



137  
516  
THS

**TELXIS**

10/10/10  
10/10/10  
10/10/10

**PLACE IN RETURN BOX** to remove this checkout from your record.  
**TO AVOID FINES** return on or before date due.  
**MAY BE RECALLED** with earlier due date if requested.

DATE DUE	DATE DUE	DATE DUE

The Apparent Density  
Of  
Silica Gel Measured in Various Liquids

Thesis

Submitted to the Faculty of Michigan  
State College in Partial Fulfillment of the require-  
ments for the Degree of Master of Science.

By

Reuben Warren Leisy

June 1929

It has been definitely proven that such physical properties of an adsorbent, as density, available pore volume, and adsorptive power vary with the liquid employed.

The variation in density or apparent density of activated carbon was studied by Harkins and Ewing<sup>1</sup>. Their conclusions were that the liquid at the surface of the carbon was compressed, giving a variation in density relative to the compressibility of the liquid used and varying inversely as the surface tension.

Cude and Hulett<sup>2</sup> observed this same phenomena, but interpreted it differently. They assumed incomplete penetration of the capillaries in the carbon and show that the densities obtained were proportional to the surface tension of the liquids employed and inversely proportional to their viscosities. They also observed that there appeared to be a lag or drift and that the density measurements increased with time. Howard and Hulett<sup>3</sup> attributed this increase to more complete penetration.

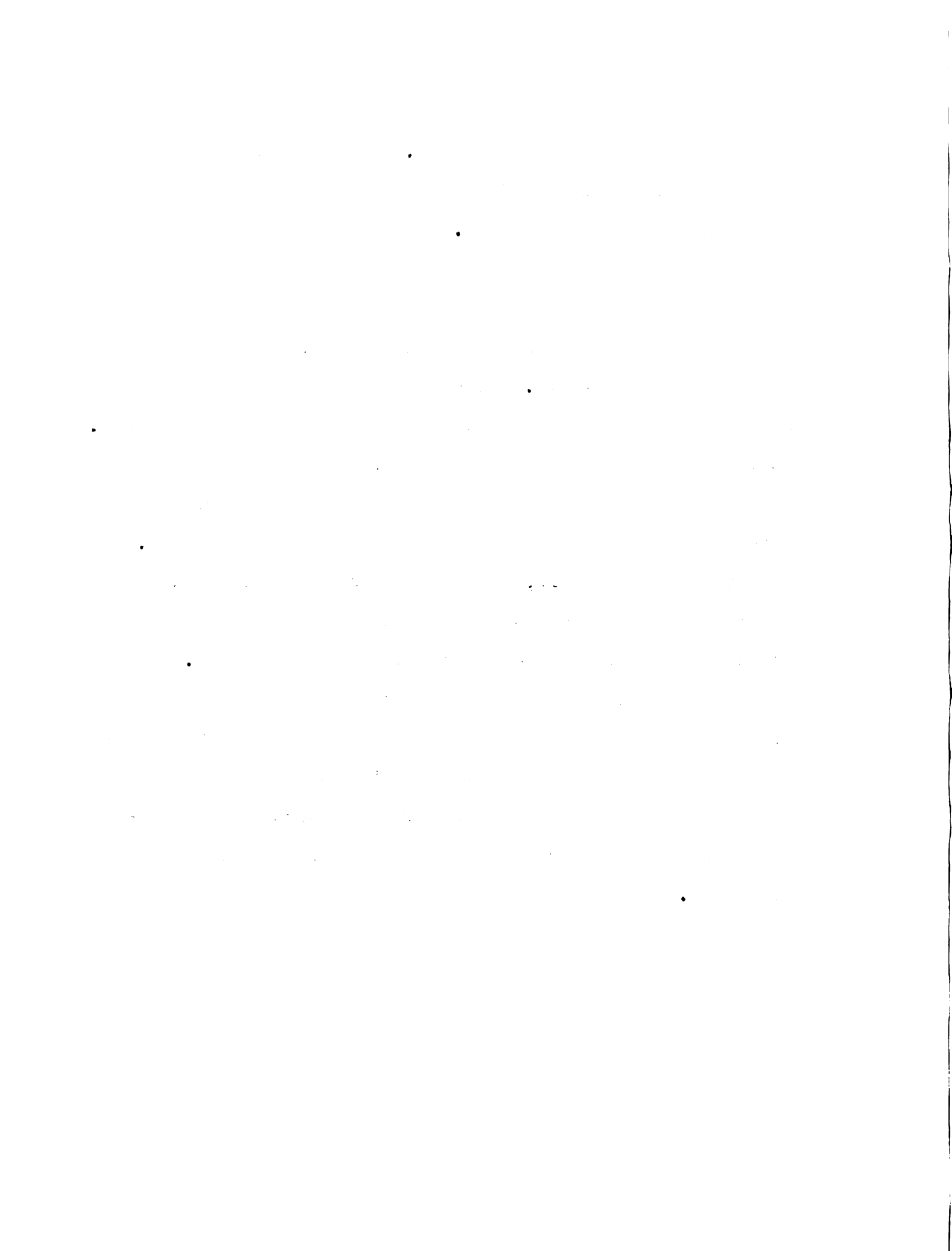
The apparent density of silica gel has been measured in various liquids by several investigators, but the data is meager and the measurements have been made for only a few liquids.

Berle and Urban<sup>4</sup> studied the variation in density of silica gel when activated under varying conditions and also of quartz, using ether as the liquid

for their density determinations. Their choice of ether was based on the assumption that it would have a greater penetrating power than water.

Nutting<sup>5</sup> calculated the pressure necessary to produce these apparent densities in the case of water with silica gel by determining the heat of wetting on gels of various water contents. He plotted the water adsorbed as a function of the heat of wetting and computed the pressure. He found that when a layer of water, 100 moles thick, had been adsorbed there was a decided break in the curve and assumed this to be the limit of the range of adsorption. He gives a value of 17,410 atmospheres pressure for a layer 100 moles thick with a pressure gradient near the silica gel surface of 237 atmospheres per mol layer.

In this work the apparent density of silica gel has been measured in 13 liquids in order that a comparison may be made with similar existing measurements on activated carbon and also gain information as to the magnitude of the pressure necessary to produce these abnormal densities.



