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XLVIII. Experiments and observations on light which has permeated coloured media, and on the chemical action of the solar spectrum

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as the first brown layer of the salt A described. Yet the deposition of this basic iron-salt must have happened under singular circumstances, for it is a well-known fact that a solution of iron-vitriol, oxidized by the atmosphere, is precipitated as a *five-fold* basic salt. It is likewise difficult to explain how the yellow layer containing alkali *suddenly* succeeded the dark-brown; it may indeed be supposed, that at the commencement of this decomposition of the iron pyrites the alum-slate resisted for some time all action, until it was attacked, and its alkali dissolved by the sulphuric acid, which commenced the formation of a new salt. But if this mode of explanation has much appearance of probability, the *sudden* cessation of the one product of decomposition, and the commencement of the second, is a strange fact. That the gypsum, as the more easily soluble substance, is found on the inferior part of the ceiling of the cavern is, on the other hand, easily conceived. The lime in it undoubtedly acted no unimportant part at the deposition of the iron salts described, aiding in their precipitation by saturating the acid.

XLVIII. *Experiments and Observations on Light which has permeated coloured Media, and on the Chemical Action of the Solar Spectrum.* *By* ROBERT HUNT.*

M. GAY-LUSSAC, when speaking of the beautiful discovery of M. Daguerre, said, "The palette of the painter is not very rich in colour, black and white compose the whole. The image in its natural and varied colours may remain long, perhaps for ever, a thing hidden from human sagacity †."

However, the production of a coloured picture of the spectrum by Sir John Herschel, and some effects produced by Mr. Talbot, together with some delicate tinting which I observed, when, during the summer of 1839, I was engaged in copying some flowers of Nature's richest painting, led me to think coloured photographs within the range of probabilities, and induced me to pursue a train of experiments from which, although little has resulted to heighten my first hopes, I have gathered much that is curious and certainly instructive.

Photographic Papers.

1. By saturating paper with different chlorides and mu-

* Communicated by the Author.

† "The History and Practice of Photogenic Drawing, &c., by L. J. M. Daguerre. Translated by J. S. Memes, LL.D."

riates, always keeping in view the definite proportion required for the quantity of the nitrate of silver used; it will be found that almost every variety of shade, from a rich dark purple to a full red, and a few other tints, may be produced at pleasure.

2. The effects of light, passing through coloured glasses on various papers, are singularly diversified. The following are a few of the most striking results. (The glasses are, a deep cobalt blue, a full laurel green, an amber yellow, and a rich orange red. They are so framed that all the papers can be exposed at the same time to the solar influence.)

Colour of Glass.

Salt used.	*Blue.*	*Green.*	*Yellow.*	*Red.*
	Effects produced.			
a. Chlor. of sodium.	Purple.	Blue.	Violet.	Chocolate.
b. Chlor. of potassa.	Light purple.	Sky blue.	Light violet.	Tinted red.
c. Muriate of lime.	Rich violet.	Faint blue.	Blue.	Reddish.
d. Muriate of iron.	Red.	Colourless.	Faint red.	Leaden hue.
e. Mur. of peroxide of iron.	Blue.	Yellowish.	Straw color.	Yellow brown.
f. Mur. of baryta ...	Purple red.	Lilac.	Chocolate.	Pink.
g. Muriate of manganese...........	Rich browu.	Reddish.	Rose hue.	Yellow.
h. Mur. of ammonia	Olive brown.	Pale brown.	Brown.	Dull orange.

3. I have found but a modified action from the interference of coloured fluids. In a few instances, under a solution of carmine in ammonia, I have obtained the richest crimson dye; but I cannot, by any means I have used, succeed in fixing the colour on the paper.

4. A paper prepared, by first washing it with a solution of twelve grains of the iodide of potassium in one ounce of water, and then with a solution of ten grains of the crystallized nitrate of silver in the same quantity of fluid, is very sensitive. When exposed beneath a solution of the ammonia-sulphate of copper to sunshine, it changes to a rich *light blue.* Acetate of copper produces a *brown.* Muriate of the peroxide of iron imparts a *green tinge*, and solutions of carmine a *brown red.*

5. The paper *f* becomes *red*, when acted on by rays passing through nitrous acid gas, and is tinged *yellow*, by the light which has been subjected to the interference of chlorine and its protoxide.

6. To have as full a volume as possible of iodine and bromine vapour, carefully closed vessels containing a small portion of these bodies, were placed upon a plate of copper warmed by water.

The paper *h* was laid beneath them, and exposed to luminous influence. Under the bromine it was unchanged, but beneath the iodine the paper became richly iridescent. The colours changed to a uniform violet tint upon a few minutes' exposure to direct sunshine.

