THE SUNBEAM

AND

THE SPECTRASCOPE.

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NOTE.

For much of this Paper we must acknowledge our indebtedness to the work of Kirchoff, of the University of Heidelberg, *Researches on the Solar Spectrum and Spectra of Chemical Elements;* also, to an article in the *Edinburgh Review*, Oct., 1862, but particularly to an article on Solar Chemistry, by Robert Hunt, F. R. S., in the *Popular Science Review*, London, 1862.

The demonstrations to illustrate this Paper, were made by Dr. George F. Barker, Professor of Chemistry in the Albany Medical College, and the Spectrascope used was made for Henry Townsend Martin, Esq., of this city, by G. C. Hiscox, Philosophical Instrument Maker.

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Lavoisier has very beautifully said—

"The fable of Prometheus is but the overshadowing of a philosophic truth: Where there is light *there* is organization and life; but where light cannot penetrate *there* death forever holds his silent court."

If a sunbeam be allowed to enter a darkened room, it falls on the floor and forms a disc of bright light. This is radiated to the eye which conveys the impression to the brain, and the phenomenon of vision is established.

Should the hand be placed in the track of the sunbeam, the sensation of warmth is communicated, and we feel there is heat in the ray.

If a piece of paper covered over with chloride of silver, which is purely white, be placed so that the sunbeam falls upon it, a darkened track will be immediately produced over the space the sun's ray has passed, it has liberated the chlorine, leaving the metallic silver.

Such remarkable phenomena teach us that we have to deal with agencies in the solar rays, which are in their visible effects very dissimilar.

Actinism, which means *ray power*, is now the term adopted to express the chemical principle of the sunbeam.

That these three functions of the sunbeam—light, heat and actinism—all differ from one another, may be thus proven.

A piece of black mica will allow no *light* to pass through it, but offers no obstruction to *solar heat.*

A plate of glass, stained apple green with oxyde of copper,

is perfectly transparent to light, but opaque or impermeable to heat.

Glass which has been stained yellow with oxide or chloride of silver allows a flood of light to pass through it, but permits no permeation of an *Actinic* ray.

And on the contrary, if we use a glass colored deeply blue, with the oxide of cobalt, though but very little light can pass through it, experiment proves that it offers no obstruction to the chemical rays, that is, it permits the permeation of the Actinic ray.

This fact of yellow glass interfering with and intercepting the actinism of the sunbeam, has lately been taken advantage of in photography. The photographer no longer shuts himself and his prepared plate in a dark dungeon, for now the old dark chamber, camera oscura, is beautifully illumined by the sun's rays passing through yellow glass which effectually excludes the actinic, the chemical rays which alone the photographer dreads in this part of his process, but which allows all illuminating rays to be transmitted.

The strength of evidence appears to be in favor of considering light, heat and actinism as three distinct principles or powers, active in regulating the great phenomena of nature. These agents are unceasingly at work. It is impossible to expose any body, however solid and persistent it may appear, to the influence of sunshine, without its undergoing a molecular or chemical change. In darkness, all bodies appear to possess the power of restoring themselves to their normal state. Should the sun shine uninterruptedly upon a granite monolith or a bronze statue, it would perish independently of any other destructive influences.

Night seems as necessary to secure the permanence of the inorganic world as darkness and sleep are essential to maintain in healthful life the organized creations.

At the enormous distance of 95,000,000 miles from us is the sun, a great orb having a diameter of 882,000 miles,

forming the centre of the solar system. Not only is the earth and all the other planets chained to the sun by the attractive power of its rays, but their motions are determined by its motion, and the physical forces which regulate all cosmical phenomena, have their source within its body.

The sun is termed the fountain of light; it is equally the source of every other power with which science has made us acquainted.

Since the time when Newton analyzed the solar beam, the advance of our knowledge has been most rapid.

We are acquainted with luminous rays which had never been seen by Newton; and of actinism or the chemical power of the sumbeam, he knew nothing.