Apparatus

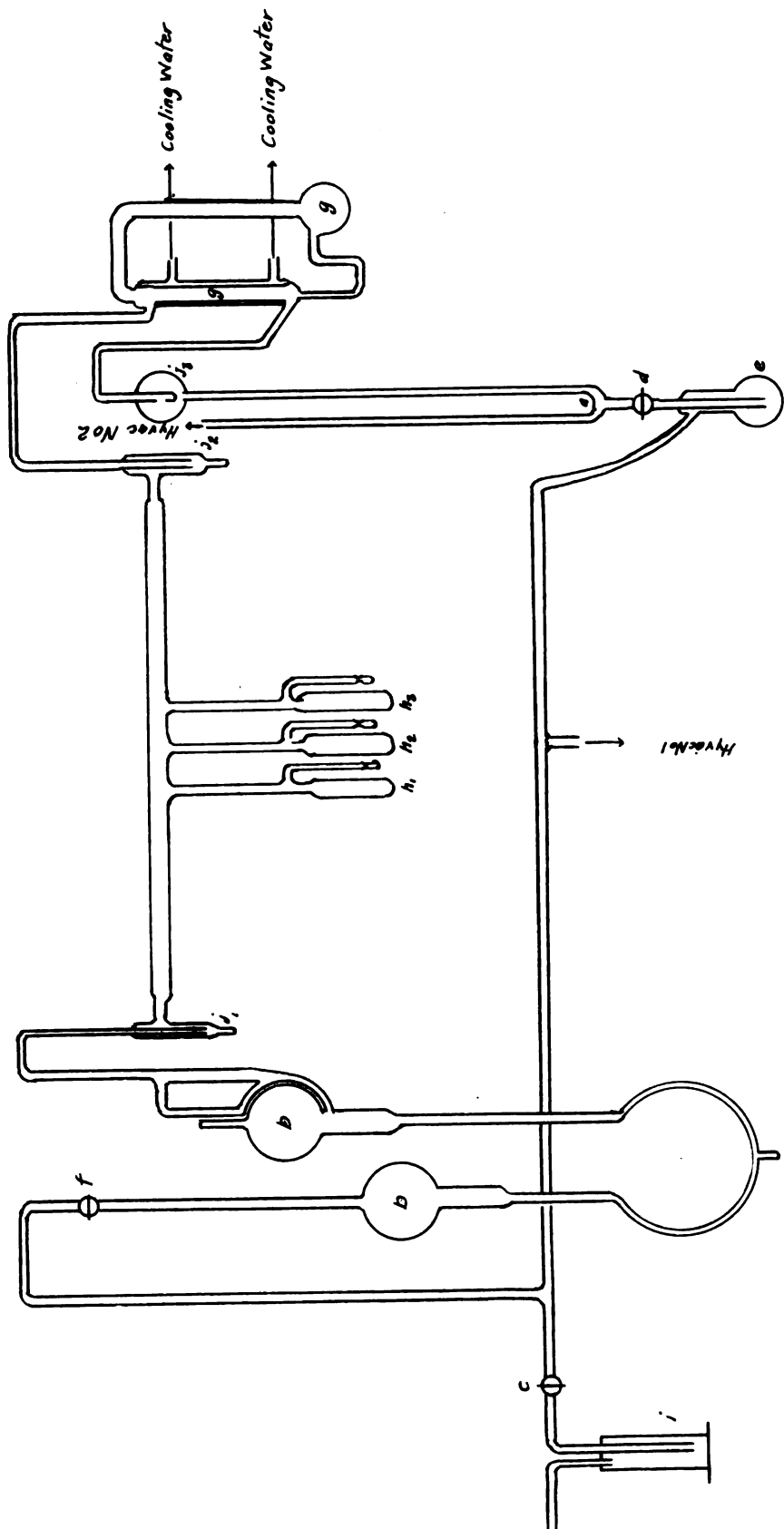
The apparatus consists essentially in a high vacuum system for evacuating the tubes filled with gel. It is unique in that the vacuum system proper is made entirely of pyrex glass, has no stopcocks, and is sealed from the atmosphere on one side by the mercury column in the McLeod gage and on the Hyvac pump side by a mercury seal.

Figure 1 is a detailed drawing of the apparatus. Two Central Scientific Hyvac pumps are used, Pump No. 1 to pull the mercury out of the McLeod gage (b) and control the mercury seal (a); pump No. 2 as an exhausting pump to the atmosphere from the Langmuir mercury vapor pump which is in series with it. In sealing off the vacuum system, stopcock (c) and (d) are opened and the mercury rises in the two arms of the mercury seal (a) to barometric height from the reservoir (e). Then stopcock (d) is closed. To continue evacuating the system after it has been sealed, stopcock (d) is opened (c) closed and the mercury pulled from the mercury seal with pump No. 1. Pulling the mercury down until the seal is open, but not to the stopcock. Now (d) is closed (c) opened to the atmosphere and the pump stopped. Stopcock (f) is used to open the McLeod gage to vacuum pump No. 1 and the atmosphere. (g) is the Langmuir mercury vapor pump. (h) 1, 2 and 3 are tubes filled with gel ready to evacuate. (i) is a calcium chloride tower to remove moisture from the air entering the gage. (j) 1, 2 and 3 are mercury traps.



Figure 2 is a detailed drawing of the tube used. C is an etched graduation on the stem to which the meniscus of the liquid under investigation is adjusted. The tubes have a capacity of approximately 25 cc. and will hold about 10 grams of gel. The side arm of the tube is constricted at (b) in order to facilitate breaking of the tip when immerced in the liquid.

Figure I



## Preparation of Materials

### (1) Mercury

The mercury was aerated over night by bubbling air through it while covered with 1 : 3 nitric acid, passed thru a capillary into a column of 1 : 3 nitric acid, through another capillary into a column of distilled water, dried with caustic soda, and then again passed through a capillary to remove the caustic soda.

### (2) Isopropyl Alcohol

A commercial c.p. product. The isopropyl alcohol was distilled from lime and then fractionated.

B.P. 79.70 - 79.80      738.9 mm.

### (3) Chloroform

A commercial c.p. product. The chloroform was treated with concentrated sulphuric to remove the alcohol, washed with dilute sodium hydroxide and finally with water. It was dried over fused calcium chloride, followed by anhydrous copper sulphate then fractionally distilled.

B. P. 60.60 - 60.80      746.2 mm.

### (4) Carbon tetrachloride

Product - Central Scientific c.p. The carbon tetrachloride was washed with water, sulphuric acid, water, sodium hydroxide and finally water. It was then dried over calcium chloride and fractionally distilled.

B. P. 75.80      734.9 mm.

(5) Carbondisulphide

Product - Central Scientific Co. c.p.

The same method of purification was used as for carbon tetra chloride.

