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THE DIELECTRIC CONSTANTS OF TYPICAL ALIPHATIC AND AROMATIC HYDROCARBONS, CYCLOHEXANE, CYCLOHEXANONE, AND CYCLOHEXANOL.

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This investigation is part of an extended research which has as its object the study of the properties of a large number of related carbon compounds.

The simplest method for the measurement of dielectric constants depends upon the comparison of the capacities of a given condenser when air, a standard substance, and the substances to be studied are successively placed between the condenser plates. As developed by Nernst[1] and his pupils the essential apparatus consists of a bridge, in which capacities as well as resistances are balanced. Into one arm of the bridge are placed two condensers in parallel, one consisting of two brass plates between which slides a movable glass plate whereby it is possible to vary the capacity of the condenser at will, the other of a vessel containing the liquid to be measured, between two metal plates. Into the other arm of the bridge is placed a balancing condenser. The details of this method have been so frequently described that it is unnecessary to repeat them here.[2]

The principal objection to the method lies in its narrow application, since a sharp minimum on the telephone receiver is not obtainable when a good conductor fills the vessel. The method was nevertheless chosen for the present work, because the major portion of the liquids to be studied were very poor conductors. For such it offered the readiest and most exact method for determining their dielectric constants.

The apparatus used was based upon that described by Nernst, but the arrangement was modified so as to secure greater percentage accuracy. The most important modification consisted in the use of larger and more similar balanced capacities in each arm of the bridge, thus gaining better minima of sound in the telephone, and a larger range of the insulating glass plate of the variable condenser. The larger capacities consisted of very narrow troughs, each possessing two nickel-plated brass plates about 0.6 mm. apart, firmly cemented upon glass plates and held apart as well as retained in position by strips of glass around the edges, the whole presenting a deep, very thin layer of dielectric between the condenser plates, which possessed considerable electrical capacity. The use of similar

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[1] Nernst, *Z. physik. Chem.*, 14, 622 (1894).

[2] B. B. Turner, *Ibid.*, 35, 385 (1900). More fully in *Dissertation*, Göttingen, 1900; Philip, *Z. physik. Chem.*, 24, 19 (1897); Bädeker, *Ibid.*, 36, 305 (1901); Cauwood and W. E. S. Turner, *J. Chem. Soc.*, 107, 276 (1915), etc.

troughs of this kind on each side of the bridge greatly promoted precision of the end-point. In the first arrangement (troughs E and E′) the glass strips forming the edges of each trough intruded somewhat between the brass plates, but this intrusion was undesirable for several reasons, causing an uncertainty in the capacity, doubt as to the attainment of exactly the same surface on successive fillings, and several minor difficulties. Accordingly, the first troughs thus constituted were soon rejected, and most of the work was done with two pairs of troughs (F and F′, G and G′) in which the opposing surfaces of the metal plates were entirely free from cement. The strips of glass which held the metal plates apart were several millimeters from their edges, and were cemented only to the glass plates. Two sizes were made, the area of the plates in F and F′ being each 7.5 × 4.6 cm., and the area of the plates in the smaller pair of troughs (G and G′) being 7.0 × 4.0 cm. The cement used was a commercial cement made entirely of inorganic materials and intended for cementing glass and porcelain. After having been cemented, the troughs were dried for 10 days at a temperature of about 90°. This cement was perhaps not the best conceivable, but it was entirely insoluble in the liquids employed, and the electrical capacities of the troughs thus made remained essentially the same at the end as it was at the beginning of the work, thus showing that the apparatus had served its purpose satisfactorily.

As is well known, the use of a suitable interrupter and telephone receiver is of great importance in this method. Instead of using the ordinary conductivity-telephone receiver, we tested several commercial telephone receivers intended for long distance wireless telegraphy, and found by experience one which worked admirably in conjunction with our interrupter and gave results of great precision, being sensitive to within 0.1 mm. on the condenser-graduation. The interrupter was of the type used by earlier experimenters—a fine, platinum wire stretched to suitable tension between two vertical posts, the wire being wound in the middle for a few millimeters with fine, iron wire, to be attracted by the solenoid magnet. This was regulated so that the pitch was exceedingly high, almost at the upper limit of audibility.

