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V. *A Note on the Relation between the Thermal Conductivity and the Viscosity of Gases with reference to Molecular Complexity.* By J. A. POLLOCK, D.Sc., Professor of Physics in the University of Sydney*.

IN the equation $k=f\eta c_v$, expressing the thermal conductivity of a gas in terms of the viscosity and specific heat, the coefficient f is a numerical factor which is approximately constant for gases of the same atomicity. Such a fact suggests the probability of a relationship between f and γ , the ratio of the specific heats. But long before the result, just mentioned, was fully established, the probability of f being a function of γ was recognized, though it was not generally appreciated. As early as 1876 Boltzmann†, from theoretical considerations, obtained the expression $f=3f'(\gamma-1)/2$, where f' is the constant for monatomic gases. It has been known for some time that the equation is physically inaccurate, but the matter does not seem to have been followed further.

Recently new results for the thermal conductivities of a number of gases have been published by Eucken‡. In connexion with these measures, Eucken discusses the dependence of f , not only on the properties of the molecule, but also on the temperature. As possibly lying outside the main lines of his investigation, he does not consider the relationship of f to γ , but, from the zero temperature values of the thermal conductivities and viscosities given by him, a relation appears to exist between the two factors which can be expressed by an equation of the form

$$f = \frac{a(\gamma-1)}{\gamma^n},$$

where a and n are constants. The precise arithmetical adjustment of these constants may well await further measures; in the meantime, with numerical simplicity as well as physical accuracy in view, the equation may be written

$$f = \frac{7.32(\gamma-1)}{\gamma^{1.3}}.$$

If, in the original expression, n , the power of γ , is put

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† Boltzmann, Pogg. Ann. clvii. p. 457 (1876); see also Schleiermacher, Wied. Ann. xxxvi. p. 346 (1889); and Chapman, Trans. Roy. Soc. cexi. A. p. 433 (1912).

‡ Eucken, Phys. Zeitschr. xiv. p. 324 (1913).

equal to unity, the equation, with an appropriate value of the constant, quite well represents the experimental results with the exception of those for the monatomic gases. This leads, in the case of perfect gases, to the simple relation

$$\frac{m\gamma k_0}{\eta_0} = \text{constant},$$

where m is the molecular mass.

In the following table, with the zero temperature measures of k and η , taken from Eucken's paper, I give, for the calculation of f , the experimental results for c_p and γ instead

TABLE I.

1	2	3	4	5	6
Molecule.	m .	$k_0 \times 10^6$.	$\eta_0 \times 10^6$.	c_p .	γ .
He	4	336	187.6	1.260*	1.63
A	40	39.0	210.2	0.123	1.667
H ₂	2	397	85	3.422†	1.402†
N ₂	28	56.6	167.6	0.2429†	1.412†
O ₂	32	57.0	192.2	0.2173†	1.402†
Air	29	56.6	171	0.2376†	1.405†
Cl ₂	71	18.29	123.7	0.115	1.323‡
CO	28	54.25	167.2	0.2502*	1.401
NO	30	55.5	179.4	0.232	1.394
H ₂ S	34	30.45	118.4	0.245	1.340
CO ₂	44	33.7	138	0.2010	1.300
N ₂ O	44	35.15	136.2	0.213	1.324
SO ₂	64	19.5	118.3	0.1544‡	1.256
CS ₂	76	16.15	92.4	0.160	1.239
NH ₃	17	51.35	92.6	0.520	1.336
C ₂ H ₂	26	44.0	94.3	...	1.26
CH ₄	16	71.45	102.9	0.591	1.313
C ₂ H ₄	28	40.7	90.66	0.404	1.264
C ₂ H ₆	30	42.6	85.5	...	1.22

* Scheel and Heuse, *Ann. d. Physik*, xl. 3, p. 473 (1913). † Escher, *Ann. d. Physik*, xlii. 4, p. 761 (1913). ‡ Landolt-Börnstein Tabellen. All other values in columns 5 and 6, from Kaye and Laby's Tables.

of the values of c_p . The figures given for f in column 2 of Table II., deduced from the equation $k=f\eta c_p/\gamma$, are thus wholly dependent on the results of experiment.

In this second table, the values of f , derived from the expression $f=7.32(\gamma-1)/\gamma^{1.3}$, are entered in column 3. An idea of the physical accuracy of the calculated results may, therefore, be obtained from a comparison of these figures

TABLE II.

1	2	3	4
Molecule.	f obs.	f cal.	$\frac{m\gamma k_0}{\eta_0}$
	$\frac{\gamma k_0}{\eta_0 c_p}$	$\frac{7.32(\gamma-1)}{\gamma^{1.3}}$	
He	2.32	2.45	11.6
A	2.51	2.51	12.4
H ₂	1.91	1.90	13.2
N ₂	1.96	1.93	13.4
O ₂	1.91	1.90	13.3
Air	1.96	1.91	13.5
Cl ₂	1.70	1.63	13.8
CO	1.82	1.89	12.7
NO	1.90	1.87	12.9
H ₂ S	1.41	1.70	11.7
CO ₂	1.58	1.56	14.0
N ₂ O	1.60	1.65	15.0
SO ₂	1.35	1.39	13.3
CS ₂	1.35	1.32	16.5
NH ₃	1.79	1.69	12.6
C ₂ H ₂	15.3
CH ₄	1.52	1.61	14.6
C ₂ H ₄	1.40	1.43	15.9
C ₂ H ₆	18.3

with those in column 2. There are certainly large differences between the calculated and observed values for some gases, but the experimental determinations cannot be considered in all cases as final.

The last column of Table II. contains the values of $m\gamma k_0/\eta_0$. As previously mentioned, with the present experimental results, constancy of the value of the ratio is only to be expected in the case of perfect gases with molecules of an atomicity greater than 2. The approximate similarity of the figures in some number of instances is, therefore, perhaps more remarkable than the divergencies in the other cases.

It is interesting to note the rise that has taken place in the values of the thermal conductivities. For many years the determinations of f for diatomic gases were cited in support of Meyer's well-known theoretical deduction, $f=1.6027$. Now, from Eucken's measures of the thermal conductivities, the value of f for these gases is 1.9.

The University of Sydney,
September 20th, 1915.