VIII. *On the Action of the Rays of the Spectrum on Vegetable Juices. Extract of a Letter from Mrs.* M. SOMERVILLE *to Sir* J. F. W. HERSCHEL, *Bart., dated Rome, September* 20, 1845. *Communicated by Sir* J. HERSCHEL.

Received November 6,—Read November 27, 1845.

IN the following experiments the solar spectrum was condensed by a lens of flint glass of $7\frac{1}{2}$ inches focus, maintained in the same part of the screen by keeping a pin-hole, or the mark of a pencil constantly at the corner of the red rays, which were sharply defined by using blue spectacles to protect my eyes from the glare of light, and the apparatus was covered with black cloth in order to exclude extraneous light.

Thick white letter paper, moistened with the liquid to be examined, was exposed wet to the spectrum, as the action of the coloured light was more immediate and more intense than when the surface was dry. As I had not access to the morning sun, the observations were made between noon and three in the afternoon.

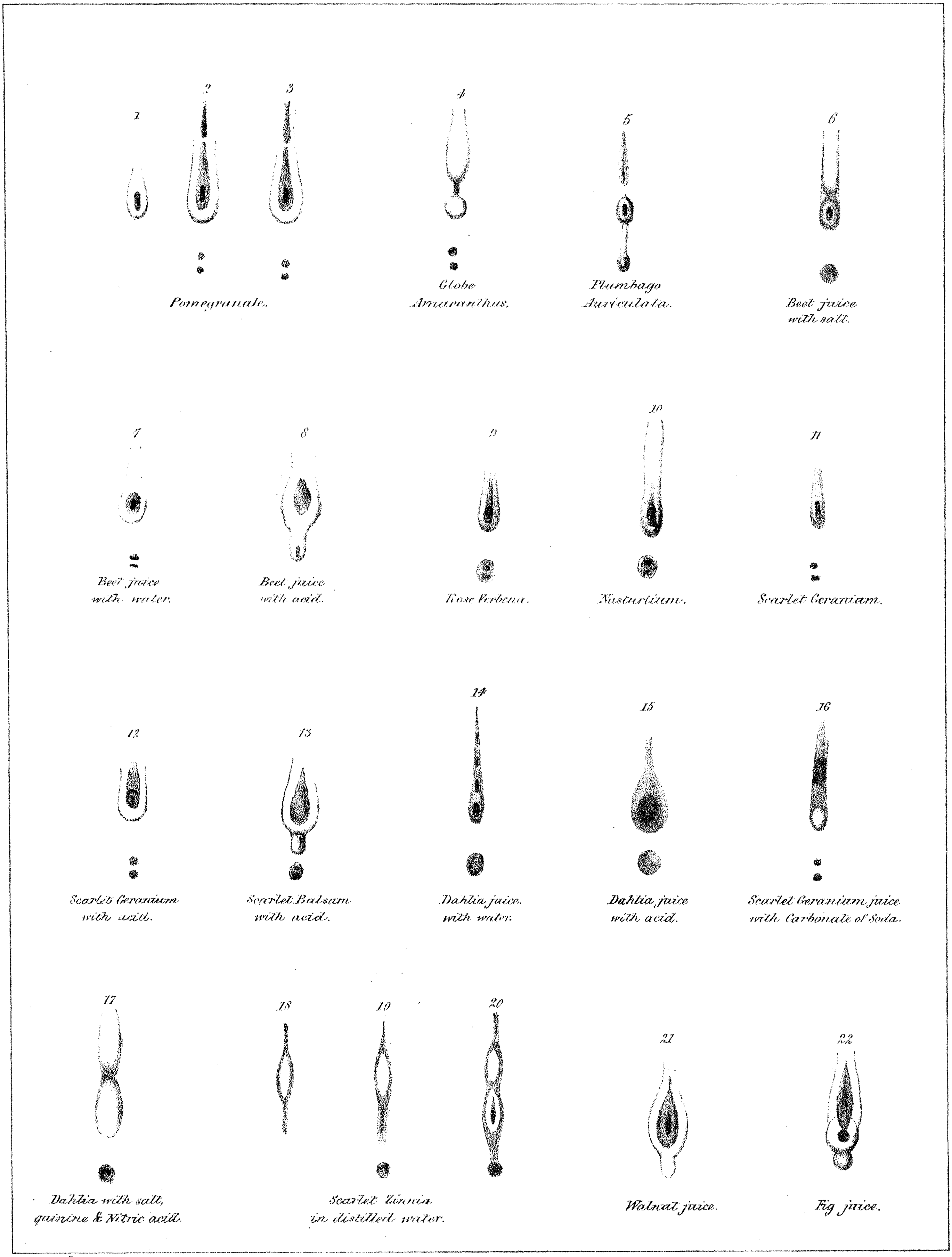
The lavender rays came vividly into view under a condensed spectrum on white paper washed with a solution of sulphate of quinine in dilute sulphuric acid: they were narrow, and their length, by rough measurement, was equal to the distance between the upper edge of the violet and the lower edge of the blue. They were very brilliant on black silk or other dark surfaces, and invariably of lavender colour; and even on paper stained with turmeric, the pale yellow rays which you had observed, were tipped with lavender on being washed with this liquid, though its duration was momentary, as it vanished as the surface became dry; but they were permanent in other instances.