In each case the two similar troughs, one to contain the substance to be studied, and the other to serve as a balance or "tare-capacity," were placed in a carefully insulated constant temperature air bath, which consisted of a moderately roomy rectangular glass vessel within a second larger glass vessel, also rectangular, supported upon the bottom of the latter by two glass "horses." The space between the two rectangular vessels was usually filled with water, to help in maintaining constant temperature. The condenser-troughs stood vertically edge to edge on the bottom of the air-chamber (the inner rectangular vessel) and during an experiment did not in any respect change their positions relative to one another or to the different parts of the apparatus. In order to eliminate as far as possible the effects of changing humidity upon the troughs, they were surrounded by a dry atmosphere. This was obtained by passing a stream of dry air through a coil of tubing in the bottom of the outer vessel and down inside of the inner one. The air escaped in a series of holes from a horizontal branch lying along the bottom of the air chamber, and by preventing the access of the atmosphere of the laboratory obviated the necessity of an elaborate air-tight covering for the inner box.

In a few cases where the amount of material was very small the old style of trough like that employed by Nernst (designated Z) was employed. Such results are, therefore, no better as regards precision than the work of that investigator, but within their limit of error they are exactly identical with those obtained with the larger capacity, as is shown by the results for cyclohexane. Since the more important reading is that of the variable condenser, the precision of the work is proportional to the range of this instrument, assuming equality of definiteness of sound in the telephone. The range was about 6-fold greater with trough G and 7-fold greater with trough F than in the case of the Nernst form Z.

The thermostats of the heating system of the laboratory kept the room temperature constant to within about 0.5° on each side of the average, 20°. This was quite near enough, since no appreciable change in the capacity of the system was observed by changing the temperature by one degree,[1] except in the case of cyclohexanol, which will receive special discussion in another paper.

The whole apparatus was rested on sheets of ebonite; and the air bath was mounted on two glass rods lying on ebonite, and was arranged symmetrically with regard to the variable condensers. No change whatever was made in the relation of the parts during a determination. The carrier containing the liquid whose dielectric constant was being determined was undisturbed even while being filled; it was charged and emptied by means of a small pipet and dried between trials by a current of dry air. In this way the effect of changing outside capacity was eliminated, for the readings for air, benzene, and liquid whose dielectric constant was unknown were made successively without disturbing any part of the system. It was found that this procedure was absolutely essential in order to obtain consistent results; strict compliance with this precaution is the key to success.

As usual, the relative capacities of the several parts of the system varied slightly day by day, for no obvious reason. The variation was sometimes as much as one mm. on the condenser scale; but very seldom was any important variation observed during the time required for a full determination. If any difference between the initial and final readings for air (al-

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[1] See also Cauwood and W. E. S. Turner, *J. Chem. Soc.*, **107**, 278 (1915).

ways taken both before and after each determination) was observed, the determination was discarded. Probably the variations were due to change in the outside or balancing capacities with change of humidity, or to changing electrical conditions. The dry air of the steam-heated laboratory is especially favorable to work of this kind, and we had less trouble in regard to accidental changes of capacity than usual.

The water surrounding the air bath was temporarily replaced by oil without causing any change in the capacity of the system. Neither were the slight daily changes in outside capacity thereby eliminated. Owing to greater viscosity, its tendency to cling to glass, and its lower specific heat, oil was less convenient than water.

