

wide to give a good average. I doubt if such variations can be attributed wholly to experimental error; but on the other hand, it is difficult to imagine that potassium should have more than one dispersion equivalent, while in the same series of dissolved salts it has apparently one and the same refraction equivalent. I am more disposed to believe, that the uncertainty lies in the value of the radicles to which the metal is joined; but this will require a more extended research.

It is also an important enquiry:—To what extent does the modification of the dispersion equivalent affect the refraction equivalent for the line A? On this question, and others of a similar nature, I hope shortly to submit a further communication. I think it will be already sufficiently obvious that the specific dispersive energy of a compound body is a physical property analogous to, but distinct from, its specific refractive energy, and that it is capable in like manner of throwing light upon chemical structure.

XXI. “On the Rate at which Electricity leaks through Liquids which are Bad Conductors of Electricity.” By J. J. THOMSON, M.A., F.R.S., Fellow of Trinity College, and Cavendish Professor of Experimental Physics in the University of Cambridge, and H. F. NEWALL, M.A., Assistant Demonstrator in Physics, Cambridge. Received May 26, 1887.

The experiments here described were undertaken to test whether the rate at which electricity leaks through a liquid which conducts electricity badly, does or does not follow Ohm's law.

The method used is described later on; it consists in establishing by a battery a difference of potential of about 100 volts between the plates of a condenser, in which the dielectric is the faulty insulator to be experimented on, then disconnecting the battery, and measuring with an electrometer the rate at which the difference of potential dies away.

Let v_1 and v_2 be the differences of potential at the beginning and end of an interval T , and let

$$\frac{v_1}{v_2} = x.$$

If c be the capacity of the condenser, q the quantity of electricity which has leaked away in the time T , then

$$v_1 - v_2 = \frac{q}{c};$$

so that
$$\frac{q}{v_2} = c(x-1).$$

The rate of leak = q/T , so that

rate of leak

 difference of potential at the end of the interval = $\frac{c}{T}(x-1) = \Sigma$, say.

Now if the conduction follows Ohm's law, Σ will be constant; hence Ohm's law will be obeyed if x be constant. The tables given later on show how nearly constant x is.

To test the accuracy of the law, we have—

$$\frac{\delta\Sigma}{\Sigma} = \frac{\delta x}{x-1} = \frac{\delta x}{x} \cdot \frac{x}{x-1},$$

so that a change of 1 per cent. in x will correspond to a change of $x-1/x$ per cent. in Σ , and a deviation from Ohm's law to this extent.

The liquids tried were benzene, olive oil, carbon bisulphide, and paraffin oil. We could detect no deviation from Ohm's law for the first three of these substances, though the difference of potential fell from 500 scale divisions to 20. For paraffin oil, however, the conductivity seemed slightly greater when the difference of potential was large than when it was small. The departure from Ohm's law even in this case was small.

Quincke* has found that when the E.M.F. is comparable with that which would cause a spark to pass through the liquid, Ohm's law ceases to be even approximately obeyed. Thus, for carbon bisulphide, when the E.M.F. was 29.21 C.G.S. units, the current was 6.2; when the E.M.F. was 47.74, the current was 36; showing that with large electromotive forces the current increases much more rapidly than the E.M.F.

With the small electromotive forces which we used, the current, however, is proportional to the E.M.F., showing that when the E.M.F. is comparable with that required to produce a spark through the liquid, other methods of dissipating the energy of the electric field must exist besides those which are active in conductors conveying a current according to Ohm's law.

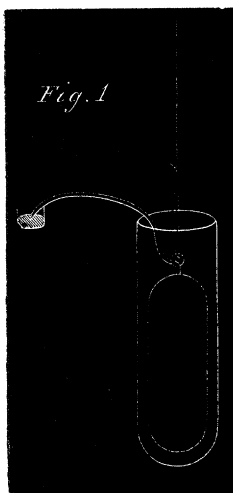
We found that carbon bisulphide showed a phenomenon analogous to electric absorption, the only case we know where this has been observed in a liquid dielectric.

The conductivity of all the liquids on which we experimented increases as the temperature rises, so that in this respect they behave like electrolytes.

* 'Wiedemann, *Annalen*,' vol. 28, p. 529.

Description of Apparatus.

The condenser consisted of two copper cylinders, the outer one being formed into a pot 12 inches deep and 4 inches in diameter, closed at the bottom by a rounded end carefully worked inside, the inner one, 8 inches long and 3 inches in diameter, being closed, rounded off at both top and bottom, and carefully worked outside. The outer cylinder was held in position on a bracket attached to a brick wall, and was always connected to earth through the gas-pipes; the inner one was suspended by a silk thread, 5 feet long, also from a bracket on the wall, vertically above the first, and was connected to an insulated mercury cup by means of a thick wire, which was carefully soldered into the top of the cylinder, and bent into a loop to attach the silk thread to. The figure shows the arrangement in elevation, the outer cylinder being represented as transparent, to show the inner cylinder and attachment.



The liquid to be experimented on was poured into the outer pot, and the inner cylinder was lowered into it, both being set vertical by means of a plumb-line. It was found necessary to load the inner cylinder with shot to keep it sunk in the liquid.

The suspension by a single silk thread was found very satisfactory, as it insulated well, and avoided the introduction of solid dielectrics, and the suspended cylinder if disturbed came again to rest after a very few oscillations.

The condenser was charged by means of a number (varying between 20—80) of Post Office Daniell cells, and Thomson's quadrant electro-

meter (White's form) was used to show the fall of potential as the charge leaked through the faulty insulating liquids.

To facilitate changes of connexion between the condenser, the electrometer, and the cells, a paraffin block, with holes bored through it and filled with clean mercury, was used. The whole arrangement of apparatus was as shown in fig. 2.

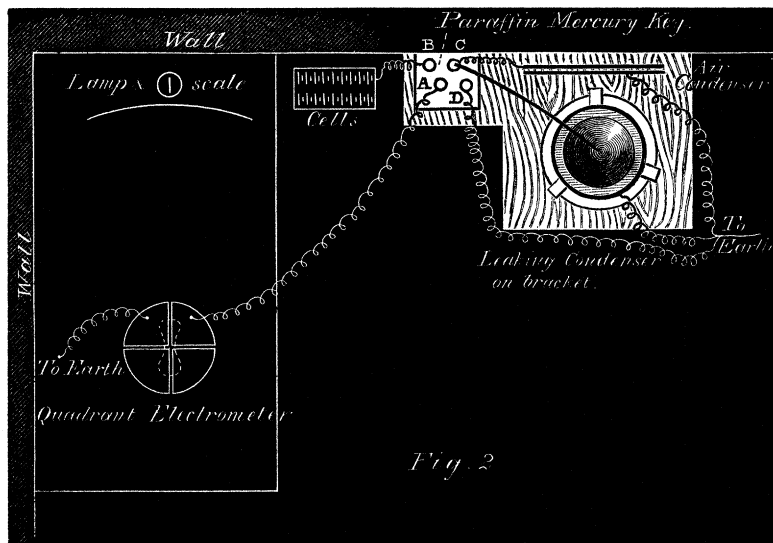


Fig. 2

In testing the arrangement the condenser was used as an air-condenser, and it was found that there were signs of some electrical absorption. These were traced to the paraffin key and the wire connecting it with the electrometer. The key was improved by the use of very clean mercury, and very careful amalgamation of the ends of the copper wire dipping into the mercury cups. The wire at first used to connect the cup A in the key with the electrometer was covered with gutta-percha, and the whole passed through lead pipe, put to earth to protect it electrically from the experimenter. But it was found that there was absorption on charging and the appearance of residual charge on discharging the electrometer; the gutta-percha-covered wire was therefore discarded, and bare wire stretched between insulating points, and this was then protected electrically by a shield of zinc, enclosing it and put to earth.

In testing, the condenser was connected with the electrometer by laying a piece of wire, so as to connect the cups C and A. A second piece of wire carefully insulated in a bar of paraffin which was attached to a metal handle was then used to connect the cells by the cup B to

either A or C, and the condenser and electrometer were then charged; the cells were then disconnected, and the fall of potential as noted by the electrometer readings was observed at equal intervals. A metronome was used to beat half-seconds; the position of the spot of light on the scale was noted every 5 seconds generally, and a curve was then plotted with the time for abscissæ and the potentials as denoted by the electrometer deflection for ordinates.

In preliminary experiments, in which a sample of benzene (later experiments showed it to be very impure) was used in the condenser, it was found desirable to introduce an air condenser, so as to diminish the rate of fall of potential, and to get more reliable readings. The air condenser consisted of two worked brass plates, held very slightly apart by three dots of shellac. One plate was attached to the inner cylinder, the other connected to earth with the outer cylinder of the experimental condenser.

