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Report CC-822

Metallurgical Project

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Metallurgical Laboratory

S. K. Allison, Director

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CHEMICAL RESEARCH

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THE PRESENT STATUS OF P-9 SPECIFICATIONS, PURITY AND DANGER COEFFICIENTS

Samuel K. Allison

July 26, 1943

* * *

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THE PRESENT STATUS OF P-9 SPECIFICATIONS, PURITY AND DANGER COEFFICIENTS

Samuel K. Allison
July 26, 1943

I. Analyses

Up to the present time, July 24, 1943, the following shipments of P-9 have been received.

Receipts of P-9 from Consolidated Mining & Smelting Company

No.	Date Received	% Purity Claimed by Shipper	Weight in Lbs.
1	1-22-43	0.103	37.75
2	3-1-43	99.5	2.20
3	4-27-43	--	8.75
4	4-27-43	--	7.50
5	5-28-43	--	7.25
6	6-24-43	--	6.50

Three analyses of these shipments, all of which originated at the Consolidated Mining & Smelting Co., Trail, B.C., have been made. The numbers in the following discussion refer to columns in Tables I and II.

#1. This consists of water which had been put through the Trail plant and shipped in an early type of container to see what impurities might be picked up in the plant process and in the shipping container. The P-9 content was stated to be 0.103%. The analysis was carried out at the Bureau of Standards. After analysis, the material was discarded and the container returned to Trail, B.C.

#2. This was the initial shipment of P-9, and was received about March 1, 1943. It was stated by the producer to be 99.2-99.8% pure. Ten cc of this material were sent to the SAM Project, Columbia University, on March 18, 1943 for analysis. Only a P-9 content analysis was made, there being no analyses for other impurities. The material was shipped in a copper container and is obviously colored with some dissolved copper.

#3. An analysis of the P-9 used by H. L. Anderson

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in experiments at the Argonne pile as reported in CP-718, page 6. This material is a composite of shipments 3, 4, and 5 above.

In addition to the analyses of the P-9 content reported in #2 and #3 above, the Columbia group has analyzed other material received from Trail as follows.

Date Received	% P-9
February 28, 1943	99.32-99.56%
March 10, 1943	99.28%

The findings of the analyses are reported in Tables I and II. The analyses of the P-9 used in the Argonne tests were carried out at the Metallurgical Laboratory, University of Chicago.

II. Danger Coefficients

Since the measurements on P-9 in the Argonne pile have revealed the unexpectedly low capture cross section of oxygen, the estimates of the amounts of P-9 necessary to sustain a chain reaction have been altered, and the possibility of a homogeneous pile has appeared. These new findings necessitated a revision of the table of danger coefficients for impurities in P-9. The first such table was drawn up by S. K. Allison and A. M. Weinberg in February 1943, and is now obsolete. On July 16, 1943, the danger coefficients of Table III were drawn up. The danger coefficient assigned to water content neglects the contribution from the slowing down power of hydrogen and is essentially what is obtained from the cross section for capture of thermal neutrons by hydrogen. Wigner has estimated that in the homogeneous plant the true danger coefficient, that is, with the slowing down effect included, is 5 instead of 6 quoted in the table.

III. Specifications

A. As given to the Consolidated Mining and Smelting Co.

On November 16, 1942, a meeting was held to discuss the specifications for P-9. S. K. Allison, L. Szilard, J. A. Wheeler, E. P. Wigner, J. H. Manley, and E. W. Thiele were present. The only source of P-9 considered at that time was the Consolidated Mining & Smelting Co., Trail, B.C.

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TABLE I.

GENERAL PROPERTIES AND CHEMICAL ANALYSES OF P-9 RECEIVED

Property	#1 Water Put through Trail process and Shipped in Cu Container - Jan.1943	#2 First Shipment 2.2 lbs. P-9	#3 P-9 Used in Argonne Tests (CP-718)
P-9 content (Report from SAM Project, Columbia - 2L-437-1)	<0.5%	99.44-99.68%*	98.9-99.1%
pH	6.4	--	6.2
Sediment collected by filtration and dried at 110° C	106 ppm.	--	present, but no quantitative data
Sediment collected by filtration and ignited	76 ppm.	--	present, but no quantitative data
Residue from evaporation of filtrate, dried at 110° C	47 ppm.	--	present, but no quantitative data
Residue from evaporation of filtrate, ignited	25 ppm.	--	present, but no quantitative data
Copper in filtrate only	12.5 ppm.	--	24 ppm.
Cd in filtrate only	--	--	<0.2 ppm.
Boron (including sediment)	0.001 ppm.	--	0.17-0.43 ppm.
Fe (in filtrate only)	--	--	<1 ppm.

*The two values arise from two slightly different, but equally reliable, determinations of the density of pure P-9.

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TABLE II.