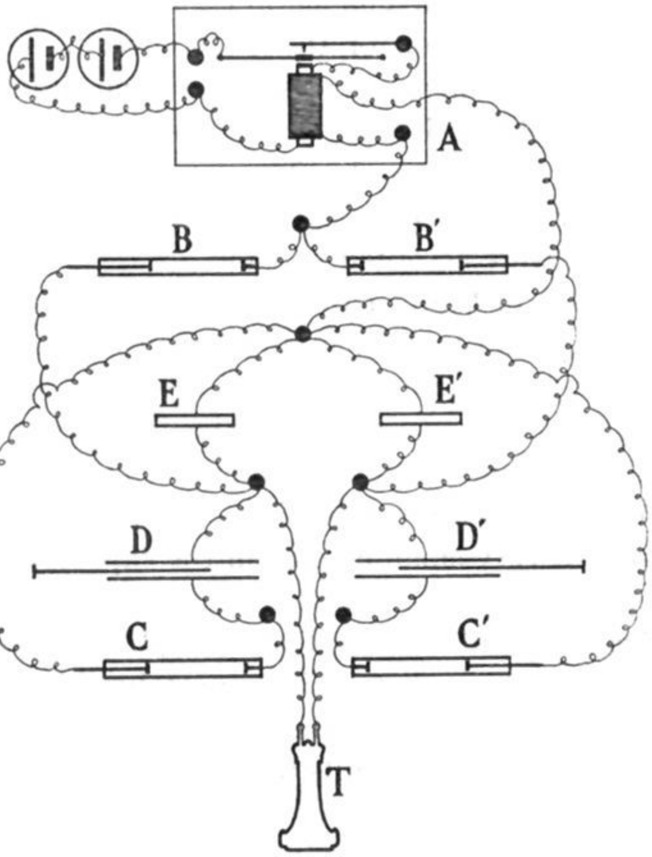

Fig. 1.

Usually only the left variable condenser of the Nernst apparatus was varied, in order to restrict as much as possible any change in the relative positions of the parts of the apparatus.

The connections, which were arranged as symmetrically as possible, keeping the wires insulated and far apart, are indicated by the accompanying diagram. Here A is the interrupter; B and B′, the two large resistances composed of a solution of boric acid and mannite; C and C′, two other similar resistances forming the other arms of the bridge; D and D′, variable condensers; E and E′, two narrow troughs serving, one as container for the liquid to be studied, and the other as balancing capacity (which were in the constant air chamber); and T, the telephone receiver.

The variable condenser scale D was calibrated in the following manner: A strip of glass (a microscope mounting slide) large enough when introduced between the plates of the condenser to cause a change in capacity equal to about one cm. on the variable condenser scale was alternately slipped in and out of the trough E, each time in precisely the same position. By moving the right hand variable condenser, this constant capacity could be measured on any part of the left hand variable condenser, whose scale was thus calibrated along its entire length. A curve, plotted with corrections as ordinates and the scale readings as abscissas, yielded the corrections applied to the results.

The gravest source of error in using the apparatus was found to result from altering the relative positions of the electrodes in the liquid resistances of the Wheatstone bridge when a substance possessing considerable conductivity was introduced into the containing trough. The capacity of these liquid resistances between the electrodes changed considerably when the electrodes approached each other very closely, and also when the conductivity of the liquids in these tubes was increased. The latter fact was determined by adding sodium chloride to the boric acid-mannite solution and reading the change in capacity on the variable condenser scale as the relative position of the electrodes in the liquid resistance was altered.[1] The phenomena were studied quantitatively, and the exact range over which the resistances could be varied without appreciably changing the capacity was noted. The details need not be discussed here; it is enough to say that no determinations involving conditions beyond the permissible range were accepted as valid.

Each of the resistances C and C′ (in the diagram) possesses two tubes, a wide one for coarse adjustment, and a capillary one containing only a fine wire for adjustment, or for very great resistances. In the cases of most of the substances studied the fine wire electrode alone was used, and so low was the conductivity that a change of only a few millimeters was needed to balance the conductivity of the liquid in the trough. This produced only a very small change in the capacity.

The standard substances used for comparison in this research were benzene and ether. Toluene also served as a standard of reference, since its dielectric constant is accurately known. It was especially used in testing the efficiency of the troughs, being convenient on account of its lesser volatility. The results were calculated by means of the following equation:[2]

$$D_s = (D_{\text{benzene}} - 1)\frac{S_1 - S}{S_2 - S} + 1$$

where D_s is dielectric constant of the substance; S_1, the corrected reading on condenser for substance in trough; S the corrected reading for air in trough; and S_2 the corrected reading for benzene in trough. The dielectric constant of benzene at 20° was taken as 2.286, according to B. B. Turner's careful investigation already quoted.[3] When ether was used as

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[1] For another form of liquid resistance, which to some extent obviates this difficulty, see Nernst, *Wied. Ann.*, **66**, 611 (1897).