From time to time throughout the course of the experiments, which were continued through about three months, the apparatus was tested for leaking (i) through the electrometer, (ii) through the key, (iii) through the air condenser, (iv) through the attachments of the experimental condenser.

To get rid of dirt and dust from the liquids to be placed in the condenser, very careful filtering was necessary; but generally after ten or twelve times, first through Swedish filter-paper, and finally through a tight plug of "glass-wool," as much as could be done by filtering had been done.

Difficulties were at first met with on account of what were probably chemical impurities in the samples used. We finally decided to use much smaller quantities of the liquids in the condenser. There was scarcely ever more liquid than would half immerse the inner cylinder, that is, more than would extend 4 inches up the straight part of it; but there was never less than would extend three-eighths of an inch up the straight.

Mode of Entering Results of Experiments.

The potential of the inner cylinder was noted at equal intervals of time (generally five seconds) from the deflection of the electrometer needle. These deflections were recorded in tables, and the ratios of succeeding deflections were deduced. Two curves are drawn, one showing the fall of potential with the lapse of time, the other showing the value of the ratio of successive values of the potential. The mean value of the ratios is found, and a line drawn with this value. This cuts the curve of ratios, and shows at a glance the departures from the constant ratios, which would obtain if the leak through the dielectrics took place according to Ohm's law.

Experiments on Benzene.

The first successful experiments were made with an impure sample of benzene, and the method was shown to be practicable. But before more careful readings were taken the cylinders had to be re-worked, because of some irregularities on the surfaces. On setting the apparatus up again, it was found that the impure benzene no longer insulated well enough to allow us to get readings. The reason of the change we have not been able to discover.

A pure sample of benzene was got, and after the usual filtering processes, the condenser was filled and charged, and readings were taken at five seconds intervals.

Tables I—IV give the electrometer deflections, and the ratios of successive pairs for different sets of readings under varying conditions, which are specified at the head of each table.

Tables II and IV are shown graphically in fig. 3, which gives two curves of falling potential and two ratio curves.

Table I.
Experiment 12. Pure Benzene. $\frac{1}{4}$ inch up straight.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
440	1·11	212	1·09	103	1·11
396	1·10	191	1·09	93	1·11
357	1·11	174	1·12	84	1·09
321	1·11	155	1·11	77	1·10
290	1·11	140	1·11	70	1·11
261	1·11	126	1·09	62	1·08
235	1·10	115	1·11	57	1·11
				51	

Table II (see Fig. 3).
Experiment 13. Pure Benzene. $\frac{3}{8}$ inch up straight.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·069	229	1·070	106	1·070
468	1·073	214	1·070	99	1·087
436	1·076	200	1·081	91	1·070
405	1·077	185	1·069	85	1·075
376	1·071	173	1·074	79	1·067
351	1·073	161	1·073	74	1·088
327	1·072	150	1·095	68	1·079
305	1·077	137 ?	1·054	63	1·050
283	1·075	130 ?	1·083	60	1·071
263	1·073	120 ?	1·071	56	1·076
245	1·069	112	1·056	52	

Table III.

Experiment 16. Pure benzene. 2 inches up straight.

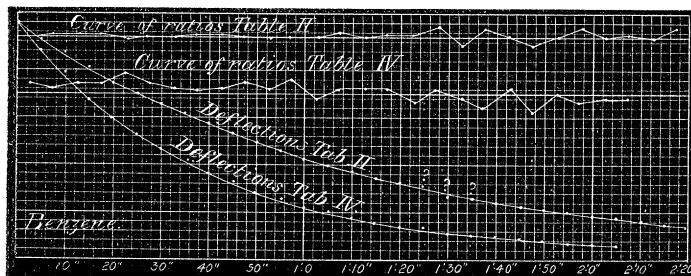
Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·108	195	1·123	81	1·112
442	1·133	173	1·111	72	1·100
390	1·111	155	1·122	65	1·101
350	1·123	137	1·095	59	1·113
310	1·123	125	1·136	53	1·081
274	1·123	110	1·100	49	1·113
242	1·110	100	1·123	44	1·100
218	1·122	89	1·098	40	

Table IV (see Fig. 3).

Experiment 17. Pure Benzene. 2 inches up straight.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·13	205	1·15	89	1·12
440	1·12	180	1·12	79	1·12
385	1·13	160	1·13	70	1·09
339	1·13	141	1·12	64	1·12
300	1·15	126	1·14	57	1·10
261	1·13	111	1·10	51	1·08
230	1·12	100	1·12	47	

FIG. 3.



Curves plotted for benzene from Tables II and IV.

The straight lines through the ratio curves are drawn to show the mean value of the ratios.

In the ratio curves 1 division of the ruled paper corresponds with 0·01 in the ratio values.

In the deflection curves 1 division = 20 in the deflection.

Experiments on Paraffin Oil.

Little or no difficulty was met with in the case of the paraffin used. It was an ordinary sample of the oil used in lamps. After careful filtering it was put into the condenser, and readings were taken. These are given in Tables V—VII. Experiments 36 and 37 gave readings almost identical throughout. They are represented graphically in fig. 4. The interval between successive readings was 5 seconds.

Table V (see Fig. 4).

Experiments 36 and 37. Paraffin Oil. 1 inch up straight. Condenser charged for 10" only before readings were taken.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
420		136		55	
355	1·183	116	1·172	47	1·170
300	1·183	100	1·160	40	1·175
257	1·170		1·163		1·143
217	1·184	86	1·179	35	1·13
187	1·162	73	1·177	31	1·14
160	1·169	62	1·127	27	
	1·179				

Table VI.

Experiment 38. Paraffin Oil. 1 inch up straight. Condenser charged for 3' 0" before readings were taken.

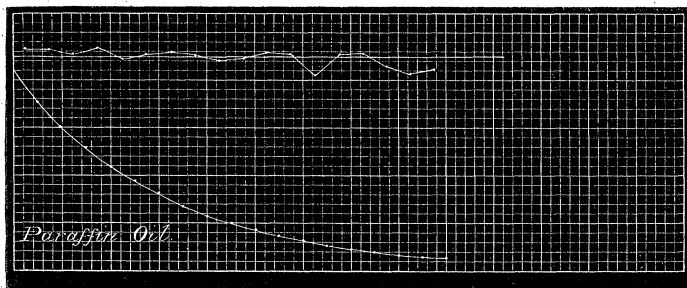
Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
420		170		75	
360	1·166	147	1·156	65	1·15
310	1·161	129	1·140	56	1·16
265	1·169		1·163		1·12
230	1·150	111	1·156	50	1·13
199	1·159	96	1·129	44	1·13
	1·161	85	1·13	39	

Table VII.

Experiment 39. Paraffin Oil. $\frac{1}{2}$ inch up straight. Short Charge.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
450		176		84	
380	1·184	151	1·165	73	1·150
325	1·169	130	1·161	64	1·140
280	1·161	113	1·150	55	1·163
240	1·166	98	1·153	47	1·172
205	1·170		1·166		
	1·164				

FIG. 4.

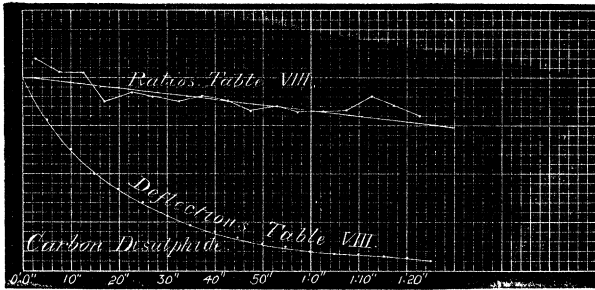


Curve plotted for paraffin from Table V. Same scales as in fig. 3.

Experiments on Carbon Disulphide.

When carbon disulphide was used as the leaking dielectric, considerable discrepancies appeared; the ratio curve fell or remained steady in what seemed a capricious manner. Filtering seemed to make no difference, although again and again repeated; the condenser cylinders were cleaned carefully; the liquid was distilled several times, and the discrepancies only seemed to be exaggerated, especially in experiments made very soon after distillation. The still was cleaned and again used, but to no effect. The irregularities still remained, the ratio curve in some instances being as steadily horizontal as in the case of benzene and paraffin oil; at other times the values of the ratios falling as much as 12 or 15 per cent. Fig. 5 gives Table VIII graphically, showing the great fall of the ratio curve. The changes in the zero of the electrometer were such as to lead us to the notion that we had to deal with something analogous to electric absorption. We therefore tried the effect of varying the time of charging the

FIG. 5.



Curve plotted for carbon disulphide from Table VIII.
Time of charge probably short.

condenser, and in this way found that the discrepancies were due to accidental differences in the time of charge.

