was brought to a close, the forest would fall, and the flowers of the field, which now clothe the earth with gladness, perish in the utterness of a lamentable decay. It has been supposed that the vegetable world was called into existence long previous to the creation of animals, and to this period is referred the formation of the coal strata. There might have been an epoch when the disturbed condition of the earth — its earthquake shocks, and volcanic strugglings, may have poured so large a quantity of carbonic acid into the atmosphere, as to have rendered this planet unfit for the habitation of animals, until a teeming and most gigantic vegetation, by exhausting it for their own supply, purified the air, and rendered the more quiet earth a fitting abode for creatures endowed with reason and with instinct. But such events do not appear again likely to occur, and it is not within the range of probabilities that the animal or vegetable kingdoms will ever have an independent existence.

(334.) The animal kingdom is constantly producing carbonic acid, water in the state of vapour, nitrogen, and, in combination with hydrogen, ammonia. The vegetable kingdom continually consumes ammonia, nitrogen, water, and carbonic acid. The one is constantly pouring into the air what the other is as constantly drawing from it, and thus is the equilibrium of the elements maintained.

(335.) Plants may be regarded as compounds of carbon vapour, oxygen, hydrogen, and nitrogen gases, consolidated by the all-powerful, all-pervading influences of the solar ray; and all these elements are the produce of the living animal, the conditions of whose existence is also greatly under the influence of those beams, which are poured in unceasing flow from the centre of our system. Can any thing more completely display a system of the loftiest design, and most perfect order, than these phenomena?

(336.) The most casual observer could not fail to remark the peculiar influences of the solar agencies, at different seasons of the year. In spring, a fresh and lively green pervades the field and forest; this in summer assumes a darker hue, and in the autumn passes gradually into a russet brown. In a very early stage of my photographic researches, I discovered a remarkable difference in the chemical action exerted by the solar rays an hour or two before noon, or an hour or two after it. I am now convinced, although it will require continued observations for many years to prove it, that the same difference is to be detected between the solar emanations of the vernal and the autumnal periods. The change in the colour of the leaves appears to be entirely dependent upon the absorption of oxygen, which all the green parts of plants have the power of absorbing, particularly in the dark. This true case of chemical affinity, it would appear, goes on equally with the spring or the summer leaves; but during these periods the vital force, under the stimulus of the Light, is exerted in producing the assimilation of the oxygen for the formation of the volatile oils, the resins, and the acids. In the autumn this exciting power is weakened; the summer sun has brought the plant to a certain state, and it has no longer the vital energy necessary for continuing these processes. Consequently, the oxygen now acts in the same manner on the living plant, as we find in experiment it acts upon the dried green leaves, when moistened and exposed to its action. They absorb gas and change colour.

(337.) Sir John Herschel observes, in reference to the action of Light on the juices of plants: "The earlier flowers of any given species reared in the open air, are more sensitive than those produced, even from the same plant, at a late period in its flowering, and have their colours more completely discharged by Light. As the end of the flowering period comes on, not only the destruction of the colour by Light is slower, but residual tints are left which resist obstinately." These residual tints are the same which produce the brown of the autumnal leaf; and the same agent may be traced in the production of photographs upon papers spread with expressed juices, and on the changing colours of flowers and of leaves.

(338.) A remarkable example of the influence of Light upon the juice of plants, is the Cacalia ficoides, cited by Liebig. During the hours of darkness, this plant, like others, absorbs oxygen, and in the morning it is as acid to the taste as the sorrel. By the influence of the morning sun it loses this oxygen, and at noon it is tasteless, and by the continued action of the Light still more is abstracted, and the plant is positively bitter in the evening.

(339.) Experiments have been instituted with a view of ascertaining, if any particular ray of the spectrum had the power of inducing, more powerfully than others, the progress of plants towards the Light, a phenomenon which is strikingly exhibited by the potato. It would appear that the yellow or pure luminous rays exert this influence with the greatest force; but it must be admitted that the results obtained have not been so satisfactory as could be desired. Indeed, no correct conclusion can be arrived at, until the experiments are tried with the isolated rays of the prismatic spectrum themselves. I am every day more and more convinced of the defects of absorbent media in these and similar researches.

SECTION II.

ON THE ACTION OF LIGHT ON INORGANIC BODIES.

CHAPTER I.

ON PHOSPHORESCENCE.

(340.) We have thus far been considering Light as an emanation from the sun: how far this view is borne out by the facts discovered remains to be decided. There are circumstances which might lead us to consider Light as an essence independent, and universally diffused, and amongst these the most striking are the phenomena of phosphorescence. It has already been stated that Benvenuto Cellini observed it in gems; and a considerable degree of attention was bestowed upon phosphori by the Honourable Robert Boyle. Many minerals have the property of emitting Light when rubbed or broken, and Sir David Brewster has observed the phenomena in upwards of fifty minerals, when they are exposed to a heat below redness in the dark. From these facts we might argue that this *essence* was capable of existing in an invisible state for any period of time; and that it would, when properly excited, produce the effect of Light.* The eminent authority just now quoted has stated, that the phosphoric Light of minerals has the same properties as the direct Light of the

* Edinburgh Phil. Journal, vol. i.

sun. This statement must, however, be received with some consideration, if Sir David Brewster means the undecomposed sun-beam. We have no satisfactory evidence which shows that any heat ever accompanies phosphorescent Light, and we have never discovered that it is capable of producing any chemical change. By the prism we detect the same number of colours in a phosphorescent beam as in the sun's rays; and this is all, I presume, that this talented philosopher intended to imply.

(341.) Many bodies exposed to the solar rays give out Light when examined in the dark: this is particularly the case with some flowers, as the Nasturtium; and if the human hand is held in the sunshine for half an hour, it will emit Light for some minutes in the dark. The bodies, however, which exhibit this peculiarity in the most remarkable manner, are the Bolognian stone, a sulphuret of barium; and Canton's phosphorus, which is prepared by calcining oyster shells and sulphur together. If these substances are exposed to the solar rays, they acquire the property of shining in the dark so strongly, as to enable the observer to distinguish the printed letters on the white page of a book. There are some other substances which exhibit these phenomena: Homberg's phosphorus — the melted chloride of calcium — Baldwin's phosphorus — melted nitrate of lime — the sulphuret of strontian, &c.

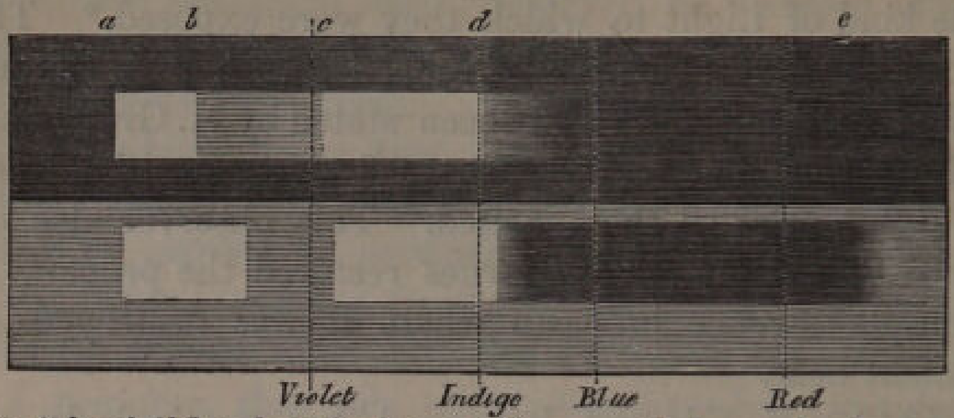
(342.) Some of the elder natural philosophers particularly examined the solar phosphori, especially Beccaria, who stated that the violet ray was the most energetic, and the red ray the least so, in exciting phosphorescence in these bodies.

Dessaignes has remarked that the solar-phosphori emit the same kind of light, whatever may have been the kind of Light to which they were exposed.* This is not, however, very easily reconciled with M. E. Becquerel's experiments. It has been stated by M. Grotthouss, that in some diamonds the most efficacious exciting Light is different from that excited. This observer also noticed that electrical discharges restored the property of phosphorescence in cases where it was destroyed by violent heat.

(343.) M. Edmond Becquerel has particularly examined the action of the spectrum upon the solar phosphori. The result of his inquiries has been, the determination with considerable exactness of the spaces occupied by the rays which impart phosphorescence. He states, that the sulphuret of calcium is rendered phosphorescent by the rays which extend from the indigo to a little beyond the violet; and that two points of maximum intensity are to be detected; one within the visible violet rays, and the other beyond it. The sulphuret of barium exhibits the action of the same rays, but shows only one maximum point, which is situated beyond the violet. M. E. Becquerel has also observed, that the rays below the indigo unto the red, or a little beyond it, have the power of destroying the phosphorescence which the more refrangible rays have excited. Those exciting rays, this observer is inclined to think, have a definite action, and hence he would distinguish them as the "Phosphorogenic Spectrum."

(344.) Many of the experiments of E. Bequerel are instructive. Paper being covered with gum Arabic is dusted over with the sulphuret of calcium, and exposed to the action of the spectrum. Upon examining the paper in the dark, two luminous bands are visible, *a*, *b*, *c*, *d*: these spaces correspond with the violet rays, and

* Mem. Inst., tome xi.



the "invisible chemical rays" so called; a dark space exists between these bands, which mark the region occupied by the extreme violet rays, and the lavender rays of Sir John Herschel. If this action is allowed to continue during a certain time, a quarter of an hour for instance, the diffused Light impresses the remainder of the surface over nearly all parts, so that on examining the paper in the dark, almost the whole surface appears luminous, the parts *a*, *b*, *c*, *d* being the brightest, but the space from the least refrangible violet to the lowest edge of the red rays is completely dark. The upper part of the above wood-cut shows the effect produced. It would appear from this, that the rays of less refrangibility than the indigo have the power of preventing phosphorescence, which exactly accords with Beccaria's statement.

(345.) If, before exposing the phosphorescent surface to the action of the spectrum, it is exposed for a few seconds to the solar rays, or diffused Light, it becomes luminous in all its parts. If now we project a spectrum upon it for a few minutes, and then examine it in the dark, it will be found that every part remains luminous except the part *d*, *e*, which has become dark. If the temperature of the surface is raised by a spirit lamp, all the parts previously luminous become vividly phosphorescent, whilst this part remains completely dark.

(346.) By the aid of coloured glass screens, this is rendered very evident. If a piece of paper prepared with sulphuret of calcium is exposed to daylight, it becomes luminous. By placing immediately on this surface a card which partially covers it, and then a red glass permeable only to the red and orange-coloured luminous rays, and the chemical rays which accompany them, and exposing this arrangement to the sun for a minute, it will be found, on examining the paper in the dark, that the part which has been acted upon by the rays has entirely lost its phosphorescence, whilst every other part is still luminous. The same effect takes place if sulphuret of barium (Bologna phosphorus) is used.

(347.) These experiments distinctly prove that the obscure rays of the spectrum produce phosphorescent Light, which Light is destroyed by the most luminous and the calorific rays; a fact which was previously noticed by Seebeck.*

(348.) M. Biot and the elder Becquerel have proved that the slightest electrical disturbance is sufficient to produce these phosphorescent effects. May we not, therefore, regard the action of the most refrangible rays as analogous to that of the electric disturbance? May not electricity itself be but a development of this mysterious solar emanation?

(349.) A great many animals in the living state emit Light of the character which we have been considering: — the *pholas*, the *medusa phosphorea*, and many other *molluscæ;* the *lampyris* or glow-worm, the *fulgora*, the *scholopendra electrica*, the *cancer fulgens*, and a variety of the *annelids* found in the bogs of Ireland, may be adduced as examples. Nearly all fish in a state of decomposition emit this kind of Light; and

* See Goethe's Optics.

the flesh of most quadrupeds in the progress of putrefaction. Rotten wood, it is well known, also evolves a considerable quantity of Light in the dark. The dependence, or otherwise, of these phenomena upon solar influence, remains to be proved. In the Philosophical Transactions for 1790, Dr. Hulme published a very excellent Treatise on Phosphorescence, to which I must refer those who are desirous of obtaining further information on this part of the subject. I cannot refrain from suggesting the importance of experiments to determine if any class of the prismatic rays have the power of exciting or destroying the phosphorescence in living animals. It would appear from the experiments of Becquerel, that the luminous and calorific rays should possess that power. That artificial heat interferes with the phenomena in organised bodies is very certain. The whole question, however, is one of great difficulty, but it is an inquiry which is calculated to clear up much of the doubt which exists at present as to the theories of the emission of luminous particles, and the excitement of an all-pervading luminiferous ether.

CHAP. II.

INFLUENCE OF THE SOLAR RAYS ON CHEMICAL COMBINATION.

(350.) Already, in the first part of this work, a great number of examples, which show the influence of the sun's rays upon combination, have been brought forward: a few instances of a remarkable kind remain to be noticed. If we take the saturated solution of any salt, and expose it, so that one portion may be under the influence of the solar rays, whilst the other is preserved in darkness, it will be found that crystallisation commences sooner, and proceeds more rapidly under the influence of the Light, than it does in darkness.

(351.) Vogel observed, that if chlorine was passed into alcohol nearly saturated with that gas, and at the same time exposed to the sunshine, each bubble of chlorine, as it entered the spirit, exploded, giving a bright purple flame and a white vapour. This experiment I have many times repeated, and I have found that the effect depends entirely upon the agency of the blue rays. The interposition of an orange glass, or a yellow fluid, is quite sufficient to stop this energetic chemical combination.

(352.) It has long been known to chemists, that a mixture of chlorine and hydrogen gases might be preserved in darkness, without combining for some time; but that exposure to diffused daylight gradually occasioned their combination, whilst the direct solar rays produced the sudden inflammation of the mixture. This combination has been investigated by Gay Lussac, and Thenard, and also by Davy. Sir Humphry Davy found that a mixture of chlorine and hydrogen acted more rapidly upon each other, combining without explosion when exposed to the red rays, than when placed in the violet rays. But he found that a solution of chlorine in water, became a solution of muriatic acid most rapidly, when placed in the most refrangible rays.

(353.) My own experiments appear to show that the combination of these gases may be effected in every part of the prismatic spectrum, but that it is entirely independent of the luminous rays. I have kept chlorine and hydrogen without uniting, behind a yellow medium, for as long a period as I have been able to preserve the mixture in the weakest diffused daylight. It does not, however, appear to be quite independent of calorific influence; for I find that the combination is speedily effected under the influence of the dark rays of heat.

(354.) We have evidence to show that the chemical agent, whatever it may be, which accompanies Light, is diffused over every part of the prismatic spectrum, although its action is modified by the luminous and calorific influences. Now, as it is proved that a very small amount of "force" will occasion the chemical combination of these gases, we can well understand that the whole of the rays possess that power, although in different degrees. Dr. Draper has shown that the Light of a taper produces a decided effect upon the mixed gases, and also that the Light emitted during the rapid passage of the electric spark, acts powerfully upon them. "For speed of action no *tithonographic** compound can approach it; a Light which perhaps does not endure the millionth part of a second, affects it energetically." In the red ray the chemical influence is pretty active, and this, combined with the thermic power of that ray, easily accounts for the phenomenon observed by Davy. I have found, however, that the combination is effected with the greatest speed by the extreme blue and the indigo rays. Dr. Draper has fixed the maximum in the indigo rays, and giving a numerical value to the forces exerted by the different rays, he calls the maximum power of the

Indigo ray - - -	240·00
Blue ray - - - -	144·00
Violet ray - - - -	121·00
Green ray - - - -	54·00

* Tithonicity is a name given by Dr. Draper to the chemical rays; but which is, it appears to me, badly chosen; and certainly not at all in accordance with the Lavoiserian principle of nomenclature, which teaches, that the *word* should give birth to the *idea*, the idea depict the *fact*.