[2] Nernst, *Z. physik. Chem.*, **14**, 622 (1894).

[3] B. B. Turner, *Loc. cit.* His determination was at 18°; to this was applied a correction of —0.0007 per degree. See Ratz, *Z. physik. Chem.*, **19**, 104 (1896); also Cauwood and Turner, *Loc. cit.* Nernst found a lower value, 2.255 at 17°, but Turner's results are more recent and appear to be more accurate.

a standard, instead of $D_{\text{benzene}} = 2.286$ must be substituted $D_{\text{ether}} = 4.355$, and S_2 becomes the reading for ether.

Source and Preparation of Materials.

Benzene.—The best commercial C. P. benzene was further purified by shaking with 4 portions of conc. sulfuric acid, washing several times with water, shaking with mercury, washing yet again, and distilling. After two crystallizations the product was dried over sodium. Thorough drying is essential. No change in the dielectric constant was observed throughout the course of the research and the value for this sample was the same as that given by two more carefully purified products prepared for another purpose.[1]

Ether of good quality was washed several times with water, shaken with mercury until the surface of the mercury was no longer blackened, and again washed. After drying over sodium it was distilled and kept tightly stoppered, over sodium in the dark. At the end of the research a portion of this sample was redistilled and its dielectric constant determined. No change from that of the original sample could be observed.

Toluene (the purest obtainable commercial material) was shaken with sulfuric acid, washed, shaken with conc. sodium hydroxide solution, again washed, and then shaken with mercury. After filtering, the toluene was dried over sodium and distilled. The product all came over between 110.1–110.6° (786 mm. pressure) and no difference in the dielectric constant of the different fractions could be detected. That fraction distilling between 110.4–110.5° was used for the various determinations of toluene.

Hexane.—Normal hexane (synthesized in this laboratory) dried over sodium, was distilled at a temperature of 69.2° (758 mm. pressure) the entire product distilling within 0.3°. The dielectric constant was determined before and after the last distillation.

Heptane.—A quantity of "heptane" of questionable purity, prepared by a well known German firm from petroleum, was dried over sodium and fractionated. The dielectric constants of the several fractions were determined in succession; as will be seen, all the fractions gave essentially the same value. The average boiling points of the samples I, II, III and IV were, respectively, 100°, 98°, 97.6° and 96.5°. Probably the result represents an average value for several heptanes.

Octane.—A quantity of 2,2,3-trimethyl pentane prepared by Dr. Latham Clarke was redistilled from sodium. The fraction 110.8–111.4° (765 mm. pressure) was used.

Decane.—Commercial diisoamyl was dried over sodium and fractionated. Two fractions, boiling, respectively, between 159.5–159.7° and 160.1–160.3° (761 mm. pressure) were studied.

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[1] Richards and Shipley, THIS JOURNAL, **36**, 1826 (1914).

Xylene.—A sample of German "xylol" probably a mixture of *o*-, *m*- and *p*-xylene, dried over sodium, was fractionated, and the several fractions were determined. These fractions boiled over the following ranges: Xylene I, 137–137.7°; Xylene II, 137.7–138.8°; Xylene III, 138.8–139.6°. No differences in their dielectric constants were found. In addition to this unsatisfactory material a sample of the best obtainable *m*-xylene was dried over anhydrous copper sulfate and distilled, collecting the fraction between 138.8–139.2° (741 mm. pressure). As will be seen, it gave essentially the same result.

Besides toluene and the *m*-xylene already mentioned, 5 other aromatic hydrocarbons with saturated side-chains were obtained in a high state of purity. These had been prepared synthetically at Harvard for the express purpose of determining their physical constants and were the same samples as were used in the work on compressibility[1] and heat of combustion.[2] They were as follows: *Ethyl benzene* I (Fittig method), b. p. 136.3–136.4°, d_4^{20} 0.8678; *Ethyl benzene* II (Friedel-Crafts method), b. p. 136.4–136.5° (767 mm.), d_4^{20} 0.8697; *Normal propyl benzene*, b. p. 157.9–158.2° (765 mm.), d_4^{20} 0.8617; *Isopropyl benzene* (*cumene*), b. p. 152.6–152.8° (759 mm.), d_4^{20} 0.8620; *Mesitylene*, b. p. 164.8–164.9° (760 mm.), d_4^{20} 0.8634; *Tertiary butyl benzene*, b. p. 168.6–168.7° (759 mm.) d_4^{20} 0.8671.

