3. It has been shown that the adsorption of nitrogen and carbon dioxide by charcoal may be considered to be in a condensed layer one molecule deep.

4. Measurements of the isothermal adsorption of water vapor by charcoal at 25° show that water is not *ad*sorbed by charcoal but is held by capillary action, *i. e.*, is *ab*sorbed.

5. Using Anderson's formula connecting the radius of a capillary with vapor pressure, the mean diameters of the capillaries of the 4 charcoals used have been calculated and have been found to vary between 2.8×10^{-7} cm. and 9.2×10^{-7} cm. The maximum diameter in any of the charcoals was determined to be 1.3×10^{-6} cm.

6. By means of this same formula and the isothermals for water, the surfaces of the various charcoals were found to vary from 160 square meters to 436 square meters per gram of charcoal.

7. It was pointed out that this variation in surface was not always accompanied by a corresponding variation in adsorptive capacity. This makes the concept of "elementary spaces" as postulated by Langmuir necessary.

8. No relation between the service time of the different charcoals with the volume of the capillaries was found. The same was true for the saturation point and the retentivity of these charcoals. This lack of relation must indicate that other indeterminate factors must influence largely the minute service of a charcoal; *i. e.*, the 2 phenomena, adsorption and capillary action are insufficient in themselves to explain this test.

PRINCETON, N. J.

[CONTRIBUTION FROM THE LABORATORY OF PHYSICAL CHEMISTRY, PRINCETON UNIVERSITY.]

STUDIES IN THE ADSORPTION BY CHARCOAL.

II. RELATION OF OXYGEN TO CHARCOAL.

BY H. H. LOWRY AND G. A. HULETT.

Received March 29, 1920.

De Saussure,[1] in one of the first quantitative measurements of adsorption by charcoal, was unable to obtain results for oxygen because it alone of the gases would not apparently come to equilibrium even after a year. This anomalous behavior in the adsorption of oxygen by charcoal has been largely overlooked by recent investigators though previously recognized and recorded by R. Angus Smith,[2] who found that the adsorption of oxygen continued for at least a month, though this was not true for hydrogen, nitrogen or carbon dioxide; and that, when it was sought to remove the oxygen by heat, carbon dioxide was given off in place of

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[1] De Saussure, *Gilb. Ann.*, 47, 113 (1814).

[2] R. A. Smith, *Proc. Roy. Soc.*, 12, 424 (1863).

oxygen, by H. Kayser,[1] who found that the adsorption of oxygen had not reached an end after two weeks; and by J. Böhm,[2] who found that nitrogen absorbed by charcoal could be completely removed but that oxygen could be only partly removed "even by boiling water."

However, in the exhaustive work on adsorption by Dr. Ida F. Homfray,[3] as in that of Baerwald[4] and in that of Lemon,[5] no such peculiarities in the behavior of oxygen were noticed. Dr. Homfray obtained equilibrium with the various gases in from a few minutes to $^1/_2$ hour, depending on the temperature, and so apparently missed this peculiar effect first recorded by De Saussure. These later investigators also were not concerned with the recovery of the adsorbed gases as such, so they did not observe the second peculiarity mentioned by Smith, *i. e.*, the fact that the oxygen may be recovered only partly as oxygen, the rest being recovered only as oxides of carbon.

In our work on the adsorptive power of the war charcoals we noticed this singular difficulty of obtaining equilibrium with oxygen. Furthermore, in attempting to determine the moisture and gas content of these charcoals,[6] it was noticed that gases continued to be given off to a vacuum as the temperature was raised. Up to 900°, these gases consisted almost entirely of carbon dioxide and carbon monoxide, the first predominating at the lower temperatures and the latter at the higher. At about 1000°, carbon dioxide and monoxide practically ceased to be obtained. Above 1000° hydrogen began to be more noticeable and to come off in increasingly large quantities as the temperature was raised. The hydrogen was presumably from hydrocarbons undecomposed in the original preparation of the charcoals.

