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VIII. *On the Change in the Volumes and Refractive Indices of Fluids produced by Hydrostatic Pressure.* By Professor G. QUINCKE*.

IN order to determine the compressibility of a liquid, the apparent decrease in the unit volume was measured which the liquid showed at 0° and at a mean temperature of t° when the pressure on the liquid was increased by an amount measured by means of a mercury-manometer, the liquid being contained in a glass vessel provided with a capillary tube under the receiver of an air-pump. The change in volume of the containing glass vessel was determined by separate experiments, and added to the apparent change in volume of the liquid so as to determine the absolute decrease in volume of the liquid. Both of these changes were found nearly proportional to the increase in pressure. From these data we obtain the actual decrease of unit volume of the liquid for an increase in pressure of one atmosphere, or the compressibility of the fluid at 0° and at t° .

Compressibility, or decrease of volume of Fluids produced by a Hydrostatic Pressure of one Atmosphere, in millionths of the original volume.

Fluid.	$\mu \cdot 10^6$.		Temperature t° .
	At 0° .	At t° .	
	volume.	volume.	
Glycerine	24.24	25.10	19.00
Rape-oil.....	48.02	58.18	17.80
Almond-oil	48.21	56.30	19.68
Olive-oil.....	48.59	61.74	18.30
Water	50.30	45.63	22.93
Sulphide of carbon	53.92	63.78	17.00
Turpentine	58.17	77.93	18.56
Benzol from benzoic acid....		66.10	16.78
Benzol		62.84	16.08
Rock-oil.....	64.99	74.50	19.23
Alcohol	82.82	95.95	17.51
Ether	115.57	147.72	21.36

The change in the refractive index at the temperature t° for the same liquids was determined when the pressure on the

* Translated from the *Sitzungsberichte der königlich preussischen Akademie der Wissenschaften* of Berlin, April 1883.

liquid was increased by a certain amount measured by means of a mercury-manometer.

The liquids, contained in glass or metal tubes of 230 millim. length, were introduced into an interference-apparatus previously employed*, which I have already described. The liquid was traversed by one of the two interfering pencils of rays, and the number of interference-bands measured which corresponded to a given Fraunhofer line in a pure spectrum. The changes of pressure were produced by means of an air-pump.

The compressibility of the liquid may be calculated from these optical experiments, under certain assumptions as to the constancy of the so-called specific refractive power or of the refraction-constant. If we call

y the number of interference-bands which pass through the fixed Fraunhofer line for an increase in pressure of p millim. mercury in a layer of liquid of D millim. length;

Y the number of interference-bands which would pass through the same line of the spectrum for an increase in pressure of one atmosphere, and a layer of liquid of 1000 millim. length.;

n, n_1 the refractive index } of the liquid before and after the
 σ, σ_1 the specific gravity } compression;

λ the wave-length of the reference-line of the spectrum in air;

μ the compressibility of the liquid;

then, since change of volume is proportional to increase of pressure,

$$\frac{\sigma_1}{\sigma} = 1 + \mu \frac{p}{760}, \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$y = Y \cdot \frac{p}{760} \cdot \frac{D}{1000} = \frac{D}{\lambda} (n_1 - n). \quad . \quad (2)$$

The difference in the refractive indices may be calculated by the aid of equation (1) in different ways, according to the assumption we make as to the so-called refractive power, or some analogous quantity.

If we assume with Dale and Gladstone†, Landolt‡, and others that the so-called specific refraction is constant, then

$$\frac{n-1}{\sigma} = \frac{n_1-1}{\sigma} = \text{constant}. \quad . \quad . \quad . \quad (3A)$$

* Quincke, Pogg. *Ann.* cxxxii. p. 53, and Table II. fig. 13, 1867.

† Phil. Trans. 1863, p. 377.

‡ Pogg. *Ann.* cxxiii. p. 596 (1864); *Berl. Sitzungsber.* ix. 1. 1882, p. 64.

