ART. XXII.—*Contributions from the Sheffield Laboratory of Yale College.* No. XV.—*Observations on the native hydrates of Iron;* by GEORGE J. BRUSH, with analyses of *Turgite* by CHARLES S. RODMAN.

THE well known iron mines of Salisbury, Conn., have long enjoyed a reputation among mineralogists as furnishing superior specimens of *limonite*, and hitherto this has been thought to be the only ferric hydrate occurring in quantity at this locality. Minute crystals of supposed *Göthite* have occasionally been found, but not in quantity sufficient to render certain their mineralogical determination.

On a recent visit to these mines Mr. Rodman obtained a considerable number of specimens, lining pockets in the ore, which had the usual brilliant metallic luster on the interior surface, and showed on the fracture a fibrous structure, but differed from brown hematite in having a decidedly red color, and in affording when pulverized a red powder, closely resembling that of ordinary red hematite. This red layer was in some cases an inch or more in thickness, and was deposited on a bed of limonite (brown hematite); the line of demarcation between the brown and the red ore was so perfect, in most instances, as to readily admit of a complete separation of the two minerals.

An examination of this red ore showed it to be an oxyd of iron, containing not far from five per cent of water, a number of specimens yielding very uniform results; and a complete analysis proved the mineral to be a ferric hydrate with the formula Fe^2H , identical with the *Turgite* of Hermann,* and with Breithaupt's *hydro hematite*, as analysed by Fritzsche.† The physical characters are so nearly those of ordinary anhydrous hematite that it is difficult to distinguish the species without having recourse to an estimation of the loss on ignition. The *turgite* yields an abundance of water when heated in the closed tube, and it decrepitates in a remarkable manner. Hardness, about 5.5. $G.=4.14$. For analysis the mineral was carefully dried over sulphuric acid until of constant weight, and this dessicated mineral was then heated for several hours in an air bath at 100°C . without showing any further diminution of weight. The amount of hygroscopic moisture abstracted from the air-dried mineral by treatment in the dessicator was 1.40 per cent. The iron in one instance was determined by titration with permanganate of potash; in the second case it was thrown down by ammonia, the precipitate washed, dried and weighed, and then the iron was separated from the silica and alumina by Deville's

* Journal für praktische Chemie, xxxiii, 97.

† Breithaupt, Vollständiges Handbuch der Mineralogie, iii, 846.

method by first reducing with hydrogen, and subsequently volatilizing the iron by heating in a current of dry hydrochloric acid gas. The analytical results were all obtained by Mr. Rodman.

Composition :

	1.	2.	Mean.
Ferric oxyd, - - -	91.45	91.29	91.36
Manganic oxyd, - - -	0.67	0.55	.61
Alumina, - - - -	0.75		.75
Silica, - - - -	0.22	0.24	.23
Phosphoric acid, sulphuric acid and cobaltic oxyd, }	traces		traces
Insoluble in acid, - - -	1.83		1.83
Water, - - - -	5.20	5.21	5.20
	100.12		99.98

Other determinations of water on different specimens gave 5.02 and 5.09 per cent.

Five grams of the mineral yielded only minute traces of sulphuric acid, and three grams showed but an unweighable trace of phosphoric acid. A very perceptible trace of cobalt was found even on examination of one gram of the mineral. The portion insoluble in acid proved on analysis to consist entirely of silica, and excluding this, with the small amount of silica and alumina found in the soluble portion, the result of the analysis is

	Fe 94.00	Mn 0.63	H 5.35 = 99.98
Oxygen,	28.20	0.19	4.75
	28.39		

giving the oxygen ratio 6:1 or Fe^2H .

