

tained by the employment of sulphuret of carbon. He proposes to crush the bones almost to powder; then to treat them with this agent, which almost instantly dissolves all the grease contained in them; and from this it may be separated by distillation, which is greatly facilitated by the low temperature at which this fluid boils, and the ease with which it may be condensed. The quantity of grease thus obtained is 10 or 12 per cent., and it is superior to that procured by boiling.

He adds, that the same agent may be applied to the extraction of oils from oleaginous seeds and of the grease from wool. In the latter case the grease extracted becomes a useful product; it is a butyraceous substance, adapted for the manufacture of some kinds of soap.—*Comptes Rendus*, February 4, 1856, p. 207.

*On the Compounds of Carbon and Iron, and their Influence on the Production of Pig Iron.** By A. GURLT.

The compounds of iron with carbon, which are of such great importance in the commercial production of iron, inasmuch as, owing to the very difficult fusibility of pure iron, it would be impossible to obtain the metal without them on the large scale, belong to that class of chemical compounds in which several atoms of the electro-positive constituents are united to one atom of the electro-negative body; they may therefore be considered as subcarburets analogous to certain combinations of iron with sulphur. The tetracarburet, as it occurs most frequently in the white crystalline pig iron (*spiegeleisen*) or specular iron, and the varieties related to it, has long been familiar to us from the researches of Karsten. In it the iron is completely saturated with carbon, and cannot be made to take up more by prolonged fusion with charcoal. In its pure state it consists of 94.88 parts of iron, and 5.12 carbon, corresponding to the formula Fe^4C . In this compound the whole of the carbon is chemically combined with the iron; it is rarely met with however in a state of absolute purity. In general it contains, in addition to iron and carbon, a variable amount of manganese, occasionally amounting to 6 per cent. As it is most frequently obtained from ores containing much manganese, on the other hand it usually contains a rather larger amount of carbon than the pure tetracarburet. As, however, the manganese replacing the iron in this compound possesses a lower atomic weight than the iron, a certain weight of manganese will combine with a larger amount of carbon than an equal weight of iron; and the amount of carbon which may exist in it without exceeding the maximum for the pure tetracarburet, will depend on the proportion of manganese existing in the specular cast iron.

The pure tetracarburet of iron possesses a specific gravity of 7.65 to 7.66, a silver white color, great hardness, is very brittle, and is commonly crystalline, although its form is of very difficult determination. According to Karsten and Hausmann, it does not belong to the cubic system, but the crystals consist of oblique prisms, among which an oblique terminal plane can occasionally be discovered, so that it would rather appear to belong to the oblique system. The crystals are most frequently tabular, and then appear to be merely rudimentary, intersect-

ing one another at indefinite angles. Mitscherlich observed an angle of 120° ; Rammelsberg one of 116° , also of 130° to 131° ; and the author found in a specimen from Silesia, angles belonging to oblique prisms measuring respectively 128° to 129° and 52° to 53° ; still the primitive form cannot with certainty be determined from these measurements. The fracture is highly radiate crystalline, and frequently exhibits cavities between the crystalline laminae. The specular iron is the most fusible of all the combinations of iron with carbon. Its melting-point is about 1600°C. , and it becomes solid without previously assuming a thick pasty condition.

The octocarburet of iron, Fe^8C , does not appear to have been recognised hitherto, although it not frequently occurs crystallized in gray pig iron, never, however, in white pig iron. It is distinguished from the tetracarburet not only by its chemical composition, but also very distinctly by its crystalline form and its other physical properties. The crystals which were observed by Karsten, but not further examined, belong to the regular or cubic system, and almost always appear in the form of confused octohedral groups, with the planes not well defined, but the angles occasionally sharp.

The author examined a piece of such crystallized cast iron from the works of Gleiwitz, in Upper Silesia, found in the core of a cast iron gun. It presented the following composition:—

Carbon	.	.	.	.	.	.	2.46
Graphite	.	.	.	.	.	.	2.84
Silicium	.	.	.	.	.	.	0.26
Iron	.	.	.	.	.	.	94.20
Sulphur	}	.	.	.	.	.	traces
Phosphorus							
<hr/>							99.76

The absolutely pure octocarburet of iron should contain by calculation 2.63 carbon, and 97.37 iron. In the above specimen, however, a small portion of the chemically-combined carbon was replaced, as has often been observed to be the case, by a small portion of silicium, while the graphite must be considered as mechanically mixed with the iron.

