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PRELIMINARY REPORT ON ANALYSIS OF THORIUM METAL

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PRELIMINARY REPORT ON ANALYSIS OF THORIUM METAL

Introduction

The analysis of thorium metal is of interest to many laboratories in both the producer and the consumer field.

As of this date, the methods and the results may vary to the extent of the number of laboratories doing the analysis. Some knowledge of the analysis must be had in order to establish confidence in the purity of the metal.

It is the purpose of this paper to list the several methods now employed with some correlation of the accuracy that may be expected in the results.

The specifications for the impurity content of the metal have been little changed in the past two years. The tentative specifications as supplied for the Materials Testing Reactor are as follows:

Element	ppm	Element	ppm
C	1000	Mg	Trace
O	500	Zn	Trace
N	100	Ce	15
Al	100	La	5
Fe	300	Nd	2
Be	1000	Dy	0.05
U	5	Pr	0.4
Ca	Trace	Sm	0.1
Ni	Trace	Y	0.05
Si	Trace	Gd	0.2

The above specification does not include all the elements that are probably present. Since a more complete analysis may be desired in the future, there has been additional work done on the determination of other elements.

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There has not been a great deal of correlation data obtained as yet on thorium samples. The metallurgical laboratory at Ames, Iowa, has made several lots of thorium metal with great care to guard against contamination and segregation. Triplicate portions of the samples were taken and analyzed by both the Ames Laboratory and the New Brunswick Laboratory.

From a spectrographic standpoint and considering that many of the NBL values were visual estimations, the agreement in the results was quite satisfactory for the elements determined. There is insufficient data at this time for satisfactory comparison of chemical results.

In addition to the pure metals prepared, there have been several lots of impure metal on which both Ames and NBL have made analysis. Compilation of the data are shown in Tables I and II at the end of this report.

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CHEMICAL PROCEDURES

Carbon

BMI - A combustion procedure for the determination of carbon is used at the Battelle Memorial Institute.

NBL - A combustion procedure similar to that used for the determination of carbon in uranium is used at NBL.

AMES - A report indicates difficulty is experienced in the determination of carbon in thorium by their combustion method.

Nitrogen

BMI - The Kjeldahl method for determination of nitrogen is used.

NBL - A micro-kjeldahl method similar to that used for nitrogen in uranium is used at NBL.

Oxygen

BMI - Oxygen is determined by a vacuum fusion technique. A thorium sample (0.2 - 0.5 gm) is dissolved in an outgassed tin bath (5-20 gms) contained in a graphite crucible. Using an operating temperature of 3200^{o}F, the oxygen content of the specimen is extracted as carbon monoxide. Oxygen results are repeatable on duplicate specimens to ±5 to 10 percent of the obtained values.

NBL - Combined oxygen in thorium metal is determined by dissolving' the metal in oxygen free 6N HCl. The insoluble material is ignited, weighed, and reported as HCl insoluble.

HYDROGEN

BMI - The tin fusion method for hydrogen in thorium appears to give better results than does the vacuum fusion. This method consists of dissolving the sample in a large bath of tin (100 grms) contained in a carbon free furnace assembly. The operating temperature is 1000°C. The gas extraction is usually complete within 15 minutes. Practically all the gas evolved appears to be hydrogen.

NBL - Hydrogen has not been determined in any of the samples of thorium metal.

MANGANESE

NBL - The manganese is determined in a nitrate solution of the thorium metal by adding a weighed amount of potassium iodate, developing the color, and reading the transmittancy in a spectrophotometer.

IRON

NBL - The iron in thorium metal is determined on the nitrate solution by a method similar to that used for uranium. Solutions of ortho-phenanthroline and hydroxylamine hydrochloride are added, the pH adjusted and the transmittancy of the solution measured in a spectrophotometer.

URANIUM

AMES - The reclaimed thorium metal is analyzed for uranium by extracting the uranium with diethyl ether and then measuring the absorbency of the thiocyanate complex. This method seems to be good to ± 0.5 ppm of uranium in thorium.