B. P. 44.50 747.5 mm.

(6) Nitrobenzene

Product - Central Scientific Co. c.p.

The nitrobenzene was shaken with an equal volume of 10% solution of sodium sulphite and stood in contact with the solution for 24 hours. The nitrobenzene was separated by use of a separatory funnel and washed with water. It was then dried over calcium chloride and fractionally distilled.

B.P. 209.9 - 210.2° 744.6 mm.

(7) Benzene

Product - Wilkins Anderson Co., c.p. Thiophene free.

The benzene was treated with concentrated sulphuric acid until a sample of acid did not darken on standing in contact with the benzene for a day. It was treated with sodium hydroxide to neutralize the acid washed with distilled water, dried over calcium chloride and fractionally distilled three times. The purified benzene was stored in glass stoppered bottles over metallic sodium.

B.P. 77.9 - 78° 738.6

(8) Pentane

Product - Eastman Kodak Co. Practical

No purification

B. P. 27.4° 740.1 mm.

(9) Water

Distilled water collected directly from the still which supplies the laboratories with water.

(10) Petroleum Ether (Benzene)

Product - Baker Analyzed. B.P. 30° - 60°

No purification.

(11) Ethyl Alcohol

The ethyl alcohol used was purified in this laboratory by Clark G. Sinclair<sup>(1)</sup>.

B. P. 77.6° 740.1 mm.

(12) Acetone

Product - Wilkins and Anderson Co., c.p.

The acetone was fractionally distilled and dried over calcium chloride.

B.P. 55.2°-56° 743.7 mm.

(13) Ether

Product - Wilkins and Anderson Co. c.p.  
over sodium.

The ether was washed with water, then alkaline permanganate until there was no green coloration of the

•  
• • • • •

• • • • •

• • • • •  
• • • • •

• • • • •

• • • • •

• • •

permanganate over a period of ten minutes and with water until free from alkali. The green coloration shows the presence of alcohol. The purified product was dried over calcium chloride then phosphorus pentoxide and fractionally distilled.

B.P. 34° 743.0 mm.

All the liquids were shaken in a flask under reduced pressure before using in order to remove any absorbed air.

#### Silica Gel

Product - Silica Gel Corporation, Battemore.

This gel was hand picked to remove the obvious blanks, crushed and screened through a 3 mm. sieve.

## Experimental

### Evacuation:

The tubes in groups of three as shown under description of apparatus were filled with silica gel, sealed on to the apparatus, and evacuated for a period of six hours at a temperature of 250°C, then sealed off under vacuum. All tubes were sealed at a pressure from  $10^{-4}$  mm. to  $10^{-5}$  mm. as shown by the McLeod gage.

### Weighings:

After the sealed tube had cooled to room temperature it was scratched with a file at the points (a) and (b), then its weight in air ( $W_1$ ) and water ( $W_2$ ) determined. The end of the side arm was then immersed in the liquid under investigation and the tip broken off with forceps at the file scratch (b), thus filling the evacuated system with liquid. The top of the tube was broken off at the file mark (a), the tube placed in a thermostat regulated to  $25^{\circ} \pm .01^{\circ}\text{C}$  and the meniscus adjusted to the etched mark on the stem. The tube adjusted to volume was stoppered and weighed ( $W_5$ ). In most cases this adjustment was made two or more times and the mean weight used. The tube was emptied and filled with the liquid, meniscus adjusted to the mark and weighed as before ( $W_6$ ). The liquid was emptied out of the tube and the dry weights of the top and tip ( $W_4$ ) and tube ( $W_3$ ) determined.



## Formulae &amp; Computation:

From the above weights the apparent density of the silica gel was calculated with the following formulae:

$$W_{t-g} + W_1 + \frac{(W_1 - W_2) D_a}{D_w} - \frac{W_1 \frac{1}{D_b} D_a}{D_b}$$

$W_1$  = Weight of evacuated tube gel system in air

$W_2$  = Weight of evacuated tube gel system in water

$D_a$  = density of air

$D_b$  = density of brass

$D_w$  = density of water at temperature of weighings

$W_{t-g}$  = corrected weight of tube and gel

$W_t$  = corrected weight of tube, tip and top

$$W_t = (W_3 + W_4) + (W_3 + W_4) D_a \left( \frac{1}{D_p} - \frac{1}{D_b} \right)$$

$W_3$  = weight of dry tube

$W_4$  = weight of top and tip

$D_p$  = density of pyrex glass

$W_g$  = corrected weight of gel

$$W_g = W_{t-g} - W_t$$

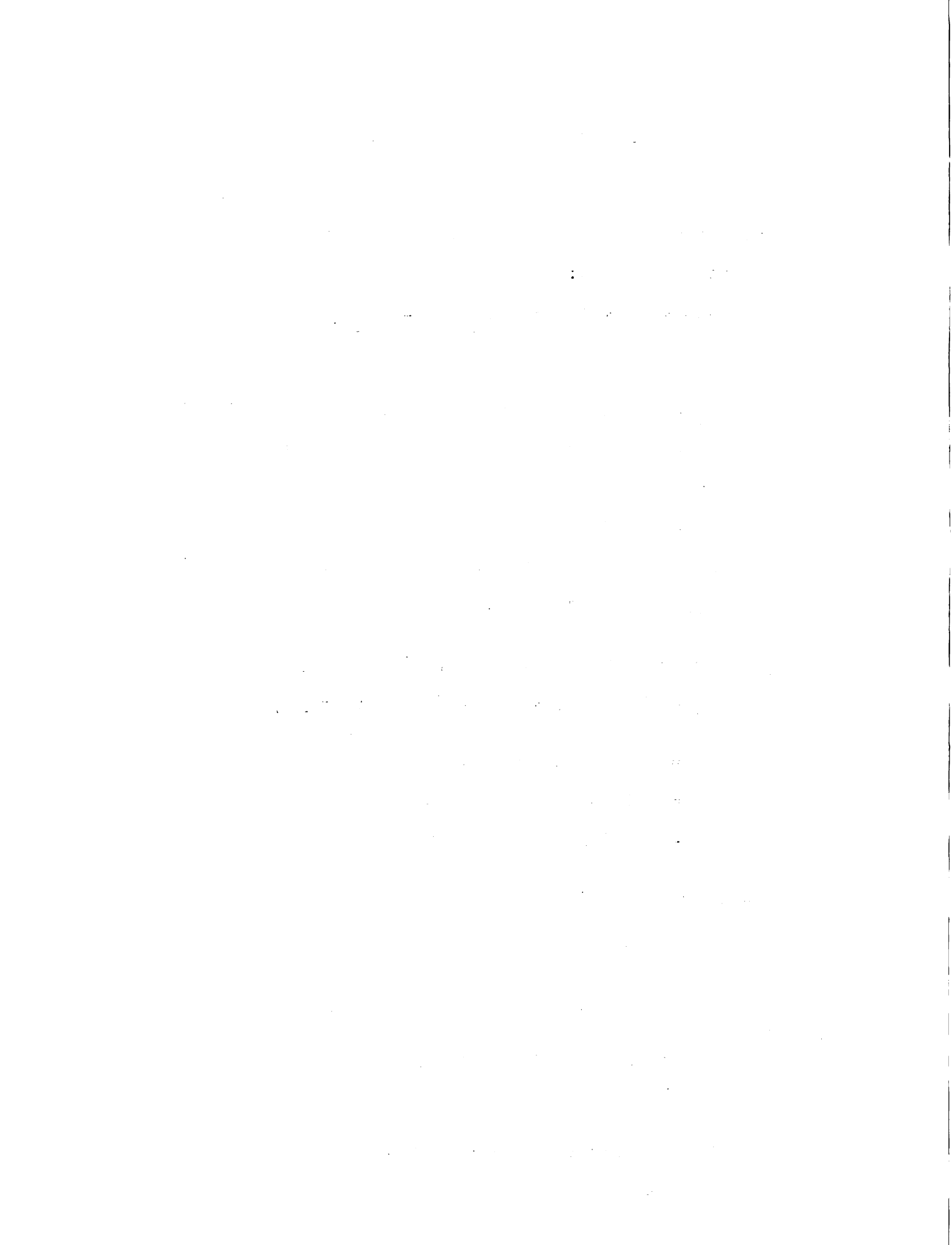
$W_{dl}$  = Corrected weight of displaced liquid

