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days, and the direction of the current was reversed. It will be seen that the value of this quantity increases slightly with the temperature, as we should expect from the slight difference in size of the two tubes used. The values of x will be seen to agree quite closely, with the exception of experiments 2 and 21.

A comparison of these results with those of Meyer, Maxwell, Puluj, or von Obermayer will show the superior accuracy of this method. Such a comparison can be most easily made by means of a graphical construction. Let $\eta = c\tau^x$ be the general form of the equation; then

$$\log \eta = \log c + x \log \tau,$$

which is of the form of the equation to a straight line referred to rectangular axes, and making an angle whose tangent is x with the axis of X, the value of $\log c$ being the intercept on the axis of Y. Therefore, if we plot the various values of $\log \eta$ as ordinates, and of $\log \tau (\tau_0 = -273° \text{ C.})$ as abscissæ, we shall obtain points lying along a straight line, from whose tangent with X the value of x may be determined. An inspection of the lines thus obtained from the data of various experimenters furnishes the most ready means of comparing the accuracy of their results. By such an examination it will be seen that, while Meyer obtained values of x from $x=2{\cdot}3$ to $x=0{\cdot}21$, and Puluj from $x=0{\cdot}65$ to $x=0{\cdot}47$, the above Table shows variations from $x=0{\cdot}799$ to $x=0{\cdot}738$ only in these preliminary experiments.

As a result, then, of these experiments, it would appear that the viscosity of air increases proportionally to the 0·77 power, nearly, of the absolute temperature between 0° and 100° C. But more determinations at temperatures between these limits are necessary to prove the law of this variation.

XIII. *On the Fixed Lines in the Ultra-red Invisible Region of the Spectrum.* *By* John William Draper.

To the Editors of the Philosophical Magazine and Journal.

Gentlemen,

I DESIRE to call the attention of those experimenters who are at present occupied in investigating the less-refrangible end of the spectrum, to a paper illustrated by an engraving in the Philosophical Magazine for May 1843. From this it will be seen that in the preceding year I had made photographs, not only of the Fraunhofer lines, but also of many others at both ends of the spectrum, and in exploring the less-refrangible region had found three great lines far beyond the line A, and had designated them as α, β, γ. Of the existence of a fourth, still lower down, I had obtained imperfect evidence.

Three years subsequently these lines were rediscovered by MM. Foucault and Fizeau, who used the photographic method previously discovered by me. In 1871 they were again detected by M. Lamansky by the aid of a thermo-multiplier.

I formerly supposed that the experiments of Sir John Herschel, made with paper blackened on one side and washed with alcohol on the other, indicated the existence of these lines; but a more attentive consideration of the apparatus he employed has led me to change that opinion. He did not use a slit, but the direct image of the sun, which with the optical train he had was more than a quarter of an inch in diameter. Under such circumstances it was impossible that either these or any other lines could be seen. The result he obtained was a succession of circular patches or spots—solar images—commencing above the yellow, and continuing into the ultra-red.

More recently Captain Abney has experimented in the same direction, using collodion containing various colouring or other material supposed to promote the photographic action of the less-refrangible rays; and in a very recent Number of Poggendorff's *Annalen* (No. 10, 1876), MM. H. C. Vogel and O. Lohse have published similar experiments. It is this last paper that leads me to make the present remarks; for those physicists seem not to be aware that what they are attempting now was accomplished in America thirty-five years ago.

I think, from some expressions that Captain Abney has used in one of his papers, that he entertains a very low estimate of the photographs so produced; he depreciates the process by which they were obtained very much. Sir John Herschel, than whom no one was a more competent judge of a fine photograph, says of one of these that I sent him (Philosophical Magazine, February 1843), "I should hardly be doing justice to the beauty of the specimen itself as a joint work of nature and art were I to forbear acknowledging its arrival, and offering a few remarks on it..... The spectrum itself is extremely remarkable and beautiful..... Want of habitude in the manipulation of the daguerreotype process, and by no means want of sun, prevented my obtaining any thing like so fine an impression." If Captain Abney will for once excuse an inventor for praising his own invention, I who have seen very many photographs, and know the difference between a good and an imperfect one, will assure him that these spectrum-impressions were superb. If he will only try the process, he will never give himself any concern about collodion spectra again.

