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UNIVERSITY OF CALIFORNIA

Radiation Laboratory

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Availability and Sources of the Ninety-Six Elements in High Purity Forms

Elwin H. Covey

Revised March 1, 1949

Berkeley, California

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Radiation Laboratory
University of California
Berkeley, California

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Availability and Sources of the Ninety-Six Elements in High Purity Forms

Elwin H. Covey

Department of Chemistry, Radiation Laboratory
University of California

Revised March 1, 1949

The need for higher purity of materials in production and in research is becoming increasingly important. The Atomic Energy Commission and its associated groups, and more recently industry, have given a tremendous impetus to this demand.

The scientist who seeks suppliers for a given element turns to directories of vendors where he finds a scarcity of information concerning purity and form. In some cases he finds no listing at all of the elements he requires. The source list which follows endeavors to clarify this problem by considering the following points:

1. Pure forms of element obtainable.

2. Detailed information on the kind and amount of impurities present.

3. Availability of each element in metallic form, particularly in thin foils a few inches square.

4. Analytical information given by supplier and additional sources.

5. Availability of macro amounts, i.e., for use in machining of specially fabricated parts.

High purity in this report means purities considerably greater than 99.5 percent. A few elements with purity less than this figure have been listed where there is no source for samples of high purity.

For a more comprehensive listing of all sources for each element Thomas Register of American Manufacturers should be consulted. Another useful directory is the Annual Buyers Guide Section of the magazine, Chemical Industries. An

authoritative collection in this field is the National Registry of Rare Chemicals maintained by the Armour Research Foundation (See address in Appendix A). It supplies source information to all industrial and research institutions without charge. No lists of information are published, although available information is furnished and sources located for specific items.

Compounds and metals are listed in order of decreasing purity. Johnson Mathey and Company generally heads each list. This company's products serve as reference points to indicate the most reliable high purity material generally available. Other materials and sources may be judged relative to this company with its products as standards. It is suggested that information as to sources for these high purity materials be approached in the following manner:

1. Consult this source list to see what is available in regard to purity, form and supplier. If the request cannot be met by suppliers in this list, the following steps should be taken.

2. Consult the Buyers Guide Section of Chemical Industries by element for additional best known sources of supply.

3. If the Buyers Guide lists no suitable sources of supply, consult Thomas Register by element for an exhaustive list of suppliers.

4. Finally, the National Registry of Rare Chemicals may be consulted.

If the technical reader notices undue simplification of terminology, he should bear in mind that this report was initially prepared to meet the needs of two types of readers: first, the research worker who needs detailed information on the elements listed herein and second, the purchasing agent, perhaps a non-technically trained person, who obtains such materials for the research worker. Those in the second category may find this simplification helpful in understanding more technical matters presented in this report.

In the compilation of data the material was assembled in a continuous tabular fashion beginning with actinium and running alphabetically through zirconium. At some future date similar elements will be grouped together (i.e., rare gases,

alkali metals, non-metals, precious metals, etc.), and will be arranged in some order which corresponds to progressive changes in their respective chemical and/or physical properties. The data for each successive element in the group will then be arranged in looseleaf form.

Suggestions from the reader for revisions will be appreciated.

Acknowledgments

Grateful acknowledgment for advice and assistance is made to Mr. L. A. Ray, Chief Storekeeper, University of California Department of Chemistry; Mr. E. Chambers, Secretary of the Purchasing Agents' Association of Northern California and Editor of Pacific Purchaser magazine; Mr. L. Fitzgerald, Radiation Laboratory Inventory Department; Mr. C. L. Blue, Mr. J. H. Patterson, Mr. W. Parry, and Mr. D.A. Bruce, Radiation Laboratory Purchasing Department; Dr. I. Perlman and Dr. G. T. Seaborg, Radiation Laboratory Chemical Research Division; Mr. E. D. Fleckenstein, U.S. Atomic Energy Commission; and to my wife, Mrs. E. H. Covey.

EXPLANATION AND QUALIFICATIONS
for the
Source List of the 96 Elements

A. UNDER COLUMN NO.: (Vertically)

I. Elements — Characteristics of compounds and metals are listed in detail. Generally speaking, the characteristics of products of suppliers listed under "Other Sources" are not personally known to the author. Although the latter list of sources of information is partially out-of-date, it is included for the sake of completeness to indicate additional past or potential suppliers.

II. Purity

a) Certainty of Purity — (C) = Certain. Such a designation indicates that, based on past experience, (specific analyses, or analyses of other products of the supplier) one can have reasonable certainty that the percent of purity claimed is close to the actual purity.

(E) = Estimated. Such a designation indicates that the percent of purity is the author's estimate. Usually no analytical information whatsoever was available on these samples, or a typical analysis was submitted by the supplier. The estimate is based on qualitative (use) reports from the laboratory staff supplemented by past experience with other products from the same supplier. Considerable difference between actual purity and the alleged purity (or the probable purity stated on typical analyses) is often found upon careful analysis.

b) Percent of Purity — The figure given in this column is either: 1) that stated by the supplier; 2) the author's revision of said figure where past experience indicates the necessity of doing so; 3) actual analytical information from the laboratory staff; 4) calculation by difference (designated "d" in this column) where other considerations indicate the validity of such treatment. To obtain the percent of purity "By Difference," one subtracts the sum of the percentages of stated impurities present from 100 percent.

c) Analytical Information Furnished — The information in this column will indicate to purchasers who do not have spectrographic analysis facilities available, the character of the analytical information (if any) which the supplier does or is able to furnish. Where occasions have arisen for the Radiation Laboratory to re-analyze samples, our findings (except for typical analyses) have agreed quite closely with most detailed suppliers analyses.

A typical analysis is one covering a whole batch or production run, indicating the usual impurities found in such samples in past analyses. A typical analysis may or may not correspond very closely to the actual analysis of the material supplied.

III. Physical Form — This column gives dimensions and physical form of samples received. Such information is given to indicate to others exactly what is currently and has been obtainable. Special limitations on available forms, where known, are stated in general terms.

IV. Price (Relative) — In a market as specialized as this one, extending over some period of time (and even drawing upon foreign sources) it is clear that any price given is only relative to other prices of similar materials. Prices should not be considered as accurate or absolute (except at the time the material was purchased).

The prices listed were obtained from the University of California Radiation Laboratory purchase orders beginning October 1946 to the present. Some prices are those of the initial purchase, and some represent the arithmetic averages of two or three replenishment purchases during this period. As purchases were made a few at a time more or less evenly scattered through the period, it is felt that any seasonal or random price variations are probably fairly well cancelled out.

These prices are the result of quotations from two to six bidders when they could be found. It is the author's estimate that 20 to 40 percent of the requests for bids on items in this list were answered by a single bidder. Price considerations at times are as indefinable as those in establishing prices on antiques or on paintings.

V. Source of Supply — Supplier's name is given in full where space permits. Standard abbreviations are used in other cases. Refer to Appendix A for the detailed address of each source of supply. Attention is called to footnote (2) on page 11 concerning the additional usefulness of Appendix A.

B. AFTER THE NAME OF THE ELEMENT: (Horizontally)

1. Symbol[1] of the Element — This is a form of "chemical shorthand" used to designate the name of the element, e.g., 1. (Li)=Lithium.

2. Atomic Number[2] — This is an index number to contrast the chemical and physical properties of one element in relation to another. For example, the Periodic Chart of the Elements will show hydrogen, the lightest element, with an atomic number of 1 and the heaviest element, curium, with an atomic number of 96, e.g., 2. (62)=Atomic number for samarium.

[1] Data taken from Appendix B [2] Data taken from Appendix B

3. Classification-Kind of Material — This information is inserted here as a cross reference to make the list more comprehensive and understandable in use, e.g., 3. (R. E.) = Rare Earth.

4. Relative Abundance — This value is given as an indication of the relative amount of this element that exists in the earth's crust. As such, it is a rough index of the difficulty in obtaining it. Properly interpreted, the example given below indicates that 0.026 percent of the earth's crust by weight is actually zirconium. To put it differently, if 200 different 50 lb. samples (totalling 10,000 lbs.) were collected at random from all over the earth, assembled, and chemically treated, one should be able to extract 2.6 lbs. of zirconium, e.g., 4A) (0.026 percent) = relative abundance of zirconium.

a) Relative Abundance (of Most Elements)[1]

b) Rare Earth Abundance[2] — Note that the rare earths, cerium, and yttrium (which occur together in nature and are very difficult to separate from each other) as a group comprise 0.0015 percent of the earth's crust. (See Appendix C.) Of this group cerium is the most abundant member, and europium is the least abundant. Properly interpreted, the example below indicates that 6 percent of the earth's crust attributable to the rare earth elements is actually erbium, e.g., 4b) (6 percent) = relative abundance of erbium within the rare earth group.

5. Rank of Abundance — If the percentages given in (4) on the preceding page are listed in order of decreasing abundance and numbered, beginning with 1 for the most abundant element existing (oxygen), the rank of abundance of each element is thereby established, e.g., 5a) (26th) indicates that tungsten is the 26th most abundant element in the earth's crust.

a) Rank of Abundance (of most Elements)[3]

b) Rare Earth Rank[4] — e.g., 5b) (2nd) indicates that neodymium is the 2nd most abundant rare earth element existing in the earth's crust.

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1 Data taken from Appendix C.
2 Data taken from Appendix D.
3 Data taken from Appendix C.
4 Data taken from Appendix D.

THE SOURCE LIST

LEGEND[1]
for
Source List of the 96 Elements

I ELEMENT	(a)	II PURITY (b)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
	Reliability of Stated % Purity	Purity in Percent	Analytical Information Furnished by Supplier	Details and Limitations	Price per Unit	
Compounds 1) Name, Formula Metal 1) General Form Other Sources 1)	C = Certain E = Estimated	d = "By Difference"	C = Chemical analysis D = Detailed information G = General information S = Spectrographic analysis Typ. = Typical analysis	Significant information is given when known	mg = milligram gm = gram cg = centigram (100gm) kg = kilogram oz. = ounce lb. = pound l = liter (1000cc)	Name (only) is given For Addresses see Appendix A 2

NAME OF ELEMENT 1.(Symbol) 2.(Atomic No.) 3.(Classification) 4a.(Relative Abundance) 5a.(Rank of Abundance)
b.(R.E. Abundance) b.(R.E. Rank)

Alk.Met. = Alkali Metal
Non-Met. = Non-metallic Element
Com.Met. = Commoner " Element
Prec.Met. = Precious Metal
R. Met. = Rarer Metal
C. Gas = Common Gas
R. Gas = Rare Gas
R.E. = Rare Earth
Radio. = Radioactive Element

< = less than
≪ = much less than
> = greater than
~ = approximately

[1]For a more detailed explanation and qualification of the symbols used, refer to pp. 7-9
[2]This appendix can also be used as a cross reference to designate all materials appearing in the following list which are obtainable from the same source of supply.

I ELEMENT	II (a) Purity (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
1. **ACTINIUM**	1.(Ac) 2.(89) 3.(Radio.) 4.($\ll 10^{-12}$%) 5.(62nd)			
	Not generally available. Compounds only have been prepared in microgram[1] amounts by certain university research groups. Exceedingly difficult to isolate, especially so in pure form. Readily decays away radioactively. Half life =14 years.[2] For further information as to future availability, contact: (1) Director of Research, Atomic Energy Commission; (2) Canadian Radium and Uranium Corporation; (3) The Department of Chemistry of the nearest university; (4) Radium Chemical Company			
ALABAMINE see Astatine				
2. **ALUMINUM**	1.(Al) 2.(13) 3.(Com.Met.) 4.(8.13%) 5.(3rd)			
Compounds	Available in practically any compound desired with at least "reagent grade" purity (including a typical analysis) from most laboratory supply houses. Some compounds are available in even higher purity form; namely, C. P. analytical grade, microanalytical grade, and "purity meeting A.C.S. standards."[3] Compounds with purities such as these are made by (1) J. T. Baker; (2) Eimer & Amend; (3) General Chemical Co.; (4) Mallinckrodt; (5) Merck; and a few others. The highest purity compounds readily obtainable (designated "Spec Pure"; each sample accompanied by a spectrographic analytical report) are made by Johnson, Matthey & Co., Ltd. e.g.,			
1) Chloride $AlCl_3$	(C) 99.99+ D.S.	Fine Crystals	$0.60/gm	Johnson, Matthey & Co., Ltd.
Metal 1) Rods	(C) 99.998 D.S.	Supplied in 6mm diam.x15cm rods. (Metal can be made into practically any form desired.)	$0.75/rod	Johnson, Matthey & Co., Ltd.
2) Billets	(E) 99.+ None	Supplied in 3-1/2" diam. x4-8" long billets in industr. quants.	$1/lb.	National Research Corporation[4]

[1] One microgram = 1/1000 mg or 10^{-6} gm.

[2] Radioactive half life can best be explained by the following example. If you acquire 1 mg of an element having a half life of 1 month, at the end of the month you have only 1/2 mg left. The missing 1/2 mg has been radioactively transformed into a different element. At the end of the next month you have only 1/4 mg left. At the end of the following month, only 1/8 mg remains.

[3] A.C.S. denotes the American Chemical Society.

[4] Materials supplied by this corporation are especially free from dissolved gases. Prepared by vacuum distillation.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
2. **ALUMINUM** (Contd)						
Other Sources						
1) Metal		Per:		U.C.R.L. Chemical Research Files		ALCOA Research Laboratories[1]
2) Metal				" " " "		Reynolds Metal Company
3. **AMERICIUM**	1.(Am)	2.(95)	3.(Radio.)	4.(Does not exist in nature)	5.(--)	
	Not available outside the Atomic Energy Commission laboratories. One of the most recently discovered "man-made" elements.[2] The world's supply is not a weighable amount by ordinary careful methods. Its extreme rarity and radioactivity make it seem unlikely that this material will ever by available except for A.E.C. research problems.					
4. **ANTIMONY**	1.(Sb)	2.(51)	3.(Com.met.)	4.(N x 10^{-7}%)	5.(43rd)	
Compounds						
1)Chloride $SbCl_3$	The same general information applies here as is given for aluminum compounds.					
	(C)	99.92d	D.S.	Fine crystals in sealed tubes	$0.60/gm	Johnson, Matthey & Co., Ltd.
Metal						
1) Broken Ingots	(C)	99.92d	D.S.	Supplied in 1" cubes (Somewhat brittle. Not readily workable. Usually melted and cast into desired forms.)	$6.75/cg	Johnson, Matthey & Co., Ltd.
2) Irregular Lumps	(E)	95-99	None	Supplied in crystalline lumps as condensed	$3/lb.	A. D. Mackay
Other Sources						
1) Metal		Per:		U.C. Dept. of Chem. - Storeroom Files		American Smelting and Refining Co.

1 To indicate the possibility of obtaining high purity samples from research groups in large industrial production plants, note that the author received one sample .160 x 6 x 6" stated to be 99.98% pure accompaniedbby a detailed chemical analysis from this company.

2 Seaborg, G. T., "The Transuranium Elements," Science, 104, 384 (October 25, 1946)

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
5. **ARGON**	1.(A)		2.(18)	3.(R.Gas)	4.(Not in the earth's crust)[1]	5.(--)
Gas						
1) Spec. Pure	(C)	99.99+	G.S.	Put up in 1 or 2 liter sealed glass bulbs. <5 ppm total impurities.	$2.50/l	General Electric Co., Cleveland Wire Works.
Other Sources		Pure	U.C.	Dept. of Chem. - Storeroom Files		
1) Commercial			"	" " " "	"	Air Reduction Sales Co.
2) Purities			"	" " " "	"	Linde Air Products Co.
3) ~99.6%			"	" " " "	"	Ohio Chemical Company
6. **ARSENIC**	1.(As)		2.(33)	3.(Com.Met.)	4.($n \times 10^{-6}$ %)	5.(38th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide	(C)	99.99+	D.S.	Fine crystals	$0.70/gm	Johnson, Matthey & Co., Ltd.
2) Oxide	(C)	99.99	D.C.[2]	Fine crystals	$6/cg	National Bureau of Standards
Metal						
1) Crystals	(C)	99.94	D.S.	Supplied in crystalline fragments as condensed (Brittle; rolling is seldom successful. Usually remelted and cast into desired form.)	$1.50/gm	Johnson, Matthey & Co., Ltd.
2) Irregular Lumps	(E)	95-99	None	Supplied in crystalline lumps as condensed.	$2/cg	A. D. Mackay

[1] The price per liter of each rare gas is a close approximation to its relative abundance in the atmosphere. No compounds of the element are known to exist. All the rare gases are chemically inert - as they do not combine with any other element.

[2] A Certification of Purity is supplied. When the N.B.S. is temporarily unable to supply "certified standard reagents" such as this is, some samples may occasionally turn up in small chemical trading companies. This particular sample came from the Fordomes Trading Co.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
7. **ASTATINE** (formerly named Alabamine)	1.(At)	2.(85)	3.(Radio.)	4.($\ll 10^{-12}$%)	5.($>62^{nd}$)	
	Not generally available. Trace amounts only have recently been prepared by certain university research groups. Exceedingly difficult to isolate, especially so in pure form. Very rapidly decays away radioactively, enjoying but a transitory existence. Half life ~~of~~ 8 hours.[1] For further information as to future availability, contact: (1) Director of Research, Atomic Energy Commission; (2) Dr. Emilio Segrè (discoverer of astatine), Department of Physics, University of California.					
8. **BARIUM**	1.(Ba)	2.(56)	3.(Alk.Met.)	4.(0.050%)	5.(14th)	
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Chloride $BaCl_2$	(E)	99++	D.S.	Fine Crystals	$0.25/gm	Johnson, Matthey & Co., Ltd.[2]
Metal						
1) Irregular Lumps	(C)	99.95+d	D.S.	Supplied in irreg. lumps (Oxidizes rapidly; must be kept in vac. or under oil. Easily worked into most any form desired.)	$17.50/oz.	Var-Lac-Oid Chemical Co.
2) Lg. Irregular Lumps	(C)	99+	None	Supplied in large irreg. lumps as much as 3" on a side in pound quantities.	Records Lost Est. $50/lb.	Komet Laboratory Company[3]
9. **BERYLLIUM**[4]	1.(Be)	2.(4)	3.(R.Met.)	4.(1×10^{-5}%)	5.(35th)	
Compounds						
1) Oxide BeO	(C)	99.99+	D.S.	Fine Crystals	$4/gm	Johnson, Matthey & Co., Ltd.
2) Nitrate $Be(NO_3)_2$	(C)	99.5+	D.S.	" "	$2/gm	" " " " "

[1] Explanation in footnote (2), page 12.

