ally widened the colors rapidly lose their pure hues, the change at the central portion being most marked at first. Finally, if the slit be made wide enough, the color entirely disappears from the middle part, while at one end (accepting Dr. Kirschmann's description) there is a band of red, orange and yellow; at the other, one of blue and blue-green. The explanation of this is well known. A wide slit may be considered as the sum of a great number of narrow ones, each of which gives rise to a pure spectrum, but these spectra are superposed, producing perfect white in the middle and the colors mentioned at the ends.

Dr. Kirschmann explains the absence of green proper by saying that its two neighbors, blue and yellow, are here separated, and so are deprived of the power of cooperation, just as in the ordinary spectrum red and blue are separated, and thus can not produce purple. But the nature of the mixture is very different in the two cases, and even though we should grant that the sensation of green is due to the superposition of blue and yellow, we should hardly be justified in concluding that purple should be considered as simple a color as green, since blue and yellow have wave-lengths nearly equal, while the wave-length of red is approximately twice that of blue. We *know*, from physical considerations, that purple is not simple like spectral green.

From the explanation given above it would appear that the 'inverted spectrum' is far from being a pure one, though Dr. Kirschmann thinks that this statement can be proved unfounded. When we examine with a spectroscope the light reflected from a very thin sheet of mica, we see the spectrum crossed transversely by a number of dark bands. This phenomenon is one of the large interference-family of 'colors of thin plates,' and is ordinarily known as the 'channeled spectrum.' Many investigations have been made on it. Dr. Kirschmann states that he was able to obtain these 'channels' in the 'inverted spectrum.' For the production of such, however, the spectrum need not by any means be pure. In a single experiment with a direct-vision spectroscope and a sheet of mica about 1/100 of a millimeter thick, I was able to see the 'channels' when the slit was 0.6 millimeter wide, while to show the *most prominent* Fraunhofer dark lines, and thus have a slight approach to purity, the slit had to be less than 0.25 millimeter wide.

To use the channeled spectrum for the purpose of measuring wave-lengths, as suggested, is not very convenient, since the thickness of the thin plate, its index of refraction, the angle of incidence (or of refraction), as well as the 'order' of the interference, would all have to be determined. But if *some* wave-lengths are known, *others* may be conveniently located by this means. A very elegant application of this method was made by Maxwell[*] in his classical experiments on the mixing of spectral colors. His thin plate was a layer of air between two plane plates of glass, and by the channels in the spectral image shown at the end of his color-box he was able to calibrate in wave-lengths an arbitrary scale put across it.

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SURFACE TENSION; MOLECULAR FORCES.

In deducing the surface tension equations by the method of Laplace we start with the assumption that the force with which one element, dv, of the liquid attracts another δ element, v, is

$$F=\frac{1}{k}\rho^2\cdot dv\cdot\delta v\cdot f(r)$$

(usually the k is wrongly omitted), where ρ is the effective density of the liquid, and $f(r)$ is the law of the variation of the force with the distance. Finally we find that the surface tension is

$$T=\frac{1}{k}\rho^2 I,$$

where I is a definite integral (and hence a constant) derived from $f(r)$. In measuring the surface tension of liquids we are usually content to stop when we have found T, or we endeavor to find relations between the values of T for different liquids. We can do much

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[*] *Phil. Trans. of R. S.*, 1860. 'Scientific Papers,' Vol. I., p. 410, § 6.

better than this. The most superficial consideration will show that ρ can not be the ordinary density; but, if what we have designated as molecules have any physical significance whatever, ρ must be proportional to the number of molecules in unit volume. If M is the molecular weight of the liquid, and D is its density, then D/M is the number of gram molecules per unit volume, and we must have

$$\rho=\frac{mD}{M}$$

where m is the factor of proportionality and depends upon the nature of the molecule. Substituting this in the equation for the surface tension we find

$$T=\frac{1}{k}\frac{m^2D^2}{M^2}I$$

or

$$\frac{M^2T}{D^2}=I\frac{m^2}{k},$$

a quantity in which the density, which varies from liquid to liquid in a way which can not be predicted, no longer explicitly enters. This quantity M^2T/D^2 is probably very important in molecular mechanics; if k were the same for all liquids it would be *most* important, as it would give us m, which we may call the *mean molecular moment* of the liquid. k, however, probably varies from liquid to liquid.

So far we have made no assumption other than those contained in Laplace's equations. Now we shall go farther. If molecular forces are electrical in their origin, as Professor Sutherland and others think, then we are almost justified in putting k equal to the specific inductive capacity of the liquid; and if on replacing k by this quantity we arrive at values for the *molecular moment, m,* all of the same order of magnitude, we can say that the assumption is at least not an improbable one. The following table contains the various quantities involved for twenty substances (all of those for which I have the necessary data at hand), and we see that

$$\left[\frac{kM^2T}{D^2}\right]^{\frac{1}{2}}(\equiv\sqrt{I}\cdot m)$$

is of the same order in every case, the greatest (2.0) being four times the smallest (0.5), while T varies from 18 to 74, k from 2 to 75, and M from 18 to 256. This appears to me to be as satisfactory an indication of the correctness of this method of viewing the matter as we should expect.