Fig. 5 shows curves drawn from carbon disulphide, the only variable in the circumstances for the different curves being the time of charge. It will be seen that the curve corresponding to a long charge is much less steep than that corresponding to a short charge. Tables VIII—XI give the readings and ratios for the carbon disulphide experiments.

Table VIII (see Fig. 5).

Experiment 27. Carbon Disulphide. 2 inches up straight. Time of charging not noted, but from form of ratio curve probably *short*.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
400		115		41	
312	1·28	96	1·19	35	1·17
250	1·25	80	1·20	30	1·17
200	1·25	67	1·19	25	1·20
168	1·19	57	1·17	22	1·18
139	1·21	48	1·18	19	1·16
	1·20		1·17		

Table IX.

Experiment 30. Carbon Disulphide. $\frac{1}{2}$ inch up straight. Time of charging not noted, but probably *long*.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·06	302	1·05	191	1·06
470	1·07	288	1·05	180	1·04
440	1·05	273	1·05	173	1·05
419	1·06	260	1·05	165	1·04
395	1·05	248	1·05	156	1·05
375	1·05	235	1·06	149	1·05
355	1·06	222	1·05	141	1·05
335	1·05	211	1·04	134	1·05
319	1·05	202	1·06		

Table X (see Fig. 6).

Experiment 33. Carbon Disulphide. 3 inches up straight. Time of charging 2 seconds.

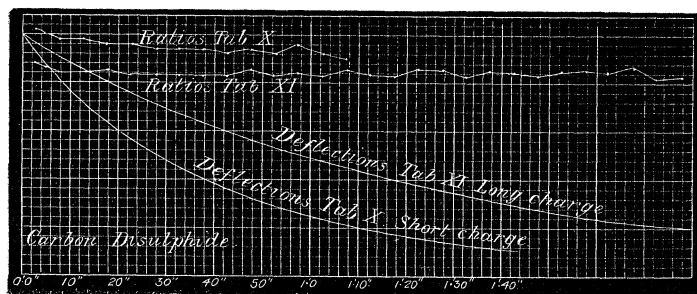
Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·15	265	1·11	156	1·10
430	1·13	238	1·11	142	1·12
380	1·13	213	1·11	127	1·10
335	1·12	191	1·10	115	1·09
298	1·12	173	1·11	105	

Table XI (see Fig. 6).

Experiment 34. Carbon Disulphide. 3 inches up straight. Time of charging 10 minutes.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·081	234	1·063	115	1·074
468	1·063	220	1·059	107	1·049
440	1·060	208	1·055	102	1·051
415	1·064	197	1·068	97	1·077
390	1·054	185	1·063	90	1·058
370	1·056	174	1·054	85	1·062
350	1·057	165	1·061	80	1·066
331	1·057	155	1·061	75	1·056
312	1·058	146	1·058	71	1·059
295	1·064	138	1·061	67	1·063
277	1·056	130	1·065	63	1·066
262	1·060	122	1·060	59	
247	1·055				

FIG. 6.



Curves plotted for carbon disulphide from Tables X and XI.

Upper curve from readings taken after a long period (10 minutes) of charging the condensers; lower curve after a short period (2 seconds). Otherwise conditions similar.

The curves of ratios are on the same scale and have the same zero line about 3 inches below the lower edge of the figure.

We deal later with further experiments on these phenomena of absorption and residual charge.

Experiments on Olive Oil.

Very little trouble was experienced with olive oil. The sample used proved to be the best insulator of all the liquids we tried. After filtering once through Swedish paper and once through a glass-wool plug, it insulated as well as after numerous filterings.

Readings of the deflections were taken, as before, every five seconds; but in Tables XII and XIII, only those taken at intervals of 25 seconds are recorded, the former being taken after a short time of charging, the latter after a long time. Fig. 7 is plotted from Table XIII, but is on a different scale from figs. 3—6, so far as the time coordinate is concerned, in order to bring more of the curve into the plate.

Table XII (see Fig. 7).

Experiment 44. Olive oil. 1 inch up straight. Time of charge short.

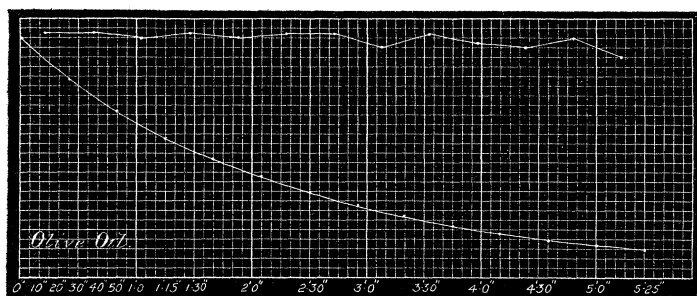
Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·19	209	1·19	91	1·16
417	1·19	176	1·19	78	1·18
349	1·18	148	1·16	66	1·14
295	1·19	127	1·19	58	
247	1·18	107	1·17		

Table XIII.

Experiment 45. Olive oil. 1 inch up straight. Time of charge long.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
500	1·196	210	1·173	107	1·202
418	1·190	179	1·185	89	1·202
351	1·185	151	1·170	74	1·200
296	1·184	129	1·205	66	
250	1·190				

FIG. 7.



Curve plotted for olive oil from Table XII.
Time of charging condenser short.

Experiments on Rate of Leak at Different Temperatures.

In all the liquids experimented on (benzene, olive oil, carbon disulphide) the leak was quicker at higher temperatures than at lower.

These liquids then must be classed in this respect with electrolytes, and not with metallic conductors.

A metal vessel was put round the outer cylinder of the condenser, and was connected by a tube with a second vessel, which could be heated or cooled, and raised or lowered. By these means the condenser could be surrounded by hot or cold water without having its position disturbed in any way.

Readings were then taken at 15 seconds intervals, the condenser being in one set of observations under the same circumstances in every way except with respect to temperature. Each set contained three (or five) readings, one reading at a high or low temperature being taken between two readings at a medium temperature, so as to

show that no permanent change had taken place by the raising or lowering the temperature of the leaking dielectric.

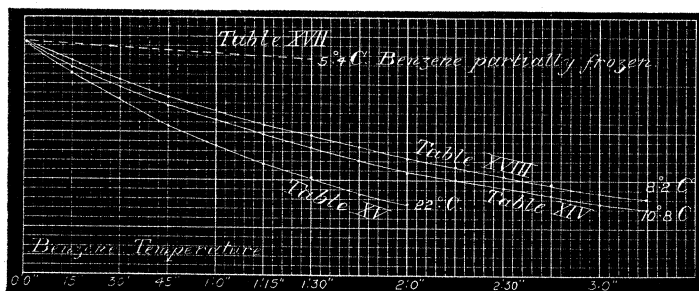
Benzene.—Tables XIV—XVIII give the readings for benzene at the temperatures specified at the head; and fig. 8 shows the tables graphically.

Benzene at different Temperatures.

Table XIV. Table XV. Table XVI. Table XVII. Table XVIII.

Temp. 10·8° C.		Temp. 22° C.		Temp. 11·4° C.		Temp. 5·4° C.		Temp. 8·2° C.		
490	1·12	490	1·16	490	1·10	490		490	1·10	
438	1·11	421	1·15	444	1·09	482		444	1·09	
395	1·11	365	1·15	405	1·09	476		407	1·09	
356	1·11	315	1·16	369	1·09	471		374	1·09	
324	1·10	272	1·15	335	1·10	465		345	1·08	
295	1·10	235	1·16	306	1·09	460		318	1·08	
267	1·10	204	1·15	278	1·10	457		292	1·09	
243	1·10	175	1·17	254	1·09	Benzene partially frozen in the condenser.	268	1·09		
219	1·11	151	1·16	231	1·10		247	1·08		
202	1·08			210	1·10		228	1·08		
183	1·10			192	1·10		210	1·09		
168	1·09			175	1·10		193	1·09		
154	1·09			158	1·10		177	1·09		
140	1·10			143	1·10		163	1·09		
Ratios—										
Mean...	1·10		1·157		1·097		..			1·088
Max...	1·12		1·17		1·10		..			1·10
Min. ...	1·08		1·15		1·09	..			1·08	

FIG. 8.



Curves plotted for benzene at different temperatures from Tables XIV, XV, XVII, and XVIII.

Dotted curve for benzene partially frozen in condenser.

In the tables the values of the ratios have been put down, and they will be seen to be fairly constant in each table.

Table XVII contains readings for benzene at $5\cdot4^{\circ}$; the leak was so slow in this case as to attract attention, and it was found that the benzene was partially frozen; hence the curve in fig. 8 is dotted to show that the benzene was in a different state.

The curve corresponding to Table XVI would come very close to that corresponding to Table XIV, and is therefore omitted from fig. 8.

Carbon Disulphide.—Tables XIX—XXII give the readings and ratios for carbon disulphide at different temperatures.

Carbon Disulphide at different Temperatures.

