CALUTRON PRODUCTION

OF

STABLE ISOTOPES

1946-1949

INCLUSIVE

OAK RIDGE NATIONAL LABORATORY

AREA

OPERATED BY

CARBIDE AND CARBON CHEMICALS DIVISION

UNION CARBIDE AND CARBON CORPORATION

OAK RIDGE, TENNESSEE

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CALUTRON PRODUCTION OF STABLE ISOTOPES, 1946-1949, INCLUSIVE

H. W. Savage

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April 20, 1950

ISOTOPE RESEARCH AND PRODUCTION DIVISION
Dr. C. P. Keim, Division Head

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Isotope Separation

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ABSTRACT

This report tabulates detailed information on the use of the calutron to produce Stable Isotopes during the period of 1946-1949, inclusive. Where chemical recovery is incomplete, estimates of calutron production are shown. Maximum purity attained for each isotope processed has been included.

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CALUTRON PRODUCTION OF STABLE ISOTOPES, 1946-1949, INCLUSIVE

Preface

This is one of a series of reports describing phases of the program of separating stable isotopes by the electromagnetic method. The phase covered in this report is the application of the calutron to isotope separation giving particularly the amounts produced and the isotopic qualities attained. Chemical qualities of the products are not discussed.

The program is under the direction of Dr. C. P. Keim, Division Head, of the Isotope Research and Production Division, Y-12 Plant, Oak Ridge National Laboratories. The author is in charge of the calutron phases of the Isotope Production and Process Development; and Leon O. Love is directly responsible for calutron operations. The preparation of charge materials and the refinement of collected isotopes is performed by the Isotope Chemistry Group under the supervision of Boyd Weaver; and Mass Analysis is performed under the direction of R. F. Hibbs in another division.

In early parts of the 4-year period reported the following persons contributed materially to the growth of the stable isotope separation program: V. C. Hall[1], H. L. Hull[2], C. Starr[3], W. A. Arnold[4], R. L. Carter[3], L. G. Chelius[5], and J. S. Hood[2].

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1. Now with TIME Magazine, New York, N. Y.
2. Now with Argonne National Laboratory, Chicago, Illinois.
3. Now with North-American Aviation, Los Angeles, California.
4. Now with the Biology Division, Oak Ridge National Laboratory.
5. Now with the Isotopes Division, Atomic Energy Commission.

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J. R. Walton assisted the writer in preparing the factual material presented in the report.

Introduction

This report summarizes all production of stable isotopes in the calutrons of Building 9731 from the start of the program late in 1945 to January 1, 1950. Future reports of this type will serve as supplements to this report particularly as they reveal actual quantities in lieu of estimates given herein. Total production has been given in terms of weights and moles of elements. These are not to be confused with the inventory of isotopes, the status of which fluctuates and is reported at intervals.

History

The electromagnetic separation of all isotopes has proceeded through several phases:

1) The trial of a wide variety of elements and compounds to ascertain primary separation problems; this occupied most of 1946 and has continued at intervals since.

2) The standardization of several ion source and receiver types to readily cover the ranges of anticipated conditions; this began in 1946, received major emphasis in 1947, and has been subject to improvement since.

3) The processing of progressively more "difficult"* elements to obtain research quantities of all isotopes, with increasing emphasis since 1947.

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* "Difficult" in the senses of being extremely non-volatile, having non-volatile compounds, being virtually non-condensible, or being extremely rare and possibly unobtainable.

4) The processing of certain elements over relatively long periods to fill special demands; these collections began late in 1947.

5) The reprocessing of many elements at intervals for further study and to supply the demand for them.

These general phases overlap and give rise to both unique and duplicate problems. The time for exploration and reprocessing is usually short compared to the time required for special problems arising from processing large quantities, meeting high isotopic purity, or overcoming special problems such as are encountered with an element like mercury. Consequently the experience with some elements is many times that with another; however, the trend with each is still to be able to improve operating conditions and production rates.

Data

The tables presented show the chronology of processing the elements, the frequency of processing, the number of isotope samples, and the quantities produced in the calutrons. The graph shows the general trend of production and distribution with relation to time.

Table 1 lists the elements processed chronologically, successive tours through the alphabet being the index.

Table 2 gives the series range during each semi-annual period, and the elements processed may then be found by referring to Table 1.

Table 3 is a measure of the productivity of each semi-annual period in terms of the number of isotope samples produced in the calutrons. Some of these samples were subsequently subdivided or combined for purposes of distribution (see table 6).

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Table 4 shows the productivity of each semi-annual period in terms of the total weight of each element produced. Where chemical recovery has been completed, the recovered weights have been tabulated; otherwise estimates based on monitored ion currents are used. Subsequent reports will revise estimates to actual values.

Table 5 shows the productivity of each semi-annual period in terms of the total moles of each element produced. These values are obtained from Table 4 by dividing each weight given therein by the appropriate atomic weight.

Table 6 indicates the demand for stable isotopes in terms of the number of isotope samples of each element obtained by users during each semi-annual period.

Figure 1 is a graph illustrating the trends observable from the data in Tables 3, 4, 5, and 6.

Table 7 is a detailed breakdown by isotopes of the information summarized in Table 4.

Table 8 is a summary of the mass analysis data for each of the isotope entries in Table 7, showing only the maximum purity attained in each particular semi-annual period. Omissions in the data will be reported subsequently.

Table 9 is a detailed breakdown by isotopes of the isotope distribution summarized in Table 6.