[2] This company prepares barium compounds only. It is ~~extremely~~ very difficult to prepare the metallic form in spectrographic purity.

[3] This company undertook a fairly large scale run of specially purified barium metal during the war. Since the author has not contacted the company for some time, in regards to this element it is not positively known whether subsequent runs were undertaken or whether this same material is still available.

[4] Also called Glucinum in the older literature.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
BERYLLIUM (Contd.)						
9. Metal						
1) Small Broken Ingots	(C)	~99.5	D.S.	Supplied in crystalline lumps. (Worked with great difficulty, under heat and high pressure. Very hard, tough; subject to edge cracking on rolling. Has been rolled down to very thin sheets and also cast into ingots of fair size.)	$0.50/gm	Johnson, Matthey & Co., Ltd.
2) Granular	(E)	~98	None	Supplied in large quantities ~#80 mesh.	Records Lost Est. $250/lb.	Brush Beryllium Company
Other Sources						
1) Metal	Per:		U.C.R.L. Chemical Research Files			Atomic Energy Commission[1]
2) Compounds			U.C. Dept. of Chem. - Storeroom Files			City Chemical Corp.
3) Metal			" " " " " "			Foote Mineral Co., Inc.
10. BISMUTH	1.(Bi)		2.(83)	3.(Com.Met.)	4.($n \times 10^{-8}$%)	5.(47th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Chloride $BiCl_3$	(C)	99.99+	D.S.	Fine Crystals	$0.75/gm	Johnson, Matthey & Co., Ltd.
Metal						
1) Rods	(C)	99.998	D.S.	Supplied in 5mm x 10cm rods. (Workable with some difficulty; brittle; cannot be rolled into thin foils. Usually melted and cast into desired forms. Is available in quantity with surprisingly high purity.)	$1.25/rod	Johnson, Matthey & Co., Ltd.
2) Ingots	(C)	99.99d	G.C.[2]	Supplied in ingots ~1x2x2"	$2.50/lb.	American Smelting & Refining Co., Omaha Plant.

[1] Contact the Director of Research or Production for information as to the availability of industrial quantities of high purity material, or specially fabricated forms of beryllium. e.g. certain A.E.C. subcontractors are the only ones in the country able to roll thin foils.

[2] Manufacturers analysis states that the only chemically detectable impurity present is 0.0005% silver.

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I ELEMENT	II PURITY (a)	(b)	(b-%)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
BISMUTH (Contd.)						
10. 3) Irregular Lumps	(E)	95-99	None	Supplied in crystalline lumps as condensed.	$2/lb.	A. D. Mackay
Other Sources						
1) Metal	Per:	U.C. Dept. of Chem. - Storeroom Files				Belmont Smelting & Refining Co.
11. **BORON**	1.(B)	2.(5)	3.(Com.Met.)	4.(1×10^{-5}%)	5.(34th)	
Compounds						
1) Boric Acid H_3BO_3	(E)	99+	D.S.	Fine Crystals	$0.30/gm	Johnson, Matthey & Co., Ltd.[1]
Metal						
1) Powder	(E)	99	None	Amorphous powder. (No source is known for metal in other than powdered form, probably because there are practically no commercial uses for the metal.)	$1/gm	Fairmount Chemical Company
Other Sources						
1) Compounds	BN	Per:	U.C. Dept. of Chem. - Storeroom Files			City Chemical Corporation
2) "	B_4C		" " " " "			The Norton Company
3) "	H_3BO_3		U.C.R.L. Chemical Research Files			Pacific Coast Borax Company[2]
4) "	H_3BO_3		" " " "			Stauffer Chemical Company[3]
5) Metal			" " " "			Cooper Metallurgical Company
12. **BROMINE**	1.(Br)	2.(35)	3.(Non.Met.)	4.(n x 10^{-6}%)	5.(40th)	
Compounds	The same general information applies here as is given for aluminum compounds, except that the Johnson Matthey Company does not prepare this element at all.					
Elemental Bromine (a liquid)	The common element bromine itself is easily prepared and purified in the laboratory by distillation, and hence poses no particular problems as to availability or high purity.					

[1] This company prepares boron compounds only. It is extremely difficult to prepare the metallic form in spectrographic purity.
[2] Samples specially purified in this company's research laboratory.
[3] Idem.

I ELEMENT	II (a) PURITY	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
12. Other Sources (Br)						
1) Liquid	Pur:		U.C. Dept. of Chem. - Storeroom Files			Griffin Chemical Company
2) Liquid			" " " " "		"	Westvaco Chlorine Products Co
13. **CADMIUM**	1.(Cd)		2.(48)	3.(Com.Met.)	4.(n x 10^{-7}%)	5.(44th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide CdO	(C)	99.99++	D.S.	Fine Crystals	$0.85/gm	Johnson, Matthey & Co., Ltd.
Metal						
1) Rod	(C)	99.99++	D.S.	Supplied in rods 7mm x 10cm (Metal available in considerable quantity and high purity. Workable with little difficulty. Malleable, ductile; thinnest sheet made without special effort is ~.015". Easily cast or machined into larger forms.)	$7/rod	Johnson, Matthey & Co., Ltd.
2) Crystals	(C)	99.99++	G.S.	Supplied in large (~½") crystalline fragments	$40/lb.	New Jersey Zinc Co. (of Pa.)
3) Sticks	(C)	99.9+d	G.S.	Supplied in sticks ½" diam. x 8"	Est.$10/lb.[1]	" " " " " "
4) Sheets	(E)	99.9	None[2]	Supplied in sheets .015" x 4" x 4"	$2/sheet	Selmont Smelting and Refining Co.
14. **CALCIUM**	1.(Ca)		2.(20)	3.(Alk.Met.)	4.(3.63%)	5.(5th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Carbonate $CaCO_3$	(E)	99++	D.S.	Fine Crystals	$0.40/gm	Johnson, Matthey & Co., Ltd.[3]

[1] Price (for larger guantities) is estimated because the small sample (½lb.) received by the author was kindly sent by this company without charge.
[2] Manufacturer claims that the only impurity present is a trace of zinc.
[3] This company prepares calcium compounds only. It is very difficult to prepare the metal in spectroscopic purity

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
14. CALCIUM (Contd.)						
Metal						
1) Chunk	(E)	95-99	None	Supplied in one piece ~1"x2"x3". (Oxidizes rapidly; vigorously reacts with water. Must be kept in vac. or under oil. Soft; easily worked into forms desired.) No purer source of Calcium Metal is Known.	$4/cg	A. D. Mackay

15. CARBON 1. (C) 2.(6) 3.(Non. Met.) 4.(.032%) 5.(17th)

Compounds The same general information applies here as is given for aluminum compounds.

Elemental Carbon Available in extremely high purity form for use as spectrographic analysis electrodes (long thin rods) from several spectroscopic supply houses and graphite producers. Also available in a variety of shapes, large sizes, and quantities, and in a wide range of very high purities from A.E.C. subcontractors. For further information as to availability, contact the Director of Research or Production, Atomic Energy Commission.

1) Carbon Rods	(C)	99.995+	D.S.	Electrodes 4.5mm x 30cm	$4.50/rod	Johnson, Matthey & Co., Ltd.
2) Graphite Rods	(C)	99.995+	D.S.	Electrodes 6.5mm x 30cm	$4.50/rod	" " " " "
3) Graphite Rods	(C)	99.97+	D.S.	Electrodes 10 mm x 30cm	$0.75/rod	" " " " "

Other Sources

1) Electrodes	Per:	U.C.R.L. Chemical Research Files	National Carbon Company
2) Bulk Graphite		" " " "	Atomic Energy Commission

16. CERIUM 1.(Ce) 2.(58) 3.(R.E.) 4a.(1.5 x10^{-4}%) b.(31%) 5a.(23rd) b.(1st)

Compounds The same general information applies here as for aluminum compounds, but to a more limited extent. The most dependable source for all cerium compounds in reagent grade or better in large quantities is the G. Frederick Smith Chemical Company. The president, a University of Illinois professor with special interest in cerium compounds, has set and maintained very high standards of purity for industrial quantities of this element and its compounds.

I ELEMENT	II (a) PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
16. CERIUM (Contd.)					
Compounds					
1) Oxide	(E) 99++	D.S.	Fine Crystals	$4/gm	Johnson, Matthey & Co., Ltd.[1]
2) Ammon. Hexa-nitratocerate	(E) 99+	G.C.[2]	Fine crystals in lg. quant.	$3.75/lb.	G. Frederick Smith Chem. Co.

Metal — Metal has been prepared in gram amounts in >98% purity by certain university research groups. Very difficult to prepare in pure form. Workable with difficulty. Quite hard and tough. Has been rolled down to .002" foils in ~2" widths. Subject to edge cracking in rolling with required heat and high pressure. For further information as to future availability, contact the Director of Research, Atomic Energy Commission.[3]

Other Sources			
1) Compounds	Per.	U.C. Dept. of Chem. - Storeroom Files	Foote Mineral Co., Inc.
2) Compounds		" " " " " "	Maywood Chemical ~~Company~~ Work.
3) Metal (80-95%)		U.C.R.L. Inventory Dept. Files	Cerium Metals Corp.
4) Compounds		" " " "	Charles Hardy, Inc.
5) Compounds		" " " "	Lindsay Light and Chem. Co.
6) Metal		" " " "	Pfaltz and Bauer, Inc.
7) Metal		" Chemical Research	~~Cooper Metallurgical Laboratory~~

17. CESIUM	1.(Cs)	2.(55)	3.(Alk. met.)	4.($n \times 10^{-7}$ ...)	5.(11st)	
Compounds						
1) Chloride $CsCl_2$	(E)	99++	D.S.	Fine crystals	$8.50/gm	Johnson, Matthey & Co., Ltd.[4]
2) Chloride $CsCl_2$	(E)	99.7+	G.S.	Fine crystals	$0.35/gm	Maywood Chemical Company
3) Nitrate $Cs(NO_3)_2$	(E)	95-99	None	Fine crystals	$0.30/gm	A. D. Mackay

1 This company prepares cerium compounds only. It is very difficult to prepare the metal in spect. purity
2 Manufacturer designates this as a "High Purity Standard of Reference."
3 At present, extremely high purity metal is not generally available outside the A.E.C. laboratories. This element, especially free from other rare earths, has been prepared in the form of chloride, oxalate, metallic lumps and thin foils.
4 This company prepares cesium compounds only. It is very difficult to prepare the metal in spect. purity.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
17 CESIUM (Contd.)						
Metal						
1) Semi-solid[1]	(E)	95-99	None	Small quantities of fused mass sealed in vac. inside glass tubes. (Oxidizes rapidly; must be kept in vac. or under oil. Soft, easily worked. Metal is not generally available in either high purity or large quantity)	$5/gm	A. D. Mackay
Other Sources						
1) Compounds	Per:		U.C. Dept. of Chem. - Storeroom Files			City Chemical Corporation
2) "			" " " "	" "		Foote Mineral Co., Inc.
3) "			" " " "	" "		General Electric Company

18 **CHLORINE** 1.(Cl) 2.(17) 3.(C.Gas) 4.(.048%) 5.(15th)

Compounds The same general information applies here as is given for aluminum compounds.

Elemental Chlorine This gas is readily prepared and purified in the laboratory by absorption of impurities with a gas purification train and hence poses no particular problems as to availability or high purity. The gas is not known to be supplied in spectrographic purity by any supplier, as are the rare gases. The customary purity of chlorine in industrial sized cylinders sold by most bottled gas companies is 99.5%.

19 **CHROMIUM** 1.(Cr) 2.(24) 3.(Com.Met.) 4.(0.37%) 5.(16th)

Compounds The same general information applies here as is given for aluminum compounds.

1) Oxide Cr_2O_3	(C)	99.99+	D.S.	Fine crystals	$0.60/gm	Johnson, Matthey &Co., Ltd.

[1] This metallic element melts at slightly above room temperature (28.5°C).

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
19 CHROMIUM (Contd.)						
Metal						
1) Crystals	(C)	99.994	D.S.	Supplied in small thin crystalline fragments as condensed. (Hard, brittle, almost impossible to work. Cannot be rolled into foils. Not known to be available in other than small crystalline pieces.)	$0.45/gm	Johnson, Matthey & Co., Ltd.
2) Crystals	(E)	99.9+	None	Supplied in medium sized crystalline fragments in industrial quantities.	$45/lb.	National Research Corporation[1]
3) Lumps	(E)	95-99	None	Supplied in small fused lumps, designated "nodules."	$3.50/lb.	A. D. Mackay
Other Sources						
1) Metal Powder	Per:			U.C.R.L. Inventory Dept. Files		Metals Disintegrating Co.
20 COBALT	1.(Co)		2.(27)	3.(Com.Met.)	4.(1×10^{-5}%)	5.(33rd)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Nitrate $Co(NO_3)_2$	(C)	99.94	D.S.	Fine crystals	$0.30/gm.	Johnson, Matthey & Co., Ltd.
Metals						
1) Sponge	(C)	99.99+[2]	D.S.	Supplied as finely divided spongy metal. (Very hard, brittle; difficult to work with. Seldom available in other than sponge or crystalline fragments. Cannot be rolled into foils.)	$1.40/gm	Johnson, Matthey & Co., Ltd.
2) Short Sticks	(E)	94-98	None	Supplied in pieces ½"diam.x 3/4"long, designated "rondelles"	$3.70/lb.	A. D. Mackay

[1] Materials supplied by this corporation are especially free from dissolved gases. Prepared by vacuum distillation.

[2] Refined by a process designed to remove most metallic impurities, especially nickel.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
20. COBALT (Contd.) Other Sources	Per: U.C.R.L. Inventory Dept. Files					Belmont Smelting and Refining Co.
21. COLUMBIUM[1]	1.(Cb)	2.(41)		3.(Com.Met.) 4.(3×10^{-5}%) 5.(29th)		
Compounds						
1) Oxide Cb_2O_5	(C)	99.99+	D.S.	Fine crystals	$2.80/gm	Johnson, Matthey & Co., Ltd.[2]
2) Potassium columbate $KCbO_3$	(C)	99.7+	D.C.	Fine crystals	$9.50/lb	Fansteel Metallurgical Corp.
Metal						
1) Powder and Rods	(C)	99.99+	D.S.	Supplied in 50mesh powder and rod 4.7mm diam. or smaller x 10 cm long. Metal available in fair quantity and high purity in several forms: e.g., wire, foil, sheet, rod. Workable with some difficulty and considerable "know how")	$28/rod	Johnson, Matthey & Co., Ltd.[3]
2) Foil	(C)	99.9+	D.C.	Supplied in foils .003" x 4" x 4".	$150/lb	Fansteel Metallurgical Corp.
22. COPPER	1.(Cu)	2.(29)		3.(Com.Met.) 4.(1.0×10^{-4}%) 5.(24th)		
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide CuO	(C)	99.9+	D.S.	Fine crystals	$0.40/gm	Johnson, Matthey & Co. Ltd.

1 also called Niobium in the older literature

2. Columbium compounds (and metal) supplied by this company were originally prepared especially for them by the Fansteel Metallurgical Corporation. The Johnson, Matthey Co. analyzes these batches chemically and spectrographically, then repackages and distributes the samples under their label "Spec Pure."

3 Idem.

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
22. COPPER (Contd)						
Metal						
1) Rods	(C)	99.999	D.S.	Supplied in rods 5-7mm diam. x 15 cm long, and sheet or foil in most sizes desired. (Metal is available in or can be readily made in practically any form or purity desired.)	$1.25/rod	Johnson, Matthey & Co., Ltd.
2) Foil and Rod	(C)	99 .999	D.S.	Supplied in lg. quants. of 3/8" rod, and any thickness of sheet desired. (This sample .003"x4"x4" is designated to be of spectrographic purity.)	$5/lb	American Smelting & Refining Co.
3) Billets	(E)	99	None	Supplied in 3" diam. +2" diam. by 2-8" long billets in industrial quantities.	$1/lb	National Research Corporation[1]
23. CURIUM	1. (Cm)		2. (96)	3. (Radio.)	4. (Does not exist in nature)	5. (--)
	Not available outside the Atomic Energy Commission laboratories. One of the most recently discovered "man-made" elements.[2] The world's supply is not a weighable amount by ordinary careful methods. Its extreme rarity and radioactivity make it seem unlikely that this material will ever be available except for A.E.C. research problems.					
24. DYSPROSIUM	1. (Dy)		2. (66)	3. (R.E.)	4a. (1.5×10^{-4}%) b. (7%)	5a. (23rd) b. (7th)
Compounds	This element is exceedingly rare and difficult to isolate, as evidenced by the fact that the highest purity sample readily available is but 82.3% pure. It is reasonable to expect that newly developed chemical separation methods (i.e., adsorption column techniques)[3] will be put into practise by future suppliers and thus result in larger quantities becoming available at lower cost and higher purities than					

[1] Materials supplied by this corporation are especially free from dissolved gases. Prepared by vacuum distillation.

[2] Seaborg, G. T., "The Transuranium Elements", Science, 104, 384 (October 25, 1946).

[3] Akin to the use of "Zeolite-type" ion exchangers for demineralizing "hard water".