Table XIX.

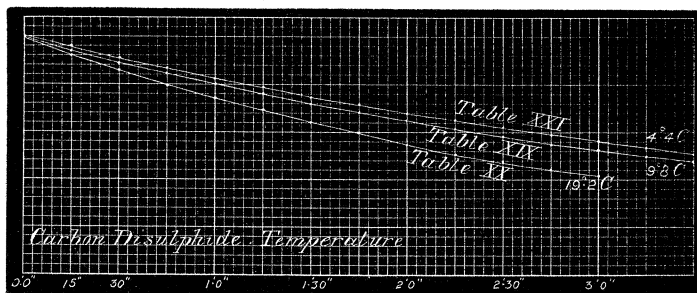
Table XX.

Table XXI.

Table XXII.

Temp. $9\cdot8^{\circ}$ C.		Temp. $19\cdot2^{\circ}$ C.		Temp. $4\cdot4^{\circ}$ C.		Temp. $8\cdot6^{\circ}$ C.	
500	1·06	500	1·08	500	1·05	500	1·05
472	1·06	463	1·07	475	1·05	474	1·06
447	1·05	430	1·08	452	1·05	450	1·06
425	1·06	398	1·07	431	1·05	425	1·05
402	1·06	370	1·07	412	1·05	404	1·05
380	1·06	345	1·07	391	1·05	383	1·06
360	1·06	320	1·07	374	1·05	362	1·05
341	1·05	298	1·07	357	1·06	345	1·06
325	1·06	276	1·07	339	1·04	327	1·06
307	1·05	257	1·07	325	1·05	310	1·05
292	1·05	239	1·07	310	1·05	295	1·05
277	1·05	223	1·07	296	1·04	279	1·06
264	1·04	208	1·07	281	1·05	264	1·06
250	1·05			269	1·04	251	1·05
238	1·05			256	1·05	236	1·06
226	1·05			244	1·05	224	1·05
215	1·05			234	1·04	213	1·05
204	1·05			224	1·04	201	1·06
				211	1·06		
				201	1·05		
Ratios—							
Mean	1·053		1·071		1·052		1·055
Max.	1·06		1·08		1·06		1·06
Min.	1·04		1·07		1·04		1·05

Fig. 9.



Curves plotted for carbon bisulphide at different temperatures from Tables XIX, XX, and XXI.

A curve plotted from Table XXII would almost coincide with that from Table XIX.

In fig. 9 the curve from Table XIX is practically the same as that from XXII; the latter is therefore omitted.

Olive Oil.—Tables XXIII—XXVIII give the readings and ratios for olive oil, and fig. 10 shows graphically the first three of these tables.

Olive Oil at different Temperatures.

Table XXIII.

Table XXIV.

Table XXV.

Temp. 11.5° C.		Temp. 47.5° C.		Temp. 18.5° C.	
490	1.10			490	1.24
444	1.10			394	1.23
403	1.10	? 390	2.36	319	1.53
364	1.10	165	2.54	260	1.24
332	1.10	65		210	1.24
301	1.10			168	
273	1.10				
247	1.10				
223	1.10				
203	1.10				
Ratios—					
Mean ..	1.10		2.45		1.236
Max. ..	1.10		2.54		1.24
Min. ..	1.10		2.36		1.23

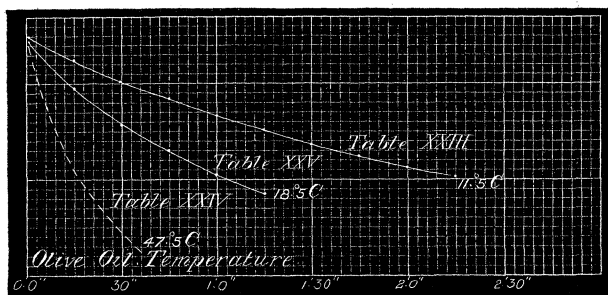
Table XXVI.

Table XXVII.

Table XXVIII.

Temp. 10° C.		Temp. 31° C.		Temp. 12° C.	
490	1·13	490	1·53	490	1·16
433	1·13	321	1·49	422	1·16
382	1·14	215		363	1·15
336	1·15			315	1·16
298	1·12			270	1·14
265	1·13			235	1·15
233	1·12			205	1·16
207				177	
Ratios—					
Mean ..	1·134		1·51		1·156
Max. ..	1·16		1·53		1·16
Min. ..	1·12		1·49		1·14

FIG. 10.



Curves plotted for olive oil at different temperatures from Tables XXIII and XXV. The dotted curve is got by a process of interpolation roughly from Table XXIV.

At the higher temperatures the rate of leak was so great that there is some doubt as to the first reading of the deflection: hence the discrepancies in the values of the ratios.

Tables XXIV and XXVII are abridged from fuller tables which give readings taken at 15 seconds intervals. These are given below.

Table XXIV.

Table XXVII.

Temperature 47.5° C.		Temperature 31° C.	
390	1.34	490	1.15
290	1.32	423	1.15
220	1.33	369	1.15
165	1.32	321	1.14
125	1.37	282	1.15
90	1.38	246	1.14
65		215	1.14
		189	1.14

Experiments with Higher Electromotive Forces.

In the experiments dealt with so far the battery used to charge the condenser was one of 20 silver chloride cells, hence of electromotive force of about 20 volts. For electromotive forces between 20 volts and zero Ohm's law is shown to hold good for the liquids experimented on. By the following experiments the limits were extended to between about 100 volts and zero.

The condenser was charged to about 100 volts, and readings were taken at intervals of 15 seconds, the electrometer having been reset so as to be less sensitive. The ratios are, without any obvious reason, less regular than in the earlier experiments.

Table XXIX.

Experiment 103. Olive oil. Charged to about 100 volts.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
490	1.12	201	1.16	79	
437	1.11	173	1.15	70	1.13
395	1.13	150	1.15	61	1.15
349	1.14	130	1.13	52	1.17
305	1.15	115	1.14	46	1.13
265	1.13	101	1.12	40	1.14
234	1.16	90	1.14	35	1.14
				32	1.13

Ratios—

Mean	1.14
Maximum	1.17
Minimum	1.11

Table XXX.

Experiment 108. Olive oil. Charged to about 100 volts.

Deflections.	Ratios.	Deflections.	Ratios.	Deflections.	Ratios.
198	1·25	88	1·21	40	1·17
160	1·23	73	1·20	34	1·21
130	1·20	60	1·25	28	1·22
108	1·22	49	1·17	23	1·21
				19	

Ratios—

Mean 1·214

Maximum 1·25

Minimum 1·17

Experiments on Residual Charge.

Carbon disulphide showed peculiarities in the above experiments. With a short and sudden charge the rate of fall of potential was much quicker at the beginning than at the end of the readings. This is what would be expected if there were electrical absorption, part of the fall being due to true leaking, part to absorption. If the rate of leak is according to Ohm's law, the ratio curve for such a liquid would be inclined to the horizontal at first, but the inclination would diminish with time. This is what is found in the case of carbon disulphide when the condenser is charged for a short time.

Again, the condenser, with carbon bisulphide between the cylinders, was charged for a time, then quickly discharged, and its inner cylinder connected with the electrometer. The deflection was at first connexion zero, then shortly rose to a maximum value, and finally diminished again after some time to zero. If the condenser was charged with opposite sign, the deflection from zero was in the opposite direction. If the condenser was charged first with one sign and then with the other, the deflections from zero were much smaller, but they appeared in the sense expected from residual charge phenomena.

These effects were greatest just after the CS₂ had been redistilled, but at times were totally absent. The still was cleaned, but the effects after fresh distillation were as marked as before.

Attempts to increase the effects by rendering the liquid less homogeneous were successful, for heating or cooling the condenser unequally always exaggerated the deflections.

The following readings are a sample of numerous experiments :—

Time.			
0' 0"	Condenser connected to battery.		
0 30	Condenser quickly discharged and connected with electro-meter.		
	Reading on scale	539
1 0	„	615 maximum.
2 0	„	557
3 0	„	544

Other liquids were tested in this way, but in no other case were similar phenomena observed. Mixtures of CS₂ and benzene or paraffin were also inactive in this sense, even when the mixtures were incomplete and the liquids were put in in such a way as to be "streaky," as was found possible.