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Conclusions

From Table 5 and Figure 1, it is apparent that calutron production has increased about 600% after four years of effort. The trend indicates that maximum productivity is near with utilized equipment, although this is flavored by changing emphasis--special collections and attempts to process "very difficult" elements acting to reduce total productivity. Table 6 and Figure 1 indicate that demand for Stable Isotopes has been greater in each successive semi-annual period since July 1, 1947.

APPROVED:

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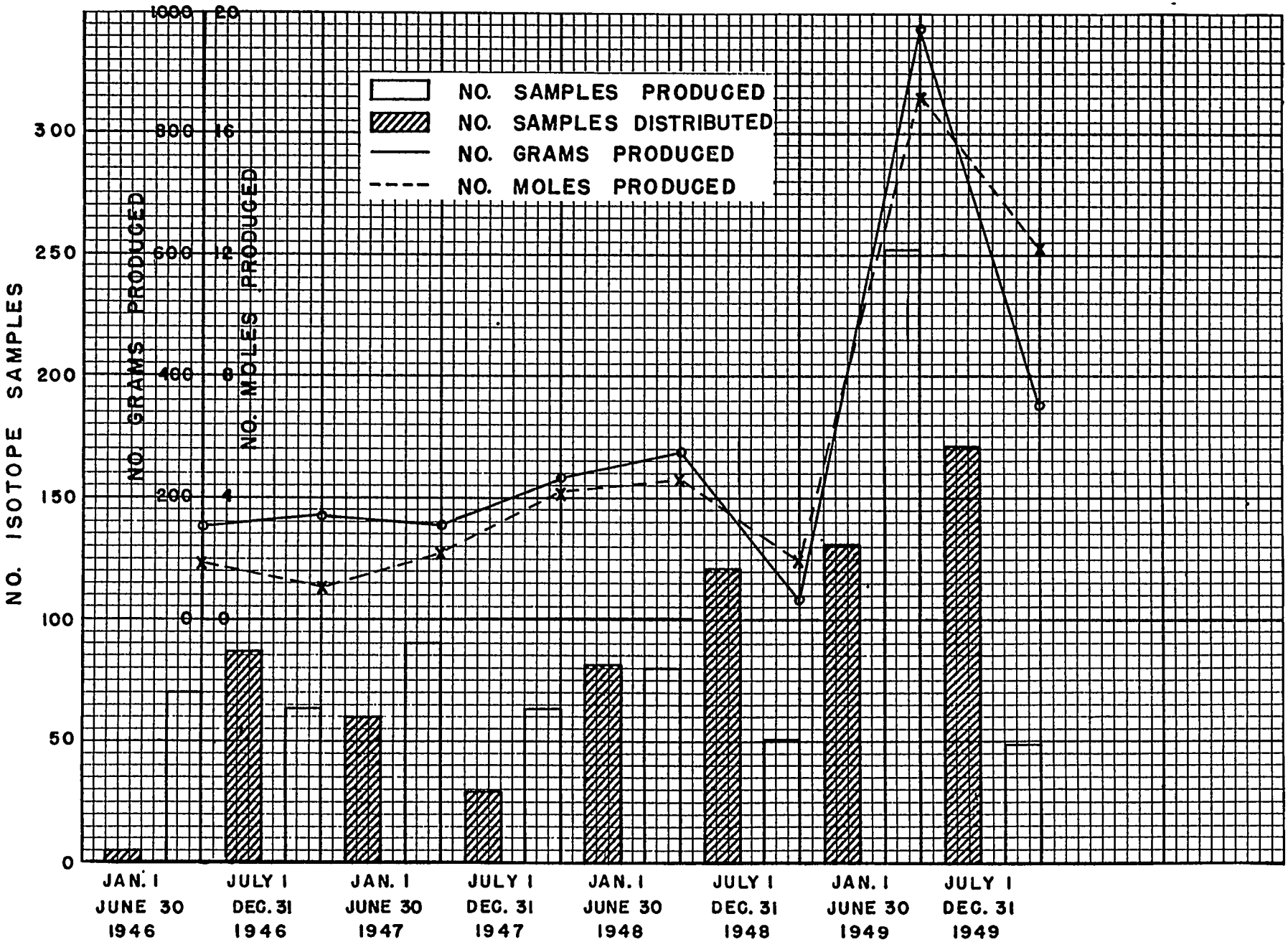

FIGURE I. TRENDS IN STABLE ISOTOPE PRODUCTION & DISTRIBUTION

Table 1

Chronological Index of Elements Processed

Series	Element	Series	Element	Series	Element
A	Copper	AA	Zirconium	BA	Iron
B	Iron	AB	Cadmium	BB	Iron
C	Iron	AC	Cadmium	BC	Tin
D	Chromium	AD	Indium	BD	Germanium
E	Iron	AE	Antimony	BE	Germanium
F	Iron	AF	Indium	BF	Titanium
G	Uranium	AG	Zinc	BG	Tungsten
H	Lithium	AH	Zinc	BH	Indium
I	Lithium	AI	Silicon	BI	Tin
J	Nickel Copper	AJ	Silicon	BJ	Potassium
K	Nickel Copper	AK	Selenium	BK	Zinc
L	Carbon	AL	Tin	BL	Strontium
M	Carbon	AM	Iron	BM	Boron
N	Silver	AN	Selenium	BN	Calcium
O	Lead	AO	Bromine	BO	Lead
P	Magnesium	AP	Uranium	BP	Tellurium
Q	Magnesium	AQ	Lead	BQ	Lithium
R	Molybdenum	AR	Lithium	BR	Thallium
S	Silver	AS	Nickel Copper	BS	Selenium
T	Molybdenum	AT	Nickel Copper	BT	Antimony
U	Silver	AU	Tellurium	BU	Thallium