The lavender rays change their colour with a change of the liquid, for instance they are lavender coloured on nitrate of silver discoloured by light to a very pale brown, washed with a solution of sulphate of quinine in dilute sulphuric acid; whereas, on a similar surface of pale brown nitrate of silver, washed with the juice of the petals of pale blue *Plumbago auriculata* in distilled water, to which sulphuric acid was added, they appeared of a vivid apple-green, and acquired a tip of lavender colour on the surface being washed with a solution of sulphate of quinine in dilute sulphuric acid of considerable strength; the effect, however, was transient. After several unsuccessful attempts to repeat this experiment next day, I at length discovered that its success depended upon the acid being strong enough to decompose the juice and give it a reddish orange hue; and even then the rays are not vivid till the paper has been frequently washed with the juice and become nearly dry; and the experiment is more successful when the liquid has been kept a night. The action of the surface in changing the colour of the lavender rays may be illustrated by passing the spectrum over paper coated with nitrate of silver brought to a clear yellow-brown by exposure to the sun; one half being washed with the liquid in question, and the other half with a solution of sulphate of quinine in dilute sulphuric acid, on the first half the lavender rays became vivid apple-green, while on passing to the other half they instantly change to an equally vivid lavender colour. These rays often darken the surface throughout their whole length; sometimes they acquire a powerful bleaching action, and sometimes they have no effect, as evidently appears from the following experiments.

There was reason to suspect that the action of the spectrum at the junction of the lavender with the violet rays, is in some cases different from what it is on either of these colours separately, a second dark image having appeared at the extremity of that which terminated with the violet, indicating a break in the continuity of action and giving the idea of a secondary spectrum.

The juice of fresh-gathered petals of double flowering pomegranate in alcohol afforded an example of this. Paper washed with this juice became rich crimson, and on being exposed wet to the condensed spectrum, a narrow line of deep crimson was formed at the junction of the green and yellow rays, or perhaps in the most refrangible yellow, surrounded by a whitish lozenge-shaped border (Plate III. fig. 1.). On again washing with the juice, instead of the white border, which had vanished, there was a crimson flame-shaped image, curved at the lower edge of the yellow rays and tapering upwards to the violet. Its colour was darker than that of the ground, though paler than the narrow line, which maintained its intensity; and although the latter increased in width, it did not become as broad as the image in question. At the upper end of the violet another little dark image was formed, apparently owing to the action of the lavender rays, having exactly their form. The orange and red rays, especially the red, had no effect, though at the distance of about half the length of the spectrum beyond the red, two distinct spots were formed of deep crimson, which I believe to be the heat spots which you discovered. After some time, a bleaching appearance surrounded the whole image from the red upwards, probably owing to rapid evaporation from the heat of the spectrum (fig. 2.). Exterior bleaching frequently took place in the course of the experiments, permanent in some instances, while in others it vanished as the surface dried. When water was used with the juice instead of alcohol, the general character of the image was similar to that described, except that the small figure beyond the violet was more distinct, and seemed to bear the same proportion to that formed by the rest of the spectrum which the length of the lavender rays bears to the length of the sum of the others. The bleached part round the whole was more extended, and a faint crimson haze encompassed the dark spots, which were very distinct (fig. 3.).

