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# THE DEVELOPMENT OF THE LITERATURE OF THE TRANSPLUTONIUM ELEMENTS[1]

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## ABSTRACT

The development of the literature of the transplutonium elements has been rapid and serves to illustrate many of the problems of conventional information handling. Nearly 5,800 articles, books, reports, patents, etc. that related directly to these elements have been abstracted in *Chemical Abstracts* (CA) and *Nuclear Science Abstracts* (NSA) during the period 1937 through 1968. The purposes of this paper are to trace the growth of the literature of the transplutonium elements and to compare the overlap of the abstracting between CA and NSA. The subject indexes of CA and NSA were searched for all references to the transplutonium elements. The references were categorized into four board areas based on the subjects of the original articles and also whether they appeared in journals or other sources. Results of the study indicated that there was a 37% overlay in abstracting between CA and NSA. About 47% of the literature items have appeared in primary journals and 53% in reports, patents, books, theses, etc. Approximately 55% of the items related to the properties of the elements, 40% to technology and about 5% to health and safety and applications of the elements. The growth of the literature of the transplutonium has paralleled the growth of the literature of plutonium.

## INTRODUCTION

The conclusion of World War II and the easing of war time security brought forth the announcement of the preparation of the first transplutonium elements (Seaborg, 1946). Prior to this announcement, fourteen papers were indexed in *Chemical Abstracts* between 1937 and 1945, which discussed the possible preparation and predicted the properties of these elements. During the period from 1944 through 1962, a total of nine elements were discovered, which completed the actinide series of elements. These elements are being constantly investigated and the number of articles, reports, etc., appearing in the literature are increasing at a rapid rate. The purposes of this study were to trace the growth of the literature of the transplutonium elements in terms of interest to users of the literature and to compare the overlap of abstracting between *Chemical Abstracts* and *Nuclear Science Abstracts.*

## DATA COLLECTION

In order to make a comprehensive survey of the literature of the transplutonium elements, numerous abstract sources should be consulted and duplications eliminated by cross-checking. The following primary abstracts should be searched: *Chemical Abstracts, Nuclear Science Abstracts, Abstracts of Classified Reports, Metallurgical Abstracts, Technical Abstracts Bulletin, U. S. Government Research Reports,* and others. A complete study of all sources by normal search methods was impractical and would have consumed too much time. Also some sources, such as *Abstracts of Classified Reports,* were not generally available. Therefore, the present study was based on two major sources, *Chemical Abstracts*(CA) and *Nuclear Science Abstracts*(NSA). These two publications were readily available and abstract a substantial portion of the literature pertinent to the problem.

In making the survey, the indexes of CA Volume 31(1937) through Volume 69(1968) were searched using the following major search terms: name of each transplutonium element, element number, transplutonium, transuranium and actinides (or appropriate variations). The indexes of Volume 1(1948) through Volume 22(1968) of NSA were searched using the same technique employed with CA.

Internal duplications of literature items were removed from the listings obtained from each abstract source, for each of the elements. Duplications among CA and NSA were also removed. However, an item may be listed for more than one element. For example; Kooi, Boden and Wijkstra (1964) published an article entitled, "Separation of Americium (Curium), Berkelium, and Californium by Extraction Chromatography," in which an extraction chromatography procedure is described for the separation of Americium, Curium, Berkelium and Californium. This reference was noted once under all four elements. However, the abstract appeared in both CA and NSA and was counted only once for each element in the net total number of items in the literature. Items were classified as "general" if they referred in broad terms to all of the transplutonium elements or if it was impossible to classify them under a specific element.

The year in which an item was first mentioned in an abstract was taken as the year of publication. This procedure introduced some inaccuracy in the results, since generally an article must be published before it can be abstracted. These inaccuracies were probably not serious since the true time between the publication of an article and the publication of the abstract in CA and NSA, currently is about three months. Many readers first learn of the publication of an article by reading about it in an abstract or locating it through a publication, such as, CA or NSA. In this sense, it might be considered that the information did not become generally available until the abstract was published.

Each reference to the literature was categorized as an item in a primary journal or in some other publication (report, patent, book, thesis, conference, report, proceedings of a meeting, etc.). This later category, for simplicity, was referred to as reports. Each literature item was also placed into one of four other categories in a scheme developed by Miner (1964). These categories included: properties, technology, health and safety, and applications. Many items could be classified into more than one area and for purposes of this study were categorized based upon their first listing in the index of the abstract sources. All items dealing with chemical and physical properties of the elements and their compounds were included under "properties." Items dealing with such topics as analytical methods, processing techniques, production and facilities were included under "technology;" while all items related to the uses of the elements, and their compounds and alloys were placed under the heading of "application." Items related to toxicity and handling of the elements and the relationship of the elements to plants and animals were categorized under "health and safety."