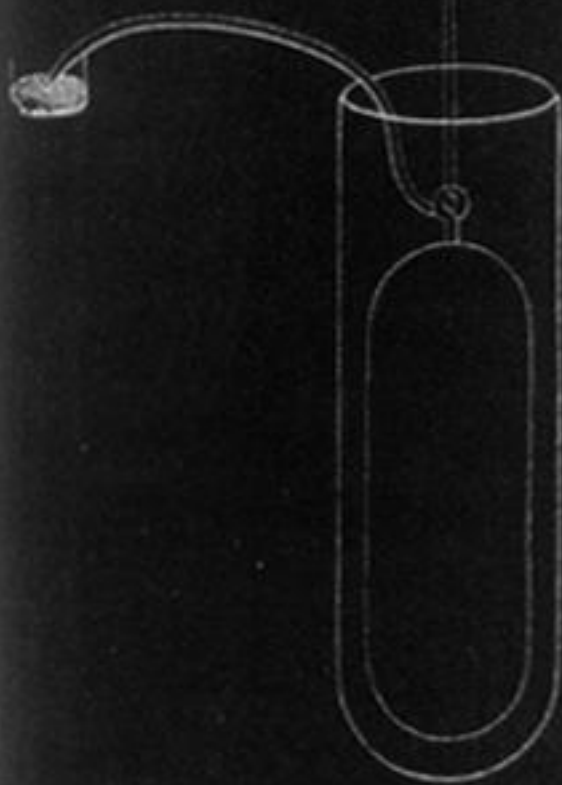
Some attempts were made to discover traces of polarisation, but no definite results were obtained. In the earliest experiments something of the kind was observed, but this was traced to the key and connexions.

XXII. "The Development of the Branchial Arterial Arches in Birds, with special Reference to the Origin of the Subclavians and Carotids." By JOHN YULE MACKAY, M.D., Senior Demonstrator of Anatomy, University of Glasgow. Communicated by Professor CLELAND, M.D., F.R.S. Received May 29, 1887.

(Abstract.)

According to the theories of Rathke, which are universally accepted at the present day, the subclavian artery is supposed to take its origin from the aortic root or fourth embryonic branchial arterial arch. In the adult bird the subclavian on each side is found springing from the extremity of an innominate artery along with the common carotid. It is presumed that the right subclavian has been, by a shortening of the aortic arch, carried forwards until it meets and fuses with the base of the common carotid artery; and the left subclavian is regarded as representing by its basal portion the fourth left arch or left primitive aorta. The subclavian of birds is thus regarded by Rathke as being developed in a manner similar to that of mammals. The author points out, however, that there is a marked difference in the relations of the artery to the surrounding parts in these two groups. In mammals the subclavian artery is crossed on its ventral aspect by the jugular vein and the pneumogastric nerve, and the recurrent branch of the latter turns round it upon the right side, but in birds the nerve

Fig. 1



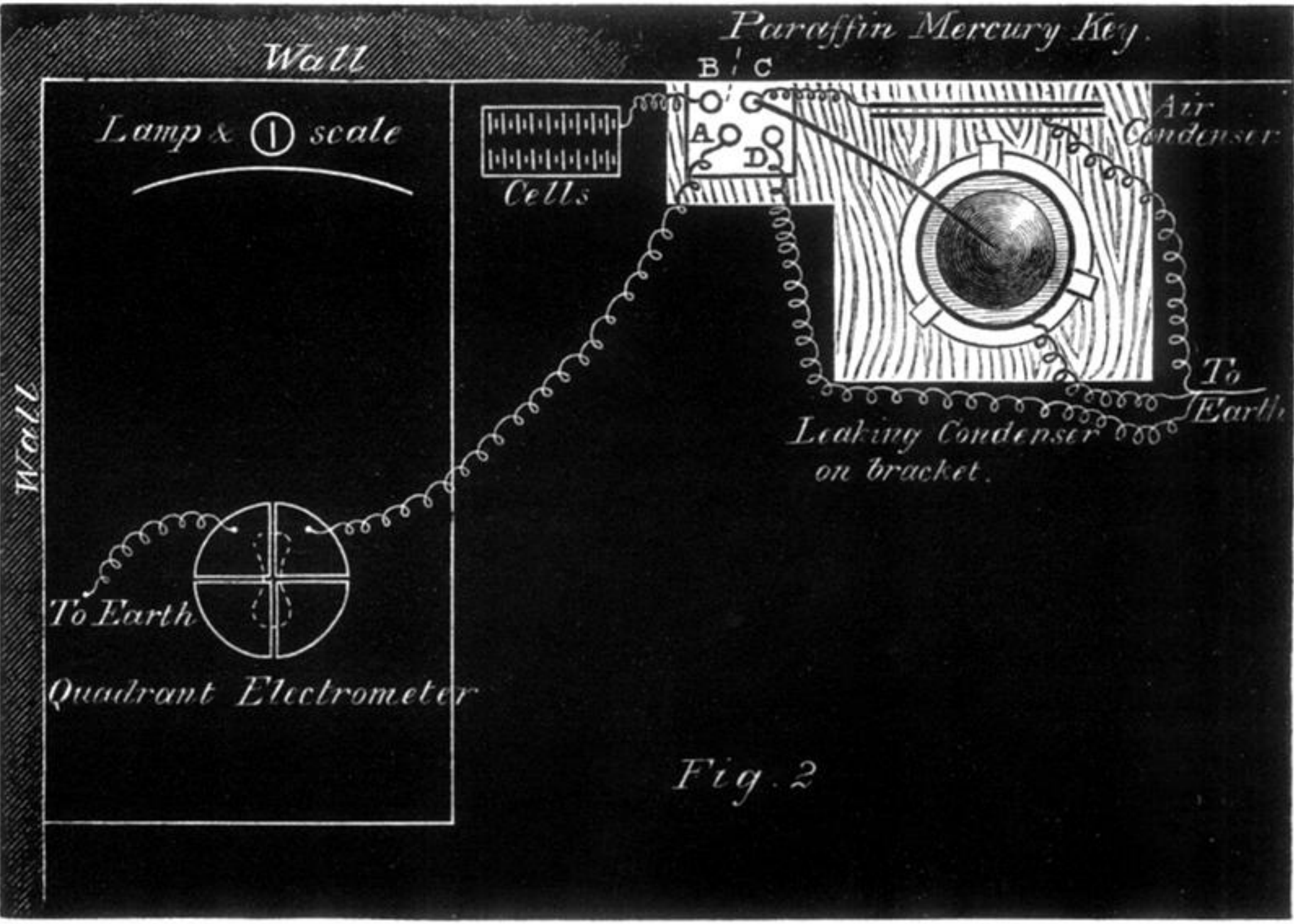
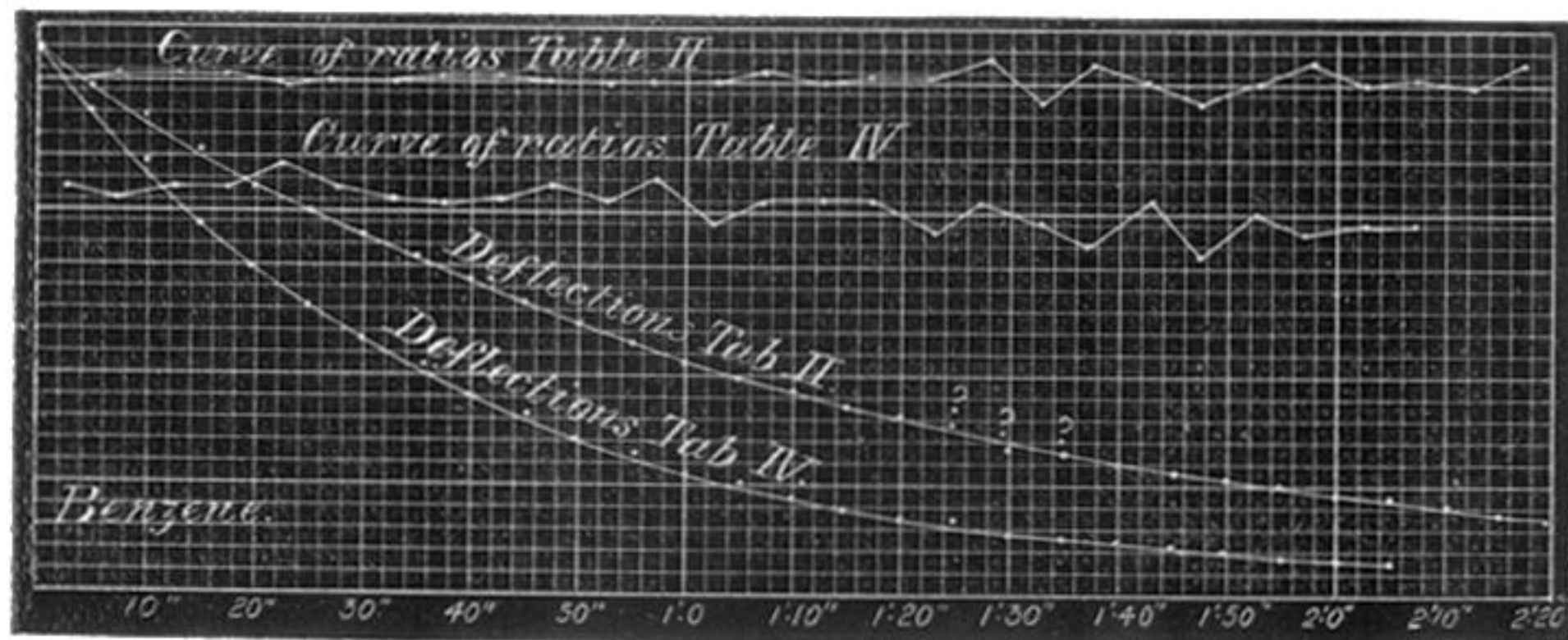


Fig. 2

FIG. 3.