When a charcoal has been thoroughly "outgassed" at 900° to 1000° and allowed to cool to room temperature in a vacuum and gases admitted, it was found possible to recover completely such gases as hydrogen, nitrogen, and carbon monoxide at room temperature, though the rate at which they could be collected in a Töpler pump was increased by raising the temperature; 90% of the carbon dioxide could be recovered, and smaller percentage of the water, at room temperature, but both could be quantitatively obtained at 184° (aniline b. p.) as rapidly as possible to collect them with a Töpler pump for the carbon dioxide and with a condenser cooled with solid carbon dioxide for the water.

However, when oxygen was admitted and allowed approximately to come to equilibrium, only about half was recovered by evacuating at

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[1] H. Kayser, *Wied. Ann.*, 12, 526 (1881).

[2] J. Böhm, *Bot. Z.*, 1883, 32–34.

[3] F. Homfray, *Z. physik. Chem.*, 74, 129 (1910).

[4] Baerwald, *Ann. Physik*, 23, 90 (1907).

[5] Lemon, *Phy. Rev.*, [2] 14, 281, 394 (1919).

[6] C. W. S. Reports, Sept.–Dec., 1918.

room temperature and only traces on increasing the temperature to 184°, though on again cooling to room temperature and again admitting oxygen, this second lot was readily recovered. Therefore attempts were made to recover completely this oxygen, which had apparently disappeared, by increasing the temperature still further, and soon carbon dioxide and monoxide began to appear, but not until a temperature of 900° to 1000° was again reached was all the oxygen recovered and then *not as oxygen* but as these *oxides of carbon.* We have interpreted this to indicate that there were here 2 phenomena, adsorption and "fixation" or "combination" of the oxygen with the charcoal. The adsorbed oxygen was regarded as that which was recoverable by evacuating at room temperature, and the "fixed" oxygen that which was recovered only as the oxides of carbon at higher temperatures.

These facts led us to a more thorough investigation of this fixation of oxygen by charcoal, both as to the length of time necessary to reach saturation and also as to the amounts of oxygen which could be held in this way by the charcoal. For this purpose we used 3 samples of war charcoal described in the preceding paper as A909, English, and German. Their moisture and adsorbed gas contents were known, and the samples were kept in carefully stoppered bottles.

Experimental.

A. Determination of Equilibrium of Charcoal and Oxygen at 250 and 760 mm.—For this purpose, 3 bulbs of about 25 cc. capacity each were filled with the above named charcoals and each was sealed to a line which led either to a Töpler pump or to a buret containing pure electrolytic oxygen. Each bulb was separated individually from the line by a one-way stopcock, and during the measurements was kept immersed in a thermostat at 25° ± 0.1°. As a preliminary treatment, the samples were thoroughly freed from adsorbed gases by outgassing at 184°, leaving in them, however, the fixed oxygen they originally contained. When the bulbs had been cooled in the thermostat, oxygen was admitted at 760 mm. by a constant pressure arrangement. From the temperature of the buret, the amount of oxygen admitted to the bulb was reduced directly to N. T. P. After the first correction for the dead space in the bulb, the amount taken up each time was divided by the weight of the moisture and gas-free sample, reducing the results to cc. of oxygen per g. of sample.

Fresh oxygen was admitted from time to time and the amounts recorded. At the end of the first 100 hours, when the amounts of oxygen taken up at successive intervals were becoming less, each sample was evacuated thoroughly at 25°. In no case was the amount of oxygen originally admitted recovered. In some cases traces of carbon dioxide and carbon monoxide were found in the gases collected. Since the samples were largely oxygen, it was thought possible that the small amounts of carbon monoxide were from the alkaline pyrogallate used to absorb the oxygen. Oxygen was then admitted and its course followed. This was repeated until equilibrium was reached. This was most quickly reached by the English charcoal at the end of 1600 hours or 66 days, while the German charcoal took just about twice this length of time. The data is presented in the form of curves as shown in Figs. 1, 2 and 3.