Extra spectral rays - - -	12·00
Yellow ray - - -	2·75
Orange ray - - -	·75
Red ray - - - -	·50 ?

The red ray should have a much higher power than is here stated; I have found it quite equal to the green ray, and, I think, superior to it in effect. I should remark that, by using glass tubes of small bore, I secure the combination of the gases without any explosion.

(355.) Taking advantage of the action of the sun's rays upon these gases, Dr. Draper has devised an instrument for measuring the chemical force exerted by Light. This instrument consists essentially of a mixture of equal volumes of chlorine and hydrogen, which is evolved from, and confined over muriatic acid, in a graduated bent tube. The gases are liberated from the liquid acid by the agency of galvanic electricity. Platina wires, which can be connected with a voltaic battery, are inserted into the tube in such a manner, that when the required quantity of the gases is formed, the decomposition ceases, owing to the fluid having fallen below the wires. The gases combine in a longer or shorter time, according to the amount of Light; the number of degrees over which the fluid falls in the graduated arm in a minute giving relatively the force in action. This instrument is certainly a very ingenious application. But it appears to me, there are so many causes which will operate to produce a very irregular action, that the results obtained by such an instrument can only be received as approximations to the truth, and indeed not that, unless the average of a great many carefully conducted experiments be taken in every case.

(356.) The formation by the sun's rays of precipitates from the solution of platina neutralised by lime (181.), from the combination of the bichromate of potash, and sulphate of copper (235.), have already been mentioned.

(357.) In addition to these I would state, that a mixture of the hydriodate of potash and the ferro-prussiate of potash will remain, without any change taking place, for a long time, in the dark; but in the sun's rays, an hour or two is quite sufficient to occasion a precipitation of Prussian blue, and the liberation of hydrocyanic acid.

As far as my own observations have gone, I find that in all cases where precipitation does not take place immediately upon mixing two solutions, there is a very marked difference in the time required for precipitation to take place in a fluid kept in the dark, and one exposed even to diffused daylight, this being, of course, more strikingly shown if one fluid is placed in the sunshine. I would refer to a former paragraph (99.) for some interesting experiments illustrating this part of the subject.

(358.) Chlorine, iodine, and bromine, it is well known, act with considerable energy upon metallic bodies. If, however, any polished metal is exposed to the action of them in a diluted state, the combination is, at first, exceedingly weak, and the films that are formed by either of these three elementary bodies, upon any metal, undergo considerable change under the influence of the sun. In most cases it appears that these bodies are set free, and the metal left in a state of very fine division or oxidisation. Copper, tin, iron, zinc, lead, pewter, bismuth, and several other metals have afforded the same results. It is still more remarkable, that films of bromine or iodine on glass are found, under the action of the sun, to act in a similar manner; and in 1841 I published an account of the power of iodine in rendering wood capable of receiving photographic images.

(359.) M. Edmond Becquerel, in 1839, first called attention to the electricity developed, during the chemical action excited by solar agency. He provided a blackened box divided by a diaphragm into two cells; in each cell he placed the fluid to be examined, and plates of platina or gold were dipped in each, and connected with a galvanometer. The cells being filled with acidulated water, and platina plates in each cell, it was found that when the red, orange, yellow, or green rays fell upon the fluids, no action was excited. The blue and indigo induced a feeble action, but a very decided deflection of the galvanometer was produced by the impact of the violet rays. In 1840, I repeated the experiments of Becquerel, with many modifications, using tubes bent into the form of U; or floating one photometric fluid upon another. The results I then arrived at, completely confirmed those of M. E. Becquerel; and I was led to adopt this method of measuring the permeability of bodies to the "chemical rays."*

(360.) Becquerel supposes the light to act on the corpuscules adhering to the surfaces of the plates. It is very convincingly proved that none of this excitement is due to calorific action. With an arrangement similar to that just described, the following results were arrived at by Becquerel when using screens of glass:—

Screens.	Intensity of Current.	Effects.
Without a screen	35·5	100
Violet glass	9	27
Blue glass	10·5	31
Green glass	1	2·5
Yellow	6·5	10·5
Red	1	2·5

* See Philosophical Magazine, February, 1840.

Here the incorrect results obtained by coloured glasses are very decidedly shown. All yellow glasses are permeable to some chemical rays; therefore, the deflection of 6·5 is to be attributed to these, and not to the luminous rays themselves. A plate of polished brass being exposed under similar conditions in various parts of the spectrum, the following results were obtained:—

Rays.	Intensity.
Red	1
Orange	0
Yellow	2
Green	4
Blue	2
Indigo	0
Violet	0

Here it would appear that the maximum effect was produced by the green rays.

The plate of brass being oxydised the effects were as follows:—

	Intensity.	Effect.
Without a screen	4·5	100
Violet glass	2	44·5
Blue	1	27
Yellow	0	0

Plates exposed to iodine, chlorine, and bromine, were tried by M. E. Becquerel, and similar results obtained.

(361.) Not considering these results so satisfactory as I could desire them to be, I instituted during the summer of 1843 a series of experiments with plates of different metals, and prepared in several ways. These plates were connected with wires from the galvanometer, and the different prismatic rays were passed separately through a slit in a card, and the transient and permanent deflections carefully noted. The galvanometer was never deflected by any ray below the green, unless by the extreme red, and this was no doubt a thermo-electrical action; but in the green a weak action was always detected, which increased powerfully as we ascended into the rays of still greater refrangibility; the maximum shifting with the kind of preparation employed, between the mean blue ray and the most refrangible violet.

(362.) This action is only to be regarded as one of the evidences of chemical disturbance, exciting electrical currents; yet, at the same time, it opens the question of the identity of the agent producing this disturbance and electricity. In the present state of the inquiry, we are bound to regard Light, Heat, and Electricity, as distinct elements; and possibly we have now to add a fourth to this list of imponderable agents. In the examples already brought forward in this treatise, we see the extreme difficulty which exists in keeping separate from each other the Light, Heat and Chemical Energy of the solar rays, and the results just stated, involve the element of Electricity in the already complicated consideration.

(363.) To name and describe the numerous cases which I might bring forward of decomposition by the agency of the solar rays, would occupy much too large a space. Therefore, particularising only the decomposition of hydrocyanic acid, and of nitric acid by the sun's rays, I shall satisfy myself by expressing the law which is now established, that ALL CASES OF CHEMICAL ACTION ARE QUICKENED OR RETARDED BY THE SOLAR INFLUENCES.

CHAP. III.

MAGNETISING POWER OF THE SOLAR RAYS.

(364.) HAVE the sun's rays the power of developing the phenomena of polarity in steel? This question has been agitated for upwards of twenty years. Dr. Morichini was the first to announce, that the violet rays of the solar spectrum had this power. The experiments were tried by collecting the violet rays in the focus of a convex lens, and exposing one half of fine needles, previously proved to be entirely free of magnetism, to the influence of these rays for half an hour. MM. Carpa and Ridolfi repeated these experiments of Morichini with the most satisfactory results, and the Italian philosopher succeeded in magnetising several needles, before Sir Humphry Davy, Professor Playfair, and others. It must, however, be stated that Berard and Professor Configliachi of Pavia failed in producing the same effects. Mrs. Mary Somerville restored the confidence of the scientific world in the results of Morichini, by a series of exceedingly beautiful experiments which were published in the "Philosophical Transactions," for 1826. Needles were ascertained to be entirely free of magnetism; they were then half covered with paper, and the exposed end placed in the violet ray of the spectrum, about five feet from the prism. In two hours, the needle was magnetised, the exposed end being the north pole. The indigo ray gave nearly the same result. The magnetic influence was imparted by the blue and green rays, but in a much less degree. The yellow, orange, and the calorific rays were tried for several days; but no magnetism was developed. Pieces of clock and watch springs gave similar results. It was also found that the same effects could be produced by exposing needles partly covered with paper to the Light which permeated cobalt blue and green glasses. Green and blue riband produced similar changes.

Baumgartner, of Vienna, discovered that a steel wire, polished in some parts and oxidised in others, became magnetic, exposed to the *white light* of the sun, the polished part becoming the north pole. The concentrated rays acted more rapidly, and in this way eight poles were obtained on as many inches of wire.

(365.) Barlocci and Zantedeschi found that an armed natural loadstone had its power nearly doubled in twenty-four hours, if exposed to the strong Light of the sun, and that an artificial magnet which carried 13½ oz. supported 3½ oz. more, after three days' exposure to sunshine; and it at last supported 31 oz. by continuing the solar action. Zantedeschi found that while the strength increased in oxidised magnets, it diminished in those highly polished. He also discovered that by concentrating the sun's rays, the magnet *acquires strength* when its north pole is exposed to them; and *loses* it when their south pole is acted on by them.

(366.) Mr. Christie found that when a magnetised needle, or a needle of copper, or of glass, vibrated by the force of torsion in white Light, the arch of vibration was more rapidly diminished in the sun's Light than in the shade; this effect being more evident on the magnetised needle.

(367.) Riess and Moser * published a series of experiments conducted with great care, which seem to throw much doubt on the results of other philosophers. They examined the number of oscillations performed in a given time, before and after the needle was submitted to the influence of the violet rays. A focus of violet Light, concentrated by a lens, was made to traverse one-half of the needle 200 times. They, however, could not detect any difference in the oscillations, which could be at all attributable to any magnetising property of the

* Edinburgh Journal of Science, New Series, No. IV. p. 225.; Annales de Chimie et de Physique, November, 1829.

solar rays. These experiments were tried at different seasons of the year, and at all hours of the day. They also endeavoured to verify the results of Baumgartner, but without success.

(368.) Connected with these researches, there appear to be many almost inexplicable phenomena, which have probably led to these discordant results. The whole series certainly require a fresh investigation. Mr. R. W. Fox, in pursuing his investigations on terrestrial magnetism, was led to observe the fact, that the oscillating needle was much affected by the sun's rays; the arch of vibration being more rapidly diminished, as was observed by Mr. Christie. These experiments were repeated by Mr. W. Snow Harris, who adopted the plan of swinging the needles in a vacuum, and this talented electrician came to the conclusion that no such retardation took place, under the exhausted receiver of an air-pump. It must, however, be borne in mind, that it is impossible to avoid the leaking in of air even with the best instruments; and this would give rise to currents which would materially influence the results.

(369.) Berzelius has stated that the results of Seebeck's experiments show, that in no circumstances do the sun's rays develope polarity in steel, which did not previously to exposure to their influence, possess magnetic properties. He therefore considers the experiments of Mrs. Somerville as illusive.

(370.) I will now name an experiment of my own, and leave the matter for still further investigation. Twelve sewing needles were carefully examined, and found to be without any polarity whatsoever. These were stuck through four cards, and one half being thus screened from the Light, the other was covered with deep blue coloured glasses. Three of the needles were placed magnetic east and west, and three others in the direction of the dip. The other six were washed with diluted nitric acid; and arranged, three on a card, in the same manner as the others. After having been exposed to sunshine for some hours, they were examined, and it was found, that those needles which had been placed in the direction of the dip had acquired polarity, but no change could be detected in the condition of any of the others.

CHAP. IV.

THERMOGRAPHY. — A PARTICULAR EXAMINATION OF ALL THE PHENOMENA CONNECTED WITH THE SUPPOSED RADIATION OF LIGHT IN ABSOLUTE DARKNESS.

(371.) It may appear to many at first, that this inquiry is not quite in place in the present volume, it having been shown that the conclusions arrived at by M. Moser, who first called particular attention to the phenomena in question, are in all probability erroneous. The subject is, however, so intimately united with those agencies whose powers we have been considering, that this treatise would be incomplete, did it not contain a particular account of the discovery, the discussion to which it has given rise, and record all those experiments of interest which bear upon these mysterious actions.

(372.) In a memoir "On Vision and the Action of Light on all Bodies*," M. Ludwig Moser first announced the following fact: "*If a surface has been touched in any particular parts by any body, it acquires the property*

* Poggendorff's Annalen, vol. lvi. p. 177. No. 6. 1842.

of precipitating all vapours which adhere to it, or which combine chemically with it on these spots, differently to what it does on the other untouched parts."

In a memoir entitled "*Some Remarks on Invisible Light* *," and in another "*On the Power which Light possesses of becoming latent* †," his views were still further developed, and I shall now endeavour to place them in as correct a light as possible.

(373.) In the Daguerreotype process those parts of the iodised silver plate upon which the Light has acted with most power, receive, when the plate is exposed to the vapour of mercury, the largest quantity of that vapour over their surfaces, and the gradations of Light are marked very beautifully by the thickness of these mercurial films. Now if we write with a piece of steatite on a looking-glass, the writing is invisible until we breathe upon it, when it appears distinctly. If we place coins on a plate of glass or metal, and allow them to remain for some few hours in contact, although no change will be visible when they are removed, we may bring out beautiful images of the coins by breathing on the plate, or exposing it to any vapour. Upon these experiments M. Moser has based his hypothesis, *That Light of a peculiar degree of refrangibility is absorbed by all bodies*, and *that they radiate it again in darkness.*

(374.) We must however observe all the phenomena which M. Moser has brought before the scientific world. These effects are produced by writing on glass or metal with any substance whatever. "We may first breathe

* Poggendorff's Annalen, vol. lvi. p. 569. No. 8. 1842.

† Poggendorff's Annalen, vol. lvii. p. 1. No. 9. 1842.