Cyclohexane.—Very pure cyclohexane was prepared for this research, made from benzene by the Sabatier-Sanderens reduction, and afterwards purified by often repeated recrystallization: (b. p. 81.3–81.5°, f. p. 6.4°, d_4^{20} 0.7791).

Cyclohexanone.—A quantity of this ketone had been prepared for the work on compressibility.[3] (B. p. 155.6–155.7°, 768 mm., d_4^{20} 0.9466.) Ketones are better conductors than the hydrocarbons and their dielectric constants are higher. Few ketones could be determined with our apparatus and of alcohols none but those of large molecular weight had conductivity low enough.

Cyclohexanol, prepared at the same time as the cyclohexanone, was purified by fractionally crystallizing it in the absence of moist air. The freezing point of the best sample was 23.9°. Several samples were used, two of which had freezing points above 20°. Hence the temperature chosen for measurement was 25° in this case. The heat of fusion of cyclohexanol is so low that the presence of a very little water makes a marked depression in the freezing point; exposing to the air for a few minutes lowers its freezing point several tenths of a degree. Probably moisture from the air was not absolutely excluded, so that the results for this substance cannot be considered corresponding exactly to a perfectly water-free sample. Fortunately the presence of a little water in this case ap-

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[1] Richards and Shipley, THIS JOURNAL, 38, 989 (1916).

[2] Richards and Barry, *Ibid.*, 37, 997 (1915).

[3] Richards and Shipley, *Loc. cit.*

peared not to affect appreciably the value of the dielectric constant, provided that the measurement was taken several degrees above the freezing point of cyclohexanol.

The Constancy of the Apparatus.

From time to time during the research, determinations of the dielectric constant of ethyl ether and of toluene were made as a check on the constancy of the apparatus. The data below give the results of these determinations, using benzene (2.286) as the standard of reference. Each of the numbers given in the following tables represents a separate filling and adjustment of the apparatus and each is an average of a number of measurements, repeated until the last figure was reasonably certain.[1]

TABLE I.—DIELECTRIC CONSTANTS OF ETHER AND TOLUENE AT 20.0°.

Readings (Corrected).

Substance.	Trough.	Air (S).	Ether (S).	Benzene (S_2).	Dielectric constant.
Ether	E	0.92	6.94	3.22	4.366
	E (cover)	1.40	7.39	3.70	4.349
	F	2.78	10.22	5.64	4.345
	G	2.22	7.55	4.26	4.360
	F	2.78	10.21	5.63	4.353
				Ether: Average,	4.355
		Air.	Toluene.	Benzene.	
Toluene	E (cover)	1.10	3.72	3.60	2.348
	E	0.33	3.10	3.01	2.329
	F	2.30	5.28	5.17	2.336
	F	2.30	5.28	5.18	2.330
	F	2.30	5.28	5.18	2.330
				Toluene: Average,	2.335

Evidently the results are as nearly constant as could be expected. They show that the apparatus is consistent and to be depended upon. Below are given the results for other substances, all referred to the dielectric constant of dry air = 1.000.

TABLE II.—DATA AND RESULTS.

(All at 20° except Cyclohexanol.)

		Corrected reading.			
Substance.	Trough.	S.	S_1.	S_2.	Dielectric constant.
Hexane	F	2.78	4.76	5.68	1.878
	F	2.78	4.76	5.70	1.872
	F	2.78	4.76	5.68	1.878
				Average,	1.876
Heptane I	F	2.70	4.87	5.57	1.972
Heptane II	F	2.70	4.87	5.57	1.972
Heptane III	F	2.70	4.87	5.57	1.972
Heptane IV	F	2.70	4.88	5.57	1.977
				Average,	1.973

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[1] As an example, at random, the following readings were taken in the case of the second experiment with ether: With air, 1.39, 1.40, 1.40, 1.40; with ether, 7.38, 7.39, 7.40, 7.39; with benzene, 3.70, 3.69, 3.70. The averages, to the nearest figures in the second decimal place, are given above.