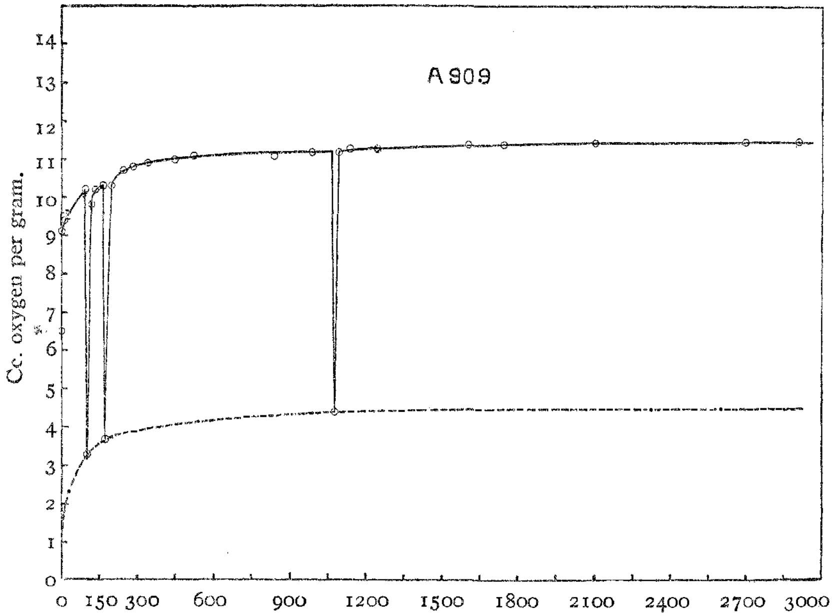

Fig. 1.—Adsorption and fixation of oxygen at 25° and 760 mm. by A909 charcoal.

It will be noticed that we really have 2 curves from each series of measurements. The upper curve represents in each case the total amount of oxygen taken up at 25° and 760 mm., while the lower dotted curve represents that which cannot be obtained by evacuation at 25°. It is also apparent that the slopes of the 2 curves are very similar. From our previous experience, we are led to the conclusion that the lower curve represents the rate of saturation of the charcoal by what we have called "fixed" oxygen, and that the upper curve is the sum of 2 effects, true adsorption and fixation. Since this is the case, it can readily be seen that the long time necessary to reach equilibrium is due to this fixation and that the true adsorption of oxygen by charcoal occurs as rapidly as for other gases.

These measurements have, therefore, shown not only that the equilibrium between oxygen and charcoal is attained only after months of

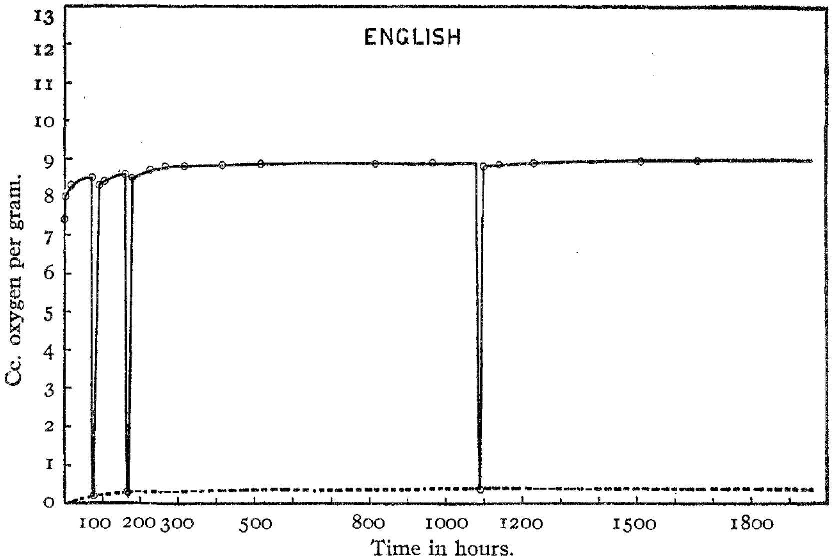

Fig. 2.—Adsorption and fixation of oxygen at 25° and 700 mm. by English charcoal.

contact, but also that the cause of this is the presence of 2 effects, true adsorption and "fixation."