The beautiful phenomena of the polarization of light were unknown to him, and he had not the most remote idea of the existence of numerous *dark lines* crossing even the most brilliant divisions of the Newtonian spectrum, and which promise to advance our knowledge by the discovery of many sublime truths.

If we place a triangular prisum in the path of the sunbeam, the rays are bent out of their course or refracted, and by this means decomposed into a beautiful flamelike chromatic image. Now if this solar spectrum be received upon a screen, it will be found to consist of several colored bands; crimson, red and orange passing into yellow from the least refracted end, while from the most refrangible one we have lavender, violet, indigo blue and green also passing into yellow as they advance to the true centre of the spectral image.

These rays constitute the Newtonian spectrum, thus called because Newton was the first to examine with precision the relative condition of these colored bands, and to establish with any approach to correctness the laws regulating the relations of color and refraction. Anno, 1675.

Beyond the most refrangible end of this spectrum there exists another class of rays, which are not visible under

ordinary circumstances. If though the rays of light be intercepted by a solution of sulphate of quinine or of horse chestnut bark, or by a crystal of fluor spar, these extra spectral rays are rendered apparent. These rays, which were unknown to Newton, have been investigated by Prof. Stokes, who has named them the *fluorescent rays.*

They are luminous probably under all circumstances to those animals whose eyes are adjusted, as are the eyes of most of the night roaming creatures, to admit the rays of the highest refrangibility and to vibrate in unison with their vibrations; but unless peculiar conditions be established, the fluorescent rays are not sensible to the human eye.

Such, then, is the amount of our knowledge respecting the luminous principle of the sunbeam.

It must be remembered that these rays vary considerably in the intensity of their illuminating power. The maximum exists in the yellow ray, and it diminishes as we recede from it towards either end of the spectrum.

The least refrangible, or the red rays, give a modified amount of light, but the maximum of heat exists in them. The most refrangible or the blue end of the spectrum is less luminous, but the maximum of chemical action is fixed at this extremity. The fluorescent rays beyond the spectrum of Newton, being only visible under the peculiar circumstances already mentioned.

If now we examine these beautifully colored bands of light when well defined upon a screen, with a small telescope, a new set of phenomena will become apparent. The spectrum is then seen crossed by a number of *black lines.* Every ray, even the most brilliant, will be found to have spaces in which there is an entire absence of light.

It was Dr. Wollaston who first observed these non-luminous spaces in the prismatic spectrum. Fraunhöfer, however, was the first to make a full investigation of these lines and to publish a map of them, and they have hence generally been called Fraunhöfer's lines.

These lines are of so fixed a character in relation to the colored bands of the spectrum, that if it be desired to indicate with great precision any special ray of the spectrum we refer to them by their letters or numbers.

The origin of these *dark lines*, spaces in which there is no light, can scarcely be said to be yet resolved.

Fraunhöfer, and others following him, thought that the light emitted from the photosphere, was from the first deficient in these rays, or that they were lost either by absorption in passing through the solar atmosphere, or possibly in passing through that of the earth. The investigations of Bunsen and Kirchoff, remarkable alike for the delicacy and caution observed in the inquiry, and for the refined nature of their deductions, lead us probably up to the true explanation of these phenomena.

These investigations of Bunsen and Kirchoff, from their exceeding interest, have lately been attracting great attention.

Angstrom discovered many *bright lines* in the spectra, from artificial light. He and others have proved that spectra obtained from the light emitted from incandescent mineral bodies, differ from that obtained from the sun; that the lines from artificial sources of light are in many cases peculiar, and that in the majority of instances, bright lines appear to take their place. So rigidly exact were the positions and characters of the lines obtained from differently colored flames, that spectral or prismatic analysis has been adopted as a means of determining the presence of exceedingly minute quantities of any substance.

