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REVIEW AND BIBLIOGRAPHY

OF THE

METALLIC CARBIDES

BY

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CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION

1898

LETTER OF TRANSMITTAL

WASHINGTON, APRIL 5TH, 1897.

The Committee on Indexing Chemical Literature, appointed in 1882 by the American Association for the Advancement of Science, has voted to recommend to the Smithsonian Institution for publication the following:—

REVIEW AND BIBLIOGRAPHY OF THE METALLIC CARBIDES,

by J. A. Mathews, M. S., M. A., School of Mines, Columbia University, New York.

H. CARRINGTON BOLTON, *Chairman.*

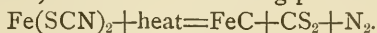
MR. S. P. LANGLEY,

Secretary of the Smithsonian Institution.

INTRODUCTION.

Most of the literature of the metallic carbides is of recent date, yet the beginnings of the studies upon compounds of carbon with metals take us back to the very dawn of the present century, for during its first years chemists described such compounds. The relation of carbon to iron in steel was said to be that of a true chemical compound as early as 1800, and in 1808 Davy prepared the carbide of potassium. At intervals from that time to the present new carbides have been described.

In looking over the old references one cannot but notice that, with few exceptions, the carbides described therein are of those metals concerning which there is to-day the greatest doubt as to their forming such compounds at all. For example, about sixty years ago a general method was given for forming the carbides of iron, copper, lead, zinc, bismuth, silver, tin, and manganese by heating in a retort their sulphocyanides, air being excluded during the operation. It was said that sulphide of carbon and nitrogen were evolved; the reactions working parallel to this:—



The preceding list contains at least four elements which are not, at this time, supposed to form carbides. Frequent mention of other carbides is made in old works on chemistry. In the light of recent investigation these seem of doubtful worth, as the compounds mentioned find no place in modern works, or else their existence has been denied. Some of these old references are given later without comment as to their value, the reader being free to accept or reject any of them.

In consideration of the interest manifested by chemists recently in this class of bodies, it seems that a brief review of the work done to date may be of considerable interest to the general reader; while this, in conjunction with the bibliographical references, it is hoped may be of some value to the chemical student or investigator. With these two ends in view the following pages were compiled.

The general plan has been to give a very condensed account of the methods of preparation, physical and chemical properties of the carbides now known, considering them in alphabetical order. Following each descriptive portion are the references to the literature bearing thereon. The titles of original papers are in most cases given in full, that the scope of the article may be judged therefrom. Minor articles and abstracts are

also largely given ; in this way the value of the bibliography is increased to those who have not ready access to extensive reference libraries, since the same matter is referred to as given in various publications, to one or another of which most chemists have access.

Within the last five years the renewed attention of chemists has been turned toward this class of compounds, and new carbides have been produced in rapid succession. Experiments upon the reduction of metallic oxides by means of carbon in an electric furnace have resulted in the production of many of the newly discovered carbides. In studying the literature of these compounds, the work of one man is especially noticeable. More than to all other chemists together is praise due M. Henri Moissan for the untiring energy with which he has investigated the carbo-metallic compounds. So often has he astonished chemists with the results of his electro-chemical experiments, that new discoveries by him are likely to be considered as a matter of course. M. Moissan's work upon artificial diamonds is one of the greatest achievements of science in imitating nature's methods.

In conducting his experiments Moissan makes use of an electric furnace of very simple construction. It consists of a limestone block in the upper surface of which is chiseled a rectangular cavity, which is lined with a coating of magnesia and of carbon. Through opposite sides of the block are inserted stout carbon electrodes, and through one of the other sides is an opening through which a carbon tube is inserted. In this tube the materials to be heated are placed and thus inserted into the arc. It is estimated that a temperature of 4000° is obtained in this furnace. Before using the furnace it is covered with another piece of limestone, on the lower side of which are layers of magnesia and carbon, which fit into or cover the cavity of the lower block. So poorly do these materials conduct heat that the hand may be kept on the outside of the furnace for several minutes after the current is started.

The literature of the metallic carbides is as yet confined to periodicals. Following the main portion of this paper is given an author's index, together with the elements to the literature of whose carbides each has contributed. By referring back to the page upon which such carbides are discussed the full references will be found. Below are given a few references having a general bearing upon the carbides.

MOISSAN. "Sur un nouveau modèle de four électrique à réverbère et à électrodes mobiles." *C. R.* 117, p. 679.

MOISSAN. "Cristallisation du carbon sous l'action d'un dissolvant métallique." *Bull. Soc. Chim.* (1895) [3] 13, p. 808.

MAISSON. "Sur la formation des carbures d'hydrogène gazeux et liquides par l'action de l'eau sur les carbures métalliques. Classification des carbures." *Bull. Soc. Chim.* (1896) [3], 16, p. 1284, or *C. R.* (1896) p. 1462, or *Ztschr. Elektrochem.* (1896) p. 134.

MOISSAN (concerning those carbides which are decomposed by cold water). *Ann. de chim.* [7] 9, p. 302 ; or *Chem. Centrbl.* (1896) pt. 2, p. 1082.

BORCHERS. "Die elektrischen Ofen zur Metallgewinnung, u. s. w." Ztschr. Elektrochem. (1896) p. 189 and p. 213.

AHRENS. "Die Metallcarbide und ihre Verwendung." Sammlung chemischer und chemisch-technischer Vorträge, vol. I, part 1, 1896.

With this explanatory introduction the following pages will, it is hoped, be clear to all whose interest in the metallic carbides leads them to consult this, — a bibliographical dictionary of those compounds.

J. A. MATHEWS.

CHEMICAL DEPARTMENT,
COLUMBIA UNIVERSITY,
January, 1897.

NOTE. — During the period since the manuscript of the present work was submitted there has appeared a great deal of original material upon the carbides. Especially must be noted a number of books, and the addition of these, together with the more important journal references, will add very materially to the usefulness of this bibliography.

Book References: —

AHRENS. Handbuch der Elektrochemie, Stuttgart, 1896.

MOISSAN. Le Four électrique, Paris, 1897. 385 pages.

ZETTEL. Authorized German translation of the above. Berlin, 1897, 360 pages.

PANAOTOVIC. Calciumcarbid und Acetylen, in Vergangenheit, Gegenwart und Zukunft. Leipzig, 1897, 8vo.

PICTET. L'Acétylène. Son passé, son présent, son avenir. Genève, 1896, 8vo.

PELLISSIER. L'Eclairage a l'acétylène. Paris, 1897, 8vo.

PERRODIL. Le carbure de calcium et l'acétylène. Les Fours électriques. Paris, 1897, 16mo.

LEFEVRE. Carbure de calcium et l'acétylène. Paris, 1898, 12mo.

Journal References: —

(Al_4C_3 .) MOISSAN. Ann. de chim. [7] 9, p. 302. (From CaC_2 and alumina) C. R. (1897) CXXV, p. 839.

(BaC_2 .) BULLIER. Ber. d. chem. Ges. XXVIII, ref. p. 41.

(CaC_2 .) MOISSAN. Nouvelle méthode de préparation des carbures par l'action du carbure de calcium sur les oxyds. C. R. (1897) CXXV, p. 839.

YVON. De l'emploi du CaC_2 pour la préparation de l'alcool absolu. C. R. (1897) CXXV, p. 1181.

LE CHATELIER. Sur les impuretés des carbures de calcium commercial. Bull. Soc. Chim. (1897) [3] XVII, p. 793.

WARREN. (CaC_2 as a reducing agent.) Chem. News (1897) 75, p. 2. J. Chem. Soc. (1897) LXXII, p. 212.

(CeC_2 .) MOISSAN. Bull. Soc. Chim. (1897) [3] XVII, p. 261.

(Cr_4C and Cr_3C_2 .) MOISSAN. C. R. (1897) CXXV, p. 839.

(Iron carbides.) HANS FREIHERR VON JÜPTNER. Kohlenstoffformen im Eisen. Sammlung chemischer und chemisch-technischer Vorträge, Vol. I, parts 11 and 12 (1896).

MOISSAN. Préparation du carbure de fer par union directe de métal et du carbone. C. R. (1897) CXXIV, p. 716. Bull. Soc. Chim. (1897) [3] XVIII, p. 540. J. Chem. Soc. (1897) LXXII, p. 375.