## RESULTS AND DISCUSSION

The first references to be made to the transplutonium elements, that are indexed in CA appeared in 1937.

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Abstracts of three papers appeared, that discussed the possible preparation and properties of the element that is now known as Curium. One of these papers also mentions the possible preparation and properties of the element Americium. Through 1941 a total of 14 references were cited in CA to the elements Americium and Curium. Because of war time security, no further mention was made of these elements in the scientific literature until 1946. In 1946, four articles were indexed in CA; two each related to the discovery and preparation of Americium and Curium. In 1947, abstracts of 14 articles appeared in CA, seven related to Americium and Curium, and seven that discussed the general field of the transplutonium elements. In 1948, 16 references were cited in CA that related to Americium, 13 related to Curium and one to the element that is now known as Berkelium (Bk was first produced in 1949). This general trend has continued, i. e., each new element has been mentioned in the scientific literature several years before its discovery. The net sum of the number of references cited in CA and NSA for the individual elements has increased from 14 at the end of 1945 to 5,798 through 1968.

The growth of the total number of references found in the literature that relate to the transplutonium elements for the period 1945 through 1968 is shown in Figure 1. Any point on this logarithmic curve represents the net cumulative total number of references cited in CA and NSA at that particular time and the steepness of the curve indicates the rapidity with which the literature was increasing during a given time. The curve shows three distinct segments, the first two representing five years growth in the literature and the third representing 13 years (1957-68). It is likely that the first two segments are not as meaningful in terms of rapidity of the growth of the literature as the third segment.

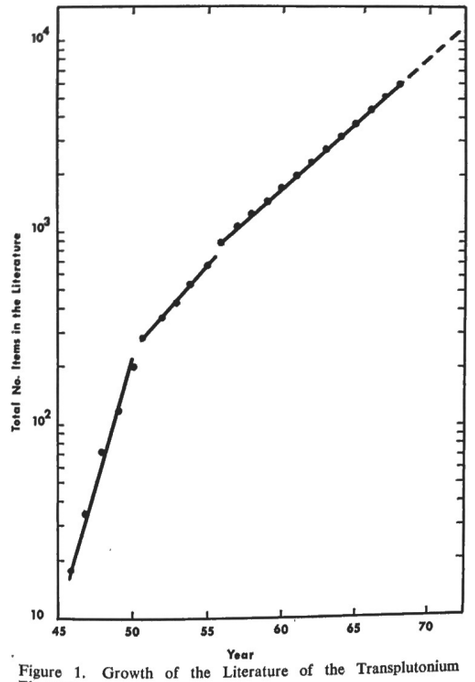


Figure 1. Growth of the Literature of the Transplutonium Elements.

Immediately following the war years, there was a very rapid growth in the literature of the transplutonium elements with the easing of war time security and also because of a renewed interest in basic research. The jump in the curve in 1950 may be attributed to the easing of security restrictions which in turn resulted in the publication of a number of articles based on formerly classified papers and reports. This jump in the curve is in evidence in the study of the development of the literature was not as rapid as during the previous period, again in evidence in the work of Miner (1964). A jump occurs in the number of articles appearing in the literature in 1955-1956 again due to external influences such as the First Geneva Conference in 1956.

The third segment of the curve (1956 through 1968) covers a 13 year period and appears to be the best fit of the three segments. If the trend indicated by this segment continues, it can be expected that the number of references in the literature will double about every four to five years. This means that through the year 1970 there will be about 7,700 references in the literature and over 16,000 by the end of 1975.

A comparison of the number and percentage of literature items placed in each of four categories (properties, technology, health and safety and applications) for each element is presented in Table 1. In addition, a comparison of the total number of items in each abstract source for the period 1937 through 1968 is shown in Table 1. An examination of the data indicated that an average of 58% and 51% of the items abstracted in CA and NSA, respectively, related to the properties of the elements. In comparison, 37% and 43% of the items in CA and NSA, respectively, were classified under technology. Only 5% of the articles abstracted in CA and 6% in NSA related to health and safety and to applications of these elements. Items related to health and safety and applications have appeared in the literature only for Americium, Curium and Californium. At present, there are only microgram quantities of the other transplutonium elements available and undoubtedly their health and safety factors and applications have not been fully investigated. Also it is likely that some of the papers classified under the "general" category related to health and safety and applications of all of the transplutonium elements.

