

ACTIVITIES ON **ACTINIDE** BURNING AT IAEA  
AND IN USSR, REP. OF KOREA, INDIA, CHINA AND CSFR

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IAEA

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INTRODUCTION

The management of radioactive waste is one of the key issues in today's political and public discussions on nuclear energy, especially the long-term disposal of high-level radioactive wastes. Rather than waiting for their radioactive decay, it is principally possible, to reduce the period of toxicity of the actinides - and long-lived fission products through transmutation of these isotopes in fission reactors or accelerators. It is claimed, that the transmutation of "burning" of the actinides and long-lived fission products could reduce their half-lives by two orders of magnitude and hence reduce the length of time for which confinement in a repository has to be assured.

IAEA

During the mid seventies, the Agency conducted a Co-ordinated Research Programme in its Division of Nuclear Safety on the "Environmental Evaluation and Hazard Assessment of the Separation of Actinides from Nuclear Wastes followed by either Transmutation or Separate Disposal", in which several related studies carried out in the Federal Republic of Germany, Italy, Sweden, the United Kingdom, the United States and the Commission of the European Communities were performed. The results and conclusions on the overall concept were published in 1982 in a report [1]. The report aimed to assist Member States to consider their future research activities and policy with regard to waste management for the actinide elements.

In the Nuclear Fuel Cycle Division there exist some activities on the separation and the partitioning of specific elements from high level waste. Recently, an IAEA report [2] on the "Feasibility of Separation and Utilization of Ruthenium, Rhodium and Palladium from High Level Wastes" was published and a similar one on Cesium and Strontium is under preparation (A draft document will be discussed at a small meeting in December). (The problem of nuclear data needed for various evaluations is taken care of in the Nuclear Data Section. In this Section a technical document is being prepared on the review of transactinium isotope decay data. At a meeting, Intermediate Energy (20 MeV - 1000 MeV) Nuclear Data for Applications, Vienna, 9-12 October 1990, data requirements for "incineration" projects in Japan, USSR and USA were discussed). A list of target materials and monitor reactions for different future accelerator incineration projects was produced. The data types of interest include the elastic scattering angular distribution of the projectiles, production cross sections for spallation products, double differential cross-sections for secondary particle production, neutron capture and fission cross sections for higher actinides. Only scarce experimental data and very few evaluations exist in the region of incident particle energies above 20 MeV. The most urgent need is to compile all existing experimental data in the intermediate energy range and to validate the existing theoretical model codes. Experimental measurements in this energy range are very costly and it was felt that the majority of data requirements in this field will be met by calculations. The exceptions would be the cases when high precision of the data is required.

An IAEA Consultants' Meeting on "Nuclear Data for Neutron Emission in the Fission Process" was held at the IAEA Headquarters, Vienna, from 22-24 October, 1990. The meeting addressed itself to the following two main objectives: 1) to review the needs and the experimental and theoretical status of data on neutron emission in fission; and 2) in the case of identified urgent needs, to formulate and establish specific tasks and goals for a new **Co-ordinated Research Programme** on "Physics of Fission Neutron Emission and its Nuclear Data Applications for **Actinide** Burner Studies". The meeting took into account the outcome of the previous Consultants' Meeting on this subject held in Mito city, Japan, 24-27 May 1988. New information was presented at the 1990 Meeting in Vienna:

1. The need of improved neutron multiplicity data  $\bar{\nu}(A, E_n)$  (as a function of fragment mass number A and neutron incident energy  $E_n$ ) for major **actinides**, and missing data on  $\bar{\nu}(A, E_n)$  for minor **actinides** of relevance to waste incineration.
2. The need of data on fission neutron spectra  $N(E, E_n)$  for various **nuclides** including minor **actinides** of relevance to waste incineration.
3. Application of new techniques for measuring  $\bar{\nu}$  and  $N(E)$  as a function of neutron energy.
4. New data on  $\bar{\nu}(E_n)$  neutron spectra  $N(E_n)$  for a few neutron incident energies for several nuclei.
5. New results obtained from **multiparameter** studies of neutron emission in fission. These results give essential information on fission neutron emission mechanisms and in particular, on nuclear level densities of neutron rich fragment nuclei. Such data often **cannot** be obtained by other means, but the information on neutron emission mechanisms and level densities is required for **example** for theoretical prediction of neutron spectra for unknown cases of minor **actinides** of importance to studies on waste incineration. Several questions still remain to be resolved concerning the ability to extrapolate from known fission neutron data to that for unknown cases.