Those papers have been translated by Henry Croft, Esq., and published in Taylor's Scientific Memoirs, vol. iii. part xi. February, 1843; from these translations all my quotations will be made.

uniformly over the whole plate, and then write on it, either with blotting-paper, a brush, or any thing else; the characters will become visible whenever the plate is breathed on, and this phenomenon lasts for some time. Not only is glass applicable to this purpose, but every other polished body exhibits the same appearances: I have tried it with metals, resins, wood, pasteboard, leather, &c. Even fluids may be used; if we take a clean and still surface of mercury, hold over it a body, and breathe on the other parts, or, what is better, breathe on the whole surface first, and then remove the moisture by any gentle means from particular parts, they will again become visible when breathed on, even after several days, if the mercury remains undisturbed. Moreover, absolute *contact* with the extraneous body is not necessary, mere juxtaposition producing similar effects. If we hold over a polished body a screen, part of which has been cut out according to pleasure, but without allowing it to touch, and then breathe on the whole, and allow the water to evaporate, we shall find that, on breathing on it again, we shall be enabled to distinguish fully the figure of the excised parts: and still farther, it does not require a polished body, inasmuch as *dull* glass exhibits the same phenomena"

(375.) These phenomena were produced in a great many ways. "An engraved metallic plate was warmed, and then held for about half a minute on a well polished piece of silver foil, or a clean mirror plate. When the plates were cold, they were breathed on, and exhibited the above-mentioned appearances in a much more perfect manner; for not only were the outlines of the body visible, but also the individual figures, letters, &c., and all with the greatest distinctness." "Frequently silver or other metallic plates were made warm, and cold bodies, variously cut stones, figures of horn, pasteboard, cork, coins, &c. allowed to remain on them for some time. The phenomena were all the same." Mercurial vapour was found to act in the same manner as the vapour of water, and the vapour of iodine the same as that of mercury. An iodised silver plate, having some of these bodies placed upon it, "was introduced into the vapours of mercury, and then the perfect image became visible, *that is to say, Daguerre's phenomenon was produced without the intervention of Light, for the experiments succeeded just as well by night as by day.*"

(376.) Moser argues from these experiments, "*that contact is capable of imitating the action of Light,*" and he considers the following experiments to prove this clearly: "A silver plate was iodised during the night, and even without the Light of a candle; a cut slab of agate, an engraved metallic plate, and a ring of horn, &c. were then laid upon it, and the plate was afterwards introduced into the vapours of mercury. A good, clear picture of all the figures, of the stones, the letters of the plate, and of the ring, was obtained. A plate which had been treated in the same manner, was exposed to day or sun light, and similar pictures were produced. Other plates of the same kind were placed under coloured glasses — yellow, red, and violet; under the first two only a trace of the image was evident; but under the violet glass it was clearly defined." Upon these experiments, Moser remarks, "*the violet rays continue the action commenced by contact.*" He then proceeds to examine the action of Light upon "simple or difficultly changeable bodies:" the results are certainly exceedingly curious and instructive.

(377.) "A new plate of silver was cleaned and polished as well as possible. A surface with various excised characters was suspended over it without touch-ing, and the whole was exposed to the sun for some hours, and directed towards it; after the plate, which of course did not exhibit the least change, had been allowed to cool, it was held over mercury heated to about 60° Reaum. A clear image of the screen was produced; those parts where the sunlight (which had been very weak) had acted, had caused the deposition of a quantity of mercury." Plates of copper and of glass were treated in the same manner, and with the same results. "If we compare the remarkable fact of the action of Light upon surfaces of silver, with the above-mentioned phenomena produced by contact, we can no longer doubt *that Light acts on all bodies*, modifying them so that they behave differently in condensing the vapours of mercury." Moser then proposes the following general expression of the fact: "*Light acts on all bodies; and its influence may be tested by all vapours that adhere to the surface, or act chemically upon it.*"

(378.) If through one of the excised screens we breathe upon a plate of metal or glass, and then removing the screen, allow the vapour to pass off, and then again breathe upon the plate, the vapour will adhere to those parts which have been protected, and the portions on which the breath was at first condensed will appear dark: the vapours of mercury act in a similar manner. Hence, Moser concludes, "*That the same modification is produced in plates when vapours are condensed, as when Light acts on them.*" (374.)

(379.) "If an iodised silver plate be allowed to remain too short a time in the camera obscura, it afterwards exhibits no image when exposed to the vapours of mercury; a Light film of mercury is deposited over the whole plate, which is not only the case with this, but with a plate of the pure metal and the blackened iodide of silver. If the plate remain a longer time in the camera obscura, a picture certainly is produced, but in which only the brightest parts are depicted, and, which is here of importance, the light parts are of a white colour, *i. e.* they condense the most mercury. If the plate remains still longer in the camera obscura, a picture with all its details is formed; but the bright parts have lost a portion of their whiteness, and appear grey, *i. e.* they do not condense so much of the mercurial vapour. If it be left still longer, on taking it out no picture at all is to be seen; if now inserted into the mercurial vapours, a negative image is produced, or, in other words, these bright parts do not condense any mercury."

(380.) "If Light acts on iodide of silver" (I still quote from the "Memoir on Vision," &c.) "it imparts to it the power of condensing mercurial vapours in an increasing ratio; but if it acts beyond a certain time, it then diminishes this power, and at length takes it away altogether, and this happens before the yellow iodide has changed its colour. The vapours of mercury have been seen to do the same, and if in the last-described phenomenon they produce a negative image, it is only what Light would have done had it been allowed to act still longer. Iodide of silver is found to blacken under the influence of the solar rays, and the vapour of mercury also renders it black: from this M. Moser contends that the action of Light and of mercurial vapours is identical. Numerous other experiments are given by Moser of a similar character. The same effects were produced upon a great many metals, and with numerous bodies, establishing in the most satisfactory manner the remarkable fact "*That when two bodies are sufficiently approximated, they reciprocally depict each other.*"

(381.) Although attention was drawn to a few of these phenomena by Dr. Draper, about two years previously to the publication of the above-mentioned Memoirs, and were used by him in explanation of the phenomena of the Daguerreotype, yet these notices were exceedingly limited; and the great discovery of the remarkable influences which all bodies exert upon each other is indubitably due to Professor Moser.

(382.) In an Addendum to the Memoir on Vision, which bears the date of June 2., M. Moser first proclaimed his hypothesis, "*that every body must be considered as self-luminous.*" In the paper on Latent Light, he further explains himself in the following words: "I have discovered and described another class of rays of Light, those emitted by every body without exception, because it is self-luminous, — rays whose presence is evidenced, by the fact of two sufficiently approximated bodies, impressing their images on each other, although every thing that the retina could denominate Light has been excluded. I call them the *invisible rays of Light*, to distinguish them from Ritter's dark rays at the violet end of the spectrum; I might also call them the most refrangible rays, for it appears that their refrangibility is greater, than that of the other rays of the spectrum. As I shall show, they are not present in day, or sunlight, and must not, therefore, be confounded with the above-mentioned dark rays."

(383.) Arguing from these facts, that whenever a body condenses vapours differently over its surface, it must have undergone some change, which is produced by some invisible radiation, Moser infers that such a defined disposition of vapour upon any body is sufficient evidence of the existence of this "*invisible Light.*" He has also, with a great diligence, pursued his inquiries with a view to determine the *colours* of this "invisible Light," and particularly to ascertain the colours of the rays emitted by each particular body.

(384.) It is necessary to understand this part of his argument. If a Daguerreotype plate is placed in the camera obscura until an image is formed upon it, and if it then be removed, and exposed to the full rays of the sun, the plate is blackened all over and the drawing obliterated. "This destruction of the images does not depend upon the simultaneous action of the differently coloured rays of which it is composed, because blue and violet Light, and partly the green, are capable of performing the same thing." This is what Moser calls "*the phenomenon of levelling.*" Having obtained images by means of the camera on Daguerreotype plates, Moser placed them "on pure silver, gold, copper, mirror-metal, iodized silver, and porcelain;" they were allowed to remain in contact or juxtaposition for a considerable time in the dark, and all the images were found to be nearly effaced. It is concluded from this, that the "invisible Light" has the power of *levelling* the work done by the solar rays. But finding that the images produced as described, by contact, cannot be obliterated by exposure to Light, he concludes "that *visible rays* are not capable of destroying images produced by those which are *invisible.*" Now, as the images produced in the camera are not destroyed by mercurial vapour, as they are by the blue and violet rays, but brought out by it, M. Moser infers that the colour of the *latent Light* of mercurial vapour is not blue or violet. A plate is exposed for a very short time in the camera, and brought to such a state that it may be destroyed by yellow Light, or rather Light which has permeated a yellow glass, and it is found that mercury produces no image;

hence it is inferred that "*the colour of the latent Light of the vapours of mercury is yellow*." The absurdity of all this will presently be shown. By precisely the same reasoning Moser has *established* the colour of the latent Light of iodine to be either blue or violet, and that the latent Light of water "is certainly not green, yellow, orange, or red, but that it appears to belong to the ordinary prismatic colours, inasmuch as I have never seen it destroy an image produced by the invisible rays."

(385.) We are now in a situation to discuss the merits of the hypotheses of the philosopher of Königsberg. In the first place, I must express my disapprobation of any term involving such a contradiction of ideas as that adopted by M. Moser. It is necessary when we engage in an inquiry that we should have a distinct idea of the matter upon which we are to operate, and by all means avoid anything which may lead to confusion in our minds.

INVISIBLE LIGHT is one of the most injudicious expressions that could be conceived. There are invisible rays — as heat rays, and rays having chemical power; but there cannot exist invisible Light. Even supposing the matter, so to speak, of Light, "a substance distinct from all other, existing in darkness, expanded through all things at all times (in a *latent* or *invisible* state), and rendered visible by being properly *excited* *;" yet it will only tend to confuse us, if we regard, even according to the above notion, this substance as Light previously to its "being properly excited." Those rays which, acting upon some part of that beautiful organ the eye, enable us to distinguish external nature is LIGHT;

* Scheme of Scripture Divinity, by Dr. John Taylor, published in 1762.

but that which does not enable animals to see is not Light.

(386.) We will now proceed to the consideration of this interesting and important question. Upon repeating the simple experiments above referred to, of placing a disc upon a metal plate and breathing on it, I find that it is necessary for the production of a good effect, to use dissimilar metals; for instance, a piece of gold or platina, on a plate of copper or of silver, will make a very decided image, whereas copper or silver on their respective plates, gives but a very faint one, and bodies which are bad conductors of heat placed on good conductors, make decidedly the strongest impressions when thus treated.

(387.) This is still more strikingly shown by the following experiments: —*

I placed upon a well-polished copper plate, a sovereign, a shilling, a large silver medal, and a penny. The plate was gently warmed by passing a spirit lamp along its under surface; when cold, the plate was exposed to the vapour of mercury; each piece had made its impression, but those made by the gold and the large medal were most distinct,—not only was the disc marked, but the lettering on each was copied.

A bronze medal was supported upon slips of wood, placed on the copper, one-eighth of an inch above the plate. After mercurialization, the space the medal covered was well marked, and for a considerable distance around, the mercury was unequally deposited, giving a shaded border to the image; the spaces touched by the wood were thickly covered with the vapour.

* "Thermography, or the Art of Copying Engravings, &c. on Metal Plates," by the Author. Transactions of the Royal Cornwall Polytechnic Society, 1842.—*Philosophical Magazine*, December, 1842.

The above coins and medals were all placed on the plate, and it was made too hot to be handled, and allowed to cool without their being removed; impressions were made on the plate in the following order of intensity,—gold, silver, bronze, copper. The *mass of the metal* was found to materially influence the result; a large piece of copper making a better image than a small piece of silver. When this plate was exposed to vapour, the results were as before. On rubbing off the vapour, it was found that the gold and silver had made permanent impressions on the copper.

The above being repeated with a still greater heat, the image of the copper coin was, as well as the others, most faithfully given, but the gold and silver only, made impressions which could not be rubbed out.

A *silvered* copper plate was now tried with a moderate warmth. Mercurial vapour brought out good images of the gold and copper; the silver had marked the plate, but its image not well defined.

By repeating these experiments it will become very evident to every one, that the relative *calorific* relations, materially influence the result, and this is still more strikingly shown by the following arrangements.

I placed upon a plate of copper, blue, red, and orange coloured glasses, pieces of crown and flint glass, mica, and a square of tracing paper. These were allowed to remain in contact half an hour. The space occupied by the red glass was well marked, that covered by the orange was less distinct, but the blue glass left no impression; the shapes of the flint and crown glass were well made out, and a remarkably strong impression where the crown glass rested on the tracing paper, but the mica had not made any impression.

The last experiment being repeated, after the exposure to mercurial vapour, heat was again applied to dissipate it, but the impressions still remained on the plate, although the vapour was volatilized.

I placed the glasses used above, with a piece of well-smoked glass for half an hour, one-twelfth of an inch *below* a polished plate of copper. The vapour of mercury brought out the image of the smoked glass only.

All these glasses were placed *on* the copper, and slightly warmed. Red and smoked glasses gave, after vaporization, equally distinct images; the orange the next; the others left but faint marks of their forms: polishing with Tripoli and putty powder would not remove the images of the smoked and red glasses.

An etching was made upon a smoked etching ground on glass, and the *glass* being placed in contact with a copper plate, the image of the glass only could be brought out, showing that no influence was exerted through the glass.

A design cut out in paper, was pressed close to a copper plate by a piece of glass, and then exposed to a gentle heat; the impression was brought out by the vapour of mercury in beautiful distinctness. On endeavouring to rub off the vapour, it was found that all those parts, which the paper covered, amalgamated with mercury, which was removed from the other parts of the plate; hence there resulted a perfectly permanent white picture on a polished copper plate.

The last experiment, in particular, proves that a very remarkable molecular change is effected; and, as it would appear, it is dependant upon the bad conducting powers of the paper.

(388.) It was now desirable to ascertain if the solar rays had anything to do with these phenomena.

The coloured glasses before named were placed on a plate of copper, with a thick piece of charcoal, a copper coin, the mica and the paper, and exposed to fervent sunshine. Mercurial vapour brought up the images in the following order: smoked glass, crown glass, red glass, mica, orange glass, paper, charcoal, the coin, blue glass; thus distinctly proving that the only rays which had any influence on the metal were the calorific rays. This experiment was repeated on different metals, and with various materials, the plate being exposed to steam, mercury, and iodine: I invariably found that those bodies which absorbed, or permitted the permeation of the most heat, gave the best images. The blue and violet rays could not be detected to leave any evidence of action at this time; and as spectra imprinted on photographic papers by Light, which had permeated these glasses, gave evidence of the large quantity of the invisible rays which passed them freely, I considered those as entirely without the power of effecting any change on compact simple bodies.

(389.) In a paper which I published in the "Philosophical Magazine," for October, 1840, I mentioned some instances in which I had copied printed pages and engravings on iodized paper, by mere contact and exposure to the influence of the calorific rays, or to artificial heat. I then, speculating on the probability of our being enabled, by some such process as the one I then named, to copy pictures and the like, proposed the name of THERMOGRAPHY, to distinguish it from Photography.

I now tried the effects of a print in close contact with a well-polished copper plate. When exposed to mercury, I found that the outline was very faithfully copied on the metal.

A paper ornament was pressed between two plates of glass, and warmed; the impression was brought out with tolerable distinctness on the under and warmest glass, but scarcely traceable on the other.

Rose-leaves were faithfully copied on a piece of tin plate, exposed to the full influence of sunshine; but a much better impression was obtained by a prolonged exposure in the dark.

(390.) With a view of ascertaining the distance from each other at which bodies might be copied, I placed upon a plate of polished copper a thick piece of plate glass, over this a square of metal, and several other things, each being larger than the body beneath. These were all covered by a deal box, which was more than half an inch distant from the plate. Things were left in this position for a night. On exposing to the vapour of mercury, it was found that each article was copied, the bottom of the deal box more faithfully than any of the others, the grain of the wood being imaged on the plate.

(391.) Having found, by a series of experiments, that a blackened paper made a stronger image than a white one, I very anxiously tried to effect the copying of a printed page or a print. I was partially successful on several metals, but it was not until I used copper plates amalgamated on one surface, and the mercury brought to a very high polish, that I produced any thing of good promise. By carefully preparing the amalgamated surface of the copper, I was at length enabled to copy from paper, line-engravings, wood-cuts, and lithographs, with surprising accuracy.

The following is the process at present adopted by me, which I consider far from perfect, but which affords us very delicate images: —

A well-polished plate of copper is rubbed over with the nitrate of mercury, and then well washed, to remove any nitrate of copper which may be formed; when quite dry, a little mercury taken up on soft leather, or linen, is well rubbed over it, and the surface worked to a perfect mirror.