These lines, *dark* and bright, have not only been employed in the analysis of the solid mass of the sun, but also in ordinary analysis, and the extreme delicacy of the indications, is proved from the discovery by Bunsen of two new metalic bodies, one called *Cæsium*, meaning bluish gray, and the other *Rubidium*, from the Latin Rubidus, used to express the darkest red color which exists in infinite-

simally small quantities in some mineral waters of Germany. Bunsen discovered these two new alkaline metals in the mineral waters of Dürkheim in the Palatinate: in examining the spectra of the alkalies contained in these waters, he observed some bright lines which he had never seen in any other alkalies which he had investigated. He was sure that no other metals but those of the alkalies could be present, because by well known chemical processes he had separated every other kind of metal. Hence he concluded that these new lines indicated the presence of an alkaline metal whose existence has as yet been overlooked.

So certain was Bunsen of his method, and so confident was he that his bright lines could not fail him, that although the weight of the substance from which he obtained his result only amounted to the one thousandth part of a grain, he hesitated not a moment but began to evaporate 40 tons of the water, in order to get enough material to separate out his new metal and examine all its chemical relations.

No sooner had he obtained more than a mere trace of the new substance, than he found that with it was associated a second new metal. He got from the 40 tons in question only about 105 grains of the chloride of one metal, and 135 grains of the chloride of the other, in such minute quantities do these substances occur. Still owing to the skill and industry of Bunsen, the great chemist of Heidelberg, we now possess a chemical history of these two new alkalies as complete and well authenticated as that of the commoner alkalies. Their names, which Bunsen has wisely chosen, indicate the nature of their origin and point out the property by means of which they were discovered. *Cæsium*, Bluish Grey, thus called because its spectrum is distinguished by two splendid violet hues. *Rubidium* owing to the presence of two bright red rays at the least refrangible extremity of its spectrum. Since the publication of the discovery of these metals, their salts have been found to be

pretty commonly diffused, but owing to their close resemblance to the compounds of Potassium, they were not recognized as separate substances, in fact had it not been for this new method, we should not have been able to distinguish them from the well known alkali potash.

Cœsium and *Rubidium*, occur in the water of almost every salt spring; and they have likewise been found in the ashes of plants, especially in those of beet-root, so that they must be contained in the soil, but in all these cases the quantity in which they are found is very minute. The mineral Lepidolite contains a certain quantity of *Rubidium*, which now may be obtained by the pound, but *Cæsium* is still extremely rare.

In a similar manner the existence of another new metal has been pointed out by Mr. Crookes, which is characterized by a spectrum containing one *bright green* band and has been called *Thallium* (Θαλλος, Green Shoot). This has lately been prepared in somewhat larger quantities by Mr Lamy, from the residue of the Belgian sulphuric acid chambers. He finds that in sp. gravity and outward properties it closely resembles lead, but that it possesses very peculiar chemical characteristics.

To render the foregoing phenomena and the hypothesis involved intelligible to those who may not have studied the subject, it will be necessary to enter a little into detail.

The image produced by decomposing a white sunbeam, consists of certain brilliantly colored rays, but those rays are crossed by spaces giving no light, *dark lines*, which dark lines are always found in the same places in the solar spectrum.

The spectra obtained from some artificial sources of light exhibit the colored rays shading one into the other; while those produced by some others consist of a series of *luminous bands*, separated by dark spaces and *these luminous bands are frequently found to coincide with the dark lines of the solar spectrum.*

Kirchoff and Bunsen say, in arguing upon these lines and the hypothesis of their representing the solar dark lines, "It was proved from theoretical considerations that the spectrum of an incandescent gas becomes *reversed* (that is, that the bright ones become changed into dark ones) when a source of light of sufficient intensity giving a continuous spectrum, is placed behind the luminous gas. From this we may conclude that *the solar spectrum with its dark lines is nothing else than the reverse of the spectrum, which the sun's atmosphere would alone produce.* Hence, in order to effect the chemical analysis of the solar atmosphere, all that we require is to discover those substances which when brought into the flame produce bright lines coinciding with the dark ones of the solar spectrum." The next step in the process of the investigation instructs us in the fact that the vapors producing those colored flames are opaque to their own rays. That is to say, if we produce a yellow soda flame, and from it obtain a spectrum, showing the peculiar soda-lines in their bright yellow color* and then impregnate the air with some soda vapor, by volatilizing soda between the flame and the spectrum the *bright yellow line* becomes at once a *black line.* This holds true for all the substances which have yet been examined. The colored bright lines are converted into dark lines, if the rays from the colored flames are made to permeate vapors of the same constitution as those which produced the particular spectrum under examination.