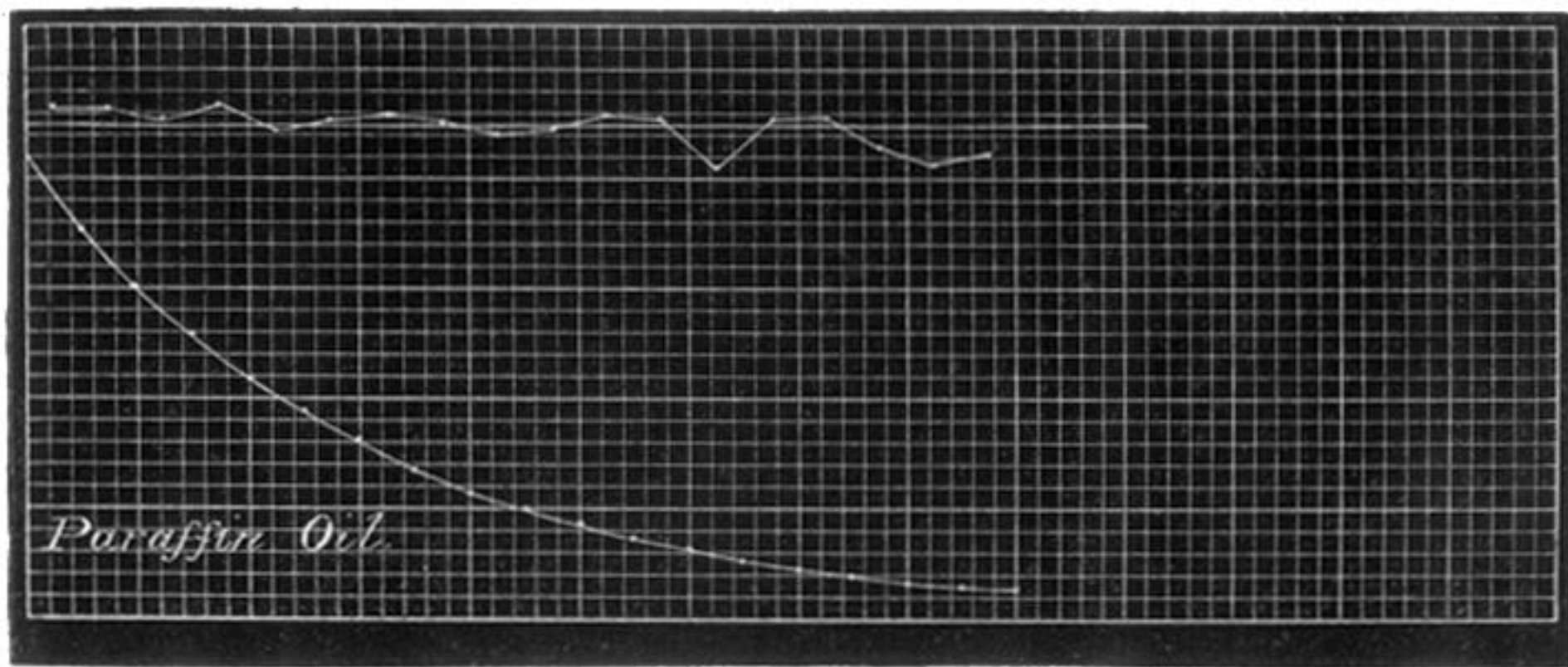
Curves plotted for benzene from Tables II and IV.

The straight lines through the ratio curves are drawn to show the mean value of the ratios.

In the ratio curves 1 division of the ruled paper corresponds with 0.01 in the ratio values.

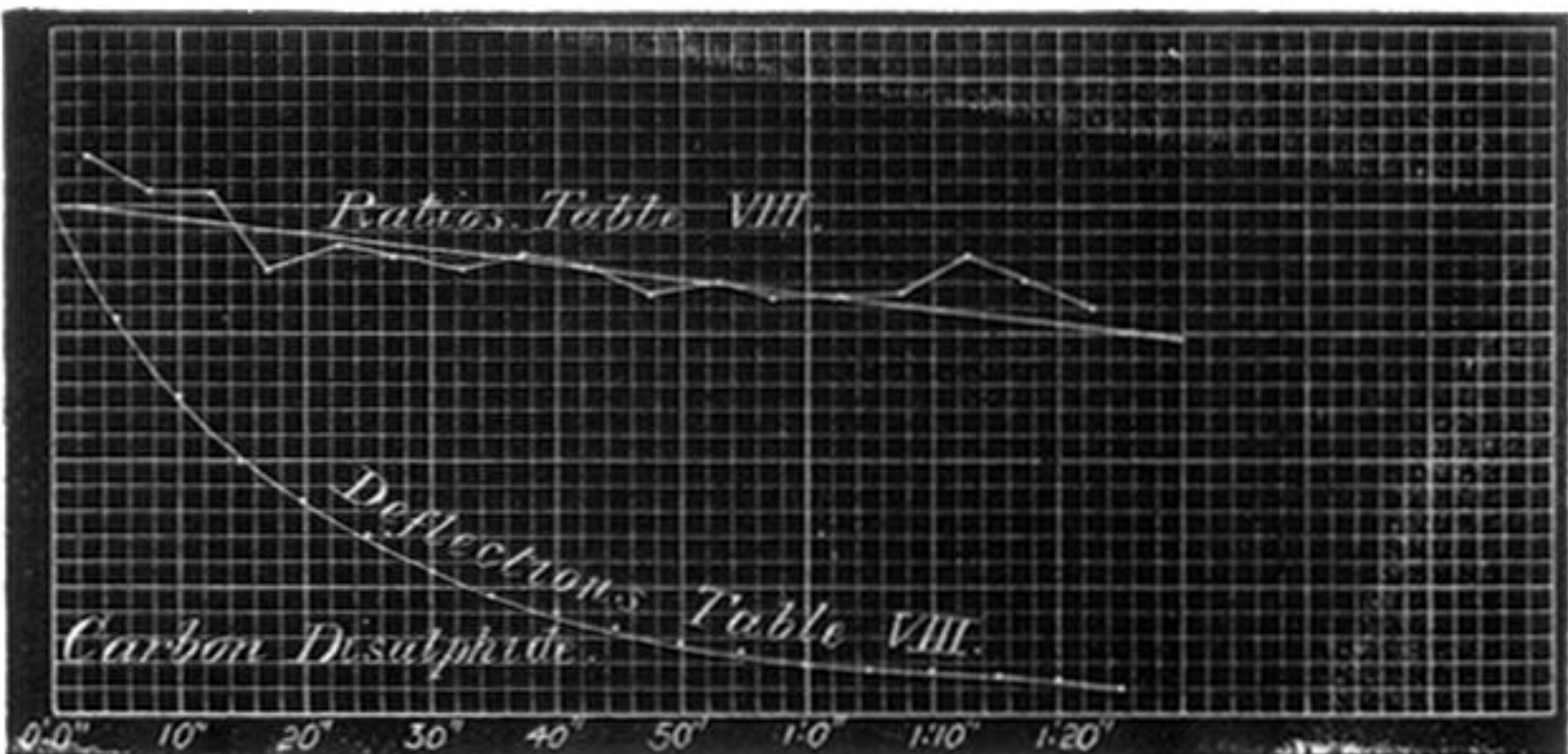
In the deflection curves 1 division = 20 in the deflection.

FIG. 4.