$$W_{dl} = W_6 - (W_5 - W_g) + (W_5 - W_6) D_a \frac{1}{D_b}$$

$W_5$  = Weight of tube liquid gel stopper

$W_6$  = Weight of tube liquid stopper

$D_{gel}$  = apparent density of gel



$$D_{gel} = \frac{W_g \times D_1}{W_{dl}}$$

$D_1$  = density of liquid used

### Precision of Measurements

The least accurate measurements are the weight of the bulb liquid gel and the weight of the bulb liquid. Their accuracy is determined by the ability to reproduce exact adjustments of the meniscus.

The following series of weights were made on a tube plus water to determine with what accuracy the weights could be duplicated:

Trial No.	Weight of tube		d.m.
1	41.5461	+	.0001
2	41.5459	-	.0001
3	41.5461	+	.0001
4	41.5459	-	.0001
5	41.5463	+	.0003
6	41.5456	-	.0004

Av a d .0002

A.D.  $\frac{.0002}{\sqrt{6}}$  =  $\pm$  .00008

This degree of accuracy is of the same order as the accuracy of the analytical balances used, thus the determinate errors are all of the same magnitude.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. This is essential for ensuring the integrity of the financial statements and for providing a clear audit trail. The records should be kept up-to-date and should be easily accessible to all relevant parties.

2. The second part of the document outlines the various methods used to collect and analyze data. This includes both qualitative and quantitative techniques, as well as the use of statistical software to process large amounts of information. The goal is to identify trends and patterns that can inform decision-making.

3. The third part of the document focuses on the results of the analysis. This section provides a detailed breakdown of the findings, including a comparison of the current period with previous periods. The results are presented in a clear and concise manner, using tables and charts to illustrate key points.

4. The fourth part of the document discusses the implications of the findings. This includes a discussion of the strengths and weaknesses of the data, as well as the potential risks and opportunities that may arise. The goal is to provide a comprehensive overview of the current situation and to offer practical recommendations for improvement.

5. The fifth part of the document concludes the report and provides a summary of the key findings. This section is intended to provide a clear and concise overview of the entire document, highlighting the most important points and the overall conclusions. The report is intended to be a valuable resource for all stakeholders involved in the organization's operations.

## Example of Calculation:

Run #9 Ethyl Alcohol

Bar 734.3 mm. 21°C Tube No. 4

Evacuated 6 hrs to  $10^{-5}$  mm.

Temperature of thermostat 25°C

$$W_{t-g} = W_1 + \frac{(W_1 - W_2)}{D_w} D_a - W_1 \frac{1}{D_b} D_a$$

$$W_1 = 51.9884 \quad D_w \text{ at } 734.3 \text{ mm. } 21^\circ\text{C} = 0.99602$$

$$W_2 = \frac{8.9000}{43.0884} \quad D_a \text{ at } 734.3 \text{ mm. } 21^\circ\text{C} = 0.001161$$

$$W_1 - W_2 \quad \frac{1}{D_b} = 0.1184$$

$$W_{t-g} = 51.9884 + \frac{43.0884 \times .001161}{.99602} - 51.9884 \times .1184 \times .001161$$

$$= 51.9884 + .0501 - .0071$$

$$W_{t-g} = 52.0314$$

$$W_t = (W_3 + W_4) + (W_3 + W_4) \left( \frac{1}{D_p} - \frac{1}{D_b} \right) D_a$$

$$W_3 = 28.6295 \quad \frac{1}{D_p} = \frac{1}{2.25} = 0.4444$$

$$W_4 = 10.3060 \quad \frac{1}{D_b} = \frac{1}{8.85} = 0.1184$$

$$D_a = 0.001161 \quad \frac{1}{D_p} - \frac{1}{D_b} = \frac{0.3260}{0.001161}$$

$$W_t = (28.6295 + 10.3060) + (28.6295 + 10.3060) \times .3260 \times .001161$$

$$= 38.2209 + 38.2209 \times .3260 \times .001161$$

$$= 38.2209 + .0144$$

$$= 38.2353$$

THE STATE OF TEXAS, COUNTY OF DALLAS.