I ELEMENT	II (a) PURITY (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
DYSPROSIUM(contd)	is now the case. Present methods involve literally hundreds of tedious chemical operations and recrystallizations to end up with over an 80% pure product. The Johnson Matthey Co. is the most dependable source, but occasionally samples of rare earths with varying purities turn up in the smaller chemical trading companies with widely varying prices. Users with sufficiently valid reasons may be able to obtain limited amounts from private university collections[1] or the National Bureau of Standards. It is possible that the work of the Atomic Energy Commission in the future may result in making certain of the least abundant rare earths available to bona fide users as an incidental by-product to some of its operations.			
1) Oxide Dy_2O_3	(C) 82.3 D.S.	Fine crystals	$132/gm	Johnson, Matthey & Co., Ltd.[2]
Metal	The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known.			
ERBIUM	1.(Er) 2.(68) 3.(R.E.)	4a. (1.5×10^{-4}%) b. (6%)	5a. (23rd) b. (8th)	
Compounds	The same general information applies here as for dysprosium compounds and footnote(1) below			
1) Oxide Er_2O_3	(E) 98+ D.S.	Fine crystals	$66/.1gm	Johnson, Matthey & Co., Ltd.[3]
Metal	The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known.			

e four best known American collections are those of (1) Dr. H. C. Fogg and (2) Dr. M. F. James (deceased) the University of New Hampshire, (3) Dr. F. H. Spedding of Iowa State College, and (4) Dr. H. N. McCoy eceased) of the Lindsay Light and Chemi. Co. In the past several years, however, some of these collections ve become broken up and widely scattered.

tside the U.S., (1) Dr. J. K. Marsh of Oxford University, England; (2) Dr. Wilhelm ~~Prandtl~~ Brandtl of Munich, Germany; d (3) Prof. Luigi Rolla of Genoa, Italy are known for their work and outstanding collections in the field rare earths. The Johnson Matthey Co. draws upon the last three men for their source of supplies.

is company also makes the following compounds of dysprosium upon request: acetate, chloride, nitrate, ide, and sulphate. They do not prepare the metal.

em., for compounds of erbium.

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I ELEMENT	II PURITY (a) (b-%) (a)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
25. **ERBIUM** (Contd.)				
Other Sources				
1) Compounds	Per: U.C. Dept. of Chem. - Storeroom Files			City Chemical Corporation
2) "	" " " " " "			Eimer and Amend
3) "	" " " " " "			A. D. Mackay
26. **EUROPIUM**	1.(Eu) 2.(63) 3.(R.E.) 4a.(1.5×10^{-4}%) b.(0.2%) 5a.(23rd) b.(14th)			
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1). It should be noted that this element is the next to the least abundant rare earth existing; hence the amount available is strictly limited. Probably the purest and largest amounts of europium are in Dr. McCoy's collection.			
1) Oxide Eu_2O_3	(E) 95+ D.S.	Fine crystals	$7/10mg	Johnson, Matthey & Co., Ltd.[1]
Metal	The metal has been prepared in minute amounts by the discoverer or co-workers, but no current source of the metal is known.			
27. **FLUORINE**	1.(F) 2.(9) 3.(C.Gas) 4.(.030%) 5.(18th)			
Compounds	The same general information applies here as is given for aluminum compounds.			
Elemental Flurcine (A Gas)	When fluorine gas is needed, most commonly it is prepared in the laboratory by an electrolytic unit. It is an extremely corrosive gas and difficult to handle industrially in standard gas cylinders. Anhydrous hydrogen fluoride (HF), which serves almost as well for most processes in which fluroine is required, is more generally available. The gas is not available in spectrographic purity. Usual industrial purity is around 99%.			
Other Sources				
1) Gas	Per: U.C.R.L. Chemical Research Files			General Chemical Company
2) Gas	" " " "			Harshaw Chemical Company

[1] This company also makes the following compounds of europium upon request: acetate; chloride; nitrate; oxide; and sulphate. They do not prepare the metal.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
28. **FRANCIUM** Formerly named Virginium	1.(Fa)	2.(87)	3.(Radio.)	4.($<<10^{-12}$%)	5.(>62nd)	
	Not generally available. Trace amounts only have been prepared by certain university research groups. Exceedingly difficult to isolate, especially so in pure form. Extremely rapid rate of radioactive decay; enjoys a very transitory existence. Half life is ~20 min.[1] For further information as to possible future availability, contact (1) Director of Research, Atomic Energy Commission, (2) Mlle. Marguerite Perey (Discoverer) Radium Institute, Paris, France					
29. **GADOLINIUM**	1.(Gd)	2.(64)	3.(R.E.)	4a.(1.5×10^{-4}%) b.(7%)	5a.(23rd) b.(5th)	
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1)					
1) Oxide Gd_2O_3	(E)	99++	D.S.	Fine crystals (prepared by Dr. Marsh)	$44/gm	Johnson, Matthey & Co., Ltd.[2]
2) Oxide Gd_2O_3	(E)	99+	G.S.	Fine crystals (prepared by Dr. Rolla)	$50/gm	Ferdemos Trading Co.
3) Oxide Gd_2O_3	(C)	98+	None	Fine crystals	$12/gm	Research Chemicals Laboratories[3]
Metal	The metal has been prepared by the discoverer or co-workers, in minute quantities; but no current source of the metal is known.					
30. **GALLIUM**	1.(Ga)	2.(31)	3.(R.Met.)	4.(n x 10^{-11}%)	5.(57th)	
Compounds	This element (though not a rare earth) is exceedingly rare in nature. Compounds not too difficult to prepare and purify once the ores are concentrated.					
1) Chloride $GaCl_3$	(C)	99.99	D.S.	Supplied as crystals in sealed tubes	$16/gm	Johnson, Matthey & Co., Ltd.
2) Oxide Ga_2O_3	(C)	99.99	D.S.	Fine crystals	$17/gm	" " " "

[1] Explanation in footnote (2), p.26 .

[2] This company also makes the following compounds of gadolinium upon request: acetate; chloride; nitrate; oxide; and sulphate. They do not prepare the metal.

[3] This company is a new source of supply in the field of rare earths. As a rare earth supplier, their products are outstandingly pure for the quantities and prices involved.

I ELEMENT	II (a)	PURITY	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
30. GALLIUM (Contd.)		(b-%)				
Metal[1]						
1) Fused pieces	(C)	99.99+	D.S.	Supplied in small fused pieces. (Metal is soft and malleable; easily worked into foil or rods if kept below room temperature.)	$26/gm	Johnson, Matthey & Co., Ltd.
2) Irregular Lumps	(E)	95-99	None	Supplied as small lumps in several-gram quantities.	$9/gm	A. D. Mackay
Other Sources						
1) Metal (99.875%)		Per:		U.C. Dept. of Chem. - Stereroom Files		Foote Mineral Company
2) "				U.C.R.L. Inventory Dept. Files		Chematar, Inc.
3) "				" " " "		City Chemical Corp.
4) "				" " " "		Var-Lac-Oid Chemical Co.
31. GERMANIUM	1.(Ge)		2.(32)	3.(R.Met.)	4.($n \times 10^{-11}$%)	5.(61st)
Compounds	This element (like gallium) is exceedingly rare in nature. Compounds are not too difficult to prepare and purify once the ores are concentrated.					
1) Oxide GeO_2	(C)	99.99	D.S.	Fine crystals	$5/gm	Johnson, Matthey & Co., Ltd.
2) Oxide GeO_2	(C)	99.9+	None	Fine crystals	$1/gm	Eagle-Pichler Co.
Metal						
1) Broken Ingot	(C)	99.99+	D.S.	Supplied as small pieces of broken ingot. (Metal is hard and very brittle; very difficult to work with. Usually melted into desired forms.)	$10/gm	Johnson, Matthey & Co., Ltd.
2) Irregular Lumps	(E)	95-99	None	Supplied in fair-sized lumps in several gm. quantities.	$1.50/gm	A. D. Mackay
Other Sources						
1) Metal		Per:		U.C. Dept. of Chem. - Stereroom Files		City Chemical Corp.
2) Compound				" " " " " "		Fairmount Chemical Co.
3) Metal				U.C.R.L. Inventory Dept. Files		Var-Lac-Oid Chemical Co.

[1] This metallic element melts at slightly above room temperature (29.75°C)

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
32. GOLD	1.(Au)		2.(79)	3.(Prec.Met.)	4.($n \times 10^{-9}$%)	5.(52nd)
Compounds						
1) Chloride $HAuCl_4$	(C)	99.999	D.S.	Fine crystals	$3.40/gm	Johnson, Matthey & Co., Ltd.
2) Chloride $HAuCl_4$	(E)	99.9+	None	Fine crystals	$1.25/gm	Goldsmith Brothers Smelting and Refining Company
Metal						
1) Foil, Rods, Wire	(C)	99.999+	D.S.	Supplied in rods, 3mm diam. x ~3cm long or longer; foil; and ire as required. (Customary refiner's purity--99.5%--readily available, but few sources are available that purify greater than this. Practically no limitations on sizes or forms desired, from gold leaf .0001" thick and fine wire filaments, up to ~150 lb. ingots.)	$5/gm	Johnson, Matthey & Co., Ltd.
2) Sheet and Miscellaneous	(C)	99.99+	D.S.	Supplied in foil .003"x3"x7"	$2/gm	S. S. White Dental Manufacturing Co.
Other Sources						
1) Metal	Per:		U.C.R.L. Inventory Dept. Files			Baker and Company, Inc.[1]
2) "			" " " "			Hanovia Chemical and Manufacturing Co.[2]
33. HAFNIUM	1.(Hf)		2.(72)	3.(R.Met.)	4.(3×10^{-5}%)	5.(30th)
Compounds	While this element is reasonably abundant (30th in rank), its extreme chemical similarity to zirconium has made it very difficult to prepare and purify many compounds. Because of this, and few industrial uses, its availability is limited to very few suppliers in small amounts at high prices.					

[1] Gold in purity 99.5% from this supplier is most likely the result of special laboratory runs, which would be undertaken only for sizeable quantities.

[2] Idem.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
33. **HAFNIUM** (Contd.)						
1) Oxide HfO_2	(E)	95+	None	Supplied as fine crystals in gram amounts.	$25/gm	Frank J. De Rewal
2) Oxide HfO_2	(E)	95+	None	Supplied as fine crystals in gram amounts.	$40/gm	A. D. Mackay[1]
3) Nitrate $Hf(NO_3)_4$	(E)	99+	None[2]	Fine Crystals in gram amounts	$50/gm	Chemical Commerce Company
Metal	The metal has been prepared by several university research groups in very pure form and perhaps by a few industrial organizations, but no current source of the metal is known. A. D. Mackay has recently informed the author that work under his auspices is underway to try to prepare the metal in gram amounts. The metal when pure is quite soft and malleable and readily rolled into thin foils, or drawn into wire.					
Other Sources						
1) Metal	Per:	U.C.R.L. Chemical Research Files				Foote Mineral Company[3]
2) Compounds		" " " "				Johnson Matthey & Co., Ltd.[4]
34. **HELIUM**	1.(He)		2.(2)	3.(R.Gas)	4.(--)[5]	5.(--)
Gas 1) Spec. Pure	(C)	99.99+	G.S.	Put up in 1 or 2 liter sealed glass bulbs. < 5 ppm total impurities. (Also available in industrial quants. (up to 200cu.ft. cylinders), around 98% pure, from most gas companies.)	$4/1	General Electric Co., Cleveland Wire Works

[1] From all indications it is likely that the material supplied by A. D. Mackay is the same material as that supplied by F. J. De Rewal, a manufacturing chemist. Both Mackay's and De Rewal's materials are outstandingly pure for the quantities and prices involved, much more so than supplies of this element have been in the past.

[2] This company makes zirconium metal in pure form. Since hafnium is so closely bound up chemically with Zr, it seems likely that some work may have been done on the hafnium which must be removed before pure Zr metal can be prepared.

[3] This company lists hafnium oxide as the one compound which they supply, but an order placed with them in Sept. 1946 still is unfilled, while they indicate that "the supply is in preparation." The purest Hf the company supplies contains 25-30% Zr and is listed at £33/gm (~$132/gm), accompanied, however, by a detailed spectrographic analytical report.

[5] Normally helium is not thought of as part of the earth's crust, even though each alpha particle given off by a radioactive element in the earth's crust is actually a helium nucleus. The price per liter of each rare gas is a close approximation to its relative abundance in the atmosphere. Helium compounds are non-existent, for Helium is chemically inert - i.e., it does not combine with any other element.

(2) This company claims principal impurities of Zr (0.3% max) and Tl (0.2% ~~95~~ 42 max).

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
35. **HOLMIUM**	1.(Ho)		2.(67)	3.(R.E.)	4a.(1.5×10^{-4}%) b.(1%)	5a.(23rd) b.(11th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote(1). It should be noted that this element comprises but 1% of the rare earth group. Consequently, the amount available is extremely limited as well as difficult to isolate in pure form.					
1) Oxide Ho_2O_3*	(E)	~80%[1]	D.S.	Fine crystals	$11/10mg	Johnson, Matthey & Co., Ltd.[2]
Metal	Holmium metal, to the best of the author's knowledge, has never been prepared in pure state.					
36. **HYDROGEN**	1.(H)		2.(1)	3.(C.Gas)	4.(0.13%)	5.(11th)
Gas 1) Spec. Pure	(E)	99.994	None	Put up in 1 and 2 liter sealed glass bulbs. Several ppm total impurities. (Also available in industrial quants. [up to 160 cu.ft. cylinders], around 99.8% pure from most gas companies.)	$5/1	The Matheson Company
~~**ILLINIUM**~~ see Promethium						
37. **INDIUM**	1.(In)		2.(49)	3.(R.Met.)	4.($n \times 10^{-11}$%)	5.(56th)
Compounds	This element is exceedingly rare in nature. Compounds are not too difficult to prepare and purify once the ores are concentrated.					
1) Oxide In_2O_3	(C)	99.99	D.S.	Fine crystals	$2.25/gm	Johnson, Matthey & Co., Ltd.
2) Nitrate $In(NO_3)_3$	(E)	95-99	None	Coarse crystals	$0.60/gm	A. D. Mackay

[1] This material, prepared by Dr. J. K. Marsh of Oxford, contains about 15% of dysprosium oxide and some yttrium oxide. The holmium oxide content therefore is thought to be about 80%.

[2] This company also prepares the following compounds of holmium upon request: acetate, chloride, nitrate, oxide, and sulphate. They do not prepare the metal.

I ELEMENT	II (a)	PURITY	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
37. INDIUM (Contd.)		(b-%)				
Metal						
1) Wire and Sheet	(C)	99.99+	D.S.	Supplied as 1.6mm diam. wire any length desired, and sheet as specified. (Metal very soft and malleable, tends to cold weld readily. Oxidizes slowly in air. Easily rolled into foils and extruded into wire and small diam. rods and other forms.)	$2.50/gm	Johnson, Matthey & Co., Ltd.
2) Foil	(C)	99.94d	D.C.	Supplied in foils .003"x3"x 6". Available in large quants. in many forms.	$1.40/gm	Indium Corporation of America
Other Sources						
1) Metal and Compounds		Per:		U.C. Dept. of Chem. - Stereroom Files		City Chemical Corp.
2) Metal				" " " " " "		Feete Mineral Company

38. IODINE 1.(I) 2.(53) 3.(Non.Met.) 4.(n x 10^{-7}%) 5.(46th)

Compounds — The same general information applies here as is given for aluminum compounds, except that the Johnson, Matthey Company does not prepare this element at all.

Elemental Iodine — The common element itself is easily prepared and purified in the laboratory by sublimation and hence poses no particular problems as to availability or high purity.

Other Sources			
1) Chloride ICl	Per:	U.C. Dept. of Chem. - Stereroom Files	Eastman Kodak Company
2) Compounds		" " " " " "	Griffin Chemical Company

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
39. **IRIDIUM**	1.(Ir)		2.(77)	3.(Prec.Met.)	4.($n \times 10^{-10}$%)	5.(53rd)
Compounds	Iridium comprises a small proportion of crude platinum ores (0.8-4%); so its availability in quantity is limited. Simple compounds are often unstable, difficult to prepare, and most are very insoluble. This element forms many complex soluble salts.					
1) Ammon. $(NH_4)_2IrCl_6$ Chloroiridate	(G)	99.995	D.S.	Fine crystals	$7/gm	Johnson, Matthey & Co., Ltd.
2) Chloride $IrCl_3$	(E)	99.8+	G.S.[1]	Fine crystals	$4/gm	American Platinum Works
Metal						
1) Sponge and Strip	(C)	99.995+	D.S.	Supplied in sponge form and in thin strips according to one's own requirements. (Metal 99.5% pure [the customary purity supplied], is readily available from most precious metals companies in different forms. Metal quite workable and malleable if extremely pure. Otherwise it is very hard, brittle, and subject to edge cracking when rolled into thin foils. Metal has been rolled down to .002" foils).	$10/gm	Johnson, Matthey & Co., Ltd.
2) Foil	(E)	99.9+	G.S.[2]	Supplied as foil .004"x4" (Almost impossible to roll thinner than this.) Available in gm quantities.	$21/gm	A. D. Mackay
Other Sources						
1) Metal and Compounds	Per:		U.C.R.L. Chemical Research Files			City Chemical Corporation
2) " "			"	"	"	Wildberg Bros. Smelting & Refining Company

[1] Spectrographic analysis is available for an additional charge.