NBL - Thorium metal is converted to the nitrate, the uranium is extracted from the nitrate solution with TBP. The TBP is stripped by carbonate solution. After destruction of the carbonate, the uranium is determined polarographically.

RARE EARTH

NBL - A 50 g. sample of metal is dissolved in nitric acid and the sample is evaporated to dryness. The dried sample, thorium nitrate, is treated with tributyl phosphate which extracts the bulk of the thorium nitrate. The aqueous layer, which is saturated with thorium nitrate also contains the rare earth nitrates, is diluted with water; the thorium is separated from the rare earth by repeated precipitations with hexamine solution (5%). Finally the rare earths are precipitated with oxalic acid and the precipitate is collected and ignited to the oxide.

BMI - A 50 g. sample of metal is dissolved in nitric acid and the sample is evaporated to dryness. The dried sample, thorium nitrate, is dissolved in 2N nitric acid and treated with cellulose powder. The sample is repeatedly treated with ether-nitric acid (200-25) and the portion of the solution is passed through a prepared cellulose column. The column is then eluted with 2N nitric acid. The elute is evaporated to a small volume and the acidity is adjusted and a repeat of the above treatment with cellulose, ether-nitric acid, and the column passing is made.

The elute from the second treatment is evaporated to dryness and any organic matter is decomposed by the addition of nitric acid.

SPECTROGRAPHIC PROCEDURE

Spectrographic procedures have been the methods generally employed for the detection of the metallic elements in the analysis of thorium samples.

Since the thorium spectrum is quite complex and the material is of a refractory nature there is no present procedure employing a direct examination for impurity content. Each laboratory engaged in the analysis of thorium metal has employed those procedures which they have generally found to be satisfactory for refractory materials.

AMES

The Ames procedure called for the simultaneous determination of Al, Fe, Mg, Ca, Si, B, Cd, Zn, and Be. The metal oxide is mixed with powdered flake graphite in the ratio 1:2 and compressed into 1/4 inch diameter conducting pellets by application of high pressure. These pellets are excited by means of a 60 cycle, 960 volt overdamped condenser discharge. Preliminary results indicate that all residual metallic impurities of interest except fractional parts per million quantities of boron, cadmium, and the rare earths can be determined in this manner.

NBL

The spectrochemical procedure used for the analysis of thorium samples at the New Brunswick Laboratory follows identically the procedure for the analysis of uranium. This procedure is described in detail in report A-2907. This method can be used for the determination of Ag, Al, As, B, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ge, In, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Si, Sn, V and Zn.

This is a carrier-distillation procedure using Ga_2O_3 in the amount of 2% of the sample weight as the carrier. The sample mixture is excited in a 10 amp 250 V d.c. arc where the sample impurities distill from the sample into the arc stream. Estimations of the amount of impurity present are made by visually comparing the spectrum of the sample against the spectra of standards run under the same conditions. By standard densitometric procedures it is possible to make more precise determinations when desirable.

The spectrographic analysis of the rare earth concentrates is only a qualitative report at this time. Since rare earth concentrates as prepared from thorium samples are generally cerium-lanthanum mixtures, it is not felt that the samples would compare at all favorably with standards that are of a yttrium matrix. Work is progressing on development of a procedure for the analysis of Ce-La matrix.

BMI

The Battelle Memorial Institute uses a very similar procedure employing AgCl, instead of Ga_2O_3 as the carrier additive.

In the BMI procedure for rare earths the resulting solution after the organic material decomposition is further treated by the addition of palladium solution for the internal standard and then adjusting the final volume with 1:1 nitric acid and so that 0.6 ml is equivalent to 10 g of thorium.

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The solution is placed on counter electrodes in the excitation stand using a 3 mm gap spacing. Oxygen is passed through the atmosphere chamber surrounding the electrodes for 30 seconds before starting the spark. The samples are then excited in the high-voltage spark using 4/3 kva capacitance, 0.32 mh inductance and 45 second exposure. Densitometric measurements are made of the impurity lines.