The sheet to be copied is placed smoothly over the mercurial surface, and a sheet or two of soft, clean paper being placed upon it, is pressed into equal contact with the metal by a piece of glass, or flat board; in this state it is allowed to remain for an hour or two. The time may be considerably shortened by applying a very gentle heat, for a few minutes, to the under surface of the plate. The heat must on no account be so great as to volatilize the mercury. The next process is to place the plate of metal in a closed box, prepared for generating the vapour of mercury. The vapour is to be slowly evolved, and in a few seconds the picture will begin to appear; the vapour of mercury attacks those parts which correspond to the white parts of the printed page or engraving, and gives a very faithful, but a somewhat indistinct image. The plate is now removed from the mercurial box, and placed into one containing iodine, to the vapour of which it is exposed for a short time; it will soon be very evident that the iodine vapour attacks those parts which are free from mercurial vapour, blackening them. Hence there results a perfectly black picture, contrasted with the grey ground formed by the mercurial vapour. The picture being formed by the vapours of mercury and iodine, is of course in the same state as a Daguerreotype picture, and is readily destroyed by rubbing. From the depth to which I find the impression made into the metal, I confidently hope to be enabled to give to these singular and beautiful productions a considerable degree of permanence, so that they may be used by engravers for working on.*

* M. Moser has made a violent attack upon the author of this volume, claiming as his own all the published experiments, particularly

This is the particular process to which I gave the name of Thermography, which name is not inappropriate to the whole class of phenomena, as if not directly the effect of a disturbance of the latent caloric, they are certainly materially influenced by the action of heat.

(392.) For the purpose of ascertaining what part, if any, the solar emanations acted in the instances above referred to, various methods were devised, some experiments being made with coloured absorbent media, and others with the prismatic spectrum itself.

The coloured media used by me, insulated respectively the following rays:—

1. Red, orange, yellow, and some of the blue.
2. Orange, yellow, green, with a faint trace of the blue, and a small portion of the red.
3. Orange, yellow, green, blue.
4. Green, blue, indigo, violet, and invisible chemical rays.
5. All the rays passed. White Light.
6. None of the visible rays.—(A bottle of ink.)

A very highly-polished plate of copper, with the above media in flint-glass bottles laid upon it, was exposed to bright sunshine for one hour. The plate was then placed in a dark box, and exposed to the vapour of mercury. The largest deposit of vapour was found to mark the space on which the most calorific rays acted (Medium, No. 1.); the next in order was that influ-

the above. The question has, however, been very satisfactorily decided in the author's favour, in the Philosophical Magazine for November and December of the present year. Indeed, in Moser's Memoir on "Invisible Light," p. 463. of the Scientific Memoirs, vol. iii., it is stated, "*Black writing on white paper depicts itself so as to be visible, but I have never seen it very well executed.*" In a recent publication, "Lerebour's Photography," the discovery of this process is, by error, attributed to M. Knorr.

enced by the blue (No. 4.)*; and then the others as follows: green (3.), yellow (2.), white (5.), and black (6.). There was less mercury deposited on the spaces which these four bottles covered than over the exposed parts of the plate.

(393.) Precisely the same arrangement *was left in the dark* for five hours, and the plate then exposed to mercurial vapour, which attacked it in the same manner as when it had been subjected to strong sunshine, except that no mercury lodged upon the uncovered parts of the plate. Another copper plate was placed one-eighth of an inch *above* the same bottles of fluids *in the dark*, and allowed to remain in that position for five hours; on exposure to mercury it was found that the action was confined to the red (No. 1.), the blue (No. 4.), and the green (No. 3.); which last could scarcely be detected, so faint was the image formed by the vapour. Here we have distinct evidences of radiations in the dark, intimately connected with the thermic properties of the media used.

(394.) Two copper-plate engravings on thin paper were placed, face down, upon two highly-polished and well-amalgamated plates of copper. One of the plates was covered with window-glass, and the other with a beautiful red glass, stained with the oxide of gold. They were exposed to daylight for four hours, during which period there were but faint gleams of sunshine. On subjecting the plates to the vapour of mercury, it was found that under the influence of the red glass a very capital impression was made; but no trace of any action could be detected on the plate which had been under the white glass.

* See Temperatures of Media, paragraph (308.).

(395.) Paper patterns were laid upon plates of polished copper, and upon these large bottles of fluids (the same used in the experiments on the influence of Light on plants (306.)) were placed. Being allowed to remain some hours *in the dark*, it was found that the best image was formed on the plate which had been placed under the bottle containing red fluid, but that very decided impressions were made under the others. Exposed to *strong sunshine* for a short period, half an hour, it was found when the plates were mercurialized that under the red fluid alone was an image formed.

(396.) By placing bad conductors of heat, as wood, glass, and paper, on metal plates, and lowering their temperatures by placing their under surfaces upon vessels filled with freezing mixtures, it was found that the same effect was produced as when the plates had been warmed,— these experiments clearly proving that the phenomena could be produced by any disturbance of the caloric latent in the bodies used.

(397.) Having adjusted a good Heliostat, so that the sun's image was reflected upon a given spot for some hours, this pencil of Light was decomposed by a prism, and then, being concentrated by a large lens, it was thrown upon a polished plate of copper, which was placed in the focus of the lens, and allowed to act upon the plate for periods which varied from one to three hours. In every case the result was the same. The quantity of diffused Light, which always accompanies a prismatic spectrum, produced its effect upon the whole surface of the plate, and a thin film of mercurial vapour covered it. On the spot upon which the rays of least refrangibility fell, a space exactly coinciding with the maximum heating point of the spectrum, as shown by Sir William Herschel, and also with the great heat spot in the thermic spectrum of Sir John Herschel, the condensation of the vapour was so exceedingly thick, that it stood a distinct white spot upon the plate. Over the whole space occupied by the visible rays, the quantity of vapour was much less than that which covered the other parts; and it was plainly distinguished from the rest of the plate by well-defined lateral lines of vapour. Here we have distinct evidence of the power of the calorific rays; and it would appear that the whole of the luminous spectrum had a negative power.

(398.) Allowing a condensed prismatic spectrum to traverse a similar copper plate for some time, it was found, after exposure to mercurial vapour, that a line of thickly deposited vapour marked the path of the red and the extreme red rays.

(399.) M. Knorr, pursuing his investigations, found that these images could be produced without any condensation of vapour on the plates, and simply by the action of heat. The process he employs is to place a copper plate over a spirit lamp; upon this is put the plates which are to receive the impressions, and upon the latter the object to be copied. The whole is then slowly heated to the degree at which a well-polished copper plate begins to change colour, when the lamp is extinguished, and the plates and medals withdrawn. Distinct impressions of the bodies to be copied are always found, and these made to a considerable depth into the surface of the metal.

(400.) From these results, it is rendered quite certain that a very extensive class of these phenomena are producible by the agency of heat. M. Moser himself admits the accelerating power of caloric, but he adopts the gratuitous assumption, that this power is only exerted to disturb the "invisible Light." We have very satisfactory evidence, that all bodies are constantly radiating some peculiar and energetic principle from their surfaces. I have frequently proved the existence of these radiations from iron heated below redness. Under their influence some of the metallic combinations of loose affinity are decomposed, and many of the organic vegetable bodies, undergo a rapid change. It is to this principle, in all probability, that the very curious production of the spectral images in question is, in many cases, due.

(401.) It must, however, be shown, that effects in all respects similar may be produced by other agencies than those of heat.

M. Karsten found that if a glass plate was placed upon a metallic one, and on the glass a medal, which was subjected to discharges of electricity, the glass received a very perfect image of the medal, which could be developed by either mercury or iodine. If several glass plates are placed between the medal and the under metal plate, and discharges passed through them, each piece of glass receives an image, but only on its upper surface. For a more detailed account of these very interesting experiments, the reader is referred to M. Karsten's Memoirs.

(402.) My own results would show, that the electro-negative metals make the most decided images upon electro-positive plates, and vice versâ. I have also found that electrical discharges have the remarkable power of restoring impressions which have been long obliterated from the plates by any polishing processes; proving, in a very convincing manner, that the disturbances upon which these phenomena depend, are not confined to the surface of the metals employed, but that a very decided molecular change has been effected for a considerable depth into the mass.

(403.) If we cover a copper plate with water or oil, to the depth of 1-16th of an inch, and support upon bits of glass, a medal, so that its under surface just touches the fluid, a very decided image is made upon the copper plate in a few hours. These images are partly visible by the tarnishing of the plate over every part but that which is covered by the medal. Upon pouring off the fluid and dry polishing, the image is rendered invisible; but on exposing the plate to vapour, it is again brought out.

Some such experiments as these have been interpretated, by Moser, into a proof of the permeability of water and oil to the "invisible Light."

(404.) We have now seen that LIGHT, *Heat*, *Machine-Electricity*, and a *Voltaic Current*, all produce that disturbance upon the surfaces, at least, of solid bodies, which disposes them to receive vapours upon definite spaces. It will also be found, that any *mechanical* disturbance to which the plates may be subjected, will act in precisely the same manner as the above elements. Is it not then most unphilosophical, and indeed exceedingly absurd, to reason in the way M. Moser has done, and upon such very insufficient evidence as is afforded by the manner in which metal or glass plates condense vapours, to build an hypothesis on the existence of a peculiar modification of Light and Colour, neither of which can be rendered evident to the organ of vision?

(405.) I must not quit this discussion without explaining, that the "levelling" action of Light, alluded to by Moser (384.) is nothing more than a darkening of the whole surface, and the "levelling" which he attributes to the "invisible Light" is nothing more than the effect of chemical action. Those parts of the iodu-retted plate which have been changed by Light are restored to their original state in the dark, by the influence of the iodine, which exists in the under unchanged layers on the plates, and in those parts which have been maintained in shadow. The same kind of changes, which are certainly curious and complicated, take place with those photographic images which are procured by the action of an hydriodate on a darkened salt of silver. (97.) With this explanation, it will be seen at once, that the elaborate reasonings of Moser on the colours of the latent Light of vapours are of no value.

(406.) M. Fizeau's speculations on this subject do not properly belong to this work, but as they show that these images may also be produced by causes which have not yet been considered, and from their interest, I give them a place. They are, however, worthy of a more attentive consideration than I can bestow upon them. In the *Comptes Rendus*, November 7. 1842, in a letter to M. Arago, Fizeau thus sets forth his ideas, and gives the results of his experiments: "Far from thinking we must admit the existence of a new species of radiations, escaping from all bodies, even in complete darkness, and subjected in their emission to laws entirely peculiar, I am convinced that no kind of radiations whatever, are to be had recourse to for the explanation of these phenomena, but that we should rather connect them with the known facts which I shall now mention.

" '1. Most of the bodies upon which we operate have their surface clothed with a slight layer of organic matter, analagous to the fatty bodies, and volatile, or at least susceptible of being carried off by aqueous vapour.

" '2. When vapour is condensed on a polished surface, if the different parts of this surface are unequally soiled by extraneous bodies, even in an exceedingly minute quantity, the condensation is effected in a manner visibly different on the different parts of its surface.'

"When, therefore, we expose a polished and pure surface to the contact of, or at a small distance from, any body whatever, with an unequal surface, it will happen that a part of the volatile organic matter which covers this latter surface will be condensed by the polished surface in the presence of which it is; and as I have supposed the body to present inequalities or projections and hollows, that is to say, its different points to be unequally distant from the polished surface, the result of this will be an unequal transfer of the organic matter on the different points of this surface; at the points corresponding to the projections of the body the polished surface will have received more, and at the points corresponding to the hollows it will have received less; hence, then, there will result a kind of image, but generally invisible. If a vapour be then condensed on this polished surface, we see that it is then under the conditions which I just now mentioned, and that the condensation will take place in a manner visibly different upon the different points, that is to say, the invisible image will become visible."* This very simple method of accounting for these phenomena, has been adopted by Professor Grove, on the strength of some experiments which shew that these images may be very readily formed by the action of any volatile body; and a very eminent authority states, that he has found "many of the phenomena ascribed to *latent Light* or to *heat*, are owing to the absorption of matter in the state of vapour or minute particles, passing from the object to the surface of the glass or metal upon which the image of that object is impressed; and by this means we have

* Scientific Memoirs, vol. iii. p. 489.

obtained very fine pictures upon glass, which are *positive* when seen by reflection, and *negative* when seen by transmitted Light." *

(407.) Many of the phenomena may be produced in the way above stated; but M. Fizeau is mistaken in applying his results in explanation of the whole class. I have proved in the most incontrovertible manner, that these images may be produced, when by processes of boiling and heating every trace of organic matter must be removed from the surface. And when we consider that these impressions are, under certain circumstances, formed to a considerable depth beneath the surface (391.), we must admit that, although this may be one of the causes, yet that is only one amongst many others, and indeed one of the least energetic of the lot. All these facts, however, substantiate my position that Light is not the agent which acts in darkness, consequently, that Moser's position is untenable. At the same time we must not too hastily dismiss the question, as it is probable that amongst the operations of those diversified powers, we may be enabled to detect the existence of one more important than either, which may enable us to trace out the influence which disposes the molecular structure of bodies, and the relations of matter as displayed in the phenomena of chemical affinity.

* Edinburgh Review, January, 1843, p. 343.

PART III.

CONSIDERATION OF THE PRECEDING PHENOMENA.

CHAPTER I.

CONDITIONS OF THE PRISMATIC SPECTRUM.

(408.) Throughout the present volume, for the purpose of rendering myself perfectly intelligible to all, I have laboured under the difficulty of being compelled to use the word Light to express an influence which has hitherto been considered as a peculiar property of the luminiferous essence, whereas it has appeared to me exceedingly doubtful if the "chemical rays," so called, were not entirely independent of solar Light.

(409.) By a careful perusal of the writings of Herschel*, of Melloni†, and of Becquerel‡,—by studying the phenomena by which Draper argues on the analogy of the chemical rays, and those of caloric§, and those curious matters to which Moser|| has directed attention, it will be very evident that the question is one of very considerable difficulty. Had the influence been due to Light (I use the term now, and shall continue to use it to designate those solar rays which produce sensible impressions on the organs of vision), we

* Philosophical Transactions.

† Bibliothèque Universelle, 1842.

‡ Comptes Rendus, for 1842–43.

§ Philosophical Magazine, vol. xix. No. 123.

|| Poggendorff Analen; Philosophical Magazine, &c.

should expect that the *colour* of the rays of that element would have no influence in modifying the chemical changes produced by it. We have, on the contrary, seen that this chemical power is greatest in the blue rays, which give us the least Light of any of the prismatic radiations, and that it is least in the yellow rays, in which the Light is most powerful.

(410.) Herschel having shewn that the largest quantity of solar heat was manifested in the least refrangible rays, and particularly in rays which were not visible to us; and also having proved that the maximum of luminous power was found in the yellow ray — Ritter having demonstrated that invisible rays of great refrangibility had a large amount of chemical power, and Seebeck pointed out that this tendency to produce change was confined to these and the blue rays; it was long the custom to consider the prismatic spectrum as divisible into three classes of rays: the red or calorific rays; the yellow or luminous rays; and the blue or chemical rays. In the first place we are bound to, and of course do, regard all the coloured rays as *luminous rays*, but differing in the intensity of their effects. In the next place an attentive consideration of the numerous researches which have been recorded in the preceding pages, will shew that the chemical influence is not only co-extensive with the luminous rays, but that it occupies a space considerably beyond these rays. And again, Sir John Herschel has distinctly traced the calorific power through all the luminous rays, and much below them.