Hence the crystals examined may be considered as a mixture of a carburet of iron and siliciuret of iron, consisting of—

$$\begin{aligned} 91.548 \text{ per cent. Fe} + 2.46 \text{ C} &= 94.008 \text{ Fe}^8\text{C} \\ 2.660 \text{ per cent. Fe} + 0.26 \text{ Si} &= 2.920 \text{ Fe}^8\text{Si} \\ \text{Graphite} &= 2.840 \end{aligned}$$

99.768

In the former constituent the carbon is to the iron as 1:37.3, and in the latter the silicium is in the proportion of 1:10.0, closely agreeing with the calculated composition; and as the octocarburet so largely preponderates in this compound, one is fully justified in describing it as such.

The physical properties of the octocarburet are very different from those of the tetracarburet or specular iron; the specific gravity is=7.15, the color iron gray, the hardness and brittleness much inferior; the former is to a certain degree malleable, as it retains the impression of the hammer when struck, while the latter flies to pieces; the fusibility

of the octocarburet is less than that of the specular iron. It appears to occur frequently, its production being invariably connected with that of gray iron. The crystals are commonly found in the form of pyramids, extending to as much as two lines in thickness, often beautifully iridescent on the surfaces, in the cavities of large castings such as rolls and pieces of ordnance. These crystals, however, are not to be confounded with those regular crystals of soft malleable iron, which are sometimes produced during the oxidizing melting processes, such as refining and puddling; these latter contain no carbon, and are so free from foreign matters that they may be considered as nearly chemically pure iron.

The author believes that similar crystals to those of the octocarburet described above, have been found at the blast-furnaces at the Königshutte in Upper Silesia Ilseberg in the Hartz, Marienhutte near Zwickau, &c., which have most probably a similar composition; but he has had no opportunity of investigating them more accurately.

As the existence of two distinct subcarburets of iron may be taken as a fact, it will become important to inquire what influence they exert on the production of pig iron. The several varieties of cast iron which are technically received at the iron works, may be brought into two groups, which differ from each other chiefly in their physical qualities. The first group will include all the varieties of white cast iron, which exhibit a silver-white color on the fracture, and a more or less radiate crystalline structure, together with a great degree of hardness and brittleness, and also a relatively high specific gravity = 7.2 to 7.6; and in them no graphite is ever to be distinguished by the naked eye. This group must, however, be subdivided into two subdivisions, determined by their chemical composition, the first of which will include all those varieties of white cast iron, containing a large amount of chemically-combined carbon, amounting to from 4 to 5 per cent., such as specular iron and varieties allied to it. The second subdivision includes all the descriptions of white cast iron containing smaller quantities of carbon, included in the technical term "white cast iron," but which generally contain considerable quantities of sulphur and phosphorus. In the second larger group are included all the varieties of gray cast iron in which graphite can be distinguished by the naked eye, possessing a specific gravity of 7 to 7.2, a granular structure, gray color, and greater toughness, but a less degree of hardness than the varieties of the first group. The gray cast iron must also be separated into two subdivisions, of which the mottled cast iron is the richer in carbon; the other is the gray pig iron proper, containing frequently a considerable amount of silicium. The essential constituents of all pig iron are but two, viz: iron and carbon, the latter in its modifications of graphite and chemically-combined carbon; all the other substances occurring in it may be considered as impurities. Among the electro-positive bodies, manganese is almost always present in cast iron, and at times zinc and copper, which replace an equivalent proportion of the iron; while the electro-negative substances, as sulphur, phosphorus, and silicium, replace the carbon combined with the iron. In proportion to the quantities in which these impurities are present, is their effect in modifying the physical qualities of the metal, such as its toughness and specific gravity.

Hitherto these impurities in the cast iron, which seldom amount to more than 4 per cent., have been neglected in considering its chemical constitution, although Karsten has directed attention to the influence which the electro-negative impurities exercise on the compounds of iron and carbon on fusion. As his experiments throw so much light on the formation of the carburets of iron, it may not be considered out of place here briefly to describe his results.

Karsten found that when cast iron containing the largest amount of chemically-combined carbon, Fe^4C , was melted with sulphur in a covered clay crucible, there was found, on cooling, on the surface, sulphuret of iron, under this a layer of separated carbon in the form of graphite, and under this again a mass of cast iron with the maximum of carbon, proving in a most striking manner that the chemically-combined carbon is separated at the temperature of fusion in the form of graphite from its combination with the iron, and on the other hand that carbon was incapable of decomposing the sulphuret of iron. When this experiment was varied by pouring melted gray cast iron containing only 3.93 per cent. of carbon (of which 3.311 was graphite, and 0.625 chemically-combined) on to sulphur, whose quantity was not sufficient to convert all the iron into sulphuret, or when gray cast iron was melted with sulphur, there was found under the stratum of sulphuret of iron white cast iron with maximum of carbon, the whole of which was chemically-combined with the iron; and when the amount of sulphur was slightly increased, graphite was also separated. From which it is clearly proved, that the carbon in the melted cast iron, on the addition of sulphur, is continually concentrating in that part of the iron not combined with the sulphur until the point of saturation is reached, when graphite begins to be separated.