At present most nuclear data files lag behind the theoretical advances that have been made in this field and discussed at this meeting.

#### Minor Actinides

The present requests, which are derived from fuel cycle considerations, from reactor **designers/physicists** [3] are for cross-sections only and it happens from validation on integral data that most of them are met, as a general figure turns around  $\pm 10\%$ .

In the future, if the burning **actinide** projects are considered for real application, then the needs will evolve towards strongly different requests, such as better accuracy on the cross-sections and new types of data [ $\bar{\nu}_p(E)$ ,  $N(E)$ ], for the already identified isotopes ( $^{237}\text{Np}$ , Am and Cm isotopes) and for new ones. In the more stringent context (**the in-situ burning of actinides**) the importance of delayed neutron yields should not be omitted.

In order to provide liaison between OECD and **non-OECD** countries, the IAEA held a small meeting for **non-OECD** countries (22-25 October 1990) to investigate their current and planned activities. Their activities are included in this report, as well as their comments on the OMEGA project. In its 1991/92 **Programme**, the Agency plans to conduct a survey on problems and prospects in fractionating of high-level waste with further transmutation and utilization of selected elements and to promote and coordinate experimental and evaluation research required for the generation of new and more accurate data bases (such as neutron fission and capture cross-sections for secondary **actinides**, neutron capture and scattering cross-sections for long-lived fission products and neutron activation and transmutation cross sections for reactor structural materials). For its medium-term **programme**, the IAEA is now investigating which additional activities related to the **actinide** burning (such as separation and recovery techniques, fabrication of **fuel/targets**, improvements of presently available nuclear data, system design, technology aspects and related physics) could be undertaken. However, in order to successfully assess prospects for future activities on **actinide** burning, all aspects and activities by other countries and organizations should be considered.

#### USSR

Today the USSR is engaged in the research connected with long-lived **actinide** isotope and most dangerous fission products burning. Progress in atomic energy requires ecologically safe waste management. On the one hand it means keeping the balance between nature on uranium activity and on the other hand wastes activity to be disposed of. It's **known** that fission products will not greatly affect the natural radioactive balance. **Actinides** will define the waste activity after about 500 years and the corresponding activity level will not sharply decrease over millions years. The recycling of Pu and actinides (Np, Am, Cm), produced through reprocessing of spent fuel, in a reactor or accelerator is the most direct way of handling long-lived radioactive wastes.

**Actinide** partitioning and separation of isotopes for industrial use remain an important part of the USSR research. A summary of these activities, on physical, chemical and material properties (including nuclear data) and on accelerators has not been provided to date.

The burning of **actinides** will be most efficient in **FBRs**, where the probability of the fissioning of **actinides** is higher than in thermal reactors. The choice of the FBR type for **actinide** burning will depend on the progress of atomic energy. One of the options may be to use currently developed FBRs while introducing gradually **actinides** from thermal reactors in its fuel cycle. Estimates carried out at the Institute of Physics and Power Engineering have shown that recycling of **actinides** from three WER-1000 reactors can be realized in the fuel cycle of one **BN-800** (with 3-4% actinides in the fuel). In this case the BN reactor core can burn up to 100 kg **actinides** per year. Further results have shown that the number of WER-1000 served by **BN-800** can be much higher, up to 20 **VVERs** [4], but it will require some drastic changes in the fuel cycle. It seems quite possible a more effective burning mode could be developed in a special reactor with a hard neutron spectrum [5]. In this case, safety problems will play a major part in developing such a core, because the sodium-void effect is expected to be up to 2 times higher.

The calculations connected with **actinide** burning will demand an increase in the nuclear data accuracy. The error *in the* cross-section component in criticality calculations of a reactor with a high **actinide** fraction does not meet the required accuracy necessary in reactor calculations. At present, integral experiments with pure samples of **actinides** are carried out. Special attention has been paid and will be paid to technological aspects connected with the **actinide** burning; such as the separating of **actinides** from spent fuel and the fabrication of full assemblies containing **actinides**.

