

ART. XXV.—*Analysis of a Meteorite from Chili*; by CHARLES A. JOY, Professor of Chemistry in Columbia College, New York.

THIS meteorite was found on a mountain pass, about fifty miles from Copiapo, in the province of Atacama, Chili, by a native of the Argentine Republic, and presented to Mr. Joseph Brower, by whom it was brought to New York, and to whose kindness I am indebted for the fragment used in the analysis. The original specimen has been deposited by Mr. Brower, with a large collection of rare silver and copper ores from Chili, in the mineralogical cabinet at Union College, Schenectady.

The outer crust of the meteorite wore the usual dark red color of oxydized iron. Its weight, uncut, was 1784 grams. The specific gravity is 4.35. A polished etched surface gave an impression on paper of scattered points rather than of regular lines. It also readily reduced copper from its solutions.

A close inspection of the specimen shewed that there was a large per-centage of stony matter interspersed through the mass. The color and hardness of a portion of this indicated olivine; other fragments recalled the appearance of partially decomposed labradorite. An unsuccessful attempt was made to withdraw the iron by means of a magnet, but the powdered mineral adhered to the magnet in association with the iron.

For the determination of the sulphur, phosphorus, copper and tin, the presence of which had been revealed by a qualitative analysis, a large fragment was taken and treated with aqua regia, at a gentle heat. The sulphur separated in finely divided grains, and care was taken to prevent them from combining into compact masses. After gently heating in a water-bath for twenty-four hours, all of the sulphur was successfully oxydized. The portion of the meteorite insoluble in acids was collected upon a filter, dried, incinerated and weighed. From the solution, sulphuric acid was precipitated by chlorid of barium, the precipitate was heated with chlorhydric acid to free it from all traces of iron, filtered, dried and weighed. The filtrate from the sulphate of baryta gave a slight brown precipitate with sulphuretted hydrogen. This was dissolved in aqua regia, and saturated with ammonia, when a slight yellow precipitate of tin was thrown down, while copper was dissolved and afterward precipitated by potash.

After expelling the sulphuretted hydrogen from the first filtrate, the phosphorus was separated by molybdate of ammonia and afterward determined as phosphate of magnesia.

For the determination of the iron, alumina, nickel, cobalt, manganese, and lime, a second portion was taken and treated as before. The iron, alumina, nickel, cobalt, and manganese were successively precipitated by ammonia and sulphid of ammonium

and the precipitate redissolved and weighed. The iron and alumina were separated from the other bases by carbonate of baryta. The nickel, cobalt, and manganese, were not determined in this portion, but were precipitated by potash and weighed. The separation of the iron and alumina was accomplished by means of the hyposulphite of soda. The alumina was found to be free from the oxyd of chromium. The lime was determined as carbonate. For the separation of the nickel and cobalt from manganese, in another portion, the insolubility of the sulphids of nickel and cobalt in chlorhydric acid was used. To separate nickel and cobalt, I preferred the method of chlorine and carbonate of baryta which I had followed in Rose's laboratory. Liebig's process, which I employed with the Cosby Creek iron,¹ was inconvenient, and the method by nitrite of potassa did not yield satisfactory results, owing to impure materials and want of time to repeat the analysis.

Results :

From 3.519 grams.	1.134 grms. insol.	2.385 grms. soluble.
BaO, SO ₃	0.688	0.0944 S
MgO ₂ PO ₅	0.015	0.00423 P
CuO	0.002	0.00159 Cu
SnO ₂	0.001	0.001 SnO ₂
No. 3. Mn ₃ O ₄	0.011	No. 2. 1.166 grms. material.
Co ₃ O ₄	0.021	0.390 grms. insoluble.
NiO	0.124	0.776 " soluble.
	0.156	
CaO, CO ₂	0.025	0.014 CaO
Fe ₃ O ₃	0.859	0.6013 Fe
Al ₂ O ₃	0.039	0.039 Al ₂ O ₃
Mn ₃ O ₄ }	0.006	0.00432 Mn
NiO }	0.077	0.06034 Ni (Calc. from No. 3.)
Co ₃ O ₄ }	0.013	0.00959 Co

From the above figures we obtain the following results :

Fe	-	-	-	-	-	77.48 pr. ct.
Ni	-	-	-	-	-	7.77 "
Co	-	-	-	-	-	1.23 "
Mn	-	-	-	-	-	0.55 "
CaO	-	-	-	-	-	1.80 "
Al ₂ O ₃	-	-	-	-	-	5.02 "
S	-	-	-	-	-	3.95 "
P	-	-	-	-	-	0.17 "
Cu	-	-	-	-	-	0.06 "
SnO ₂	-	-	-	-	-	0.04 "
						98.07

¹ Ann. Chem. Pharm., lxxxvi, 39.