[2] Idem.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
40. **IRON**	1.(Fe)	2.(26)		3.(Com.Met.)	4.(5.01%)	5.(4th)
Compounds	Same general information applies here as is given for aluminum compounds.					
1) Oxide Fe_2O_3	(C)	99.99	D.S.	Fine crystals	$0.45/gm	Johnson, Matthey & Co., Ltd.
2) Sulphate $FeSO_4$	(C)	99.99	D.S.	Fine crystals	$0.50/gm	" " " " "
Metal	Available in practically any form desired in industrial quantities up to ~99% purity.					
1) Sponge	(C)	99.995+	D.S.	Finely divided, hydrogen reduced sponge metal	$0.40/gm	Johnson, Matthey & Co., Ltd.
2) Rods	(C)	99.99+	D.S.	Supplied as rods 5mm diam.x 15cm long.	$0.50/gm	" " " "
3) Rods	(C)	99.99+	D.S.	Supplied as rods 9.5mm diam x 30cm long	$7/rod	" " " "
4) Billets	(E)	99.94d	G.S.	Supplied in billets 2"diam. x 6" long	$12/lb.	National Research Corporation[1]
5) Electrolytic Crystals	(E)	99.9+	None	Irregular crystal fragments	Est.$10/lb.[2]	Plastic Metals, Inc.
6) Wire	(C)	99.8+	D.C.	Supplied in short lengths - wire ~.020"diam.x8"long - as analytical standard.	$1.50/lb.	Mallinckrodt Chemical Works
Other Sources						
1) Metal	Pers		U.C. Dept. of Chem. - Storeroom Files			National Bureau of Standards[3]
2) "			" " " " " "			Thorn Smith Company
41. **KRYPTON**	1.(Kr)	2.(36)		3.(R.Gas)	4.(Not in the earth's crust)[4]	5.(--)
Gas						
1) Spec. Pure	(C)	99.99+	G.S.	Put up in 1 or 2 liter sealed glass bulbs. <5ppm total impurities	$11/1	General Electric Co., Cleveland Wire Works

[1] Metals supplied by this corporation are especially free from dissolved gases. Prepared by vacuum distillat

[2] Price (for larger quantities) is estimated because the small sample (1 lb.) received by the author was kindly sent by the company without charge. This company supplies iron in two grades of purity designated as regular (>99.9%) and special (>>99.9%) Plast-Iron.

[3] This source supplies metal in high purity for use as an analytical standard.

[4] The price per liter of each rare gas is a close approximation to its relative abundance in the atmosphere. No compounds of this gas are known to exist. All the rare gases are chemically inert - as they do not combine with any other element.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
42. **LANTHANUM**	1. (La)			2. (57)	3. (R.E.)	4a. (1.5×10^{-4}%) b. (7%) 5a. (23rd) b. (3rd)

Compounds

After cerium, La is said to have the most numerous commercial uses of any of the rare earth elements. Consequently, even though it comprises only 7% of the R.E. group, it is relatively easy to obtain. It is not quite as difficult to isolate and purify as some of the other rare earths. The most dependable source for high purity La compounds in lb. quantities is the Lindsay Light and Chemical Company.

1) Oxide La_2O_3	(E)	99++	D.S.	Fine crystals	$0.45 gm	Johnson, Matthey & Co., Ltd.[1]
2) Ammon. Nitrate $La(NH_4)_2NO_3$	(E)	99	Typ.	Larger crystals available in lb. quantities. Tends to absorb moisture.	$5/lb.	Lindsay Light and Chemical Co.

Metal

Metal has been prepared in gram amounts 98% purity by certain university research groups. Most difficult to prepare in pure form. Workable with considerable difficulty. Quite hard and tough unless very pure. Has been rolled down to .002" foils in 2" width. Subject to edge cracking in rolling with the required heat and high pressure. For further information as to future availability, contact the Director of Research, Atomic Energy Commission.[2]

1) Lump	(E)	99++	D.S.	Supplied as very small lumps.	Est. $5/gm (Records lost)	Johnson, Matthey & Co., Ltd.[3]

Other Sources

1) Compounds	Per: U. C. Dept. of Chem.-Storeroom Files	City Chemical Corp.
2) "	" " " " "	Fairmount Chemical Company
3) "	" " " " "	Foote Mineral Company
4) "	U.C.R.L. Inventory Dept. Files	Pfaltz and Bauer, Inc.
5) Metal	" Chemical Research	Cooper Metallurgical Lab.

[1] This company also prepares the following compounds of lanthanum upon request: acetate, chloride, nitrate, oxide, and sulphate.

[2] At present, extremely high purity metal is not generally available outside the A.E.C. laboratories. This element, especially free from other rare earths, has been prepared in the form of chloride, oxalate, oxide, metallic lumps, and thin foils.

[3] This company supplied the author with a 2 gm sample of metal in Feb. 1947; however, in their most recent catalog they no longer list the metal as a form which they prepare.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
43. **LEAD**	1.(Pb)		2.(82)	3.(Com.Met.)	4.(2×10^{-5}%)	5.(32nd)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Nitrate $Pb(NO_3)_2$	(C)	99.99	D.S.	Fine crystals	$0.70/gm	Johnson, Matthey & Co., Ltd.
2) Oxide PbO	(C)	99.99	D.S.	Fine crystals	$0.70/gm	" " " "
Metal	Available in practically any form desired in industrial quantities up to ~99% purity.					
1) Rod	(C)	99.9994	D.S.	Supplied in rods 7mm diam.x 16cm long.	$0.50/rod	Johnson, Matthey & Co., Ltd.
2) Sheet and Foil	(C)	99.9998	G.S.[1]	Supplied in sheet .002-5/16 x4"x4" in several hundred gram quantities.	$5/lb.	American Smelting and Refining Co.
3) Ribbon	(E)	99.984d	Typ.	Supplied in ribbon .005"x3" wide in lb. quantities. Especially low in Mn impurity. Designated as "assay" grade	$0.35/lb.	" " " "
44. **LITHIUM**	1.(Li)		2.(3)	3.(Alk.Met.)	4.(4×10^{-5}%)	5.(27th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Carbonate Li_2CO_3	(E)	99.4	D.S.	Fine crystals	$1.20/gm	Johnson, Matthey & Co., Ltd.[2]
Metal						
1) Cubes	(C)	994	None	Supplied in 1-2" cubes in large quants. (Oxidizes rapidly, must be kept in vac. or under oil. Easily worked into most any form desired.)	Est.$75/lb. (Records lost)	A. D. Mackay[3]
2) Cubes	(E)	99	G.C.	Supplied in 1" cubes in large quantities.	$20/lb.	Maywood Chemical Works

[1] Extremely pure material. Analytical information supplied claims that the only impurity detected is a few ppm of iron.

[2] This company prepares lithium compounds only. It is extremely difficult to prepare the metal in spectrographic purity.

[3] This company arranged for a fairly large scale production run of specially purified lithium metal during the war. Since the author has not contacted this company for some time in regard to this element, it is not positively known whether subsequent runs were made, or whether this same material is still available.

I ELEMENT	II (a)	PURITY (b)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
45. LUTECIUM	1.(Lu)		2.(71)	3.(Lu.)	4a.(1.5×10^{-4}) b.(1.5%)	5a.(23rd) b.(10th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1). It should be noted that this element comprises but 1.5% of the rare earth group. Consequently, the amount available is extremely limited as well as difficult to isolate in pure form.					
1) Oxide Lu_2O_3	(E)	95+		D.S.	Fine crystals (free from Yb)	$1.00/mg	Johnson, Matthey & Co., Ltd.[1]
Metal	The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known.					
46. MAGNESIUM	1.(Mg.)		2.(12)	3.(Com. Met.)	4.(2.09.)	5.(8th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide MgO	(C)	99.95		D.S.	Fine crystals	$0.80/gm	Johnson, Matthey & Co., Ltd.
2) Sulphate $MgSO_4$	(C)	99.95		D.S.	Fine crystals	$0.80/gm	" " " "
Metal	Available in most forms desired (those which can be cast) in industrial quants. up to 99%					
1) Rod	(C)	99.95+		D.S.	Supplied in rod 6.35mm x 10cm. (Metal is somewhat malleable. Difficult to work into thin foils; easier to melt and recast same.)	$1.40/rod	Johnson, Matthey & Co., Ltd.
2) Large Crystals	(E)	99+		None	Large crystalline mass as condensed.	Est. $15/lb	Dow Chemical Company
2) Small Crystals	(E)	99+		None	Small crystals as condensed.	Est. $15/lb	Permanente Metals Co.
Other Sources						
1) Metal Ribbon		Pers.		U.C.	Dept. of Chem. - Storeroom Files		ALCOA (Aluminum Co. of America)

1 The company also prepares the following compounds of lutecium upon request: chloride, nitrate, sulphate. They do not produce the metal. ~~This company prepares lutecium compounds only. It is extremely difficult to prepare the metal in spectrographic purity.~~

2 Price for larger quantities is estimated because the small sample received by the author was kindly sent by the company without charge.

3 Idem.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
47. **MANGANESE**	1.(Mn)		2.(25)	3.(Com.Met.)	4.(0.10%)	5.(12th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide MnO_2	(C)	99.99	D.S.	Fine crystals	$0.50/gm	Johnson, Matthey & Co., Ltd.
2) Sulphate $MnSO_4$	(C)	99.99	D.S.	Fine crystals	$0.50/gm	" " " "
Metal						
1) Crystals, Electrolytic	(C)	99.99+	D.S.	Supplied as small thin crystalline fragments. (Hard, brittle, almost impossible to work. Cannot be rolled into thin foils. Not known to be available in other than small fragments.)	$1/gm	Johnson, Matthey & Co., Ltd.
2) Crystalline Fragments	(E)	99.9+	None[1]	Supplied in larger crystalline fragments in industrial quantities.	$2/gm	Metallurgical Products Co.
3) Crystalline Fragments	(E)	99.9+	None	Supplied in largest crystalline fragments in pound quantities.	$30/lb	National Research Corporation[2]
Other Sources						
1) Metal		Per:	U.C.R.L. Inventory Dept. Files			Belmont Smelting and Refining Co.
MASURIUM see Technetium						
48. **MERCURY**	1.(Hg)		2.(80)	3.(Com.Met.)	4.(n x 10^{-7}%)	5.(45th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Chloride $HgCl_2$	(C)	99.99+	D.S.	Fine crystals	$0.45/gm	Johnson, Matthey & Co., Ltd.
2) Oxide HgO	(C)	99.99+	D.S.	Fine crystals	$0.85/gm	" " " "

[1] Supplier claims that this material is essentially free from aluminum, carbon, and silicon.
[2] Materials supplied by this company are especially free from dissolved gases.

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
48. **MERCURY** (Contd.)						
Metallic Mercury (A Liquid)	This element is quite readily available and is easily prepared and purified in the laboratory by distillation, hence poses no particular problems as to availability or high purity.					
1) Liquid Metal	(C)	99.9994	D.S.[1]	Supplied in small 100 gm ampoules.	$3/cg	Johnson, Matthey & Co., Ltd.
Other Sources						
1) Liquid Metal	Per:		U.C. Dept. of Chem. - Storeroom Files			F. W. Berk and Co., Inc.
49. **MOLYBDENUM**	1.(Mo)		2.(42)	3.(Com.Met.)	4.(n x 10^{-6}%)	5.(36th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide MoO_3	(C)	99.95	D.S.	Fine crystals	$0.60/gm	Johnson, Matthey & Co., Ltd.
2) Ammon.Molybdate $(NH_4)_6Mo_7O_{24}$	(C)	99.95	D.S.	Fine crystals. Tends to absorb moisture.	$0.60/gm	" " " "
Metal						
1) Rod	(C)	99.954	D.S.	Supplied in rods 5mm diam. x 15cm long. Metal available in fair quantity and high purity in several forms; e.g., wire, foil sheet, rod. Workable with some difficulty and considerable "know how".	$3.50/rod	Johnson, Matthey & Co., Ltd.
2) Sheet	(E)	99.3+	G.C.	Supplied in sheet .010" x 4"x4" in several gm quants.	$2/lb.	General Electric Co., Cleveland Wire Works
Other Sources						
1) Metal, Misc. Forms	Per:		U.C.R.L. Chemical Research and Inventory Dept. Files			Ransteel Metallurgical Corp.

[1] Extremely pure material. Analytical information supplied claims that the only detectable impurity is 0.0001% silver.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
50. **NEODYMIUM**	1.(Nd)	2.(60)		3.(R.E.)	4a.(1.5 x 10^{-4}%) b.(18%)	5a.(23rd) b.(2nd)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1). Nd., even though it is the 2nd most abundant rare earth, is not generally as available as, for example, lanthanum (which is less abundant), principally because very few commercial uses exist for this element.					
1) Oxide(Nd_2O_3)[1]	(E)	99.44	D.S.	Fine crystals	$4.50/gm	Johnson, Matthey & Co., Ltd.[2]
2) Oxide(Nd_2O_3)[3]	(E)	99.4	D.S.	Fine crystals	$3.85/gm	" " " "
3) Oxide(Nd_2O_3)	(E)	99	None	Fine crystals in gm amounts	$1.50/gm	Research Chemicals Labs.[4]
4) Carbonate-($Nd_2(CO_3)_3$)	(E)	80	None	Lower purity crystals in centigram amounts	Est. $0.25/gm Records Lost	Lindsay Light and Chemical Co
Metal	Metal has been prepared in gram amounts >98% purity by certain university research groups. Most difficult to prepare in pure form. Workable with considerable difficulty. Quite hard and tough unless very pure. Has been rolled down to ~.002" foils in ~2" width. Subject to edge cracking in rolling with the required heat and high pressure. For further information as to future availability, contact the Director of Research, Atomic Energy Commission.[5]					
1) Lump	(E)	95	None	Supplied in a single fused lump 1sq.in. x 1/4" thick.	$2.50/gm	Fordomes Trading Co.
Other Sources						
1) Compounds	Per:			U. C. Dept. of Chem. - Storeroom Files		City Chemical Corporation
2) "				" " " " "		Foote Mineral Company
3) Metal				U.C.R.L. Chemical Research Files		Cooper Metallurgical Lab.
4) "				" Inventory Dept. Files		Fairmount Chemical Co.
5) Compounds				" " " "		Charles Hardy

1 This material prepared by Dr. W. Prandtl of Munich is said to be free of praseodymium, lanthanum and all other rare earths.
2 This company also prepares the following compounds of neodymium upon request: acetate, chloride, nitrate, oxide, and sulphate. They do not prepare the metal.
3 This material is prepared by Dr. Luigi Rolla of Genoa and is slightly lower in purity.
4 This company is a new source of supply in the field of rare earths. As a rare earth supplier, their products are outstandingly pure for the quantities and prices involved.
5 At present, extremely high purity metal is not generally available outside the A.E.C. laboratories. This element, especially free from other rare earths, has been prepared in the form of chloride, oxalate, oxide, metallic lumps, and thin foils.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
51. **NEON**	1.(Ne)		2.(10)	3.(R.Gas)	4.(Not in the earth's crust)[1]	5.(--)
Gas 1) Spec. Pure	(C)	99.994	G.S.	Put up in 1 or 2 liter sealed glass bulbs <6ppm total impurities.	$5/l	General Electric Co., Cleveland Wire Works
52. **NEPTUNIUM**	1.(Np)		2.(93)	3.(Radio.)	4.($\ll 10^{-12}$%)	5.($>62^{nd}$)
	Not now available outside the A.E.C. laboratories. One of the more recently discovered "man-made" elements.[2] The world's supply is still measured in milligrams. Its rarity and special handling required (because of its radioactivity) practically limit its future availability to those users meeting A.E.C. requirements.					
53. **NICKEL**	1.(Ni)		2.(28)	3.(Com.Met.)	4.(.020%)	5.(20th)
Compounds	Same general information applies here as is given for aluminum compounds.					
1) Oxide NiO	(C)	99.99	D.S.	Fine crystals	$0.30/gm	Johnson, Matthey & Co., Ltd.
2) Sulphate $NiSO_4$	(C)	99.99	D.S.	Fine crystals	$0.40/gm	" " " "
Metal	Available in practically any form desired in industrial quantities up to ~99% purity.					
1) Rod[3]	(C)	99.994	D.S.	Supplied in rod 5mm x 10cm long.	$0.95/rod	Johnson, Matthey & Co., Ltd.
2) Sponge	(C)	99.994	D.S.	Supplied as finely divided sponge.	$0.40/gm	" " " "
3) Foil and Slab	(C)	99.954	D.C.	Supplied in a slab 3/8" thick x 2½" x 3", and in foil .005"x3"x20" long, in kg quants.	Est.$30/kg[4]	International Nickel Co., Research Laboratories

[1] The price per liter of each rare gas is a close approximation to its relative abundance in the atmosphere

[2] Seaborg, G.T., "The Transuranium Elements," Science, 104, 384 (October 25, 1946).

[3] The rod form is prepared from the highly purified sponge metal by powder metallurgy, thus minimizing the introduction of impurities during the remelting. Metal is practically free from other metals, especially free cobalt.

[4] Price is estimated, because the sample received by the author was kindly sent by this company without charge. This sample came from a special run undertaken by their research staff, so larger quantities of this material may not be readily available.

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
53. NICKEL (Contd.)						
4) Ribbon and Slab	(E)	99.9d	G.C.	Supplied in ribbon .003" x 2" wide x 50' long coil, and also slab 1/8" thick x 2" x 4", in kg quantities.	Est. $25/kg[1]	Driver-Harris Co.
5) Billet	(E)	99+	None	Supplied in billets $2\frac{1}{2}$" diam. x ~2" long.	$9/lb.	National Research Corporation[2]
54. NITROGEN	1.(N)		2.(7)	3.(C.Gas)	4.(not listed - ~3×10^{-4}%)	5.(not ranked - ~20th)
Gas						
1) Spec. Pure	(E)	99.99+	G.S.	Put up in 1 and 2 liter sealed glass bulbs < 5 ppm total impurities. (Also available in industrial quants. (up to 160 cu.ft. cylinders) around 99.9% pure from most gas companies.)	$1.50/l	General Electric Co., Cleveland Wire Works
55. OSMIUM	1.(Os)		2.(76)	3.(Prec.Met.)	4.($n \times 10^{-10}$%)	5.(54th)
Compounds	Osmium may comprise as much as 25-45% of certain platinum ores; so relative to platinum it is fairly abundant. It is the only preious metal which readily oxidizes. Many, if not most, of the compounds are difficult to prepare and somewhat easier to purify.					
1) Ammon Chlorosmate $(NH_4)_2OsCl_6$	(C)	99.995	D.S.	Fine crystals	$5.20/gm	Johnson, Matthey & Co., Ltd.
2) Chloride $OsCl_4$	(E)	99.5+	None	Fine crystals	$5.00/gm	American Platinum Works
3) Chloride $OsCl_4$	(E)	99+	None	Medium sized crystals	$4.50/gm	Goldsmith Bros. Smelting & Refining Co.

