XXIV.—*Examination of some Slags from copper smelting furnaces.*

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The phenomena occasioned by the continued action of heat upon mineral substances in connexion with various fluxes, such as lime, felspar, &c., have been carefully studied by several eminent philosophers, their experiments, I believe, however, have been chiefly confined to the laboratory and to the products obtained within the confines of the crucible in the assaying furnace. Many hundred analyses of slags resulting from all kinds of fluxes employed by the assayer, have been made by M. Bertier, and more recently by Mr. Mitchell, in order to shew the different states of mineral and flux before and after fusion, and their researches have been invaluable to the assayer and practical smelter, throwing considerable light upon the various and oftentimes complicated action resulting at an elevated temperature. The following analyses have been made upon the products of furnaces in which the ingredients were enabled mutually to react upon a more extended scale, the fluxes being at the same time not very unlike those employed by the assayer. The experiments described below will, I hope, not be entirely destitute of interest, phenomena frequently taking place in operations of considerable magnitude, which cannot be observed in the smaller and humbler experiments in the laboratory furnace.

The slags, the analyses of which form the subject of the present paper, were obtained from the furnaces of the South American and Mexican Company in Chile, and the analyses were performed in the laboratory of that establishment. The method of smelting copper carried on at the works of the company, is that patented by Mr. Napier.

When the mineral was mixed with 20 per cent of its weight of common salt, and 15 per cent of lime, and the whole kept in a state of fusion for some time, the slags on being skimmed, presented an uniform mass, perfectly limpid and free from metallic particles, upon cooling, however, the mass separated into two distinct portions, which could be divided from each other with the greatest facility, a slight blow of the hammer being sufficient to cause them to fly asunder: it appeared to me interesting to determine the composition of both portions, in as much as they presented very distinct physical appearances, the lower stratum having a highly crystalline texture very much resembling certain species of syenitic rock, while the upper portion had a fine glassy appearance, totally devoid of crystallization.

This latter which we shall distinguish as No. 1, or glassy slag, possessed a fine dark green colour, closely approaching to black, having exactly the appearance of the glass from which the common wine bottles are manufactured, it presented a highly conchoidal fracture, and was immediately decomposed by aqua regia, and even by boiling hydrochloric acid. A qualitative analysis shewed the presence of silicic acid, alumina, oxide of iron, lime, magnesia, manganese, chlorine, sodium, with traces of sulphur.

The following is its composition in 100 parts.

Silica	.	.	.	.	.	.	49.26
Alumina	.	.	.	.	.	.	12.37
Protoxide of iron	.	.	.	.	.	.	18.60
Lime	.	.	.	.	.	.	7.84
Magnesia	.	.	.	.	.	.	2.62
Oxide of copper	.	.	.	.	.	.	0.70
Chloride of sodium	.	.	.	.	.	.	0.48
Soda	.	.	.	.	.	.	7.93
Manganese	.	.	.	.	.	}	traces
Sulphur	.	.	.	.	.		
Loss in analysis	.	.	.	.	.	.	0.20
							100.00

The chloride of sodium was estimated from the amount of chlorine obtained by boiling 200 grains of finely pulverized slag for an hour with distilled water, and subsequent precipitation with nitrate of silver. As the slag was perfectly decomposable by aqua regia, fusion with baryta for the estimation of the soda was unnecessary, that alkali being determined by the method proposed by Heintz, for the separation of magnesia from the alkalies. The lime, alumina, iron, &c., having been separated by carbonate of ammonia, a stream of hydrosulphuric acid was passed through the filtrate previously acidulated, in order to precipitate traces of copper; after boiling with a subsequent addition of ammonia, phosphate of ammonia was added to precipitate the magnesia; an addition of acetate of lead, removed the excess of phosphoric acid, and again the excess of lead was separated by means of a mixture of carbonate of ammonia and ammonia; on evaporation to dryness and subsequent ignition, chloride of sodium remained in the platinum basin, from which the amount existing as such in the slag was deducted, and the soda estimated from the residue. This slag, as before remarked, has a clear glassy structure, and has not the most distant appearance of containing copper. The 0.70 per cent of black oxide found by analysis, is present in combination with silicic acid. In contact with metallic iron, the colour is changed from black

to a fine red, owing doubtless to the reduction of the protoxide to the suboxide in the following manner. $2(\text{Cu O Si O}_3) + \text{Fe} = (\text{Cu}_2 \text{O Si O}_3) + \text{FeO Si O}_3$. This phenomenon was always observed when the slag had come in contact with the *rabble* used by the furnace-man, or with the *fore-plate* of the furnace.