Prof. Kirchoff wishing to test the accuracy of the frequently asserted coincidence of the bright metallic and dark solar lines, made the following very remarkable experiment which is interesting as giving the key to the solution of the problem regarding the existence of sodium and other metals in the sun. He states, "I obtained a tolerably bright solar spectrum and brought a flame colored by sodi-

* This beautiful bright yellow line is observable when less than one twenty millionth of soda smoke is mixed with air.

um vapor in front of the slit. I then saw the dark lines *D* change into bright ones. The flame of a Bunsen's lamp threw the bright sodium lines upon the solar spectrum with unexpected brilliancy. In order to find out the extent to which the intensity of the solar spectrum could be increased without impairing the distinctness of the sodium lines I allowed the full sunlight to shine through the sodium flame and to my astonishment, I saw that the dark lines *D* appeared with an extraordinary degree of clearness. I then exchanged the sunlight for the Drummond's or oxy-hydrogen lime light, which, like that of all incandescent, solid or liquid bodies, gives a spectrum containing no dark lines. When this light was allowed to fall through a suitable flame, colored by common salt, dark lines were seen in the spectrum in the position of the sodium lines. The same phenomenon was observed if instead of the incandescent line a platinum wire was used, which being heated in a flame was brought to a temperature near its melting point by passing an electric current through it. The phenomenon in question is easily explained upon the supposition that the sodium flame absorbs rays of the same degree of refrangibility as those it emits, whilst it is perfectly transparent for all other rays.

This opacity of heated sodium vapor for the particular kind of light which it is capable of giving off, was strikingly exhibited by Prof. Roscoe in one of a course of lectures on spectrum analysis lately delivered by him in London, at the Royal Institution.

A glass tube containing a small quantity of metallic sodium, was rendered vacuous and then closed; on heating the tube, the sodium rose in vapor, filling a portion of the empty space. Viewed by ordinary white light, this sodium vapor appeared perfectly colorless, but when seen by the yellow light of a soda flame the vapor cast a deep shadow on a white screen, showing that it did not allow the yellow rays to pass through.

Incandescent gases and vapors give off light of certain definite degrees of refrangibility, or they furnish spectra consisting of certain fixed lines; and these incandescent gases or vapors absorb light of the same degree of refrangibility as that which they emit. This after all is only the expression in relation to *light* of the celebrated statement made in regard to *sound. That a body absorbs all the oscillations which it can propagate.* Sound is produced by the vibration of the particles of gravitating matter, whilst light is supposed to be produced by a similar vibration of the particles of a non-gravitating matter called the luminiferous ether.

We are all acquainted with the principle of resonance; if we sound a given note in the neighborhood of a pianoforte, the string capable of giving out the vibrations producing that note takes up the vibrations of the voice, and we hear it answering the sound. The intenser vibrations proceeding in one direction are absorbed by the string and emitted as waves of slighter intensity in every direction.

All the *bright* lines of the spectra, produced by the vapors of known metals, which have yet been examined, appear to be represented by the *dark lines* of the *solar spectrum.* That is to say, dark lines always existing in the solar spectral image, correspond with every line produced by a spectrum obtained by burning iron; and just so with regard to the other metals which have been examined.

The conclusion therefore is, that the radiations from the centre of our system — the sun — producing the phenomena of *light*, *heat* and *actinism*, are due to the combustion of metallic bodies such as we find on this earth.