The total number of references found in CA and NSA related to the transplutonium elements was 7,007. Of this number, 1,209 were found in both abstract sources. Therefore, the net total number of references was 5,798 with an overlap of 37%. The range of overlap was from 11% for the "General" category to 48%

TABLE 1. Comparisons of the Number of Items in Each Category for Each Element and of the Total Number of Items in Each Abstract Source for the Period 1937 Through 1968.

| | General N | % | Am N | % | Cm N | % | Bk N | % | Cf N | % | Es N | % | Fm N | % | Md N | % | No N | % | Lr N | % | Total N | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Abstracts** | | | | | | | | | | | | | | | | | | | | | | |
| Properties | 169 | 48 | 580 | 57 | 382 | 55 | 123 | 66 | 341 | 70 | 98 | 71 | 114 | 69 | 44 | 68 | 51 | 65 | 25 | 83 | 1927 | 58 |
| Technology | 162 | 47 | 341 | 34 | 267 | 38 | 62 | 34 | 129 | 26 | 41 | 29 | 51 | 31 | 21 | 32 | 28 | 35 | 5 | 17 | 1207 | 37 |
| Application | 2 | 1 | 49 | 5 | 26 | 4 | 0 | 0 | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 87 | 3 |
| H & S* | 14 | 4 | 41 | 4 | 19 | 3 | 0 | 0 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 83 | 2 |
| Total | 347 | | 1011 | | 694 | | 185 | | 489 | | 139 | | 165 | | 65 | | 79 | | 30 | | 3304 | |
| **Nuclear Science Abstracts** | | | | | | | | | | | | | | | | | | | | | | |
| Properties | 231 | 38 | 591 | 48 | 378 | 49 | 92 | 54 | 359 | 70 | 67 | 57 | 81 | 59 | 16 | 34 | 45 | 61 | 11 | 48 | 1871 | 51 |
| Technology | 342 | 55 | 525 | 42 | 320 | 41 | 79 | 46 | 134 | 26 | 50 | 43 | 57 | 41 | 31 | 66 | 29 | 39 | 12 | 52 | 1579 | 43 |
| Applications | 2 | 1 | 73 | 6 | 37 | 5 | 0 | 0 | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 123 | 3 |
| H & S* | 32 | 6 | 51 | 4 | 39 | 5 | 0 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 | 3 |
| Total | 607 | | 1240 | | 774 | | 171 | | 512 | | 117 | | 138 | | 47 | | 74 | | 23 | | 3703 | |
| **Summary of Totals** | | | | | | | | | | | | | | | | | | | | | | |
| Grand Total | 954 | | 2351 | | 1468 | | 356 | | 1001 | | 256 | | 303 | | 112 | | 153 | | 53 | | 7007 | |
| Less Overlap* | 38 | 11 | 485 | 48 | 292 | 42 | 64 | 37 | 190 | 39 | 44 | 38 | 51 | 37 | 15 | 32 | 25 | 34 | 5 | 22 | 1209 | 37 |
| Net Total | 916 | | 1866 | | 1176 | | 292 | | 811 | | 212 | | 252 | | 97 | | 128 | | 48 | | 5798 | |

* Health and Safety

** % Calculated on the bases of the smaller total number of references in CA or NSA

for the items related to Americium. In general, the longer an element has been known the more overlap between the two abstract sources. Journal articles accounted for 70% of the references in CA and 46% in NSA. Reports and other items accounted for 30% and 54%, respectively, of the references in CA and NSA. There was only a slight variation in these figures for each of the elements.

## Conclusions

This study has shown that the development of the literature of the transplutonium elements has been rapid, with a doubling of the literature every four to five years for the period 1956-1968. The development of the literature of the transplutonium elements has paralleled the development of the literature of plutonium. A total of 5,784 references appeared in the literature abstracted in CA and NSA during the first 25 years after the discovery of the first transplutonium element.

About 47% of the references to the transplutonium elements have appeared in a variety of primary journals. The remaining 54% of the literature items appeared in such publications as theses, reports, conference proceedings, etc. One of the most important problems associated with searching the literature of these elements is the confusion over material covered in reports and similar documents. The coding system for many of these items is extremely confusing and additional efforts must be made to clarify this situation.

The overlap between the two abstract sources is about 37%. For a conventional manual search of the literature for items related to the transplutonium elements, it is essential that both CA and NSA be searched thoroughly.

In order to cope with the increased volume, conventional methods of literature searching are becoming outmoded. Various groups are tackling the problems of dissemination of current information by more economical and rapid means. One of these groups is the Chemical Abstracts Service which has developed a number of chemically oriented computer data bases to meet the needs of scientists to remain current with the ever expanding literature. It is obvious that in the near future the traditional manual search of CA and NSA in the library stacks will be an insurmountable task. Information retrieval techniques such as computer based program searches will help improve this situation.

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