(411.) A brief notice of Sir John Herschel's experiments on the thermic spectrum must here have a place. To procure visible effects of the calorific power of the spectrum; the following method was adopted. The thinnest post paper, such as is sold for foreign correspondence, was stretched on a frame. One side of this paper was blackened with Indian ink, or, which is better, smoked in the flame of oil of turpentine, or over a smoky candle, by drawing it often and quickly through the flame, giving it time to cool between each exposure, till it is coated on the under side with a film of deposited black, as nearly uniform as possible. The white side of this paper is exposed to the incident spectrum, properly adjusted, keeping the blackened side hollow to admit air and to avoid rubbing off the black coat. A fiducial dot being made on it, and this brought to coincide with the standard yellow ray, a flat brush, equal in breadth to the paper, dipped in good rectified spirit of wine, is to be passed over the white surface till the paper is completely saturated, which will be indicated by its acquiring a uniform blackness in place of the white it at first exhibited.

"After a few minutes, a whitish spot begins to appear considerably below the extreme red end of the luminous spectrum, which increases rapidly in breadth until it equals the breadth of the luminous spectrum, and even somewhat surpasses it; and in length, till it forms a long appendage exterior to the spectrum, and extends moreover within it, up to and beyond the fiducial yellow. In this state, and just as the general drying of the paper begins, by whitening the whole surface to confuse the appearances, a second, sudden, and copious wash of alcohol from above downwards must be applied without disturbing the spectrum, or in any way shaking the apparatus. The superfluous alcohol will have hardly run off, when the phenomena of the thermic spectrum will begin to appear in all their characters, at first faintly, and, as it were, sketched in by a dimness and dulness of the otherwise shining and reflective surface of the wetted paper; but this is speedily exchanged for a perfect whiteness, marking by a clear and sharp outline, the lateral extent of the calorific rays, and by due gradations of intensity, in a longitudinal direction, their law or scale of distribution both within and without the luminous spectrum."

Sir John Herschel then details some of the results obtained upon different coloured papers, each of which has its peculiar *scale of action.* The results, however, obtained upon smoked paper, which are the most satisfactory, are thus explained by this able philosopher. A drawing of this thermic spectrum is given in the frontispiece.

Supposing, then, that such smoked paper is employed, the thermograph of the spectrum in its most complete state, or rather in that succession of states in which each part comes most characteristically into view, is as is represented in the drawing.

"The most singular and striking phenomenon exhibited in the thermic spectrum thus visibly impressed, is its want of continuity. It obviously consists of several distinct patches, of which α, β are the most continuous and intense, but are less distinctly separated, and of which when the sun is very strong and clear, it is even difficult to trace the separation. The spot γ, on the other hand, is round and well insulated; it begins to appear on the paper soon after the ovals α, β are fully formed, and when β has assumed a sharply rounded outline. The first symptom of its appearance is the dulling of the wet and shining surface of the paper, which is speedily followed by the appearance of a small round white speck; this continues to increase rapidly in size and whiteness, and at length assumes a definite and perfectly circular outline, within which the paper is entirely white. By degrees the oval β and this spot join and run together, forming a white streak deeply indented at the point of junction. It is not till this happens that similar symptoms begin to betray the existence of a still more remote heat spot, δ. Indeed, it generally requires another wash of alcohol before this can be fully brought into evidence. It is, however, perfectly unequivocal, though very much feebler, and rather worse defined than γ, with which also it is somewhat better connected than γ with β.

(412.) "Of the existence of a much more remote spot," says Sir John Herschel, "I have hardly a doubt, but it is very difficult to obtain a sight of it." This is the spot ϵ, situated at about —58. The very accurate measures taken of this spot on several occasions, leave no doubt of its existence, and of the correctness of the remote position assigned to it in the drawing. The great analogy between this arrangement of the heat spots along the axis of the spectrum, and the absorptive action of nitrous gas on the luminous rays, seem, as Sir John Herschel remarks, to point to a gaseous absorption. "The gaseous media through which the rays have reached their point of action, are the atmospheres of the sun and the earth. The effect of the former is beyond our control, unless we could carry our experiments to such a point of delicacy as to operate separately on rays emanating from the centre and borders of the sun's disc. That of the earth's, although it cannot be eliminated any more than in the case of the sun's, may yet be varied to a considerable extent by experiments made at great elevations and under a vertical sun, and compared with others where the sun is more oblique, the situation lower, and the atmospheric pressure of a temporarily high amount. Should it be found that this cause is in reality concerned in the production of the spots, we should see reason to believe that a large portion of solar heat never reaches the earth's surface, and that what is incident on the summits of lofty mountains differs not only in quantity, but also in *quality*, from what the plains receive."

(413.) Now these facts render it quite clear that, the calorific rays have an existence independent of the luminous rays of the solar spectrum, and that heat occupies a much larger space than Light does, or in other words, each sunbeam contains a larger amount of heat than it does of Light. Melloni has shown, by some admirable experiments, that bodies are not alike transparent to Heat and Light. Black mica, obsidian, and black glass in thin laminæ, although nearly opaque to Light, yet allow a large quantity of radiant heat to pass them, and are called by Melloni, *diathermic* bodies*; whilst glasses of a green colour, in combination with a layer of water, or a very clear plate of alum, are, on the contrary, called *adiathermic*†, from their being perfectly opaque for heat, notwithstanding Light permeates them freely. These points appear quite sufficient to establish the distinctions of the two solar radiations, Heat and Light: although it may eventually, by the advance of experimental science, be shown that they are but different states of one power, we are justified in adopting the popular notion, and regarding them as distinct principles having a common origin.

(414.) The conditions of the luminous rays as they are exhibited by the prismatic spectrum, need not again occupy much of our attention. The only question with

* From διὰ, through, and θερμὸς, warm.

† From α priv. and διαθερμικὸς, transcalescent.

which we have at present to deal, being the extent or limits of that influence which, when acting upon the organs of vision enables us to distinguish objects. It is well known that some very remarkable cases of idiochromic vision occur. Dr. Dalton and Mr. Troughton are examples; in their eyes, pure red and pure yellow excited the same sensations. Scarlet and green could not be distinguished from each other. In those instances there does not appear to have been any ray of *Light* to which the eye was not sensible; but the power of receiving the impression of colour was wanting. This is a diseased condition of the organ, which bears but slightly on the point in view. It will be found, that if several persons who are looking at the same prismatic spectrum, are requested to mark with the point of a needle the limits of the coloured rays, not many of them will mark the same spot; some see more of the violet or of the red rays than others, and consequently will point a little higher or lower as the case may be. Now, if we protect the eye from the luminous rays by a piece of cobalt blue glass, we are enabled to see a class of rays that are less refrangible than the ordinary red, and which have been called "the extreme red rays." Sir John Herschel has pointed out the means by which a "*lavender grey*" ray may be shown to exist beyond the violet. If, indeed, the spectrum is received upon paper, dyed with an alcoholic tincture of turmeric, the spectrum appears elongated beyond the violet ray; but the eye is affected with the sensation of a pale yellow colour. A paper dyed with an alcoholic tincture of the dark purple dahlia, alkalised with carbonate of soda, which becomes in about twenty-four hours a fine yellow colour, exhibits this prolongation as a pale yellow streak. "If such," says Sir John Herschel, "should be the true calorific character of these rays, we might almost be led to believe (from the evident reappearance of redness, mingled with blue in the violet rays) in a repetition of the primary tints in their order, beyond the Newtonian spectrum; and that if by any concentration rays still further advanced in the 'chemical' spectrum could be made to affect the eye with a sense of light and colour, that colour would be green, blue, &c., according to the augmented refrangibility.'"

(415.) It has been supposed that some animals may have the power of distinguishing such colours, that is that their eyes are affected by those rays of high refrangibility, which produce no impression of *Light* upon the eyes of man. M. Biot has, it would appear, found that some such effect is produced upon the eyes of some of the night-roving animals, by rays invisible to us. This may be. That which is *darkness* to us when we come from the sunshine into it, is found after a little time, when the lenticular arrangement of the eye has been adjusted to the required condition, to produce the sensation of tolerable Light. May we not, therefore, explain on the same principle, the power which the cat, the owl, and other animals possess of seeing in the circumstances we might regard as darkness? This reasoning is not calculated to settle the question, whether the eyes of any animals receive sensations of Light from the rays of heat, or of those producing chemical change. It does appear to me that a broad distinction is established between the solar influence, Heat, and the solar influence, Light. That in many phenomena their operations so run together, that it is impossible to separate the one from the other, I am ready to admit; and also that it would appear from the experiments of Delaroche that Light and Heat are convertible into one another. The curious fact, discovered by this philosopher, that radiating heat becomes more and more capable of penetrating glass as the temperature increases, till at a certain temperature the rays become luminous; almost seem to confirm this, did they stand alone. The results obtained by Melloni with the solar rays do, as it appears to me, compel us to consider Light and Heat as two distinct powers, intimately connected with each other in their operations.

(416.) It is now necessary to examine with great care the question of the identity or otherwise of the chemical principle which we derive from the same solar source. It must have been remarked, that one of the most striking peculiarities which the prismatic spectrum presents, in its action on sensitive preparations, is the remarkable difference between the scale of action on preparations, not very dissimilar from each other. This is strikingly shown in the frontispiece, and reference to it will render it unnecessary to do more than allude to two or three remarkable examples.

(417.) The limits of solar action upon twenty-nine different preparations: mineral and vegetable, is shown in the Plate. The maximum will be found, marked by the dotted line, to vary in every instance, but with the exception of the Per-cyanide of gold, and ammonia (18), and the juice of the ten weeks' stock (27), it will be seen that these maxima are confined within the limits of the least refrangible blue, and the most refrangible violet rays. No. 1. Nitrate of silver shews that the action ceases a little beyond the visible spectrum, and that the rays of the yellow space have but little action; and that those of the red are confined to very small limits. No. 4. Iodide of silver and ferro-prussiate of potash, exhibits the influence of a chemical force to a great distance beyond the luminous spectrum at the violet end. The same influence greatly modified in power is exerted through the yellow, red, and extra-spectral calorific rays; and No. 5., which is a specimen of the action of the hydriodic salts upon the darkened chloride of silver, shows the extension of a purely chemical action considerably lower in the calorific region; and this is even still further extended in No. 22., ferro-cyanate of potash, and per-chloride of iron. In all, but No. 18., the strongest impression is made by the chemical agency of those rays within the limits of the luminous spectrum; but in this remarkable instance, the action is confined entirely to the non-luminous space beyond the violet rays. In No. 14., chloride of gold, this action is entirely confined to the region of the blue, indigo, and violet rays, whilst No. 16. the protocyanide of gold, and formobenzoate of silver; the influence is extended with great force to a considerable distance beyond the violet rays, and a large amount of chemical power is exerted by the rays found in the region of the red space. These, and the other instances, which are described in their proper places, sufficiently shew, that the action is extended over the entire luminous spectrum, and spaces occupied by dark rays, nearly equal to twice the length of the visible spectral image. A singular difference is also exhibited in the action of the different spaces on different materials.*

(418.) By the investigations to which the art of photography has given rise, we have discovered, that the chemical influence is not confined to the class of blue rays, and the dark rays beyond them, as was formerly thought. This chemical power has been traced over every ray of the luminous spectrum, and to some distance beyond its least refracted end, as well as the end

* See Appendix, No. 2.

of most refrangibility. It is also found that the maximum point, although it may be said to lie within the limits of the most refrangible rays for nearly all preparations; yet, that is not found at the same point for any two, however slight the difference between them may be.

(419.) Melloni has endeavoured to explain this. The hypothesis which this philosopher has given, supposes all bodies to have, what he terms "a chemical colouration." To render his meaning clear, we must diverge from our subject slightly. If we paint a board, of the seven prismatic colours — or take, which is still better, seven pieces of cloth of the same colours as the rays; and receive the spectrum upon them, we shall find when all the rays fall upon their own colour that the colour of each is considerably exalted. If we receive the spectral image upon a red ground, all the rays will suffer diminution in intensity, except the red, which will be increased. If, on the contrary, it is received on a blue ground, the blue ray will become more intense, whereas all the others will, in different degrees, be diminished. Melloni, therefore, reasoning by analogy from these differently reflective powers of various colours, supposes all bodies, even a white sheet of paper, to have an invisible "chemical colouration;" and hence as the colour of the body presented to the spectrum belongs to that, of one or other of the rays, so is the maximum chemical power of that ray exalted, whilst all the others are depressed. We find that coloured media allow the passage of a larger quantity of the rays of their own particular colour than of any other. We also find that colourless fluids admit the permeation of the chemical influences of the solar beam in very different degrees. Hence M. Melloni argues, that according to the "chemical colouration" of the fluid, so is its permeability to different rays which produce chemical change. This is certainly an exceedingly ingenious hypothesis, and we may by it explain a great number of phenomena; but it appears to me an unnecessary refinement in speculative philosophy, to build so elaborate and complicated a structure upon a foundation so purely imaginary as this. Any speculation from so eminent a philosopher as Melloni, to whose researches on Heat we are indebted for the elucidation of some of the most complicated phenomena of this element, must be received with all the respect due to the efforts of a mind of so high an order; but at the same time we must not be led too widely astray by an entire reliance upon authority, even such an authority as Melloni. It would appear that M. Moser has borrowed his ideas of the colours of the "latent Light" of vapours from this philosopher.

(420.) It is necessary for the fair and full consideration of the question, that the views of another eminent experimental philosopher should be examined — those of the younger Becquerel. I shall, therefore, extract a few passages from the translation of E. Becquerel's Memoir on the Constitution of the Solar Spectrum in the Scientific Memoirs, Part XII. August, 1843.* "It has been generally admitted that these radiations which accompany Light are different from each other, and that according to such or such a sensible substance, the active rays were also different; but I do not suppose that the question is so complex. In fact, the luminous phenomena, according to the theory of undulations, depend on the vibrations of the molecules of the illuminating body, which are transmitted to the retina by the intermediation of the æther, the molecules of which are

* See also Annales de Chimie, November, 1843, for an extended memoir by the same author, and Appendix, No. 3.

themselves in vibration. Fresnel, whose beautiful investigations have contributed to the triumph of this theory, had stated that the chemical effects produced by the influence of Light, are owing to a mechanical action exerted by the molecules of æther on the atoms of bodies, so as to cause them to assume new states of equilibrium, dependent on the nature and on the velocity of the vibrations to which they are subjected. This idea had been suggested to him by a remarkable experiment of M. Arago, the result of which was to show, that the chemical rays which influence the chloride of silver, interfere in the same manner as the luminous rays. (See Frontispiece, last figure.) I think that the hypothesis of Fresnel is accurate, and even that it may be extended further, especially if we consider that the chemical and phosphorogenic rays possess the same physical properties as the luminous rays; thus they are subjected to the physical laws of reflection, of double refraction, of polarization, and of interference, in the same manner as are these rays; and, moreover, the spectra of these different radiations have the same lines. Thus, it would be more simple to suppose—

" 1st, That a pencil of solar rays is the union of an infinite number of rays of different refrangibility, each ray arising from undulations of æther, not having the same velocity.