- MYLIUS, FOERSTER, SCHOENE. Ueber das Carbid des geglühten Stahls. Ber. d. chem. Ges. (1897) XXIX, p. 2991. Bull. Soc. Chim. (1897) [3] XVIII, p. 531.
- (LaC₂.) PETERSSON. Ber. d. chem. Ges. (1896) XXVIII, p. 2432.
- MOISSAN. Chem. News (1896) 74, p. 84. Ber. d. chem. Ges. (1897) XXIX, ref. p. 618.
- (Li₂C₂.) MOISSAN. Bull. Soc. Chim. (1897) [3] XVII, p. 260. Ber. d. Chem. Ges. (1897) XXIX, ref. p. 210.
- GUNTZ. C. R. (1896) CXXIII, p. 1273. J. Chem. Soc. (1897) LXXII, p. 212.
- (Mn₃C.) MOISSAN. Chem. News (1896) 73, p. 141. Ber. d. chem. Ges. (1897) XXIX, ref. pp. 266 and 614. C. R. (1897) CXXV, p. 839.
- (Mn₂C.) MOISSAN. C. R. CXXII, p. 1462. Ber. d. chem. Ges. (1897) XXIX, ref. p. 614. C. R. (1897) CXXV, p. 839.
- (SiC.) RINNE. Jsb. f. Mineral. (1897) II, p. 1-27. Chem. Centrbl. (1897) Bd. II, p. 724.
- MOISSAN. (From SiO₂ and CaC₂.) C. R. (1897) CXXV, p. 839.
- FITZGERALD. (Upon the development of the CSi industry.) J. Frankl. Inst. 143, p. 81. J. Am. Chem. Soc. (abs.) (1897) XIX, p. 36.
- (Na₂C₂.) MATIGNON. Propriétés du carbure de sodium. C. R. (1897) CXXV, p. 1033. (NaHC₂) C. R. (1897) CXXIV, pp. 775 and 1026. Bull. Soc. Chim. [3] XVIII, p. 540.
- DE FORCRAND. (Heat of formation.) C. R. (1897) CXXIV, p. 1153. Bull. Soc. Chim. (1897) [3] XVIII, p. 726.
- (TiC.) MOISSAN. C. R. (1897) CXXV, p. 839. (From TiO₂ and CaC₂.)
- (W₂C.) MOISSAN. C. R. (1897) CXXV, p. 839.
- (U₂C₃.) MOISSAN. Bull. Soc. Chim. (1897) [3] XVII, p. 12. Ber. d. chem. Ges. XXIX, ref. p. 207.
- (VaC.) MOISSAN. Ber. d. chem. Ges. XXIX, ref. p. 580. Chem. News (1896) 74, p. 29.
- (ZrC₂.) TROOST. Ber. d. chem. Ges. XXVI, ref. p. 483.
- (ZrC.) MOISSAN and LENGFELD. Ber. d. chem. Ges. (1897) XXIX, ref. pp. 343 and 614. Chem. News (1896) 74, p. 175.

These additions include the more important contributions to the literature of the carbides during 1897, together with a few from the latter part of 1896, which, with the main portion of this paper, constitute a nearly complete bibliography of these compounds.

THE AUTHOR.

March, 1898.

LIST OF ABBREVIATIONS.

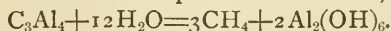
- Allg. J. Chem. — (Scherer's) Allgemeines Journal der Chemie (1798-1810).
Am. Chem. J. — American Chemical Journal (1879-96+).
Am. Drug. and Pharm. Rec. — American Druggist and Pharmaceutical Record (New York).
Am. Gas-Light J. — American Gas-Light Journal.
Am. J. Sci. — American Journal of Science (1818-96+).
Ann. Chem. — (Wöhler and Liebig's) Annalen der Chemie und Pharmacie (1840-73),
(and Liebig's) Annalen der Chemie (1874-96+).
Ann. de chim. — Annales de chimie et de physique (1789-1896+).
Ann. Mines. — Annales des mines (1817-96+).
Ann. der Pharm. — Annalen der Pharmacie (1832-39).
Ann. Phil. — Annals of Philosophy (1813-26).
Ann. der Phys. — Annalen der Physik (Gilbert, 1799-1824) and Annalen der Physik
und Chemie (Poggendorff, 1824-77).
Ber. d. chem. Ges. — Berichte der deutschen chemischen Gesellschaft (1868-96+).
Bull. Acad. Belg. — Bulletin de l'Académie Royale des Sciences, des Lettres, et des
Beaux-Arts de Belgique.
Bull. Soc. Chim. — Bulletin des Séances de la Société chimique de Paris (1864-
96+).
Chem. Centrbl. — Chemisches Centralblatt (1856-96+).
Chem. News. — Chemical News (London).
C. R. — Comptes rendus hebdomadaires des Séances de l'Académie de Sciences (Paris,
1835-96+).
D. R. P. — Deutsches Reichspatent.
Jsb. Pharm. — Jahresbericht der Pharmacie.
Jsb. Chem. — Jahresbericht über die Fortschritte der Chemie, u. s. w. (1847-90+).
J. Am. Chem. Soc. — Journal of the American Chemical Society (1876-96+).
J. Chem. Soc. — Journal of the Chemical Society (London, — Proceedings, Abstracts,
and Transactions. 1849-96+).
J. f. Gasbeleucht. — Journal für Gasbeleuchtung.
J. Frankl. Inst. — Journal of the Franklin Institute (Philadelphia).
J. Soc. Chem. Ind. — Journal of the Society of Chemical Industry (1882-96+).
J. prakt. Chem. — Journal für praktische Chemie (1834-96+).
J. I. and S. Inst. — Journal of the Iron and Steel Institute.
N. J. der Pharm. — Neues Journal der Pharmacie für Aertze, u. s. w. (Trommsdorff,
1817-34).
Oesterr. J. Berg- u. Hüttenwesen. — Oesterreiches Journal für Berg- und Hütten-
wesen.
Phil. Trans. — The Philosophical Transactions of the Royal Society of London (1665-
1896+).
Polyt. Centrbl. — Polytechnisches Centralblatt (1835-73).
Proc. Chem. Soc. — Proceedings, see under Journal of the Chemical Society (London).

- Proc. Inst. Mech. Eng. — Proceedings of the Institute of Mechanical Engineers.
- Recueil trav. chim. Pays-Bas. — Recueil des Travaux chimiques des Pays-Bas (Leiden, 1882-94+).
- School Mines Q. — School of Mines Quarterly (New York, 1879-96+).
- Trans. Am. Inst. M. Eng. — Transactions of the American Institute of Mining Engineers.
- U. S. Geol. Sur. — Bulletins of the United States Geological Survey.
- U. S. Pat. — United States patent.
- Ztschr. anorgan. Chem. — Zeitschrift für anorganische Chemie (1892-96+).
- Ztschr. angew. Chem. — Zeitschrift für angewandte Chemie (1887-96+).
- Ztschr. Chem. Pharm. — Zeitschrift für Chemie und Pharmacie.
- Ztschr. Elektrochem. — Zeitschrift für Elektrochemie.
- Ztschr. Krystall. — Zeitschrift für Krystallographie und Mineralogie (1877-96+).

REVIEW AND BIBLIOGRAPHY OF THE METALLIC CARBIDES.

ALUMINUM AND CARBON.

Moissan has prepared a carbide of aluminum (1) from kaolin and carbon, and (2) from metallic aluminum and carbon. The method employed was to put the Al in a carbon boat and heat for five to six minutes in the electric furnace. Hydrogen was passed through the carbon tube of the furnace both during heating and while cooling. A current of 300 amperes and 65 volts was used. From this process results a mixture of Al and Al_4C_3 . The Al_4C_3 consists of yellow, transparent crystals; sp. gr. 2.36; decomposed at red heat by Cl or Br, leaving a residue of amorphous carbon. Water decomposes it in the cold, thus:—



LITERATURE.

- MOISSAN. Préparation d'un carbure d'aluminium cristallisé. C. R. (1894) v. 119, p. 16, or Bull. Soc. Chim. [3] 11, p. 1010, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 450, Chem. Centrbl. (1894) 65, pt. 2, p. 268. *See also*
- MOISSAN. Réduction de l'alumine par le charbon. C. R. (1894) 119, p. 935, or Abs. J. Chem. Soc. (1895) 68, pt. 2, p. 226.
- DEVILLE. Ann. de Chim. [3] 45, p. 15.
- MALLET. Ueber Stickstoffaluminium und die Einwirkung von Aluminium auf Kohlenstoffkalium bei höher Temperatur. Ann. Chem. 186, p. 155.

ALUMINUM, BORON, AND CARBON.

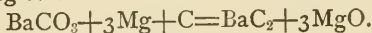
A very refractory substance, to which the formula $Al_3C_2B_{48}$ has been given, is interesting because of its great hardness, between corundum and diamond.

LITERATURE.

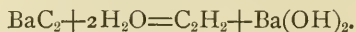
- HAMPE. Ueber das Bor. Ann. Chem. (1876) 183, p. 75. *See also*
- WÖHLER AND ST. C. DEVILLE. Ann. Chem. 101, ps. 113 and 347.

BARIUM AND CARBON.

The carbide of barium may be made in the electric furnace in the same way as calcium carbide (q. v.). It also results by heating together $BaCO_3$, Mg and C according to this reaction:—



In the electric furnace either BaCO_3 or BaO may be employed. BaC_2 forms dark colored crystals, sp. gr. = 3.75, decomposed by water, thus:—



At high temperatures the carbides of the alkaline-earths react violently with the halogens.

LITERATURE.

MAQUENNE. Sur un carbure défini du baryum. C. R. 114, p. 361.

MAQUENNE. Sur une nouvelle préparation de l'acétylène. C. R. (1892) 115, p. 558.

BULLIER. Deutsches Reichspatent, 77,168.

MOISSAN. Etude des acétylures cristallisés de baryum et de strontium. C. R. (1894) 118, p. 683, or Chem. Centrbl. (1894) 65, pt. 1, p. 856, or Bull. Soc. Chim. [3] 11, p. 1007.