Table 1 - Continued

Chronological Index of Elements Processed

Series	Element	Series	Element	Series	Element
V	Calcium	AV	Chlorine Copper	BV	Thallium
W	Potassium	AW	Molybdenum	BW	Silicon
X	Calcium	AX	Cadmium	BX	Thallium
Y	Uranium	AY	Tin	BY	Thallium
Z	Strontium	AZ	Iron	BZ	Magnesium
CA	Tellurium	DA	Potassium	EA	Silver
CB	Mercury	DB	Potassium	EB	Silicon
CC	Thallium	DC	Oxygen	EC	Tin
CD	Chromium	DD	Cerium	ED	Lithium
CE	Cadmium	DE	Indium	EE	Zirconium
CF	Thallium	DF	Nickel	EF	Lanthanum
CG	Thallium	DG	Barium		
CH	Thallium	DH	Chlorine		
CI	Iron	DI	Calcium		
CJ	Thallium	DJ	Mercury		
CK	Zirconium	DK	Iron		
CL	Tungsten	DL	Iron Copper		
CM	Potassium	CM	Iron		
CN	Lead	DN	Iron		
CO	Indium	DO	Iron		
CP	Rhenium	DP	Boron		

Table 1 - Continued

Chronological Index of Elements Processed

Series	Element	Series	Element
CQ	Indium	DQ	Beryllium
CR	Tin	DR	Mercury
CS	Calcium	DS	Beryllium
CT	Lithium	DT	Potassium
CU	Lithium	DU	Copper
CV	Zirconium	DV	Lithium
CW	Cerium	DW	Cerium
CX	Sulphur	DX	Tellurium
CY	Selenium	DY	Selenium
CZ	Iron	DZ	Magnesium

Table 2

SERIES RANGE

By 6 Month Intervals

Period	Series
January 1, 1946 June 30, 1946	A-W
July 1, 1946 December 31, 1946	X-AR
January 1, 1947 June 30, 1947	AS-BL
July 1, 1947 December 31, 1947	BM-CG
January 1, 1948 June 30, 1948	CH-DA
July 1, 1948 December 31, 1948	DB-DK
January 1, 1949 June 30, 1949	DL-DT
July 1, 1949 December 31, 1949	DU-EF

Table 3

STABLE ISOTOPE SAMPLES PRODUCED IN THE CALUTRON

By 6-month Intervals

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Totals
Lithium	4	2		2	4			4	16
Beryllium							3		3
Boron				2			2		4
Carbon	2								2
Nitrogen						1			1
Oxygen						2			2
Magnesium	6			4				3	13
Silicon		3		4				3	10
Sulphur					5				5
Chlorine			2			3			5
Potassium	3		3		6	3	3		18
Calcium	3	5		6	3	6			23
Titanium			5						5
Chromium	4			5					9
Iron	18	4	12		8	3	85		130
Nickel	10		5			7			22
Copper	3		3				2	2	10
Zinc		5	5						10
Germanium			5						5
Selenium		6		6	7			6	25
Bromine		2							2

Table 3 - Continued

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Totals
Strontium		3	4						7
Zirconium		5			13			5	23
Molybdenum	8		7						15
Silver	4							2	6
Cadmium		6	3	8					17
Indium		4	2		4	2			12
Tin		10	21		10			10	51
Antimony		2		2					4
Tellurium			8	8				8	24
Barium						9			9
Lanthanum								2	2
Cerium					3	4		4	11
Tungsten			5		6				11
Rhenium					2				2
Mercury				3		5	157		165
Thallium				18	4				22
Lead	4	4		5	5				18
Uranium	1	2				6			9
Tot. Elements	13	15	15	13	14	12	6	11	39
Tot. Samples	70	63	90	73	80	51	252	49	728
Samples/Mo.	11.7	10.5	15.0	12.2	13.3	8.5	42.0	8.2	15.2

Table 4

STABLE ISOTOPE PRODUCTION-GRAMS OF ELEMENT

By 6 Month Intervals

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Totals
Lithium	2.2	0.8		7.3	7.8			49.8*	67.8* g
Beryllium							0.004*		0.004*
Boron				0.07*			3.1*		3.2*
Carbon	0.2								0.2
Nitrogen						---**			---**
Oxygen						0.24*			.24*
Magnesium	3.6			10.2				54.9*	68.7*
Silicon		4.4		18.8				11.8	35.0
Sulphur					0.8				0.8
Chlorine			0.04			2.6			2.6
Potassium	0.7		1.7		40.0	7.7	10.8		61.0
Calcium	0.4	1.5*		9.9	0.7	28.7			40.7*
Titanium			6.7						6.7
Chromium	3.8			46.3					50.1
Iron	28.4	3.2	61.8		70.5	13.3	923.0*		1100.2*
Nickel	8.0		8.2			26.9			43.0
Copper	6.0		4.9				0.85*	38.4	50.2*
Zinc		1.9	9.5						11.4
Germanium			13.5						13.5
Selenium		1.4		10.6	6.3			11.9*	30.3*
Bromine		0.06							0.06
Strontium		6.1	2.8						8.9
Zirconium		1.2			28.0			39.5*	68.8*