Know all men by these presents, that \_\_\_\_\_

of the County of \_\_\_\_\_

State of Texas, for and in consideration

of the sum of \_\_\_\_\_ Dollars, to \_\_\_\_\_

\_\_\_\_\_

of the County of \_\_\_\_\_

State of Texas, have granted, sold, conveyed

and confirmed unto the said \_\_\_\_\_

\_\_\_\_\_ of the County of \_\_\_\_\_

State of Texas, all that certain \_\_\_\_\_

\_\_\_\_\_ of the County of \_\_\_\_\_

State of Texas, together with all and singular

rights and appurtenances in anywise

in anywise in anywise in anywise

\_\_\_\_\_ of the County of \_\_\_\_\_

State of Texas, unto the said \_\_\_\_\_

\_\_\_\_\_ of the County of \_\_\_\_\_

State of Texas, his heirs and assigns

forever, to have and to hold unto the

said \_\_\_\_\_

$$\begin{aligned}
 W_g &= W_{t-g} - W_t \\
 &= 52.0314 - 38.2353 \\
 &= 13.7961
 \end{aligned}$$

$$W_{d1} = W_6 - (W_5 - W_g) + (W_5 - W_6) D_a \frac{1}{D_b}$$

$$W_5 = 54.0150$$

$$W_6 = 44.8937$$

$$\begin{aligned}
 W_{d1} &= 44.8937 - (54.0150 - 13.7961) + (54.0150 - 44.8937) \times .1184 \times \\
 &\quad .001161 = 44.8937 - 40.2189 + 9.1213 \times .1184 \times .00161 \\
 &= 44.8937 - 40.2189 + .0013 \\
 &= 4.6716
 \end{aligned}$$

$$D_{gel} = \frac{W_g \times D_1}{W_{d1}}$$

$$D_1 = 0.7851$$

$$\begin{aligned}
 D_{gel} &= \frac{13.7961}{4.6716} \times 0.7851 \\
 &= 2.9503 \times 0.7851 \\
 &= 2.3163
 \end{aligned}$$



## D A T A

Substance	Run No.	Tube No.	$W_g/W_{dl}$	$D_{gel}$	Deviation
Mercury	21	7	0.09494	1.2849	+ .0008
	"	8	0.09480	1.2830	- .0011
	"	10	0.09490	1.2844	+ .0003
	Total		0.28464	3.8523	.0022
	AV		0.09488	1.2841	$\pm$ .0007
					Deviation of Mean $\pm$ .0004
Carbon disulphide	19	III	1.7200	2.1665	- .0008
	"	7	1.7147	2.1598	- .0074
	"	8	1.7270	2.1753	+ .0082
	Total		5.1617	6.5016	0.0164
	AV		1.7206	2.1672	$\pm$ .0054
					Deviation of Mean $\pm$ .0031
Benzene	4	1	2.5000	2.1848	- .0003
	"	2	2.5009	2.1848	- .0003
	5	1	2.5079	2.1854	+ .0003
	"	2	2.5041	2.1851	
	10	1	2.5071	2.1854	+ .0003
	Total		12.5020	10.9255	.0012
	AV		2.5004	2.1851	$\pm$ .00024
					Deviation of Mean $\pm$ .0001

Substance	Run No.	Tube No.	W <sub>g</sub> /W <sub>dl</sub>	D <sub>gel</sub>	Deviation
Carbontetra- chloride	6	1	1.3538	2.1543	+ .0065
	6	2	1.3470	2.1435	- .0043
	7	1	1.3493	2.1471	- .0007
	7	3	1.3535	2.1538	+ .0060
	12	4	1.3451	2.1405	- .0073
	Total		6.7487	10.7392	.0248
	Av		1.3497	2.1478	± .0050
Deviation of Mean				± .0020	
Nitrobenzene	18	III	1.8251	2.1870	- .0054
	18	7	1.8322	2.1955	+ .0031
	18	8	1.8315	2.1947	+ .0023
	Total		5.4888	6.5772	.00108
	Av		1.8296	2.1924	± .0036
Deviation of Mean				± .0021	
Iso propyl alcohol	17	10	2.8297	2.2100	+ .0051
	17	X	2.8168	2.1999	- .0051
	Total		5.6465	4.4099	.0102
	Av		2.8232	2.2049	± .0051
Deviation of Mean				± .0036	
Chloroform	16	III	1.4938	2.2108	+ .0015
	16	7	1.4932	2.2099	+ .0016
	16	8	1.4913	2.2071	- .0022
			4.4783	6.6278	.0044
			1.4928	2.2093	± .0015
Deviation of Mean				± .0009	

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry should be supported by a valid receipt or invoice to ensure transparency and accountability.

2. In the second section, the author outlines the various methods used for data collection and analysis. This includes both primary and secondary research techniques, as well as the use of statistical software to process large datasets.

3. The third section provides a detailed overview of the findings from the study. It highlights several key trends and patterns observed in the data, which are discussed in the context of the research objectives.

4. The fourth section discusses the implications of the findings for practice and policy. It offers recommendations based on the research results, aiming to provide actionable insights for stakeholders in the field.

5. Finally, the document concludes with a summary of the research and a list of references. The author acknowledges the limitations of the study and suggests areas for future research to further explore the topics discussed.

Substance	Run No.	Tube No.	$W_g/W_{dl}$	$D_{gel}$	Deviation
Petroleum ether	15	0	3.5320	2.2216	+ .0006
	15	3	3.5322	2.2228	- .0006
		Total	7.0624	4.4444	.0012
		Av	3.5312	2.2222	$\pm$ .0006
		Deviation of Mean			$\pm$ .0004
Water	2	2	2.2358	2.2293	+ .0083
	2	3	2.2309	2.2244	- .0011
	4	3	2.2365	2.2300	+ .0045
	5	3	2.2271	2.2206	- .0049
	6	3	2.2275	2.2210	- .0044
	10	III	2.2328	2.2263	+ .0008
	8	3	2.2332	2.2267	+ .0012
		Total	15.6238	15.5783	.0207
		Av	2.2320	2.2255	$\pm$ .0029
	Deviation of Mean			$\pm$ .0011	
Pentane	13	II	3.6190	2.2507	+ .0005
	13	X	3.6173	2.2496	- .0005
		Total	7.2363	4.5003	.0010
		Av	3.6181	2.2502	$\pm$ .0005
	Deviation of Mean			$\pm$ .0003	

Substance	Run No.	Tube No.	Wg/W <sub>d1</sub>	D <sub>gel</sub>	Deviation
Ethyl alcohol	8	1	2.9159	2.2893	- .0115
	8	2	2.9517	2.3174	+ .0166
	9	4	2.9503	2.3163	+ .0155
	9	5	2.9365	2.3054	+ .0046
	11	7	2.9213	2.2935	- .0073
	11	8	2.9080	2.2831	- .0177
		Total	17.5837	13.8050	.0783
		Av	2.9306	2.3008	± .0122
				Deviation of Mean	± .0050
		11	9	2.9768	2.3371
Acetone	10		2.9589	2.3210	- .0021
	10		2.9643	2.3252	+ .0021
		Total	5.9232	4.6462	.0042
		Av	2.9616	2.3231	± .0021
				Deviation of Mean	± .0015
Ether	14	0	3.3531	2.3730	+ .0029
	14	3	3.3612	2.3787	- .0029
		Total	6.7143	4.7517	.0058
		Av	3.3571	2.3759	± .0029
				Deviation of Mean	± .0014

