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# BIBLIOGRAPHY ON TRANSURANIUM ELEMENTS

*by*

D. D. SOOD
Fuel Chemistry Division

1991

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GOVERNMENT OF INDIA
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BHABHA ATOMIC RESEARCH CENTRE
BOMBAY, INDIA

1991

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# TRANSURANIUM ELEMENTS

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60 Abstract : A selective bibliography of prominent publications on transuranium elements is compiled. Heading papers, symposia proceedings and the textbooks are included in the bibliography. The bibliography is arranged under the headings : (1) Books, Symposia Proceedings, Reviews etc., (2) Discovery, (3) Weighable Isolation, (4) Metal Preparation, (5) Nuclear Properties, (6) Plutonium as Reactor Fuel, (7) Fuel Reprocessing, (8) Solid State Chemistry, Thermochemistry and Spectroscopy, (9) Radiation Safety, (10) Applications, and (11) Some Typical Indian Papers. Total number of references cited are 298. The bibliography, though selective, will serve as a starting point for comprehensive literature search on transuranium elements.

70 Keywords/Descriptors : TRANSURANIUM ELEMENTS; BIBLIOGRAPHIES; NUCLEAR PROPERTIES; NUCLEAR FUELS; REPROCESSING; RADIATION PROTECTION; SOLID STATE CHEMISTRY; SPECTROSCOPY; USES; HISTORICAL ASPECTS; METALLURGY

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## INTRODUCTION

In their quest for finding chemical reactions to convert baser metals into gold, the Alchemists laid a good foundation for chemical investigations but were not successful in their actual endeavour. The possibility of elemental transmutation through nuclear reactions was shown by Rutherford in 1919, ${}^{14}_{7}N(\alpha,p){}^{17}_{8}O$ but it was the discovery of artificial radioactivity in 1934 by Frederic and Irene Joliot-Curie which lead to a tremendous spurt in transmutation of elements by nuclear reactions.

Alpha particles from radium (isolated by Madam Curie from uranium) were the only projectiles available for these reactions but their energy was inadequate to cause transmutation in heavier nuclei because of the coulomb repulsion. Design and fabrication of accelerators to produce high energy projectiles therefore became an important activity in that period. Simultaneously, the potential of chargeless neutron, emitted from Ra/Rn - Be source was also tapped, particularly by the group of Enrico Fermi et al in Italy. Fermi also discovered that slowing down of neutrons increased the reaction probability several fold unlike the case of charged particles where higher energy was found more beneficial. After successfully preparing radioisotopes of many elements they thought of bombarding the heaviest element uranium. In the reaction product they found a bewildering array of $\beta^-$ emitting nuclides which could only mean the formation of several transuranium isotopes.The puzzle was solved by Hahn and Strassmann in 1938 when they attributed these activities to the products produced due to the neutron induced fission of uranium. A number of laboratories then switched their attention from the study of transmutation reactions to fission reaction. It was under these investigations that the discovery of first transuranium element was made by extremely keen observations by the experimentalists. McMillan and Abelson were studying the fission of uranium by cyclotron-produced neutrons in which the

... Kennedy and ... produced in this reaction ... in 4 months the same authors discovered the ... and the more prominent isotope, plutonium-239 by bo... of uranium with neutrons. With the neutron fluxes av... fr... it was ... ally minuscule quantities of these ...

However, the fis... its production in a nu... nuclear pile in Chicago ... reactors specifically designed for producing large ... plutonium. With the availability of plutonium the race to produce high transuranics started again. Using plutonium as target and helium ion projectiles element 96 was discovered in 1944. In the same year reactor produced plutonium was found to contain the element 95. As one went higher in the series it ... difficult to pro... of the ... alpha ... ... acti...

...nide came after ... behaviour of actinides. In fact the identification ... latter actinides was mainly because of the similarity ... the chemistry with lanthanides. However, the ... prominent actinides, namely uranium, plutonium, neptunium and to ... extent americium have chemical properties significantly different from the lanthanides. This study has led to understanding of the structure of the atom. The actinides also exhibit a variety of nuclear properties which make them highly useful. The most prominent application is the production of energy by fission using naturally occurring uranium-235 (0.72% in natural uranium), a reactor produced plutonium-239/241 and uranium-233.

From a few atoms to a few kilograms of plutonium was achieved in a short span of three years. Today plutonium is a byproduct of nuclear power production and is available in tonne quantities. Neptunium, americium and curium are also produced in the spent fuel in kilogram quantities and can be isolated for many applications. In specially designed high flux reactors it is possible to produce berkellium in 100 mg quantities; californium in gram quantities and einsteinium in milligram quantities.

Actinides have many applications, the most prominent being the fissile characteristics of some actinide isotopes. Plutonium-239 and plutonium-241 are not only fissile, but also have the capability of generating more fissile material (from uranium-238) than is consumed in a reactor. The fast breeder reactor is not only a source of energy but also a fissile factory permitting us to utilize not only the fissile isotope $^{235}U$ but also the fertile $^{238}U$. The breeder concept also has the potential to convert our vast thorium resources into uranium-233 and ensuring assured energy supply for many centuries. Among the other isotopes, $^{238}Pu$, $^{241}Am$, and $^{252}Cf$ have significant applications. Plutonium-238, because of its relatively short half-life is a source of heat and used for thermoelectric generators for a large number of space applications. Americium-241 is used in thickness gauging, smoke detectors etc. whereas californium-252 is an excellent compact neutron source - a sort of a mini reactor.

It is indeed exciting to read and think about the drama which heralded the discovery of transuranics 50 years ago. A symposium to commemorate 50 years of the discovery of the first two transuranics; neptunium and plutonium is being organised in BARC from Feb.4-7, 1991. It was considered worthwhile to bring out a bibliography of prominent literature in the field on this occasion. The field is so vast and publications so numerous that the bibliography alone may run into several volumes. By concentration mainly on the leading papers, symposia proceedings and the text books the author has made an attempt to give a very brief bibliography which could be the starting point for any serious literature survey in the field. However, we realise that there are numerous omissions, because of the bias which comes when one selects a few references out of a multitude and also because of authors ignorance. We therefore wish to be forgiven for our acts of omission or commission.

The bibliography is divided into the following sections.

1. Books, Symposia proceedings, Reviews etc.
2. Discovery
3. Weighable Isolation
4. Metal Preparation
5. Nuclear Properties
6. Plutonium as Reactor Fuel
7. Fuel Reprocessing
8. Solid State Chemistry, Thermochemistry and Spectroscopy
9. Radiation Safety
10. Applications, and
11. Some Typical Indian Papers

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