

CCXC.—*The Sorption of Saturated Vapours by Charcoal.*

By JOHN DRIVER and JAMES BRIERLEY FIRTH.

IN a previous paper (T., 1921, 119, 1126), the authors showed that the sorption of alcohol by animal charcoal, when it is exposed to the saturated vapour, is about five times as great as the sorption of water for a given specimen of animal charcoal. Further, it was shown that in the case of mixtures of alcohol and water the alcohol is preferentially sorbed.

\* Carried out at Bristol University through the kind permission of Professor Francis Francis and Professor J. W. McBain.

In the present communication, the experiments have been extended to include other liquids and charcoals. The object of the first series of experiments was to determine the sorption of different liquids by a given specimen of animal charcoal. The second series had for its primary object the investigation of the sorption of certain liquids by different charcoals. A third series of experiments was carried out to determine the influence of heat on the activity of charcoal relative to the sorption of liquids.

### EXPERIMENTAL.

#### (1) *Sorption of Liquids by Animal Charcoal.*

The animal charcoal employed was a portion of the purified sample used in the previous experiments with alcohol and water (*loc. cit.*). The liquids were carefully dried and distilled several times before use; the first and the last runnings were rejected. The densities of the respective liquids at 25° ( $d_{25}^{25}$ ) were as follow :

Methyl benzoate .....	1.0773	Ethyl propionate .....	0.8877
Carbon tetrachloride .....	1.5730	Ethyl ether .....	0.7100
Chloroform .....	1.4761	Carbon disulphide .....	1.2603
Benzene .....	0.8732	Toluene .....	0.8639

The apparatus and the experimental procedure were exactly as described in the previous communication (*loc. cit.*). The results are given in the following table, where  $m$  is the weight of charcoal used and  $x$  the c.c. of liquid sorbed.

TABLE I.

Methyl benzoate. $m = 0.7350$ gram.			Ethyl propionate. $m = 0.7882$ gram.		
Time (days).	$x$ .	$x/m$ .	Time.	$x$ .	$x/m$ .
1	0.00474	0.006449	4 hours	0.007436	0.009436
2	0.00993	0.01351	2 days	0.02952	0.03745
3	0.01328	0.01807	5 "	0.06355	0.08063
6	0.02106	0.02865	9 "	0.08631	0.1070
8	0.02423	0.03296	11 "	0.10276	0.1303
13	0.03350	0.04422	20 "	0.15549	0.1972
16	0.03815	0.05590	26 "	0.18952	0.2405
20	0.05261	0.07158	80 "	0.37663	0.4775
29	0.06542	0.08900	90 "	0.39420	0.5001
35	0.08500	0.1156	110 "	0.4253	0.5396
108	0.29166	0.3968	131 "	0.4502	0.5712
134	0.33082	0.4397	150 "	0.4823	0.6119
141	0.34802	0.4735	160 "	0.4825	0.6120
145	0.3511	0.4776	165 "	0.4824	0.6120
160	0.3582	0.4873			
180	0.3961	0.5434			
200	0.4037	0.5493			
205	0.4038	0.5494			

TABLE I. (continued).

Chloroform.			Benzene.		
$m = 1.0876$ grams.			$m = 0.9284$ gram.		
Time.	$x$ .	$x/m$ .	Time (days).	$x$ .	$x/m$ .
10 mins.	0.2014	0.1852	1	0.0976	0.1052
20 „	0.2298	0.2113	2	0.1636	0.1762
1 hour	0.3560	0.3273	4	0.2312	0.2491
2 hours	0.4338	0.3988	6	0.2766	0.2980
3 „	0.4841	0.4410	8	0.3215	0.3416
1 day	0.6482	0.5961	12	0.3522	0.3793
4 days	0.6722	0.6180	15	0.3731	0.4019
6 „	0.6821	0.6272	20	0.3975	0.4282
10 „	0.6977	0.6413	25	0.4198	0.4522
14 „	0.7103	0.6531	35	0.4201	0.4525
16 „	0.7103	0.6531	65	0.4202	0.4526

  