## Summary of Data

Substance	$W_g/W_{dl}$	$D_{gel}$	Devia tion of Mean
Mercury	0.09448	1.2841	+ - .0004
		1.277 <sup>+</sup>	
Carbontetrachloride	1.3497	2.1478	+ - .0020
Carbondisulphide	1.7206	2.1672	+ - .0031
Benzene	2.5004	2.1851	+ - .0001
Helium		2.188 <sup>‡</sup>	
Nitrobenzene	1.8296	2.1924	+ - .0021
Isopropylalcohol	2.8232	2.2049	+ - .0036
Chloroform	1.4928	2.2093	+ - .0009
Petroleum ether	3.5312	2.2222	+ - .0004
Water	2.2320	2.2255	+ - .0011
		2.226 <sup>+</sup>	
Pentane	3.6181	2.2502	+ - .0003
Ethyl alcohol	2.9306	2.3008	+ - .0005
Acetone	2.9616	2.3231	+ - .0015
Ether	3.3571	2.3759	+ - .0028

<sup>+</sup>Values by J. A. Ikerman

Table 1 and Table 1-a are a comparison of the apparent densities of silica gel with those determined by Harkins and Ewing<sup>1</sup> for gas mask charcoal, and they are arranged in order of increasing apparent densities. This table also contains the calculated pore volume, per cent compressibility at 12,000 atmospheres, surface tension  $\gamma$ , viscosity  $\eta$  in absolute units, the ratio  $\frac{\gamma}{\eta}$  and the value of  $b$  for Vander Waal's equation. The pore volumes in these tables are calculated not on a basis of compressibility of the liquids, but on a change in density of the silica gel and charcoal as calculated by Harkins.

This is not a true assumption, but was used as a basis of calculation due to the uncertainty of the true block density of carbon. The pore volume is given by the following equation:

$$1 - \frac{d \text{ in mercury}}{d \text{ in liquid}}$$

The density determined with mercury being the weight of 1 cc. of charcoal in vacuum, for the mercury does not wet the surface or enter the pores of the charcoal. On this basis any increase in density is due to the weight of liquid entering the charcoal system. This same reasoning applies to a silica gel system. There appears to be no correlation between the two sets of data which is not at all unexpected.

Table I SILICA GEL

1	2	3	4	5	6	7	8
Liquid	Apparent Density	Pore Volume 1 cc.	% compressed 12,000 atmos- pheres	Surface Tension Dynes per Cm. $\gamma$	Viscosity Absolute Units $\eta$	$\frac{\gamma}{\eta}$	$\frac{\gamma}{\eta}$ X 10 <sup>4</sup>
Mercury	1.2841			57.0			
	1.277 <sup>+</sup>						
Carbon Tetrachloride	2.1478	0.4021		26.15	0.0096		
Carbon disulfide	2.1672	0.4075	25.75	31.38	0.0037	8480	34
Benzene	2.1851	0.4123		28.88	0.0064	4510	54
Helium	2.188 <sup>+</sup>						
Nitrobenzene	2.1924	0.4143		43.4			
Iso Propyl Alcohol	2.2049	0.4176		21.3	0.0204	10430	
Chloroform	2.2093	0.4188		27.13	0.0223	4760	45
Petroleum Ether	2.2222	0.4221					
Water	2.2255	0.4229	20.51	72.8	0.0101	7200	14
	2.226 <sup>+</sup>						
Pentane	2.2502	0.4293	More than ether	About 15	0.0024	6200	65
Ethyl Alcohol	2.3008	0.4419		21.85	0.0114	19190	37
Acetone	2.3231	0.4472	27.0	23.50	0.0033	7120	44
Ether	2.3759 2.3902 <sup>00++</sup>	0.4596	30.0	17.10	0.0024	7125	39