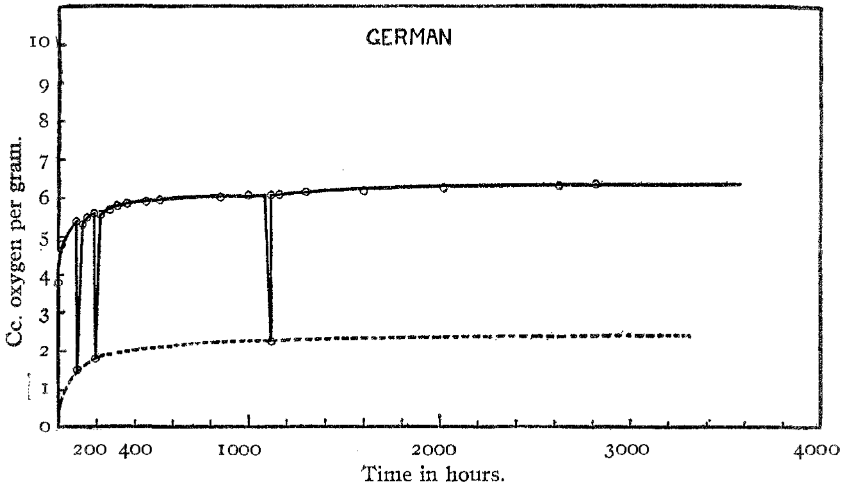

Fig. 3.—Adsorption and fixation of oxygen at 25° and 760 mm. by German charcoal.

B. Determination of Total "Fixed" Oxygen.—In order to obtain all the fixed oxygen from charcoal, it seemed necessary only to heat the sample in a vacuum, after first removing all the adsorbed gases and vapors, and to collect and analyze the evolved gases. The carbon dioxide and monoxide are calculated to cc. of oxygen, N. T. P., per g. of charcoal. The procedure first adopted was as follows: the charcoal was heated in a fused quartz tube in an aniline bath and thoroughly outgassed, then in a Nichrome resistance furnace to 1050°. Gases continued to be slowly given off for several hours at this temperature and still contained small percentages of the oxides of carbon. Since even at this temperature the charcoal acted on the fused quartz, we suspected that we were not getting the true oxygen content of the charcoal. We observed that the inner surface of the tube was markedly etched and suspected the reduction of the silica to a sub-oxide so that some of the oxides of carbon might well have been from this reduction. In view of this situation, it seemed necessary to devise a method which would obviate these difficulties and allow us to go to still higher temperatures.

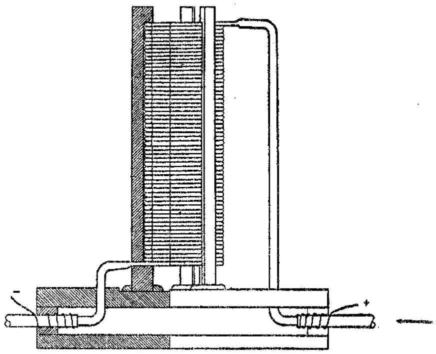

Fig. 4.

The development of the high frequency induction furnace by E. F. Northrup[1] seemed to offer a means of solving our difficulties. The compactness of the apparatus afforded by this method of heating was recognized to be one of its many advantages over other forms of electrical heating. Using this method of heating, we have found it possible to heat charcoal in a platinum cup supported in a quartz vacuum tube, keeping the quartz at a low temperature even when the cup and charcoal were at 1400°. In this way the possibility of a leak through hot quartz and reduction of the silica to a sub-oxide were prevented.

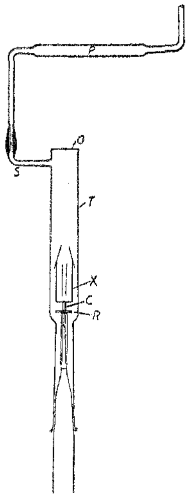

Fig. 5.