The USSR is interested in participating in an international cooperation and plans to continue R&D on **actinide** transmutation according to the following programme:

1. Theoretical development of the physiochemical concepts of **actinide** transmutation;
2. The creation of a nuclear cross-section library to provide research calculations;
3. R&D on the **actinide** extracting technology and the fabrication technology of **actinide** fuel;
4. The development of a special FBR core for **actinide** burning;
5. Nuclear fuel cycle R&D for special **actinide** burners; development of the necessary shielding and of cost estimates for such a fuel cycle.

#### REPUBLIC OF KOREA

Korea supplies about 50% of its total electricity needs through nuclear power generation. The role of nuclear power as an alternative energy source to oil has been obviously upgraded. Currently, the problem confronting the nuclear power policy is how to treat and where to store or dispose radioactive wastes including spent fuel. According to a preliminary survey to solve this problem, a plan to construct an interim storage facility of 3000 tones of spent fuel has been made and the conceptual design will be finished by the end of this year. The facility should commence operation by 1998, storage capacity **will** be saturated in the middle of 2000s.

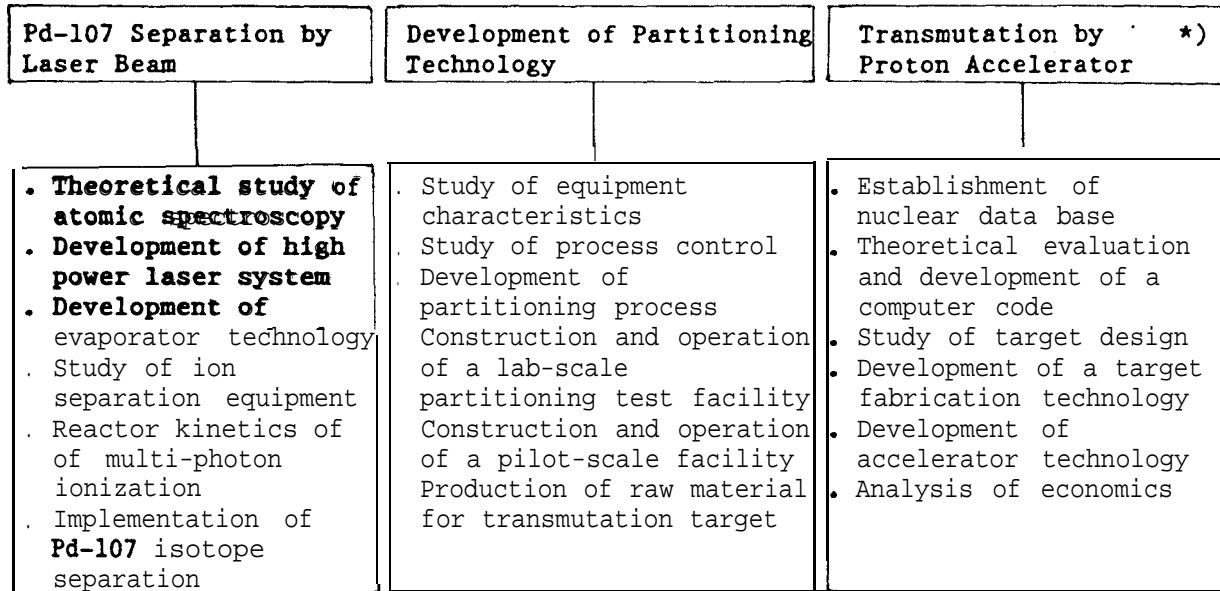
Therefore, considering of the Korean situation during this period a follow-up policy regarding spent fuel management should be established. As one feasible option, the partitioning and transmutation of radioactive waste for the further development of nuclear power could be undertaken in Korea.

A Korean research project consisting of 3 phases over a 10 year period will be undertaken in the fields of partitioning technology, recovery of platinum group elements, and transmutation through one or more methods. Twenty three researchers will be involved in this project, and the research topics for each field is summarized in Fig. 1.

#### Development of Partitioning Technology

The final purpose of the **nuclide** partitioning technology from radioactive waste is the development of separation and purification technologies of selected key elements. The various separation techniques include solvent extraction, precipitation, and crystallization, ion exchange and ultra filtration. Because each element, especially the **transuranium (TRU)** elements, has its own peculiar properties, it is expected that a high purity of each element must be reached for the simplification of the transmutation. In order to **develop** the separation and purification technologies, the Korean, R&D programme has 3 research phases.