REFERENCES

All results and procedures in the report were obtained from the following references.

The Technology of Thorium, BMI-76

The Determination of Rare Earths in Thorium, BMI-260

Semi-Annual Progress Report in Chemistry - April 1 - September 30, 1951, ISC-184

Quarterly Summary Research Report, Oct., Nov., and Dec. 1951, ISC-220

Communication, V. A. Fassel to H. R. Mullin, May 9, 1952.

COMPARISON OF RESULTS FROM

NEW BRUNSWICK LABORATORY AND AMES LABORATORY

ON THORIUM METAL SAMPLES

TABLE I.

TRIPLICATE PORTIONS FROM SAME INGOT

	520A				520B				520C			
	NBL Chem	NBL Spec	AMES Chem	AMES Spec	NBL Chem	NBL Spec	AMES Chem	AMES Spec	NBL Chem	NBL Spec	AMES Chem	AMES Spec
Al		a15	16	12		a25	11	12		< 10	13	16
Ag		a3				a3				a3		
As		a5				< 5				< 5		
B	.4	a0.3		< 0.5	.2	a1		0.15	.2	a0.2		0.20
Be				80				75				60
Bi		< 1				< 1				< 1		
C	360				350				310			
Ca		a50		< 50		a100		< 50		a25		< 50
Cd				< .20				< 0.20				< 0.20
Cb		n.d.				n.d.				n.d.		
Cl	11				16				8			
Cr		< 5				< 5				< 5		
Cu		4.4				5.0				2.0		
F	< 100				< 100				< 100			
Fe	47	a50	46	55	50	a50	45	50	51	a50	42	40
Li		< 1				< 1				< 1		
Mg		a15		< 20		a25		< 20		a10		< 20
Mn	< 2	a3			< 2	a3			< 2	a3		
Mo		5				2				< 2		
N	49				48				42			
Na		a10				a10				a10		
Ni		a40				a60				a60		
Pb		3.5				2.5				1.5		
Si		a80		< 50		a50		< 50		a50		< 50
Sn		a10				a15				a10		
Ta		n.d.				n.d.				n.d.		
W		n.d.				n.d.				n.d.		
Zn		n.d.	47	20		n.d.	36	< 10		n.d.	53	20
Zr		500				200				200		
RE	44				63				114			
HCl insol.	1.03%				1.18%				1.27%			

	521A				521B				521C			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.5				a0.5				a1		
Al		a15	16	12		a15	14	12		a15	16	14
As		< 5				< 5				< 5		
B		a0.5		0.20	.4	a2		0.25	.3	a0.5		0.25
Be				80				100				105
Bi		< 1				< 1				< 1		
C	390				410				420			
Ca		a75		< 50		a25		< 50		a25		< 50
Cd				< 0.20				< 0.20				< 0.20
Cl	10				14				6			
Cr		< 5				< 5				< 5		
Cu		1.2				1.6				2.5		
F	< 100				< 100				< 100			
Fe		a50	40	65	50	a50	43	60	49	a50	40	50
Li		< 1				< 1				< 1		
Mg		a20		< 20		a20		< 20		a20		< 20
Mn		a5			< 2	a5			< 2	a5		
Mo		< 2				< 2				< 2		
N	60				54				56			
Na		a30				a30				a10		
Ni		a30				a30				a30		
Pb		a50				a100				a50		
Si		a30		< 50		a30		< 50		a50		< 50
Sn						a20						
Zn		18	< 20	< 20		28	53	20		10	20	20
Zr		400				400				400		
RE	39				41				68			
HCl insol.	1.29%				1.21%				1.3%			

[redacted] [redacted]