SPECTROSCOPIC ANALYSES OF P-9 SHIPMENTS

Constituent	#1 Water Put through Trail Process and Shipped in Cu Container		#3 P-9 Used in Argonne Tests (CP-718, page 6)
	Sediment	Filtrate	Ignited Sediment
Ag	T	T	T, F.T.
Al	M	M	V.W.
As	--	--	--
Au	--	--	--
B	V.W.	V.W.	F.T., T.
Ba	T	W	not looked for
Be	V.W.?	--	--
Bi	V.W.	V.W.	not looked for
Ca	W	V.S.	V.W.
Cd	--	--	T, --
Co	T	V.W.	--
Cr	T	W	T
Cu	V.S.	V.S.	S
Fe	V.S.	S	V.S.
Ga	--	--	--
Ge	--	--	--
Hf	--	--	not looked for
Hg	--	--	--
In	--	--	--
Ir	--	--	not looked for
La	--	--	not looked for
Li	T	V.W.	--
Mg	W	M	M
Mn	W	M	M, W
Mo	--?	--?	--
Na	W	S	--
Ni	M	M	T
Os	--	--	--
P	not looked for	not looked for	--
Pb	W	W	V.W., T.
Pd	--	V.W.	--
Pt	V.W.	S	not looked for
Rh	--	M	
[illegible]	--	--	
Sb	--	--	--
Se	--	--	not looked for
Si	S	M	S
Sn	V.W.	V.W.	--
Sr	--	W	not looked for
Ta	--	--	not looked
Th	--	--	[illegible]
Ti	V.W.	V.W.	[illegible]
Tl	--	--	[illegible]
U	V.W.	W	not looked for
V	V.W.	V.W.	not looked for
W	--	--	not looked for
Y	--	--	not looked for
Zn	V.W.	V.W.	V.W., T.
Zr	--	--	not looked for

TABLE III.

DANGER COEFFICIENTS FOR P-9

Impurity	Homogeneous Plant 0.016 atoms U per molecule D_2O Weight ratio 1:5.25	Heterogeneous Plant 30:1 Volume ratio 1.74:1 D_2O to U weight ratio
Ag	90	32
Al	1.2	0.42
B	10,500	3650
Br	14	5
Ca	1.5	0.53
Cd	5100	1800
Cl	190	51
Co	97	34
Cu	11	39
F	0.09	0.030
Fe	6.5	2.2
Hg	430	151
I	7	2.5
K	13	4.8
Li	1750	618
Mg	2.2	0.8
Mn	36	13
N	15	5.3
Na	3.6	1.3
Ni	18	6.3
P	1.3	0.45
Pb	0.21	0.07
S	2	0.7
Si	1	0.35
Sn	1	0.3
Sr	2.8	1.0
Zn	2.6	0.9
Water	6	2.5

(per cent by weight of impurity) x (danger coefficient)
= (per cent loss of "k" in impurity)

As a result of that conference and some subsequent discussions, Dr. Thiele in a letter to Dr. Wright of Consolidated Mining & Smelting Co. set specifications as follows.

(1) For impurities other than water.

A table of danger coefficients for impurities in heavy metal as used for heavy metal specifications was sent Dr. Wright with the instruction that the sum of the danger products should be <0.33%. This was guided by an estimate that a heterogeneous plant would have three times as much P-9 as heavy metal by weight.

(2) For water.

It was stated that any product over 99% P-9 would be acceptable and that there would be little use in raising the purity over 99.9%. This was set up on the expectation that only a heterogeneous system would be built having considerable excess k.

At the present time, these specifications are still in force as regards Consolidated Mining & Smelting product. Analyses #3 in Table I. which pertain to recent batches of the Trail product would indicate that the purity is remaining near the lower limit specified.

B. As given to the duPont Company.

A meeting was held on July 8, 1943 with Mr. Thayer of duPont's P-9 Division to discuss P-9 specifications. Present were Messrs. Boyd, Potratz, Smyth, Vernon, Huffman, Chapin, Chilton, Wigner, Weinberg, Peterson, and Thayer. The following preliminary specifications were agreed upon.

(1) For impurities other than water.

Impurity	Ppm. Maximum
Al	<20
B	< 0.05
C	<30
Cd	< 0.05
Fe+Co+Ni	<10
Li	<0.05
Rare Earths	<0.05
All solids except Al,C,Fe,Co,Ni	<1
O^{18}	<1.5

The O^{18} content should be <1.5 times the O^{18} fraction in normal oxygen, that is, <3000 ppm. by weight of the P-9 should be O^{18}.

(2) For water.

The material should assay at least 99.8% P-9 with the possibility that if a homogeneous plant is built, this may be raised to 99.5%.

It is seen from the above that the purity specifications given to Consolidated Mining & Smelting Co. are at present much more liberal than those under which duPont is working. It is probable that the Consolidated Mining & Smelting specifications should be raised to the duPont level. If the danger coefficients for the heterogeneous plant in Table III. are applied to the duPont specifications listed above, we find that the permitted content of Al, B, Cd, Fe+Co+Ni, Li, and Rare Earths would cause a decrement in k of 0.06%. In the homogeneous plant, the corresponding decrement in k would be about 0.16%. The water content of 0.2% permitted in the duPont specifications would cause a 0.5% k loss in the heterogeneous plant, and a 1.2% loss in the homogeneous plant. If the specification were raised later to 99.95% P-9, the 0.05% water would cause a 0.3% loss in k in the homogeneous plant.

IV. Documents Relating to P-9

The following documents have been prepared or received concerning P-9, and should be consulted by persons working with it.

Columbia Serial No. 2L-437-1, File Index 2.10-1 of June 19, 1943, R. H. Crist to S. K. Allison, reports the analysis #2 of Table I. in some detail.

Columbia Serial No. 100 U-L-183, File Index 2.13 of July 10, 1943, from H. C. Urey to S. K. Allison, discusses the concentration of P-9 by electrolysis, giving a formula from which the amount of separation after electrolysis can be estimated.

These two documents are in the files of S. K. Allison.

Columbia Serial No. 2R-225, File Index 2.10-1, of June 18, 1943, is a report by R. H. Crist containing a summary of methods of isotopic analysis of P-9. It is rather comprehensive and quite valuable. It is on file in the Library.

It might also be noted that samples of partially separated oxygen isotopes are available as discussed in

Memo 95 by S. K. Allison. These samples, although originally acquired because of the oxygen separation, have an even greater separation of the deuterium from the hydrogen. A sample is available in which the normal deuterium content of water has been reduced by a factor of 15, and one in which the normal deuterium content has been raised to 9.1 atom per cent from the normal 0.015 atom per cent.

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