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is 51×10^6 , and even than any of the woods as given in volume iii. of Lord Kelvin's 'Collected Papers.' On account of the thread not being circular, the calculation of the Rigidity Modulus would of course be valueless.

A rough trial was made of the Torsional Rigidity; but as the thread was very much finer than that used by Professor Tanakadate, being about one third the diameter, it was difficult to obtain a light enough twisting-weight. The result obtained, however, agreed with that given by Prof. Tanakadate; in so far as it showed that the torsional rigidity of spiders' thread is considerably less than that of silk fibre.

XLIX. *The Method of Fractional Distillation illustrated by the Investigation of Kerosene.* By J. ALFRED WANKLYN and W. J. COOPER*.

A LIQUID known as kerosene, or Russian kerosene, is imported into this country in immense quantities. The liquid is produced by the distillation of crude natural Russian petroleum in Baku, and is conveyed in tank-ships to London. It arrives in this country in the condition of an almost colourless oil, with very little smell, and of sp. gr. 0.825 at $15^{\circ}5$ C. Apparently it is very constant in quality and composition.

The knowledge of it which we owe to former investigators is that it is a mixture of hydrocarbons of the general formula C_nH_{2n} ; that these hydrocarbons are not olefines, but are isomers of the olefines, being not readily attacked by reagents. Very few of the members of the series have been described by former investigators. We have made a study of kerosene as follows:—

When kerosene is rapidly distilled in a glass retort, 70 per cent. comes over below 250° C., about 20 per cent. between 250° and 300° , and the residual 10 per cent. may be almost completely volatilized; the last 5 per cent. requiring, however, a temperature much above the boiling-point of mercury.

By careful quantitative experiment, a carefully measured litre of kerosene being distilled in two operations, half a litre at a time, it was ascertained that there is neither expansion nor contraction during distillation. The observation was also made that not until the temperature had risen to 170° C. did the first drop of liquid distil over.

* Communicated by the Authors.

The actual figures of the experiment were as follows :—

	cub. centim.
Distillate between 170° and 250° . . .	688
„ „ 250° and 300° . . .	205
Residue	107
	<hr/> 1000

That nothing should distil over below 170° is most remarkable, inasmuch as there is actually present in kerosene a liquid with a boiling-point of 78° C. The proportion of this low-boiling liquid is indeed small ; but there are other volatile ingredients, and the sum total of the ingredients boiling below 170° C. amounts to more than one fifth of the total kerosene.

The 688 cub. centim. of distillate (which has just been mentioned) were submitted to redistillation, and they yielded 505 cub. centim. below 210° C. And in that manner one litre of kerosene was caused to yield 505 cub. centim. of distillate below 210° C. When it is directly distilled a litre of kerosene does not give anything like half its volume of distillate at temperatures below 210° C.

Continuing the investigation, the 505 cub. centim. of distillate were redistilled, and they began to distil at 125° C., and up to 170° C. 270 cub. centim. came over. And in that manner a litre of kerosene (which when directly distilled yields only one drop of distillate below 170° C.) may be caused to evolve 270 cub. centim. of distillate below 170° C.

All this illustrates how admixture with a high-boiling liquid raises the boiling-point of low-boiling liquids.

We have carried out a most laborious investigation of kerosene, and, operating on a considerable scale, after many months of fractionation have separated 24 different liquids, which, with probably a few others, and together with about 13 per cent. of residue boiling at temperatures above 290° C., make up the complex mixture known as kerosene. As to the proportions of the different ingredients of the mixture, it is to be noted that there is no one preponderating ingredient. There appears to be a very small proportion of the two most volatile terms of the series, but for the rest the distribution is not very uneven. We doubt whether the proportion of any one ingredient exceeds 5 per cent. of the whole kerosene.

In the following table are set forth the main results of our work :—

Tabular statement of the Constituents of Kerosene.

Label.	Boiling-point.	Vapour-density.		Formula.
		Found.	Theory.	
A	77° C.			
Az	87			
Aa	96·5	3·69	3·63	$C_{7\frac{1}{2}}H_{15}$
Ab	106	3·91	3·87	C_8H_{16}
B	116·5	4·08	4·11	$C_{8\frac{1}{2}}H_{17}$
Bb	127	4·36	4·35	C_9H_{18}
Bc	138	4·59	4·59	$C_{9\frac{1}{2}}H_{19}$
C	148	4·84	4·84	$C_{10}H_{20}$
D	158	5·02	5·08	$C_{10\frac{1}{2}}H_{21}$
Dd	168	5·20	5·32	$C_{11}H_{22}$
De	176	5·51	5·56	$C_{11\frac{1}{2}}H_{23}$
E	186	5·77	5·80	$C_{12}H_{24}$
F	197	6·08	6·04	$C_{12\frac{1}{2}}H_{25}$
Ff	205	6·28	$C_{13}H_{26}$
G	214	6·53	6·52	$C_{13\frac{1}{2}}H_{27}$
Gg	222	6·83	6·77	$C_{14}H_{28}$
H	230			
Hh	237			
I	246			
K	253			
L	260			
M	267			
N	274			
O	280			
Z	Residue—a dark coloured liquid (sp. gr. about 0·880 at 15°·5 C.), being a mixture of several liquids of very high boiling-point.			