The apparatus designed for this experimental work is shown in Fig. 5. It consists primarily of a fused quartz tube, T, 25 cm. long and 2.5 cm. outside diameter, with a side tube, S, connected to a glass tube by a de Khotinsky joint leading to a Töpler pump through a phosphorus pentoxide tube, P. The upper end of the quartz tube was closed by an optically clear piece of fused quartz; and the lower end by a stopper of Pyrex glass with a ground joint, which also served indirectly as a support for a platinum-rhodium crucible, X. The crucible was 3.5 cm. long and 1.5 cm. in diameter and had a platinum pin riveted to the bottom. This pin fitted in a fine porcelain tube, C, which in turn was held in the Pyrex

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[1] Northrup, *Trans. Am. Electrochem. Soc.*, 35, 69 (1919).

support. In order to prevent radiation downwards, a porcelain disk, R, was fastened to the small porcelain tube. The crucible served as the resistor and was rapidly heated by the induced currents from the primary. When the charcoal was heated it also became a conductor and so could be directly heated by the induced currents. The primary was a coil of flat, copper tubing (Fig. 4), the inside diameter of which was 3.6 cm. and the height 15 cm. The coil was kept cool by passing a stream of cold water through the tubing, and the proximity of this coil to the walls of the quartz vacuum tube kept the quartz at a low temperature in spite of the radiation from the platinum crucible.

For measuring the temperature of the charcoal, a Leeds and Northrup optical pyrometer of the Morse type was used. This was calibrated against a standard thermocouple between 800° and 1400°. Since the temperatures were to be measured optically, black body conditions had to be obtained. This was done, as is shown in the cut, by placing a very thin, platinum truncated cone over the top of the crucible to minimize the radiation from the surface; and then a platinum tube of very thin foil of 0.4 cm. diameter was placed in the center of the sample and focusing was made on the surface of the charcoal at the bottom of this tube.

The procedure in making a determination was as follows: The crucible was filled with a known weight of charcoal and the apparatus assembled as described. The heater shown in Fig. 6, containing naphthalene (b. p. 218°), was placed around the quartz tube and the lower end stoppered and covered with mercury. The naphthalene was then brought to boiling and the vapors allowed to condense to C above the position of the platinum crucible. During the heating the charcoal was continually outgassed by means of the Töpler pump and this gas, being regarded as adsorbed gas, discarded. Then the naphthalene bath was replaced by the primary coil of the induction furnace and the charcoal heated rapidly. All the gas was collected by the Töpler pump and was stored in a large gas buret over mercury and a sample of this analyzed.

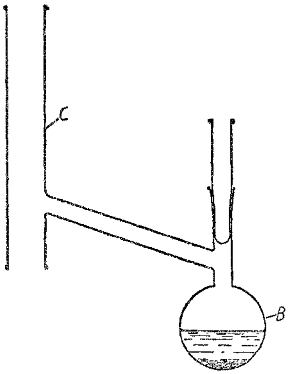

Fig. 6.

A preliminary run was made on the A909 in order to determine at what temperature the oxides of carbon ceased to be obtained. The results of this experiment are shown in Table I.

They show that the amounts of oxygen remaining combined with the charcoal above 1180° are extremely small and could be neglected. It seemed important to see what gases could be obtained at still higher temperatures, however, and so in 2 of the experiments the temperature was raised to 1400°. The gas at these high temperatures was more than 99% hydrogen and was slowly decreasing in amounts obtained as the temperature was raised.

TABLE I.

	Total gas. Cc. per g.	Temp. limits.	Time of heating.	Cc. per g.				Fixed oxygen. Cc. per g.
				CO_2.	CO.	H_2.	CH_4.	
I....	36.42	200–1000°	2 hrs.	4.66	23.40	8.32	0.04	16.36
II....	17.60	1000–1180°	$2^{1}/_{2}$ hrs.	0.08	0.53	16.93	0.06	0.35
III....	4.78	1180–1260°	$1^{1}/_{4}$ hrs.	0.00	0.07	4.76	0.04	0.03

Since the object of this part of the work was to obtain quantitatively the amount of oxygen capable of being fixed by charcoals, after standardization of the method with ordinary A909, the determinations were made on the 3 samples which had been saturated in pure electrolytic oxygen. The results obtained are presented in Table II. In this table are first given the results from 2 successive runs on two samples of A909 in order to get some idea as to the reproducibility of the results. Considering that charcoal is not a pure substance, the agreement is regarded as very good

TABLE II.