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	548A				548B				548C			
	NBL Chem	NBL Spec	AMES Chem	AMES Spec	NBL Chem	NBL Spec	AMES Chem	AMES Spec	NBL Chem	NBL Spec	AMES Chem	AMES Spec
Ag		a0.3										
Al		a10	20	22			15	15			20	17
As		< 5										
B	.2	a1		0.25				0.20				0.30
Be				180				150				120
Bi		< 1										
C	530											
Ca				< 50				< 50				< 50
Cd				<0.20				<0.20				<0.20
Cl	6											
Cr		a10										
Cu		2.4										
F	<.01%											
Fe	68	a30	36	55			37	50			36	60
Mg		a50		< 20				< 20				< 20
Mn	< 2	a3										
Mo		a3										
N	49											
Ni		a50										
Pb		3.0										
Si		a100		< 50				< 50				< 50
Sn		a8										
Ti		a3										
U	< 1											
Zn		13	150	25			45	15			45	25
Zr		a300										
RE	59											
HCl insol.	1.2%											

COMPARISON OF RESULTS FROM

NEW BRUNSWICK LABORATORY AND AMES LABORATORY

ON THORIUM METAL SAMPLES

TABLE II.

ROUTINE RECAST THORIUM METAL

[redacted]

	MX-397				MX-405			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a1				a0.5		
Al		a20		a25		a20		a30
As		<5				<5		
Au								
B		a1		0.55		a1		0.45
Ba								
Be		>500		340		>500		375
Bi		<1				<1		
C	850		770		960		1130	
Ca				<50				<50
Cd		n.d.		<0.20		n.d.		<0.20
Co		n.d.				n.d.		
Cr		a15				a15		
Cs								
Cu		a50				a50		
Fe		a10				a10		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a30		<20		a5		<20
Mn		a5				a5		
Mo		n.d.				n.d.		
N	240		406		290		437	
Na								
Ni		a300				a100		
P		n.d.				n.d.		
Pb		a5				a5		
Rb								
Sb		n.d.				n.d.		
Si		a150		<50		a80		<50
Sn		a1				<1		
V		n.d.				n.d.		
Zn		n.d.		<20		a30		<20

[redacted]

	MX-413				MX-414			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.2				a2		
Al		a20		a20		a20		
As		<5				<5		
Au								
B		a0.5		0.30		a10		
Ba								
Be		>500		340		>500		
Bi		n.d.				n.d.		
C	790		900		1000		1120	
Ca				<50				
Cd		n.d.		<0.20		n.d.		
Co		n.d.				n.d.		
Cr		a15				a30		
Cs								
Cu		a50				a50		
Fe		a10				a10		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a5		<20		a30		
Mn		a5				a5		
Mo		n.d.				n.d.		
N	240		427		280		481	
Na								
Ni		a200				a200		
P		n.d.				n.d.		
Pb		a5				a5		
Rb								
Sb		n.d.				n.d.		
Si		a100		<50		a100		
Sn		<1				<1		
V		n.d.				n.d.		
Zn		a20		<20		a20		

[redacted]

	MX-415				MX-445			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a1				a2		
Al		a20				a20		
As		<5				<5		
Au								
B		a2				a2		
Ba								
Be		>500				>500		
Bi		a1				<1		
C	840		1355		830		805	
Ca								
Cd		n.d.				n.d.		
Co		n.d.				n.d.		
Cr		a30				a30		
Cs								
Cu		a50				a50		
Fe		a10				a10		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a10				a10		
Mn		a5				a5		
Mo		n.d.				n.d.		
N	320		560		270		318	
Na								
Ni		a300				a150		
P		n.d.				n.d.		
Pb		a5				a5		
Rb								
Sb		n.d.				n.d.		
Si		a100				a100		
Sn		a2				<1		
V		n.d.				n.d.		
Zn		<20				<20		

[redacted]

[redacted]