* Estimated
** Experimental

Table 4 - Continued

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Totals
Molybdenum	17.3		9.4						26.7
Silver	12.2							9.0	21.2
Cadmium		2.3	4.7	28.3*					35.3*
Indium		4.4*	2.2		28.3	20.7			55.6*
Tin		3.8*	19.8		46.3			76.9*	146.8*
Antimony		4.4		2.0					6.4
Tellurin			6.7	29.1				24.2	60.0
Barium						12.7			12.7
Lanthanum								25.0*	25.0*
Cerium					4.6	16.4		11.6	32.6
Tungsten			4.8		10.4				15.2
Rhenium					6.0				6.0
Mercury				0.03		0.2	39.6*		39.9*
Thallium				48.0	7.4				55.4
Lead	1.3	4.0		19.3	17.9				42.5
Uranium	65.1	127.1				0.013***			192.3
Total	149.2	166.6*	156.7	229.9*	275.0	129.5[a]*	977.35*	353.00*	2437.0
Avg./Sample	2.1	2.6	1.7	3.1	3.4	2.5	3.9	7.2	3.3

* Estimated
** Experimental
*** Special AEC Order
a Low Due to Special AEC Order

Table 5

STABLE ISOTOPE PRODUCTION-MOLES OF ELEMENT

By 6 Month Intervals

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Totals
Lithium	.317	.115		1.052	1.123			7.176*	9.769*
Beryllium							.0004*		.0004*
Boron				.006			.287*		.294 *
Carbon	.017								.017
Nitrogen						---**			---**
Oxygen						.015*			.015*
Magnesium	.148			.419				2.257*	2.825*
Silicon		.157		.670				.421	1.248
Sulphur					.025				.025
Chlorine			.001			.073			.074
Potassium	.018		.043		1.023	.197	.276		1.560
Calcium	.010	.037*		.247	.017	.716			1.015 *
Titanium			.140						.140
Chromium	.073			.890					.961
Iron	.509	.057	1.107		1.263	.238	16.53*		19.7*
Nickel	.136		.140			.458			.733
Copper	.094		.077				.013*	.604	.790*
Zinc		.029	.145						.174
Germanium			.186						.186
Selenium		.018		.134	.080			.150*	.384*
Bromine		.0008							.0008
Strontium		.070	.032						.102

*Estimated
**Experimental

Table 5 - Continued

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Totals
Zirconium		.013		[illegible]	.307			.433*	.754*
Molybdenum	.180		.098						.278
Silver	.113							.083	.196
Cadmium		.020	.042	.252*					.314*
Indium		.038*	.019		.247	.180			.484*
Tin		.032*	.167		.390			.648*	1.236*
Antimony		.036		.016					.053
Tellurium			.053	.228				.190	.471
Barium						.092			.092
Lanthanum								.180*	.180*
Cerium					.033	.117		.083	.233
Tungsten			.026		.057				.083
Rhenium					.032				.032
Mercury				.001		.001	.197*		.199*
Thallium				.235	.036				.271
Lead	.006	.019		.093	.086				.205
Uranium	.273	.534				.00005***			.807
Totals	1.894	1.176*	2.276	4.243*	4.719	2.087[a]	17.299*	12.225*	45.904*
Avg.Samp.	.027	.019	.025	.058	.059	.041	.069	.249	0.063

* Estimated
** Experimental
*** Special AEC Order
a Low due to Special AEC Order

Table 6

Stable Isotope Samples Shipped*

By 6-Month Intervals

Element	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Lithium		4			9	6	6	4	29
Beryllium								2	2
Boron						1			1
Carbon		1							1
Nitrogen									
Oxygen									
Magnesium		9			5		6	6	26
Silicon					2	3		3	8
Sulphur								2	2
Chlorine							1	2	3
Potassium		4		1	3	10	7	8	33
Calcium		2	6	2	4	2	3	3	22
Titanium					3	4		9	16
Chromium		8		1	1	5	3	7	25
Iron	3	4	2	1	7	3	6	4	30
Nickel		12		2	6	4	2	7	33
Copper	2	3		2	1	1		3	12
Zinc		1			5	5	2	9	22
Germanium					2	1	6	4	13
Selenium		1	7		3	1	3	12	27
Bromine									
Strontium						3		3	6

* Information supplied by L. G. Chelius, Isotopes Division, Atomic Energy Commission

Table 6 - Continued

Elements	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Zirconium			9		1	10	5	6	31
Molybdenum		17	8	2	3	5	6	7	48
Silver		4		2	1	2	1	4	14
Cadmium		5	9		2	7	15	7	45
Indium		3	2	1	2			4	12
Tin		1	8	3	11	17	13	6	59
Antimony			4	5	2		2	2	15
Tellurium			1	2		23	14	8	48
Barium							14	6	20
Lanthanum									
Cerium						1	4		5
Tungsten					1	7	5	12	25
Rhenium							4	4	8
Mercury								3	3
Thallium				2	4			5	11
Lead		8	4	2	4		3	9	30
Uranium									
Total	5	87	60	28	82	121	131	171	685

Table 7

Stable Isotope Production-Grams of Isotope

By 6-Month Intervals

Element	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Lithium	6	.100	.020		.457	1.098			3.296*	4.971*
	7	2.106	.730		6.800	6.692			46.459*	62.787*
		2.206	.750		7.257	7.790			49.755*	67.758*
Beryllium	9	-	-		-	-		-		-
	10							.004*		.004*
								.004*		.004*
Boron	10				.017*			.524*		.541*
	11				.052			2.567*		2.619*
					.069*			3.091*		3.160*
Carbon	12	.216								.216
	13	.011								.011
		.227								.227
Nitrogen	14						---**			---**
	15						---**			---**
Oxygen	16						.218*			.218*
	17						.008*			.008*
	18						.014*			.014*
							.240*			.240*
Magnesium	24	2.561			4.199				43.128*	49.888*
	25	.551			2.959				5.875*	9.385*
	26	.539			2.932				5.899*	9.370*
	28	-			.091				-	.091
		3.651			10.181				54.902*	68.734*
Silicon	28		3.949		16.598				10.975	31.522
	29		.278		1.078				.473	1.829
	30		.183		0.678				.310	1.171
	32		-		0.515				-	.515
			4.410		18.869				11.758	35.037
Sulphur	32					.424				.424
	33					.179				.179
	34					.185				.185
	36					.020				.020
	38					.006				.006
						.814				.814