[1] Price is estimated because the sample received by the author was kindly sent by this company without charge. This sample came from a special run undertaken by their research staff, so larger quantities of this material may not be readily available.

[2] Materials supplied by this company are especially free from dissolved gases.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
55. **OSMIUM** (Contd.)						
Metal						
1) Sponge	(C)	99.995+	D.S.	Supplied in finely divided sponge. (Sponge metal 99.5% pure [the usual purity supplied] is readily available from most precious metals companies. Metal is workable with great difficulty; extremely hard and brittle; densest element known. Impossible to roll into foils. Rarely available in other than sponge form.)[1]	$10/gm	Johnson, Matthey & Co., Ltd.
56. **OXYGEN**	1.(O)		2.(16)	3.(C.Gas)	4.(46.50%)	5.(1st)
Gas						
1) Spec. Pure	(E)	99.7+d	C.C.	Put up in 1 liter sealed glass bulbs. Several total ppm impurities. (Also available in industrial quants. [up to 170 cu. ft. cylinders] around 99.6% pure from most gas companies.)	$5/1	Air Reduction Sales Co.
57. **PALLADIUM**	1.(Pd)		2.(46)	3.(Prec.Met.)	4.(n x 10^{-11}%)	5.(59th)
Compounds	Palladium comprises but a small proportion of crude platinum ores (~2%) so its availability in quantity is limited. The compounds are generally the most stable and easiest to prepare of any of the rarer platinum metals.					
1) Ammon. Chloro-palladite $(NH_4)_2PdCl_4$	(C)	99.995	D.S.	Fine crystals	$/gm	Johnson, Matthey & Co., Ltd.

1 Two 20gm pieces of osmium metal in tiny rough cubes (~1cm³) have turned up in U.C.R.L. chemical stocks. It has not been possible to trace down any information as to source through the Purchasing Dept. files. (Perhaps they were prepared by a graduate student some time ago in the course of his own work?) Several of the best known precious metals suppliers were contacted recently toward duplicating this same material without success. To the best of the author's knowledge, no current source exists for metal in other than sponge form.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
57 **PALLADIUM** (Contd.)						
2) Chloride $PdCl_2$	(C)	99.8+d	D.S.[1]	Fine crystals	$0.70/gm	American Platinum Works
3) "	(E)	99.5+	None	Fine crystals	$0.65/gm	Goldsmith Bros. Smelting & Refining Co.
Metal						
1) Wire	(C)	99.995+	D.S.	Supplied in wire 1.0 and 1.5mm diam.x4.5mm long. (Metal 99.5% [the usual purity supplied] is readily available in gm quantities from most precious metals companies in many different forms. Metal is slightly harder than platinum but workable with ease into thin foils and wires.)	$4/gm	Johnson, Matthey & Co., Ltd. Jarrell-Ash Co. National Spectrographic Labs.[2]
2) Sponge	(C)	99.995+	D.S.	Supplied in finely divided sponge.	$3.25/gm	Johnson, Matthey & Co., Ltd.
3) Foil	(C)	99.8+d	D.S.[3]	Supplied in foil .003"x3½" wide x 15" long in gm quants.	$1.20/gm	American Platinum Works
4) Foil	(E)	99.5+	None	Supplied in foil, dimensions as above.	$0.90/gm	Baker and Company
5) Sponge	(E)	99.5+	None	Supplied as finely divided sponge.	$0.85/gm	Wildberg Bros., Smelting & Refining Company.

58 **PHOSPHORUS** 1.(P) 2.(15) 3.(Non.Met.) 4.(0.13%) 5.(10th)

Compounds The same general information applies here as is given for aluminum compounds, except that the Johnson, Matthey Company does not prepare this element at all.

Elemental Phosphorus Though this is a very common element, few suppliers have taken the trouble to prepare highly purified samples; consequently its availability in pure form is limited. Preparation is not too difficult if proper precautions are taken. Element is some forms is highly pyrophoric.[4]

1 Spectroscopic analysis is available for an additional charge.
2 The latter two American sources seem to work together in supplying most of the British Johnson, Matthey & Company "Spec Pure" compounds.
3 Spectroscopic analysis is available for an additional charge.
4 White phosphorus, if finely divided, rapidly oxidizes in air with sufficient vigor to ignite. Element is kept in vacuum or under water. Red phosphorus, howev r, is stabie and unreactive in air.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
58. PHOSPHORUS (Contd.)						
1) Red Phosphorus	(E)	99+	None[1]	Amorphous, finely divided powder. Available in cg quantities.	No charge for research purposes.	Tennessee Valley Authority, Wilson Dam Research Lab.
59. PLATINUM	1.(Pt)		2.(78)	3.(Prec.Met.)	4.(n x 10^{-9}%)	5.(50th)
Compounds						
1) Ammon. $(NH_4)_2PtCl_6$ Chloroplatinate	(C)	99.999	D.S.	Fine crystals	$5.20/gm	Johnson, Matthey & Co., Ltd.
2) Chloride $PtCl_4$	(C)	99.84 d	None[2]	Medium sized crystals. Tends to absorb moisture rapidly	$0.90/gm	American Platinum Works
Metal						
1) Rod	(C)	99.9994	D.S.	Supplied in rods 3mm diam. x 3cm long (~4.8 gm/rod) (Customary refiner's purity [99.5%] readily available, but few sources are available that purify greater than this. Practically no limitations on sizes or forms desired.)	$12/gm	Johnson, Matthey & Co., Ltd.
2) Sponge	(C)	99.9994	D.S.	Supplied in finely divided sponge.	$11/gm	" " " "
3) Rod	(C)	99.9944	None	Supplied as rod ½" diam. x 3/8" long, in gm quants.	$76/oz.[3]	Wildberg Bros. Smelting & Refining Co.

[1] No analytical information is furnished; however, detailed information is given as to the special method of preparation used.

[2] Spectroscopic analysis is available for an additional charge.

[3] This material was specially purified for a particular experiment here. The analytical work was done by the U.C.R.L. It is included in this list to indicate the price one might expect to encounter in additionally purifying the usual 99.5% pure material.

I ELEMENT	II (a) PURITY (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
60. PLUTONIUM	1.(Pu) 2.(94) (b-%)	3.(Radio.)	4.(10^{-18}%)	5.([redacted])
	Available only to research and production groups under the control of the Atomic Energy Commission. One of the more recently discovered "man-made" elements.[1] This element is one of the two fissionable elements used in the atomic bomb; consequently, any further information is classified as "Secret" and is unavailable to groups outside the A.E.C.			
61. POLONIUM	1.(Po) 2.(84)	3.(Radio.)	4.(10^{-12}%)	5.(62nd)
	Not generally available. Microgram amounts have been prepared by certain university research groups. Exceedingly difficult to isolate, especially so in pure form. Rapidly decays away radioactivity. Half life = 140 days.[2] For further information as to future availability, contact: (1) Director of Research, Atomic Energy Commission; (2) Canadian Radium and Uranium Corporation; (3) Radium Chemical Company; (4) The Department of Chemistry of the nearest university.			
62. POTASSIUM	1.(K) 2.(19)	3.(Alk.Met.)	4.(2.6%)	5.(7th)
	The same general information applies here as for aluminum compounds.			
Compounds 1) Chloride	(C) 99++ D.S.	Fine crystals	$0.40/gm	Johnson, Matthey & Co., Ltd.[3]
Metal 1) Sticks	(E) 95-99 None	Supplied in sticks 1" diam. x 3" long in cg quantities. (Oxidizes rapidly; vigorously reacts with water. Must be kept in vac. or under oil. Soft: easily worked into forms desired. No purer source of K metal is known.)	$4/cg	A. D. Mackay

1 G. T. Seaborg, "The Transuranium Elements," Science, 104, 382 (October 25, 1946)
2 See footnote (2), p.26
3 This company prepares compounds of potassium only. It is very difficult to prepare the metal in spec. purity. This particular sample (KCl) is especially free from cesium, sodium and rubidium.

I ELEMENT	II PURITY (a)	(b-%)	(b)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
PRASEODYMIUM	1.(Pr)		2.(59)	3.(R.E.)	4a.(1.5 x 10^{-4}%) b.(5%)	5a.(23rd) b.(9th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1)					
1) Oxide Pr_6O_{11}	(E)	9944	D.S.	Fine crystals	$22.50/gm	Johnson, Matthey & Co., Ltd.[1]
2) Oxide Pr_6O_{11}	(E)	994	None	" "	$2/gm	Research Chemicals Labs.[2]
3) Nitrate $Pr(NO_3)_3$	(E)	99	None	" "	Est.$5/gm Records Lost	Maywood Chemical Company
Metal	Metal has been prepared in gram amounts > 98% purity by certain university research groups. Most difficult to prepare in pure form. Workable with considerable difficulty. Quite hard and tough unless very pure. Has been rolled down to ~.002" foils in ~2" width. Subject to edge cracking in rolling with the required heat and high pressure. For further information as to future availability, contact the Director of Research, Atomic Energy Commission.[3]					
1) Fused Lump	(E)	98-98	None	Supplied as a single irreg. 10gm lump, a few mm on a side.	$4.50/gm	Fordomes Trading Co.
Other Sources 1) Metal	Per:		U.C.R.L. Chemical Research Files			Cooper Metallurgical Labs.
4. **PROMETHIUM**	1.(Pm)		2.(61)	3.(Radio.)[4]	4.(Probably does not exist in nature)	5.(—)
	This element has been the subject of considerable scientific controversy as to whether its existence in nature has been conclusively proven. If it exists at all in nature, its total abundance is limited to an unweighably small number of radioactive					

[1] This company also prepares the following compounds of praseodymium upon request: acetate, chloride, nitrate, oxide, and sulphate.

[2] This company is a new source or supply in the field of rare earths. As a rare earth supplier, their products are outstandingly pure for the quantities and prices involved.

[3] At present, extremely high purity metal is not generally available outside the A.E.C. laboratories. This element, especially free from other rare earths, is principally available in the form of oxide and metallic lumps.

[4] Actually this element is a rare earth, but for simplicity of treatment it is classified here as a radioactive element because of its physical characteristics.

I ELEMENT	II PURITY (a) (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY

64. **PROMETHIUM** (Contd.)

disintegrations.[1] Here is another case where man has helped nature. Incidental to the operation of the atomic energy plants, limited amounts (in millicuries)[2] of this element have been produced, partially separated, and purified to some extent after considerable effort; and are available to qualified research groups. This element readily decays away radioactively. Half life ≈ [redacted].[3] For further information as to future availability contact the Isotopes Branch PO Box, US Atomic Energy Commission, Oak Ridge, Tenn.

65. **PROTACTINIUM** 1.(Pa) 2.(91) 3.(Radio.) 4.($\ll 10^{-12}$%) 5.(>62nd)

Not generally available. Milligram amounts only have been prepared by certain university research groups and a few radium companies. Abundance is very low, relative to radium. Extremely difficult to isolate[4], especially so in pure form. Decays away radioactively very slowly. Half life ≈ several thousand years.[5] For further information as to availability contact: (1) Director of Research, Atomic Energy Commission; (2) Canadian Radium and Uranium Co.; (3) Radium Chemical Co.; (4) Department of Chemistry of the nearest university.

66. **RADIUM** 1.(Ra) 2.(88) 3.(Radio.) 4.(n x 10^{-12}%) 5.(62nd)

Readily available up to gram quantities. Mined and extracted commercially where pitchblende and other uranium ores contain ~1 gram of radium per 8-15 tons of ore. World supply in 1928 (Bureau of Mines figures) was 600 grams. Estimated annual production since that time is 80-100 grams. Current market price is around $25/mg. This element can be purified chemically only with great difficulty; and then not for long since other impurities "grow" into the purified sample by the radioactive transformation of radium into other elements. Half life ≈ 1,600 years.[6] When radium is needed

1 Each active atom as it disintegrates emits a radioactive particle (α, β, or γ ray) which can be counted by an electronic instrument. Thus one can calculate the amount of the element a certain number of counts represent, even though the total amount may be too small to weigh or otherwise measure.
2 A unit defining the amount of radioactivity present.
3 Explanation in footnote (2), p. 12
4 The author is familiar with a company which placed an order for one gm of Pa with a commercial supplier (who should be qualified to isolate this element). Nearly two years have elapsed and the order is still unfilled. upon solicitation of an order by this supplier.
5 Explanation in footnote (2), p. 12
6 Idem.

I ELEMENT	II (a) PURITY (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
66. **RADIUM** (Contd.)				
	for its radioactive properties (rather than for its chemical properties) it sometimes can be rented rather than purchased.			
Sources				
1) --	Per:	U.C. Dept. of Chem. - Storeroom Files		Hammer Laboratories
2) --		U.C.R.L. Chemical Research Files		Canadian Uranium [redacted] Radium & Corporation
3) --		" " " "		Radium Chemical Co.
67. **RADON**	1.(Rn)	2.(86) 3.(Radio.)[1] 4.($\ll 10^{-12}$%) 5.($>62^{nd}$)		
	Widely available in small volumes. Very rapidly decays away radioactively. Half life 3 days.[2] Most large hospitals have their own radium supply; and the gas which emanates from radium, namely radon, is periodically pumped off and sealed into fine tubes ("needles" or "seeds", as they are called) for radiation treatments. The short period of radon's effectiveness compels locating a local source. Many hospitals will cooperate in supplying small quantities to qualified research groups.			
Other Sources				
1) --	Per:	U.C.R.L. Chemical Research Files		Canadian Radium & Uranium Corporation
2) --		" " " "		Radium Chemical Co.
68. **RHENIUM**	1.(Re)	2.(75) 3.(R.Met.) 4.(Not listed ~ 2 x 10^{-11}%) 5.(Not ranked ~ 61st)		
Compounds	This element (though not a "rare earth) is exceedingly rare in nature. Compounds are not too difficult to prepare and purify once the ores are concentrated.			
1) Potass. $KReO_4$ Perrhenate	(C) 99.99 D.S.	Fine crystals	$8.20/gm	Johnson, Matthey & Co., Ltd.
2) " "	(C) 99.99 G.S.	Fine crystals available in decigram quantities.	$1.75/gm	Prof. A. D. Melaven, Univ. of Tennessee

[1] Actually this element is one of the rare (so called "noble") gases, but for simplicity of treatment it is classified here as a radioactive element because of its more important radioactive characteristics.

[2] Explanation in footnote (2), p. .

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
68. **RHENIUM** (Contd.)						
Metal						
1) Powder	(C)	99.994	D.S.	Supplied as a fine pseudo-crystalline powder.	$16/gm	Johnson, Matthey & Co., Ltd.
2) Powder	(C)	99.99	G.S.	Supplied as a fine pseudo-crystalline powder. (Metal is hard, tough, and very dense. Quite difficult to work with but can be hot forged or cold rolled to some extent. No supplier, however, is known for other than a powder form.)	$3/gm	Prof. A. D. Melaven, Univ. of Tennessee

69. **RHODIUM** 1. (Rh) 2.(45) 3.(Prec.Met.) 4.($n \times 10^{-11}$%) 5.(58th)

Compounds Rhodium may comprise, at the most, 7% of certain platinum ores, so its availability in quantity is limited to some extent. Many compounds are difficult to prepare. This element forms many complex compounds.

1) Ammon. $(NH_4)_3RhCl_6$ Chlororhodite	(C)	99.995	D.S.	Fine crystals	$4/gm	Johnson, Matthey & Co., Ltd.
2) Chloride $RhCl_3$	(E)	99.5	None	Fine crystals	$3/gm	American Platinum Works
Metal						
1) Sponge	(C)	99.995+	D.S.	Supplied in finely divided sponge. (Metal 99.5% (the usual purity supplied) is readily available from most precious metals companies in different forms. Metal quite workable and malleable if extremely pure. Otherwise it is very hard, brittle, and subject to edge cracking when rolled into thin foils. Metal has been rolled down to .002" foil.)	$11/gm	Johnson Matthey & Co., Ltd.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
69. RHODIUM (Contd.)						
2) Wire	(C)	99.995+	D.S.	Supplied in wire 0.5mm diam. in lengths desired (~0.8 gm/ft.)	$14.40/gm	Johnson, Matthey & Co., Ltd.
3) Wire	(C)	99.995+	D.S.	Supplied in wire 1.5mm diam. in lengths desired (~7 gm/ft.)	$14/gm	" " " "
4) Foil	(E)	99.8+d	D.S.[1]	Supplied in foil .003"x 2" x 4-6" in gm quantities	$12/gm	American Platinum Works
5) Wire	(E)	99.8+	D.S.	Supplied in wire .020" diam.	$0.75/in.	" " "
70. RUBIDIUM	1.(Rb)		2.(37)	3.(Alk.Met.)	4.(n x 10^{-6}%)	5.(37th)
Compounds						
1) Chloride RbCl	(E)	99++	D.S.	Fine Crystals	$7.80/gm	Johnson, Matthey & Co., Ltd.[2]
2) Nitrate $RbNO_3$	(E)	95-99	None	" "	$0.45/gm	A. D. Mackay
Metals						
1) Fused	(E)	95-99	None	Supplied in small quantities of a fused mass sealed in vac. inside glass tubes. (Oxidizes rapidly, [illegible] easily worked. Melts not far above room temperature. (38.4°C) Metal is not generally available in either high purity form or large quantity.)	$6.50/gm	A. D. Mackay
Other Sources						
1) Metal		Pers	U.C. Dept. of Chem. - Storerson files			Foote Mineral Co.

[1] Spectrographic analysis is available for an additional charge.

[2] This company prepares rubidium compounds only. It is very difficult to prepare the metal in spectrographic purity.