	MX-528				MX-529			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.5				a0.1		
Al		a15		a25		a15		a25
As		<5				<5		
Au								
B		a0.5		0.35		a3		0.30
Ba								
Be				175				145
Bi		<1				<1		
C	540		640		480		595	
Ca				<50				<50
Cd		n.d.		<0.20		n.d.		<0.20
Co		n.d.				n.d.		
Cr		a10				a10		
Cs								
Cu		a10				a10		
Fe		a100		140		a100		140
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a8		<20		a8		<20
Mn		a3				a3		
Mo		n.d.				n.d.		
N	124		181		128		172	
Na								
Ni		a60				a60		
P		n.d.				n.d.		
Pb		a5				a5		
Rb								
Sb		n.d.				n.d.		
Si		a30		<50		a300		<50
Sn		a20				a10		
V		n.d.				n.d.		
Zn		n.d.		<20		n.d.		<20

[redacted]

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[redacted]

	MX-530				MX-572			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.3				a0.3		
Al		a15		a25		a50		a20
As		<5				<5		
Au								
B		a3		0.30		a3		0.3
Ba								
Be				200		>2000		310
Bi		<1				n.d.		
C	520				700			
Ca				<50				<50
Cd		n.d.		<0.2		n.d.		<0.2
Co		n.d.				n.d.		
Cr		a10				a10		
Cs								
Cu		a10				a10		
Fe		a100		155		a100		35
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a8		<20		a5		<20
Mn		a3				a2		
Mo		n.d.				n.d.		
N	112				136			
Na								
Ni		a60				a30		
P		n.d.				n.d.		
Pb		a4				a4		
Rb								
Sb		n.d.				n.d.		
Si		a50		<50		a500		a75
Sn		a10				n.d.		
V		n.d.				n.d.		
Zn		n.d.		<20		n.d.		<20

[redacted]

[redacted]

	MX-573				MX-575			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.5				a0.3		
Al		a30		a20		a30		a25
As		<5				<5		
Au								
B		a0.5		<0.2		a0.3		0.2
Ba								
Be		>2000		245		>2000		265
Bi		n.d.				n.d.		
C	620				660			
Ca				<50				<50
Cd		n.d.		<0.2		n.d.		<0.2
Co		n.d.				n.d.		
Cr		a10				a10		
Cs								
Cu		a10				a10		
Fe		a100		100		a100		70
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a5		<20		a5		<20
Mn		a2				a2		
Mo		n.d.				n.d.		
N	127				166			
Na								
Ni		a30				a20		
P		n.d.				n.d.		
Pb		a2				a2		
Rb								
Sb		n.d.				n.d.		
Si		a100		<50		a200		<50
Sn		n.d.				n.d.		
V		n.d.				n.d.		
Zn		n.d.		<20		n.d.		<20

[redacted]

	MX-580				MX-582			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.2				a0.1		
Al		a10				a15		
As		<5				<5		
Au								
B		a0.5				a1		
Ba								
Be								
Bi		n.d.				<1		
C	620		775		530		610	
Ca								
Cd		n.d.				n.d.		
Co		n.d.				n.d.		
Cr		a15				a15		
Cs								
Cu		a20				a15		
Fe		a100				a100		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a15				a10		
Mn		a3				a3		
Mo		n.d.				n.d.		
N	150		200		86		135	
Na								
Ni		a50				a30		
P		n.d.				n.d.		
Pb		a4				a4		
Rb								
Sb		n.d.				n.d.		
Si		a500				a800		
Sn		a10				n.d.		
V		n.d.				n.d.		
Zn		<20				n.d.		

[redacted]

	MX-563 NBL Chem	MX-563 NBL Spec	MX-563 Ames Chem	MX-563 Ames Spec	MX-568 NBL Chem	MX-568 NBL Spec	MX-568 Ames Chem	MX-568 Ames Spec
Ag		a0.1				a0.1		
Al		a10		a20		a15		a2
As		<5				<1		
Au								
B		a0.4		0.2		a0.3		0.25
Ba								
Be				165				250
Bi		n.d.				n.d.		
C	560				660			
Ca				<50				<50
Cd		n.d.		<0.2		n.d.		<0.2
Co		n.d.				n.d.		
Cr		a15				a15		
Cs								
Cu		a20				a20		
Fe		a100		60		a150		85
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a15		<20		a15		<20
Mn		a3				a3		
Mo		n.d.				n.d.		
N	94				108			
Na								
Ni		a30				a30		
P		n.d.				n.d.		
Pb		a4				a4		
Rb								
Sb		n.d.				n.d.		
Si		a800		<50		a1000		a50
Sn		a3				a1		
V		n.d.				n.d.		
Zn		n.d.		<20		n.d.		<20