Ethyl ether.			Toluene.		
$m = 1.1245$ grams.			$m = 1.0018$ grams.		
Time.	$x$ .	$x/m$ .	Time (days).	$x$ .	$x/m$ .
5 mins.	0.3132	0.2785	1	0.0813	0.08035
10 „	0.4214	0.3748	2	0.1153	0.1140
15 „	0.4936	0.4389	3	0.1502	0.1485
30 „	0.5163	0.4592	4	0.1823	0.1802
1 hour	0.5281	0.4697	6	0.2536	0.2506
2 hours	0.5192	0.4618	8	0.2611	0.2583
14 „	0.5104	0.4539	10	0.2823	0.2790
24 „	0.5003	0.4450	14	0.3238	0.3200
48 „	0.5000	0.4447	18	0.3571	0.3530
72 „	0.4998	0.4446	25	0.4010	0.3963
96 „	0.4999	0.4446	30	0.4112	0.4063
			36	0.4220	0.4171
			48	0.4221	0.4172

  

Carbon tetrachloride.			Carbon disulphide.		
$m = 0.6452$ gram.			$m = 0.6491$ gram.		
Time.	$x$ .	$x/m$ .	Time.	$x$ .	$x/m$ .
4½ hours	0.09687	0.1502	5 mins.	0.30309	0.4667
21 „	0.30151	0.4673	20 „	0.48944	0.7534
100 „	0.42245	0.6548	160 „	0.52325	0.8061
124 „	0.43359	0.6720	25 hours	0.45992	0.7086
61 „	0.43358	0.6720	72 „	0.44373	0.6836
			144 „	0.44373	0.6836

## (2) Sorption of Liquids by Various Charcoals.

A second series of experiments was carried out in which different charcoals were employed. The charcoals were, lampblack, blood charcoal, sugar charcoal, cocoa-nut charcoal from the shell, cocoa-nut charcoal from the fruit. The cocoa-nut charcoal from the white tissue and from the shell were prepared by carbonisation at as low a temperature as possible. The blood charcoal gave initially 9.31 per cent. of ash, which diminished to 4.21 per cent. after repeated digestion with concentrated hydrochloric acid and

boiling for eight hours with distilled water. The cocoa-nut charcoal from fruit as prepared gave 21.30 per cent. of ash, and that from shell 1.21 per cent.; after purification as above, the ash was 3.98 and 0.371 per cent., respectively. The lampblack and the sugar charcoal, after purification, contained less than 0.1 per cent. of ash. In the following table the time required for equilibrium and the value of  $x/m$  at equilibrium are given.

TABLE II.

Charcoal.	Water.		Chloroform.		Benzene.		Alcohol.	
	Time in days.	$x/m$ .	Time in days.	$x/m$ .	Time in days.	$x/m$ .	Time in days.	$x/m$ .
Lampblack .....	33	0.3842	19	0.9361	22	0.6992	23	0.8751
Blood charcoal .....	42	0.2649	23	0.8362	23	0.6410	28	0.7436
Sugar charcoal .....	51	0.1214	31	0.4212	31	0.3851	28	0.4016
Cocoa-nut charcoal from shell .....	53	0.0513	60	0.2235	54	0.1714	38	0.1936
Cocoa-nut charcoal from fruit .....	54	0.0936	47	0.3961	42	0.2107	41	0.4104

### (3) *The Influence of Heat on the Activity of the Charcoal.*

It has previously been shown by one of us (Firth, T., 1921, 119, 927) that the activity and the sorptive capacity of the charcoal, with regard to the sorption of gases, are greatly influenced by its previous heat treatment. A similar series of experiments has been carried out with liquids. The charcoals were heated in a vacuum at different temperatures for periods varying from six to forty-eight hours, the temperature being approximately determined by means of a pyrometer. The charcoal was allowed to cool in the vacuum and transferred as quickly as possible to the sorption apparatus. The results obtained are given in Table III. The two liquids used were chloroform and benzene, and the results are given in columns (a) and (b), respectively, in the table.

### *Discussion of Results.*

The results in Table I show that the rate of sorption varies considerably with the different liquids, equilibrium being attained most rapidly in the cases of ether and carbon disulphide and exceptionally slowly with methyl benzoate and ethyl propionate.