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7. Papers already darkened by sunlight during prolonged exposure to the influence of the dissevered rays of the spectrum, assume a variety of colours. The same changes may be effected by carefully arranging glasses, and placing the photographic preparations beneath them. I shall copy exactly the memoranda of my journal.

Dec. 12, 1839.—I placed under blue, green, yellow, and red glass the following papers:

A. *Muriate of ammonia*, with two washings of solution of the nitrate of silver, darkened by exposure to a rich chocolate.

B. *Muriate of manganese.* Silver, two washings, darkened to a full brown.

C. *Iodide of potassium.* Silver, one washing, darkened to a yellow brown.

D. *Iodide of potassium* and silver, two washings, darkened to a red brown.

E. *Chloriodic acid.* Silver two washings, darkened to a rich bronze.

F. *Chloriodic acid* with *Liquor potassæ*. Silver, two washings, darkened to a blue-brown.

Dec. 13.—After twelve hours exposure to the dull light of rainy weather, the paper E has become blue under the blue glass. No change is apparent on the others.

Dec. 27. *Colours of Glass.*

	Blue.	*Green.*	*Yellow.*	*Red.*
A. has become	Olive.	Deep green.	Dirty yellow.	Red.
B.	Deep brown.	Bat colour.	Blue brown.	Red.
C.	Do.	Darkened.	No change.	Red brown.
D.	Black.	Light brown.	Rich brown.	Brick red.
E.	Blue black.	Darkened.	Darkened.	Dusky red.
F.	Black brown.	Dull plum.	Bluish.	Reddened.

Jan. 2, 1840.—All the papers go on increasing the distinctness of their colours, except E and F, which have assumed different shades of blackness.

(E *and* F *were removed, and a paper* G, *prepared with muriate of baryta and two washings of silver, darkened to a chocolate, substituted.*)

Feb. 7. *Colours of Glass.*

	Blue.	*Green.*	*Yellow.*	*Red.*
A.	Rich olive.	Green.	Yellow.	Purple.
B.	Black.	Chocolate.	Light brown.	Red.
C.	Do.	Red brown.	Do.	Brown.
D.	Chocolate.	Umber brown.	Black.	Red brown.
G.	Bright olive.	Yellow brown.	Pale olive.	Reddish.

The two papers A and G exhibit much more sensitiveness to luminous influence than any others I have yet tried.

8. The paper A, when washed with a weak solution of the hydriodate of baryta, gives under the pencil of light a beautiful picture, whether used in the camera or for surface drawings.

These pictures exhibit the peculiarities mentioned by Mr. Talbot at the British Association*. Sunshine changes "the colour of the object delineated from reddish to black with great rapidity." This gentleman adds, "after which no further change occurs." I much regret I have not been fortunate enough to succeed thus far in fixing my drawings. The continued influence of light in a few months obliterates the impression.

A singular change follows the exposures of these pictures to coloured light.

If placed under vessels containing coloured fluids (4.) and exposed either to sunshine or to diffused light, in a few days the picture becomes a full *red* under the blue; a *rose hue* under the green; a *light blue* under the yellow, and a *deep blue* under the red. These colours after deepening for some time gradually change to different shades of *green* under the blue and green fluids, to a *pink* under the yellow, and a *red* under the red fluid (25.). After this, the colours alter no more, and the picture bears exposure to light much better than at first; but I doubt if it is rendered perfectly permanent, for the dull light of January and February has spread a downiness, like a mist, over those photographs which have been constantly exposed.

Daguerreotypes.

9. Exposing a plate, over which some lace was carefully placed, under four coloured glasses (2.) for three minutes to diffused light, I obtained, under the blue glass a beautiful copy; no trace of a drawing beneath the green; a tolerable impression beneath the yellow; but the mercury would not attack the space beneath the red.

10. A plate similarly arranged beneath four bottles of coloured fluid (4.) exposed to diffused light for fifteen minutes, was found on being acted upon by the mercurial vapour to present the same appearance as above (9.), excepting that a faint design was evident over the space the carmine fluid had covered.

11. I arranged a dark chamber, to which no other rays could pass but such as had permeated *two inches* of coloured fluid.

* Athenæum, No. 618.

Having filled my trough with a saturated solution of the bichromate of potassa, I exposed a plate for five minutes to its influence in full sunshine. *There was not the slightest action.*

12. In one hour on a similar plate, under the same circumstances, I obtained a faint, but still defined outline of a dried fern.

13. I exposed a bare iodidated plate for two hours to the same influence. On removing it from the chamber no difference was apparent; but I found it was no longer sensitive to light, and the iodide adhered more closely to the metal than it did (28.).

This is a reverse action, for after the exposure of a prepared daguerreotype plate to light, the sensitive film is most easily rubbed off* (28.).

14. Red solutions impart a very decided rose hue, or more strictly speaking the influence of red light on the iodidated plate occasions that peculiar arrangement of the mercurial particles, which is necessary to the production of red colour.