" 2dly, That, by refracting a pencil of solar rays through a prism, we have the solar spectrum which possesses different properties, on account of its different action on external bodies.

" 3dly, That, with respect to certain substances, the molecules of which are united by weak affinities, such as salts of silver, of gold, of mercury, &c. The solar rays act according to the velocities of undulation, which may be transmitted to the molecules of matter, and consequently between certain limits of refrangibility. I have called the whole of the rays which affect a substance a *chemical spectrum*.

"4thly, That phosphorescent bodies becoming luminous by means of the molecular movement impressed on their molecules, a movement which gives rise to the separation of the two electricities, necessary for maintaining the molecular equilibrium, and the neutralization of which forms the flashes we observe, we may consider the action of the solar rays on these bodies, as analogous to that of these rays on bodies chemically sensible, with this difference only, that the mechanical action of the molecules of æther is transmitted to these bodies without chemical decomposition. According to their nature, therefore, these phosphorescent substances are sensible between certain limits of refrangibility, in the solar spectrum.

"5thly, Besides, if we consider the retina as an organ which perceives the vibrations of the æther, it is only sensible to rays contained between certain limits of refrangibility, and the active rays form a spectrum, which in this case, is found to be the luminous spectrum.

"According to this hypothesis, we shall bring back all the effects produced under the influence of Light, to the action of one same radiation upon different bodies, and there will be as many spectra, as there are sensible substances. This mode of viewing the subject is verified on all the phosphorescent bodies, and on those whose molecular state changes under the action of the solar rays. As to the luminous rays, or those which act upon the retina, we can only judge of them by our own sensations; but it is probable, that the retina of the different beings which exist on the surface of the globe, are not all sensible between the same limits of refrangibility. We have some examples of this; amongst others of fish which live in the depths of the sea; and which see how to find their way where none of the rays which would be perceptible to our organs penetrate."*

(421.) In the drawing which I have given of the fixed lines of the spectrum (Frontispiece), the great lines only of the luminous portion are represented. By forming a spectrum on a Daguerreotype plate, M. E. Becquerel discovered the same lines in the chemical impression, and similar ones formed over the parts acted upon by the obscure rays. A very broad line is formed at I by the union of many smaller lines. After it, at M Y, four other lines are formed; and at N, four others. There are at O two great lines, and another at P, which is very strong and black. A great number of others are formed, and many of them represented in the plate attached to M. E. Becquerel's memoir, but I have not thought it necessary to represent them. It is upon the strength of the fact of the existence of these inactive spaces in the "chemical," as well as in the "luminous," spectrum, that Becquerel inclines to the above views.

(422.) M. Arago, it appears, first suggested to M. E. Becquerel these inquiries, and also some others connected with the action of the rays of the spectrum on the same body placed in different media—say *air* and *water*. It was not found that any difference was produced by either of these media. The fixed lines were the same in each, although the velocity of Light is much quicker in water than in air. On this M. Arago remarks,—"The velocity with which a luminous ray *passes through* a given body, depends exclusively on the refringency of this body, and on the *velocity of emission of the ray*, on the velocity it had *in vacuo*. The ray which reached the surface of the stratum of iodine

* See Appendix, No. 3.

through the water at the point where it meets this surface, possesses a velocity superior to that which the ray that moved through the air had at the same point; but *in the interior itself of the stratum*, at a sufficient depth, the two rays possess exactly the same velocity. Let us make the photogenic phenomena depend not upon an action exerted at the surface, but upon an action originating in the interior of the stratum, and every difficulty disappears; only—a single result—we are compelled to establish an essential distinction between the interior and the surface of a stratum, the thickness of which is incredibly small."

(423.) I have now given the hypotheses of M. E. Becquerel and M. Arago, which both lead to the conclusion, that the chemical influences of the solar rays are one of the phenomena of Light. If we admit the necessity of referring chemical changes to the theory of undulations, nothing can be more satisfactory than the explanation which these views afford. But although this ably supported theory has explained in a most facile manner the phenomena of interference, it does not appear to me, that it assists us in the least in the elucidation of the very remarkable class of phenomena we have been considering. That the fixed lines, by whatever cause produced, should be found to be the same in the spectrum impressed on iodized plates, and in the luminous image, is not surprising. Another element may come with Light, obeying the same physical laws, of reflexion, refraction, &c., but which may be essentially different in many of its important principles. Indeed, to adopt M. Arago's own words, "It is by no means proved that the photogenic modifications of sensitive substances result from the action of solar light itself. These modifications are perhaps engendered by invisible radiations, mixed with Light, properly so called, proceeding with it, and being similarly refracted. In this case the experiment would prove, not only that the spectrum formed by these invisible rays is not continuous, that there are solutions of continuity as in the visible spectrum, but also that in the two superposed spectra these solutions *correspond exactly*."

I incline to the opinion that it is proved that these chemical and molecular changes which we have been considering, are not formed by LIGHT, but that they are produced by the influence of the invisible radiations of another power which always accompanies it. This position it will now be my endeavour to prove.

CHAP. II.

IS THE CHEMICAL PRINCIPLE OF THE SUN'S RAYS A NEW ELEMENT?

(424.) THE experimental results of M. Melloni on radiant Heat, particularly the separation of the Heat rays from the Light rays, have been thought sufficiently conclusive to establish these two elements as principles broadly distinguished from each other. I certainly incline to the view that the imponderable elements with which we are acquainted will eventually, by the great advance of experimental philosophy, be proved to be but modifications of one all-pervading principle. But it would be a most unphilosophical proceeding to declare at once the identity of Light, Heat, and Electricity. There is much in common amongst them. Electricity developes both Heat and Light: Heat appears capable of being almost transformed into Light and Electricity, and

Light appears frequently naturally associated with Heat, and in all probability it has the power of imparting Electricity to bodies. These elements do indeed seem to be resolvable into one another. But until we can prove them to be identical, we must regard them as distinct agents.

(425.) If we pass the sun-beams through a deep yellow glass, or, which is still better, a solution of the sulphate of chromium, we rob them of but very little of their Light or Heat; but it will be found that they are deprived of the greatest part of their chemical influence. Sensitive papers may be exposed behind such a glass or such a fluid for a considerable length of time without undergoing any change.

(426.) An instance of the intense power of pale yellow media is the following: Dalton's solution of quadro-sulphuret of lime, prepared by boiling lime and sulphur in plenty of water, "scarcely seems to impair the brightness of white objects seen through it in thicknesses of an inch or two."

The spectral image, passed through such a fluid, exhibited but "small apparent loss of illuminative power;" "*but its total photographic effect must have been diminished, by the loss of at least four-fifths of its amount.*" (Herschel.)

(427.) A coloured atmosphere acts in the same manner. The case mentioned by Sir John Herschel in his Memoir "On the Chemical Action of the Rays of the Solar Spectrum," which I will quote, is to the point:—"It is probable that other atmospheric relations than those which refer to the extinction of the merely luminous rays are concerned in this phenomena. The tint of coal smoke is yellow (as may be seen in perfection in a London November fog), and more than one instance of the *intense power* and capricious singularities of very pale yellow media in their action on the *chemical rays* will come hereafter under our notice. In the locality from which this paper is dated (Slough), a light easterly wind brings with it abundant smoky haze from London, to which rural prejudices assign the name of 'blight,' and attribute an insect origin. *On such occasions, when the sky has been otherwise cloudless, I have been continually at once annoyed and surprised by the slowness of photographic action, and by the fugitive nature of its results under the process of fixing.*"

(428.) The power which chlorine gas, diluted with common air, has of absorbing this chemical principle is very great. Although so pale a yellow is the mixture, it does not appear that there is any actual loss of Light, by the interposition of a vessel thus filled, over that which would occur with a bottle of common air: it will be found that the influence producing chemical change is absorbed in a remarkable manner, and photographic preparations of the most sensitive kinds, change with the utmost slowness, behind even this pale yellow gaseous medium.

(429.) At the Cork meeting of the British Association a paper from Dr. Draper was read, detailing the following experiment, which is interesting:—Within a very large vessel, filled with a mixture of chlorine and hydrogen, was placed a small one filled with the same gaseous mixture; and this arrangement was exposed to the sunshine. Of course the gases in the outer vessel speedily combined, and the vessel was filled with the vapour of muriatic acid; but the gases in the interior vessel, although Dr. Draper has shown that an exceedingly small influence will occasion them to combine, were found to be unaffected. The atmosphere surrounding this inner vessel had, although allowing the passage of a flood of Light, separated the chemical principle, which alone had the power of inducing the combination.

(430.) It has been observed by Daguerre, and almost by every photographist since the announcement of his discovery, that the sun two hours after it has passed the meridian, is much less effective in the photographic processes, than it is two hours previously to its having reached that point. May not this depend upon an absorptive power of the air, which we may reasonably suppose to be more charged with vapour two hours after, than two hours before, noon?

(431.) If, on the contrary, we take a considerable thickness of a dense purple fluid, as, for instance, a solution of the ammonia-sulphate of copper, we shall find that the quantity of Light is considerably diminished — at least four-fifths of the luminous rays are absorbed; but the so-called "chemical rays" permeate it with the greatest facility, and sensitive preparations are effected by this influence, notwithstanding the deficiency of Light, nearly as powerfully as if exposed to the undecomposed sunbeams. Those deep blue glasses which are coloured with cobalt, and which are commonly used for finger glasses, have nearly the same effect of obstructing LIGHT, but allowing the free passage of this principle which accompanies it.

(432.) In the valuable paper to which I have already several times referred, Sir John Herschel mentions the curious property of the muriate of chromium, "which reduces the spectrum to two narrow and pretty well defined spaces, coloured the one red and the other green, the red being that of the extremity of the spectrum, and the green of great purity and richness of tint." On photographic papers this analysed spectrum impresses two circular spots, whose centres coincide with those coloured images exactly in the green, and nearly so in the red: one spot is intensely black, and the other white. The same authority has also proved that a preparation of the colouring matter archil — the rocellate of potash — admits the permeation of a great quantity of green light; "such as, had its properties not been altered by the medium it had traversed, could not have failed in the time the exposure lasted to have produced a considerable blackening of the paper," which was however unchanged over the green luminous spaces. These experiments are very illustrative: they show the existence of a chemical principle in the region, but at the same time quite independent of the colour of the ray.

(433.) If we examine the photographic images impressed by the spectrum itself, as represented in the plate, or any other series, it will be seen that the

luminous rays occupy but a very small space compared with the influences of heat and chemical power.

If the linear measure, or the diameter of a circle which shall include the luminous rays, is 25, that of the calorific spectrum will be 42.10, and of the chemical spectrum 55.10. Such a series of circles may well be used to represent a beam from the sun, which may be regarded as an atom of *Light* surrounded with an invisible atmosphere of *Heat*, and another still more extended, which possesses the remarkable property of producing chemical and molecular change.

(434.) We may regard the center or maximum of this power as situated somewhere about the most refrangible blue or the lower edge of the indigo ray, the shifting of this point, as we vary the materials, preventing us from fixing the spot with precision. Towards the most refrangible end of the spectrum we find, as might be expected, the power slowly diminishing in force with the most perfect regularity, until at a certain point, even the *most sensitive* preparations can detect no chemical action. On the contrary, as we approach the most luminous rays, the action is abruptly stopped, the light-giving power has interfered with the chemical power, and in a great many cases all action ceases at this point. In some others this point, where the effect of Light is the greatest, having been past, the chemical power is again exerted, and a similar interference is, in some cases, strikingly shown by the maximum calorific rays, although we have abundant evidence of a chemical principle extending far into that invisible region of the spectrum.

(435.) If the separation of the rays of Heat and the rays of Light from each other by absorbent media, and the difference in the effects produced by these elements is sufficient to mark their distinct characters, and to fix them as separate elements, surely the experiments which have been given, and which might be very considerably multiplied if it were necessary, are quite enough to mark in a still more decided manner the existence of this chemical principle in perfect independence of Light or Heat, and indeed to establish the existence of a *fourth imponderable element.*

(436.) Although it is necessary to regard this principle as an independent one, yet it must be remembered that it appears to associate most intimately with Light, and is guided by the same laws. It is reflected and refracted in the same way as Light, and it is capable of being in like manner polarised, as has been proved by M. Arago, M. J. E. Bérard, Dr. Sutherland, and myself. Dr. Sutherland has published in the "Philosophical Magazine" for July, 1841, a very complete investigation of this subject, in which he explains the methods he employed. He succeeded in polarizing these rays, 1st. As they proceed directly from the sun; 2d. as they exist at the extreme violet end of the spectrum; 3d. as they fall from the sky; and by three different processes, double refraction, reflexion, and repeated single refraction. To this valuable paper I must refer those readers who may desire further information on this point. During the summer of 1842, I had the advantage of using a very large polariscope, constructed on the principle devised by Mr. Goddard, and capable of exhibiting all the phenomena of polarization to large assemblies; and with it I was quite successful in producing all the results which are described by Dr. Sutherland in a very striking manner, not only by sunlight and diffused daylight, but by the artificial Light formed by throwing mixed oxygen and hydrogen on a ball of lime.

(437.) It must be evident to every one who will attentively consider the question, that the researches which have been pursued by various experimentalists during the last three or four years, have materially modified the views which were entertained of the conditions of the solar spectrum. Sir John Herschel admits the three classes of phenomena to be distinct from each other, and all the researches of Becquerel, of Moser, of Draper, and others, have led to the same conclusion. It is true that Becquerel has sought to give another explanation to the phenomena he has discovered, and is now inclined to regard this chemical power as nothing more than the modified influences of Light. The weight of evidence is greatly in favour of the position I have maintained, and, until this element and Light are proved to be identical, they must be regarded as separate; and it is essential that it should be distinguished by a characteristic name.

(438.) Dr. Draper, as I have previously mentioned, has proposed a name, which is so purely imaginary and inexpressive, that it can never be generally adopted. "Every physical science," writes Lavoisier, "is necessarily formed of three things — the series of facts which constitute the science, the ideas which call them to mind, the words which express them. *The word should give birth to the idea, the idea depict the fact: they are three impressions of one seal.*" With these conditions scientific men have almost always complied, and we must not depart from them in the present instance. It is no easy matter to suggest a name at once philosophically expressive and philologically correct. The greatest difficulty arises from our limited knowledge of the origin of the power and of its principle. We find that certain chemical compounds undergo a very decided change of state when exposed to the solar rays. In some instances decomposition is produced, in others combination is effected. We also learn by experiment that the principle regulating chemical affinities is very decidedly influenced by Heat, whether derived from natural or from artificial sources; and in many respects the resulting phenomena are similar. It has also been shown, particularly in the elaborate and beautiful researches of Dr. Faraday, that Electricity is most energetic in bringing about changes in elementary combinations. Indeed it must be admitted, that a very remarkable analogy exists between the operations of Light, Heat, and Electricity.* By the examination which we have given to the power emanating from the sun, it would appear that the agent which is concerned in bringing about chemical change is not the agent which produces Light; and although we see that similar effects may be produced by Heat and Electricity, yet as the phenomena in general belong to a different class, and are in their mode of operation broadly distinguished, it does appear necessary to mark this principle by some peculiar epithet, to prevent a confusion of ideas. The propriety of distinguishing this principle by a name at all, has been questioned by several natural philosophers, whose opinions are of great value. There are others, and amongst them we must reckon M. E. Becquerel, who regard the phenomena connected with the solar emanations as due to the same agent. He concludes his Memoire "On the Effects produced upon Bodies by the Solar Rays" in these words: — "Dans le courant de ce Mémoire, j'ai employé les noms de rayons lumineux, chimiques, et phosphorogéniques, pour désigner, dans chaque cas, la portion des rayons solaires qui agit pour produire, en particulier, les effets lumineux, chimiques, et phosphorogéniques; mais cela sans préjudice de l'opinion

* See Appendix, No. 4.

que je viens de mettre touchant l'existence d'un seul et même rayonnement. J'ai même dû d'abord supposer ces rayonnements des agents distincts, afin de montrer leur dépendance mutuelle, et d'arriver en suite à la conclusion que je viens d'énoncer. On peut donc, pour simplifier la description des phénomènes, continuer à se servir de ces noms, rayons lumineux, chimiques, phosphorogéniques, sans attacher plus d'importance qu'il n'en faut aux mots qui désignent des parties différentes d'un même agent." * The very industrious experimentalist arrives at this conclusion from the fact — of great interest in itself — that the dark bands of the luminous spectrum exactly coincide with the inactive spaces of the chemical and phosphorogenic spectra; but this, it appears to me, proves nothing more than the dependence of these principles upon similar laws.