BORON AND CARBON.

Two carbides of boron have been described, BC or B_2C_2 , and B_6C . According to Moissan two compounds are formed in the electric furnace, one of which is permanent and resists the action of $\text{KClO}_3 + \text{HNO}_3$, while the other compound is broken down by this treatment. He has given the more stable compound the formula B_6C . It is produced when boron and certain boron compounds are heated with carbon in the electric furnace. Black, shining crystals, sp. gr. 2.51, harder than carborundum, and with it new facets may be cut upon diamonds. Cl at high temperatures decomposes it with deflagration, chloride of boron and carbon resulting. Very slowly oxidized at 1000° , it is not acted upon by mineral acids, nor by S , P , N , Br , or I .

Mühlhäuser heated together in an electric furnace boric-anhydride and carbon. The product he treated twice with hot HCl , then with HF , and H_2SO_4 . There remained a graphite-like mass, which by analysis showed the composition BC or B_2C_2 . The compound is fusible at a high temperature and is decomposed by fusion with alkali.

LITERATURE (B_6C).

MOISSAN. Action de l'arc électrique sur le diamant, le bor amorphe et le silicium cristallisé. Bull. Soc. Chim. [3] 11, p. 993, or C. R. 117, p. 423, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 42.

MOISSAN. Préparation et propriétés du borure de carbone. C. R. (1894) 118, p. 556, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 279, or Bull. Soc. Chim. (1894) [3] 11, p. 998. *See also*

HAMPE. Ueber das Bor. Ann. Chem. (1876) 183, p. 75.

WÖHLER and ST. C. DEVILLE. Ann. de chim. (1858) [3] 52, p. 63.

(B_2C_2) MÜHLHÄUSER. Ztschr. anorgan. Chem. 5, p. 92, or Chem. Centrbl. (1893) 64, pt. 2, p. 747, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 570.

CALCIUM AND CARBON.

In 1862 Wöhler gave a method of producing acetylene gas from a compound of calcium and carbon. This compound was prepared from a zinc-

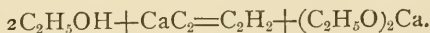
calcium alloy by heating with carbon. Wöhler gave some of the properties of the carbide which resulted. In 1893 Travers recorded another method of preparing calcium carbide, and in the following year Moissan produced it in his electric furnace, both from CaCO_3 and from CaO heated with sugar carbon. About the same time the Willson Aluminum Company, in this country, while experimenting upon the reduction of the alkali earths by means of carbon, found that carbide of calcium was formed, although when first produced the compound was not recognized by them, but was considered as a waste product. As soon as its properties were learned, Willson took out patents for its production in this country. Bullier holds a German patent for the production of Ca-, Ba-, and Sr-carbides, although the method patented is said to be of Moissan's discovery. The carbides of calcium and silicon seem thus far to be the only carbides of commercial value in themselves. The value of calcium carbide lies in its ready decomposition with water, yielding nearly pure acetylene gas, which under proper conditions is unexcelled as an illuminating gas. When made upon a commercial scale, calcium carbide is produced from lime and coke. The cost of production is still rather high, and the chances of acetylene gas being generally introduced for lighting purposes in the immediate future are not very bright. In time the necessary improvements may be made which will do away with present difficulties. The cost of the electric power is the chief obstacle now.

CaC_2 forms in opaque, brownish-red crystals, sp. gr. 2.22. It is quite insoluble in most of the ordinary solvents in the cold. Dry hydrogen is without action in the cold and seems to be without effect even when hot upon the pure calcium carbide. The commercial article may contain tarry products which a stream of dry hydrogen will drive out. Air acts in about the same way as hydrogen. At a very high temperature a sample, submitted to the action of a stream of oxygen, glows and is partly oxidized.

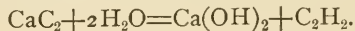
HCl (gas) decomposes it when hot. Cl and Br at even moderate temperatures cause the sample to glow brightly, to swell up, and then fuse together. Very slight action in the cold when treated with H_2SO_4 , but by heating the action is increased and a gas is evolved which burns with a luminous flame.

With a mixture of H_2SO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$, calcium carbide reacts violently, vigorous oxidation taking place. Little or no C_2H_2 is evolved in the above reaction.

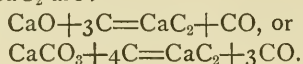
With strong HNO_3 there is an evolution of brown fumes and a gas which burns with a smoky flame. Glacial acetic acid slowly decomposes it. By fusion with NaOH this carbide is decomposed and a gas is evolved which is probably acetylene. At 180°C calcium carbide is decomposed by alcohol, thus:—



The simple reaction with water is:—



Moist air slowly effects this decomposition. Since it is the decomposition product of this carbide which makes it valuable we include below some references to acetylene, its properties, production, etc. The equations for the production of CaC_2 are:—



LITERATURE.

- WÖHLER. Bildung des Acetylenes durch Kohlenstoffcalcium. *Ann. Chem.* (1862) 124, p. 220, or *Jsb. Chem.* (1862) p. 441.
- TRAVERS. *Proc. J. Chem. Soc.* (1893) 118, p. 15.
- MOISSAN. Préparation au four électrique d'un carbure de calcium cristallisé; propriétés de ce nouveau corps. *C. R.* (1894) 118, p. 501; *Bull. Soc. Chim.* [3] 11, p. 1002, or *Chem. Centrbl.* (1894) 65, pt. 1, p. 719, or *Chem. Centrbl.* (1895) 66, pt. 1, p. 947.
- BULLIER. *D. R. P.* 77,168.
- WYATT. Calcium carbide, and acetylene. *Am. Gas-Light J.* (1894) 61, p. 903.
- WYATT. *J. Frankl. Inst.* (1895) 139, pp. 72 and 321.
- WEDDING. *J. f. Gasbeleucht* (1894), p. 253 and p. 273; (1895), p. 242.
- JONES. *Am. Gas-Light J.* (1895) 63, p. 252.
- MOREHOUSE and DE CHALMONT. *J. Am. Chem. Soc.* 18, p. 311.
- WILLSON. Calcium carbide process, U. S. pat. 541,137, June 18 (1895), and reissue 11,511.
- WILLSON. Product existing in form of crystalline calcium carbide, U. S. pat. 541,138, June 18, 1895.
- WILLSON. Method of converting calcium carbide for enriching illuminating gas, U. S. pat. 542,320 (1895), or *Am. Gas-Light J.* (1895) 63, p. 211; *see also*, U. S. pat. 545,466, Apr. 1895; 552,027, Dec. 1895; 552,028, Dec. 1895.
- DICKERSON. Process and apparatus for producing acetylene from calcium carbide, U. S. pat. 541,526 (1895), or *Am. Gas-Light J.* (1895).
- CLARKE. For producing calcium carbide, U. S. pat. 551,461, Dec. 17, 1895.
- VENABLE and CLARKE. Some properties of calcium carbide. *J. Am. Chem. Soc.* 17, p. 306, or *Am. Gas-Light J.* (1895) 62, p. 528, or *Bull. Soc. Chim.* (1895) [3] 14, p. 870, or *Abs. J. Chem. Soc.* (1895) 68, pt. 2, p. 265.
- FORGRAND. Chaleur de formation de l'acétylure de calcium. *C. R.* 120, p. 682, or *Bull. Soc. Chim.* (1895) [3] 13, p. 745.
- KRÜGER. Laboratoriumsversuche über CaC_2 . *Ztschr. Elektrochem.* (1895) p. 30, also p. 111, or *Chem. Centrbl.* (1895) 66, pt. 1, p. 1105.
- FRANK and WEYL. *J. Soc. Chem. Ind.* (1895) p. 227.
- CARO. *J. Soc. Chem. Ind.* (1895) 18, p. 454.
- KRÜGER and PUCKERT. *J. Soc. Chem. Ind.* (1895) 18, p. 226.
- WILLGERODT. Ueber die Entfernung des Phosphorwasserstoffs aus dem aus CaC_2 dargestellten C_2H_2 , u. s. w. *Ber. d. Chem. Ges.* (1895) 28, p. 2107.
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- BREDEL. *The Gasworld* (London) (1895), p. 286.
- BREDEL. *Ztschr. angew. Chem.* (1896) p. 16.
- FROHLICH. *Ztschr. Elektrochem.* II, p. 165.
- LEWES. Acetylene and the part it plays in the luminosity of flame. *Am. Gas-Light J.* (1895) 63, p. 42.
- LEWES. Commercial synthesis of illuminating hydrocarbons. *Am. Gas-Light J.* (1895) 62, p. 146. Discussion of preceding paper, *Am. Gas-Light J.* (1895) 62, p. 182. *Ztschr. angew. Chem.* (1895) pp. 140, 162, 231, 282, 338, 354, 380, and 671.