I have attempted ineffectually to draw attention to this process. There is, in my opinion, no fact more striking among the chemical effects of light, none that promises, from its investigation, more important results.

There are two modes by which this process can be carried into effect.

1st. Submit a silvered plate to the vapour of iodine until it has acquired a yellow tarnish; or, better (since the plate will become thirty times more sensitive), submit it to iodine, bromine, and again to iodine, until the same tint of tarnish has been obtained.

Now expose it to a pure spectrum in a room to which a feeble daylight is admitted. On developing by the vapour of mercury, a photograph will be obtained of the visible spectrum from end to end, and extensive regions beyond the violet and the red respectively. In all the part above the blue the daylight and the sunlight have acted in unison, in all that below the blue they have antagonized, and the plate remains unacted upon, except where the Fraunhofer lines occur, and where, therefore, there has been no sunlight. Then the daylight has depicted those lines in white, while the more refrangible are black.

2nd. Prepare a plate as before. Expose it to a feeble daylight or lamp-light, until, if developed with mercury, it would whiten all over. But instead of developing it, now let it receive a pure spectrum. Then develop, and the result will be the same as in the preceding case.

So it is not necessary that the daylight and the sunlight should act simultaneously; they may act successively —an important fact in settling the nature of their antagonism.

To produce a perfect result, the two (the daylight and the sunlight) must be exactly balanced. If the daylight should preponderate, the protection is only in the extreme red; as it is diminished the protection extends higher and higher; and the exact equipoise being attained, it reaches the confines of the blue. All the Fraunhofer lines in the less-refrangible portion of the spectrum come out in white; all those in the more refrangible are dark. In my early experiments I could not obtain D, E, F; but my son, Henry Draper, operating under this rule, has since photographed them all.

Of all photographic facts this antagonizing action is the most extraordinary. I still work at its elucidation, though in a very desultory manner. I earnestly commend it to the attention of those interested in an examination of the chemical action of radiations, as one of the most important and promising topics.

JOHN W. DRAPER.

University, New York,
December 13, 1876.

XIV. *Contributions to the Theory of Luminous Flames.*— Part II. *By* Dr. KARL HEUMANN*.

Influence of Withdrawal of Heat from, and Addition of Heat to Luminous Flames.

ALTHOUGH the phenomenon of a small distance existing between flame and burner, or flame and a cold substance placed therein, is most apparent in the case of non-luminous flames, or of those flames which have been diluted by indifferent gases, nevertheless this appearance is also noticeable in the case of luminous flames. In the latter flames the eye is somewhat overpowered by the light, and hence has difficulty in observing the vacant space; the recognition of this space is made easier by placing a screen in such a position as to cover the luminous part of the flame as completely as possible.

Mention has already been made of the fact that a flame loses luminosity by being pressed down or widened out by the introduction of a cold substance; and by properly regulating the experiment, it has been shown that the withdrawal of heat is *of itself* sufficient to account for the observed diminution in luminosity. By combining the results so obtained with those which we have gained concerning the distance between flame and burner, or flame and cold object placed therein, we are led to deductions of great practical interest.

If a cold metallic wire be placed in a luminous gas- or candle-flame, the flame is totally extinguished in the immediate neighbourhood of the wire, and the luminosity of the flame is diminished throughout a very considerable area.

In this experiment the low conductivity for heat of gases comes into play, aided by the great freedom of motion and diffusibility of the particles, whereby highly heated particles are continually brought into fresh contact with the cold wire. The cooling action of the wire is therefore the greater, and extends throughout a larger space, the lower the temperature of the wire itself. The wire is therefore also more potent in

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