(439.) Light, Heat, and Photographic power, are, beyond all doubt, three distinct classes of phenomena. Now, the science of Optics has its nomenclature well confirmed by established use. The science of Thermotics †, or of Thermochroology ‡, is also considered of sufficient importance to have its nomenclature; and M. Melloni, in a paper published in the "Bibliothèque Universelle de Génève," October, 1841, has entered very fully into the matter. It is therefore essential to the successful prosecution of our inquiries, that the third class of phenomena, which we have been particularly engaged in the consideration of, should have a term by which it might be distinguished. Sir John Herschel, in his memoir "On the Chemical Action of the Rays of the Solar Spectrum," uses the epithet *Actinograph* to indicate an

* Annales de Chimie et de Physique, Nov. 1843.
† Whewell. ‡ Melloni.

instrument of a very ingenious kind, devised by him for registering the different degrees of chemical power, accompanying the solar Light during the day. M. E. Becquerel also uses *actinomètre* as the name of an arrangement for measuring the amount of electro-chemical action induced by the chemical principle of the solar rays. We might, therefore, upon the strength of these authorities, adopt the substantive ἀκτιν (ray), and give some compound term formed from this radical to indicate this principle accompanying the other solar rays. There is, it must be admitted, some difficulty involved in the adoption of such a term as it will apply to any radiant power, whether Light, Heat, or Photographic energy. Several terms have suggested themselves, but they have been, all of them, open to some great objections. One epithet (Helioplaston), which I was strongly inclined to adopt, I have abandoned, as it would imply a material agent, and also indicate rather a moulding into form, than a change of condition. I should, therefore, prefer an expression which might sufficiently express some one characteristic feature of this principle, and thus distinguish it from Light and Heat without involving any kind of hypothesis. Might we not then, with strict propriety, regarding this principle as the sun's *energetic* power working in and producing change in bodies, adopt such a term as ενεργημα, ENERGEMA, energy; or, slightly modifying it, use such a coinage as ENERGIA, which is capable of being readily adapted to all the combinations we are likely to require. If it was thought desirable to connect this name with the substantive *ray* for the purpose of expressing its origin more clearly, we might use ACTENERGIA; but it appears to me the whole subject would be kept more distinct and clear by the application of the epithet ENERGIA, simply to distinguish the principle without involving it in any way with its solar source, or its radiant character.

(440.) LIGHT, HEAT, and ENERGIA, for it is necessary to recapitulate, are the three principles (or the modifications of an elementary first principle) detected in the solar rays. The first, acting upon the organs of vision, and enabling us to distinguish external objects, and giving colour to all. The second is that principle which regulates the solid, liquid, or gaseous states of matter, and which maintains this planet in the condition which is essential to the well-being of its inhabitants. And the third, ENERGIA, that power which effects all the changes, whether chemical or molecular, which are constantly in progress; it is that agent which is for ever quickening all the elements of growth, and maintaining the conditions of a healthful vitality; and it is no less energetically employed in the processes of corruption, which, indeed, are no other than the necessary changes of matter in its progress from one state of organization to another.

(441.) Melloni and M. E. Becquerel have both suggested the probability that the solar rays are but one principle—Light; and that, as they are received upon bodies differently constituted, they produce the phenomena of Colour and Vision, of Heat, or Chemical Action. Melloni has, indeed, endeavoured to explain all the phenomena of photographic action, and the peculiar influence of the dissevered rays of the prismatic spectrum upon different preparations, upon the supposition that all bodies, even those which are the most colourless, possess, what he calls, a *chemical colouration*. (419.) For example: if a sheet spread with the chloride of silver is exposed to the spectrum, we find that the greatest action takes place over the space on which the *blue rays* fall (58.); whence it is argued, from a supposed analogy between the effects which would be produced if the spectrum was thrown upon a piece of blue cloth, in which case the blue ray would be exalted, that the *chemical colour* of the white chloride of silver is chiefly blue. This system of reasoning is extended to all the chemical compounds, which are known to undergo change of state by the influence of the solar power; and it is also used to explain the phenomena of absorption by colourless transparent fluids. It must be admitted that the memoir in which this philosopher sets forth his views, is one of extraordinary excellence; but, although it will explain many of the phenomena, we have not a single fact which can be brought in support, otherwise than analogically, of this hypothetical view. Becquerel founds his assumption, as I have already stated, on the fact of the correspondence of the fixed lines detected in the different spectra. This fact does not appear to bear upon the argument. We already know that the physical properties of Heat and Light are similar—that they can be similarly reflected, refracted, and polarized; and the same applies to the chemical principle: but it is not, therefore, contended that we have arrived at such conclusions as would warrant our determining the identity of all the phenomena of Heat and Light. I do not mean to deny the possibility of their being modifications of some all-pervading principle, with which our researches have not, owing to their want of refinement, made us acquainted. The philosophy of chemistry teaches us to regard those bodies as elementary, which do not admit of decomposition. But it at the same time imposes upon us the necessity of abandoning the idea, that the solar radiations are a single independent element, when we can resolve them into three independent orders of phenomena. We now reckon three imponderable elements, Light, Heat, and Electricity. Now, are we not bound by the principles which guide us in every step of the inductive system, to add to these a fourth—ENERGIA?

By more refined experiments, we may eventually determine the existence of a principle, upon which the phenomena connected with some of these elements may depend, and we shall then be compelled to abandon the idea and name, which argues a separate existence. Is it not probable that the principle ENERGIA, which has been shown to be capable of producing some of the most extraordinary and unexpected changes in the state and structure of solid bodies, may be a superior element, of which some one of the imponderable powers is but a modification? A few more facts may be adduced in support of the independence of Light and Energia.

(442.) When M. Arago made his "Report on the Daguerreotype," before the Chamber of Deputies in 1839, he used these words—"Upon examining several of the pictures to be submitted for your inspection, all will consider the immense advantages which would have been derived, during the expedition to Egypt for example, of a means of reproduction, so exact and so rapid; all will be struck with this reflection that, if Photography had been known in 1798, we should this day have possessed faithful representations of many valuable antiquities now, through the cupidity of the Arabs and the vandalism of certain travellers, lost for ever to the learned world." Now, this hope has not been entirely fulfilled. It was of course imagined that, under the brilliant sun and clear skies of the south, photographic pictures would be produced with much greater quickness than they could be in the atmosphere of Paris. It is found however that a much longer time is required. Even in the clear and beautiful light of the higher Alps, it has been proved that the production of a photographic picture requires many minutes more, even with the most sensitive preparations, than it does in London. It has also been found that, under the influence of the brilliant light of Mexico, twenty minutes, and half an hour, are required to produce effects, which in England would occupy but a minute; and travellers engaged in copying the antiquities of Yucatan have on several occasions abandoned the use of the photographic camera, and taken to their sketch-books. Dr. Draper has observed a similar difference between the chemical action of the light in New York and in Virginia. This can only be explained on the supposition that the intensity of the Light and Heat of those climes interferes with the action of the ENERGIC rays on these sensitive preparations which are employed. Dr. Draper furnished a prismatic image, impressed upon a Daguerreotype plate in Virginia, which exhibits some remarkable peculiarities, it has been described in a previous chapter (123.). Nothing could be more valuable than a series of such spectral pictures, produced in different degrees of latitude, and at different elevations. It would be very easy to procure them from our magnetic observatories in different parts of the world, and these would afford much valuable information on this point. Captain Sir E. Belcher of the Samarang, was furnished with very complete Daguerreotype and Calotype apparatus; the value of these in such an expedition must be exceedingly great. I endeavoured to impress upon Sir E. Belcher, the valuable assistance he would render to science by procuring, at different places in the progress of his voyage, impressions of the prismatic spectrum; and I hope, on the return of the Samarang to England, we shall find that some such have been obtained by her scientific commander, or some of his talented officers.

In the last Memoir of M. E. Becquerel, the conditions of the prismatic spectra, impressed upon various materials at Paris, are given with much minuteness; and an engraving accompanies the memoir, in which most of the spectra described are represented. In this series the maxima are found in the violet and indigo spaces, and the blue ray appears in all cases to produce a minimum effect, or nearly so. Now, all Sir John Herschel's, Draper's, and my own experiments give a high maximum to the chemical influence of the blue ray. Are these differences due to some peculiar atmospheric absorption, arising from geographical position, or are they dependent on some peculiarities in the prisms employed, or on the manner of performing the experiments?

(443.) The Roman astronomers state that they have procured Daguerreotype impressions of the Nebula of the Sword of Orion. Signor Rondoni has a secret method of receiving photographic images on a lithographic stone: on such a prepared stone they have succeeded in impressing an image of the Nebula and its stars; and "from that stone they have been able to take impressions upon paper, unlimited in number, of singular beauty, and of perfect precision; each star, each filmy nebulous streak, faithfully depicting its own position." Professor Robinson, of Armagh, stated at a meeting of the British Association at Cork, that he was led by the report of these experiments to endeavour to procure a Daguerreotype impression of the moon's surface. A portion of the disc of the moon was brought within the range of a powerful reflecting telescope, at which time the Crater of Copernicus was in active operation, and giving out a most intense Light. This brilliant image was thrown upon a Daguerreotype plate, which was placed in the focus of the reflector, and left exposed to its action for twenty minutes. Although a good impression of a building could be procured upon plates similarly prepared in a minute, yet this prolonged exposure to this Light produced no impression. The experiments of Forbes have shown that no heating power exists in the moon's rays; and this experiment of Dr. Robinson proves, in the first place, that lunar LIGHT will not act chemically upon the ioduret of silver, and in the next that it is not combined with that chemically active principle which I have called Energia, and which exists, according to Signor de Vico, in the rays of the remote stars which form the Nebula of Orion's Sword and of Andromeda.

CHAP. III.

ON THE PROBABILITY OF PRODUCING COLOURED PICTURES BY THE SOLAR RADIATIONS.

(444.) M. BIOT, in 1840, speaking of Mr. Fox Talbot's beautiful calotype pictures, considers as an illusion "the hope to reconcile, not only the intensity but the tints of the chemical impressions produced by radiations, with the colours of the object from which these radiations emanate." It is true three years have passed away, and we have not yet produced coloured images; yet I am not inclined to consider the hope as so entirely illusive.

(445.) It must be remembered that the colour of bodies depends entirely upon the arrangement of their molecules. We have numerous very beautiful experiments in proof of this. The biniodide of mercury is a fine scarlet when it is precipitated. If this precipitate is heated between plates of glass, it is converted into crystals of a fine sulphur yellow, which remain of that colour if left undisturbed, but which become very speedily scarlet if touched with any pointed instrument. This very curious optical phenomena has been investigated by Mr. Fox Talbot and by Mr. Warrington. Perfectly dry sulphate of copper is white; the slightest moisture turns it blue. Muriate of cobalt is of a pale pink colour, a very slight heat, by removing a little moisture, changes it to a green. These are a few instances selected from many which might be given.

(446.) If we receive a prismatic spectrum on some sensitive papers, we have evidence that the molecular or chemical disturbance bears some relation to the colour of each ray, or, in other words, that coloured Light so modifies the action of Energia, that the impression it makes is in proportion to the colour of the Light it accompanies, and hence there results a molecular arrangement capable of reflecting colours differently. In the preceding pages, some instances have been given in which the rays impressed, corresponded with the colours of the luminous rays in a very remarkable manner. One of the most decided cases is that of the paper prepared with the fluoride of soda and nitrate of silver. (138.) Sir John Herschel was, however, the first to obtain any good specimens of photographically impressed prismatic colourations.

(447.) It was noticed by Daguerre that a red house gave a reddish image on his iodized silver plate in the camera obscura; and Mr. Fox Talbot observed, very early in his researches, that the red of a coloured print was copied of a red colour, on paper spread with chloride of silver.

(448.) In 1840 I communicated to Sir John Herschel some very curious results obtained by the use of coloured media, which he did me the honour of publishing in one of his memoirs on the subject, from which I again copy it.

A paper prepared by washing with muriate of barytes and nitrate of silver, allowed to darken whilst wet in the sunshine to a chocolate colour, was placed under a frame containing a red, a yellow, a green, and a blue glass. After a week's exposure to diffused Light, it became red under the red glass, a dirty yellow under the yellow glass, a dark green under the green, and a light olive under the blue.

The above paper, washed with a solution of a salt of iodine, is very sensitive to Light, and gives a beautiful picture. A picture thus taken was placed beneath the above four glasses, and another beneath four flat bottles containing coloured fluids. In a few days, under the red glass and fluid, the picture became a dark blue, under the yellow a light blue, under the green it remained unchanged, whilst under the blue it became a rose red, which in about three weeks changed into green. Many other experiments of a similar nature have been tried since that time with like results.

(449.) In the summer of 1843, when engaged in some experiments on papers prepared according to the principles of Mr. Fox Talbot's calotype, I had placed in a camera obscura a paper prepared with the bromide of silver and gallic acid. The camera embraced a picture of a clear blue sky, stucco-fronted houses, and a green field. The paper was unavoidably exposed for a longer period than was intended—about fifteen minutes;—a very beautiful picture was impressed, which, when held between the eye and the light, exhibited a curious order of colours. The sky was of a crimson hue, the houses of a slaty blue, and the green fields of a brick red tint. Surely these results appear to encourage the hope, that we may eventually arrive at a process, by which external nature may be made to impress its images on prepared surfaces, in all the beauty of their native colouration.

CONCLUSION.

(450.) All the experimental evidence connected with the chemical powers exerted by the solar rays which has been gained up to the present time, has now been given, and I feel certain that, notwithstanding the very great progress which has been made in this inquiry during the last three years, the present volume must, in a short time, become merely a record of the stages by which one of the mightiest truths of nature has been revealed. Setting aside the curious and beautiful applications of the solar power in the production of pictures drawn with unerring fidelity, let us consider the conclusions to which the details I have given will lead us.