This experiment is one of many instances in which I have observed the powerful



J. Basire, lith.

influence of the yellow and green rays upon vegetable substances, an influence which seems to be unconnected with heat, since the darkening generally was least under the red rays, and immediately below them, where the calorific rays are most abundant. I found that the action of the rays of mean refrangibility on vegetable juices was much increased by the addition of a little sulphuric acid. In most cases this powerful influence was simultaneous with the appearance of two dark spots below the visible spectrum, sometimes sharply defined, sometimes in the centre of a disc of a paler hue; and in some instances the disc was seen without spots, though it rarely happened that they did not appear under one or other of these forms.

The following are some of the cases in which the simultaneous effect was produced: for example, paper washed with juice of the petals of *Globe amaranthus* in distilled water, on exposure to the spectrum acquired a delicate pink tint, which was soon bleached to whiteness, from the upper edge of the green to the end of the lavender rays, while at the same time a perfectly circular spot of equal whiteness was seen under the red rays, and a little way below them, which had the appearance of being an image of the sun. After more washing with the juice, the two bleached parts were united by a long white neck, which speedily vanished, and was succeeded by a dark crimson image, whose greatest intensity of colour was under the yellow rays. At some distance below the red rays, two crimson spots were strongly marked, especially the uppermost, both surrounded by a paler halo (fig. 4.).

The juice of the petals of pale blue *Plumbago auriculata* in distilled water imparted its tint to writing-paper, which, after exposure to the action of diffused light, acquired a pale yellowish green hue. The part under the lavender and violet rays of the spectrum, repeatedly washed with the juice, assumed a pale brown colour: the indigo rays seemed to have no effect, although from their lowest edge to the distance of half the length of the spectrum below the red rays, a lavender blue image was formed. Under the orange rays a minute indigo-coloured spot appeared, and also a larger spot of the same colour under the yellow, which were soon blended into one, forming a single oblong figure of maximum intensity, surrounded by a halo of paler indigo (fig. 5.). An insulated disc of the same colour as the halo, with two dark spots in its centre, appeared at some distance below the red rays. The juice of this plant is easily decomposed; by the addition of sulphuric acid it became a delicate pinkish grey, which was also the colour of paper wetted with it, while under the spectrum a pale yellow figure of considerable width was impressed, extending under the whole of the visible rays, and soon after a deep yellow image with a paler halo was seen in its centre. The halo or paler part of the image lay between the red and the end of the lavender rays, while the deep yellow, or perhaps more properly the yellow-brown figure, extended under the yellow-green and blue rays, the maximum of breadth and of colour lying in the yellow and green. Two insulated spots of the same yellowish-brown in the centre of a yellow disc were formed below the visible spectrum, and the whole surface soon became bright yellow from the action of the scattered light, consequently the extensive pale figure was obliterated, leaving only the interior dark image with its halo and the spots with their disc permanent.

The juice of beet-root in a strong solution of common salt imparted a pink colour to the paper, and the most refrangible rays acquired a powerful bleaching energy. The pink ground was whitened under the lavender, indigo and blue; a deep crimson spot was formed under the yellow, with a rose-coloured halo elongated to the bleached part on one side, and to the end of the orange on the other, while a hazy rose-coloured disc was visible at a distance below the red (fig. 6.). The crystallization of the salt on this figure was in proportion to the intensity of colour; most on the crimson spot and its halo and on the coloured disc, but scarcely any on the bleached portion.

A solution of hyposulphate* of potash in the beet-juice had nearly the same effect as the salt, only that the dark spot with its halo was more extended, and the latter formed a long neck beyond the red, ending in a deep rose-coloured disc. The appearance was precisely similar when muriate of ammonia or iodide of potassium was used, I therefore inferred that the alkali imparted the bleaching property to the most refrangible rays.