ELEMENT	(a)	PURITY (b-%)	(c)	PHYSICAL FORM	PRICE	SOURCE OF SUPPLY
71. **RUTHENIUM**	1(Ru)		2.(44)	3.(Prec.Met.)	4.(m x 10^{-11}%)	5.(60th)
Compounds	Although ruthenium may comprise from 0.5-12% of certain platinum ores, its abundance relative to platinum is very low; hence its availability is rather limited. Very few commercial uses exist for this element, a fact which serves to counterbalance its rarity. Many compounds are difficult to prepare. This element forms many complex compounds					
1) Ammon.$(NH_4)_2RuCl_5$ Chlororuthenite	(C)	99.995	D.S.	Fine crystals	$3.30/gm	Johnson, Matthey & Co., Ltd.
2) Chloride $RuCl_4$	(E)	99.5	None	" "	$1.30/gm	Baker and Co.
Metal						
1) Sponge	(C)	99.9954	D.S.	Supplied in finely divided sponge.	$8/gm	Johnson, Matthey & Co., Ltd.
2) Powder	(C)	99.84 d	D.S.[1]	Supplied in a fine powder. (Metal > 99.0% pure [the usual purity supplied] is readily obtainable from most precious metals companies in powder form only. Very difficult to fabricate. Metal is hard and brittle. Recently available for the first time is sintered and forged metal in foil form from Baker & Co. Foil can not be made thinner that .005".	$2.65/gm	American Platinum Works
72. **SAMARIUM**	1.(Sm)		2.(62)	3.(R.E.)	4a.(1.5 x 10^{-4}%) b.(7%)	5a.(23rd) b.(4th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1) This element is somewhat easier to separate and purify than many of the other rare earths. Substantial amounts of very pure Sm_2O_3 have been prepared by certain of the Atomic Energy Commission subcontractors. At present this material is available only to A.E.C. research groups.					

[1] Spectrographic analysis is available for an additional charge.

I ELEMENT	II (a)	PURITY	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
72. **SAMARIUM** (Contd.)		(b-%)				
1) Oxide Sm_2O_3	(E)	99.94+	D.S.	Fine Crystals	$14.75/gm	Johnson, Matthey & Co., Ltd.[1]
2) " "	(E)	99.9+	None	" "	$7.50/gm	Research Chemicals Labs.[2]
3) " "	(C)	99.	None	" "	$1.25/gm	" " "

Metal — Metal has been prepared in mg amounts by certain university research groups. Most difficult to prepare in pure form. Metal is very hard and cannot be rolled into foils. No current source of the metal is known. For information as to future availability, contact the Director of Research, Atomic Energy Commission.

73. **SCANDIUM** — 1.(Sc) 2.(21) 3.(R.E.)[3] 4.(n x 10^{-7}%) 5.(42nd)

Compounds — The availability of this element is exceedingly limited because of the lack of commercial uses and its low abundance. Somewhat easier to separate and purify than most rare earths once the ores are concentrated.

1) Oxide Sc_2O_3	(E)	99+	D.S.	Fine crystals	$40/gm	Johnson, Matthey & Co., Ltd.[4]
2) " "	(E)	99+	G.S.	Fine crystals	$66/gm	Fordomes Trading Co.

Metal — The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known. Further information may be obtainable from: (1) Director of Research, Atomic Energy Commission; (2) Mr. O. Ivan Lee. (For address see Appendix A)

74. **SELENIUM** — 1.(Se) 2.(34) 3.(Com.Met.) 4.(n x 10^{-8}%) 5.(4th)

Compounds — The same general information applies here as is given for aluminum compounds except that fewer selenium compounds are available above reagent grade purity.

1 This company also makes the following compounds of samarium upon request: acetate, chloride, nitrate, oxide, and sulphate. They do not prepare the metal.

2 This company is a new source of supply in the field of rare earths. As a rare earth supplier, their products are outstandingly pure for the quantities and prices involved.

3 Actually, this element is a rarer metallic element; but for simplicity of treatment it is classified here as a rare earth, because its occurence and behavior are so similar to the rare earths.

4 This company also makes the following compounds of scandium upon request: acetate, chloride, nitrate, oxide, and sulphate. They do not prepare the metal.

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
74 **SELENIUM** (Contd.)						
1) Selenious Acid H_2SeO_3	(C)	99.92	D.S.	Fine crystals	$0.30/gm	Johnson, Matthey & Co., Ltd.
2) Potass. K_2SeO_3 Selenate	(E)	95-99	None	" "	$5/cg	A. D. Mackay
Metal						
1) Shot	(C)	99.984	D.S.	Supplied in doubly distilled shot (~¼" diam.)	$8/cg	Johnson, Matthey & Co., Ltd.
2) "	(C)	99.924	D.S.	Supplied in chemically refined shot (~¼" diam.)	$7/cg	" " " "
3) Sticks	(E)	95-99	None	Supplied in sticks 3/4" diam. x 2-3"	$4/lb.	A. D. Mackay
4) Powder	(E)	95	None	Supplied as finely divided powder. (Metal is hard, brittle, and workable with difficulty. Cannot be rolled into thin foils. No source is known for pieces any larger than the sticks.)	$4.80/lb.	City Chemical Co.
Other Sources 1) Metal		Per:		U.C. Dept. of Chem. Storeroom files		Foote Mineral Co.
75 **SILICON**	1.(Si)		2.(14)	3.(Non.Met.)	4.(27.72%)	5.(2nd)
Compounds	The same general information applies here as for aluminum compounds, except that fewer silicon compounds are available above reagent grade purity.					
1) Chloride $SiCl_4$	(C)	99.94	D.S.	Supplied in lcc ampoules of $SiCl_4$ in carbon tetrachloride solution, each containing ~0.01gm of Si	~$1/cc[1]	Johnson, Matthey & Co., Ltd.
2) Oxide SiO_2	(C)	99.94	D.S.	Supplied as a fine light powder.	$0.40/gm	" " " "

[1] One cc = 1 cubic centimeter or 1/1000 liter.

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
75. SILICON (Contd.)						
Elemental Silicon		Element is extremely hard, brittle, and crystalline. Almost impossible to fabricate into more massive forms. No source known for forms other than crystalline fragments.				
1) Crystals	(C)	99.99+	D.S.	Supplied as thin plate-like crystals.	$0.85/gm	Johnson, Matthey & Co., Ltd.
2) Powder and Granules	(E)	99.9	None	Supplied in fine (325 mesh) powder and 30 mesh granules in lb. quantities.	$1-3/oz.	Electrometallurgical Co.
3) Granules	(E)	95-99	None	Supplied in coarse granules	$10/cg	A. D. Mackay
Other Sources 1) Element		Per.	U.C. Dept. of Chem. - Storeroom Files			Foote Mineral Co.
76. SILVER	1.(Ag)		2.(47)	3.(Prec.Met.)	4.(n x 10^{-8}%)	5.(48th)
Compounds						
1) Nitrate $AgNO_3$	(C)	99.999	D.S.	Fine crystals	$0.40/gm	Johnson, Matthey & Co., Ltd.
2) Chloride AgCl	(E)	99+	None	Supplied as single large "grown" crystals, or sheets up to few inches in length and width x several mm thick.	(----)[1]	Harshaw Chemical Co.
Metal						
1) Foil	(C)	99.999+	D.S.	Supplied as pieces of foil 3 cm sq. x 0.25 mm thick.	$0.20/pc	Johnson, Matthey & Co., Ltd.
2) Rod and Wire	(C)	99.999+	D.S.	Supplied in rods 7 mm x 10cm, and wire 1.2mm x 15cm	$0.40/rod	" " " "
3) Sheet	(C)	99.99+	G.S.	Supplied in sheets .005" x 4"x4" in kg quantities	$1.10/tr.oz.	Handy and Harman

[1] No specific estimate can be made because prices depend upon size, form, and purity desired. By way of example, grown crystals 1" diam. x ½" thick cost $35.00 each. These crystals can be machined to some extent. Each type of crystal prepared is essentially made to order.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
76 **SILVER** (Contd.) **Metal**				(Customary refiner's purity (99.5%) is readily available, but few sources are known that purify greater than this. There are practically no limitations on sizes or forms desired, from foils .001" thick, fine wire filaments, and precipitated powder, to ingots > 25 lbs.)		
77. **SODIUM**	1.(Na)		2.(11)	3.(Alk.Met.)	4.(2.85%)	4.(6th)
Compounds	The same general information applies here as for aluminum compounds.					
1) Carbonate Na_2CO_3	(C)	99.99+	D.S.	Fine crystals	$0.40/gm	Johnson, Matthey & Co., Ltd.[1]
2) Chloride NaCl	(C)	99.99+	D.S.	" "	$0.40/gm	" " " "
Metal 1) Bar	(E)	99.95+	G.C.	Supplied in bar 1"sq. x 10" long in lb. quantities (Oxidizes rapidly, vigorously reacts with water. Must be kept in vac. or under oil. Soft, easily worked into forms desired. No purer source of Na metal is known.)	$2.50/lb.	Charles Hardy Inc.
78. **STRONTIUM**	1.(Sr)		2.(38)	3.(Alk. Met.)	4.(1.9×10^{-4}%)	5.(21st)
Compounds	The same general information applies here as is given for aluminum compounds, except that fewer strontium compounds are available above reagent purity.					
1)Carbonate $SrCO_3$	(E)	99++	D.S.	Fine crystals	$0.80/gm	Johnson, Matthey & Co., Ltd.[2]

[1] This company prepares sodium compounds only. It is very difficult to prepare the metal in spectrographic purity. The chloride sample is stated to be free from other alkali metals.

[2] This company prepares strontium compounds only. It is very difficult to prepare the metal in spectrographic purity.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
78 **STRONTIUM** (Contd.)						
Metal						
1) Lump	(E)	99.7+	G.S.	Supplied in irregular lump packed in a vac. tin. Available in lb. quantities. (Metal oxidizes readily. Workable without too much difficulty. Metal is not generally available in high purity form in large quantities.)	$30/lb.	Kemet Laboratory Co.
79 **SULPHUR**	1.(S)		2.(16)	3.(Non.Met.)	4.(0.052%)	5.(13th)
Compounds	The same general information applies here as is given for aluminum compounds except that Johnson, Matthey Co. does not prepare this element at all.					
Elemental Sulphur	Though this is a very common element, few suppliers have taken the trouble to prepare highly purified samples; consequently its availability in pure form is limited. Preparation is not too difficult if proper precautions are taken.					
Sources	Per.		U.C.R.L. Chemical Research Laboratories " " " "			Stauffer Chemical Co.[1] Texas Gulf Sulphur Co.[2]
80 **TANTALUM**	1.(Ta)		2.(81)	3.(Com.Met.)	4.([illegible])	5.(29th)
Compounds						
1) Chloride $TaCl_5$	(C)	99.98	D.S.	Fine crystals	$3.[illegible]/gm	Johnson, Matthey & Co., Ltd.
2) Oxide Ta_2O_5	(C)	99.98	D.S.	" "	$2.[illegible]/gm	" " " "
Metal						
1) Rod	(C)	99.98+	D.S.	Supplied in rod[3] 4.5mm x [illegible]	$[illegible]/rod	Johnson Matthey, & Co., Ltd.[4]

[1] This sample was specially purified in this company's research laboratory. Detailed information as to its preparation is given.
[2] Idem.
[3] Dimensions can be reduced to smaller diameter upon request.
[4] Tantalum compounds (and metal) supplied by this company were originally prepared especially for them by the Fansteel Metallurgical Corporation. The Johnson, Matthey Co. analyzes these batches chemically and spectrographically; then repackages and distributes the samples under their label "Spec Pure."

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
80. **TANTALUM** (Contd.)						
2) Powder	(C)	99.98+	D.S.	Supplied as finely divided powder.	$19/gm	Johnson, Matthey & Co., Ltd.
3) Sheet	(C)	99.95+d	G.C.	Supplied in sheet .005" x 4"x2"wide x 9" in gm quanta.[1] (Metal available in fair quantity and high purityin several forms, e.g., wire, sheet, rod, and foil down to .002". Workable with some difficulty and considerable "know how."	$74/lb.	Fansteel Metallurgical Co.

81. **TECHNETIUM** 1.(Tc) 2.(43) 3.(Radio.) 4.(Probably does not exist in nature) 5.(—)

This element has been the subject of considerable scientific controversy as to whether its existence in nature has been conclusively proven. If it exists at all in nature, its total abundance is limited to an unweighably small number of radioactive disintegrations.[2] Here is another case where man has helped nature. Incidental to the operation of the atomic energy plants, limited amounts (in millicuries)[3] of this element have been produced, partially separated, and purified to some extent after considerable effort, and are available to qualified research groups. This element decays away radioactively extremely slowly. Half life ≈ 2,000,000 years.[4] For further information as to future availability contact the Isotopes Branch, U.S. Atomic Energy Commission, Oak Ridge, Tennessee.

82. **TELLURIUM** 1.(Te) 2.(52) 3.(Com.Met.) 4.(n x 10^{-9}%) 5.(51st)

Compounds The same general information applies here as is given for aluminum compounds, except that fewer tellurium compounds are available above reagent grade purity.

1) Dioxide TeO_2	(C)	99.99	D.S.	Fine crystals	$1.60/gm	Johnson, Matthey & Co., Ltd.

[1] This particular high purity sample came from a special laboratory run.
[2] Each active atom as it disintegrates emits a radioactive particle (α, β, γ or ray) which can be counted by an electronic instrument. Thus one can calculate the amount of the element a certain number of counts represent, even though the total amount may be too small to weigh or otherwise measure.
[3] A unit defining the amount of radioactivity present.
[4] Explanation in footnote (2), p.12 .

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
82. TELLURIUM (Contd.)						
2) Telluric Acid H_6TeO_6	(C)	99.99	D.S.	Fine crystals	$2.25/gm	Johnson, Matthey & Co., Ltd.
3) Potass. K_2TeO_4 Tellurate	(E)	95-99	None	" "	$4/cg.	A. D. Mackay
Metal						
1) Rod	(C)	99.994	D.S.[1]	Supplied in rod 5mm diam. x 6.5cm long (wt./rod ≅ 8gm)	$0.55/gm	Johnson, Matthey & Co., Ltd.
2) Powder	(C)	99.994	D.S.[2]	Supplied in finely divided powder	$0.45/gm	" " " "
3) Sticks	(E)	984	None	Supplied in sticks 5/16" diam. x 1-2" long in cg quants.	$2.50/cg	City Chemical Corporation
4) Sticks	(E)	95-99	None	Supplied in sticks 1" diam. x ~1" long. (Metal is hard, extremely brittle and crystalline. Workable with great difficulty. Usually melted and cast into forms desired. No source is known for pieces larger than the sticks listed above.)	$1/cg	A. D. Mackay
83. TERBIUM	1.(Tb)		2.(65)	3.(R.E.)	4a.(1.5×10^{-4}%) b.(1%)	5a.(23rd) b.(13th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1). It should be noted that this element comprises but 1% of the rare earth group. Consequently, the amount available is extremely limited as well as difficult to isolate in pure form.					
1) Oxide Tb_4O_7	(E)	954	D.S.	Fine crystals	$100/.1gm	Johnson, Matthey & Co., Ltd.[3]

[1] This metal is especially free from selenium and all metallic impurities.

[2] Idem.

[3] This company also prepares the following compounds of terbium upon request: acetate, chloride, nitrate, oxide and sulphate. They do not prepare the metal.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
83. **TERBIUM** (Contd.) **Metal**	The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known.					
84. **THALLIUM**	1.(Tl)		2.(81)	3.(Com.Met.)	4.($n \times 10^{-10}$%)	5.(55th)
Compounds	This element is quite rare in nature. Compounds are not too difficult to prepare and and purify once the ores are concentrated.					
1) Chloride TlCl	(C)	99.99	D.S.	Fine crystals	$2.25/gm	Johnson, Matthey & Co., Ltd.
2) Oxide Tl_2O_3	(C)	99.99	D.S.	" "	$2.25/gm	" " " "
Metal						
1) Wire	(C)	99.99+	D.S.	Supplied in wire 1.5mm diam. x whatever length desired (1cm ≅ .24gm)	$2/gm	" " " "
2) Large Rods	(E)	99.97	Typ.	Supplied in rods 5/16" diam. x 10" long in lb. quantities. (Metal is fairly soft and malleable, rolled into thin foil and extruded into wire with little difficulty. Oxidizes rapidly in air.)	Est.$50/lb. Recs.Lost	American Smelting & Refining Co.
85. **THORIUM**	1.(Th)		2.(90)	3.(Radio.)	4.(2×10^{-5}%)	5.(31st)
Compounds	This element, although reasonably abundant in nature, until recent atomic energy developments came along, had seldom been prepared in very pure form. Compounds are reasonably difficult to prepare and purify once the ores are concentrated. Because this element has been designated as a possible source of fissionable materials, regulations have recently been issued by the Atomic Energy Commission requiring the licensing of all Th metal or Th compounds held by individuals in quantities in excess of ten lbs.[1] Purities obtainable from Johnson, Matthey & Co. and the usual laboratory					

[1] See Pike and Fischer (Legal Service) "Atomic Energy Regulation" for the current status of this ~~regulation~~.

I ELEMENT	II (a) PURITY (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
85 **THORIUM** (Contd.)				
	supply houses are well below that prepared by the A.E.C. laboratories, and at much higher than warranted prices (since this element is not the laboratory rarity it once was). For further information concerning the possibility of obtaining > 10 lbs. of very pure thorium compounds, contact the Director of Research or Production, A.E.C.			
1) Nitrate $Th(NO_3)_4$	(E) 99+ D.S.	Fine crystals	$0.30/gm	Johnson, Matthey & Co., Ltd.[1]
2) Oxide ThO_2	(E) 99+ D.S.	" "	$0.30/gm	" " " "
Metal	Prior to the war, this element in metallic form was a laboratory curiosity. Now large quantities of extremely pure metal have been prepared by the Atomic Energy Commission subcontractors. The metal, though workable with difficulty, has been prepared in many different physical forms. (See preceding paragraph concerning the compounds in regard to the licensing requirements.) For further information concerning the possibility of obtaining > 10 lbs of pure thorium metal, contact the Director of Research or Production, A.E.C.			
Other Sources				
1) Metal	Per:	U.C. Dept. of Chem. - Storeroom Files		Foote Mineral Co.
2) Metallic Powder		U.C.R.L. Inventory Dept. Files		Westinghouse Research Lab.
86 **THULIUM**[2]	1.(Tm)	2.(69) 3.(R.E.)	4a.(1.5×10^{-4}%) b.(1%)	5a.(23rd) b.(12th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1). It should be noted that this element comprises but 1% of the rare earth group. Consequently, the amount available is extremely limited as well as difficult to isolate in pure form.			
1) Oxalate $Tm_2(C_2O_4)_3$	(C) 94.5+	None[3]	Fine crystals	$2.75/mg[4] Pordomes Trading Co.
2) Oxide Tm_2O_3	(E) 90-98 D.S.		" "	(-------) Johnson, Matthey & Co., Ltd.