As the analysis was conducted with great care, and as we have alumina and lime evidently derived from the decomposition of a portion of the mineral, and as protoxyd of iron is easily attacked in silicates, it is proper to assume that the difference is due to oxygen combined with iron as protoxyd. Assuming 1.90 pr. ct. oxygen, we require 6.65 pr. ct. Fe to form 8.55 FeO. This will give us for the soluble portion :

Fe	70.83 pr. ct.	Mn	0.55 pr. ct.
Ni	7.77	Al ₂ O ₃	5.02
Co	1.23	FeO	8.55
Cu	0.06	CaO	1.80
S	3.95	SnO ₂	0.04
P	0.17		99.97

The average of several analyses gave 68.19 pr. ct. soluble in acids, and 31.81 pr. ct. insoluble in acids.

Insoluble mineral portion.

This was fused with carbonate of soda: an intense green color indicated the presence of manganese. The fused mass treated with water yielded a green solution of NaO, MnO₃, which turned red upon further heating, and colorless upon addition of alcohol. The solution was evaporated to dryness and the silica separated as usual. It was afterwards fused by itself and found to be pure and to contain no undecomposed mineral. Sulphuretted hydrogen was passed through the filtrate from the silica, by which a slight precipitate of a brown sulphid was produced. This was collected upon a filter, dried, treated with a few drops of aqua regia, incinerated and weighed. It was then nearly all dissolved in chlorhydric acid. Ammonia produced a yellow white precipitate of SnO₂, HO which becomes brown in NH₄S and was dissolved in an excess of that reagent and upon addition of HCl yielded brown sulphid of tin. The ammoniacal filtrate from SnO₂ was colored distinctly blue by copper.

The filtrate from the sulphid of tin and sulphid of copper was treated with chlorid of ammonium and ammonia and saturated with sulphid of ammonium and heated, by which iron, manganese, nickel, cobalt, and chromium were precipitated. This precipitate was dissolved in aqua regia. From the filtrate from the sulphur metals the lime was precipitated by oxalate of ammonia and the magnesia by phosphate of soda.

From the solution in aqua regia, the oxyds of iron, alumina, and chromium, were precipitated by carbonate of baryta in the cold. The excess of baryta was removed by sulphuric acid and the manganese precipitated by potash: this precipitate was examined for nickel and cobalt and found to contain traces.

The precipitate containing the oxyds of iron, alumina, and chromium, and excess of carbonate of baryta, was dissolved in chlorhydric acid, the baryta removed by sulphuric acid, and the iron and alumina separated by hyposulphite of soda.

The sesquioxyd of chromium was separated from the oxyds of iron and alumina, as follows: The Al_2O_3 was fused with NaO , Co_2 and KO , NO_5 , the fused mass dissolved in water, saturated with chlorhydric acid and evaporated with additions of chlorate of potassa and the alumina precipitated with ammonia and the chromic acid as chromate of lead.

The Fe_2O_3 was also fused with carbonate of soda and nitrate of potassa, and the mass lixiviated with water, filtered, saturated with chlorhydric acid, alcohol added, heated to boiling, and the sesquioxyd of chromium precipitated by ammonia.

Results:

Substance taken = 0.518 grms.

Found, SiO_3	0.334 grms.	64.478 per cent.
FeO	0.0729	14.073
MgO	0.06737	13.005
MnO	0.01678	3.239
Cr_2O_3	0.00907	1.750-2.575 Cr_2O_3 FeO
Al_2O_3	0.00593	1.144
CaO	0.00448	0.864
$\text{SnO}_2 + \text{CuO}$	0.005	0.965
NiO, CoO	0.002	0.386
	0.51753	99.904

Second Analysis.

Substance taken = 1.114 grms.

Found, SiO_3	0.713	65.61 per cent.
MgO	0.1549	13.90
FeO	0.1647	14.78
Cr_2O_3	0.0140	1.25
Al_2O_3	0.0120	1.07
MnO_3	0.0325	2.91
CaO	0.0128	1.15
Ni, Co	0.0010	0.09
		100.76

Average.