* Estimated
** Experimental

Table 7 - Continued

Element	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Chlorine	35			.039			1.823			1.862
	36			-			.072			.072
	37			.003			.665			.668
				.042			2.560			2.602
Potassium	39	.514		1.620		35.428	5.682	9.408		52.652
	40	.072		.024		1.850	.727	.029		2.702
	41	.111		.093		2.730	1.339	1.372		5.645
		.697		1.737		40.008	7.748	10.809		60.999
Calcium	40	.031	1.369		8.034	-	27.115			36.549
	42	-	.019		.111	-	.822			.952
	43	-	.015		.028	-	.113			.156
	44	.009	.039		1.689	.597	.634			2.968
	46	.003	.001*		.006	.014	.020			.044*
	48	-	.008*		.008	.042	.013			.071*
		.043	1.451*		9.876	.653	28.717			40.740*
Titanium	46			.582						.582
	47			.524						.524
	48			4.666						4.666
	49			.477						.477
	50			.445						.445
				6.694						6.694
Chromium	50	.237			2.489					2.726
	52	3.190			38.688					41.878
	53	.295			4.001					4.296
	54	.086			1.069					1.155
	56	-			.014					.014
		3.808			46.261					50.069
Iron	54	1.809	.397	2.393		3.662	-	45.655*		53.916*
	56	24.867	2.650	58.379		65.023	12.980	866.888*		1030.787*
	57	.695	.090	.809		1.563	.258	5.715*		9.130*
	58	1.005	.068	.254		.266	.022	4.704*		6.319*
		28.376	3.205	61.835		70.514	13.260	922.962*		1100.152*
Nickel	56	-		-			.318			.318
	58	5.110		2.548			18.465			26.123
	60	2.382		4.680			7.162			14.224
	61	.135		.228			.172			.535
	62	.313		.640			.691			1.644
	64	.073		.089			.067			.229
	66	-		-			.005			.005
		8.013		8.185			26.880			43.078

* Estimated

Table 7 - Continued

Element	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Copper	63	4.392		4.942				.596	21.371	31.301
	65	1.628		.003				.250*	16.997	18.878*
		6.020		4.945				.846*	38.368	50.179*
Zinc	64		.423	3.309						3.732
	66		.989	2.080						3.069
	67		.004	.625						.629
	68		.463	3.109						3.572
	70		.043	.405						.448
			1.922	9.528						11.450
Germanium	70			3.049						3.049
	72			3.851						3.851
	73			.924						.924
	74			4.484						4.484
	76			1.226						1.226
				13.534						13.534
Selenium	72		-		-	.118			-	.118
	74		.093		.217	.338			.220*	.868*
	76		.168		.921	1.004			2.080*	4.173*
	77		.197		1.232	.949			1.503	3.881
	78		.366		2.021	1.873			3.351	7.611
	80		.411		5.039	1.175			3.083	9.708
	82		.186		1.194	.864			1.670*	3.914*
			1.421		10.624	6.321			11.907*	30.273*
Bromine	79		.017							.017
	81		.038							.038
			.055							.055
Strontium	84		.089	.026						.115
	86		.714	.648						1.362
	87		-	.992						.992
	88		5.255	1.177						6.432
			6.058	2.843						8.901
Zirconium	88		-			.002			-	.002
	90		.538			15.074			20.489*	36.101*
	91		.197			3.385			4.444*	8.026*
	92		.213			4.163			6.699*	11.075*
	94		.237			4.664			6.810*	11.711*
	96		.055			.593			1.066*	1.714*
	98		-			.132			-	.132
			1.240			28.013			39.508*	68.761*

* Estimated

Table 7 - Continued

Element	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Molybdenum	92	2.223		1.314						3.537
	94	1.709		.812						2.521
	95	2.812		1.643						4.455
	96	3.993		1.822						5.815
	97	2.168		1.152						3.320
	98	2.623		1.676						4.299
	100	1.581		.994						2.575
	102	.147		-						.147
		17.256		9.413						26.669
Silver	107	6.014							2.232	8.246
	109	6.123							6.778	12.901
		12.137							9.010	21.147
Cadmium	106		.184	-	.489					.673
	108		-	.611	.404					1.015
	110		-	2.092	3.010					5.102
	111		.348	-	4.102					4.450
	112		-	1.967	5.863					7.830
	113		.431	-	5.882					6.313
	114		.869	-	6.850*					7.719*
	116		.455	-	1.744					2.199
			2.287	4.670	28.344*					35.301*
Indium	113		.144*	.833		1.012	1.752			3.741*
	115		4.245*	1.386		27.302	18.900			51.833*
			4.389*	2.219		28.314	20.652			55.574*
Tin	112		.006	.031		.061			.493*	.591*
	114		.013	.015		.110			.460*	.598*
	115		.010*	.098		.160			.515*	.783*
	116		.732	1.851		4.194			9.936*	16.713*
	117		.409	.903		4.788			6.164*	12.264*
	118		1.453	3.476		8.549			17.608*	31.086*
	119		.027	1.809		5.059			6.798*	13.693*
	120		1.107	9.945		18.230			27.359*	56.641*
	122		.048	.893		2.732			3.340*	7.013*
	124		.036	.728		2.371			4.235*	7.370*
			3.841*	19.749		46.254			76.908*	146.752*
Antimony	121		2.209		.391					2.600
	123		2.175		1.618					3.793
			4.384		2.009					6.393