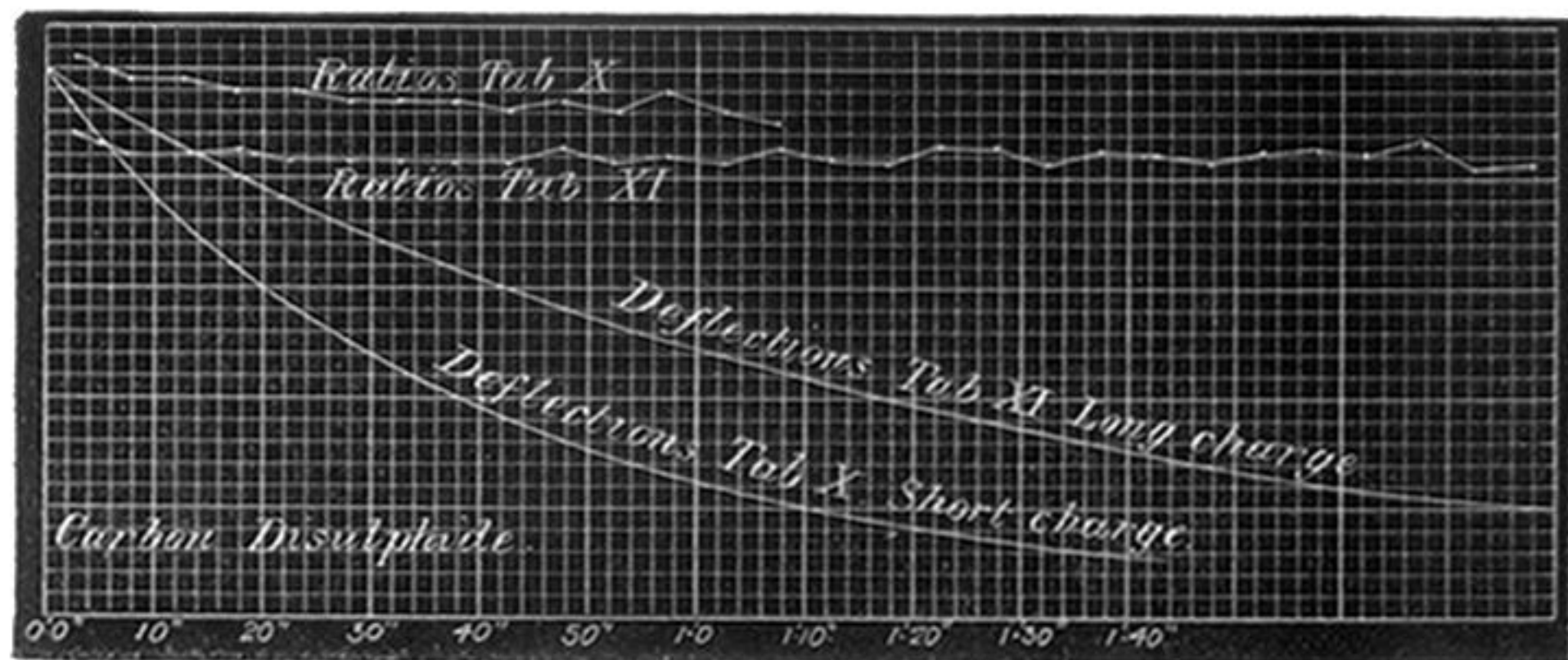
Curve plotted for paraffin from Table V. Same scales as in fig. 3.

FIG. 5.



Curve plotted for carbon disulphide from Table VIII.
Time of charge probably short.

FIG. 6.

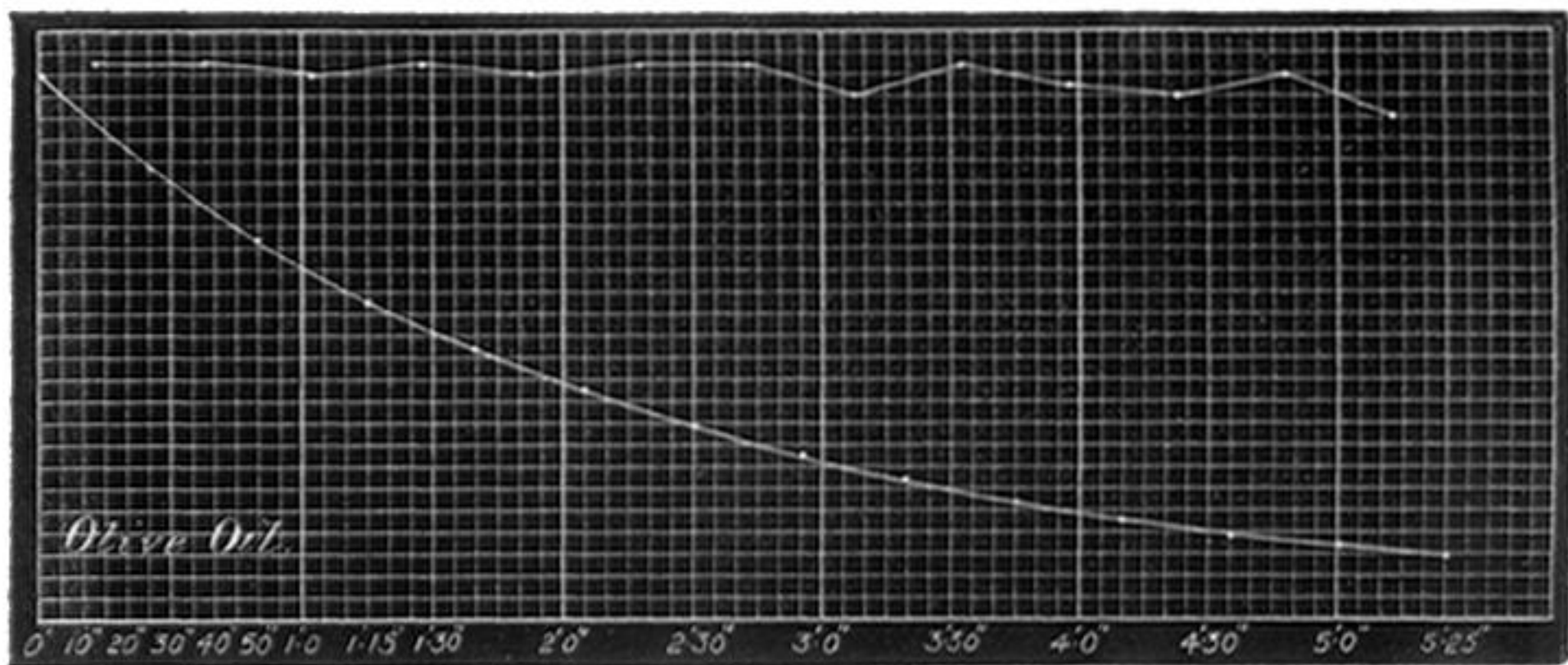


Curves plotted for carbon disulphide from Tables X and XI.

Upper curve from readings taken after a long period (10 minutes) of charging the condensers ; lower curve after a short period (2 seconds). Otherwise conditions similar.

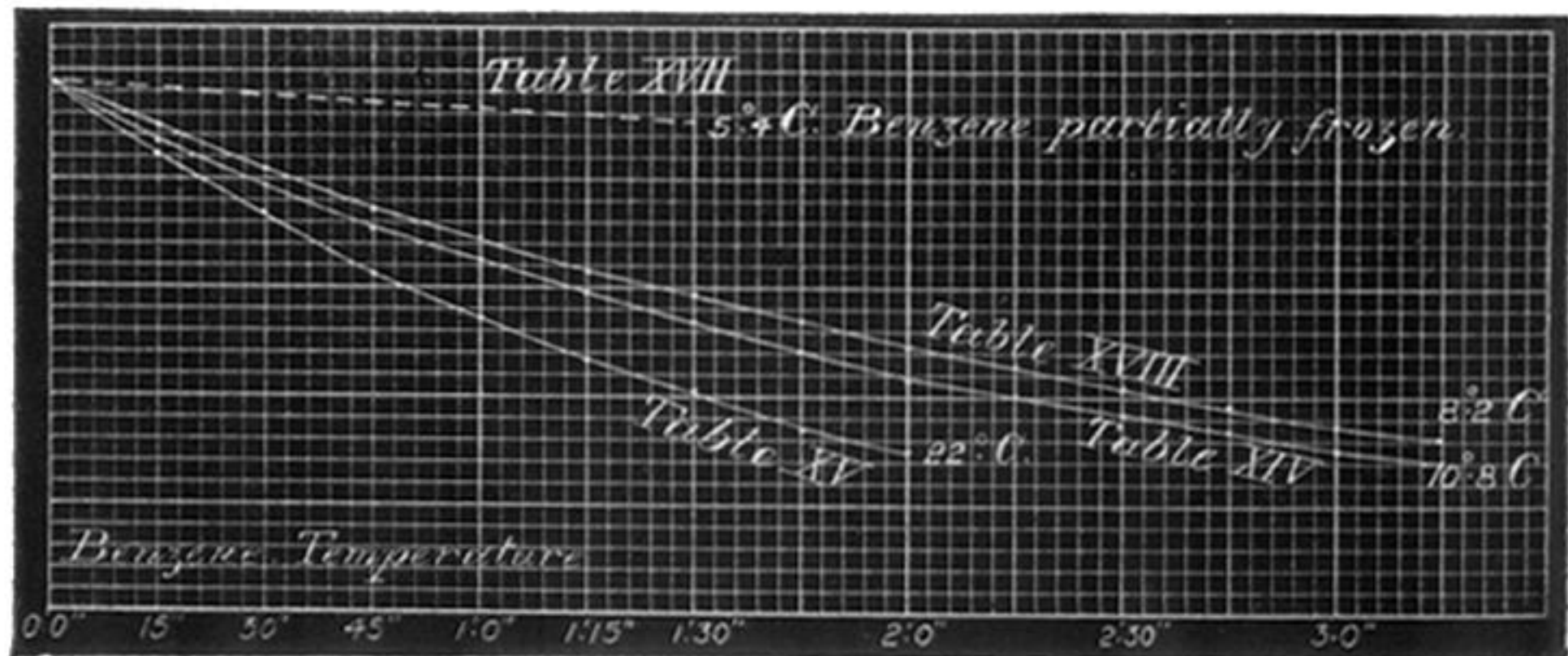
The curves of ratios are on the same scale and have the same zero line about 3 inches below the lower edge of the figure.