[redacted]

[redacted]

	MX-600				MX-613			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.1				a0.1		
Al		a15		a20		a25		a20
As		<5				<5		
Au								
B		a1		0.45		a0.5		0.3
Ba								
Be				180		>2000		125
Bi		n.d.				<1		
C	600				600			
Ca				<50				<50
Cd		n.d.		<0.2		n.d.		<0.2
Co		n.d.				n.d.		
Cr		a25				a20		
Cs								
Cu		a20				a10		
Fe		a150		125		a200		125
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a15		<20		a10		<20
Mn		a3				a3		
Mo		n.d.				n.d.		
N	176				176			
Na								
Ni		a50				a50		
P		n.d.				n.d.		
Pb		a4				a2		
Rb								
Sb		n.d.				n.d.		
Si		a1000		a75		a1000		a50
Sn		n.d.				n.d.		
V		n.d.				n.d.		
Zn		20		<20		n.d.		<20

[redacted]

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	MX-627 NBL Chem	MX-627 NBL Spec	MX-627 Ames Chem	MX-627 Ames Spec	MX-621 NBL Chem	MX-621 NBL Spec	MX-621 Ames Chem	MX-621 Ames Spec
Ag		a0.5				a0.2		
Al		a20		15		a15		15
As		<5				<5		
Au								
B		a0.5		<0.2		a0.5		0.35
Ba								
Be		>2000		360		>2000		230
Bi		<1				<1		
C	560				580			
Ca				<50				<50
Cd		n.d.		<0.2		n.d.		<0.2
Co		n.d.				n.d.		
Cr		a 0				a10		
Cs								
Cu		a10				a10		
Fe		a200		75		a150		100
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a10		<20		a10		<20
Mn		a2				a2		
Mo		n.d.				n.d.		
N	167				104			
Na								
Ni		a40				a40		
P		n.d.				n.d.		
Pb		a2				a2		
Rb								
Sb		n.d.				n.d.		
Si		a1000		<50		a1000		a50
Sn		n.d.				n.d.		
V		n.d.				n.d.		
Zn		n.d.		<20		n.d.		<20

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	MX-635				MX-639			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
A-		a0.2				a0.1		
Al		a15		a15		a15		15
As		<5				<5		
Au								
B		a1		<0.2		a1		0.25
Ba								
Be		>2000		200		>2000		235
Bi		<1				<1		
C	600				480			
Ca				<5				<50
Cd		n.d.		<0.2		n.d.		<0.2
Co		n.d.				n.d.		
Cr		a10				a10		
Cs								
Cu		a10				a10		
Fe		a150		65		a15		65
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a10		<20		a10		<20
Mn		a2				a2		
Mo		n.d.				n.d.		
N	102				122			
Na								
Ni		a40				a40		
P		n.d.				n.d.		
Pb		a3				a3		
Rb								
Sb		n.d.				n.d.		
Si		a1000		<50		a1000		<50
Sn		n.d.				n.d.		
V		n.d.				n.d.		
Zn		n.d.		<20		n.d.		<20

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	MX-606				MX-55[illegible]			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.2				a0.5		
Al		a30		a15		a30		
As		<5				<5		
Au								
B		a[illegible]		0.45		a1		
Ba								
Be		>2000		250		>500		
Bi		n.d.				<1		
C	470				800			
Ca				<50				
Cd		n.d.		<0.2		n.d.		
Co		n.d.				n.d.		
Cr		a20				a15		
Cs								
Cu		a10				a15		
Fe		a200		125		a150		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a15		<20		a5		
Mn		a3				a3		
Mo		n.d.				n.d.		
N	154				306			
Na								
Ni		a80				a30		
P		n.d.				n.d.		
Pb		a3				a10		
Rb								
Sb		n.d.				n.d.		
Si		a1000		a75		a2000		
Sn		n.d.				a2		
V		n.d.				n.d.		
Zn		<20		<20		n.d.		

