is passing, and we need resources with which to carry our investigations into the new fields.

It is true that Priestley, Lavoisier, Liebig, Rumford, all produced classic researches without expensive laboratories or equipments. Yet a careful inventory of the resources and appliances available to some of these scholars will bear a striking similarity to the equipment of some of the present-day laboratories attempting research. Chemical laboratory development has not kept pace with the development of the science itself and the progressive difficulties of the problems to be undertaken. The so-called modern laboratory for research bears a strong resemblance to the arena in an obstacle race. Young men unselfishly offer their service in the fields of research, often at great sacrifices to themselves and others dependent upon them, only to find that they are obliged to waste their time hurdling the obstacles of meagre equipment and inadequate facilities.

Researches are often either entirely abandoned, or limited to a narrow field through lack of simple appliances, or competent mechanical assistance. Other demonstrations give negative or misleading results through improperly constructed apparatus or because there is not a mechanic with a suitable tool equipment available to build needed parts, or to make the necessary rearrangements. Research men are trained in *inefficiency* by being compelled to use makeshift and "junky" apparatus, and also by being compelled to do work which could be done better and at less cost by others.

The laboratory requirements for industrial study are no more exacting, expensive, or difficult to develop than those of mechanical, electrical or metallurgical engineering. The chief difference between chemical engineering laboratories and those of the other engineering subjects seems to be that we chemists have not developed our facilities while other engineers have kept pace with the advancement of their respective industries.

The writer recently visited a number of the leading engineering schools and industrial establishments in Europe for the purpose of observing their equipment and comparing it with that provided for similar work in this country. Mechanical, metallurgical, electrical and chemical engineering laboratories were examined with equal care, in Charlottenburg, Dresden, Munich, Freiberg, Zurich, London, Manchester and other places. Mechanical laboratories were invariably provided with steam engines, compound Corliss engines, turbines, pumps, gas engines, pro-

ducer gas sets, Diesel oil engines, and a long list of standard mechanical engineering appliances, equipped with instruments for observing, measuring and recording data. Metallurgical laboratories contained every facility for making, testing and studying alloys. At Freiburg the government smelters, mines and ore-dressing establishments are used for both study and instruction. Electrical engineering equipment always includes every type and kind of modern machine for generating, measuring and using electricity. But laboratories do not seem to exist where chemical students and investigators may study the applications of physics and chemistry to fundamental industrial operations as other engineers are studying the applications of their fundamentals in mechanical, electrical, and metallurgical fields.

Researches can not be undertaken which involve single and multiple effect distillation, evaporation, filtration, calcination, condensation, absorption, drying, controlled temperature reactions, vacuum and special atmosphere reactions, etc., except on a test tube or beaker scale.

It is the purpose of a large portion of this Society to further the interests of Industrial Chemistry. We are all vitally interested in its aims and purposes. There are many suggestions for ways and means of accomplishing something in this great field.

We might establish scholarships and encourage young men to study chemistry; grant funds to promote special research; accumulate reference libraries; suggest to the teachers courses of training better adapted to produce the class of men needed in Industrial Chemistry; there are many ways in which the support and influence of this Society might profitably be directed.

But there is one field which is richer in the promise of results than all others combined; a field which will yield a more immediate, direct, and tangible return to our own industry, our own profession, and to our own members; and that is in *recognizing the necessity of systematic study of industrial problems and throwing the undivided influence of this Society into the establishment and maintenance of laboratories equipped to answer the eternal questions arising as a result of industrial progress*. Laboratories to solve problems and establish facts, not from the standpoint of fundamental theories and principles involved, which presumably have been established by the test tube and beaker method but to *solve problems from the standpoint of their proposed application*.

ORIGINAL PAPERS.

TRANSFORMATION OF OTHER FORMS OF CARBON INTO GRAPHITE.

By W. C. ARSEM.

Received Oct. 1, 1911.

INTRODUCTION.

The conditions under which "Amorphous carbon" is transformed into graphite have been the subject of much discussion, and many statements have found

their way into the literature which are not supported by experimental evidence. The following theories are commonly held:

1. A high temperature alone will convert "amorphous carbon" into graphite (Moissan).
2. Pure carbon is not converted to graphite by heat alone (Berthelot).
3. Graphite is the result of intermediate formation

and decomposition of carbides, due to the presence of mineral matter as an original constituent, or purposely added (Acheson).