FIG. 7.



Curve plotted for olive oil from Table XII.
Time of charging condenser short.

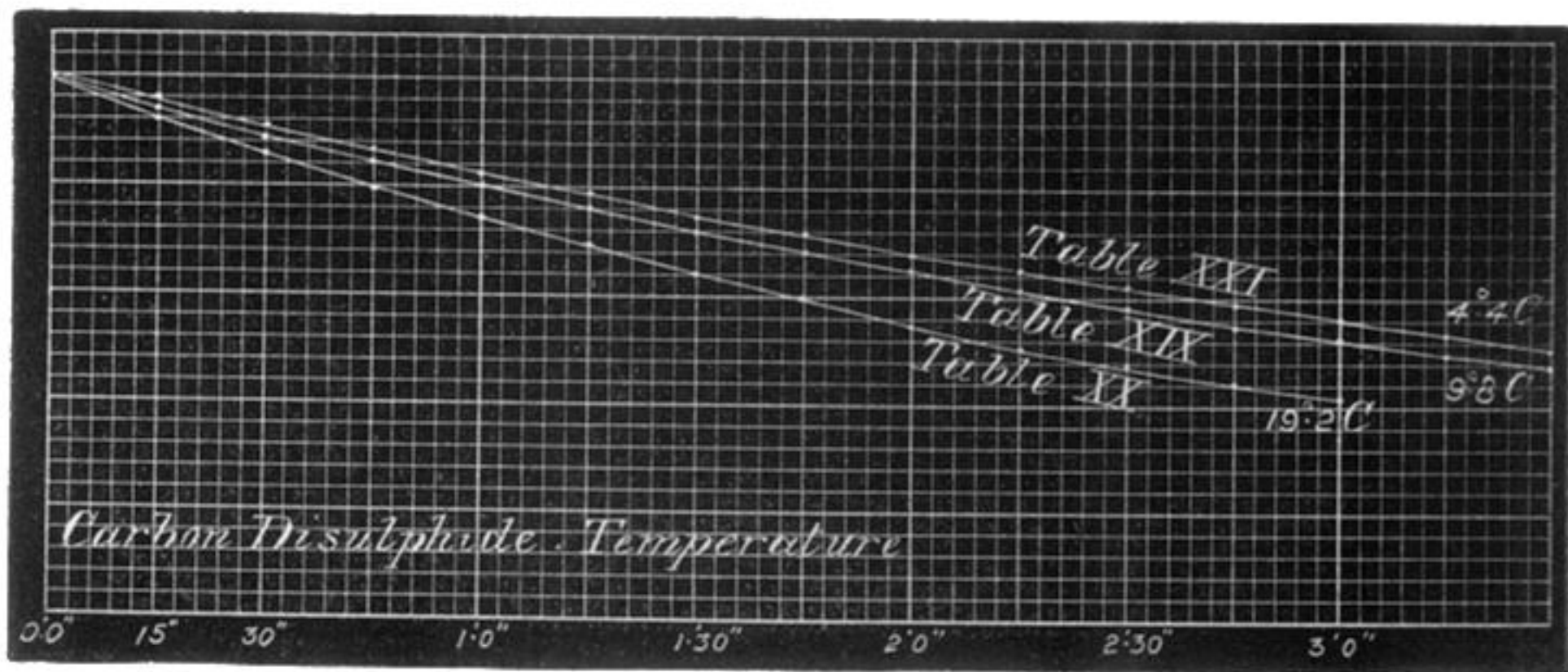
FIG. 8.



Curves plotted for benzene at different temperatures from Tables XIV, XV, XVII, and XVIII.

Dotted curve for benzene partially frozen in condenser.

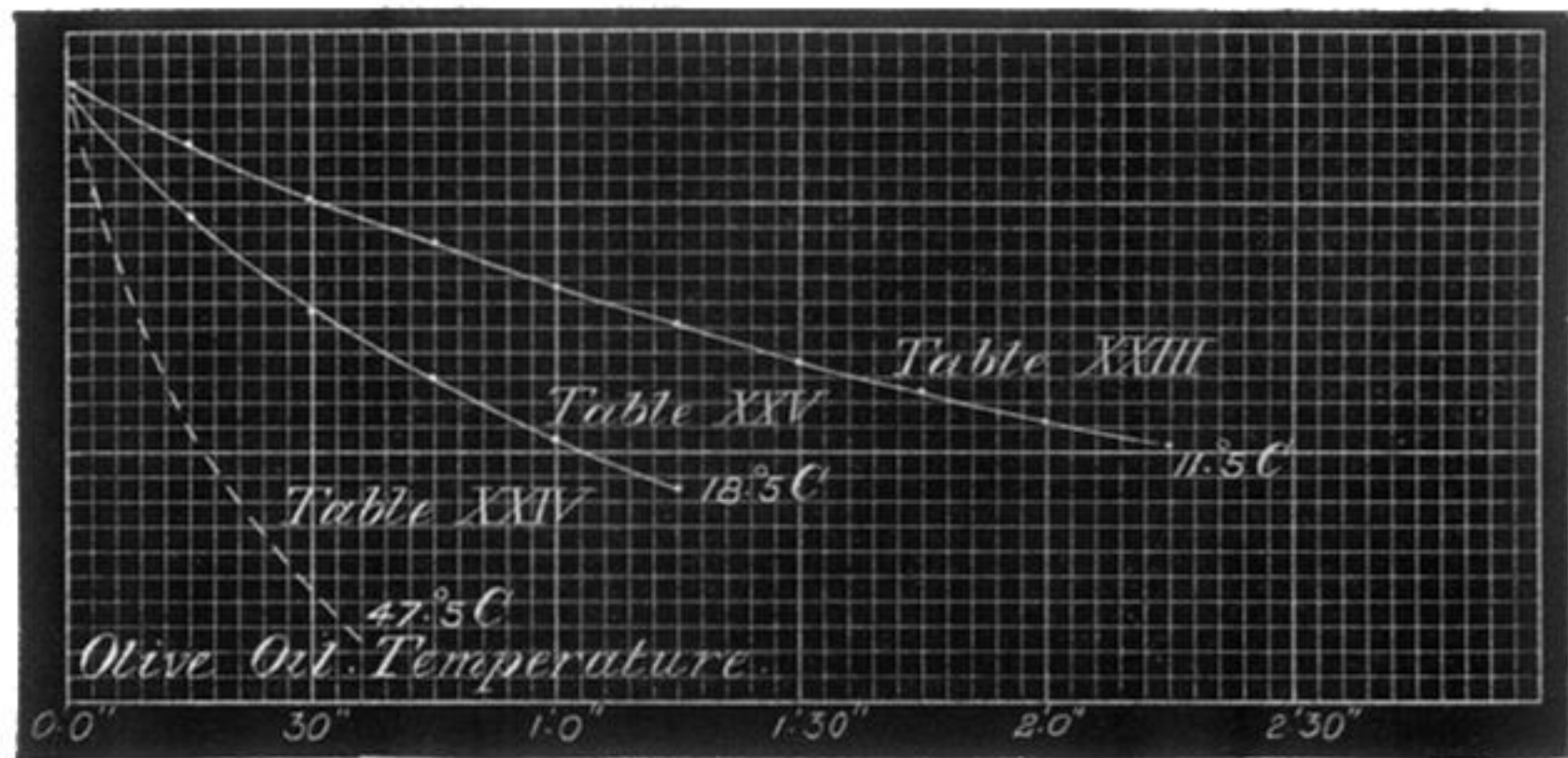
FIG. 9.



Curves plotted for carbon bisulphide at different temperatures from Tables XIX, XX, and XXI.

A curve plotted from Table XXII would almost coincide with that from Table XIX.

FIG. 10.



Curves plotted for olive oil at different temperatures from Tables XXIII and XXV. The dotted curve is got by a process of interpolation roughly from Table XXIV.