+ J.A. Ikerman<sup>5</sup>; ++ Berle and Urban<sup>4</sup>; Values by Markins



Table I-a  
GAS MASK CHARCOAL

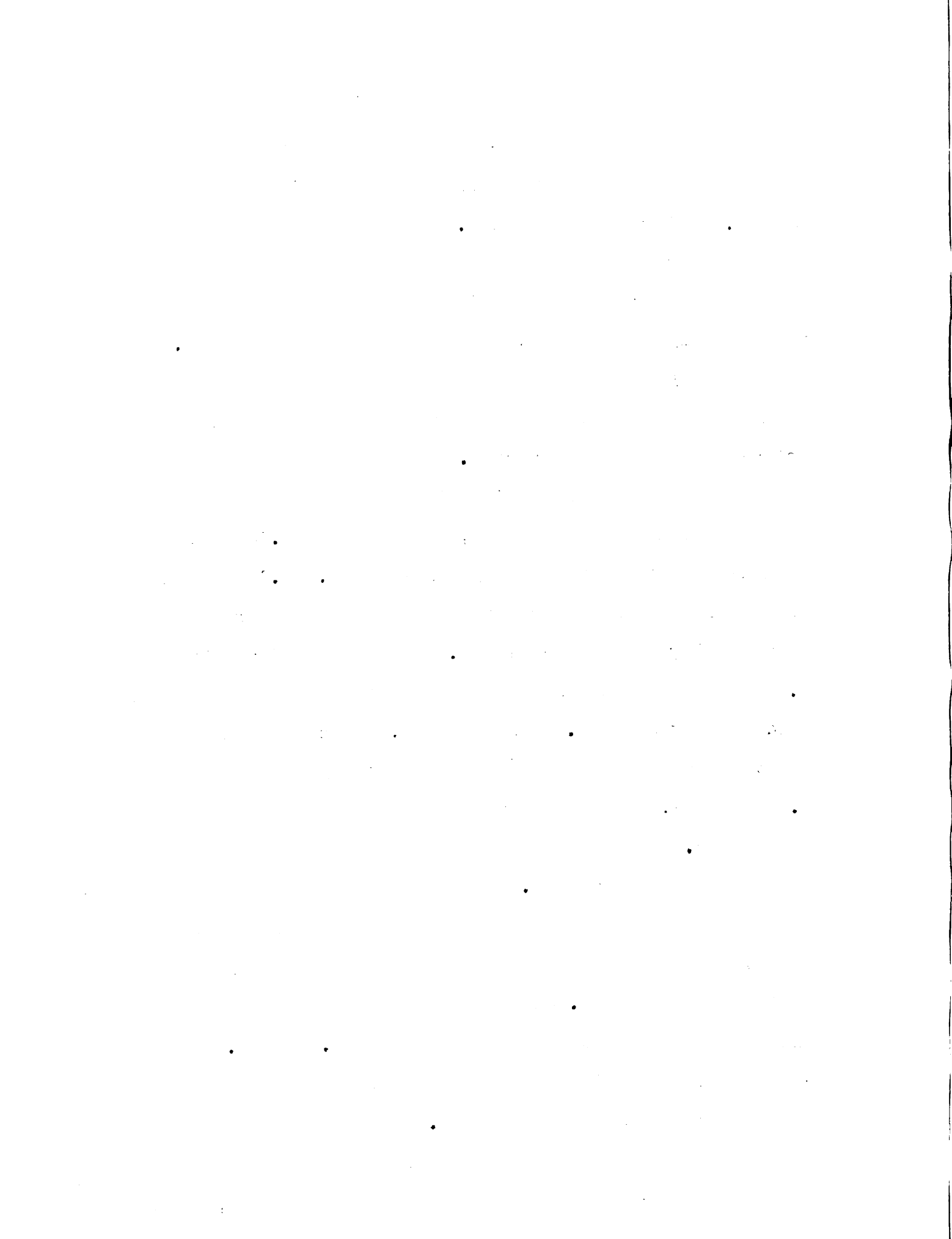
1	2	3	4	5	6	7	8
Liquid	Apparent Density	Pore Volume 1 cc.	% compressed 12,000 atmospheres	Surface Tension Dynes per Cm.	Viscosity Absolute Units	$\frac{\gamma}{\eta}$	$\frac{\gamma}{\eta}$ x 10 <sup>4</sup>
Mercury	0.865			57.0			
Water	1.843	0.534	20.51	72.8	0.0101	7200	14
Propyl Alcohol	1.960	0.559	22.93	23.7	0.0223	1062	76
Chloroform	1.992	0.566		27.13	0.0057	4760	45
Benzene	2.008	0.568		28.88	0.0064	4510	54
p-Xylene	2.018	0.571		28.33	0.0064	4430	81
Petroleum Ether	2.042	0.579					
Carbon disulfide	2.057	0.580	25.75	31.38	0.0037	8480	34
Acetone	2.112	0.590	27.0	23.50	0.0033	7120	44
Ether	2.120	0.592	30.0	17.1	0.0024	7125	39
Pentane	2.129	0.593	More than Ether	About 15	0.0024	6200	65

Table 2 and 2-a shows the pore volumes for carbon and silica gel recalculated on a basis of density change. Using a density of 2.26 for the true density of the charcoal for this was the value found by Howard and Hulett<sup>3</sup> using helium as a non-polar indifferent medium and checks very closely with their value determined for graphite. This density is also verified by the fact that the xray analysis made by Debye and Scherrer<sup>6</sup> shows no difference between graphite and charcoal.

In recalculating it should be pointed out that the pore volume of silica gel, a density of 2.651<sup>(7)</sup>, has been used as the true density for the gel. 2.651 is the density of quartz and is based on the work of Berle and Urban<sup>4</sup> using ether as a liquid. They obtained a value of 2.625 for a gel that had been dehydrated with hydrochloric acid and a value of 2.685 for quartz. This same gel when activated at 3000 gave an apparent density with ether of 2.390 at 20°. This is in agreement with our value determined with ether.

The value 2.651 may be too high, but in calculating the degree to which the various liquids must be compressed to give the apparent density measured, we are using the limiting value, for 2.651 is the maximum density of quartz and will give the maximum pore value for 1 cc. of gel. Thus in calculating the volume change in the various liquids, we are determining the minimum possible.

The following values are also tabulated in tables 2 and 2-a: Normal density of liquid at 25°, grams of



liquid adsorbed per cc. of system, grams liquid adsorbed per gram gel or carbon, density of adsorbed liquid, compression of 1 cc. of liquid, volume of liquid adsorbed per cc. of system, available data per cent compressibility of liquids at 8000 atmospheres, and pressure necessary to cause compression. The pressure calculations are only approximations, as no exact data exists for the higher pressures.

Table 2

SILICA GEL VOL GEL 1 CC SYSTEM .4844 CC PORE VOLUME 1 CC SYSTEM .5156 CC

Liquid	Density of Liquid 25°	Grams adsorbed per cc. system	Grams Liq. adsorbed per gram SiO <sub>2</sub>	Density of liquid adsorbed	1 cc. compressed to	Liq. adsorbed per cc. of system	Vol. of pressed at 8000 At.	Pressure At.
Mercury	13.5340							
Carbon-tetrachloride	1.5913	0.8637	0.6726	1.6751	0.9500	0.5427		
Carbon-disulfide	1.2596	0.8831	0.6877	1.7127	0.7354	0.7011	22.16	10,470
Benzene	0.8739	0.9010	0.7017	1.7474	0.5001	1.0310		
Nitrobenzene	1.1983	0.9083	0.7073	1.7616	0.6820	0.7560		
Isopropyl-Alcohol	0.7810	0.9208	0.7171	1.7859	0.4373	1.1790		
Chloroform	1.4800	0.9252	0.7205	1.7944	0.8247	0.6252		
Petroleum ether	0.6293	0.9381	0.7306	1.8194	0.3459	1.4906		
Water	0.9971	0.9414	0.7331	1.8258	0.5461	0.9441	17.64	20,550
Pentane	0.6219	0.9661	0.7524	1.8737	0.3319	1.5534	22.92	20,975
Ethyl-Alcohol	0.7851	1.0167	0.7918	1.9719	0.3981	1.2951		
Acetone	0.7844	1.0390	0.8091	2.0151	0.3893	1.3244	23.87	12,580
Ether	0.7077	1.0918	0.8502	2.1175	0.3342	1.5428	26.68	19,980
Water+			.7694					
No Temp. given								

+ Nutting  
1 international critical tables

10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000

Table 2-a

Liquid	GAS MASK CHARCOAL VOL 1 CC SYSTEM		.3827 cc PORE VOLUME 1 CC SYSTEM		.6173 cc			
	Density of Liq. 250	Grams adsorbed per cc.	Grams Liq. adsorbed per gram charcoal	Density of Liquid	1 cc. of adsorbed Liq. compressed to	Vol of Liq. adsorbed per cc. system	% Com-pressed at 8000 atmos.	Pressure Atmospheres
Mercury	13.5340							
Water	0.9971	0.978	1.131	1.584	0.629	0.981	17.64	16,850
Propyl-Alcohol	0.8001	1.095	1.266	1.773	0.451	1.368	20.58	17,010
Chloroform	1.4800	1.127	1.303	1.825	0.811	0.761		
Benzene	0.8739	1.143	1.321	1.851	0.472	1.308		
p-Xylene	0.8600	1.153	1.333	1.868	0.460	1.341		
Petroleum Ether	0.6293	1.177	1.361	1.907	0.321	1.923		
Carbon-disulfide	1.2596	1.192	1.378	1.931	0.652	0.947	22.16	16,300
Ether	0.7077	1.255	1.451	2.033	0.348	1.774	26.68	19,600
Acetone	0.7844	1.247	1.442	2.020	0.388	1.591	23.87	20,500
Pentane	0.6219	1.264	1.461	2.048	0.304	2.031		

1 International Critical Tables

.....