Paper washed with the juice of beet-root in distilled water assumed a fine rose-colour, on which a figure was bleached by the spectrum, wide and rounded in the yellow, but tapering upwards: after another wash, a dark crimson image was formed in its centre reaching to the blue, with a still darker spot under the yellow. The red rays had no effect, below which at the usual distance two indistinct spots appeared. A drop of sulphuric acid in the juice changed the tint of the paper to a purple colour, on which, after various alternations of bleaching and darkening, the spectrum impressed a dark figure, broad and rounded on the yellow, and tapering to the blue, beyond which there was scarcely any action (fig. 8.). The whole was surrounded by a broad pale border, stretching in a neck far beyond the red, with an indefinite dark line in its centre.

In these experiments almost the only part of the visible spectrum that darkened the surface was that of mean refrangibility, but even when the whole had that effect, the maximum was generally produced by the rays in question, the insulated spots, or some indication of them, appearing at the same time. This was the case with the juice of *Amaranthus caudata*, which stained white paper rose-colour, and the spectrum impressed a deeper rose-coloured image from the lowest edge of the red to the end of the blue, with a dark crimson oval figure under the yellow and green, while two insulated crimson spots appeared in a rose-coloured halo below.

White paper washed with the juice of rose-coloured verbena in distilled water assumed a lemon-colour (fig. 9.), while the spectrum impressed a pale rose-coloured image from the lowest edge of the red to the end of the indigo rays, in the centre of

* *Sic in MS.* but probably meaning hyposulphite, a salt in common use in photographic research, which the hyposulphate is not. The two salts have totally different properties. The mistake is a very common one.—(J. F. W. H.)

which, under the green, yellow, and part of the orange rays, a narrow figure of very deep crimson was formed, and two rose-coloured spots appeared in a rose-coloured disc below the red.

Dark orange-coloured nasturtium stained writing-paper the colour of prussian blue, the image impressed on which was a deeper shade of the same, extending from the lowest edge of the red to the end of the blue, while a still deeper tint appeared under the orange, yellow and green, with a point of maximum intensity in the lowest part of the yellow. There was a tendency to bleaching from the blue upwards, and below the other end of the spectrum two well-defined dark spots were surrounded by a paler blue penumbra (fig. 10.).

The juice of the velvety petals of a scarlet geranium was very sensible to the action of light (fig. 11.), and stained white paper rose-colour. A deeper rose-coloured tint was impressed by the spectrum from the lowest edge of the red to the end of the blue, feeble in the red and deeper in the orange, while a crimson image extended from the zero point in the yellow to the end of the green; the maximum of intensity was in the latter. Two crimson-coloured spots in a rose-coloured halo were strongly marked at some distance below the red.

With the addition of acid this juice gave a scarlet tint to paper, and a darker scarlet image was formed from the middle of the yellow to the end of the indigo. Then a very dark scarlet oval appeared between the zero point and the upper edge of the blue, with a small point of maximum intensity on the upper part of the yellow. The orange and red rays had no effect, but a pale rose-coloured border surrounded the lower part of the figure, which became of a bluer tint and darker than the ground when dry. Two spots of scarlet were distinct at some distance below (fig. 12.).

The juice of the petals of scarlet balsam in distilled water is another instance; it gave a pale scarlet tint to paper, and a lake-coloured image extended throughout the spectrum from a point considerably above the violet to below the spots, which were distinctly visible, though not sharp. The greatest intensity of colour and breadth were under the yellow and green. When a little sulphuric acid was added to the same liquid, the action was feeble above the blue rays, but a very broad dark image was formed under the orange, yellow and green rays; possibly under part of the blue also, which gradually became nearly black, with a blackish red penumbra, surrounded by a broad border of bright scarlet of a deeper tint than the ground, passing under the blue and indigo at one end, and under the red at the other, while below the latter an indistinct appendage of a paler colour projected; an insulated scarlet disc appeared still lower down, in which two spots were evident, though not sharply defined (fig. 13.). The breadth of the image was very remarkable, and it was so deeply impressed that there was little difference in its intensity on the two sides of the paper. On repeating the experiment with a hot iron behind the paper, the figure was the same, only that the central part was brown and the border merely a paler shade of the same: a disc of the same colour as the border appeared below the red, which vanished the following day.

