smooth sliding; the decrease in the amount of adhesion and transfer is very marked. Similar results were obtained on copper surfaces.

An attempt was also made to make the method quantitative by measuring the effect on a photographic plate of known surface concentrations of radioactive lead electrodeposited on a platinum surface. It was found that the effect on the plates was approximately linear with time and concentration. (For example, for any given concentration, two plates of, say, one hour's exposure when superimposed gave a darkening, measured visually, equal to that of one plate with two hours' exposure. A similar relationship was found for the effect of concentration.) The track concentration could then be estimated by visual comparison. Results were consistent to within 50 per cent. Fig. 2 shows some standards compared with a track of lead on lead. The lubricant was relatively ineffective, μ being greater than 1·0. The exposure was for 24 hours, and an estimate gives an average track density of about 0·08 mgm./cm.[2]. It is obvious, however, that the film is thicker than this in certain spots.

The accompanying table shows a summary of the quantitative results:

Track	Av. coeff. of friction (μ)	Av. surface density (mgm./cm.[2])	Average film thickness	
			A.	Atoms of lead
Unlubricated lead on steel				
(*a*) Heavy spots on sticks	0·40	0·04	360	120
(*b*) Light parts on sticks		0·010	90	30
(*c*) During the slip		0·005	45	15
Lubricated lead on steel	0·10	0·002	20	6
Unlubricated lead on copper				
(*a*) Heavy spot on sticks	0·33	0·060	550	180
(*b*) Lighter parts on sticks		0·006	60	20
		0·002	20	8
(*c*) During the slip		0·005	45	13
Lubricated lead on copper	0·13	0·005	45	13
Lubricated lead on lead	1·0	0·08	700	230

It is seen that in general the reduction in friction produced by the lubricant is accompanied by a reduction in the amount of metallic transfer. This supports the view that metallic friction is dependent on the amount of adhesion between the surfaces. The role of the lubricant is to reduce the area over which intimate metallic contact occurs.

The radioactive method is particularly valuable in studying the sliding of similar metals where chemical methods of detecting transfer are impossible. It can be made extremely sensitive by using larger concentrations of the active isotope in the slider. So far, only lead has been used, but it is clear that the method can be extended to other radioactive metals. Work is proceeding along these lines.

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[1] Bowden and Moore, *Nature*, **155**, 451 (1945).
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Interferometers and the Group Index

RAYLEIGH pointed out the importance of the group index in optics more than half a century ago, but the simplifications which the use of a group index G make possible do not appear to have been recognized, though Craven[1] has pointed the way. G is defined as

$$(N + \nu\delta N/\delta\nu),$$

where ν is the wave-number $1/\lambda$ and N is the refractive index.

The range without overlap measured in wave-numbers and written $\Delta\nu_R$ of *all* interferometers is simply $1/L_G$, where L_G is the group optical path difference between successive beams leaving the interferometer. L_G is defined by the equation

$$L_G = Nl + \nu\delta(Nl)/\delta\nu,$$

where l is the geometric path difference. Nl is here the quantity usually known as the optical path difference, which is more strictly the phase-path as opposed to the group-path.

Applied to four interferometers used in the study of hyperfine structure, which are all based on a plate of thickness D, this equation leads at once to well-known equations for the useful range:

Reflexion echelon,	$L_G = 2PD$	$\Delta\nu_R = 1/2PD$
Transmission echelon,	$L_G = (G-1)PD$	$\Delta\nu_R = 1/(G-1)PD$
Fabry-Perot etalon,	$L_G = 2D$	$\Delta\nu_R = 1/2D$
Lummer plate	$L_G = 2D\,(NG-1)\,(N^2-1)^{-1/2}$	

The equation for the Lummer plate follows from the optical path difference between successive beams

$$Nl = 2D(N^2 - 1)^{1/2},$$

where the incidence is taken as grazing.

The limit of resolution $\Delta\nu_L$ assumes an equally simple form; it too may be written $1/LG$, but the term L_G is defined as the group-path difference, not between successive beams but between the extreme beams leaving the interferometer. The argument which leads to this equation assumes the Rayleigh criterion of resolution and is valid only if all the interfering beams are equally intense. The formula is not therefore applicable to the Fabry-Perot etalon or Lummer plate.