- KORDA. Acetylene and calcium carbide. *Ztschr. Elektrochem.* (1896) p. 175.
- PELISSIER. *Ztschr. Elektrochem.* (1896) p. 225.
- PELISSIER. *L'éclairage électrique* (1896), VIII, p. 500, and IX, p. 442.
- GREHAUT. *Mélanges explosifs d'acétylène et d'air.* *C. R.* (1896) p. 832.
- CLARKE. Manufacture of calcium-carbide, U. S. pat. 552,890, and for generating acetylene, U. S. pat. Jan. 14, 1896, 556,736, Mar. 24, 1896.
- KING and WYATT. Apparatus for generating acetylene, U. S. pat. 562,401, June 23, 1896.
- KING and WYATT. Process of forming calcium carbide, U. S. pat. 562,402, June 23, 1896.
- KING and WYATT. Electric furnaces, U. S. pats. 562,400; 562,403; 562,404, June 23, 1896.
- WILLSON. (Gas patents, etc.) 553,443, Jan. 21, 1896, and 553,550, Jan. 28, 1896; 555,198, Feb. 25, 1896.

CERIUM AND CARBON.

A carbide of the composition CeC_3 results by heating cerium formate or oxalate in an apparatus from which the air is excluded. When the residue from this operation is extracted with HCl a compound remains of the above composition, which is not soluble even in hot, concentrated acids. Many chemists doubt the existence of this compound.

The carbide which Moissan has produced in the electric furnace has the formula Ce_2C . It is prepared from CeO_2 and sugar carbon. It forms transparent crystals, sp. gr. 5.23. When acted upon by water it is decomposed, evolving C_2H_2 , CH_4 , C_2H_4 , and the residue extracted with ether contains a small amount of fluid and solid hydrocarbons. The reaction must obviously be very complex.

LITERATURE.

- GMELIN. Carbide of cerium (?). *Handbook of Chemistry*, Vol. III, p. 264 (Watt's translation, 1849).
- BERZELIUS. *Lehrbuch der Chemie* (1836), III, p. 495.
- DELAFONTAINE. *Jsb. Chem.* (1865) p. 176.
- PETTERSSON. Supplement to the report of the Royal Academy of Sweden (1895), II, 2 series, number 1.
- MOISSAN. Préparation et propriétés du carbure de cerium. *C. R.* 122, p. 357, or *Chem. Centrbl.* (1896) 67, pt. 1, p. 686, or *Abs. J. Chem. Soc.* (1896) 70, pt. 2, p. 422.

CHROMIUM AND CARBON.

When chromium is heated in an electric furnace for ten to fifteen minutes with a large excess of carbon, with a current of 70 volts and 350 amperes, there is produced Cr_3C_2 ; brilliant laminae, greasy lustre, sp. gr. 5.62, not acted upon by concentrated or dilute HNO_3 or aqua regia. Fused KNO_3 attacks it vigorously, not so KOH . It is not decomposed by H_2O , hot or cold. It is harder than the topaz. Somewhat soluble in dilute HCl.

Cr_4C obtains as long, shining needle-like crystals which are found upon

the surface of ingots of metallic Cr or in cavities existing in such ingots. It is harder than quartz; sp. gr. 6.75; melts at a higher temperature than Pt. One of the above carbides is also said to result by passing CS_2 vapors over hot Cr. Certain compounds of Fe, Cr, and C are known, such as $\text{Fe}_7\text{Cr}_2\text{C}_3$ and Cr_3FeC_2 .

LITERATURE.

- DEVILLE and DEBRAY. (Foot-note) *Ann. de chim.* [3] 56, p. 408.
 MOISSAN. *Nouvelles recherches sur le chrome.* C. R. (1894) 119, p. 185, or *Abs. J. Chem. Soc.* (1894) 66, pt. 2, p. 452.
 MOISSAN. *Bull. Soc. Chim.* [3] 11, p. 13, and p. 1014.
 MOISSAN. *Ann. de chim.* (1896) [7] 8, p. 559.
 BEHRENS and VAN LINGE. (On the chromium ferro-carbides) *Recueil trav. chim. Pays-Bas*, 13, p. 155, or *Abs. J. Soc. Chim.* (1894) 66, pt. 2, p. 451.

COBALT AND CARBON.

Over thirty years ago Thompson described a compound containing about 4% C, which was very hard and brittle, of bismuth color, sp. gr. 8.43. It was made by heating Co_2O_3 and argol in a closed carbon crucible for several hours.

LITERATURE.

- THOMPSON. Ueber die Fabrication von Kobalt und Nickel. *Chem. Centrbl.* (1863) p. 956, or *Le Technologiste* (1863) p. 337.
 MOISSAN. (Foot-note) *Bull. Soc. Chim.* [3] 11, p. 13.

COLUMBIUM AND CARBON.

A double compound of columbium carbide and nitride of this composition, $3\text{CbC}_2\text{CbN}$, has been mentioned by Joly.

LITERATURE.

- JOLY. Sur les combinaisons du niobium et du tantale avec l'azote et le carbone. *Bull. Soc. Chim.* (1876) [2] 25, p. 506, or C. R. 82, p. 506, or *Jsb. Chem.* (1876) p. 279.

COPPER AND CARBON.

An explosive compound to which various formulas have been given results by passing acetylene through ammoniacal copper solutions. Very little carbon is taken up by direct heating of copper and carbon. A little copper is said to be taken up in combination during the poling process of refining copper. Some very good work has been done recently upon the acetylids in this country and England, but with not altogether accordant results. The formulas usually given for copper acetylide are C_2Cu_2 and $\text{C}_2\text{Cu}_2 + \text{H}_2\text{O}$. See especially *Keiser*, *Am. Chem. J.* 14.

LITERATURE.

- QUET. (On certain explosive compounds of Cu and C.) C. R. 46, p. 903, and *Ann. Chem.* 108, p. 116, *also*

- BÖTTGER. Ann. Chem. 109, p. 351.
 TORREY. Jsb. Chem. (1859) p. 222. *See also*, Ber. d. chem. Ges. 21, ref. 609.
 VIVIAN. Ann. Phil. 21, p. 121.
 CROVA. C. R. 55, p. 435, and Ztschr. Chem. Pharm. (1862) p. 598, and J. prakt. Chem. 88, p. 124, also Jsb. Chem. (1862) p. 442.
 See Ann. Chem. 118, p. 330, Chem. News, VII, p. 2, and Chem. Centrbl. (1863) p. 80.
 NICKLES. C. R. 55, p. 505.
 BROWN. J. prakt. Chem. (1839) 17, p. 492.
 KEISER. Am. Chem. J. 14, p. 285, and Abs. J. Chem. Soc. 62, p. 1416.

GLUCINUM AND CARBON.

P. Lebeau describes the preparation of a compound to which he gives the formula Gl_4C_3 . Henry advances the formula Gl_2C for Lebeau's compound. It is prepared by heating for ten minutes a mixture of glucinum oxide and carbon (Zuckerkohle); the current used was 950 amp., 40 volts. With a weaker current a nitrogen-containing compound results. Gl_4C_3 forms fine crystals, sp. gr. = 1.9, brownish-yellow color, and resembling Al_4C_3 in many of its properties. It is very hard, and by decomposition with H_2O methane is produced.

LITERATURE.

- P. LEBEAU. Sur un carbure de glucinum. C. R. (1895) 121, p. 496, or Chem. Centrbl. (1895) 66, pt. 2, p. 959, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 169, or Bull. Soc. Chim. (1895) [3] 13, p. 1065.
 HENRY. A propos du carbure de glucinum. C. R. (1895) 121, p. 600, also Bull. Soc. Chim. (1896) [3] 15, p. 165.

IRIDIUM AND CARBON.

IrC_4 results by heating thin strips of iridium in the alcohol flame. The product forms a velvet-black coating. It is inflammable, and burns, leaving a residue of Ir. The oxide of Ir heated in the presence of some hydrocarbons yields IrC_4 , with a display of incandescence. (Berzelius.)

LITERATURE.

- BERZELIUS. Einige nachträgliche Beobachtungen über das Ir und das Os. (Pogg.) Ann. der Phys. 15, p. 208.
 GMELIN. (Watt's transl.) Handbook of Chemistry (1849), VI, p. 375.
 BERZELIUS. Lehrbuch der Chemie (1836), III, p. 223. *See also*,
 MOISSAN. Sur la solubilité du carbone dans le rhodium, l'iridium, et le palladium. C. R. 123, p. 16, or Bull. Soc. Chim. (1896) [3] 16, p. 1292.
 MOISSAN. Research on the metallic carbides. Chem. News (1896), 74, p. 15.

IRON AND CARBON.

The subject of carbon in iron and steel has been extensively discussed, but not always from a chemical standpoint. The mechanical effect of carbon in iron and steel is studied often without taking into consideration

the condition in which that carbon exists ; but the carbides of iron, as such, — as definite chemical compounds, have not been so widely written upon. The point of view from which the subject is often studied seems so different from the view in which the other carbides are here considered, that we do not feel justified in going into the literature exhaustively from all standpoints, yet the references given below cover a broad consideration of the subject.

A great many compounds of Fe and C have been mentioned by different chemists, but the existence of some of them is doubtful. Some of these are Fe_{24}C , Fe_3C , Fe_4C , Fe_3C , Fe_2C_3 , and Fe_2C , beside some compounds of three or more elements, such as $\text{Fe}_7(\text{CrMo})_3\text{C}_4$, $\text{Fe}_7(\text{CrW})_3\text{C}_4$ and $\text{Cr}_2\text{Fe}_7\text{C}_3$, and Cr_3FeC_2 .