When the juice was extracted in alcohol instead of water, the action of the spectrum was somewhat different; the image extended from the lowest edge of the yellow to the end of the violet with three points of maximum intensity, the greatest in the yellow, the next in the green, and the last in the indigo. The red rays had no effect, but the spots, or rather their place was indicated. With water containing a little borax, there were only two points of greatest intensity, the first on the yellow, the other under the indigo and violet. Notwithstanding these differences the principal action was still in the rays of mean refrangibility, especially the yellow.

I have found no vegetable juice so sensible to light as that of the maroon-coloured or dark red dahlia in distilled water. It gave a lavender hue to white paper, while the part under a condensed spectrum became rapidly dark, from the edge of the orange to the end of the lavender rays, but with variable colour and intensity. A dark reddish oval was formed under the orange, yellow and green rays, with a narrow line of a still deeper colour in the centre of the yellow, while spots of less intensity and of a bluer tint appeared under the blue and violet rays, with some indication of another above; but these three points of inferior intensity were not always very distinct. At a little distance below the extreme red rays, two dark spots were formed in the centre of a hazy disc of reddish purple. A hot iron behind the paper occasioned no change in the figure, though it accelerated the action and increased its sharpness. In this and various other instances I found that repeated washing with diluted juice answered better than when it had a deeper colour (fig. 14.).

The addition of a little sulphuric acid to this juice accelerated the action of the rays of mean refrangibility, increased the intensity and breadth of the image, and changed the tint of the liquid to bright scarlet, which imparted its hue to white paper. Exposed wet to the spectrum a dark red figure by degrees appeared, extending from the upper edge of the orange to the end of the violet, in the midst of which a kind of oval of great intensity of colour was formed under the yellow and green rays, leaving a broad red border around. The red rays seemed to have little or no effect, though at some distance below them there were two dark spots on a dark haze. When the experiment was repeated with a hot iron behind the paper, the central image became almost black, and extended from the lowest edge of the yellow to almost the middle of the blue rays, while the dark crimson border passed under the orange at one end of the spectrum, ending at the indigo at the other, beyond which a pale crimson shade reached certainly to the end of the violet, and probably further, but it was so gradually shaded off that it was not possible to define its termination. There was a nebulous disc of pale crimson at some distance below the last visible red. This image, as well as that in the preceding experiment, were so deeply impressed that they penetrated the paper (fig. 15.).

Various other plants might be mentioned to show the peculiarly strong influence of the rays of mean refrangibility in darkening vegetable juices, and in this respect there seems to be a difference in the action of the spectrum on vegetable matter and metallic salts; it would however require a more extensive series of experiments to establish this point.

The very frequent recurrence of two insulated dark spots, or of some indication of them, is another peculiarity in the action of the spectrum on by far the greater number of vegetable juices which I have used. If these be identical with the heat spots discovered by you, there surely must be a difference in the nature of the calorific rays in the visible and invisible part of the spectrum, since these spots, or a darkish disc, often appeared when the red rays had little or no effect, or even possessed a powerful bleaching energy, as on the juice of the violet-coloured *Globe amaranthus.*

Since the simultaneous appearance of the insulated spots and the maximum intensity of darkening under the rays of mean refrangibility occurred so often, I am led to suspect a similarity, possibly identity, in the nature of the agent producing these phenomena. The greatest heat does not lie in the mean rays of the spectrum, nor does the greatest chemical action; and as you have shown that the parathermic rays are situate there, may not they be the cause of the phenomena in question, being also mixed with those rays of caloric which form the heat spots, and which I have no doubt are identical with the insulated spots in these experiments?

Some cases have occurred, and there may be many more, in which the maximum intensity was produced by those rays in which the chemical energy is most active, as for instance in the juice of *Coreopsis tinctoria*, which was darkened from the red to the end of the violet rays with almost equal intensity; the maximum, if there was any, lay under the blue and indigo; also the juice of the red and yellow variegated *Marvel of Peru*, which was darkened under the whole of the visible spectrum, the lavender rays excepted. But by far the greater number of vegetable juices which I have examined, were most affected by the most luminous rays.