The under slag, (No. 2), which is termed sharp or metallic slag, presented a very different appearance from the former, it was undecomposable by aqua regia, and a long continued fusion with carbonate of soda was necessary for its entire decomposition. A qualitative analysis proved the existence of the same substances as in the former specimen. On ignition to whiteness with carbonate of baryta only very small quantities of alkali were observable.

The following is the quantitative analysis of this slag :

Silica	49·60
Alumina	14·00
Oxide of iron	32·94
Lime	1·23
Magnesia	0·11
Oxide of copper	1·06
Soda	0·70
Chloride of sodium	0·43
Manganese	traces.
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	100·07

It will be observed that the amount of silica is nearly equal in these two analyses ; in the former it is 49·26, in the latter 49·00, but all the other ingredients, the alumina excepted, are in widely different proportions. In fact, slag No. 2 may almost be considered as a silicate of iron and alumina, these three bodies alone forming more than 96 per cent of the whole mass. We may imagine that slag No. 1 acted as a bath from which No. 2 had crystallized ; that silica, in certain combinations, with soda, iron, lime, &c., dissolved a silicate containing an excess of iron and deposited it, on cooling, in crystalline forms more or less defined ; in other words, that the metallic slag was held in solution in the glassy slag, the latter containing nearly the whole of the soda, lime, and the more fusible compounds. However small the quantity taken from the furnace, the same phenomenon always occurred, viz., the complete separation of a crystalline slag from a homogeneous mass resembling black glass.

When smaller proportions of salt, but the same quantity of lime were employed, viz. 10 per cent of the former, and 15 per cent of the latter, in regard to the mineral of copper, no separation of the

slags took place on skimming, but the mass presented a very different aspect to the two former specimens. It was now highly variegated, and had a beautiful serpentine appearance, very much resembling many specimens of igneous rock I have since seen in this country, (Chile), and so hard as to be capable of receiving a beautiful polish. A qualitative analysis gave me the same ingredients as in the two former slags, with the addition of sulphur and unburned carbonaceous matter. This slag, also, had to be decomposed by fusion with carbonate of soda, and the alkali it contained, was estimated by fusing it with baryta. 100 parts gave me :

Silica . . .	42·20
Alumina . . .	10·80
Lime . . .	6·43
Magnesia . . .	2·14
Protoxide of iron . .	31·00
Oxide of copper . .	0·45
Chloride of sodium . .	0·34
Soda . . .	3·44
Sulphur . . .	1·43
Escoria . . .	1·56
Loss in analysis . .	0·21
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	100·00

On examining some escorias from a furnace some few leagues from Coquimbo, I observed, on breaking a portion, beautiful needle-shaped crystals grouped together in large and distinct cubes in one of the cavities, having very much the appearance of those in No. 2, only larger. They were separated, with some difficulty, from the mass, and in qualitative analysis shewed the existence of lime, silica, oxides of iron and copper, alumina and magnesia. Twenty-four grains were analysed and yielded the following per-centage composition :

Silica . . .	35·60
Protoxide of iron . .	50·46
Alumina . . .	6·85
Lime . . .	4·48
Magnesia . . .	0·16
Oxide of copper . .	2·32
Loss. . .	0·13
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	100·00

The large amount of protoxide of iron is here to be observed, and from many experiments not yet concluded, it appears to me that the other ingredients in the crystals, besides the silica and iron, are not essential to the crystalline structure of the mass, but may be reckoned as foreign substances. I have not, as yet, however, met with any that contained only silicium, oxygen, and iron.

As I am, at present, constantly engaged in investigations regarding the nature of the substances placed in the furnace, and the condition they present after fusion, I trust to be able, at some future time, to lay before the Society a more detailed account of the various silicates obtained. Every different proportion of ingredients, every prolongation of temperature, causes not only a difference in constitution, but an entire change in physical appearance, so that, perhaps, by many careful analyses we may arrive at more satisfactory conclusions regarding the formation of natural silicates and other minerals of igneous origin.