Fe_4C is a dark-gray, fusible crystalline substance, formed directly from Fe and C at a high temperature. The formula Fe_{24}C has been given to high carbon steel.

Fe_3C occurs in all kinds of malleable iron, and remains behind after treating the iron with a 10% H_2SO_4 solution, the operation being conducted with the air excluded. That the subject of carbon in iron has been long studied will be seen from the following references. Many of these are of little value to those studying the chemistry of steel, etc., and having the advantages of access to the modern reports upon the subject. We arbitrarily divide the literature into the old and the recent.

LITERATURE (OLD).

- GUYTON. Versuche mittelst des Diamanten das geschmeidige Eisen in Guss-stahl zu verwandeln. (Gilb.) Ann. der Phys. (1800) 3, p. 65.
- FARADAY and STODART. Versuche über die Legirungen des Stahls. (Gilb.) Ann. der Phys. (1820) 66, p. 183.
- BERTHIER. Ann. Mines (1833), III, p. 229.
- BERZELIUS. Lehrbuch der Chemie (1836), III, p. 450, and (1844), II, p. 732.
- BROWN. J. prakt. Chem. (1839) 17, p. 492.
- KARSTEN. [Fe_4C] Ueber die Carburets des Eisens. J. prakt. Chem. (1847) 40, p. 229.
- RAMMELSBERG. [FeC_2] Ueber das Verhalten der Cyanmetalle in der Hitze. Chem. Centrbl. (1847) p. 59.
- MARGUERITE. Carburation du fer par contact ou cementation. C. R. 59, p. 139.
- GMELIN. (Watt's trans., 1849) Handbook of Chemistry, V, p. 202.
- VALERIUS. [FeC_2 and Fe_2C_3] Fabrication de la fonte et du fer (1851), I, p. 41.
- GURLT. [Fe_3C] Polyt. Centrbl. (1856) p. 366, or Chem. Centrbl. (1856) p. 273, or Jsb. Chem. (1856) p. 781, Chem. Gaz. (1856) p. 230.
- TUNNER. Polyt. Centrbl. (1861) p. 1227.
- ARNOLD. [Fe_{24}C] Bull. Soc. d'Enc. Ind. Nat. (5) 1, p. 97.

LITERATURE (RECENT).

- TROOST and HAUTEFEUILLE. Etude calorifique sur les carbures de fer et de manganèse. Ann. de Chim. (5) 9, p. 56, or C. R. (1875) 80, p. 964.
- DROWN. Condition of carbon in white and gray iron. Trans. Am. Inst. M. Eng. III, p. 41.
- PEARCE. Iron and carbon, mechanically and chemically considered. Trans. Am. Inst. M. Eng. IV, p. 157.

- ABEL. Proc. Inst. Mech. Eng. (1883) p. 56, also (1885) p. 30, also Reports of Iron and Steel Inst. (1881, 1883).
- BARUS and STROUHAL. The electrical and magnetic properties of iron carburets. Bull. 14, U. S. Geol. Sur. (1885) and School Mines Q. VII, p. 24.
- BARUS and STROUHAL. Physical properties of iron carburets. Bull. 35, U. S. Geol. Sur. (1886).
- OSMOND and WERTH. Ann. Mines (1885), and Eisen und Stahl (1886), p. 376.
- ABEL. Eisen und Stahl (1886) p. 373.
- MÜHLER. Grundzüge einer Theorie des Stahls. Eisen und Stahl (1890), VIII, p. 291.
- WEDDING. Eisen und Stahl (1891), IX.
- LEDEBUR. Ueber das Benennung des verschiedenen Kohlenstoffformen in Eisen. Eisen und Stahl (1888), VIII (Nov.).
- DUDLEY and PEASE. Carbon combined in cast-iron. Trans. Am. Inst. M. Eng. XIV, p. 797.
- LEDEBUR. J. Iron and Steel Inst. (1893) no. 2, p. 53.
- OSMOND. Microscopic metallography. Trans. Am. Inst. M. Eng. (1893) 22, p. 252.
- CHARPY. Sur le rôle des transformations du fer et du carbone dans le phénomène de la trempe. C. R. 118, p. 1258, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 420. *See also* p. 451.
- MOISSAN. Déplacement du carbone par le bore et le silicium dans la fonte en fusion. C. R. (1894) 119, p. 1172.
- MOISSAN. Etudes des graphites du fer. C. R. (1894) 119, p. 1245, or Abs. J. Chem. Soc. (1895) 68, pt. 2, p. 220, or Bull. Soc. Chim. (1895) [3] 13, p. 811.
- ARNOLD and READ. The chemical relations of carbon and iron. J. Chem. Soc. 65, p. 788, or Bull. Soc. Chim. (1895) [3] 14, p. 5.
- JUPTNER. Arten des gebundenen Kohlenstoffs. Oesterr. J. Berg- u. Hüttenwesen, 44, p. 211, or Chem. Centrbl. (1896) 67, pt. 1, p. 1094.
- CAMPBELL. A pure carbide of iron. Am. Chem. J. (1806) 18, p. 836.

See also the following:—

- MENDELEEF. Principles of Chemistry, I, p. 365.
- NERNST. (Palmer's Trans.) Theoretical Chemistry, p. 146.
- DAMMER. Anorganische Chemie, III, p. 354.
- PROST. Bull. de l'Académie Royale des Sciences de Belgique, XVI, p. 216.
- MORVEAU and CLOUET. (Scherer's) Allg. J. Chem. 4, p. 170.
- HADFIELD. Iron alloys with special reference to manganese steel. Trans. Am. Inst. M. Eng. (1893) 23, p. 156.
- DE BENNEVILLE. Two definite carbides of iron with Cr (Mo and W), $[\text{Fe}_7(\text{CrMo})_8\text{C}_4$ and $\text{Fe}_7(\text{CrW})_6\text{C}_4]$. J. Am. Chem. Soc. 17, p. 791, or Chem. Centrbl. (1895) 66, pt. 2, p. 1068, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 175.
- DE BENNEVILLE. A study of some alloys with iron carbides, mainly tungsten and manganese. Jour. of the Iron and Steel Inst. (1896) no. 1.

LANTHANUM AND CARBON.

C_2La has been made from lanthanum oxide and sugar-carbon. These heated for ten minutes in the electric furnace under the action of a current of 350 amp. and 50 volts combine to form yellow crystals, sp. gr. 5.02. This carbide is decomposed by water, yielding C_2H_2 , CH_4 , C_2H_4 , and leaving a residue of fixed hydrocarbons. The carbide appears golden yellow on a fresh fracture. It is attacked by the atmospheric moisture Pettersson gives H_2 and C_2H_2 as the decomposition products.

LITERATURE.

- O. PETERSSON. Kohlenstoffverbindungen von den Metallen der seltenen Erden. Ber. d. Chem. Ges. (1895) 28, p. 2419, or Chem. Centrbl. 66, pt. 2, p. 960, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 25.
- MOISSAN. Etude du carbure de lanthane. C. R. 123, p. 148, or Zeitschr. Elektrochem. (1896) III, p. 108, or Chem. Centrbl. (1896), pt. 1, p. 731, or Bull. Soc. Chim. (1896) [3] 16, p. 1293.

LEAD AND CARBON.

Certain old chemistries mention the existence of a compound of lead and carbon. No carbide of lead has been made as yet in the electric furnace, and the same is true of tin, bismuth, and gold.

LITERATURE.

- GMELIN. Handbook of Chemistry (Watt's translation), V, p. 122.
- JOHN. Berlinisches Jahresbericht der Pharmacie (1820) p. 320.
- BERZELIUS. Lehrbuch der Chemie (1836), III, p. 361.
- BROWN. J. prakt. Chem. (1839) 17, p. 492.

LITHIUM AND CARBON.

This carbide has been but recently made. Its formula is Li_2C_2 . $\text{LiCO}_3 + 4\text{C}$, heated for ten minutes, using a current of 350 amp. and 50 volts, will yield it, or with 950 amp. it may be made in four minutes. A higher temperature than this current produces in the furnace either volatilizes or decomposes this carbide. Li_2C_2 forms shining crystals, sp. gr. = 1.65 at 18°C . Decomposed by moist air and water, C_2H_2 being formed. It is easily broken up and is not so hard as glass. Burns in the cold in Cl or Fl, and by gentle heating in Br or I. Concentrated acids have little effect upon it. In hot water the decomposition is quite violent.

LITERATURE.

- MOISSAN. Sur le carbure de lithium. C. R. 122, p. 362, or Chem. Centrbl. (1896) 67, pt. 1, p. 685, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 419.
- MOISSAN. Errata se rapportant à cette communication. C. R. (1896) p. 496.

MAGNESIUM AND CARBON.

In Dammer's Anorg. Chem. it is stated that magnesium heated in benzol vapors yields a dark mass of this composition, MgC_2 . No such compound has been made in the electric furnace. The reference given does not mention a definite compound of Mg and C.

LITERATURE.