The point of maximum intensity was sometimes altered by the addition of an acid or alkali, and sometimes by using alcohol instead of water; when a drop of acid was added to the juice of the crimson marvel of Peru, the greatest intensity of colour appeared under the indigo and blue, and a little carbonate of soda changed the point of greatest intensity from the yellow and green to the blue rays in the juice of *Plumbago auriculata.* A still greater change was produced on the juice of the scarlet geranium by the addition of carbonate of soda. The colour of the liquid was violet, but it stained the paper pale bluish-green. There was no action under the red rays, but a circular spot of a decided yellow colour was formed under the orange and yellow rays. A brownish tint was impressed by the green and blue, from the end of which up to the termination of the lavender rays, the ground assumed an inky colour of considerable intensity, with a strong maximum in the violet. At the usual distance below the red, two green spots appeared (fig. 16.).

The action of the different parts of the spectrum seems very capricious; for example, the most refrangible rays from the green to the end of the lavender darken some substances and bleach others. Instances of this bleaching action have been given in the juices of *Globe amaranthus* and *Plumbago auriculata*, both being bleached to whiteness by the rays in question. The red rays occasionally possess this property, as in the juice of the *Globe amaranthus*, those of mean refrangibility more rarely, yet an instance has already been given in the case of geranium juice with carbonate of soda; and another occurred when a drop of nitric acid, a little common salt, and sulphate of quinine were mixed with the juice of the dark red dahlia in distilled water. White paper repeatedly washed with this liquid acquired a tint of pale lilac, while the part under the spectrum was marked by a broad dark crimson image from the orange to the end of the violet. After another washing the paper was bleached to a very pale yellowish-white under the lavender and violet rays, while at a small interval below a second bleaching process began, and changed the interior of the dark image to a very pale reddish-yellow down to the beginning of the orange, leaving a dark crimson border on each side only, broadest and darkest under the yellow rays, and diminishing in width both up and down. Under the orange and red rays the surface acquired a pink tinge, and at some distance below, the same pink tinge formed a round hazy mark. Although the colours were very tender in this experiment they penetrated letter-paper, remaining unchanged many days (fig. 17.).

Singular changes were produced by the spectrum on the juice of the petals of the scarlet *Zinnia* in distilled water, which though not very sensible to the influence of light alone, became highly so on the addition of sulphuric acid. White paper washed with this liquid acquired a pinkish-grey tint, on which the first effect of the spectrum was a very broad dark image under the violet and indigo, with a long narrow appendage of the same inky tint going down to the end of the red, and also a dark shade upwards far beyond the violet. Being again washed with the liquid, the broad image under the violet and indigo was bleached white, leaving a dark margin (fig. 18.). The dark appendage then gradually became broader, the greatest intensity lying under the green and yellow, and a dark disc appeared below the red (fig. 19.). After another washing a bleaching action changed all the interior of the dark appendage, from the upper edge of the green to the end of the red rays, to a very pale buff colour: after a while a yellow brown or dark buff image appeared in its interior under the orange, yellow and green, leaving a very dark margin; and now the whole image was surrounded by an inky pink-coloured border, much wider than the visible spectrum, extending on a long neck to the dark disc already mentioned, in which the uppermost spot was seen, but the whole of the dark border had vanished next day.

I have not found much variety of colour, although it was occasionally remarkable: the juice of the thread-shaped petals of a yellow thistle in distilled water gave a bright yellow colour to white paper, on which the spectrum impressed a very long narrow image throughout the whole visible rays, varying in colour and intensity.

The darkest part lay between the lowest edge of the blue and the highest extremity of the lavender rays: that under the lavender was bright red, while the part under the violet, indigo and blue, was orange-coloured. From the blue to the end of the red was deep yellow, and below the red rays two insulated spots of the same deep yellow were formed, though somewhat blended together. On the juice of *Plumbago auriculata* the lavender and violet rays produced a pale brown image; the indigo rays had no effect, while all the rest of the image under the mean and least refrangible rays was blue and indigo; some of the juice having remained till next day, the moisture had evaporated from it, leaving a yellowish-brown sediment in the bottom of the cup, surrounded by a border of indigo, the very same colours that were separated by the solar rays and impressed upon paper the day before, showing a striking analogy between the action of the two ends of the spectrum and that of the poles of a galvanic battery. There was a green ring between the brown and the blue where the two colours were blended, and this also was visible in the greenish-yellow tint of the general ground of the paper after exposure to light. I now expected to find that paper washed with the brown sediment, dissolved in distilled water, would be impressed with the brown part of the image only, and this was the case, with the exception of some slight indication of brown at the place of the spots. There was not enough of the blue pure to enable me to obtain the indigo part of the figure alone.