SiO_3	-	-	-	65.04
MgO	-	-	-	13.45
FeO	-	-	-	14.42
Cr_2O_3	-	-	-	1.50
Al_2O_3	-	-	-	1.10
MnO	-	-	-	3.07
CaO	-	-	-	1.01
Ni, Co	-	-	-	0.23
				99.82

From these analyses we have the composition of the meteorite as a whole, as follows:

Fe	-	-	-	48.298 per cent.
Ni	-	-	-	5.298
Co	-	-	-	0.838
Mn	-	-	-	0.375
Cu	-	-	-	0.040
S	-	-	-	2.693
P	-	-	-	0.115
SiO ₃	-	-	-	20.689 insoluble.
MnO	-	-	-	0.976 "
Cr ₂ O ₃	-	-	-	0.477 "
NiO, CoO	-	-	-	0.073 "
FeO	-	-	-	5.830 soluble.
FeO	-	-	-	4.587 insoluble.
CaO	-	-	-	1.227 soluble.
CaO	-	-	-	0.321 insoluble.
Al ₂ O ₃	-	-	-	3.423 soluble.
Al ₂ O ₃	-	-	-	0.349 insoluble.
MgO	-	-	-	4.278 "
SnO ₂	-	-	-	0.027 soluble.
SnO ₂	-	-	-	0.162 insoluble.

100.076

Metallic portion.

Fe	48.298 per cent.
Ni	5.298
Co	0.838
Mn	0.375
Cu	0.040
S	2.693
P	0.115
	57.657

Mineral portion.

SiO ₃	20.689 per cent.
MnO	0.976
Cr ₂ O ₃	0.477
NiO, CoO	0.073
FeO	10.417
MgO	4.278
Al ₂ O ₃	3.772
CaO	1.548 Another anal.
SnO ₂	0.189 0.332
	42.419

*In 100 parts.**Metallic.*

Fe	83.76
Ni	9.18
Co	1.45
Mn	0.65
Cu	0.07
P	0.20
S	4.67 (12.84 FeS.)
	99.98

Mineral.

SiO ₃	48.61
FeO	24.47
MgO	10.05
Al ₂ O ₃	8.86
CaO	3.63
MnO	2.29
Cr ₂ O ₃	1.12
NiO, CoO	0.17 Another anal.
SnO ₂	0.44 0.78
	99.64

If we examine the mineral portion under a microscope and study its behavior towards reagents, we shall find at least two silicates in the meteorite; one of them, like olivine, having the formula $\text{RO}_3 \cdot \text{SiO}_3$, not so easily attacked by acids, and the other resembling labradorite, with the formula $x \text{R}_2\text{O}_3 \cdot \text{SiO}_3 + y \text{RO} \cdot \text{SiO}_3$. Assuming that the Cr_2O_3 was combined with the FeO as chrome iron, the 1.12 Cr_2O_3 will require 0.52 FeO , which must be deducted from the 24.47 pr. ct. FeO . Assigning MgO , MnO , NiO , CoO , to the mineral $\text{RO}_3 \cdot \text{SiO}_3$ and the Al_2O_3 , CaO , to the mineral $x \text{R}_2\text{O}_3 \cdot \text{SiO}_3 + y \text{RO} \cdot \text{SiO}_3$, and dividing the FeO between them, we have for the mineral portion:

Chrome iron	-	-	1.64 pr. ct. $\text{Cr}_2\text{O}_3 \cdot \text{FeO}$
Olivine,	-	-	27.43 $\text{RO}_3 \cdot \text{SiO}_3$
Labradorite	-	-	70.13 $\text{Al}_2\text{O}_3 \cdot \text{SiO}_3 + 4 \text{RO} \cdot \text{SiO}_3$
			99.20

This will give for the composition of the meteorite:

Nickel iron (with Co, Mn, and Cu)	48.689
Sulphid of iron, FeS	7.405
Chrome iron, $\text{Cr}_2\text{O}_3 \cdot \text{FeO}$	0.701
Schreibersite, (Fe 1.38, Ni 0.67, P 0.115)	1.563
Olivine, $\text{RO}_3 \cdot \text{SiO}_3$	11.677
Labradorite,* ($\text{R}_2\text{O}_3 \cdot \text{SiO}_3 + 4 \text{RO} \cdot \text{SiO}_3$)	29.852
Tin stone, SnO_2	0.189
100.076	

Calculations were made referring the silicates to hornblende, hypersthene, augite, and anorthite, but I omit them in the summary as being of a purely theoretical character. The above is believed to give the fair average constitution of this meteorite.

I must express my obligation to my assistant, Mr. Charles A. Stetefeldt, for skillful aid in hastening the completion of the analysis.

New York, Jan. 1st, 1864.