15. Green solutions act with more or less effect in obstructing the passage of the so-called chemical rays according to their depth of colour. But in no instance have I found them to produce that close combination, which the yellow and sometimes the red fluids do, of the iodide and the under surface of unattacked silver (28.). By examining the effects produced by green media (2, 7, 16.) a peculiar order of interference will be remarked (19.).

Germination and the growth of Plants.

16. I planted in a box some curled cress seed, and so arranged bottles of carmine fluid, chromate of potassa, acetate of copper, and the ammonia sulphate, that all but a small space of the earth was exposed to light which had permeated three-fourths of an inch of these media.

For some days the only apparent difference was that the earth continued damp under the green and blue fluids, whereas it rapidly dried under the red and yellow. The plumula burst

* On this principle I now polish my silvered plates, by which the troublesome process with nitric acid and pumice is got rid of. I wash the surface of silver over with a solution of the iodide of potassium holding a little iodine free, and rub it lightly until all the parts are equally attacked. I then expose the plate to light for a few minutes, and polish off with dry cotton. In five minutes by this process the most perfect lustre may be given to the silver, and it has the advantage of rendering the plate more susceptible to the influence of the iodine vapour.

the cuticle in the blue and green lights, before any change was evident in the other parts.

After ten days, under the blue fluid there was a crop of cress, of as bright a green as any which grew in full light, and *far more abundant.*

The crop was scanty under the green fluid and of a pale unhealthy colour (15.).

Under the yellow solution but two or three plants appeared, yet they were less pale than those which had grown in green light. Beneath the red bottle the number of plants which grew was also small, although rather more than in the spot the yellow covered. They too were of an unhealthy colour.

17. I now reversed the order of the bottles, fixing the red in the place of the blue, and the yellow in that of the green. After a few days' exposure the healthy cress appeared blighted, while a few more unhealthy plants began to show themselves, from the influence of the blue rays, in the spot originally subjected to the red.

It is evident from this that the red and yellow rays not merely retard germination, but positively destroy the vital principle in the seed. Prolonged exposure uncovered, with genial warmth, free air, and indeed all that can induce growth, fails to revive the blighted vegetation.

I have repeated the experiment many times, varying the fluids, but the results have been the same. At this time I have the above facts strikingly exemplified where the space covered by the bichromate of potassa is without a plant.

These results merit the attention of those who are engaged in the study of vegetable œconomy. Do they not point at a process by which the productions of climes more redolent of light than ours may be brought in this island to their native perfection?

Dr. Draper's "experiments" (Philosophical Magazine, Feb. 1840, pres. vol. p. 81) appear at variance with mine.

Under the influence of a nearly tropical sun permeating half an inch of solution of the bichromate of potassa, cress grew of a green colour, whilst it took five days to give a sensitive paper a faint yellow green colour. From this Professor Draper argues the existence of two classes of rays, a different class being necessary to produce the green colouring of vegetable foliage from that which darkens chloride of silver.

With submission to one whose facilities for such inquiries are so much greater than my own, I would suggest a repetition of the experiments with some of the recently discovered photographic preparations. The papers *f* and *h*, both under coloured glass and great thicknesses of yellow fluid are deepened to a plum-brown in less than an hour *.

Under three inches of the bichromate of potassa the paper, *f*, became in eight hours sunshine of a full blue-brown.

18. The fact of cress and pea plants growing green, under the influence of such powerful light as penetrated Professor Draper's yellow media, will not appear at all surprising when we examine the rays which pass through such fluids.

This I have done by forming a spectrum, interposing the coloured body between the prism and the sun. The following are the effects of a February sun at Devonport.

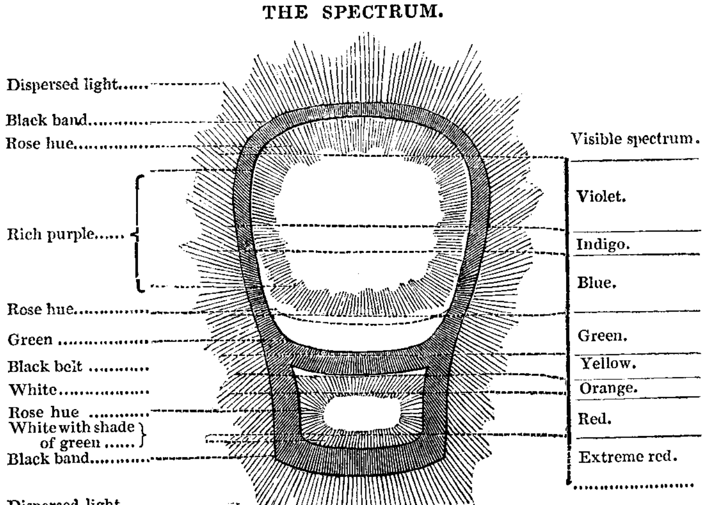
Through a deep blue solution of the ammonia-sulphate of copper, the violet, indigo, blue, and a portion of the green rays pass.