Liquid.		k	D	M	T	$\frac{M^2T}{D^2}=I\frac{m^2}{k}$	$\left[\frac{kM^2T}{D^2}\right]^{1/2}=\sqrt{I}.m$ *molecular moment.*
Benzene	C_6H_6	2.3	0.88	78	27.5	216 x 10^3	0.71 x 10^3
Toluene	C_7H_8	2.3	0.89	92	27.9	299	0.82
Cymene	$C_{10}H_{14}$	2.3	0.87	134	27.9	660	1.22
Methyl alcohol......	CH_4O	33.	0.80	32	23.8	38	1.14
Ethyl "	C_2H_6O	26.	0.79	46	23.1	78	1.41
Propyl "	C_3H_8O	23.	0.79	60	24.1	139	1.79
Amyl "	$C_5H_{12}O$	16.	0.83	88	23.8	267	2.06
Acetic acid............	$C_2H_4O_2$	9.7	1.05	60	29.0	95	0.96
Butyric "	$C_4H_8O_2$	3.0	0.96	88	27.2	228	0.82
Ethyl formate........	$C_3H_6O_2$	9.1	0.95	74	25.8	156	1.18
" acetate	$C_4H_8O_2$	6.5	0.90	88	25.1	239	1.26
" propionate...	$C_5H_{10}O_2$	6.0	0.91	102	26.0	328	1.41
" butyrate......	$C_6H_{12}O_2$	5.3	0.90	116	25.0	416	1.48
Methyl acetate.......	$C_3H_6O_2$	7.8	0.96	74	25.3	150	1.08
Ethyl "	$C_4H_8O_2$	6.5	0.90	88	25.1	239	1.26
Propyl "	$C_5H_{10}O_2$	6.3	0.91	102	26.2	330	1.45
Ethyl ether...........	$C_4H_{10}O$	4.4	0.79	74	18.2	160	0.84
Carbon bisulphide..	CS_2	1.81	1.29	76	32.3	150	0.52
Water	H_2O	75.	1.00	18	74.	24	1.34
Sulphur................	S_6	2.8	1.98	192	44.6	430	1.13

In dealing with similar compounds, very evident relations exist between the different values of M^2T/D^2 and also of $[kM^2T/D^2]^{1/2}$, but the consideration of these and of other interesting points will be deferred until I shall have been able to assemble more extensive and newer data.

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Annapolis Junction, Maryland,
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THE OVERSPUN STRING.

Loading a string by 'overspinning' with wire, as is well known, causes it to produce a deeper tone without adding to its length. It, also, can be strung over a finger-board, where it may be 'stopped,' thus enabling a single string to produce an octave or more with its chromatic intervals, and to take the place of eight or more long open strings. So far as my information goes, the overspun string was introduced into France by St. Colombe about 1675. The chitarrone with its very long open bass strings dates from 1589 and was used in orchestras in 1607. I am desirous of ascertaining whether the superiority of the overspun string over the long open string for the deeper tones was known earlier than I have mentioned, and whether the chitarrone was used because the overspinning was unknown.

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NOTES ON THE JUDITH RIVER GROUP.

In August, 1876, Mr. J. C. Isaac (who had been my assistant earlier in the season in the chalk of Kansas) and myself joined Professor E. D. Cope at Omaha, to go with him as his assistants to the Judith River region in Montana. From Franklin, Idaho, we made the journey of 600 miles to Fort Benton by stage. Here the professor purchased a wagon, four work horses and three saddle ponies, employed a cook (to act also as teamster) and a scout, who was to warn us of danger from Indians. Sitting Bull with his thousands of braves was south of our field, fighting the soldiers. We traveled down the Missouri River opposite Clagett, an Indian trading post, 120 miles below Fort Benton. Here we crossed the river, and went into camp on Dog Creek, a few miles east of the Judith River, and about ten miles from its mouth. The cañon of this creek was narrow. We were shut in by the dark and desolate Bad-lands, which, as I remember, the professor estimated as over 1,000 feet high. The lower slopes were composed of beds of lignite, from a few inches to six feet in thickness, and black shale, the lignite layers not appearing in the great bed of shale in its upper part. Professor Cope made a sketch of the wonderful panorama, which I afterwards saw published. The shale disintegrated into dust on the surface, into which one sank to his knees in climbing some steep ascent. This formation, Cope assured me, belonged to the Fort Pierre group of the Cretaceous. We found many bones in it, of mosasaurs and fishes, similar to those I had already collected in western Kansas. After my return from Montana I felt sure the black shales then called Niobrara belonged to the Fort Pierre, on account of their faunal and stratigraphical resemblances to those on Dog Creek. It was years, however, before this view was generally accepted. I remember one very good quadrate I picked up on Dog Creek which I thought belonged to a *Platecarpus*. We could have made large collections of these fishes and mosasaurs but for the fact they were poorly preserved and interfered with the main object of the expedition.

On top of the Pierre deposits, which were the thickest, were the buff-colored sandstones of the Fox Hills group. We found no fossils in it, but I was assured by Cope of their position in the series. The Judith River beds, or Cretaceous No. 6, as Cope identified them, were above the Fox Hills. The rocks of this formation were composed of sandstone and clay. On the very highest summits of the Bad-lands was a thin bed of oyster shells. We remained in our camp over a month here. Every morning at sunrise we were in the saddle, taking a lunch of crackers and bacon. We returned late in the evening. Our chief discoveries were from a yellowish sandstone, in which we found many bone-beds, where loose teeth, bones and fragments of turtle shells were mingled together, often weathered out, lying loose on the surface. I have been deeply interested in reading Professor H. F. Osborn's and Mr. L. M. Lambe's 'Contributions to Canadian Paleontology,' Vol. III.,