Reflexion echelon,	$L_G = 2PD$	$\Delta\nu_L = 1/2PD$
Transmission echelon,	$L_G = (G-1)PD$	$\Delta\nu_L = 1/(G-1)PD$
Diffraction grating,	$L_G = mP\,(\sin I + \sin I')$	

P is here the number of plates, or more strictly the number of interfering beams. In the equation for the grating, m is the order of the spectrum and I and I' the angles of incidence and diffraction.

The formula for the limit of resolution is also valid for a prism. The rays travelling through the vertex and through the base of the prism travel equal phase optical paths, but the rays travelling through the vertex travel in air, so that the path is not a function of λ and we may write it simply ND, where D is the thickness of the base; the optical path through the base varies with wave-length and must be written GD. Thus

$$L_G = (G - N)D = \nu D\,\delta N/\delta\nu,$$

so that the limit of resolution is $\Delta\nu_L = 1/\nu D\,\delta N/\delta\nu$, another well-known result.

The formula here given for the limit of resolution is identical with Ewart Williams's statement[2] that "the resolving power is the path-difference between the extreme beams measured in wave-lengths", if and only if the path is in a non-dispersive medium. Thus Williams's rule leads to the same result as that given above in the reflexion echelon and diffraction grating, but not in the transmission echelon or prism.

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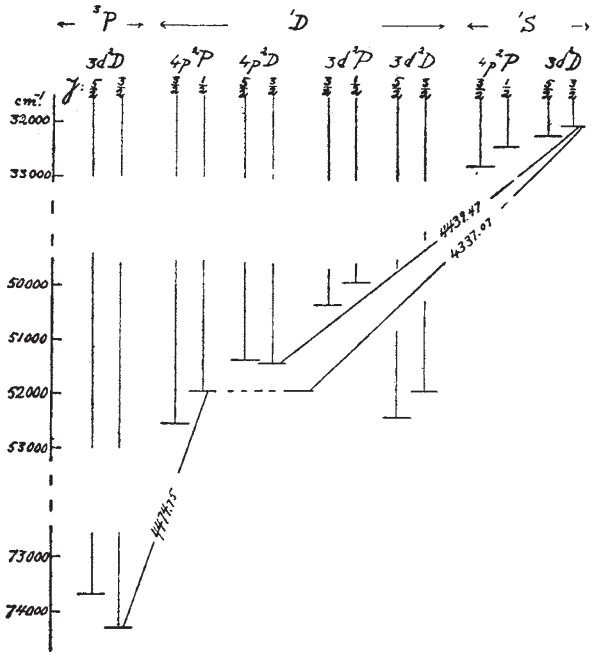
[1] Craven, *Proc. Phys. Soc.*, **57**, 97 (1945).
[2] Williams, W. E., "Interferometry", 27 (1929).

Stark Effect of Spectrum Lines with Predominating Shifts in Final Levels

THE displacement of a spectrum line caused by an electric field is composed of the displacements of the initial and the final level. In general, the shifts for a given field-strength increase rapidly with an increasing principal quantum number, and for the non-hydrogenic atoms so far observed the Stark effect in the final level is usually found to be negligible. While investigating the Stark effect of singly ionized argon (Ar II), however, some cases have been observed—as I believe for the first time—where the final levels are shifted much more than the initial ones. An example of this effect will be given here.



PARTIAL LEVEL DIAGRAM OF AR II.

In the accompanying chart some of the Ar II levels are plotted according to de Bruin's analysis[1]. The term value of $(^1D)4p^2P_{1/2}$ is 51938·2 cm.$^{-1}$ and of $(^1D)3d^2D_{3/2}$ 51924·5 cm.$^{-1}$. According to the perturbation theory applied to the Stark effect, two levels will repel each other if they have opposite parities and $\Delta J = 0$ or ± 1, the repulsion being proportional to the nearness of the levels. Thus, $(^1D)4p^2P_{1/2}$ is pushed strongly downwards by $(^1D)3d^2D_{3/2}$, the level separation being only 13·7 cm.$^{-1}$. The displacement of the level $(^1D)4p^2P_{1/2}$ could be determined from the transition $(^3P)3d^2D_{3/2} - (^1D)4p^2P_{1/2}$, λ 4474·75, as the shift of this line (towards the red) must be entirely due to the displacement of its initial level. Likewise the slight shift of $(^1D)4p^2D_{3/2} - (^1S)3d^2D_{3/2}$, λ 4439·47, must be ascribed to the displacement of its initial level $(^1S)3d^2D_{3/2}$. The transition from the level $(^1S)3d^2D_{3/2}$ to $(^1D)4p^2P_{1/2}$, which are both influenced by the