PARTITIONING AND TRANSMUTATION OF RADIOACTIVE WASTE



\* temporarily decided upon in Korea.

Fig. 1. Research topics of the partitioning and transmutation programme.

Phase 1: a survey of the published data and experiments regarding the chemical and physical properties of each element in aqueous and organic solutions will be carried out by 1993.

Phase 2 (1994-1996): the partitioning **behaviour** of each group (TRU group, platinum elements group, **Sr-Cs**, and others) or element, by using simulated high level waste, will be studied in a lab-scale mock-up system. The optimal separation and purification process will also be determined in this study considering interaction phenomena among the multi-components.

Phase 3: the design and operation specifications of the partitioning process will be established by constructing and operating a pilot-scale partitioning process by 2000.

Palladium-107 Separation by Laser Beam

It is well known that the amount of platinum group elements in spent nuclear fuel (**burnup: 30,000 Mwd/t in PWR**) is about 4 kg/ton **H.M.** Even if the spent fuel has a high content of platinum group elements these elements cannot be directly used as functional raw material in the industry without the separation of the **Pd-107** isotope (half-life of 6.5 million years).

Consequently, it is foreseen that the laser beam technology will be adapted to separate **Pd-107** from the platinum group elements partitioned from the simulated radioactive waste. This programme consists also of 3 phases.

The basic research to develop the isotope separation technology will be carried out in phase 1 (1991-1993). In this phase, a narrow band laser system, a vacuum leak detection systems, and a monochronator will be developed. Phase 2 includes construction and test operation of a small scale mock-up system to remove Pd-107 by. 1996.

Based on the results obtained from phase 1 and 2, pilot-scale tests will be performed in phase 3 (1997-2000).

#### TRU Transmutation by Proton Accelerator

In view of the Korean situation, even if there are many methods to transmute Np-237, Am-241, Am-243, and Cm-244, the proton accelerator has been temporarily selected as the most promising method at this time.

In the field of transmutation, the main research and development topics in the Korean programme are computer code development and the elemental technology development for a conceptual design, target system, RFQ and accelerator tubes. It is expected that real transmutation tests will be carried out through international co-operation.

#### International Co-operative Work

With an eye to the public acceptance for the nuclear industry and the flexibility and safety of radioactive waste treatment and disposal, pioneering research on **nuclides** partitioning and transmutation technologies is believed to be very important in those countries that have nuclear reactors. As such an effort requires various research activities, a long research period, and a huge research budget, it is strongly recommended that the research and development implementation be conducted through an international co-operation.

Korea suggests the following international co-operative strategy for the partitioning and transmutation of **nuclides**:

participation in OMEGA projects to be granted to **non-OECD** countries;  
an international conference be convened on a regular basis for an extensive exchange of information;  
the R&D activity in each country be performed under IAEA co-ordination and the results be reported to IAEA for the peaceful and effective application of this technology.

#### INDIA

Significant quantities of special **actinides** like Np, Am and Cm have accumulated in the spent fuel of nuclear fission reactors over the last four decades. These **actinide nuclides** are generally looked upon as nuclear waste. Criticality parameters like  $M_C^b$ ,  $K_\infty$ ,  $K_\infty^*$ ,  $\sigma_C^b$  for over twenty **fissile** and **fissible** isotopes of different **actinide** elements have been calculated for both fast and thermal systems. These results clearly showed that every isotope of the **transuranic** elements is a more valuable nuclear fuel than, the corresponding **fissile/fissible** isotopes of plutonium. This finding has a profound bearing on the long lived fission waste problem and supports the view that the byproduct **actinide** elements should be separated from the high level waste stream and recycled back into fission reactors, thereby eliminating one of the commonly voiced concerns regarding the acceptability of nuclear fission power [6]. Further a number of interesting systematic and correlations have been deduced by **analysing** the criticality data of the special **actinide nuclides** using the concepts embodied in the Trombay Criticality Formula (TCF).