TABLE II (*continued*).

Substance.	Trough.	Corrected reading.			Dielectric constant.
		S.	S_1.	S_2.	
Octane	F	2.80	4.97	5.70	1.962
N-Nonane	F	2.74	4.92	5.64	1.967
4-Methyl octane	F	2.80	4.98	5.70	1.967
4-Methyl octane	F	2.74	4.92	5.64	1.967
2-Methyl octane	F	2.74	4.92	5.64	1.967
2,6-Dimethyl heptane	F	2.70	4.37	4.87	1.989
2,6-Dimethyl heptane	F	2.70	4.38	4.87	1.995
2,6-Dimethyl heptane	F	2.70	4.35	4.87	1.978
2,4-Dimethyl heptane	Z	2.40	2.69	2.82	1.89
2,4-Dimethyl heptane	Z	2.40	2.69	2.82	1.89
2,5-Dimethyl heptane	Z	2.40	2.69	2.82	1.89
Decane I	F	2.30	4.44	5.18	1.955
Decane II	F	2.30	4.44	5.18	1.955
Decane II	F	2.30	4.44	5.18	1.955
Decane II	F	2.30	4.45	5.18	1.960
				Average,	1.956
Xylene I	F	2.70	5.77	5.57	2.375
Xylene II	F	2.70	5.77	5.57	2.375
Xylene III	F	2.70	5.77	5.57	2.375
				Average,	2.375
Xylene	F	2.30	5.40	5.17	2.389
	F	2.30	5.38	5.18	2.375
	F	2.30	5.38	5.18	2.375
	F	2.30	5.37	5.18	2.371
				Average,	2.378
Ethyl benzene I	G	2.62	5.18	4.84	2.482
Ethyl benzene II	G	2.62	5.19	4.85	2.482
Ethyl benzene III	G	2.62	5.18	4.84	2.482
				Average,	2.482
N-Propyl benzene	G	2.53	4.88	4.74	2.367
	G	2.53	4.89	4.76	2.361
				Average,	2.364
Cumene	G	2.21	4.43	4.26	2.393
(isopropyl benzene)	G	2.52	4.95	4.74	2.408
				Average,	2.400
Mesitylene	G	2.53	4.86	4.74	2.356
Tert. butyl benzene	G	2.30	5.40	5.18	2.384
	G	2.30	5.39	5.18	2.380
	G	2.30	5.41	5.18	2.388
				Average,	2.384
Cyclohexane	E	0.95	2.90	3.32	2.058
	E	0.95	2.89	3.32	2.053
	Z	2.40	2.75	2.82	[2.07]
				Average,	2.055

TABLE II (*continued*).

Substance.	Trough.	Corrected reading.				Dielectric constant.
		S.	*S*₁.		*S*₂.	
Cyclohexanone	Z	3.26	9.21	Ether.	4.42	18.2
	Z	3.28	9.85		4.57	18.1
	Z	3.24	7.82		4.13	18.3
	Z	3.24	7.81		4.13	18.2
					Average,	18.2
Cyclohexanol at 25°	Z	2.70	6.99	Benzene.	3.09	15.2
	Z	2.70	7.00		3.10	14.8
	Z	2.70	7.00		3.09	15.2
	Z	2.70	7.00		3.10	14.8
					Average,	15.0

TABLE III.—COMPARISON OF RESULTS WITH THOSE OF FORMER EXPERIMENTS.