This result confirms the conclusions of Hermann and Breithaupt that there is a native ferric-hydrate with one-half an equivalent of water. Several years since the attention of the writer was called to this subject by Prof. W. T. Roepper, of Bethlehem, who stated that he had found Breithaupt's hydrohematite to be of frequent occurrence with the limonite ores of the Lehigh valley. A water determination on the Lehigh mineral made by Prof. Roepper, and kindly communicated for this article, gave 5.34 per cent, and Prof. Roepper calls especial attention to the characteristic decrepitation of this mineral when heated. On examination of the specimens of limonite in the Yale College collection, a fine specimen of the red hydrate was found occurring with the limonite of Düsseldorf in Prussia, this yielded on examination by Mr. Rodman 4.75 pr. ct. water. Another specimen was found from Ioditz in Bavaria, besides numerous specimens from Salisbury in Connecticut. A mineral of like composition has also been found by Bergemann* at the Louisa Mine near Horhausen in Prussia. From these numerous

* Rammelsberg, Handbuch für Mineralchemie, 988.

localities it would appear that the mineral is of common occurrence. It has heretofore been confounded by most mineralogists with hematite which it so strongly resembles in physical characters. It may be readily distinguished from hematite by simply heating a fragment in the closed tube, when it decrepitates violently and gives off a large amount of water.

Hermann does not give the pyrognostic characters of *turgite*, but Breithaupt in his description of *hydro-hematite* makes particular mention of its characteristic decrepitation when heated. The *turgite* is described by Hermann as being associated with copper ores; its chemical composition is however identical with hydrohematite, and as it has priority of publication the species must bear the name of *turgite*, and hydrohematite be used only as a synonym.

We have therefore three well defined hydrates of iron occurring native and forming three distinct and well-established mineral species, differing from each other in physical characters and in their relative content of water.

Turgite,	$\text{Fe} + \frac{1}{2}\text{H}$
Göthite,	$\text{Fe} + \text{H}$
Limonite,	$\text{Fe} + 1\frac{1}{2}\text{H}$

Two other hydrates have been described containing respectively two and three atoms of water. Murray* found in a brown iron ore from Hüttenrode in the Hartz—

Fe 81.41, H 17.96, Si 0.17, Carbon 0.46=100, giving the formula $\text{Fe} + 2\text{H}$.

A compound of similar composition from Kilbride in Ireland, having a pitchy color, analyzed by Haughton, gave—

Fe 77.15 H 20.43 Si 0.30 Al tr. P 1.60 = 99.48

Xanthosiderite also appears to be a mineral of like composition, but its mixture with a silicate of unknown composition renders it difficult to conclude positively that it belongs here.

A. H. Church† has analyzed a stalactite of a rust-colored ferric hydrate from Botallack mine in Cornwall, which gave—

Fe 73.73, H 24.40, loss, P , and organic matter 1.76 = 100, giving the formula
 $\text{Fe} + 3\text{H} = \text{Fe}$ 74.77, H 25.33.

Other analyses of ferric hydrates by many different analysts, and from a great range of localities, give an amount of water which correspond to one or the other of these last two hydrates; but as these contain also either organic matter, phosphoric acid, or silica in the combined state, it is impossible, without further investigation, to know to what hydrate to refer them.

The artificial ferric hydrate precipitated by ammonia from ferric chlorid varies in composition according to the method of

* Rammelsberg Mineralchemie, 150.

† Journ. Chem. Society, II, iii, 214.

treatment. Schaffner obtained a hydrate with 1 atom, Gmelin with 2 atoms, and Wittstein with $\frac{3}{2}$ atoms of water; this last kept for some time under water became crystalline and was converted into a hydrate with $1\frac{1}{2}$ atoms of water. Recent investigations by E. Davies* show that the ordinary precipitated ferric hydrate loses water on being boiled in water; in one case the amount of water was reduced to 3.52 per cent. Similar experiments conducted in this laboratory by Mr. Rodman showed that by continued boiling in water the amount of water remaining in the hydrate could be reduced even to 2 per cent. These facts, as Mr. Davies suggests, explain in a very satisfactory manner the association of the different ferric hydrates in nature and do not necessarily demand the supposition of great heat to account for the large beds of anhydrous hematite found in different parts of the world.

Sheffield Laboratory, February, 1867.