- PARKINSON. Behavior of magnesium with non-metallic elements. J. Chem. Soc. (London) (1867) vol. 20, p. 125.
- GMELIN-KRAUT. (?)
- DAMMER. Handbuch der anorganischen Chemie, Vol. II, 2 (1893).

MANGANESE AND CARBON.

Troost and Hautefeuille are the discoverers of the carbide whose formula is Mn_3C . This carbide was also produced by Moissan; he stated that with a current of 900 amp. and 50 volts the reduction is practically instantaneous, while with the same voltage and 350 amp. only five to six minutes' heating is necessary. Mn_3C has a sp. gr. of 6.89. Fl attacks it cold and Cl by gentle heating. It burns in oxygen at a low temperature. When decomposed by water there result equal parts of CH_4 and H_2 . The equation is:—



No fluid or liquid hydrocarbons are produced. In some early references mention is made of MnC and Mn_2C .

LITERATURE.

- BROWN. [MnC] Ueber Kohlenmetalle. J. prakt. Chem. (1839) 17, p. 492.
 GMELIN. [Mn_2C and MnC] Handbook of Chemistry (Watt's trans., 1849), IV, p. 213.
 GMELIN-KRAUT. [Mn_2C] (1882) II, 2.
 MENDELEEF. Principles of Chemistry, I, p. 65 (note 19); II, p. 112-3.
 TROOST and HAUTEFEUILLE. [Mn_3C] Etude calorifique sur les carbures de fer et de manganèse. Ann. de chim. (1876) [5] 9, p. 60, or Jsb. Chem. (1876) p. 87, and C. R. (1875) 80, p. 964, and Sur les fontes manganésifères, C. R. (1875) 80, p. 909.
 ARNOLD and READ. Trans. J. Chem. Soc. (London) (1894) 65, p. 788.
 DE BENNEVILLE. A study of some alloys with iron carbides. J. Iron and Steel Inst. (London) (1896) no. 1.
 MOISSAN. Sur la préparation rapide du chrome et du manganèse à haute température. Bull. Soc. Chim. (1894) [3] 11, p. 13.
 MOISSAN. Sur le carbure de manganèse [Mn_3C]. C. R. (1896) 122, p. 421, or Bull. Soc. Chim. (1896) [3] 16, p. 1266; Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 423, and Chem. Centrbl. (1896) 67, pt. 1, p. 741.

MERCURY AND CARBON.

A mercury acetylid is formed in several ways. It results as a heavy white powder by passing C_2H_2 through freshly precipitated mercuric oxide suspended in water. Several days are required to prepare it. Sp. gr. = 5.3. Insoluble in H_2O , alcohol, and ether. Slowly decomposed by gradual heating above 110° into Hg and C. The compound explodes by rapid heating or by a blow. Its formula seems to be $3HgC_2 + H_2O$. Keiser gives HgC_2 .

LITERATURE.

- PLIMPTON and TRAVERS. Metallic derivatives of acetylene. J. Chem. Soc. (London) 65, p. 264. See also
 BERTHELOT. Ann. de chim. [4] 9, p. 386.
 BASSET. Chem. News, 19, p. 28.
 KEISER. Am. Chem. J. 15, p. 535. See also
 KUTSCHEROW. Ber. d. Chem. Ges. 17, p. 13.

MOLYBDENUM AND CARBON.

Mo_2C is best prepared by heating together 5 pts. MoO_2 and 1 pt. C for eight to ten minutes in a carbon crucible. 800 amp. and 50 volts is sufficient current. The carbide shows a brilliant, crystalline fracture, exhibits easy cleavage; sp. gr. 8.9. If this carbide is heated with an excess of molybdenum dioxide, molybdenum is produced, and inversely, fused molybdenum readily takes up considerable carbon.

LITERATURE.

- MOISSAN. Préparation au four électrique de quelques métaux réfractaires; tungstène, molybdène, vanadium. C. R. 116, p. 1225, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 471, or Bull. Soc. Chim. [3] 11, p. 857.
- MOISSAN. Préparation et propriétés du molybdène pur fondu. C. R. (1895) 120, p. 1320, or Abs. J. Chem. Soc. (1895) 68, pt. 2, p. 497, or Bull. Soc. Chim. (1895) [3] 13, p. 967.

NICKEL AND CARBON.

Nickel and carbon act in many ways like iron and carbon. By heating $4\text{Ni}(\text{CN})_2 + 3\text{H}_2\text{O}$ under proper conditions carbon-containing nickel results. (See Dammer.) When carbon monoxide is passed over finely divided nickel at a temperature between 300° and 350°C , there results a black powder consisting of Ni and C, varying with the temperature at which the operation was conducted. Ni is said to act in the same way with certain hydrocarbon gases.

LITERATURE.

- DÖBEREINER. N. J. der Pharm. [Trommsdorff, 1820 (?)] 4, pp. 1 and 293.
- ROSS and IRVING. Ann. Phil. (1862) p. 149.
- MOND, LANGER and QUINCKE. [Action of CO on Ni] Trans. J. Chem. Soc. (1890) vol. 57, p. 749, Chem. News (62) p. 97.
- See also GAUTIER and HALLOPEAU. C. R. (1889) 108, p. 1111.
- MOND and LANGER. D. R. P. 51,572, 14/6, 1889; Patentblatt (11), p. 356; Chem. Centrbl. (1890) II, p. 32.
- MOISSAN (foot-note). Bull. Soc. Chim. (1894) [3] 11, p. 13.

PALLADIUM AND CARBON.

According to Moissan palladium forms no carbide in the electric furnace. Other chemists mention a carbide of palladium.

LITERATURE.

- WÖHLER. Ueber die Wirkung des Palladium auf die Weingeist Flamme. (Pogg.) Ann. der. Phys. 3, p. 71. See also
- II. B. MILLER. Ann. Phil. 28, p. 20, and
- BERZELIUS. Lehrbuch der Chemie (1836), III, p. 249, and
- MOISSAN. Sur la solubilité du carbone dans le rhodium, l'iridium et le palladium. C. R. 123, p. 16, or Bull. Soc. Chim. (1896) [3] 16, p. 1292.
- MOISSAN. Research on the metallic carbides. Chem. News, 74, p. 15.

PLATINUM AND CARBON.

No platinum carbide has been produced by Moissan in his electric furnace. Pt at that temperature takes up some carbon, but upon cooling gives it up as graphite and without forming a definite compound. PtC_2 is mentioned in a number of chemical publications, as is also PtS_2C . This platinum sulphocarbide is produced by leading a stream of H or N saturated with CS_2 vapors over spongy platinum at a temperature somewhat below dark red heat. The product is black and finely divided, neither HCl or HNO_3 attacks it and aqua regia is almost without effect. Heated in a stream of oxygen, SO_2 , CO_2 , and Pt result.

LITERATURE.

- ZEISE. [PtC_2] Ueber Acechlorplatin, nebst Bemerkungen uber einige andere Products der Einwirkung zwischen Platinchlorid und Aceton. J. prakt. Chem. (1840) 20, p. 209.
- GMELIN. (Watt's trans., 1849) Handbook of Chemistry, VI, p. 146.
- FISCHER. Kastner's Archiv, 14, p. 148.
- SCHÜTZENBERGER. [PtS_2C] Sur un sulpho-carbure de platine. C. R. (1890) 111, p. 391.

POTASSIUM AND CARBON.

K_2C_2 is formed by the direct action of carbon and potassium at a red heat. It is decomposed by water, yielding acetylene. Davy prepared it nearly ninety years ago by means of electric heat, and described his product before a London Society in 1808. He made it from graphite and potassium by heating them together in a glass tube in an atmosphere of hydrogen. The product is described as being somewhat like graphite in appearance, infusible at red heat, taking fire in the air, potassium oxide being formed and leaving a black residue. Strongly effervescent with water, giving off a gas which Davy thought was hydrogen. This is the first carbide of which we find record. Davy repeated his experiments, using potassium and willow charcoal.

LITERATURE.

- Gilb. Ann. (1810) 35, p. 433.
- DAVY. Ueber Kohlenstoffkalium und einen neuen Doppelt-Kohlenwasserstoff. Ann. der Pharm. (1837) 23, p. 144.
- BERZELIUS. Lehrbuch der Chemie (1836), II, p. 315, and (1844), II, p. 84.
- GMELIN. (Watt's trans., 1849) Handbook of Chemistry, III, p. 17.
- BERTHELOT. Sur une nouvelle classe de radicaux métalliques composés. Bull. Soc. Chim. (1866) V, p. 182, and Ann. Chem. 139, p. 150, and Jsb. Chem. (1866) p. 514.

RHODIUM AND CARBON.

Moissan states that the metals of this group, Rd, Ir, Pd, and Pt, form no carbides in the electric furnace; for, while these metals dissolve carbon readily under such conditions, they give it up in the form of graphite upon solidifying, no carbide resulting.

LITERATURE.

- MOISSAN. Sur le solubilité du carbone dans le rhodium, l'iridium, et le palladium. C. R. 123, p. 16, or Bull. Soc. Chim. (1896) [3] 16, p. 1292; Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 609. See also Abs. J. Chem. Soc. (1893) p. 320.
- MOISSAN. Research on the metallic carbides. Chem. News (1896) 74, p. 15.