.....

.....

.....

.....

.....

.....

.....

.

.

.

.

.

.

.

.

.

.

.

.

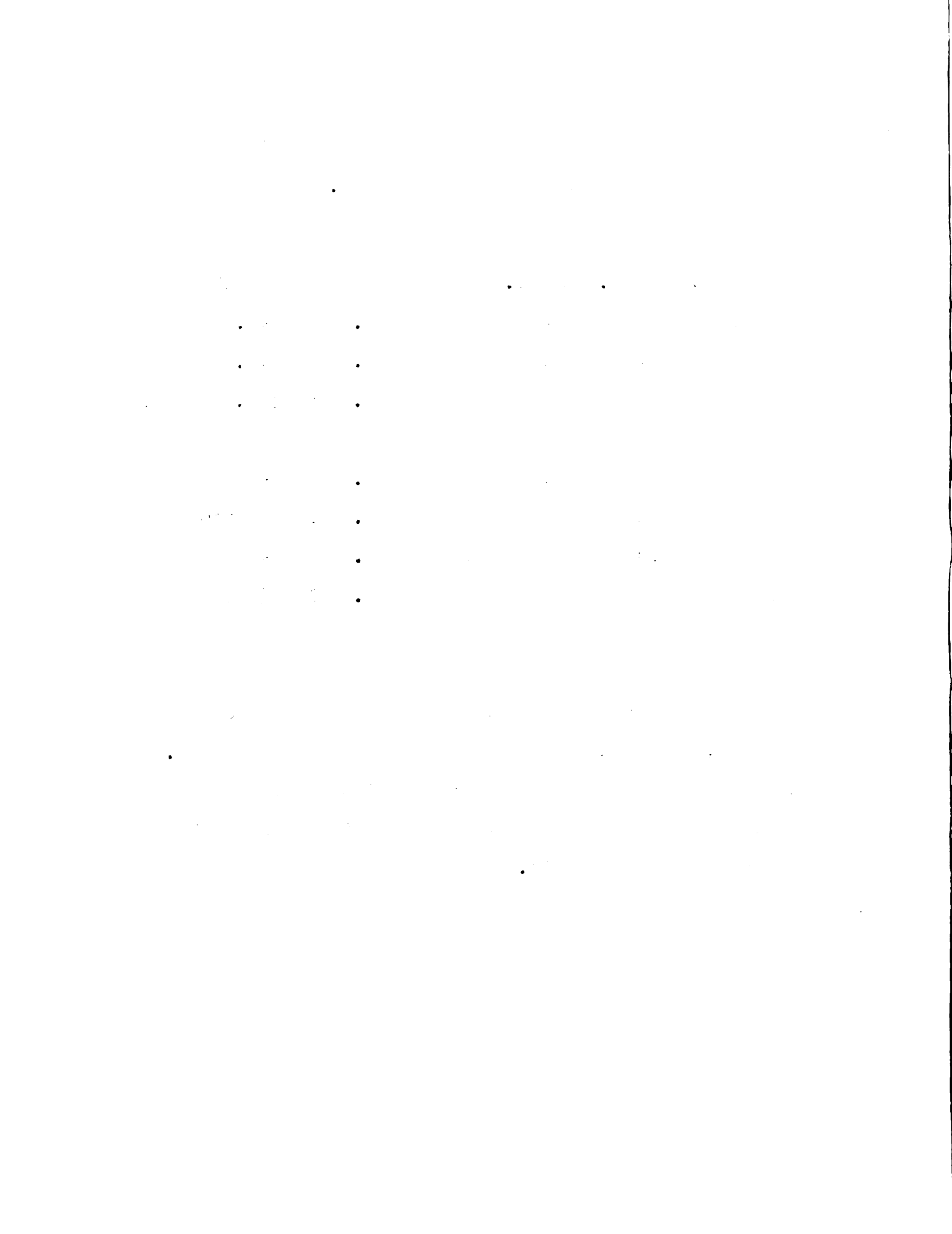


Table 3 is a tabulation of data in regard to change in apparent density with time.

Table 3

Substance	Run No.	Tube No.	Time	Density	Deviation
Water	8	3	5 days	2.2267	+ .0020
Water	10	III	20 "	2.2263	+ .0016
Mean 5 determinations (1-6) hrs				2.2247	$\pm$ .0040
Av deviation of 5 determinations					
Alcohol	11	7	19	2.2935	- 0136
Alcohol	11	8	19	2.2831	- 0240
Alcohol	11	9	41	2.3371	+ 0300
Mean 4 determinations (1-6) hrs				2.3071	$\pm$ 0072
Av deviation of 4 determinations					

Water shows no increase over a period of 5 to 20 days, and alcohol no increase at the end of 19 days. The tube which run 41 days does show an increase, but this being an isolated case and not checked on definite conclusions can be made in regard to it.



## Conclusions

The apparent density of silica gel was determined in thirteen liquids. There seems to be no correlation between the densities in this series and the corresponding apparent densities determined with the same liquids in charcoal.

Evacuated silica gel treated with a liquid reaches equilibrium conditions with it in a few hours.



## Bibliography

1. Jour. Amer. Chem. Soc., 43, 1787 (1921)
2. Jour. Amer. Chem. Soc., 42, 391 (1920)
3. Jour. Phys. Chem., 28, 1083 (1924)
4. Z. Agnew Chemie 36, 57-60 (1923)
5. J. Phys. Chem. 31, 531-534 (1927)
6. Physik Z. 18, 291 (1917)
7. International Critical Table

MICHIGAN STATE LIBRARIES



3 1293 02244 8181