I have collected all available references relating to this problem and have given briefly the evidence in favor of each theory.

Despretz¹ heated several varieties of carbon in an arc. He states that "any carbon which is submitted for a long time to a high temperature becomes proportionately softer. Finally it is transformed into graphite." No physical or chemical tests for graphite are described.

Berthelot² was first to recognize the ambiguity in the use of the term graphite, and proposed the Brodie test as a criterion.

He was not able to convert amorphous carbon to graphite at a *white heat* in hydrogen. A retort carbon rod which had been ignited, thrust into a stream of oxygen, and quenched in water when fully incandescent, was found to have been graphitized on the tip.

WORK OF MOISSAN.³

Moissan heated in the arc furnace different varieties of carbon enclosed in carbon crucibles, and after heating determined their specific gravity and their behavior toward nitric acid and potassium chlorate. He found that the products differed in specific gravity, but in all cases they yielded yellow graphitic acid with the oxidizing mixture. He concluded that heat alone will convert "amorphous carbon" into graphite. His results are given in the following table:

TABLE 1.

Carbon.	Ash after firing. Per cent.	Specific gravity after firing.
Sugar carbon.....	0.11	2.19
Carbon from Al_4C_3	..	2.11
Cryst. graphite from cast iron, 1150°.....	1.30	2.17
Cryst. graphite from cast iron, 1150° high temperature.....	0.17	2.18
Cryst. graphite from cast iron cooled in water.....	1.29	2.16
Graphite from cast iron by silicon.....	0.85	2.20
Graphite from platinum.....	1.10	2.06-2.18

He showed also that graphite separates during the cooling of a saturated solution of carbon in various metals and that graphitic carbon is a product of the decomposition of many carbides, but gives no specific gravity determinations except for Fe and Al.

WORK OF ACHESON.

Acheson noted the formation of graphite by the decomposition of silicon carbide at high temperatures. He also noted that the furnace core of bituminous coal coke in the carborundum furnace became converted, to a considerable extent, into graphite. The following statements, made by Acheson, are to be found in the literature and in patents:

(a) The amount of graphite produced by highly heating pure carbon is insignificant and impracticable, but if the carbon is mixed with considerable mineral matter the yield of graphite is enormously increased. (U. S. Patent, 568,323, Sept. 29, 1896.)

¹ *Compt. rend.*, **29**, 709-24.

² *Ann. chim. phys.*, **19**, series 3, 392.

³ "Le Four Electrique."

(b) A mixture of 97 parts coke, or charcoal, and 3 per cent. iron oxide, can be changed, to a greater or less extent, into graphite by varying the time and temperature of heating. As the iron is insufficient to convert all the carbon to carbide, it is assumed to have a catalytic effect, first forming a carbide which decomposes, yielding graphite and setting free iron, which again forms carbide, and the cycle is repeated. (U. S. Patent, 617,979, Jan. 17, 1899.)

(c) A natural variety of carbon containing mineral matter, such as anthracite coal with 5.783 per cent. ash, gives practically pure graphite with 0.033 per cent. ash. This result is assumed to be due to the intimate admixture of "inherent impurities," it being stated that even with the best artificial mixing and distribution of carbon and mineral matter, the conversion to graphite will be more or less irregular and incomplete. (U. S. Patent 645,285, March 13, 1900.)

(d) Petroleum coke, to which has been added 5 per cent. iron in the form of oxide, is heated to the vaporizing point of iron in a specially constructed electric furnace. The iron vapor is stated to cause conversion of the petroleum coke to graphite. (U. S. Patent 711,031, October 14, 1902.)

(e) Acheson also makes the following statements in an article presented before the Franklin Institute:

1. "Comparatively pure petroleum coke produces practically no graphite.

2. "Impure bituminous coal coke produces large quantities.

3. "The larger the known percentage of impurities in the bituminous coal coke, the greater the amount produced.