SILICON AND CARBON.

The compound of carbon and silicon known as carborundum (CSi) is of great commercial value, being a good abrasive. Its hardness is between that of corundum and the diamond. A compound is mentioned by Colson which has the formula C_2Si , and a doubtful compound C_7Si_2Al is also mentioned in chemical literature.

On a large scale carborundum is made from coke and sand, these being mixed with salt and sawdust before submitting to the electric heat. The charge is put in a long box-shaped furnace surrounding a coarse carbon core which extends between the electrodes. These are from six to eight feet apart, from one to nine carbons being in each end of the furnace. The current passes from eight to ten hours. CSi forms long needle-shaped crystals usually of a greenish-yellow color, sometimes blue. It is unacted upon by mineral acids, decomposed by fusion with alkalis, and oxidizable by $PbCrO_4$. The crystals are infusible except in the electric arc. An amorphous product of about the same composition is formed at some distance from the carbon core and beyond the zone in which the crystalline product is found.

The patents for making carborundum are owned by Mr. Acheson in this country and in a number of European countries. It is found to be very useful as an abrasive, and its introduction into the mechanical arts has been rapid.

The di-carbide of silicon, of Colson, is made by passing a stream of C_2H_4 or H_2 saturated with benzine vapors over silicon for several hours. The silicon is contained in a porcelain tube and heated to a bright heat during the conduction of the gas. SiC_2 is decomposed by KOH or by a mixture of $PbCrO_4$ and PbO , but is not acted upon even at red heat by acids, oxygen, or chlorine.

Tetra-silico-carbo-sulphide, Si_4C_4S , is formed by conducting CS_2 vapors over white-hot silicon contained in a porcelain vessel. Other products are produced at the same time, and hence the contents of the dish are treated with hot KOH solution, and with HF. After this treatment the above compound remains as a greenish powder, decomposable by boiling HF, H_2S being evolved. It oxidizes to Si_2C_2O .

Silicon nitro-carbide (C_2Si_2N) results when Si is heated in the presence of C and N, or in cyanogen, or in the presence of certain carbonaceous substances in an atmosphere of nitrogen.

LITERATURE (CSi).

- GMELIN. (Watt's trans., 1849), Handbook of Chemistry (CSi), III, p. 359.
- SCHÜTZENBERGER. Contributions à l'histoire des composés carbosiliciques. C. R. (1892) 114, p. 1089.
- ACHESON. Production of artificial crystalline carbonaceous materials. U. S. pat. 492,767 (Feb. 1893). Reissue, 11,473, Feb. 1895.
- ACHESON. D. R. P. 76,629.
- ACHESON. Carborundum, Its History, Manufacture and Uses. J. Frankl. Inst., Sept. 1893.
- ACHESON. Oesterr. Ztschr. f. Berg- u. Hüttenwesen (1894), 421, p. 115.
- MOISSAN. Sur la volatilisation de la silice et de la zircone et sur la réduction de ces composés par le charbon. C. R. (1893) 116, p. 1222, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 532.
- MOISSAN. Préparation et propriétés du silicium de carbone cristallisé. C. R. (1893) 117, p. 425, or Bull. Soc. Chim. [3] 11, p. 995, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 43, or Chem. Centrbl. (1893) pt. 2, p. 909.
- MOISSAN. Action de l'arc électrique sur le diamant, le bor amorphe, et le silicium cristallisé. C. R. 117, p. 423, or Chem. Centrbl. (1893) 64, pt. 2, p. 909, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 42, or Bull. Soc. Chim. [3] 11, pp. 863 and 993.
- MOISSAN. C. R. (1895) p. 1393, or Abs. J. Chem. Soc. 68, pt. 2, p. 497.
- MÜHLHÄUSER. On carborundum. J. Am. Chem. Soc. (1893) 15, p. 411.
- MÜHLHÄUSER. Ztschr. angew. Chem. (1893) p. 484; (on analysis of CSi) p. 641.
- MÜHLHÄUSER. Ztschr. anorg. Chem. 5, p. 105, or Chem. Centrbl. (1893), 64, pt. 2, p. 933, or Abs. J. Chem. Soc. (1894) 66, pt. 2, p. 42.
- MATHEWS. Carborundum; Its history, physical properties, and chemistry. School Mines Q. (N. Y.) (1894) v. 16, or Am. Drug. and Pharm. Rec. (1895) or J. Soc. Chem. Ind. (1895) 14, p. 755.
- VOLKMANN. Das Carborundum. Oesterr. Ztschr. f. Berg- u. Hüttenwesen (1894), 42, p. 7 and p. 115.
- BECKE. Beitrag zur Kenntniss der Carborundumkrystalle. Ztschr. Krystall. 24, p. 537, or Chem. Centrbl. (1895) 66, pt. 2, p. 959.
- LURMAN. Siliciumkohlenstoff u. Ferrosilicium. Ztschr. Elektrochem. (1896) III, p. 113.
- MOISSAN. Ann. de Chim. [7] 9, p. 289, or Chem. Centrbl. (1896) pt. 2, p. 1080.
- See also these:—*
- KUNZ. (Note on hardness) Am. J. Sci. 46, p. 471.
- ROTHWELL. (Statistics of production) Mineral Industry (N. Y. 1893).
- HALLER. L'Industrie chimique (Paris, 1895), p. 332.
- Ztschr. Angew. Chem. (1894) p. 118.
- ACHESON. Electric furnace, U. S. pat. 560,291, May 19, 1896.
- DAMMER. (C₇Si₂Al?) Handbuch der anorganischen Chemie, II, 1, p. 546.
- COLSON. (C₂Si) Bull. Soc. Chim. (1882) [2] 38, p. 56, or Jsb. Chem. (foot-note) (1882) p. 257.
- COLSON and SCHÜTZENBERGER. (C₂Si₂N) Sur le Silicium. C. R. (1881) 92, p. 1508, or Jsb. Chem. (1881) p. 202.
- COLSON. (Si₄SC₄) Sur de nouveaux composés carbosiliciques. C. R. (1882) 94, p. 1316.
- COLSON. Action du sulfure de carbone sur le silicium. C. R. (1882) 94, p. 1526, or Bull. Soc. Chim. (1882) [2] 38, p. 56.

SILVER AND CARBON.

Gay-Lussac states that when silver is melted with lamp-black in a crucible, about three per cent. of carbon is taken up and Ag₃C is formed. Ag₂C results by heating the silver salt of cuminic acid [C₆H₄(C₃H₇)(COOAg)],

in an open dish. It is a yellowish substance, not decomposed by heat. It contains 5.52% C, which remains when this carbide is treated with HNO_3 (Gerhardt and Cahours).

Ag_2C_2 is said to result by long heating of the silver salt of pyrrocemic acid ($\text{CH}_3\text{COCOOAg}$). It is a gray powder of metallic appearance, containing about 10.51% C. The same compound results from the silver salt of maleic acid [$\text{C}_2\text{H}_2(\text{COOAg})_2$]. This carbide is produced by passing acetylene gas through ammoniacal silver solutions. It is very unstable and difficult to work with. See Keiser's and Plimpton's work.

LITERATURE.

- BROWN. *J. prakt. Chem.* (1839) 17, p. 492.
 LIEBIG and REDTENBACHEN. [Ag_2C] Ueber das Atomgewicht des Kohlenstoffs. *Ann. Chem.* 38, p. 129.
 BEHAL. *Bull. Soc. Chim.* 49, p. 335, and *Ber. d. Chem. Ges.* 21, ref. 609.
 BERZELIUS. (Foot-note) *Pogg. Ann. der Phys.* 36, p. 28.
 GERHARDT and CAHOURS. (?)
 GAY-LUSSAC. (?)
 BEREND. [C_2Ag_2] Ueber einiger neue Derivate des Acetylens. *Ann. Chem.* 135, p. 257.
 REGNAULT. (Maleic acid) Untersuchung einiger ihrer Salze. *Ann. der. Pharm.* 19, p. 153.
 PLIMPTON. On silver acetylide. *Proc. J. Chem. Soc.* (1892) p. 109.
 KEISER. *Am. Chem. J.* 14, p. 285, or *Abs. J. Chem. Soc.* 62, p. 1416; see also *Ann. Chem.* 118, p. 330.

SODIUM AND CARBON.

C_2HNa and C_2Na_2 result by passing acetylene gas over sodium at a dark red heat. C_2Na_2 is decomposed by water yielding acetylene.

LITERATURE.

- BERTHELOT. Sur une nouvelle classe de radicaux métalliques composés. *Bull. Soc. Chim.* (1866) V, p. 182, and *Ann. Chem.* 139, p. 150, and *Jsb. Chem.* (1866) p. 514.
 FORGRAND. Chaleur de formation de l'acétylure de sodium. *C. R.* 120, p. 1215, and *Bull. Soc. Chim.* (1895), [3], 13, p. 996.

STRONTIUM AND CARBON.