Through solutions of the muriate, acetate and nitro-muriate of copper with iron, the green ray, and a considerable portion of the yellow; a trace of the blue also is evident.

Through solutions of the bichromate and chromate of potassa, the chloride of gold and decoction of turmeric, the red, the yellow and the green rays are seen, *and by taking their impression on a daguerreotype plate a line of the blue is distinctly marked.*

Through nitro-muriate of cobalt in ammonia, carmine in ammonia, and sulphuric acid and decoction of cochineal, the red and yellow rays alone appear to penetrate.

THE SPECTRUM.



* The papers which accompany this article were exposed under the glasses and three-fourths of an inch of fluids for forty minutes. The order of interference and consequent colouring is plainly shown.

19. It will be observed, that the light which has passed through a green medium (2, 7, 9, 10, 15, 16) acts less powerfully in darkening photographic papers, and occasions vegetable leaves to be even paler than that which has been subjected to the interference of a yellow medium.

I am led to suspect that the band of rays formed by the meeting of the yellow and the green has an influence similar to the extreme red, in neutralizing the powers of the other adjacent rays, as was first noticed by Sir John Herschel, (22.), (23.), (26.).

20. The figure on the preceding page represents the solar spectrum, as it impresses itself on a daguerreotype plate, not in shadows merely, but in colours, which have the peculiar appearance of the down upon the nectarine.

The most refrangible portion of the spectrum is represented in full colours, shading from indigo to a delicate rose, which is lost in a band of pure white.

21. Beyond this a protecting influence is powerfully exerted, and notwithstanding the chemical effect produced over the plate, by the dispersed light, a line is formed free of mercurial vapour, and which consequently appears black.

22. The green portion of the spectrum is represented in its true colour, but it is considerably less in size than the space occupied by these rays.

23. The yellow rays are without action, or rather they do not prepare the silver for the reception of the mercury, and consequently a black belt marks the space on which they fell, and extends a little beyond it into the green (19.).

24. A white line marks the place of the orange light.

25. The red is represented by a well-defined rose colour, bounded, as were the more refrangible rays, by a white line, shaded at the lower extremity with a green.

This passing of the red into a green and of the blue into a rose colour (20.) is strikingly similar to the effect produced, by the interference of coloured media, on some photographic drawings (8.).

26. The lowest dark space on the picture is a beautiful illustration of the influence of the extreme red rays in protecting the silver from luminous action (19.) (21.).

27. What appears more surprising to me than even the detection of the *negative?* rays at each end of the prismatic spectrum, is the continuation of the dark line throughout *its whole length,* evidently showing the influence of the same cause as is so effective at the least refrangible extremity.

This band is not equally defined throughout its entire circumference. It is the most strikingly evident from the extreme red to the green; it fades in passing through the blue and increases in intensity 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.

Does not this protected surrounding band appear to indicate the existence of rays of a peculiar and unknown order, proceeding from the extreme edge of the sun?

28. By lightly rubbing a daguerreotype picture of the prismatic rays, it is obliterated, except over the space of the yellow and red portion. This effect corresponds with my experiments on media of these colours (11. 12. 13).

Until we have more experience than we now have of the effects of the solar rays individually and collectively, we can offer no satisfactory explanation of the process in action, on a daguerreotype plate, by which the subtle painter LIGHT impresses such delicate designs.

The existence of two iodides of silver, is, I think, certain. In my photometric experiments I have always observed the formation of an iodide which speedily darkens, and of another portion which is unalterable by light*.

The sensitive film on the silver plate appears to be the former of these iodides. Throughout the range of the chemical spectrum, *particularly so called*, the iodide is I imagine converted into an oxide of silver; that a partial oxidation takes place numerous experiments have rendered certain; whilst the influence of the rays of least refrangibility is to form the unchangeable iodide of silver. Experiments, however, are wanting to prove this satisfactorily.

An attentive consideration of the facts I have enumerated, will, I think, satisfy all, that we can no longer with propriety attach the name of chemical to the most refrangible rays only. Every ray has its particular chemical office, either of composition or of decomposition; and although Seebeck has attributed the acquirement of a rose hue by chloride of silver when put into the red ray, to the heating power of that portion of the spectrum, it is now proved to be dependent upon some other influence, for where it has been shown the most calorific rays exist this salt undergoes no change.

Devonport, February 29, 1840.

* [See Mr. Talbot's account of the processes employed in Photogenic Drawing, Lond. and Edinb. Phil. Mag., vol. xiv. p. 210 (2).—EDIT.]