4. "Only a part of the core in the carborundum furnace (bituminous coal coke) is converted into graphite, this not being increased even by repeated use of the same grains in successive carborundum furnaces." He concludes: "The amount of graphite produced in the core of the carborundum furnace, and also in graphite articles I have made, is much too great to be accounted for by the theory that it is formed by the dissolution of the fixed carbides formed by the contained impurities, and carbon sufficient to satisfy the chemical formula. The most probable and satisfactory explanation is that a catalytic action occurs—a progressive formation and dissolution of carbides. The temperature being much above the point of volatilization of silica and all other possible impurities, a rapid dissipation of the active agents takes place, and it is completed in this case before the conversion of all the amorphous carbon can occur."

No experimental evidence is given by Acheson to show that pure carbon is not graphitized by simple heating. Direct proof is also lacking to show that a small amount of mineral matter can cause, or facilitate, the conversion of a large amount of carbon to graphite.

The only experiment bearing on this point that I could find described in the literature was in an article by F. A. J. Fitzgerald,² from which I quote as follows:

¹ *J. Frank. Inst.*, **147**, 475, 486.

² *Ibid.*, **154**, 338.

"Two carbon rods, one composed of very pure lampblack carbon, and containing less than 0.2 per cent. ash, the other made of petroleum coke carbon which had been intimately mixed with a certain amount of ferric oxide, were heated side by side in an electric furnace. At the end of the experiment, the rod that had contained the iron was found to be graphitic, could be easily cut with a knife, took a beautiful metallic luster on rubbing, and would mark paper like an ordinary pencil.

"The pure carbon rod showed little change, was dull black in color, nearly as hard as before heating, and would not leave a mark on paper. One end of this carbon rod, however, was clearly graphite, from the fact that it had been exposed to the action of carbide-forming elements. These vapors had even penetrated to a certain depth in the carbon rod, and in so far as this had occurred the rod showed a brilliant graphitic appearance, was soft, etc."

This experiment would seem to be inconclusive, because two different varieties of carbon were employed, one being heated with iron oxide and the other without. It should have been determined whether or not pure petroleum coke is graphitized when heated without admixture with iron oxide.

Borchers¹ claims that a small amount of Al or Al_2O_3 can convert a considerable quantity of amorphous carbon to graphite.

He does not state what kind of amorphous carbon is used or what happens if this carbon be heated without addition of mineral matter, but refers to work by Borchers and Mögenburg ("Graphit aus Amorpher Kohler in Borchers' Institut für Metallhüttenwesen und Elektrometallurgie") which was not available.

Borchers¹ claims priority for the theory that graphite is produced from amorphous carbon by the formation and decomposition of carbides, on the basis of an article in *Zeit. f. Elektrochem.*, 3, 394 (Mar. 20, 1897), from which he quotes:

"Metals which form carbides, alloys, or more or less dissociable compounds, can assist the crystallization of carbon." The article mentioned was a discussion of methods for the production of the diamond, no reference being made to graphite in this connection.

Moreover, Moissan² had previously prepared graphite by crystallization of carbon from solution in metals and by decomposition of many carbides.

Other patents relating to the manufacture of graphite are:

E. G. Acheson, 542,982, July 23, 1895. Purifies carbon by volatilizing impurities in an electric furnace.

H. Y. Castner, 572,472, December 1, 1896. Heats rods of retort carbon or other carbon by current. Product has lower density and greater conductivity.

Herbert H. Wing, 598,549, February 8, 1898. Amorphous carbon converted into graphite by prolonged heating at high temperature. (Ordinary coke mentioned.)

¹ *Elektrometallurgie*, third edition, 564 (1903).

² *Ann. Phys. Chem.*, [7] 8, 466 (1896).

DEFINITION OF GRAPHITE.

Much confusion has arisen from the uncertainty as to the exact significance of the term "graphite." Many different varieties of graphite have been described, and widely differing values for the various physical constants have been published.

Berthelot was the first to adopt the Brodie¹ test as a criterion. He defined graphite as any variety of carbon which yields graphitic oxide when oxidized with nitric acid and potassium chlorate. Moissan seems to have felt the need of a further criterion, as he defined graphite as a variety of carbon, usually crystalline, having a specific gravity about 2.2, which yields graphitic acid when oxidized.

Some of the uncertainty has been removed by the recent work of Le Chatelier and Wologdine.² They showed that a number of natural graphites, when freed from mineral matter and air, had practically the same specific gravity, 2.255, this value being also obtained for a sample of Acheson graphite.