SrC_2 forms under about the same conditions obtaining in the production of Ca or Ba carbides. It forms a dark mass, with yellowish fracture; sp. gr. = 3.19; with dilute acids and water it decomposes, giving off chiefly acetylene. Reacts with halogens, oxygen, and sulphur at high temperatures, but not with nitrogen, silicon, or boron. Both SrO and SrCO_3 have been used in making SrC_2 , and a current of 350 amp. and 70 volts employed.

LITERATURE.

- MOISSAN. Etude des acétylures cristallisés de baryum et de strontium. *C. R.* 118, p. 683, or *Bull. Soc. Chim.* [3] 11, p. 1007, or *Chem. Centrbl.* (1894) 65, pt. 1, p. 856.
 BULLIER. *D. R. P.* 77,168.

THORIUM AND CARBON.

ThC_2 is made from thorium oxide, the reduction being more easily effected than is the case in preparing zirconium carbide from zircon. ThC_2 is decomposed by water, H_2 and hydrocarbons being formed. Moist air, also, slowly decomposes thorium carbide, sp. gr. = 10.15. Burns at a red heat. Concentrated acids are almost without action upon it. The gases are evolved in about the following percentages: C_2H_2 (48.44), CH_4 (27.69), C_2H_4 (5.64), and H_2 (18.23).

LITERATURE.

- TROOST. Sur la préparation du zirconium et du thorium. C. R. 116, p. 1227, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 473.
 MOISSAN et ETARD. Sur les carbures d'yttrium et de thorium. C. R. 122, p. 573, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 422, or Bull. Soc. Chim. (1896) [3] 16, p. 1271.

TITANIUM AND CARBON.

TiC is produced by heating together TiO_2 and carbon in the electric arc, but according to conditions a variety of compounds may result, some containing C, Ti, and N. A current of 1000 to 1200 amp. and 70 volts is required for this reduction. The resulting TiC has a sp. gr. = 4.25, and occurs either as a crystalline aggregate or a fused mass showing crystalline fracture. This is treated with HCl to remove titanium. The carbide takes fire at red heat, burning with so much heat as to raise it to a white heat. One of the combinations of Ti, C, and N that has been studied a good deal has this formula $\text{Ti}_{10}\text{C}_2\text{N}_8$. Joly considers this to be a mixture of TiN_2 and TiC . It was discovered in the furnace products from certain titaniferous ores.

LITERATURE (TiC).

- SCHIMMER. Titanium carbide in pig-iron. Chem. News (1887) 55, p. 156, and Ber. d. Chem. Ges. 20, ref. 361, and Jsb. Chem. (1887) p. 2522.
 * VIOLLE. L'industrie électrique (1894), III, v. 568.
 MOISSAN. Préparation et propriétés du titane. C. R. (1895) 120, p. 290, or Bull. Soc. Chim. (1895) [3] 13, p. 963.
Concerning the nitro-carbides, etc., see
 WOLLASTON. Phil. Trans. (1823) p. 400.
 SANDBERGER. Cyanstickstoff-Titan, Pogg. Ann. der Phys. (1851) 83, p. 596, or Jsb. Chem. (1851), p. 343.
 WÖHLER. Ueber die Natur des metallischen Titans. Ann. Chem. (1850) 73, p. 34.
 WÖHLER and DEVILLE. Ueber die Affinität zwischen Stickstoff und Titan. Ann. Chem. (1857) 103, p. 230, or Jsb. Chem. (1857) p. 173. *See also*
 DAMMER, Handbuch der Anorganischen Chemie.

TUNGSTEN AND CARBON.

CW_2 is made from tungstic acid with an excess of carbon, or in a carbon crucible. The carbon in excess of that required by the formula,

CW_2 , is given up as graphite on cooling. CW_2 is an iron-gray compound, very hard, not decomposed by atmospheric moisture, and of a sp. gr. = 16.06.

LITERATURE.

- MOISSAN. Préparation au four électrique de quelques métaux réfractaires ; tungstène, molybdène, vanadium. Bull. Soc. Chim. [3] 11, p. 857, and C. R. (1893) 116, p. 1225, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 471.
- MOISSAN. Recherches sur le tungstène. Bull. Soc. Chim. (1896) [3] 16, p. 1289, and C. R. 123, II. p. 13, or Ztschr. Elektrochem. (1896) III, p. 109.

URANIUM AND CARBON.

Commercial uranium oxide is purified and mixed with sugar-carbon and submitted to the action of a current of 900 amp. and 50 volts for five to ten minutes. The operation is carried on in a carbon crucible. C_3U_2 is the product ; crystalline ; sp. gr. = 1128 ; harder than quartz but not as hard as corundum. This carbide is peculiar in its decomposition with water. The reaction must be quite complex, for the products are : H_2 , C_2H_2 , CH_4 , and beside these there are produced hydrocarbons, liquid and solid, boiling between 70° and $200^\circ C$. Some of these are unsaturated bodies which will reduce alkaline silver solutions. After distilling off the hydrocarbons mentioned above, a bituminous residue remains. U_2C_3 burns in Fl by gently heating, also in Cl, O, N_2O_4 , and Br, at temperatures between 350° and 390° .

LITERATURE.

- MOISSAN. Etude du carbure d'uranium. C. R. 122, p. 274, or Bull. Soc. Chim. [3] 11, p. 11, or Chem. Centrbl. (1896) 67, pt. 1, p. 640, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 364.
- BULLIER and BIGNON. D. R. P. 77,166, and Ztschr. Angew. Chem. (1894) p. 655.

VANADIUM AND CARBON.

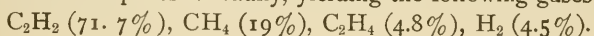
Vanadium anhydride and sugar-carbon subjected to the action of a current of 900 amp. and 50 volts for nine to ten minutes in the electric furnace yield VaC ; a beautifully crystalline compound, sp. gr. = 5.36, harder than quartz, attacked by HNO_3 in the cold. It burns vigorously in oxygen at a dull red heat. Becomes incandescent if heated to 500° in an atmosphere of Cl.

LITERATURE.

- MOISSAN. Préparation au four électrique de quelques métaux réfractaires ; tungstène, molybdène, vanadium. C. R. 116, p. 1225, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 471, or Bull. Soc. Chim. [3] 11, p. 857.
- MOISSAN. Etude de la fonte et du carbure de vanadium. C. R. 122, p. 1297, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 608, or Ztschr. Elektrochem. (1896) III, p. 92, or Bull. Soc. Chim. (1896) [3], 16, p. 1278.

YTTRIUM AND CARBON.

Pettersson first made this carbide, YC_2 . It has a specific gravity of 4.13. This carbide is golden yellow on a fresh fracture, but remains so only a short while, as the moisture of the air attacks it. The halogens act upon it in the cold. Readily attacked by acids. Burns in oxygen and in the vapors of sulphur and selenium. In making YC_2 in the electric furnace more heat is required than is necessary in the preparation of cerium carbide. A current of 900 amp. and 50 volts effects the reduction in about six minutes. Vapors of the metal are given off during the operation. Water decomposes it readily, yielding the following gases:—



LITERATURE.

- O. PETERSSON. Kohlenstoffbindungen von den Metallen der seltenen Erden. Ber. d. Chem. Ges. 28, p. 2419, or Bull. Soc. Chim. (1896) [3] 15, p. 101, or Chem. Centrbl. (1895) 66, pt. 2, p. 960, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 25.
 MOISSAN et ETARD. Sur les carbures d'yttrium et de thorium. Bull. Soc. Chim. (1896) [3] 16, p. 1271, or C. R. 122, p. 573, or Abs. J. Chem. Soc. (1896) 70, pt. 2, p. 422.

ZINC AND CARBON (?)

A compound of zinc and carbon is of doubtful existence although mentioned in old books on chemistry.

LITERATURE.

- BERZELIUS (and Gmelin-Kraut), 6th ed. 3, 2, 11.
 GMEIN. Handbook of Chemistry (Watt's translation) (1849), V, p. 13.
 BROWN. J. prakt. Chem. (1839) 17, p. 492.

ZIRCONIUM AND CARBON.

ZrC is produced by heating for ten minutes anhydrous ZrO and sugar-carbon. A current of 1000 amp. and 50 volts was used by Moissan. Gray metallic appearance, scratches quartz, not decomposed by damp air at 100° . In this it differs from the thorium compound. Burns brilliantly in oxygen at a dull red heat. ZrC_2 is also known (Troost).

LITERATURE.

- BERZELIUS. Kohlenstoffzirconium. Pogg. Ann. der Phys. (1825) 4, p. 123.
 GMEIN. (Watt's trans., 1849.) Handbook of Chemistry, III, p. 343.
 TROOST. (ZrC_2) Sur la préparation du zirconium et du thorium. C. R. 116, p. 1227, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 473.
 MOISSAN. Sur la volatilization de la silice et de la zircone et sur la réduction de ses composés par le charbon. C. R. 116, p. 1222, or Abs. J. Chem. Soc. (1893) 64, pt. 2, p. 532, or Bull. Soc. Chim. [3] 11, p. 863.
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AUTHOR'S INDEX.

[Following each author's name is given a list of all the elements to the literature of whose carbides he has contributed.]

- ABEL. Fe, 19.
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- Barus. Fe, 19.
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