	Total gas. Cc. per g. (N. T. P.)	Maximum temp.	Time of heating.	Cc. N. T. P. per g.				Fixed O_2 per g	
				CO_2.	CO.	H_2.	CH_4.	Cc. N. T. P.	Wt. %.
A909 (1)	54.99	1100° ± 50	$2^{1}/_{2}$ hrs.	5.19	22.11	27.57	0.12	16.25	2.32
A909 (2)	58.89	1260°	$5^{3}/_{4}$ hrs.	4.74	24.00	30.01	0.14	16.74	2.39
(O_2 sat.)									
A909	56.90	1226°	3 hrs.	5.76	24.80	26.19	0.15	18.16	2.59
English	43.79	1412°	$2^{1}/_{4}$ hrs.	2.76	18.36	22.56	0.11	11.94	1.71
German	201.00	1412°	$3^{1}/_{4}$ hrs.	9.76	32.92	154.5	3.79	26.25	3.75

The data in this table show that the larger part of the oxygen held by the charcoal had been fixed before the samples had been "soaked" in pure oxygen. A comparison of the amounts of oxygen which is fixed by the different charcoals with the amounts adsorbed is given in Table III, together with the ratio of fixed to adsorbed oxygen. This shows that as much as 6 times the amount of oxygen adsorbed by a charcoal may be held as "fixed" oxygen.

TABLE III.

	Cc. N T. P. oxygen per g. of charcoal.		Ratio of fixed to adsorbed O_2.
	Fixed.	Adsorbed.	
A909........................	18.16	7.2	2.5
English......................	11.94	8.6	1.4
German......................	26.25	4.2	6.3

In Table IV are given the actual observations on a run, in order to give an idea of how an experiment proceeded, after the sample had been thoroughly outgassed at 200°.

TABLE IV.

Sample Used—A909 = 2.948 g.

Time.	Cc. gas.	Temp.	Time.	Cc. gas.	Temp.
2 : 05	0.00	25°	...	....	...
2 : 15	97.4	959	3 : 45	2.5	1190°
2 : 25	19.0	1045	3 : 55	1.7	1226
2 : 35	13.0	1091	4 : 05	1.2	1208
2 : 45	17.0	1160	4 : 15	1.10[a]	1196
2 : 55	10.5	1178	4 : 25	1.06	1211
3 : 05	10.0	1172	4 : 35	0.90	1211
3 : 15	6.0	1181	4 : 45	0.72	1205
3 : 25	4.0	1196	4 : 55	0.61	1211
3 : 35	2.7	1166	5 : 05	0.46	1208

[a] These small volumes were measured in the fall tube of the Töpler pump (*J. Ind. Eng. Chem.*, **12**, 40 (1920)).

At the end of each determination, the walls of the quartz tube held on their inner surface a thin film of a solid varying in color from white to brown, which had vaporized from the charcoal at the high temperatures. A similar observation has been recorded by A. Schuller,[1] who concluded that this was organic matter. On attempting to remove this film, however, the odor of acetylene was noticed. This suggested that a carbide had been formed during the determination and that accordingly some of the oxides of carbon obtained might well have been from reduction of mineral matter contained in the ash. In order to determine what might be the magnitude of this effect on the data obtained, the percentage of ash was determined for each charcoal and the ash analyzed. In the A909 and English charcoals this was mostly alkali carbonates with slight traces of alkaline earths, iron, and alumina. In the German charcoal the ash was principally iron with some alkali carbonates. Table V presents this data and the maximum amount of oxygen which could under any circumstances be attributed to the ash. It is thought, however, that the amount of reduction at these comparatively low temperatures was in all cases much less than these figures would indicate. In any case, as shown in this table, the ash can account for only a small part of the oxygen obtained in the experiments as oxides of carbon.