Charpy³ considers the density a much better criterion than the Brodie test.

My own work indicates that any variety of carbon, after heating to 3000°, will give a green or yellow oxidation product by the Brodie test, although many samples have a relatively low specific gravity and lack the physical characteristics of graphite. There is no proof that the yellow oxidation product has the same composition in every case. It may be that a variety of structurally related oxidation-products may exist.

It was found, however, on examination of a large number of carbon samples, that the graphitic properties become more pronounced as the specific gravity approaches 2.26. We have then either a series of carbons of varying molecular complexity, the end member being graphite, or a series of mixtures of graphite with other forms of carbon. In either case it seems to me that there can be little objection to the following definition:

Graphite is that allotropic form of carbon having a specific gravity of 2.25 to 2.26.

Those varieties of carbon which have some of the physical properties of graphite, such as color, softness, and streak, but a lower specific gravity, may perhaps be regarded as impure graphites; that is to say, mixtures of graphite with other forms of carbon.

PURPOSE OF THE INVESTIGATION.

The points at issue are the following:

1. Can a pure form of carbon be transformed into graphite by simply heating to a high temperature?
2. If this is not the case, is it possible to cause this transformation to occur by heating the carbon, well mixed with a quantity of mineral matter, insufficient to form carbides from all the carbon present?

There are two ways of attacking the problem:

(a) To determine the effect of heating various forms of pure carbon alone and with small amounts of added mineral matter.

¹ B. C. Brodie, *Liebig's Ann.*, 114, 57, 1860.

² *Compt. rend.*, 146, 49 (1908).

³ *Ibid.*, 148, 920 (1909).

(b) To remove the mineral matter from certain varieties of impure carbon, which ordinarily change to graphite when heated, and see if the change will still occur.

Both methods were tried.

EXPERIMENTAL METHODS.

All samples were ground to fine powder before firing, to facilitate the determination of specific gravity, and all samples were tested, after firing, by treatment with potassium chlorate and nitric acid.

Grinding.—To insure freedom from enclosed air which would vitiate the specific gravity results, all samples of carbon were ground in a roller-mill. This is a steel cylinder with a tightly fitting cover on each end, and contains four steel rolls. All the surfaces are case-hardened and polished, to insure a minimum of wear. As to the extent to which iron is introduced, it was found that after 50 hours' grinding of a 20-gram sample of petroleum coke, the ash had increased only 0.09 per cent. The mill is rotated at 200 r. p. m., and from two to eight hours is sufficient to grind most substances, so that the largest particles are not over 0.005 mm. in diameter.

Firing.—The samples were packed in small Acheson graphite crucibles with tightly fitting covers. These, in turn, were placed in larger tubular graphite crucibles, closed at both ends, the space between the smaller and larger crucibles being packed with Acheson granular graphite, previously fired and containing only mere traces of ash. The samples thus protected were fired at approximately 3000 to 3300° C., in an experimental tube furnace for 15 minutes. This furnace consists of a heater tube of Acheson graphite surrounded by an insulated carbon tube with an annular free space between them. The outer carbon tube

is well packed in granular petroleum coke, but no packing material is in contact with the heater. With the exception of the graphite heater tube, which was renewed for each run, the furnace has been used for a great many runs and is practically free from metallic impurities.

When making tests of purified and unpurified samples of the same kind of carbon, the purified samples were always fired in a tube which had not previously been used for firing impure carbon.

Specific Gravity.—Specific gravity determinations were made on samples pulverized as above stated, using a pyknometer of the form shown in sketch holding about 7 cc. The sample was weighed in the pyknometer, which was then half-filled with Kahl-

baum's C. P. benzene, and heated to the boiling point of the benzene to remove air and fill the pores of the carbon. Owing to the fineness of the powder, this can be accomplished in a few minutes. The pyknometer was then cooled to 20° C., filled to the mark with benzene, and weighed. Results are referred to water at 4° C. The limit of accuracy is about 0.005.

BRODIE'S TEST.

All samples before and after firing were tested by Brodie's method, which consists in heating the sample with fuming nitric acid and potassium chlorate. "Amorphous carbon" is converted into brown soluble substances, while graphite is changed to green graphitic oxide, or yellow graphitic acid, according to the concentration of the nitric acid, or the duration of the treatment.