* Estimated

Table 7 - Continued

Element	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Tellurium	120			.013	.047				.080	.140
	122			.060	.462				.633	1.155
	123			.049	.315				.404	.768
	124			.198	.841				1.821	2.860
	125			.289	2.878				.928	4.095
	126			1.535	6.264				4.482	12.281
	128			2.245	10.010				7.835	20.090
	130			2.262	8.326				7.986	18.574
				6.651	29.143				24.169	59.963
Barium	128						.003			.003
	130						.012			.012
	132						.053			.053
	134						.527			.527
	135						1.102			1.102
	136						1.175			1.175
	137						2.754			2.754
	138						6.886			6.886
	140						.220			.220
							12.732			12.732
Lanthanum	138								2.5*	2.5*
	139								22.5*	22.5*
									25.0*	25.0*
Cerium	136					-	.076		.266	.342
	138					.156	.234		.754	1.144
	140					3.867	14.823		8.708	27.398
	142					.539	1.256		1.904	3.699
						4.562	16.389		11.632	32.583
Tungsten	180			.017		.180				.197
	182			.379		3.076				3.455
	183			.846		1.716				2.562
	184			1.926		3.262				5.188
	186			1.587		2.104				3.691
	188			-		.080				.080
				4.755		10.418				15.173
Rhenium	185					3.267				3.267
	187					2.691				2.691
						5.958				5.958

* Estimated

Table 7 - Continued

Element	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
Mercury	196				.010		-	.300*		.310*
	198				.005		-	5.352*		5.357*
	199				-		-	15.009*		15.009*
	200				.011		-	1.491*		1.502*
	201				-		-	10.208*		10.208*
	202				-		-	5.122*		5.122*
	204				-		.198	2.154*		2.352*
					.026		.198	39.636*		39.860*
Thallium	203				26.479	1.624				28.103
	205				21.513	5.774				27.287
					47.992	7.398				55.390
Lead	204	.172	.405		.461	2.258				3.296
	206	.270	1.566		4.798	6.582				13.216
	207	.280	1.107		4.411	6.913				12.711
	208	.610	.877		9.452	1.582				12.521
	210	-	-		.198	.561				.759
		1.332	3.955		19.320	17.896				42.503
Uranium	238	65.14	127.123							192.263

* Estimated.

Table 8

Maximum Purities of Concentrated Stable Isotopes-Per Cent

By 6-Month Intervals

Element	Isotope	Nat. Abund. Per Cent	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Best Prod.
Lithium	6	7.39	93.91	95.5		95.4	99.4			X[a]	99.4
	7	92.61	99.91	99.5		99.8	99.6			X	99.91
Beryllium	9*	100.0							Y[b]		Y
	10*	.0002*							0.27		0.27
Boron	10	18.83				X			X		X
	11	81.17				X			X		X
Carbon	12	98.9	X								X
	13	1.1	X								X
Nitrogen	14	99.62						X			X
	15	0.38						X			X
Oxygen	16	99.757						X			X
	17	0.039						X			X
	18	0.204						X			X
Magnesium	24	78.60	99.5			99.52				X	99.52
	25	10.11	83.22			86.8				X	86.8
	26	11.29	97.0			95.91				X	97.0
	28**	-				<0.04					<0.04
Silicon	28	92.28		99.4		98.1				X	99.4
	29	4.67		68.6		63.6				X	68.6
	30	3.05		63.9		49.6				X	63.9
	32**	-				<0.01					<0.01
Sulphur	32	95.06					X				X
	33	0.74					X				X
	34	4.18					X				X
	36	0.016					X				X
	38**						X				X
Chlorine	35	75.4			79.5			92.4			92.4
	36**	-			-			X			X
	37	24.6			34.0			65.6			65.6

a-X Mass Analysis not yet available.
b-Y Material not recovered.
* Pile-produced radio-isotopes; abundance estimated by activity
** Isotope not established.

Table 8 - Continued

Element	Isotope	Nat. Abund. Per Cent	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Best Prod.
Potassium	39	93.3	99.93		99.5		99.94	99.74	99.89		99.94
	40	0.011	0.16		0.40		1.31	0.40	7.13		7.13
	41	6.7	88.36		92.9		95.45	91.61	98.94		98.94
Calcium	40	96.96	98.6	99.97		98.9	-	X			99.97
	42	0.64	-	61.4		56.1	-	28.3			61.4
	43	0.15	-	34.4		59.9	-	X			59.9
	44	2.06	95.8	21.1		85.4	96.2	91.9			96.2
	46	0.0033	X	X		96.4[B]	4.8	X			96.4[B]
	48	0.19	-	13.1		83.9	62.2	X			83.9
Titanium	46	7.95			84.26						84.26
	47	7.75			82.05						82.05
	48	73.45			99.23						99.23
	49	5.51			77.62						77.62
	50	5.34			84.69						84.69
Chromium	50	4.49	73.76			41.2					73.76
	52	83.79	99.14			99.1					99.14
	53	9.43	88.59			92.1					92.1
	54	2.30	61.0			83.1					83.1
	56**	-	-			-					-
Iron	54	5.81	83.03	49.2	87.9		84.3	-	-		87.9
	56	91.64	98.62	98.9	99.0		96,5	X	-		99.0
	57	2.21	73.01	33.2	77.6		50.7	X	74.6		77.6
	58	0.34	40.7	10.3	35.1		46.0	55.9	86.0		86.0
Nickel	56**	-	-	-	-	-	-	-	-		-
	58	67.76	98.51		99.3			92.7			99.3
	60	26.16	94.4		97.7			95.0			97.7
	61	1.25	78.83		80.4			72.2			80.4
	62	3.66	94.25		94.7			91.2			94.7
	64	1.16	85.1		97.4			80.6			97.4
	66**	-	-		-			-			-
Copper	63	69.09	97.0		99.7				X	X	99.7
	65	30.91	93.1		90.6				X	X	93.1

B Repeat Assay exhausted sample.
X Mass Analysis not yet available.
** Isotope not established.

