[From The American Journal of Science, Vol. XVI, August, 1903.]

Art. XV.—*On the Formula of Bornite;* by B. J. Harrington.

The subject of the formula of bornite is one which has long required investigation. If we refer to the standard works on mineralogy we generally find that the formula of the *crystallized* mineral is given as Cu_3FeS_3 (or $3Cu_2S{\cdot}Fe_2S_3$ as originally written by Plattner) and that numerous analyses of the *massive* mineral from various parts of the world show little agreement with this formula and often differ widely from one another. The difference in the composition of the massive specimens has been explained by saying that they were mixtures of bornite with chalcopyrite and chalcocite, and no doubt in the case of some analyses these or other mixtures have been called upon to do duty for bornite.

So far as the writer is aware, crystallized bornite has not been met with in Canada. The massive mineral of evident purity, however, occurs at many localities, and it was thought that an examination of carefully selected specimens might throw some light on the question under consideration. Those chosen were from widely separated points in the Provinces of Quebec, Ontario, and British Columbia, and the results of their analysis are as follows:

	I.	II.	III.	IV.	V.
Copper	63·55	62·78	62·73	63·34	63·18
Iron	10·92	11·28	11·05	10·83	11·28
Sulphur	25·63	25·39	25·79	25·54	24·88
Insoluble	----	0·30	----	0·38	0·24
	100·10	99·75	99·57	100·09	99·58
Sp. gr. at 15°C	5·085	5·055	5·090	5·029*	----

I. Harvey Hill, P. Q.
II. Bruce Mines, Ontario.
III. Dean Channel, How Sound, B. C.
IV. Copper Mountain, South Fork of Similkameen River, B. C.
V. Texada Island, B. C. The two last analyses were made by Mr. J. E. A. Egleson.

It will be observed that the results agree well with one another and also with the formula Cu_5FeS_4, which gives:

	Cu_5FeS_4
Copper	63·27
Iron	11·18
Sulphur	25·55
	100·00

* The fragment used for this determination contained a little malachite, the effect of which would be to lower the specific gravity slightly.

Nor are such concordant results likely to have been obtained from mere mixtures of different sulphides. Furthermore, they are in close accord with a number of previously published analyses of massive bornites. Out of fifty analyses cited by Hintze* about one-fifth agree well with the formula Cu_5FeS_4 and the average of eight of these gives:

Copper	62·85
Iron	11·57
Sulphur	25·34
	99·76

We pass now to the consideration of crystallized bornite. Through the kindness of Professors Dana and Penfield of Yale University, the writer has been able to obtain a specimen of the crystallized mineral from Bristol, Connecticut, which, though long known, had apparently never been analyzed.† It came from the Brush collection (specimen No. 805) and though partly massive showed at one end a group of fairly distinct rhombic dodecahedrons, which, so far as could be ascertained microscopically, were entirely free from other minerals and were found to have a specific gravity of 5·072 at 15° C. Their analysis gave:

		Cu_5FeS_4
Copper	63·24	63·27
Iron	11·20	11·18
Sulphur	25·54	25·55
	99·98	100·00

Here then we have a *crystallized* bornite which does not agree in composition with the commonly accepted formula Cu_3FeS_3. As to this formula, which has so long been assigned to the crystallized mineral, we find that it was based upon the analysis of a Cornish specimen published by Plattner in 1839.‡ This was followed in the same year by an analysis of another Cornish specimen by Varrentrapp,§ while a third analysis by Chodney appeared in the same journal in 1844.‖ These three analyses, together with two others, also of Cornish specimens, are given below:

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	I.	II.	III.	IV.	V.	Cu_3FeS_3
Copper	56·76	58·20	57·89	57·71	57·68	55·58
Iron	14·84	14·85	14·94	13·89	15·11	16·36
Sulphur	28·24	26·98	26·84	27·17	26·46	28·06
	99·84	100·03	99·67	98·77	99·25	100·00

I. Condorra Mine, Cornwall. Analysis by Plattner.
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III. Redruth, Cornwall. Analysis by Chodney.
IV. and V. Cornwall. Exact locality not known. Analyses by the writer.

It is obvious that none of these analyses agrees well with the formula Cu_3FeS_3, nor could it be expected that satisfactory results would be obtained from the analysis of the Cornish crystals, all of which, so far as the writer has had an opportunity of observing, are very impure.* Not only have they generally been altered by oxidation, but they almost always contain a yellow sulphide with the characters of chalcopyrite. In some specimens nearly every crystal when broken shows a yellow nucleus of chalcopyrite and the writer found it impossible to obtain material which could be regarded as pure. The early analysts, too, evidently found difficulty, if we are to judge from their descriptions. Plattner, for example, tells how he broke up the crystals and picked out the pieces which he considered to be free from copper pyrites. He further trusted to washing with distilled water in order "as far as possible" to remove the superficial portion of the crystals which appeared to be somewhat oxidized. Varrentrapp, again, states that the small cubical crystals examined by him all contained a nucleus (kern) of chalcopyrite and had their surfaces covered with a layer of copper oxide. He admits also that his results do not agree well with those of Plattner.

There is then good reason for believing that the formula Cu_3FeS_3 was deduced from analyses of impure material, and, as we have seen, it does not apply to the crystallized mineral as found at Bristol, Connecticut. If a mineral having this formula really exists, then we have two distinct species—bornite and something else. Artificial products agreeing well with the formula Cu_3FeS_3 are said to have been prepared,† and there

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Bornite	Cu_5FeS_4
Chalcopyrite	$CuFeS_2$

$$Cu_6Fe_2S_6 = 2Cu_3FeS_3.$$

Such a mixture would contain 73·20 per cent of bornite and 26·8 per cent of chalcopyrite.

The range for the specific gravity of bornite is sometimes stated to be 4·9 to 5·4; but a substance with as definite a composition as pure bornite evidently possesses should not show so great variation, and it will probably be found that when the material is carefully selected the range will be more like 5·05 to 5·10. As we have seen, the crystallized mineral from Bristol gave 5·072.

Department of Chemistry and Mineralogy,
McGill University, May, 1903.

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ON THE FORMULA OF BORNITE.

By B. J. Harrington.

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