A 35-group cross-section set with  $P_3$  anisotropic scattering matrices have been generated with the MINX code from the ENDL-82 basic point cross-section data library for a number of actinide nuclides, whose half-life is more than one month. However, for uranium and plutonium isotopes and for hydrogen, oxygen,  $^{237}\text{Np}$  and  $^{244}\text{Cm}$  the BARC-35 group cross-section set based on ENDF/B-IV files has been used. Since point cross-section data of  $^{231}\text{Pa}$  are not available to India, the cross-section set for this actinide was obtained by combining BARC evaluated data in the 1-20 Mev energy range with the  $^{233}\text{Pa}$  data of JENDL-2 file for below one Mev.

The transport theory code DTF IV was used for a spherical geometry with  $S_{16}-P_3$  approximation. Criticality data were generated for both bare and reflected fast systems. Minimum critical masses of fissile actinides in solutions and  $k_\infty$  values of both fissile and fissionable actinides as a function of the moderation ratio were also calculated [7].

A plot of the fast system  $k_\infty$  values against the fissibility parameter  $(Z^2/A)$  for the fissile actinide nuclides showed a remarkable linear correlation with  $k_\infty$  increasing linearly with  $(Z^2/A)$ . An "eye-fit" to the data points gave the following relation.

$$k_\infty = 1 + 0.682 [(Z^2/A) - 34.1]$$

The above equation suggests that a threshold  $(Z^2/A)$  value of at least 34.1 is required to sustain a fission chain reaction in non-moderated fissile systems.

Another important observation was that the variation  $[1/\sigma_c^b]$  with  $(Z^2/A)$  for fast systems was also linear and a simple expression for  $[\sigma_c^b]$  was obtained as

$$\sigma_c^b = \frac{94}{[(Z^2/A) - (Z^2/A)_{th}]}$$

where  $(Z^2/A)_{th}$  is 34.1 for fissile and 34.9 for fissionable nuclides. (NOTE:  $\rho$  is a surface mass density, b stands for bare system and c for critical).

Plots of neutrons leakage probability for fast critical actinides showed that  $\rho_{std}$  values (i.e. standard size  $\rho$  values) for the fissile and fissionable fast assemblies are 77 and 107  $\text{g/cm}^2$  respectively.

The variation of the nonleakage probability with critical core radius for both bare and water, reflected solution systems of fissile nuclides in general exhibited a linear relationship. For further details see [8] and [9].

The fast criticality data of  $^{247}\text{Cm}$  and  $^{241}\text{Am}$  did not fit into data of other actinides as far as the different correlations mentioned above. This suggests that the basic point cross section data for these nuclides need a fresh appraisal. Comparison of Indian fast critical mass data with ANSI values for fissile nuclides clearly indicates that there is a need to look for new nuclear data of  $^{231}\text{Pa}$  and  $^{241}\text{Am}$ . Scrutiny of Indian data and ANSI data shows that considerable disagreement exists in the criticality data of  $^{242}\text{Am}$ ,  $^{243}\text{Cm}$ ,  $^{245}\text{Cm}$ ,  $^{247}\text{Cm}$  and  $^{251}\text{C}$  nuclides.



Presently there are two options available to take the pressing problem of **actinide** waste. In the first approach, **actinides** embedded in suitable targets are transmuted with the help of high energy protons or electrons. In the second approach, **actinides** are to be used as fuels in fast breeder reactors. In either case the successful design and operation very much depends upon the quality of basic cross section data available.

Even though a members of libraries like **ENDF/B-V**, **JEFF 2** are available, nor much effort has been put to test these libraries **BARC**, India has reported criticality data for most of special **actinides** using **ENDL-SL** and **ENDF/B-IV** libraries. It is therefore suggested to generate similar data using latest available libraries to find out discrepancies among these libraries. It is also important to carry out sensitivity analysis to specify accuracy requirements on the basic data. These libraries can be tested to some extent by measuring the reactivity worths of small samples of the individual **actinide nuclides** in zero energy fast reactor systems.

## **CHINA**

Reprocessing of spent fuel in China started in the late sixties. Since then a large volume of high radioactive waste was accumulated and stored in underground tanks. Before vitrification of HLW, it is advised to separate **actinides** from the rest of the fission products due to its long half-life and high biological hazard to mankind. On the other hand, some transuranium elements and fission products could be used for different purposes in the industry and scientific research, if these elements could be recovered from HLW in pure state. During the last decade, three different chemical **flowsheets** for separation and recovery of **actinides** have been developed in China. Research activities are still ongoing at present **in order** to optimize the process.