Table 8 - Continued

Element	Isotope	Nat. Abund. Per Cent	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Best Prod.
Zinc	64	48.89		83.8	93.4						93.4
	66	27.81		78.4	76.1						78.4
	67	4.07		62.6	X						62.6
	68	18.61		72.6	93.9						93.9
	70	0.62		32.9	32.0						32.9
Germanium	70	20.55			88.1						88.1
	72	27.37			89.2						89.2
	73	7.61			68.9						68.9
	74	36.74			95.2						95.2
	76	7.67			79.3						79.3
Selenium	72**	-		-		-	<0.005			-	<0.005
	74	0.87		6.5		14.1	12.3			X	14.1
	76	9.02		43.5		41.5	54.8			X	54.8
	77	7.58		50.1		53.6	49.4			X	53.6
	78	23.52		79.3		72.7	81.7			X	81.7
	80	49.82		86.7		94.6	91.7			X	94.6
	82	9.19		49.6		44.4	51.6			X	51.6
Bromine	79	50.5		90.54							90.54
	81	49.5		91.41							91.41
Strontium	84	0.56		27.2	61.6						61.6
	86	9.86		69.9	88.2						88.2
	87	7.02		-	73.1						73.1
	88	82.56		98.9	99.5						99.5
Zirconium	88**	-		-			-			-	-
	90	51.46		91.7			98.00			X	98.00
	91	11.23		54.4			86.6			X	86.6
	92	17.11		85.6			92.7			X	92.7
	94	17.40		82.1			92.8			X	92.8
	96	2.80		40.6			74.6			X	74.6
	98**	-		-			-			-	-
Molybdenum	92	15.86	92.07		95.5						95.5
	94	9.12	74.68		79.1						79.1
	95	15.7	80.75		88.0						88.0
	96	16.5	85.94		90.6						90.6
	97	9.45	77.97		75.4						77.97
	98	23.75	95.00		96.3						96.3
	100	9.62	90.24		93.0						93.0
	102**	-	<0.21		-						<0.21

** Isotope not established.

X Mass analysis not yet available.

Table 8 - Continued

Element	Isotope	Nat. Abund. Per Cent	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Best Prod.
Silver	107	51.35	88.96							X	88.96
	109	48.65	95.88							X	95.88
Cadmium	106	1.215		19.94	-	32.9					32.9
	108	0.875		-	14.2	24.8					24.8
	110	12.39		-	55.8	70.0					70.0
	111	12.75		53.3	-	64.5					64.5
	112	24.07		-	79.3	83.5					83.5
	113	12.26		25.5	-	54.1					54.1
	114	28.86		79.52	-	94.2					94.2
	116	7.58		24.01	-	71.2					71.2
Indium	113	4.23		X	22.8		65.4	14.2			65.4
	115	95.77		99.56	99.6		99.9	99.92			99.92
Tin	112	0.90		X	30.8		45.5			X	45.5
	114	0.61		X	19.2		24.1			X	24.1
	115	0.35		X	4.5		12.1			X	12.1
	116	14.07		76.3	74.5		X			X	76.3
	117	7.54		X	75.3		X			X	75.3
	118	23.98		X	91.8		X			X	91.8
	119	8.62		X	78.5		X			X	78.5
	120	33.03		X	95.4		X			X	95.4
	122	4.78		X	70.7		X			X	70.7
	124	6.11		X	71.0		83.1			X	83.1
Antimony	121	57.25		99.4		97.7					99.4
	123	42.75		96.7		95.6					96.7
Tellurium	120	0.091			18.0	13.7				X	18.0
	122	2.49			77.8	79.4				X	79.4
	123	0.89			34.9	45.8				X	45.8
	124	4.63			72.5	83.9				X	83.9
	125	7.01			81.1	87.9				X	87.9
	126	18.72			93.2	95.4				X	95.4
	128	31.72			93.5	94.4				X	94.4
	130	34.46			93.0	97.4				X	97.4
Barium	128**	-						-			-
	130	0.101						16.0			16.0
	132	0.10						7.43			7.43
	134	2.42						51.39			51.39
	135	6.59						67.32			67.32
	136	7.81						50.02			50.02
	137	11.32						38.98			38.98
	138	71.66						98.04			98.04
	140**	-						-			-

** Isotope not established.

X Mass analysis not yet available.

Table 8 - Continued

Element	Isotope	Nat. Abund. Per Cent	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Best Prod.
Lanthanum	138	0.09								X	X
	139	99.91								X	X
Cerium	136	0.19					-	16.6		8.94	16.6
	138	0.25					-	8.9		4.42	8.9
	140	88.48					98.5	98.7		X	98.7
	142	11.07					X	87.4		83.42	87.4
Tungsten	180	0.12			9.0		4.95				9.0
	182	25.77			94.25		91.58				94.25
	183	14.24			86.21		82.01				86.21
	184	30.68			95.72		91.14				95.72
	186	29.17			97.94		97.17				97.94
	188**	-			-		<0.05				<0.05
Rhenium	185	37.07					X				X
	187	62.93					98.22				98.22
Mercury	196	0.15				-		-	8.44		8.44
	198	10.1				-		-	83.29		83.29
	199	17.0						-	73.09		73.09
	200	23.3				84.5		-	91.3		91.3
	201	13.2				-		-	71.8		71.8
	202	29.6				-		-	98.3		98.3
	204	6.7				-		49.6	92.8		92.8
Thallium	203	29.1				86.0	X				86.0
	205	70.9				98.7	90.5				98.7
Lead	204	1.5	7.8	16.69		23.4	27.0				27.0
	206	23.6	75.67	77.9		71.3	81.0				81.0
	207	22.6	61.55	48.2		66.8	61.6				66.8
	208	52.3	92.1	X		96.6	95.8				96.6
	210**	-	-	-		0.15	<0.01				0.15
Uranium	238	99.28	99.996	99.997							99.997

** Isotope not established.

X Mass analysis not yet available.