(451.) It is now established that the sun's rays cannot fall upon any body without producing a molecular disturbance, or a chemical change. Wherever a shadow falls, a picture is impressed. It matters not, whether the material which receives the images be one of these chemical compounds which are so susceptible of change, or a plate of metal, or a block of stone. The surfaces of all material things are constantly, under the influences of sunshine, undergoing a mysterious change, which is communicated by molecular vibrations to the entire mass, and new conditions established, which, with all the powers of chemistry, we cannot yet follow.

(452.) The influence of this power on the vegetable kingdom is strikingly evident, and we are now enabled to trace nearly all the functions of the plant up to the operations of a principle which appears to have its origin in the sun.

Is it not also evident that the condition of the animal kingdom is not merely influenced, but dependent for health and vigour on this solar power?

(453.) Where the influence which accompanies each ray of Light can penetrate, there we find organisation and life. In those abysses to which it cannot reach, is an eternal blankness. Even in the pellucid ocean, we find, at no very considerable depth, where the faint gleam of Light is dying into darkness, a few animals, and these few of the lowest order of organization, and colourless. Below this region, neither vegetable nor animal is found. As we ascend toward the surface of the sea, distinct zones of animal and vegetable life present themselves, each differing from the other; those of the superior zone being higher in the scale of organization and of brighter colour than those immediately beneath it; whilst near the surface of the sea the most exquisitely developed forms exist, adorned with all the beauty of prismatic colouration.

(454.) Even on the surface of the globe the influence of the sun is shown in the most marked manner. The animals and the plants of the tropical climes glow with the richness of colour; those of the temperate zones are of a duskier hue; whilst in the arctic regions we find them nearly colourless. The races of men are characteristic of the clime in which they are found, not in colour merely, but in physical power, in animal passions, and in mental energy. It has been asked, and the question is deserving the attention of the physiologist—Is not the short-lived beauty of the Oriental women to be attributed to the influence of that sun

"Shining on, shining on, by no shadow made tender,"

which, we well know, gives all the grandeur and beauty to the vegetable world of the East.

(455.) It will not be denied by any one, that the sun's rays have a quickening, an almost life-kindling, power. The fable of Prometheus, says Lavoisier, was the expression of a philosophic truth. To which then of those principles, which we have detected in the sunbeam, are we to ascribe this influence? Is it to Light, to Heat, or to ENERGIA, or whatever else we may call it, that we are to attribute all the great phenomena of creation which appear to be dependent on the solar emanations? The accumulated evidence would seem to show, that all those great changes, which we have been considering, are the result of this mysterious and most energetic power; that to it almost every phenomenon connected with the growth of plants is to be traced; that the animal kingdom is most powerfully influenced by it; and that all those chemical changes, which have been attributed to Light, are due to ENERGIA.

(456.) There are several questions of the greatest importance which remain for the investigation of philosophers. Amongst them it would appear, that the most important are the following:—

Is ENERGIA absorbed by material bodies? Does it influence their internal constitution? Is it radiated from bodies in the dark, or at all concerned in the production of any of those changes which have been attributed to dark rays? And, lastly, is this power at all connected with the production of the phenomena of Electricity?

(457.) To investigate this subject, a patient perseverance in the accumulation of facts is the greatest requirement. At present the question is involved in much obscurity; but if we regard the elements of the solar rays as distinct in character, although mostly united in action, until we can prove them to be identical, we shall free it from a large amount of that complexity which has been thrown around it, by endeavouring to reconcile the chemical action of this force, ENERGIA, with the undulatory theory of LIGHT. New ground has been broken, and in pursuing our researches over it, we must be guided by the facts which we may discover, and study to interpret them, not with reference to any favourite theory, but by the reflections, which they may themselves give of the pure and holy Truth, which diffuses itself over all creation, and exhibits to the eye of the intelligent, the supreme order which is manifested in all the works of nature.

APPENDIX.

No. I.

HIMLY'S METHOD OF PREPARING THE PROTO- AND PER-CYANIDES OF POTASSIUM AND GOLD.

[*Referred to from page* 119.]

The Protocyanide of Potassium and Gold is best obtained by dissolving seven parts of pure gold in nitro-muriatic acid, precipitating with excess of ammonia, washing the fulminating gold that is formed, and then putting it into a hot solution of six parts of the cyanide of potassium in water. The liquid is decolorised and ammonia disengaged. From the concentrated solution the double salt crystallizes in beautiful prisms.

The Percyanide of Potassium and Gold is very easily obtained when thirty-five parts of gold are converted into chloride of gold, as neutral as possible, and the aqueous solution of that salt is united gradually with a hot solution of forty-six parts of cyanide of potassium. The liquid looses colour, and on cooling of the concentrated solution, the double salt separates, in large prisms, which, on exposure to the air, or in vacuum, become milk white, giving off their water of crystallization.

No. II.

ON THE "CHEMICAL RAYS," BY M. E. BECQUEREL.

[*Referred to from pages* 252. *and sequel.*]

The following extract from the memoir previously referred to will show the discrepancies in the results obtained by Becquérel in Paris, and those procured in England. Reference to the frontispiece will render the descriptions of M. E. Becquérel sufficiently clear: —

"Si l'on étend du chlorure d'argent sur du papier blanc, ou sur une surface quelconque, et qu'on l'expose dans le spectre, on voit, au bout d'un temps plus ou moins long, une réaction commencer vers l'extrême violet, entre les raies H et G de Fraünhoffer, et s'étendre d'un côté dans le spectre presque jusqu' en F dans le bleu, et de l'autre bien au delà du violet visible; mais si le chlorure d'argent, après avoir été préparé dans une chambre parfaitement obscure, est exposé pendant un temps très-court à la lumière diffuse ou solaire, mais de manière à ce qu'il ne soit pas noirci, mais qu'un três-faible commencement d'action ait en lieu, si on le place après dans le spectre, on voit non-seulement une colouration vers le violet extrême, mais encore une action se manifester en même temps dans la partie la moins réfrangible du spectre jusqu' au rouge extrême, de sorte que l'espace noirci se trouve dans toute l'étendue du spectre lumineux, et bien au delà du violet. D'après le mode d'action da la lumière, j'avais nommé les premiers rayons situés vers le violet *rayons excitateurs,* et les autres *rayons continuateurs,* parce qu'ils continuent une action chimique commencée sous l'influence des premiers. ——Ainsi, lorsque le chlorure a été primitivement un peu impressioné, l'étendue de la partie colorée se trouve depuis le rouge extrême, jusque bien au delà du violet, mais il y a deux maxima d'intensité d'action, l'un entre G et H, l'autre entre D et E, vers le jaune, et correspondant aux rayons continuateurs. — Si l'on emploie du bromure d'argent préparé par double précipitation au bien par double décomposition sur du papier en étendant un bromure soluble, puis du nitrate d'argent on obtient les mêmes effets, se ce n'est que l'action s'étende plus ou moins loin au delà du violet, et que les maxima ne sont peut-être pas aux mêmes places; mais s'il y a une différence, elle est très-faible. L'iodure d'argent, et en général presque tous les sels d'argent, éprouvent la même action de la part des rayons solaires; les plaques d'argent iodurées à la manière de M. Daguerre, et même rendues plus sensibles à l'aide du chlore et du brome, éprouvent les mêmes réactions, si ce n'est que les rayons excitateurs s'étendent un peu plus ou un peu moins loin; et même on a remarqué que les maxima changent un peu de place, de sorte qu'en employant telle on telle préparation d'argent, la position du maximum des rayons excitateurs n'est pas la même; mais ils sont généralement situés entre H et G, et entre D et E. * * * Si, au lieu de placer dans le spectre des papiers ou des surfaces enduites de matières impressionnables formées avec des sels d'argent, ou place un papier préparé avec du bichromate de potasse, alors, au bout de quelque temps, on voit une réaction commencer vers F à la limite du vert et du bleu, puis s'étendre d'un côté en E, et de l'autre au delà de H vers M, de sorte que le maximum a lieu vers E.

Si l'on emploie un papier enduit de résine de gaïac, on le voit bleuir au delà de H, le maximum étant vers M; si au contraire, on place dans le spectre du gaïac bleui à la lumière, alors le gaïac redevient blanc dans le spectre, depuis le rouge A jusqu' en H le maximum étant vers F.—(*Annales de Chimie et de Physique*, November 1843.)

No. III.

THE NON-EXISTENCE OF ANIMAL AND VEGETABLE LIFE IN THE DEPTHS OF THE OCEAN.

[*Referred to from page* 257.]

Professor Forbes of King's College, London, who was engaged during eighteen months on researches in the Ægean Sea and on the coasts of Asia Minor, during which time particular explorations of the sea bottom were made by means of the dredge, has defined the depths at which various species of animals and vegetables exist. He has proved by the decisive evidence of actual examination that, below the depth of thirty-five fathoms, the number of animals diminishes as we descend, until at the depth of about 200 fathoms the number of testacea was found to be only 8, and a zero in the distribution of animal life was indicated at probably about 300 fathoms. Green fuci were not found below 55 fathoms, and millepora not deeper than 105 fathoms. I am informed by my friend, Mr. Richard Couch of Polperro, who has exhibited the most indefatigable spirit in his researches around the south coast of Cornwall, that he has found the same law to be maintained over this portion of the British Channel.

Vegetable and animal life ceases at about the same depths as in the Ægean Sea. We may therefore infer that this condition is maintained, or nearly so, over every part of the ocean. Professor Forbes and Mr. Couch have, both of them, remarked that the vegetables and animals near the surface of the sea are brilliantly coloured, but that they gradually lose the brightness of their hues as they descend, until the animals of the lowest zone are found to be nearly colourless. Hence we see the dependence of marine animal and vegetable life upon the solar influences, to as great an extent as over the surface of the dry land. M. E. Becquérel's position is not a good one, and it affords us no evidence that any marine animal has the powers of vision under the influence of such rays of Light as would not excite the optic nerve of man. Organization and life exist only at the surface of our planet and under the influence of Light. Those depths of the ocean at which an everlasting darkness prevails is the region of silence and eternal death.

No. IV.

ON THE DISCOLORATION OF PHOTOGRAPHIC PAPERS BY ELECTRICITY, AND THE PRODUCTION OF ELECTOGRAPHS.

[*Referred to from page* 267.]

M. Aug. Pinaud has studied the action of static-electricity on the chloride, iodide, and bromide of silver, comparing it with the action of Light on the same bodies. A notice of these researches has appeared in the "Comptes Rendus." He has found that electricity proceeding from a point, whether positive or negative, imparted brilliant spots of a bluish colour to the ioduret of silver on a prepared daguerreotype plate, and by this means all sorts of figures can be traced upon it. M. Matteucci has shown that an instantaneous escape of electricity, without *visibly* affecting a silver plate, occasions on its surface a deep and lasting alteration, which is rendered evident by the condensation of the breath or any vapour on the plate. The vapour condenses around the part which has received the electricity, and tarnishes the metallic surface, but the points, which have been acted on by the electric fluid, remain bright. This fact serves to confirm the position I have maintained in opposition to Moser, that the condensation of vapours may be effected by other influences than Light. M. Pinaud exposed paper pasted on an insulated metallic plate and covered with dry bromide of silver to the action of electricity from a very fine metallic point electrized *negatively* by induction. Opposite the point a spot of a blackish brown colour is immediately formed. By passing the point over the paper any figure can be sketched out. The discoloration thus obtained has a deep brown shade like that produced by Light. If the metallic point touches the paper, the discoloration is then a deep black, and limited to the points which are touched; and the effect is that of a black lead pencil. Positive electricity does not appear to produce any effect upon the bromide of silver. On the nitrate of silver and the chloride the electric fluid effects but little change; iodide of silver on the contrary is, when spread over paper, readily changed by either positive or negative sparks. The negative spark forming a round black spot, the positive developing in all the filaments of the paper, amongst which it is diffused, a violet discoloration in a radiated form. If paper covered with the iodide of silver is placed upon the insulated stand of a universal discharger, and the spark of a highly-charged jar is passed from point to point along a distance of an inch or two, the trace of the spark is instantly impressed upon the paper by a reddish train, which records all its windings and sinuosities.

Another method adopted by M. Pinaud for obtaining electric pictures is, to place a sheet of dry iodized paper upon a spotted glass plate, and retain it by means of a glass plate slightly pressed against it. The discharge of a powerful Leyden jar is then passed along the metallic ribbon, and each space is marked by a spark, and spots are formed on the paper at all the corresponding points. The analogy between these phenomena and those produced by solar agency are striking, and they well deserve investigation.

No. V.

IMPROVEMENTS IN THE CALOTYPE PROCESS BY W. H. FOX TALBOT, ESQ.

These improvements, which have been secured by a second patent, consist of the following particulars: —

1. Removing the yellowish tint, which is occasioned by the iodide of silver, from the paper by plunging the picture into a hot bath composed of hyposulphite of soda dissolved in ten times its weight of water, and heated nearly to the boiling point. The picture should remain in the bath about ten minutes, and be then washed in warm water and dried.* After undergoing this operation, the picture is placed upon a hot iron, and wax melted into the pores of the paper to increase its transparency.

2. The calotype paper is rendered more sensitive by placing a warm iron behind it in the camera whilst the light is acting upon it.

3. The preparation of *io-gallic paper,* which is simply washing a sheet of iodized paper with gallic acid. In this state it will keep in a portfolio, and is rendered sensitive to the Light by washing it over with a solution of nitrate of silver.

4. Iodized paper is washed with a mixture of twenty-six parts of a saturated solution of gallic acid to one part of the solution of nitrate of silver ordinarily used. It can then be dried without fear of spoiling, may be kept a little time, and used without further preparation.

5. The improvement of photographic drawings, by exposing them twice the usual time to the action of sunlight. The shadows are thus rendered too dark, and the lights are not sufficiently white. The drawing is then washed and plunged into a bath of iodide of potassium, of the strength of 500 grains to each pint of water, and allowed to remain in it for one or two minutes,

* Sir John Herschel, in his "Memoir on the Chemical Action of the Rays of the Solar Spectrum, &c." Feb. 1840, recommends the use of *hot hyposulphite of soda* to fix photographic drawings which have been procured on the iodide or bromide of silver.

which makes the picture brighter, and its lights assume a pale yellow tint. After this it is washed, and immersed in a hot bath of hyposulphite of soda, until the pale yellow tint is removed, and the lights remain quite white. The pictures thus finished have a pleasing and peculiar effect.

6. The appearance of photographic pictures is improved by waxing them, and placing white or coloured paper behind them.

7. Enlarged copies of Daguerreotype and calotype portraits can be obtained by throwing magnified images of them, by means of lenses, upon calotype paper.

8. Photographic printing. A few pages of letter-press are printed on one side only of a sheet of paper, which is waxed, if thought necessary, and the letters are cut out and sorted; then in order to compose a new page, a sheet of white paper is ruled with straight lines, and the words are formed by cementing the separate letters in their proper order along the lines. A negative photographic copy is then taken, having white letters on a black ground; this is fixed, and any number of positive copies can be obtained. Another method proposed by the patentee, is to take a copy by the camera obscura from large letters painted on a white board.

9. Photographic publication. This claim of the patentee consists in making, first, good negative photographic drawings on papers prepared with salt and the ammonia-nitrate of silver; secondly, fixing them by the processes above described; thirdly, the formation of positive drawings from the negative copy and fixing.

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