In my experiments I used in some cases nitric acid, distilled from a mixture of concentrated nitric and sulphuric acids. In other cases the nitric acid was made by distilling well-dried potassium nitrate with concentrated sulphuric acid, as recommended by Moissan.

EXPERIMENTAL RESULTS.

Petroleum Coke.—This was obtained from the Standard Oil Company, in lump form, and contained 0.10 per cent. ash. These lumps, when fired, had all the physical properties of graphite, being soft, and of a silver-gray color. They marked paper easily. A sample of this graphite, pulverized before firing, had, after firing, a specific gravity of 2.26. This value was checked a number of times. A sample of the coke ground with 5 per cent. ferric oxide had a specific gravity after firing, of only 2.22.

It is thus seen that quite pure petroleum coke, when fired without additions, yields a very good grade of graphite, and that the addition of iron oxide is, if anything, disadvantageous.

Bituminous Coal Coke.—This was ordinary foundry coke, containing about 10 per cent. of red ash, mostly iron, and silica.

Lumps of this coke, when fired, became bright gray, and gave the characteristic gray streak on paper. This material seemed harder than petroleum coke graphite. Some of the powdered coke, when fired, had a specific gravity of 2.192.

A sample of unfired coke was treated with fused sodium hydroxide, then with water, and finally with hydrochloric acid. The ash was now reduced to 5.70. After firing, its specific gravity was 2.225.

The results of these experiments are given in Table No. 2.

TABLE 2.

	Ash before firing.	Ash after firing.	Specific gravity after firing.
Crude coke.....	10.00	2.07	2.192
Treated with fused NaOH, then with HCl.....	5.70	0.78	2.225

Here we see again that the *smaller* the amount of mineral matter present, the *higher* the specific gravity reached on firing.

Anthracite Coal.—A sample of Lackawanna coal,

Pyknometer.

Transformation of other forms of carbon into graphite.

containing 6.46 per cent. ash, when fired in lump form came out bright gray, rather hard, and with a tendency to cleave into plates and angular fragments like the unfired coal. It marked paper with some difficulty, and its feel and appearance were much less graphitic than in the case of the fired foundry coke and petroleum coke.

A pulverized sample, when fired, had a specific gravity of 2.133.

Some of the pulverized coal, when treated with fused NaOH, then washed and treated with HCl, had its ash reduced to 0.20 per cent., and this purified coal, when fired, had a specific gravity, of 2.149, a value slightly higher than that given by the crude coal.

To check this result, some samples of coal obtained from the U. S. Geological Survey were treated in the same way. The results were even more striking, as may be seen from Table 3.

TABLE 3.

Results of firing anthracite coal above 3000°.

Coal samples.		Ash before firing.	Sp. gr. after firing.
Lackawanna.....	Crude	6.46	2.133
Lackawanna.....	Purified	0.20	2.149
U. S. G. S. "Buckwheat No. 1"...	Crude	17.68	2.125
U. S. G. S. "Buckwheat No. 1"...	Purified	1.73	2.170
U. S. G. S. "Buckwheat No. 5"...	Crude	13.30	2.138
U. S. G. S. "Buckwheat No. 5"...	Purified	0.93	2.180

Anthracite coal, therefore, is a form of carbon which graphitizes only imperfectly, in spite of the high percentage of ash which is well distributed throughout the material. We have here excellent conditions for catalytic action without a corresponding effect. The results show that the presence of ash *hinders*, rather than *assists* graphitization. Some samples of coal seem to yield purer graphite than others, especially after the ash has been removed.

Lampblack.—A commercial variety of lampblack, known as "Patton's Sun-proof," containing about 0.2 per cent. ash, principally iron oxide, when fired in the tube furnace reaches a specific gravity of 2.090. Some of the lampblack, unfired, was ground with 5 per cent. ferric oxide and fired. This had a specific gravity of 2.094. Another sample of lampblack was impregnated with ferric oxide so as to obtain as good a distribution as possible in the following way:

The lampblack was stirred into a solution of ferric chloride and ammonia was added to precipitate ferric hydrate, when the lampblack precipitated with the ferric hydrate, forming an apparent homogeneous mixture. This mixture was well dried and divided into two portions: the first was heated one hour *in vacuo* at 1600° and the other one hour at 2000°, to reduce the iron oxide to metal, and then both were fired in the graphite tube furnace at about 3300°. After firing, the specific gravity of the first portion was 2.122, and of the second portion 2.109. All these fired samples were indistinguishable from each other by physical or chemical tests. We have here a pure form of carbon which reaches a limiting density of about 2.10, and this limit is not appreciably raised by the presence of even 5 per cent. ferric oxide, al-

though the distribution of the latter was about as perfect as possible and the conditions especially favorable for a catalytic transformation into a more graphitic variety of carbon if this were possible. They are all grayish black, non-crystalline powders. They all yield by Brodie's test, a yellow graphitic acid but have none of the characteristic properties of graphite.

Another sample of lampblack, Reichard's No. 7, was also fired, and reached a density of 2.074.

Patton's Sun-proof lampblack was also heated with small percentages of different substance, but no catalytic effect was noticeable.

The results are summarized in the table:

	Sp. gr. after firing.
Patton's L. B., 0.2 per cent. ash.....	2.090
Patton's L. B., 5 per cent. Fe ₂ O ₃ ground together.....	2.094
Patton's L. B., 5 per cent. Fe ₂ O ₃ by pptn. (a).....	2.122
Patton's L. B., 5 per cent. Fe ₂ O ₃ by pptn. (b).....	2.109
Patton's L. B., 5 per cent. Al ₂ O ₃	2.080
Patton's L. B., 1 per cent. Si.....	2.076
5 per cent. MnO ₂	2.091
5 per cent. NiO.....	2.099
Reichard's L. B.....	2.074

RETORT CARBON.

The carbon obtained from the inside walls of gas retorts occurs in three varieties, black, gray and white. These differ in ash content and in behavior on heating, and show in a striking way that the ability to graphitize is independent of the amount of ash present. Both the white and the gray varieties yield excellent graphite, although the former is very low in ash and the latter high.

The black variety which is also low in ash does not graphitize but reaches a density of 2.11. Four different substances tried as catalyzers had no effect, the density after firing being practically the same as that of the same carbon fired without mineral additions:

TABLE 4.

Effect of heating retort carbon above 3000°.

	Ash before firing.	Ash after firing.	Sp. gr. after firing.
White retort carbon.....	0.34	0.10	2.265
Gray retort carbon.....	2.66	0.16	2.263
Black retort carbon.....	0.23	0.10	2.110
Black retort carbon, 1 per cent. CaO.....	..	0.31	2.123
1 per cent. SiO ₂	..	0.12	2.117
1 per cent. Li ₂ CO ₃	..	0.05	2.120
2 per cent. Fe ₂ O ₃	..	0.09	2.178

DIAMOND.

Some white diamonds when fired became converted into a coke-like carbon having a specific gravity of 1.915, which does not mark paper.

Parsons and Swinton¹ heated a diamond in the focus of a cathode ray tube at 1890° and state that it was converted into coke. The specific gravity was not stated.

These results are especially interesting since it has been commonly supposed that the diamond is converted into graphite by heat, and statements to that effect appear in most text-books.

CONCLUSIONS.

All the pure forms of carbon which have been tested, when fired above 3000°, reach a limiting density

¹ *Proc. Roy. Soc.*, 80, 184 (1908).

which is not appreciably raised by the addition of small amounts of mineral matter. The end product is graphite in some cases and not in others. Pure petroleum coke, heated without addition of mineral matter, is converted into graphite of excellent quality, while lampblack, although it increases in density, does not reach the value corresponding to graphite, nor acquire any of its other physical properties, even when heated with various oxides.

The impure carbons show a similar behavior. The properties of these carbons after firing are characteristic for each variety of carbon and independent of the amount of ash present.

Anthracite coal is only imperfectly graphitized by heating. The specific gravity of the fired material was approximately the same for three samples having a range of ash content from 6.46 to 17.68 per cent. Moreover, coal from which most of the ash has been previously removed graphitizes better than the crude material.

Bituminous coal coke, which graphitizes fairly well, yields an even better product if a part of its ash has been removed before firing.

It must, therefore, be concluded that a small amount of mineral matter exercises no beneficial effect in the manufacture of graphite by the heating of carbon and that the quality of the product cannot be improved in this way. As to the effect of mineral matter on the rate of conversion, no data are yet available, although some experimental work along this line has been started. At 3000° the maximum density is reached in less than 15 minutes, for any variety of carbon.