TABLE V.

	% ash.	Calc. cc. O_2 per g. of charcoal.	Cc. O_2 remaining "fixed" by charcoal.
A909	1.11	3.00	15.16
English	2.04	5.41	6.53
German	1.91	4.35	21.90

Discussion.

Since it has been definitely shown that oxygen can be "fixed" by charcoal, other than by adsorption, it becomes an interesting problem to consider the origin and state of this oxygen. The original material from which

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[1] Schuller, *Wied. Ann.*, **18**, 317 (1883).

all these charcoals were prepared was organic matter and as such contained in the molecular complexes both oxygen and hydrogen. It seemed possible that *both* the oxygen and hydrogen obtained by us were from some of the original material which had not been decomposed in the preparation of the charcoals, but against this view we find the following facts. The temperature of charring this original material was in all cases very close to the temperature, above which no oxides of carbon were obtained and only above which hydrogen and methane were obtained. This would lead us to the conclusion that the hydrogen alone was from the original undecomposed organic material. This conclusion is supported by the fact, which was pointed out in the introduction, that the oxygen obtained as oxides of carbon on heating in a vacuum was reversible while the hydrogen was irreversible. An actual experiment showed that 90% of the oxygen obtained as oxides of carbon above 184° was fixed by the charcoal a second time in 99 hours. On the other hand, in every case hydrogen admitted to a charcoal after outgassing at 1050° and cooling to room temperature could be readily and quantitatively recovered at room temperature.

In view of these facts, we have concluded that this fixed oxygen is held by the charcoal as a surface compound or compounds. These compounds would be, therefore, solid oxides of carbon high in carbon and low in oxygen content, but not necessarily in which the ratio of carbon to oxygen was constant. These oxides must be stable at ordinary temperatures, or at least have a very low rate of decomposition, the decomposition not taking place appreciably until a temperature of about 200° is reached. The data shows that these oxides then break down slowly, giving carbon dioxide and carbon monoxide and presumably leaving a residue of carbon. Although the carbon dioxide predominates at the lower temperatures in the decomposition and carbon monoxide at the higher, no conclusions as to the mechanism of the original decomposition can be made, since carbon dioxide liberated in immediate contact with carbon at the higher temperatures would react immediately with the carbon and be reduced to the monoxide, *i. e.*, there would be a tendency to attain equilibrium between carbon, carbon monoxide and carbon dioxide at any given temperature.

This conception of a solid oxide of carbon, stable at ordinary temperatures, is not new. Brodie[1] isolated 2 oxides of carbon which were amorphous, brown and transparent solids to which he assigned the formulas C_5O_4 and C_4O_3, and indicated that he considered that they belonged to a series of oxides corresponding to the hydrocarbons of the acetylene series. Berthelot[2] showed that these oxides decomposed on heating to 300° in an

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[1] Brodie, *Ann.*, **169**, 270 (1873).

[2] Berthelot, *Bull. soc. chim.*, **26**, 102 (1876).

atmosphere of nitrogen to an oxide still higher in carbon content by loss of equal volumes of carbon dioxide and carbon monoxide and to which he assigned the formula $C_{16}O_6$. Mellitic anhydride, $C_{12}O_9$, has recently been prepared and its properties described in 2 independent investigations.[1] The most recent work on graphitic acid[2] and work done in this laboratory (which has not yet been published) indicates that this is a colloidal oxide of carbon with an empirical formula approaching C_8O.