The series of liquids, A to O, presents the following characters. Each liquid, when distilled separately in the well-known fractionation-flask, begins to distil about 10 degrees higher than its predecessor begins to distil. Thus the first term A begins to distil at 77°·5; the second term Az at 87°; the third term Aa at 96°; the fourth term Ab at 105°·5; the fifth term B at 116°; the sixth term Bb at 127°; the seventh term Bc at 138°, and so on up to the last term O.

Except the few highest terms the members of the series fulfil the requirement, viz. that half of the liquid shall distil without the thermometer rising more than 2 or 3 degrees, that three-quarters shall distil within 5 or 6 degrees of the starting-point, and that by the time the boiling-point of the next in the series is reached 90 per cent. shall have distilled over.

Within the last few weeks the seven lowest terms, viz. A

to Bc inclusive, have been prepared anew from fresh kerosene and fractionated with great perseverance. The first two terms A and Az have not yet been procured in sufficient quantity to admit of the very elaborate treatment to which we should like to subject them, but the five next terms, Aa to Bc inclusive, have been obtained in abundance and have been exhaustively treated.

As an example we will quote the record of the final testings of Aa :—

Exp. I.—Vol. of Aa employed = 136 cub. centim.

° C.		
At 96·2	. . .	5 cub. centim. had distilled.
97·2	. . .	50 " "
98	. . .	75 " "
99·2	. . .	100 " "
105	. . .	retort dry.

Exp. II.—Vol. of Aa, 132 cub. centim.

° C.		
96	. . .	5 cub. centim. had distilled.
97	. . .	50 " "
99	. . .	100 " "
105	. . .	dry.

Exp. III.—Vol. of Aa, 130 cub. centim.

° C.		
95·8	. . .	5 cub. centim. had distilled.
96·8	. . .	50 " "
98·8	. . .	100 " "
104	. . .	dry.

Showing that three-quarters of Aa distils over without a greater rise than 3 degrees, and that the retort becomes dry before the boiling-point of Ab is reached.

Before making the three final distillations Aa had been deprived of traces of Az (the next lower term) by the following course of procedure.

139 cub. centim. of Aa was placed in a retort and 50 cub. centim. was then distilled off. Next the 50 cub. centim. of distillate was redistilled thus :—

94°·8 C.	. . .	5 cub. centim.
96	. . .	16 " "

Then the 16 cub. centim. of distillate was redistilled,

94°	. . .	5 cub. centim.
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and 8 cub. centim. was distilled off and rejected.

As has been said, five consecutive terms, viz. Aa, Ab, B, Bb, and Bc, have been exhaustively treated, and each one has been proved to be incapable of being resolved into fractions with different boiling-points. We believe that the conclusion cannot be resisted that the kerosene series of hydrocarbons mounts by increments of 7 instead of by increments of 14, and we hold that the real atomic weight of carbon is 6 and not 12.

Laboratory, New Malden, Surrey.
14th April, 1894.

L. *Notices respecting New Books.*

UNIPLANAR ALGEBRA : being Part I. of a *Propædæutic to the Higher Mathematical Analysis*. By IRVING STRINGHAM, Ph.D., Professor of Mathematics in the University of California. San Francisco, the University Press.

"THE logical grounding of Algebra," writes the author in his preface, "may be essentially arithmetical or geometrical. I have chosen the geometrical form of presentation and development." "The point of departure is Euclid's doctrine of proportion, the fundamental propositions of which are enunciated and proved in an Introduction (pp. 1-20) in which I have followed the method recommended by the Association for the Improvement of Geometrical Teaching."

With Chap. I. commences the explanation of the "Laws of Algebraic Operation" as affecting real, or magnitudes involving only the idea of length; imaginary, including also the idea of turning through a right angle, and complex, embodying length and rotation through *any* angle. The product is obtained as a fourth proportional to the unit, or "*idemfactor*" (Peirce), and the factors of that product; the quotient as a fourth proportional to the unit, the dividend, and the reciprocal of the divisor. Indeterminate Forms are here introduced, their evaluation being treated of lower down; combinations of signs, the Associative, Commutative, and Distributive Laws are successively treated of and proved. Logarithms are defined in Napier's manner, treated so as to introduce the conceptions of the modulus and base as well as exponential, whose Laws—of Involution and the Index—are proved. The law of the interchange of indices and coefficients in Log Operations is called by the distinct name "*Metathesis*." To conclude the chapter, Indeterminate Exponential forms are touched on, and a useful synopsis of the matter of the chapter added.

Chap. II. contains an introduction to the circular hyperbolic and Gudermannian functions, with proofs of some fundamental limits.

Chap. III. is occupied with "Complex Quantities," represented