1 This company prepares compounds of Th only. This company states "The metal is not available in sufficiently pure form for use as a spec. standard." Note the contradiction to this statement above.

2 To the author, Tm presented the greatest difficulty of any element in locating any source whatsoever.

3 Spec. analysis done by the U.C.R.L. spectroscopic analyst confirms the supplier's stated purity. The principal impurity is erbium. This is an exceptionally pure sample considering the rarity and difficulty of preparing this sample. The sample was presumably prepared by an American manufacturing chemist for this company.

4 An order was placed with this company in Feb. 1947 at which time this company stated that "Further supply is in preparation." To date (5/24/48) the order remains unfilled. This is a fair indication of difficulty involved in isolating this element.

I ELEMENT	II PURITY (a)	(b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
86. **THULIUM** (contd.) **Metal**	The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known.					
87. **TIN**	1.(Sn)		2.(50)	3.(Com.Met.)	4.(m x 10^{-6}%)	5.(39th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Chloride $SnCl_2$	(C)	99.99	D.S.	Fine crystals	$0.70gm	Johnson, Matthey & Co., Ltd.
2) Oxide SnO_2	(C)	99.99	D.S.	" "	$0.70/gm	" " " "
Metal						
1) Rods	(C)	99.994	D.S.	Supplied as rods 7mm diam. x 15 cm long	$1.80/rod	" " " "
2) Ingot	(C)	99.994+	Typ. D.S.	Supplied in ingots 5/8" x 5/8" x 3½" as spectrographic standards in og quantities.	$15/og	Vulcan Detinning Co.
3) Ingot	(C)	99.994	D.C.	Supplied in ingots 1¼" x 1½" x 4" in less pure material in lb. quantities. (Metal is quite soft, malleable, and ductile though quite crystalline in character. Readily worked into most forms desired.)	$0.73/lb	" " "
Other Sources						
1) Metal Foil	Per:		U.C.R.L. Chemical Research Files			National Lead Company[1]
2) " "			" " " "			Reynolds Metals Co.[2]
88. **TITANIUM**	1.(Ti)		2.(22)	3.(Com.Met.)	4.(0.63%)	5.(9th)
Compounds	This element, although common (9th most abundant) is limited in availability in pure form because of the difficulty of preparation and purification.					

1 Sample was kindly supplied by the company without charge, representing some of their purest commercially available metal.

2 Idem.

I ELEMENT	(a)	II PURITY	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
88 **TITANIUM** (Contd.)						
1) Hydride TiH_2	(E)	99.94d	G.C.	Supplied as finely divided 200 mesh powder inside a vacuum tin, available in lb. quants.	$12/lb.	Charles Hardy, Inc.
2) Oxide TiO_2	(E)	98	D.S.	Fine crystals	$1.20/lb.	Johnson, Matthey & Co., Ltd.
Metal a) Ingot and Sponge	(C)	99.5+	G.C.	Supplied in lumps, sponge form and ingots up to 100#	$7.50/lb	E. I. Du Pont de Nemours Co.
1) Wire	(E)	98+	D.S.	Supplied in wire 3mm diam. in lengths desired.	(------)[1]	Johnson, Matthey & Co., Ltd.
2) Powder	(E)	98	G.C.	Supplied as finely divided powder in lb. quants.	$8/lb.	Metal Hydrides, Inc.
3) Lump	(E)	97	G.C.	Supplied as irregular lump in lb. quants.	$10/gm	" " "
4) Sticks	(E)	95-99	None	Supplied in sticks ½" diam. x 3½" long in og quants. (Metal is extremely difficult to prepare because of very high melting point and ease with which it combines with O_2 and N_2 in the air, with H_2 and C used in preparing it, or with the vessels in which it is prepared. Metal may be drawn or forged only when extremely pure; otherwise is hard, extremely brittle. Must be cast into forms desired. No source is known for higher purities than indicated.)	$75/lb.	A. D. Mackay
89 **TUNGSTEN**	1.(W)		2.(74)	3(Com.Met.)	4.(5×10^{-5}%)	5.(26th)
Compounds	The same general information applies here as is given for aluminum compounds.					
1) Oxide WO_3	(C)	99.99	D.S.	Fine crystals	$0.80/gm	Johnson, Matthey & Co., Ltd.

[1] This company's catalog #1760 of December 1947 states that "The Supply is in Preparation." Nitrogen, oxygen, vanadium, and iron are the principal impurities present.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
89 **TUNGSTEN**						
Metal						
1) Rod	(C)	99.99+	D.S.	Supplied in rod 4 mm diam. x 10 cm long.	$4/rod	Johnson, Matthey & Co., Ltd.[1]
2) Sheet	(C)	99.94 d	D.S.	Supplied in sheet .016" x 3" x 15" in lb. quants. (Metal available in fair quantity and high purity in several forms; e.g., wire, sheet, foil, rod. Workable with some difficulty and considerable "know how")	$27/lb.	General Electric Co., Cleveland Wire Works
Other Sources						
1) Compounds	(NC)	Per:		U.C.R.L. Inventory Dept. Files		Molybdenum Corporation of America
90 **URANIUM**	1.(U)		2.(92)	3.(Radio.)	4.(8 x 10^{-5}%)	5.(25th)
Compounds	This element, although reasonably abundant in nature, until recent atomic energy developments came along, had seldom been prepared in very pure form. Compounds are reasonably difficult to prepare and purify after the ores are concentrated. Because this element has been designated as a source of fissionable materials, regulations have recently been issued by the Atomic Energy Commission requiring the licensing of all U metal or U compounds held by individuals in quantities in excess of ten lbs.[2] Purities obtainable from Johnson, Matthey & Co, and the usual laboratory supply houses are well below that prepared by the A.E.C. laboratories, and at much higher than warranted prices (since this element is not the laboratory rarity is once was). For further information concerning the possibility of obtaining > 10 lbs. of very pure uranium compounds, contact the Director of Research or Production, A.E.C.					
1) Nitrate $UO_2(NO_3)_2$	(C)	99.9	D.S.	Fine crystals	$0.55/gm	Johnson, Matthey & Co., Ltd.
2) Oxide U_3O_8	(C)	99.9	D.S.	" "	$0.70/gm	" " " "

[1] Metal supplied by this company was originally prepared especially for them by the General Electric Co. The Johnson, Matthey Co. analyzes these batches chemically and spectrographically; then repackages and distributes them under their label "Spec Pure." The analysis states that the only impurity is a trace of molybdenum.

[2] See Pike and Fischer (Legal Service) Atomic Energy Regulation for the current status of this ~~regulation~~ ruling.

I ELEMENT	II (a)	PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
90 **URANIUM** (Contd.)						
Metal	Prior to the war, this element in metallic form was a laboratory curiosity. Now large quantities of extremely pure metal have been prepared by the Atomic Energy Commission subcontractors. The metal, though workable with difficulty, has been prepared in many different physical forms. (See preceding paragraph concerning the compounds in regard to the licensing requirements.) For further information concerning the possibility of obtaining >10 lbs. of pure uranium metal, contact the Director of Research or Production, A.E.C.					
1) Rod	(C)	99.9+	D.S.	Supplied in rod 2 mm diam. x 16 mm (approx. 1 gm)	$3.30/gm	Johnson, Matthey & Co., Ltd.
Other Sources						
1) Compounds and Metal	"	Pure	U.C.	Dept. of Chem. - Storeroom Files		City Chemical Co.
2) "	"		"	" " "	"	Foote Mineral Co.
3) "	"		"	" " "	"	A. D. Mackay
91 **VANADIUM**	1.(V)		2.(23)	3.(Com. Met.)	4.(1.7×10^{-4}%)	5.(22nd)
Compounds	This element, although reasonably common (22nd most abundant) is limited in availability in pure form because of the difficulty of preparation and purification.					
1) Ammon NH_4VO_3 Metavanadate	(E)	98	D.S.	Fine crystals	$0.65/gm	Johnson, Matthey & Co., Ltd.[1]
2) Oxide V_2O_5	(E)	98	D.S.	" "	$0.35/gm	" " " "
Metal						
1) Pellets	(C)	99.8	G.C.	Supplied in pellets ~ 3 mm diam.	$4/gm	Vanadium Corporation of Am.[2]
2) Lumps	(E)	95	None	Supplied in irregular crystalline lumps	$6/lb	A. D. Mackay

[1] This company does not prepare the metallic form.

[2] This sample was from some very special laboratory runs and represents probably the purest vanadium made commercially. Quantity is strictly limited.

I ELEMENTS	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
91. **VANADIUM** (Contd.)				(Metal is extremely difficult to pre- free from gas and impurities. High melting point. Has been prepared >98% by very few research workers. When extremely pure, metal is capable of being worked into wire or sheet. Usually hard, brittle; must be cast into forms desired. No source is known for pure metal in large quantities.)		
92. **XENON**	1.(Xe)		2.(54)	3.(R.Gas)	4.(not in the earth's crust)[1]	5.(—)
Gas 1) Spec. Pure	(C)	99.994	G.X.	Put up in 1 liter sealed glass bulbs. < 5 ppm total impurities.	$103/1	General Electric Co., Cleveland Wire Works
93. **YTTERBIUM**	1.(Yb)		2.(70)	3.(R.E.)	4a.(1.5×10^{-4}%) b.(7%)	5a.(23rd) b.(6th)
Compounds	The same general information applies here as for dysprosium compounds and its footnote (1). Though this element comprises 7% of the rare earth group, its availability is limited because of the difficulty of its chemical separation. Limited amounts of Yb_2O_3 have been prepared by certain of the A.E.C. subcontractors. At present this material is available only to A.E.C. research groups.					
1) Oxide Yb_2O_3	(E)	99+4	D.S.	Fine crystals	$200/gm	Johnson, Matthey & Co., Ltd.[2]

1 The price per liter of each rare gas is a close approximation to its relative abundance in the atmosphere. No compounds of this gas are known to exist. All the rare gases are chemically inert; i.e., they do not combine with any other element.

2 This company prepares the following compounds upon request: acetate, chloride, nitrate, oxide, and sulphate. They do not prepare the metal.

I ELEMENT	II (a) PURITY (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
93. **YTTERBIUM** (Contd.)				
Metal	The metal has been prepared by the discoverer or co-workers in minute quantities, but no current source of the metal is known.			
94. **YTTRIUM**	1.(Y)	2.(39)	3.(R.E.)[1]	4a.(1.5×10^{-4}%) b.(~7%) 5a.(23rd) b.(~3rd)
Compounds	The availability of this element is rather limited because of the lack of commercial uses and its low abundance. Somewhat easier to separate and purify than most rare earths once the ores are concentrated.			
1) Oxide Y_2O_3	(E) 99++ D.S.	Fine crystals	$33/gm	Johnson, Matthey & Co., Ltd.[2]
2) Nitrate $Y(NO_3)_3$	(E) 95-99 None	" "	$0.75/gm	A.D. Mackay
3) Oxide Y_2O_3	(E) 85 None	" "	Est.$0.30/gm Recs. Lost	Fairmount Chemical Co.
4) " "	(E) 65[3] None	" "	$0.50/gm	City Chemical Co.
Metal	Metal is rarely available, principally because it has practically no commercial uses. Metal is hard; has a high melting point; difficult to work. No source is known for other than its powder form.			
1) Powder	(E) 95 None	Supplied as finely divided powder in a 5 gm lot.	$5/gm	Fordomes Trading Co.
Other Sources 1) Compounds	Per:	U.C. Dept. of Chem. Storeroom Files		Foote Mineral Co.
95. **ZINC**	1.(Zn)	2.(30)	3.(Com.Met.)	4.($n \times 10^{-5}$%) 5.(28th)
Compounds	The same general information applies here as is given for aluminum compounds.			

1 Actually, this element is a rarer metallic element; but for simplicity of treatment it is classified here as a rare earth, because its occurence and behavior are so similar to the rare earths.
2 This company prepares the following compounds upon request: acetate, chloride, nitrate, oxide, and sulphate. They do not prepare the metal.
3 This value was reported by the project analyst.

I ELEMENT	(a)	II PURITY (b-%)	(c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
95. ZINC (Contd)						
1) Oxide ZnO	(C)	99.999	D.S.	Fine crystals	$0.80/gm	Johnson, Matthey & Co., Ltd.
2) Sulphate $ZnSO_4$	(C)	99.999	D.S.	" "	$0.40/gm	" " "
Metal						
1) Rod	(C)	99.999+	D.S.	Supplied in rods 7 mm diam x 10 cm long	$4.25/rod	" " "
2) Crystals	(C)	99.999+	G.C. and G.S.	Supplied as a large crystalline aggregate in cg quantities--a spec.standard.	$20/lb.	New Jersey Zinc Co. (of Pa.)
3) Rod	(C)	99.99+	G.C. and G.S.	Supplied in rods ¼" diam. x 8" long in cg quants. (Metal is soft, somewhat malleable, though quite crystalline in character. Can be worked or cast into most forms desired.)	Est. $10/lb[1]	" "

96. ZIRCONIUM 1.(Zr) 2.(40) 3.(Com.Met.) 4.(0.026%) 5.(19th)

Compounds The same general information applies here as is given for aluminum compounds, except that fewer zirconium compounds are available above reagent grade purity.

1)Nitrate $Zr(NO_3)_4$	(C)	99.99	D.S.	Fine crystals	$0.70/gm	Johnson,Matthey & Co.,Ltd.
2)Oxide ZrO_2	(C)	99.99	D.S.	Fine crystals	$1.30/gm	Jarrell-Ash Co.[2]
Metal						
1) Rods	(C)	99.99+	D.S.	Supplied in rods 3mm diam in lengths as desired (1.4gm/inch)	$2.50/gm	Johnson,Matthey & Co.,Ltd. Jarrell-Ash Co.[3]
2) Foil	(C)	99.6	D.S.	Supplied in foils .001-.010" x 3" x 6" (Can be supplied up to 3/16" thick)	$.09-.42/sq in	Foote Mineral Co.

1 Price (for larger quantities) is estimated because the small sample (½ lb.) received by the author was kindly sent by this company without charge.

2 This company is the only authorized American representative of the British Johnson,Matthey & Co. to supply this company's "Spec.Pure" compounds.

3 Idem.

I ELEMENT	II (A) PURITY (b-%) (c)	III PHYSICAL FORM	IV PRICE	V SOURCE OF SUPPLY
96 **ZIRCONIUM** (Contd.)				
		(Metal is soft, malleable and easily worked into most any form desired. Available in cg quantities in high (99.6%) purity.)		
Other Sources				
1) Compounds - ZrN Perz	U.C.R.L. Inventory Files			Metal Hydrides, Inc.
2) Compounds and Metal	"	"	"	Pfaltz-Bauer, Inc.
3) Compounds	"	"	"	Rohn and Haas
4) "	"	"	"	Titanium Alloy Mfg. Co.
5) "				Chemical Commerce Co.

APPENDIXES

APPENDIX A

ADDRESSES OF SOURCES OF SUPPLY

Air Reduction Sales Co. — A, O
Lincoln Bldg.
42d St. oppos. Grand Central
New York 17, N. Y.

Aluminum Company of America — Al, Mg
801 Gulf Bldg.
Pittsburgh 19, Pa.

American Platinum Works — Ir, Os, Pd, Pt, Rh, Ru
1026 Oliver Street
Newark, N. J.

American Smelting and Refining Co. — Sb, Bi, Cu, Pb, Tl
Barber Stn.
Perth Amboy, N. J.

Armour Research Foundation
See: National Registry of Rare Chemicals

Atomic Energy Commission — Ac, Am, At, Be, C, Ce, Cm, Fr, Np, Pu
The United States
Director of Research
1901 Constitution Ave, NW
Washington 25, D. C.
also: Isotopes Branch
U.S. Atomic Energy Comm.
P.O. Box E
Oak Ridge, Tennessee

Po, Pm, Pa, Tc, Th, U Possibly all Rare Earths, Particularly: Ce, Gd, La, Nd, Pr, Sm, Yb

Baker and Co. Inc. — Au, Pd, Ru
113 Astor St.
Newark 5, N. J.

Belmont Smelting Refining Works, Inc. — Bi, Cd, Co, Mn
330 Belmont Ave.
Brooklyn 7, N. Y.

Berk, F.W. and Co. Inc. — Hg
Wood Ridge Division
Wood Ridge, N. J.

Brush Beryllium Co. — Be
3714 Chester Ave.
Cleveland, Ohio

Canadian Radium and Uranium Corp. — Ac, Po, Pa, Ra, Rn
630 - 5th Ave.
New York City, N. Y.

Cerium Metals Corp. — Ce, La, Pr, Nd, Sm, Il
522 - 5th Ave.
New York City, N. Y.

Chematar Inc. — Ga
40 Exchange Place
New York City, N. Y.

Chemical Commerce Co. — Hf, Zr
470 Avon Ave., Newark, N.J.

City Chemical Corp. — Be, B, Cs, Er, Ga, Ge, In, Ir, La, Nd, Se, Te, U, Y
132 W. 22d St.
New York City, N.Y.

Cooper Metallurgical Laboratory, Division of Acme Aluminum Alloys, Inc. — Be, Ce, La, Nd, Pr
2135 Columbus Rd.
Cleveland 13, Ohio

DeRewal, F. J. — Hf
846 N. Orlanra St.
Philadelphia, Pa.

Dupont, E.J. de Nemours Co. Ti
Pigments Dept., Wilmington, Dela.

Driver-Harris Co. Ni
P.O. Drawer 31
Harrison, N. J.