Furthermore, H. E. Armstrong,[3] in his studies on the combustion of carbon, concluded that the simple oxides, carbon dioxide and carbon monoxide, were obtained only by the breakdown of the more or less completely oxidized carbon complex. The later extensive researches of Rhead and Wheeler[4] on the same subject lead to the conclusion that oxygen combines with a mass of carbon directly to form a "physico-chemical" complex C_xO_y of variable composition, which is decomposed by heat into carbon monoxide and dioxide. These investigators performed some interesting experiments to determine the amount of this solid carbon-oxygen complex present at temperatures from 100° to 900° during the combustion of carbon. Their results indicate that the higher the temperature, the less the amount of the complex present. If we extrapolate their results, it would appear that at room temperature practically no carbon monoxide or dioxide would be formed but only the complex, while above about 1200° very little of the complex would be formed. This agrees entirely with our observations, which, interpreted by means of assuming the formation of this C_xO_y complex, shows that the first stage in the combustion of carbon takes place at ordinary temperatures. Langmuir[5] has shown that a similar complex of carbon and oxygen, presumably an extremely stable solid oxide of carbon, was formed by a highly graphitized filament of very pure carbon. This decomposed only slowly at 1425° but readily at 1925° and seems to have been even more stable than the complex formed by oxygen with amorphous carbon. These facts all indicate that oxygen does combine with carbon to form a complex, C_xO_y, high in carbon and low in oxygen content, which decomposes on heating to give the ordinary oxides of carbon.

We are led further to the conclusion that this complex must be formed on the surface of the charcoal. This would therefore be likely to alter the adsorptive capacity of a charcoal, which would thus depend in part on the amount of this complex on the surface. No conclusive data on this point have been collected, however, since, although it was observed

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[1] Meyer and Steiner, *Ber.*, **46**, 813 (1913); and Jarrad, *J. Chem. Soc.*, **29**, 106 (1913).

[2] Kohlschütter and Haenni, *Z. anorg. Chem.*, **105**, 121 (1919).

[3] Armstrong, *J. Soc. Chem. Ind.*, **24**, 473 (1905).

[4] Rhead and Wheeler, *J. Chem. Soc.*, **101**, 831 (1912); and **103**, 461 (1912).

[5] Langmuir, THIS JOURNAL, *Chem. Soc.*, **27**, 1154 (1915).

that the adsorptive power of the German charcoal with the most fixed oxygen was the lowest and the English charcoal with the least fixed oxygen the highest, the presence of undecomposed hydrocarbons was also greatest in the German and least in the English charcoal. So, since in the preliminary treatment of the charcoals (Part I), most of the fixed oxygen was removed while the hydrocarbon content was not much altered, the differences observed are more likely due to this latter cause.

Conclusions.

1. The anomalous behavior of the adsorption of oxygen by charcoal extending over long periods of time, overlooked by recent investigators, has been confirmed. This is shown to be due to the presence of 2 phenomena, adsorption and surface combination.
2. A method has been developed for heating charcoal in a vacuum out of contact of oxygen-containing materials, as quartz, to high temperatures by use of the Northrup induction furnace. The gases evolved were collected and analyzed.
3. The formation of a carbon-oxygen complex, essentially a stable solid oxide of carbon, has been shown to occur on the surface of charcoal at ordinary temperatures. This complex decomposes on heating to carbon dioxide and carbon monoxide and can thus be considered to be an intermediate step in the combustion of charcoal, which supports the view suggested by Armstrong and supported with experimental evidence by Rhead and Wheeler and by Langmuir.
4. The amounts of oxygen thus combined to the charcoal has been found to vary with 2 samples of charcoal from 1.71% to 3.75% of the *weight* of the charcoal.

PRINCETON, N. J.

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA.]

POLARITY AND IONIZATION FROM THE STANDPOINT OF THE LEWIS THEORY OF VALENCE.

BY WENDELL M. LATIMER AND WORTH H. RODEBUSH.

Received April 26, 1920.

Some years ago Abegg and Bodlander[1] discussed the general facts concerning strong and weak electrolytes, the solubility of salts and the formation of complex ions in solution. They showed that these facts may be coördinated and explained to a surprising extent by attributing to each element or radical, in greater or less degree, a property which they called electro-affinity. This property has been more commonly designated as electropositive or electronegative character, and its relation to position in the periodic table is clearly recognized. It now seems possible to go

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[1] Bodlander, *Z. anorg. Chem.*, **20**, 453 (1899).