The mass of the sun is, according to this hypothesis, regarded as being intensely incandescent. Matter, in all respects similar to that with which we are acquainted, is undergoing combustion, and of course surrounding the sun with a vaporiform atmosphere, consisting of the emanations from the ignited nucleus. But for this atmosphere—

or *photosphere*, a better term—the solar spectrum would give a series of brilliantly colored *bright bands*. It has been stated that vapors are opaque to their own class of rays; therefore, since the rays produced by burning iron or magnesia or lithium or other metals, are NOT transmitted through the vapors produced by the combustion of those metals, the solar spectrum gives an extensive series of *dark bands*. That every *black* line in the solar spectrum represents rays emitted from some metallic body in the state of combustion in the sun, is exceedingly doubtful. It has been already shown that many of the dark lines are due to the want of absolute transparency of our own atmosphere. But, Kirchoff's view of the coincidence of the black lines of the solar spectrum with the bright lines of terrestrial flames is a fair deduction from his experimental observations.

Whilst these inquiries of Kirchoff, Bunsen and others have been progressing, investigations elsewhere have brought corroborative evidence. The party of Astronomers who went to Spain in 1860, to note with all accuracy the phenomena of the solar eclipse of that year, brought back evidence of tongues of flame or clouds glowing with the reflected lights of an intense combustion coming strongly into view when the bright light of the sun was obscured by the moon's body.

Prof. Airy, states it as his belief "*that the sun is boiling up* and that the *prominences* observed were *fumes given off*.

The sun's disc is covered by masses of curiously shaped and ever moving forms, called by their discoverer, Mr. Hasting, the "willow leaves." The inference is that these are tongues of flame ever bursting from this incomprehensible mass and dispersing light and its attendant forces to all the planets.

By the aid of optical science, of chemical experiments, and astronomical observations, we are advanced to the following deductions:

That the sun is constituted of matter similar to that which we find in this world. That this matter is ever burning, but, as Newton supposed, returning in a changed form into itself by the force of attraction in the mass.

That the physical forces which are developed by those vast chemical changes are radiated in waves through space.

Of Stellar chemistry we have at present but little knowledge. Fraunhöfer observed that the spectra of the fixed stars contained dark lines differing from those seen in the solar spectrum. A half century has elapsed since Fraunhöfer made these observations, and our knowledge on this point is no further advanced, though we have become assured of the truth of his statements. In the spectrum of Sirius he observed no dark lines in the orange colored region, but in the green there was a distinct line, and in the blue two dark bands, none of which were seen in solar light. The spectra of other stars were likewise examined by Fraunhöfer, and they appeared each to differ from the other. The difficulties attending the exact observation and measurement as regards dark lines in the spectra of the stars are very great, but doubtless with the vastly improved optical instruments of the present day, astronomers will overcome these difficulties. The astronomer royal of England, in his last annual report announces that he is about to undertake the examination of the spectra of the fixed stars, and perhaps ere long we will know why Mars looks so red and some of the other stars so blue.

How wonderful is it that man by the power of mind is enabled to extend his investigations from the earth directly to the sun ; and that he can determine the chemical composition of a body millions of miles distant from him, is most surprising, and proves the divine origin of his intelligence, and even more than this has he accomplished by his philosophy, in proving the completeness of the balance of forces throughout the universe.

Vast chemical changes are taking place in the sun, and for every grain of matter altering its form there, an equivalent of physical forces is given out in a radiant state.

These rays pass through space and reach our earth, where they are employed in producing exact equivalents of vital and other phenomena.

The minutest terrestrial organism is the result of chemical changes taking place in the sun, which stupendous orb is the great laboratory where those powers are generated, by whose agencies all the planets of the system are regulated.

In obedience to the fiat of the Great Creator, who causeth the "day spring to know his place," those mysterious agencies, whose source man is now becoming acquainted with, are flooding out in profuse abundance from the sun, causing crude inert matter to pulsate into life, and beauty upon every rolling orb within the solar realm.