### 1. Reverse Talspeak Process

Np has a limited application and usually spreads over the whole solvent extraction cycle due to its peculiar chemical **behaviour** in nitric acid. The ratio of  $\text{NpO}_2^+$  to  $\text{NpO}_2^{2+}$  strongly depends on the concentration of  $\text{HNO}_2$  present in the nitric acid, which is unstable and easily decomposes into  $\text{NO}$  and  $\text{NO}_2$ . China's main attention has been focused on the restriction of Np into HLW. Therefore, the first step is to keep Np in the **penta-valent** state in the first co-decontamination cycle. Results of experiments show that if an additional aqueous stream of  $\text{NaNO}_2$  is introduced in the middle of extraction cascade and the concentration of  $\text{HNO}_2$  in HLW is kept around 0.05 **M**, more than 90% of Np will be in the HLW, if the concentration of  $\text{HNO}_3$  in the feed solution is 1.5 **M** or less; less than 90% of Np will be in the HLW, if the concentration of  $\text{HNO}_3$  in the feed solution is more than 2 **M** [10].

The next step is to separate **Pu** and **Np** from **tri-valent transplutonium** elements and **FP** by extraction with 30 **vol% TBP/OK**. First, the HLW is treated with  $\text{Fe}(\text{NO}_3)_2$  and  $\text{N}_2\text{H}_4$  for reduction of Np and Pu to its lower **valent** state.  $\text{Np}^{4+}$  could be quantitatively extracted when concentration of  $\text{HNO}_3$  in the cascade remains relative high, for example, 4 **M**  $\text{HNO}_3$ , then,  $\text{Np}^{4+}$  in the organic phase can be stripped with diluted  $\text{HNO}_3$ , for example, 0.2 **M**. Recovery of **Np** in this step achieves more than 95%. Then, Np goes through an **ion** exchange column for further purification, especially for removal of **Th** being in co-existence with Np. In this case, the purity of the final Np product meets the specification of Np [11].

Separation of **tri-valent transplutonium** elements from RE is accomplished by extraction with 0.3 M HDEHP - 0.2 M TBP - OK. The better extraction of both **actinides** and **lanthanides** can be obtained only when the PH of the solution is in the range of 2-3. So, the solution coming from the extraction process for recovery of Np must be treated with formaldehyde for denigration of HLW. In the second cascade,  $\text{Np}^{4+}$  is stripped with a completing agent DTPA - Lactic Acid (PH $\approx$ 3). **Transplutonium** elements will go into aqueous phase and **R.E.** remains in the organic phase. The separation factor is about  $10^3$ . In the third cascade, RE is stripped by 2M  $\text{HNO}_3$  [12]. For separation of **transplutonium** elements itself, liquid chromatography could be used.

If it would be desirable to recover Cs and Sr, the HLW should after removal of Np and Pu pass through a column filled with **zeolite** to absorb Cs and, after removal of **tri-valent actinides** and **R.E.**, the solution should pass through a cation exchange column to absorb Sr.

## 2. DHDECMP Process

DHDECMP is a **bidentate** organophosphorous extractant which is able to extract **tetra-**, **hexa-** and **tri-valent actinides** and **lanthanides** from aqueous solution with high acidity [13]. So, it is applicable directly to extract both **actinides** and **lanthanides** from HLW without pre-denitration. The chemical **flowsheet** for separation of **actinides** and **lanthanides** consists of three cascades. In the first cascade, all **actinides** and **lanthanides** are extracted into 30 vol% DHDECMP in diethyl benzene (DEB). 0.05 M Oxalate in washing solution is used for improvement of  $^{95}\text{Zr}$ - $^{93}\text{Nb}$  decontamination. More than 99% of the **actinides** and **lanthanides** could be recovered from HLW. In the second cascade, the majority of **actinides** and almost all **lanthanides** are stripped from the organic phase into an aqueous phase by **re-extractant** consisting of 0.05 M  $\text{HNO}_3$  - 0.005 M  $\text{Fe}(\text{NO}_3)_2$ . The rest of U, Np and Pu in the organic phase can be stripped in the third cascade by means of a completing **agent-oxalate** at low acidity, for example, 0.01 M  $\text{HNO}_3$ .