Substance.	Earlier results at various temperatures.			Present results at 20°.
	Temp. Degrees.	Observer.	Dielectric constant.	Dielectric constant.
Benzene	20.0	B. B. Turner[b]	2.286	Standard[a]
Ether	18.0	B. B. Turner[b]	4.368	4.355
N-Hexane	17.0	Nernst[c]	1.88	1.876
N-Hexane	12.4	Landolt & Jahn[d]	1.86	1.876
Heptane (average)	....	....	...	1.973
N-Octane	17.0	Nernst[c]	1.95	1.962
2,2,3-Trimethyl pentane	....	....	...	1.962
N-Nonane	....	....	...	1.967
4-Methyl octane	....	....	...	1.967
2-Methyl octane	....	....	...	1.967
2,6-Dimethyl heptane	....	....	...	1.987
2,4-Dimethyl heptane	....	....	...	1.89
2,5-Dimethyl heptane	....	....	...	1.89
Decane	13.8	Landolt & Jahn[d]	1.966	1.956
Toluene	19.0	Drude[e]	2.31	2.335
Toluene	14.4	L. & J.[d]	2.375	.....
M-Xylene	18.0	B. B. Turner[b]	2.376	2.377
Xylene (mixture of isomers)	....	....	...	2.375
Ethyl benzene	17.0	Nernst[c]	2.42	2.482
Ethyl benzene	14.6	L. & J.[d]	2.42	.....
Propyl benzene	13.8	L. & J.[d]	2.35	2.364
Cumene (isopropyl benzene)	17.0	Nernst	2.37	2.400
	18.0	Drude[e]	2.42	.....
Mesitylene	14.2	L. & J.[d]	2.30	2.356
Tertiary butyl benzene	....	....	...	2.384
Cyclohexane	25.0	Cauwood and W. S. E. Turner	2.07	2.055
Cyclohexanone	....	....	...	18.2
Cyclohexanol	....	....	...	15.0 (25°)

[a] In each case the last figure is more or less uncertain—often not over one unit.

[b] B. B. Turner, *Z. physik. Chem.*, 35, 385 (1900).

[c] Nernst, *Ibid.*, 14, 622 (1894); *Wied. Ann.*, 60, 600 (1897).

[d] Landolt & Jahn, *Z. physik. Chem.*, 10, 289 (1892).

[e] Drude, *Ibid.*, 23, 267 (1897); *Ann. d. Phys.*, [4] 8, 336 (1902) (improvement of method).

[f] Cauwood & W. S. E. Turner, *J. Chem. Soc.*, 107, 276 (1915).

Evidently our results for substances already investigated by others agree essentially in most cases with the earlier results, especially with those of B. B. Turner, whose investigation was a model of care and accuracy. This leads us to hope that the other determinations, which give for the first time the dielectric constants of a number of typical carbon compounds, are also trustworthy.

The data are not plentiful enough to form the basis of far-reaching conclusions concerning the effect of structure on dielectric constant, but nevertheless at least one outcome is unmistakable, namely, the fact that both in the aliphatic and the aromatic series the substitution of the methyl group for hydrogen has usually but slight tendency to change the dielectric constant. With the higher members, this effect is less than that which is produced by variation in structure. Thus the values for hexane, heptane, octane, the average of the nonanes, and decane are, respectively, 1.88, 1.97, 1.96, 1.94, 1.96, whereas the range among the nonanes alone is from 1.89 to 1.99. Some of the nonanes with side-chains have a higher, some a lower, dielectric constant than normal nonane. The aromatic hydrocarbons, as is well known, all possess higher dielectric constants than the aliphatic hydrocarbons. Benzene, toluene, *meta*-xylene, and mesitylene give, respectively, 2.29, 2.33, 2.38, 2.36. Aromatic hydrocarbons with more complicated side-chains (*n*-propyl-, isopropyl-, and tertiary-butyl benzene) give about the same values (respectively, 2.36, 2.40 and 2.38) with the incomprehensible exception of ethyl benzene, which gives the highest of all those studied (2.48). The effect of the benzene ring is evidently to increase the dielectric constant by about 0.4, or 20% of its value for the paraffins.

We are indebted to the Carnegie Institution of Washington for financial assistance in the prosecution of this work.

Summary.

1. A modified form of the Nernst apparatus is described. Percentage error was much decreased by the use of larger, suitably balanced condenser-troughs.

2. The dielectric constants of 21 organic liquids have been determined, some of them for the first time. The values for aromatic hydrocarbons average about 20% higher than for aliphatic hydrocarbons.

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