Dupont E.J. de Nemours Co.
Pigments Dept. Wilmington 98, Dela. Ti

Dow Chemical Co. Mg
Magnesium Division
Midland, Michigan

Eagle Pichler Co. Ge
Joplin, Missouri

Eastman Kodak Co. I
Chemical and Organic Cl
Sales Dept.
Rochester, N. Y.

Eimer and Amend Er
633-35 Greenwich
New York 14, N. Y.

Electro-Metallurgical Co. Si
Carbide and Carbon Bldg.
30 East 42d Street
New York 17, N. Y.

Fairmount Chemical Co. B,Ge
136 Liberty St. La,Nd
New York City, N. Y. Y

Fansteel Metallurgical Cb,Ta
Corp. Mo
2200 Sheridan Rd.
North Chicago, Ill.

Fogg, Dr. H. C. Almost
Dept. of Chemistry all
Univ. of New Hampshire Rare
Durham, New Hampshire Earths

Foote Mineral Co.Inc. Be,Ce
10 East Chelton Ave. Cs,Ga
Philadelphia 44, Pa. Hf,In
Rb,Se,Si,Th,U,Y,Zr La,Nd

Fordomes Trading Co. As,Gd
21 Lafayette Place Nd,Pr
Arlington, N.J. Sc,Tm,Y

General Chemical Co. F
40 Rector St.
New York 6, N. Y.

General Electric Co. A,Ca
Lamp Department He,Kr
Cleveland Wire Wks. Ne,N
1331 Chardon Road W,Xe
Euclid, Ohio Mo

Goldsmith Bros.Smelt- Au,Os
ing & Refining Co.
74 West 46th Street
New York City, N. Y.

Griffin Chemical Co. Br,I
1000 - 16th Street
San Francisco, Calif.

Hammer Laboratories Ra
624 Monaco Blvd.
Denver, Colorado

Handy & Harman Ag
82 Fulton Street
New York City, N. Y.

Hanovia Chemical and Au
Mfg. Co.
Chestnut and RR Aves.
Newark, N. J.

Hardy, Charles, Inc. Ce,Nd
420 Lexington Ave. Na,Ti
New York 17, N. Y.

Harshaw Chemical Co. F
1945 E. 97th St. AgCl
Cleveland 6, Ohio Crystals

Indium Corp. of America In
1676 Lincoln Ave.
Utica, N. Y.

International Nickel Co.Inc. Ni
Research Laboratory
P.O.Box U-Bergen Point Stn.
Bayonne, N. J.

James, Dr. M.F.(deceased) Almost all Rare Earths
Dept. of Chemistry
Univ. of New Hampshire
Durham, N. H.

Jarrell-Ash Co. Pd Zr
165 Newbury St.
Boston 16, Mass.

Johnson,Matthey & Co. Al,Sb, As,Ba Be,Bi
73-83 Hatton Garden
London E.C.1,England

B,Cd,Ca,C,Ce,Cs,Cr,Co,Cb,
Cu,Dy,Er,Eu,Gd,Ga,Ge,Au.
Hf,Ha,Ln,Ir,Fe,La,Pb,Li,
Lu,Mg,Mn,Hg,Nd,Ni,Os,Pd.
K,Pr,Re,Rh,Rb,Ru,Sm,Sc,
Se,Si,Ag,Sr,Ta,Te,Tb,Tl,
Th,Tm,Sn,Ti,W,U,V,Yb,Y,
Zn,Zr,Mo

Kemet Laboratory Co. Ba Sr
Madison Ave. & W.117th St.
P.O.Box 6087
Cleveland 1, Ohio

Lee, Mr. O. Ivan Sc
2684 Boulevard St.
Jersey City, N. J.

Linde Air Products Co. A
114 Sansome St.
San Francisco 4, Calif.

Lindsay Light and Chemical Co. Ce La Nd
258 Ann St.
West Chicago, Ill.

Mackay, A. D. Sb,As,Bi Ca,Cs Cr,Co
198 Broadway
New York City, N.Y.

Er,Ga,Ge,Hf,In,Li,Ir,K
Rb,Se,Te,Ti,U,V,Y

Mallinckrodt Chemical Works Fe
2nd & Mallinckrodt Sts.
St. Louis,Mo.

Marsh, Dr. J. K. Almost all Rare Earths
Dept. of Chemistry
Oxford University
London, England

The Matheson Company H
East Rutherford
New Jersey

Maywood Chemical Works Ce,Cs Li,Pr
Maywood, N. J.

McCoy, Dr. H.N.(deceased) Almost all Rare Earths
Lindsay Light and Chem.Co.
258 Ann Street
West Chicago, Illinois

Melaven, Prof.A.D. Re
Dept. of Chemistry
Univ. of Tennessee
Knoxville, Tenn.

Metal Hydrides, Inc. Ti,Zr N
12-24 Congress St.
Beverly, Mass.

Metallurgical Products Co. Mn
35th & Moore Sts.
Philadelphia, Pa.

Metals Disintegrating Co. 1170 Arthur Blvd. Elizabeth, N. J.	Cr
Molybdenum Corp. of America 3005 Grant Bldg. Pittsburgh, Pa.	W C
National Bureau of Stds. U.S. Dept. of Commerce Washington, D. C.	As_2O_3 Many Rare Earths
National Carbon Co. Inc. 30 East 42d St. New York City, N. Y.	C
National Lead Co. 111 Broadway New York City, N. Y.	Sn
National Registry of Rare Chamicals M.H. Heeren, Director Armour Research Foundation Illinois Inst. of Technology 33d, Federal and Dearborn Sts. Chicago, Illinois Authoritative information on sources of hard to locate materials.	
National Research Corp. 100 Brookline Ave. Boston 15, Mass.	Al, Cr Cu, Fe Mn, Ni
National Spectrographic Labs. 6300 Euclid Ave. Cleveland 3, Ohio	Pd
New Jersey Zinc Co. (of Pa) Carbon County Palmerton, Pa.	Cd Zn
Norton Company 50 Newbond St. Worchester, Mass.	
Ohio Chemical Company 1400 E. Washington Ave. Madison, Wis.	A
Pacific Coast Boarx Co. 510 W. 6th St. Los Angeles, Calif.	B
Permanente Metals Corp. Permanente, Calif.	Mg
Pfaltz and Bauer, Inc. 330 - 5th Ave Empire State Bldg. New York City 1, N. Y.	Ce La Zr
Plastic Metals, Inc. 113 Bridge St. Johnstown, Pa.	Fe
Prandtl, Dr. Wilhelm Univ. of Munich Munich, Germany	Almost all Rare Earths
Radium Chemical Co. 1 East 42nd St. New York City, N. Y.	Ac, Po Pa, Ra Rn
Research Chemicals Laboratories 831 No. Lake St. Burbank, Calif.	Gd Nd Pr Sm

Reynolds Metals Co. Al
Reynolds Metals Bldg. Sn
Richmond 19, Va.

Rohm and Haas Company Zr
Washington Square
Philadelphia, Pa

Rolla, Dr. Luigi Almost
Dept. of Chemistry all
Royal University Rare
Genoa, Italy Earths

Segré, Dr. Emilio At
Dept. of Physics
Univ. of California
Berkeley 4, Calif.

Spedding, Dr. F. N. Rare
Dept. of Chemistry Earths
Iowa State College
Ames, Iowa

Smith, The G. Frederick Ce
Chemical Company
P.O.Box 2611, Station D
867 McKinley Ave.
Columbus, Ohio

Smith, Thorn Company Fe
1847 No. Main St.
Royal Oak, Michigan

Stauffer Chemical Co. B
636 California St. S
San Francisco 8, Calif.

Tennessee Valley Authority P
Chemical Engineering Dept.
Wilson Dam, Alabama

Texas Gulf Sulphur Co. S
Wharton County
New Gulf, Texas

Titanium Alloys Mfg. Co. Zr
Box C, Bridge Stn.
1940 Sugar St.
Niagara Falls, N. Y.

Vanadium Corp. of America V
430 Lexington Ave.
New York City 17, N. Y.

Var-Lac-Oid Chemical Co. Pa
116 Broad Street Ga
New York City 4, N. Y. Ge

Vulcan Detinning Co. Sn
Sewaren,
New Jersey

Westinghouse Research Th
Laboratory
Bloomfield, New Jersey

Westvaco Chlorine Br
Products Corp.
405 Lexington Ave.
New York 17, N. Y.

White, S.W., Dental Mfg. Au
Company
10 East 40th St.
New York City 16, N. Y.

Wildberg Bros. Smelting Ir
and Refining Co. Pd
742 Market St. Pt
San Francisco, Calif.

APPENDIX B

INTERNATIONAL ATOMIC WEIGHTS - 1940
(Arranged by Symbol)

SYMBOL	NAME OF ELEMENT	AT. NO.	ATOMIC WEIGHT	SYMBOL	NAME OF ELEMENT	AT. NO.	ATOMIC WEIGHT
A	Argon	18	39.944	Mn	Manganese	25	54.93
(Ab)	Alabamine, see At			Mo	Molybdenum	42	95.95
Ac	Actinium	89	(227)	N	Nitrogen	7	14.008
Ag[1]	Silver	47	107.880	Na[7]	Sodium	11	22.997
Al	Aluminum	13	26.97	Nd	Neodymium	60	144.27
Am	Americium	95	-----	Ne	Neon	10	20.183
As	Arsenic	33	74.91	Ni	Nickel	28	58.69
At	Astatine	85	(221)	Np	Neptunium	93	-----
Au[2]	Gold	79	197.2	O	Oxygen	8	16.0000
B	Boron	55	10.82	Os	Osmium	76	190.2
Ba	Barium	56	137.36	P	Phosphorus	15	30.98
Be	Beryllium	4	9.02	Pa	Protactinium	91	231
Bi	Bismuth	83	209.00	Pb[8]	Lead	82	207.21
Br	Bromine	35	79.916	Pd	Palladium	46	106.7
C	Carbon	6	12.010	Pm	Promethium	61	(146)
Cb	Columbium	41	92.91	Po	Polonium	84	(210)
Ca	Calcium	20	40.08	Pr	Praseodymium	59	140.92
Cd	Cadmium	48	112.41	Pt	Platinum	78	195.23
Ce	Cerium	58	140.13	Pu	Plutonium	94	-----
Cl	Chlorine	17	35.457	Ra	Radium	88	226.05
Cm	Curium	96	-----	Rb	Rubidium	37	85.48
Co	Cobalt	27	58.94	Re	Rhenium	75	186.31
Cr	Chromium	24	52.01	Rh	Rhodium	45	102.91
Cs	Cesium	55	132.91	Rn	Radon	86	222
Cu[3]	Copper	29	63.57	Ru	Ruthenium	44	101.7
Dy	Dysprosium	66	162.46	S	Sulphur	16	32.06
Er	Erbium	68	167.2	Sb[9]	Antimony	51	121.76
Eu	Europium	63	152.0	Sc	Scandium	21	45.10
F	Fluorine	9	19.00	Se	Selenium	34	78.96
Fa	Francium	87	(224)	Si	Silicon	14	28.06
Fe[4]	Iron	26	55.85	Sm	Samarium	62	150.43
Ga	Gallium	31	69.72	Sn[10]	Tin	50	118.70
Ge	Germanium	32	72.60	Sr	Strontium	38	87.63
Gd	Gadolinium	64	156.9	Ta	Tantalum	73	180.88
H	Hydrogen	1	1.0080	Tb	Terbium	65	159.2
He	Helium	2	4.003	Tc	Technetium	43	-----
Hf	Hafnium	72	178.6	Te	Tellurium	52	127.61
Hg[5]	Mercury	80	200.61	Th	Thorium	90	232.12
Ho	Holmium	67	163.5	Ti	Titanium	22	47.90
I	Iodine	53	126.92	Tl	Thallium	81	204.39
(Il)	Illinium, see Pm			Tm	Thulium	69	169.4
In	Indium	49	114.76	U	Uranium	92	238.07
Ir	Iridium	77	193.1	V	Vanadium	23	50.95
K[6]	Potassium	19	39.096	(Vi)	Virginium, see Fa		
Kr	Krypton	36	83.7	W[11]	Tungsten	74	183.92
La	Lanthanum	57	138.92	Xe	Xenon	54	131.3
Li	Lithium	3	6.940	Y	Yttrium	39	88.92
Lu	Lutecium	71	174.99	Yb	Ytterbium	70	173.04
(Ma)	Masurium, see Tc			Zn	Zinc	30	65.38
Mg	Magnesium	12	24.32	Zr	Zirconium	40	91.22

Derived from:
1 L. argentum
2
3 L. cuprum
4 L. ferrum
5
6 L. kalium
7 L. natrium
8
9 L. stibium
10 L. stannum
11

APPENDIX C

ABUNDANCE AND RANK OF ELEMENTS IN THE EARTH'S CRUST

"The Average Elementary Composition of Igneous Rocks"[1,2,3,4]

RANK	ELEMENT	PERCENT	RANK	ELEMENT	PERCENT
1	Oxygen	46.59	31	Thorium	2×10^{-5}
2	Silicon	27.72	32	Lead	2×10^{-5}
3	Aluminum	8.13	33	Cobalt	1×10^{-5}
4	Iron	5.01	34	Boron	1×10^{-5}
5	Calcium	3.63	35	Beryllium	1×10^{-5}
6	Sodium	2.85	36	Molybdenum	$n \times 10^{-6}$
7	Potassium	2.60	37	Rubidium	$n \times 10^{-6}$
8	Magnesium	2.09	38	Arsenic	$n \times 10^{-6}$
9	Titanium	0.63	39	Tin	$n \times 10^{-6}$
10	Phosphorus	0.13	40	Bromine	$n \times 10^{-6}$
11	Hydrogen	0.13	41	Cesium	$n \times 10^{-7}$
12	Manganese	0.10	42	Scandium	$n \times 10^{-7}$
13	Sulphur	0.052	43	Antimony	$n \times 10^{-7}$
14	Barium	0.050	44	Cadmium	$n \times 10^{-7}$
15	Chlorine	0.048	45	Mercury	$n \times 10^{-7}$
16	Chromium	0.037	46	Iodine	$n \times 10^{-7}$
17	Carbon	0.032	47	Bismuth	$n \times 10^{-8}$
18	Fluorine	0.030	48	Silver	$n \times 10^{-8}$
19	Zirconium	0.026	49	Selenium	$n \times 10^{-8}$
20	Nickel	0.020	50	Platinum	$n \times 10^{-9}$
	Nitrogen	3.3×10^{-4}	51	Tellurium	$n \times 10^{-9}$
21	Strontium	1.9×10^{-4}	52	Gold	$n \times 10^{-9}$
22	Vanadium	1.7×10^{-4}	53	Iridium	$n \times 10^{-10}$
	Cerium		54	Osmium	$n \times 10^{-10}$
23	Yttrium and Rare Earths	1.5×10^{-4}	55	Thallium	$n \times 10^{-10}$
			56	Indium	$n \times 10^{-11}$
			57	Gallium	$n \times 10^{-11}$
24	Copper	1.0×10^{-4}	58	Rhodium	$n \times 10^{-11}$
25	Uranium	8×10^{-5}	59	Palladium	$n \times 10^{-11}$
26	Tungsten	5×10^{-5}	60	Ruthenium	$n \times 10^{-11}$
27	Lithium	4×10^{-5}	61	Germanium	$n \times 10^{-11}$
28	Zinc	4×10^{-5}		Rhenium	9×10^{-11}
29	Columbium and Tantalum	3×10^{-5}	62	Radium	$n \times 10^{-12}$
30	Hafnium	3×10^{-5}			

[1] F. W. Clarke and H. S. Washington, The Composition of the Earth's Crust, U.S. Geological Survey, Professional Paper 127 (Washington, D.C.: Government Printing Office, 1924), Table 11, pp. 20-21.

[2] See also J. S. Anderson, "Chemistry of the Earth," Journal and Proceedings of the Royal Society of New South Wales, 76, 329-45, 1943.

[3] Wolfgang Riesler, "Ein Fuhrung in die Kernphysik," (Meyers Kleine Handbucher, No. 6) Bibliographisches Institut, Leipzig, 1944, p. 206.

[4] Georg Von Hevesey, Chemical Analyses by X-rays and its Application, New York: McGraw-Hill, 1932, Chapter III, pp. 255 ff. and Table LVII, pp. 277 ff.

APPENDIX D

RELATIVE ABUNDANCE AND RANK OF THE ELEMENTS OF THE RARE EARTH GROUP[1,2]			
RANK[3]	RARE EARTH ELEMENT	SYMBOL AND ATOMIC NO.	PERCENT OF GROUP[5]
1	Cerium	$_{58}Ce$	31%
2	Neodymium	$_{60}Nd$	18%
3	Lanthanum	$_{57}La$	7%
-	Yttrium[4]	$_{39}Y$	-
4	Samarium	$_{62}Sm$	7%
5	Gadolinium	$_{64}Gd$	7%
6	Ytterbium	$_{70}Yb$	7%
7	Dysprosium	$_{66}Dy$	7%
8	Erbium	$_{68}Er$	6%
9	Praseodymium	$_{59}Pr$	5%
10	Lutecium	$_{71}Lu$	1.5%
11	Holmium	$_{67}Ho$	1%
12	Thulium	$_{69}Tm$	1%
13	Terbium	$_{65}Tb$	1%
14	Europium	$_{63}Eu$	0.2%
15	Promethium[5]	$_{61}Pm$	-

1 Data rearranged and taken from D. M. Yost, H. Russell, and C. S. Garner, The Rare Earth Elements and their Compounds (New York: John Wiley & Sons, 1947), p. 40.

2 See also Georg von Hevesy, Chemical Analysis by X-Rays and its Applications, (New York: McGraw Hill, 1932) Chapt. III, pp. 255ff and Table I, pp. 264.

3 Elements with the same "Percent of Group" are listed in order of rank suggested in B. S. Hopkins, Chapters in the Chemistry of the Less Familiar Elements, (Champaign, Illinois: Stipes Publishing Co., 1939), pp. 12, 20.

4 Yttrium, which occurs in nature along with the rare earths, though not a member of this group, is listed here to indicate that its abundance is comparable to that of lanthanum.

5 This element probably does not exist in nature because of its very short half-life.

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