The variation in the width of the images impressed by the same spectrum on different vegetable substances was remarkable; on the juice of the yellow thistle already mentioned, the image was but a mere line, nor was it much broader on the juice of Plumbago: it was wider on the juice of the dahlia, but the addition of a drop of sulphuric acid increased the width greatly, as in the images formed on the juice of beetroot, the petals of dahlia, balsam and others. Possibly the cause of this may have been the dispersion of the rays by the acid, which was particularly great in the most luminous rays of the spectrum, though in various instances, where acid was not used, the action of the spectrum seemed to extend laterally beyond its visible edges. This occurred especially when a surface of slightly browned nitrate of silver was washed with vegetable juices or other liquids. Under these circumstances the image frequently consisted of a succession of borders of various breadth and intensity surrounding a central oblong nucleus, resembling the section of a bulbous root cut longitudinally and exhibiting its coatings. For example, a slightly sunned surface of nitrate of silver, washed with the juice of the young green walnut in a strong solution of common salt became lilac, though the liquid itself was brownish; but under the spectrum an olive-brown image was formed from the upper edge of the orange rays to a considerable distance beyond the violet, where it tapered to nearly a point. After two or three washings with the liquid, the internal part was changed to a paler tint from the indigo rays to below the red. The part projecting down from the red was much narrower than the rest of the figure and ended in a curve. Then a dark and almost elliptical figure was formed within the pale part inclosing part of the paler surface, and in the centre of which a very dark oblong spot appeared; thus from the exterior lilac ground on each side of the image to the central spot, there were five changes of intensity and tint, reckoning the central spot, but not the lilac ground; and though several of these were mere lines, the whole figure was considerably larger than the visible spectrum (fig. 21.). Another remarkable instance occurred, both of these bands and of the breadth of the image, when paper coated with white nitrate of silver was washed with the milky juice of the fig-tree in alcohol, exposed wet to the spectrum. The first effect was a fine clear brown image, beginning with a curve at the orange, and extending far beyond the violet rays, within which an olive-green centre began to appear under the green rays, which by degrees extended to the end of the violet. The brown edges bordering the olive-green were strongly marked, and seemed to spread beyond the sides of the visible spectrum throughout the violet, indigo, blue and green, but were united by a very black round spot under the yellow, and this spot was inclosed on the under side by a brick-red cusp stretching up on each side beyond the orange rays, at the lower end of which was a circular spot of very pale yellowish-white; the whole figure was surrounded by a broad reddish border, and after long exposure the centre of the green assumed a dark greyish hue, so that there were various tints, estimating laterally from the ground to the centre of the figure (fig. 22.).

Juice of the dark purple flower of a kind of mint in alcohol afforded another instance of several bands. The liquid gave the paper a brownish tint, on which the spectrum impressed a long dark line about the breadth of a common pin, cut off by the orange rays, but reaching to the end of the violet. On being again washed with the juice, the dark brown line gradually increased in width, taking a curved termination in the yellow, where it was broadest and tapering upwards; the interior afterwards assumed a pale hue, leaving a dark margin; the whole at last was surrounded by a pale border bounded by a very dark line, which were barely visible next day. Two insulated dark spots were distinctly marked below the image.

These out of many instances are sufficient to show the peculiar appearance alluded to, which it is difficult to account for, unless that at each successive washing the heat of the spectrum, by drying the parts immediately around it more rapidly than the rest of the surface, may thus produce the various borders, and extend the figure beyond its visible edges; however, some of the other phenomena could not be so explained, and possibly may have been connected with the action of the atmospheres of the sun or earth, as you have remarked, or to a difference in the action of the rays at the edges of the sun's disc from those in its centre. I fear I may have made some mistakes, especially in the estimation of the action of the different coloured rays, the limits of which it was extremely difficult to determine in so small a spectrum as that with which I worked.