The results given in Table II show that for a given liquid the volume sorbed for 1 gram of charcoal varies over a very wide range with the various charcoals used. In the case of lampblack, which was the most efficient charcoal used, the value varies from 0.3842 c.c. in the case of water to 0.9361 c.c. in the case of chloroform; with cocoa-nut shell charcoal, the values are 0.0513 c.c. and 0.2235 c.c., respectively. Again, the time required for equilibrium to be

TABLE III.

		$a = \text{Chloroform.}$				$b = \text{Benzene.}$				Charcoal heated to 1000—1100°.			
		Charcoal heated to 600°.				Charcoal heated to 900°.				Charcoal heated to 1000—1100°.			
	Period of heating in hours.	Time in days for equilibrium.		$x/m.$		Time in days for equilibrium.		$x/m.$		Time in days for equilibrium.		$x/m.$	
		(a).	(b).	(a).	(b).	(a).	(b).	(a).	(b).	(a).	(b).	(a).	(b).
Animal charcoal	6	16	24	0.6672	0.4530	14	20	0.8972	0.6897	17	21	0.8962	0.6904
	12	13	20	0.7211	0.5371	11	16	0.9354	0.7138	14	17	0.8901	0.6851
	24	12	17	0.8036	0.6382	11	14	0.9698	0.7610	14	15	0.8720	0.6621
	48	11	16	0.9012	0.7019	9	13	0.9863	0.7714	13	14	0.7963	0.6010
Sugar charcoal	6	28	29	0.4310	0.3921	22	24	0.5492	0.5146	22	23	0.5938	0.4936
	12	21	24	0.4721	0.4454	17	21	0.5998	0.5297	18	22	0.5792	0.4798
	24	18	20	0.5639	0.4962	15	16	0.6105	0.5396	17	20	0.5801	0.4784
	48	18	19	0.6031	0.5367	14	14	0.6263	0.5437	17	21	0.5020	0.4692
Lamp-black	6	19	22	0.9299	0.7101	15	19	1.0436	0.8369	14	20	0.9853	0.8098
	12	15	19	1.1042	0.7729	12	15	1.1984	0.8615	12	16	0.9965	0.8087
	24	11	17	1.2136	0.8314	10	10	1.2513	0.8801	11	12	0.9402	0.7823
	48	10	13	1.2542	0.8763	9	9	1.2602	0.8903	10	11	0.8710	0.7516

attained is much less with lampblack than with cocoa-nut shell charcoal. From the results given in Table III it is again apparent that not only the activity but also the sorptive capacity is materially affected by heat treatment. In the cases given, heating at  $900^{\circ}$  for forty-eight hours results in an increased sorption of approximately 100 per cent. When the charcoals are heated rapidly to temperatures above  $1000^{\circ}$ , their sorptive capacities show a diminution; this, however, cannot be regarded as a diminution in the activity of the charcoal as a whole, but is the result of the conversion of a portion of the charcoal into a dense and more compact form of low sorptive power, and also possibly to the formation of a more stable crystalline phase. Hence the quantity of really active charcoal is less than the total charcoal, the actual amount diminishing with increase of period of heating (compare Firth, T., 1921, **119**, 929).

The results cannot be considered to support the view of Gurvitsch (*J. Russ. Phys. Chem. Soc.*, 1915, **47**, 805) that the volumes of liquid adsorbed vary over a relatively small range from 0.61 to 0.684 c.c. per gram of sorbing substance. Yet it would appear from Table I that under certain conditions a number of liquids may fall within this range; on the other hand, many fall outside it. Again, the results show that the sorptive capacity of a given charcoal for a given liquid can be varied over a wide range; hence any particular result falling within the range given by Gurvitsch must be regarded as a coincidence. It has been shown that, for the several charcoals used, the sorptive capacity for a given liquid varies considerably; which is in further disagreement with the general conclusion of Gurvitsch.

THE CHEMICAL DEPARTMENT,  
UNIVERSITY COLLEGE, NOTTINGHAM.

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