Table 9

Stable Isotope Shipments - By Isotope*

By 6-Month Intervals

Atomic Number	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
3	Li 6		2			6	5	4	4	21
	7		2			3	1	2		8
4	Be 10								2	2
5	B 11						1			1
6	C 12		1							1
12	Mg 24		2			2		2	1	7
	25		4			2		2	3	11
	26		3			1		2	2	8
14	Si 28					1	1		1	3
	29					1	1		1	3
	30						1		1	2
16	S 32								1	1
	34								1	1
17	Cl 35							1		1
	37								2	2
19	K 39		1				3	1		5
	40		2		1	3	5	4	7	22
	41		1				2	2	1	6
20	Ca 40		2		1			1	1	5
	42			1		1			1	3
	43			1	1	1				3
	44			2		2	1	1		6
	46			1				1		2
	48			1			1		1	3
22	Ti 46						1		3	4
	47						2		1	3
	48					1			1	2
	49					1	1		3	5
	50					1			1	2
24	Cr 50		2			1	1	2	2	8
	52		2		1		1		1	5
	53		2				2		3	7
	54		2				1	1	1	5

* Information supplied by L. G. Chelius, Isotopes Division, Atomic Energy Commission.

Table 9 - Continued

Atomic Number	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
26	Fe 54	1	2		1	3		1	1	10
	56		1			2				3
	57	1	1	1		1	1	3	1	8
	58	1	1	1		1	2	2	2	10
28	Ni 58		3		1	1	1	1	2	9
	60		3			1	1		1	6
	61		2			2	1		1	6
	62		1		1	1			1	4
	64		3			1	1	1	2	8
29	Cu 63	1	2		1	1	1		1	7
	65	1	1		1				2	5
30	Zn 64					1	1	1	2	5
	66					1			2	3
	67					2			2	4
	68					1	1	1	2	5
	70		1				3		1	5
32	Ge 70					1		2	1	4
	72							1	1	2
	73						1	1	1	3
	74							1		1
	76					1		1	1	3
34	Se 74			1		1		1	2	5
	76			1		1			1	3
	77			1			1	1	2	5
	78			2		1		1	1	5
	80		1	1					3	5
	82			1					3	4
38	Sr 84						1			1
	86						1		1	2
	87						1			1
	88								2	2
40	Zr 88							1		1
	90			1			2	1	2	6
	91			2		1	2		1	6
	92			2			2		2	6
	94			2			2		1	5
	96			2			2	3		7

Table 9 - Continued

Atomic Number	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
42	Mo 92		2	1		1	1	3	2	10
	94		2	1	1	1	1	1		7
	95		2	1			2			5
	96		1	2					1	4
	97		1	2				1	1	5
	98		3	1		1		1		6
	100		5		1		1		3	10
	102		1							1
47	Ag 107		2		1		1	1	2	7
	109		2		1	1	1		2	7
48	Cd 106		1	1		1	1	2	1	7
	108			2		1	1	2	1	7
	110			2			1	1		4
	111		1				2	1		4
	112			2				2	1	5
	113		2					2		4
	114		1	1			1	3	2	8
	116			1			1	2	2	6
49	In 113		2			1			2	5
	115		1	2	1	1			2	7
50	Sn 112		1					1		2
	114							3		3
	115							3		3
	116			1		2	2	1		6
	117			1		1	1			3
	118			2		1	1	1		5
	119					2	1		1	4
	120			2	1	1	3	1	1	9
	122			1	1	2	3	1	2	10
	124			1	1	2	6	2	2	14
51	Sb 121				3	1		2	1	7
	123			4	2	1			1	8
52	Te 120						2			2
	122						3	3	1	7
	123				1		2			3
	124						3	3	1	7
	125				1		4	2	2	9
	126						3	2	1	6
	128			1			3	2	1	7
	130						3	2	2	7

Table 9 - Continued

Atomic Number	Isotope	1946 Jan. June	1946 July Dec.	1947 Jan. June	1947 July Dec.	1948 Jan. June	1948 July Dec.	1949 Jan. June	1949 July Dec.	Total
56	Ba 130							1		1
	132							2		2
	134							3	2	5
	135							2	1	3
	136							3		3
	137							1	2	3
	138							2	1	3
58	Ce 136						1	1		2
	138							1		1
	140							1		1
	142							1		1
74	W 180						1	1		2
	182						1	2	1	4
	183						2	1	3	6
	184					1	1		4	6
	186						2	1	4	7
75	Re 185							2	2	4
	187							2	2	4
80	Hg 199								1	1
	201								1	1
	204								1	1
81	Tl 203				1	2			3	6
	205				1	2			2	5
82	Pb 204		2	1	1	1		3	1	9
	206		2	1	1				4	8
	207		2	1		1			2	6
	208		2	1		2			2	7
Total 34	138	5	87	60	28	82	121	131	171	685

Total Elements: 34
Total Isotopes: 138
(different)
Total Shipments: 685