ART. XXXI.—*Contributions from the Laboratory of the Lehigh University.* No. 2.—*On certain compounds of Chromium with Iron ;* by J. HAYNES H. CORBIN.

PERCY, in his work on iron and steel (p. 186), describes several crystalline compounds of chromium with iron prepared and analyzed by Mr. Smith under his direction.

These compounds contained respectively the chromium percentages of 4·24, 27·07, 54·63, and 76·58, corresponding to the formulæ $Fe_{19}Cr$, Fe_3Cr, $FeCr$ and $FeCr_3$. The experiments were performed in pursuance of the investigations of Berthier,

who found an alloy of the formula Fe_5Cr, containing 17 per cent of chromium, and another containing as much as 60 per cent of this element. Berthier, Faraday and Stodart observed that the addition of 1 per cent of chromium to steel communicated to this compound great hardness and the quality of acquiring a beautiful damask by the action of dilute acids.

Boussingault has lately published (Chem. News, vol. xvii, p. 267, Eng. ed.) the analysis of a chromiferous wrought iron from Central America, containing 1·95 per cent chromium and 4·40 of combined carbon, which he obtained by a new method proposed by himself, viz: dissolving the powdered iron in a solution of corrosive sublimate.

The American Tool Steel Company of Brooklyn has been engaged in preparing alloys of chromium with steel upon a manufacturing scale. They placed a number of specimens of the various compounds in the hands of Dr. Charles M. Wetherill of this University, under whose instruction I have made the following examination of certain of them in the laboratory of the Lehigh University.

The specimens analyzed consist of:

1. Chrome iron ore from the neighborhood of Baltimore.
2. A specimen of chromiferous cast iron obtained by the reduction of 1.
3. Turnings of No. 1 steel prepared by use of 2.

1. The chrome ore possessed the ordinary character of the mineral, and analyzed by the method of Dr. Genth, gave the following percentage result:

Silica	2·12
Chromic oxyd	40·79
Alumina	4·20
Ferrous oxyd	44·48
Manganous oxyd	trace
Lime	2·32
Magnesia	5·21
Phosphoric acid	trace
	99·12

2. The chromium cast iron is a very hard silver-white metal; apparently a mass of interlacing crystal needles. Hardness of feldspar, but very brittle and of density 7·25. It is attacked with great difficulty by the different acids and was brought into solution for analysis by fusion with potassic bisulphate. On attempting to decompose it by means of the battery, only a partial decomposition ensued; the skeleton of carbon which remained contained a good deal of undissolved and crystalline

metal. The process of Boussingault, already referred to, was used for the determination of the carbon. Although this process worked satisfactorily with Boussingault, whose compound contained a small percentage of chromium, it failed with me to fully decompose this specimen, which contains more than 26 per cent of that metal.

The carbon was weighed as $C\Theta_2$ in a potash bulb. The compound yielded by the analysis :

	1.	2.	3.
Iron	70·18*	70·12	70·23
Chromium	26·25	----	----
Aluminum	·26	---	----
Calcium	2·16	----	----
Magnesium	·58	----	----
Silicon	trace	----	----
Carbon	1·69	----	----
Phosphorus	none	----	----
Sulphur	none	----	----
	101·12		

By eliminating carbon and supposing the small percentage of other metals than iron and chromium to be replaced by iron, the analysis yields almost exactly the formula Fe_5Cr_2 ; which is intermediate between 2 and 3 of Smith's compounds alluded to in the beginning of this article. Since the proportion of carbon in white cast iron varies from 3·5 to 5·75 per cent, this specimen is peculiar in having a much lower percentage of that element.

3. The chrome steel is a compound possessing some peculiar properties, a marked one being that of assuming a highly crystalline structure and cracking badly when tempered at the usual heat for tempering steel ; but at a low red heat, a product of very fine grain is the result. Another property is, that it may be submitted to considerable torsion without breaking. A bar twenty-four inches in length and one half inch square, was twisted while cold by two men at the end of a powerful lever two and one half feet in length, until the lever described three complete circles. The twisted bar was now bent in the shape of an ellipse until the ends touched : on examination no injury to the steel could be detected, as it appeared to possess the same properties after as before the operation. The steel is very hard. The hardness of a tempered specimen is equal to that of quartz, and that of an untempered specimen to that of feldspar. The density of the tempered specimen is 7·79 and that of the untempered one 7·8. The density of the latter,

* Mean of 2 and 3.

however, had been raised by its having been struck with a hammer. Its fracture is white, conchoidal, and very fine in structure. Like ordinary steel it is attacked readily by chlorhydric acid, evolving f tid hydrogen and forming an oily scum. On treating the polished steel, both tempered and untempered, with dilute and strong acids, no damask could be obtained.

The analysis gave:

	1.	2.
Iron	95·92	95·27
Chromium	1·66	2·22
Aluminum	2·38	1·69
Calcium	0·44	
Magnesium	0·12	
Silicon	0·12	
Carbon	0·98	
Phosphorus	trace	
Sulphur	trace	
	101·62	

The carbon was determined as in 2. In analysis 1 the iron, chromium and aluminum were determined from an aliquot part of the oxyds precipitated together, by the addition of ammonia; while in the second analysis the iron was separated as sulphid, the chromium and aluminum being held in solution by addition of tartaric acid to the alkaline solution. On comparing this specimen with one quoted by Berthier, (Percy, p. 187) containing about the same percentage of chromium, it is found that his specimen by treatment with dilute acid yielded a beautiful damask, while this does not; from which one would conclude that there is a more thorough incorporation of the chromium throughout the entire mass in this compound, brought about by the process of manufacture, than in Berthier's. This would lead to a more uniformly hard, and probably harder, steel, on account of there being no interstices between crystals of iron and chromium, which, together with the carbon produced the damask in Berthier's specimen. It would seem that the properties of this steel are not due to the replacement of carbon by chromium as is thought by the manufacturers; for although the presence of the chromium may greatly tend to enhance the value of this compound as a steel, yet we find its content of carbon to be within the limits for producing a good quality of steel.

The extraordinary properties possessed by the chromium steel, may, in a great measure, be attributed to the uniform distribution of a hard uncrystalline alloy of iron and chromium through the mass of steel—so homogeneous, in fact, does this compound appear to be, that there is no veined structure or

damask to be noticed when treated with dilute acid. The almost total absence of the deteriorating elements, phosphorus, sulphur and silicon, has probably much to do with the quality of this steel; for the manner in which it may be twisted when cold, and heated to whiteness without "burning," forged and welded, presents an anomaly in the behavior of steel.