In the strict analogy to that of sulphur is the action of phosphorus, and also of silicium, which form phosphuret and siliciuret of iron, while the carbon is concentrated in the remaining iron, or the excess separates in the form of graphite. This behavior of the electro-negative constituents of the cast iron will explain the occasional occurrence of graphite in white cast iron, and even in well characterized specular iron; and this appearance is usually to be attributed to the presence of a little silicium, which combines with the iron at a very high temperature, and decomposes a portion of the carburet of iron. In fact, a small portion of silicium is always found in the analyses of white cast iron with graphite. The uncombined carbon, however, exists in such a small proportion in white cast iron as not to be seen by the eye, but is only discovered in its chemical analyses. From the action of sulphur, phosphorus, and silicium, on the carburets of iron above described, it follows that they must be considered as chemically-combined with the iron, replacing the carbon chemically-combined with it.

It is well known that the absolute quantities of carbon are different in white and gray pig iron, even when they are prepared from the same ores and under similar circumstances, the proportion of carbon being always less in the gray than in the white cast iron. The only exceptions to this rule are the varieties of iron produced by remelting in a reverberatory furnace, by which white cast iron can be converted into gray, and *vice versa*. In such irons the altered product usually contains the same

amount of carbon as the material employed originally contained, one portion of the carbon merely passing from one modification to the other, viz: from the state of chemically-combined carbon to that of graphite when the product is gray, or from graphite to chemically-combined carbon when the product is white. In gray pig iron a large proportion of its carbon is not in a state of chemical combination, that is to say, it is in the form of graphite; with white cast iron this is very rarely the case, and those rare cases existing in very minute degree. It was mentioned above, that the conversion of the chemically-combined carbon into graphite was effected by the decomposition of the tetracarburet by sulphur, silicium, and phosphorus; there is, however, another method of separating the carbon from the tetracarburet in the form of graphite, that is, by heat.

It is known from experience that white pig iron may be converted into gray, causing a separation of carbon in the form of graphite, by exposing it to a degree of heat much above that required to effect its fusion; specular iron may even be converted into gray cast iron in this way; now this can only take place when its composition, as tetracarburet is destroyed, and it passes to some lower degree of carburization, setting free carbon as graphite. This high degree of temperature therefore effects this decomposition of the tetracarburet, and slow cooling favors the separation in large flakes; but even when this cooling is rapidly effected, the pig iron contains an equal quantity of graphite, which may be determined by chemical analysis, but which is difficult to be detected by the eye, from its being disseminated in minute particles throughout the mass, and for this reason a gray cast iron rapidly cooled appears to the eye like white cast iron. The degree of heat above that of its fusing point necessary to convert completely the specular iron into gray iron, has not been ascertained with accuracy, owing to the difficulty of measuring such high degrees of temperature; so much experience has taught, however, that in order to obtain gray pig iron, the temperature of the furnace must range far above the fusing point of specular iron.

As the absolute, as well as the relative quantity of carbon in the several varieties of cast iron is different, it may be asked whether it exists in any definite proportion to the iron not combined with any other electro-negative substance. With regard to white cast iron, the view is held that the combined carbon is united to the whole mass of the iron, though not in definite proportions. With regard to gray cast iron, however, it has been assumed that only a proportionally small quantity of the iron was chemically united to the carbon, forming a carburet, which was held in solution as it were in the remainder of the iron which existed in the state of malleable iron; still this soft iron was not to be considered altogether free from carbon, but to contain a minute quantity of carbon combined with it in the same manner as in bar iron. Against this view, which even yet has many supporters, it may be urged, that although it certainly is possible for carburetted iron to dissolve soft iron, as in the natural steel refinery and in the fabrication of cast steel; still the product is steel and not pig iron, and that its production depends upon processes essentially differing in principle from those upon which the production of pig iron depends. Steel is produced under all circumstances, directly or indi-

rectly, by an oxidizing melting process, in which the separation of the sulphur, phosphorus, silicium, and also both the chemically-combined and free carbon, is so far affected by the oxygen of the air, that only a portion of the iron remains in the state of carburet, while the whole remaining mass is in the condition of soft iron. In the production of pig iron exactly the reverse occurs; the melting process is a reducing one, in which the iron is exposed to the action of a large excess of carbon and carburetted gases in the most intimate contact. If it be now considered that the affinity of iron for carbon at high temperatures is very powerful, as the process of cementation sufficiently proves, it must necessarily be admitted that if by any chance soft malleable iron should be present in gray pig iron, it must necessarily unite with carbon to pass again into a combination of iron and carbon, for it is impossible it could exist uncombined under the influence of the reducing gases of the furnace in the presence of the graphite, always intimately mixed with the gray iron.