We need some theory of the nature of graphite and of amorphous carbon which will permit a rational explanation of the changes which occur on heating. The following discussion is a tentative step in this direction.

THE NATURE OF GRAPHITE.

Graphite in the most restricted sense of the term is an allotropic form of carbon having a definite and perhaps not very complex molecular configuration. The molecule might, for example, be regarded as two benzene rings side by side, and joined at all six angles, the extra bonds being satisfied as in the usual centric formula. Such a formula might be used to explain the formation of mellitic acid and graphitic acid by oxidation of graphite.

AMORPHOUS CARBON.

When an organic compound is decomposed, there results a mixture of substances constantly increasing in complexity until finally carbon is obtained. This carbon need not be regarded as a simple substance, but may be considered to be a mixture of many varieties of carbon each with a different number and arrangement of atoms in the molecule. According to this view it seems better not to regard "amorphous carbon" as the name of a distinct allotropic form, but rather as a general term covering all varieties of carbon except graphite and diamond. In speaking of amorphous carbon, therefore, the source of each sample should be stated.

THE MODE OF TRANSFORMATION.

In a given sample of amorphous carbon, some of the molecules will be capable of easily undergoing rearrangement under the influence of heat to form graphite molecules, while others will not, and the proportion of molecules capable of such change will determine the character of the final product.

Petroleum coke would therefore consist almost wholly of graphitizable molecules, while anthracite coal contains a smaller proportion.

RESEARCH LABORATORY,
GENERAL ELECTRIC COMPANY,
SCHENECTADY, N. Y.

A METHOD OF ANALYZING SOME COMMERCIAL GOLD ALLOYS. METALS PRESENT: GOLD, SILVER, COPPER AND OCCASIONALLY ZINC AND TIN.¹

By JAS. O. HANDY.
Received August 9, 1911.

PREPARATION OF SAMPLE.

Use a sharp file. Remove particles of steel with a magnet. Weigh out 0.5 gram of filings in a 4-ounce beaker. Add 50 cc. of *aqua regia* (40 HCl and 10 HNO₃). Heat just to boiling for 15 minutes or until decomposed. The AgCl is almost all dissolved, when boiled with the strong acid. Boil down to 10 cc., add 25 cc. HCl and again boil down to 10 cc. or until the AgCl begins to separate.

SILVER.

Dilute to 150 cc. with water. Boil until the AgCl coagulates well. Cool, let stand until clear. Filter on a weighed paper, and wash the AgCl. Dry and weigh. ($\text{AgCl} \times 0.7527 = \text{Ag}$.)

ZINC.

Add sufficient HCl to the filtrate to make 5 per cent. of concentrated HCl by volume. Pass H₂S through the cold solution rapidly for fifteen minutes. Filter and wash with H₂S water. The filtrate contains only the zinc. Boil off H₂S and precipitate with Na₂CO₃. Boil for fifteen minutes. Filter and wash with hot water. Dry, burn off in porcelain and weigh ZnO after blasting. ($\text{ZnO} \times 0.8034 = \text{Zn}$.)

TIN.

For the separation of Sn from Au and Cu in the sulphide precipitate, we take advantage of its solubility in HCl. The precipitate (and filter paper) is placed in a beaker and covered with 50 cc. of a mixture of water (35 cc.) and HCl (15 cc.). Boil for ten minutes. Cool. Filter. Add HCl to make 25 per cent. of concentrated acid by volume. Pass H₂S to reprecipitate any dissolved Cu. Filter and wash with H₂S water. Neutralize filtrate with ammonium hydroxide. Acidify with 1 cc. of HCl. Pass H₂S to precipitate the Sn. Filter. Wash with H₂S water. Burn off in a porcelain crucible, igniting finally over a blast. Weigh SnO₂. ($\text{SnO}_2 \times 0.788 = \text{Sn}$.) The CuS recovered as above is converted into CuO and is then dissolved in 5 cc. conc. HNO₃, by warming. Any SnO₂ present is recovered and weighed, the amount being added to that already obtained.

¹ Paper read at the Indianapolis Meeting of the American Chemical Society before the Industrial Section, June 30, 1911.