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	MX-758 NBL Chem	MX-758 NBL Spec	MX-758 Ames Chem	MX-758 Ames Spec	MX-759 NBL Chem	MX-759 NBL Spec	MX-759 Ames Chem	MX-759 Ames Spec
Ag		a0.1				a1		
Al		a10				a15		
As		<5				5		
Au								
B		a2				a4		
Ba								
Be		>500				>500		
Bi		n.d.				n.d.		
C	450				620			
Ca								
Cd		n.d.				n.d.		
Co		n.d.				n.d.		
Cr		a5				a5		
Cs								
Cu		a10				a15		
Fe		a200				a200		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a10				a10		
Mn		a2				a2		
Mo		n.d.				n.d.		
N	110				120			
Na								
Ni		a40				a40		
P		n.d.				n.d.		
Pb		a2				a2		
Rb								
Sb		n.d.				n.d.		
Si		a500				a200		
Sn		a2				a2		
V		n.d.				n.d.		
Zn		n.d.				n.d.		

	MX-762				MX-763			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a1				a0.5		
Al		a10				a15		
As		<5				<5		
Au								
B		a2				a2		
Ba								
Be		>500				>500		
Bi		n.d.				n.d.		
C	510				500			
Ca								
Cd		n.d.				n.d.		
Co		n.d.				n.d.		
Cr		a5				a5		
Cs								
Cu		a15				a15		
Fe		a150				a150		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a15				a10		
Mn		a2				a2		
Mo		n.d.				n.d.		
N	230				160			
Na								
Ni		a20				a20		
P		n.d.				n.d.		
Pb		a2				a2		
Rb								
Sb		n.d.				n.d.		
Si		a500				a1000		
Sn		a2				a2		
V		n.d.				n.d.		
Zn		59				n.d.		

	MX-767				MX-768			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.5				a0.2		
Al		a10				a10		
As		<5				<5		
Au								
B		a1				a0.5		
Ba								
Be		>500				>500		
Bi		n.d.				n.d.		
C	500				540			
Ca								
Cd		n.d.				n.d.		
Co		n.d.				n.d.		
Cr		a5				a5		
Cs								
Cu		a15				a10		
Fe		a200				a200		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a10				a8		
Mn		a3				a2		
Mo		n.d.				n.d.		
N	120				121			
Na								
Ni		a20				a30		
P		n.d.				n.d.		
Pb		a2				a4		
Rb								
Sb		n.d.				n.d.		
Si		a1500				a800		
Sn		a2				a2		
V		n.d.				n.d.		
Zn		<10				n.d.		

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10475-29

	MX-770				MX-775			
	NBL Chem	NBL Spec	Ames Chem	Ames Spec	NBL Chem	NBL Spec	Ames Chem	Ames Spec
Ag		a0.2				a0.4		
Al		a10				a10		
As		<5				<5		
Au								
B		a1				a0.2		
Ba								
Be		>500				>500		
Bi		n.d.				n.d.		
C	510				560			
Ca								
Cd		n.d.				n.d.		
Co		n.d.				n.d.		
Cr		a5				a5		
Cs								
Cu		a10				a10		
Fe		a200				a250		
Ge		n.d.				n.d.		
In		n.d.				n.d.		
K								
Li								
Mg		a8				a8		
Mn		a2				a3		
Mo		n.d.				n.d.		
N	123				133			
Na								
Ni		a30				a30		
P		n.d.				n.d.		
Pb		a2				a2		
Rb								
Sb		n.d.				n.d.		
Si		a1000				a1000		
Sn		a2				a2		
V		n.d.				n.d.		
Zn		n.d.				n.d.		