While therefore we are forced to admit that the iron never exists in pig iron in the condition of malleable iron, but must always be, throughout its whole mass, in a state of combination with the electro-negative constituents, as carbon, sulphur, phosphorus, and silicium, the hypothesis of the existence of a polycarburet, which Karsten and Berthier assumed in order to account for the peculiar properties of crude iron, and which, according to Berthier, would contain 18.3 per cent. of carbon, must fall to the ground, because such a polycarburet could only exist simultaneously with soft iron. But independently of this reason, the hypothesis of a polycarburet is upset by the simple fact, that iron, by taking up rather less than 6 per cent. of carbon, is already saturated; and therefore its combination with 18 per cent. is an impossibility. We may therefore consider it as proved, that the chemically combined carbon is chemically united to the whole mass of the iron not already combined with the other electro-negative substances, and that the graphite is the only mechanical admixture in pig iron. If we are no longer permitted to doubt the existence in every description of pig iron of certain definite carburets, it becomes important to know the combining proportions of the carburets from which these different varieties of cast iron have originated.

In the specular iron, the pig iron containing the largest amount of carbon, these proportions are known: they are those of the tetracarburet, which contains one atom of carbon to four of iron. With regard to the gray cast iron, it is certainly remarkable that the crystalline octocarburet described above should occur so frequently and exclusively in it; and it becomes important to seek herein a close relation between the gray cast iron and the octocarburet. In fact, the following reasons appear to warrant the conclusion, that the carburet of iron existing in gray cast iron is the octocarburet:—1st, the physical properties, as color, hardness, toughness, specific gravity, malleability, agree in both; 2d, the octocarburet occurs very frequently in gray cast iron, and separates in the crystalline form from gray cast iron only; 3d, the tetracarburet (specular iron), at a temperature much above its melting point, becomes converted completely into gray cast iron, in which the proportion of chemically combined carbon represents that of the octocarburet.

If therefore we are authorized in considering the carburet of gray cast

iron as identical with the octocarburet, and we bear in mind that gray cast iron is produced by the decomposition of Fe^4C at an elevated temperature, it becomes exceedingly probable that gray cast iron is always formed from the tetracarburet. If now the decomposition of the Fe^4C should not be complete, owing to the necessary temperature not being sufficiently protracted, it is clear that a cast iron will be produced composed of a mixture of tetra and octocarburet, such as the mottled cast iron. Mixtures of octo and tetracarburets of iron are found, however, in other cast irons differing much from the above, and which contain a large amount of white cast iron poor in carbon. This white pig iron, which often contains much sulphur and phosphorus, is always produced at a proportionately lower temperature and with an overcharged furnace. The small quantity of fuel consumed in the reduction of the iron produces this effect: the reduced iron does not remain long enough in contact with the fuel, and the supply of carbonizing gases being deficient, it does not become thoroughly saturated with carbon, and a portion of the iron remains as octocarburet, and is mixed with that portion which has been saturated with carbon to form the tetracarburet.

(To be Continued.)

*Wetherhed's Method of Superheating Steam.**

The method invented and introduced by Mr. Wetherhed, late member of the United States Congress, for superheating steam, has been submitted to various trials during the last six months, in the dockyard at Woolwich, and has at length assumed a practical form. During the series of experiments to which the system has been subjected, various improvements were suggested from time to time, and it was, therefore, considered advisable to prolong the trials, and if possible to render the system complete. The method was first tried in the *Black Eagle*, Admiralty yacht, and was attended with a considerable saving of fuel; and before the late voyage of the *Dæd* to the western coast of England, the machinery was fitted up with the appurtenances necessary for a further test of the system. The apparatus was at work on alternate days during the voyage, which was specially extended for the purpose, and the results obtained exceeded what was anticipated. The economy realized in fuel amounted to no less than 30 per cent. as compared with the ordinary system of using steam. The apparatus consists of iron pipes carried from the steam pipe along the front of the tube plate, and extending into the uptake or chimney, in which they are coiled to increase the surface. These pipes rejoin the steam pipe at or near the cylinders. Part of the steam passes through these pipes, and becomes considerably heated—superheated, as engineers say—and, combining with the ordinary steam before entering the cylinders, brings the mixed steam to about 340°Fahr . It is in this method of passing part of the steam used through coiled pipes in the uptake, and combining it with the common steam, before entering the cylinder, that Mr. Wetherhed's invention consists. The system of simply superheating without mixing the steam has been known for some time past, and has been attempted on

* From the Lond. Mech. Mag., August, 1856.