Whilst there is no theoretical ground for this hypothesis, the theory of light requires that the *specific refractive power* should be constant, or

$$\frac{n^2-1}{\sigma} = \frac{n_1^2-1}{\sigma} = \text{constant.} \quad \dots \quad (3B)$$

M. H. A. Lorentz*, of Amsterdam, and M. L. Lorenz†, of Copenhagen, have recently drawn the conclusion, from different theoretical grounds, that another quantity, the so-called *refraction-constant*, is constant, whence

$$\frac{n^2-1}{n^2-1} \cdot \frac{1}{\sigma} = \frac{n_1^2-1}{n_1^2-2} \cdot \frac{1}{\sigma_1} = \text{constant.} \quad \dots \quad (3C)$$

From the three equations (3A), (3B), (3C) the ratio of the specific gravities is obtained, observing that n_1-n is a very small quantity,

$$\frac{\sigma_1}{\sigma} = 1 + \frac{n_1-n}{n-1}, \quad \dots \quad (4A)$$

$$\frac{\sigma_1}{\sigma} = 1 + \frac{2n(n_1-n)}{n^2-1}, \quad \dots \quad (4B)$$

$$\frac{\sigma_1}{\sigma} = 1 + \frac{6n(n_1-n)}{(n^2-1)(n^2+2)}. \quad \dots \quad (4C)$$

If in these equations we put for n_1-n its value from equation (2), and for $\frac{\sigma_1}{\sigma}$ its value from equation (1), we have

$$\mu_a = Y \cdot \frac{\lambda}{1000} \cdot \frac{1}{n-1}, \quad \dots \quad (5A)$$

$$\mu_b = Y \cdot \frac{\lambda}{1000} \cdot \frac{2n}{n^2-1}, \quad \dots \quad (5B)$$

$$\mu_c = Y \cdot \frac{\lambda}{1000} \cdot \frac{6n}{(n^2-1)(n^2+2)}, \quad \dots \quad (5C)$$

the suffix *a*, *b*, or *c* denoting whether the value of μ has been obtained by calculation from formula (3A), (3B), or (3C).

The values of the compressibility of water calculated from these equations (5) are compared in the following Table with those obtained by direct observation, and the numbers of interference-bands *Y* for the particular Fraunhofer line.

* Wied. Ann. ix. p. 642 (1880).

† Wied. Ann. xi. p. 77 (1880).

Fraunhofer line.	Interference-bands, Y.	Temperature, t° C.	Calculated compressibility of water.		
			$\mu_a \cdot 10^6$.	$\mu_b \cdot 10^6$.	$\mu_c \cdot 10^6$.
C	ϕ 22.55	20.40	vol. 44.69	vol. 50.12	vol. 40.60
D	25.72	20.42	45.51	52.00	41.31
E	28.92	19.60	45.43	51.95	41.22
F	31.59	18.12	45.52	52.08	41.26
G	35.32	19.41	44.66	51.16	40.40
Directly observed, $\mu \cdot 10^6 = \begin{cases} 46.15 \text{ at } 18^{\circ} \dots\dots \text{Grassi*} \\ 45.63 \text{ at } 22^{\circ} \cdot 9 \dots \text{Quincke.} \end{cases}$					

Similar measurements with different liquids for the Fraunhofer line D give the following results:—

Liquid.	Interference-bands.	Temp.	Refractive index.	Compressibility.			
				Obs.	Calculated from interference-phenomena.		
	ϕ .						
Glycerin.....	18.17	20.53	1.4689	25.09	22.81	27.14	19.60
Rape-oil.....	46.24	20.3	1.4753	59.61	57.30	68.30	49.08
Almond-oil	45.42	17.0	1.4720	55.19	56.67	67.46	48.59
Olive-oil.....	46.47	20.5	1.4690	63.32	58.34	69.42	50.09
Water	26.02	20.42	1.3330	46.14	46.04	52.60	41.78
Sulphide of carbon ...	73.89	15.0	1.6710	62.62	64.88	81.17	50.80
Turpentine	66.56	19.7	1.4712	79.14	77.76	92.56	66.68
Rock-oil.....	61.07	19.4	1.4484	74.58	74.96	88.72	64.94
Alcohol	61.53	20.18	1.3616	101.41	100.2	115.4	89.84
Ether	86.96	18.0	1.3537	142.65	144.83	166.6	130.4

With all these liquids we find agreement between the observed values of the compressibility and those calculated from the optical experiments by the aid of equation (5A); whilst the values calculated by means of equations (5B) and (5C) show greater differences than can be accounted for as resulting from experimental errors. Hence we draw the conclusion that, at constant temperature and varying hydrostatic pressure, the specific refraction for the liquids which I have examined,

$$\frac{n-1}{\sigma} = \text{constant},$$

or that the decimals of the refractive index are proportional to the density.

* *Ann. de Chim.* [3] xxxi. p. 477 (1851).