For separation of **actinides** from **lanthanides**, a modified reverse **Talspeak** process, as mentioned above, can be used. However, the problem is the acidity of the solution coming from the CMP process. The acidity of the above solution is about 0.2 M, which is higher than the acidity needed for the typical reverse **Talspeak** process. There are two choices, one is denigration and the other is to apply a high concentration of HDEHP, saying 1 M for more effective extraction of **actinides** and **lanthanides**.

## 3. TRPO Process

TRPO is a mixture of **tri-alkyl phosphine** oxide with 6 to 8 carbon atoms per molecule and is a by-product from the **petro-refining** factory. TRPO can extract all **actinides** and **lanthanides** with different **valent** state except for  $\text{NpO}_2^+$  in the range of acidity from 0.05 M to 1.5 M. It can strongly extract Zr and Tc too. The chemical flowsheet consists of denigration of HLW to 1-1.5 M  $\text{HNO}_3$ ; reduction of Np and Pu to its low **valent** state, extraction of **actinides** and **lanthanides** with 30 vol% TRPO-OK; strip 1 with 5.5 M  $\text{HNO}_3$  for recovery of **tri-valent actinides** and **lanthanides**; strip 2 with 0.6 M  $\text{H}_2\text{C}_2\text{O}_4$  for recovery of Np and Pu and strip 3 with 5%  $\text{Na}_2\text{CO}_3$  for recovery of U. Preliminary experiments show that TRPO has a potential to be used as industrial application for removal of **actinides** from HLW. Further work must be done for optimization of process condition [14].

The transmutation of **actinides** after their separation from HLW has not been considered at the moment.

China will be interested in the following research programme:

CMP + Reverse **Talspeak** process for separation of **actinides** and **lanthanides**  
Separation of Ru, **Rh**, and Pd from both residues and HLW.  
Yield of **radiolytic** degradation product and its influence on property of extractant. Recovery of used extractant.  
Semi-industrial operation of extraction process for removal of **actinides** in hot cell.

#### THE CZECH **AND** SLOVAK FEDERAL REPUBLIC

In the **CSFR**, preliminary analyses have been carried out, considering possible options about the backend of the fuel cycle:

final storage of spent fuel on the USSR territory without **Czechoslovak** participation;  
construction of a new reprocessing plant or final disposal facilities in the USSR with Czechoslovak participation, in the meantime the spent fuel would be stored in the **CSFR**;  
final long-term storage of spent fuel in the **CSFR**;  
reprocessing on a commercial basis in a commercial reprocessing plant and accept receiving vitrified waste.

The choice of one of the above mentioned alternatives which is expected be realized after the year of 2000 is presently being considered.

As early as 1965, the first laboratory Purex reprocessing was carried out in collaboration with the Boris **Kidrich** Institute in **Belgrad** by staff of the Institute of Nuclear Research (Rez, **CSFR**). In 1973 several hundred grams of plutonium were isolated on a laboratory scale in **NRI** (Rez) by a Purex procedure using cascades of mixer-settlers. Since 1977 laboratory work on the isolation of  $^{137}\text{Cr}$  and/or  $^{90}\text{Sr}$  has been performed using the method of solvent extraction.

Together with specialists of the Institute of Inorganic Chemistry of the Academy of Sciences in Prague a novel extractant, cobalt **dicarbolyde**  $[(\pi-(3)1.2 - \text{C}_2\text{B}_9\text{H}_x\text{Cl}_{11-x})_2\text{Co}]^-$  was synthesized and suggested as an efficient isolation of  $^{137}\text{Cr}$  and - using the addition of a synergistic reagent, polyethylene **glycol** - also for the extraction of  $^{90}\text{Sr}$ . The development of technological flow-charts and their testing was carried out in collaboration with specialists of Radium **V.G. Khlopin** Institute in Leningrad. The basic chemical "reactions, methods of back-extraction, radiation stability and mechanism of **radiolysis** were studied in Czechoslovakia; laboratory and pilot plant experiments with real high level waste were carried out in the USSR. The technological schemes developed were used to prepare on a semi-industrial scale tens of tons of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  in USSR. Laboratory work in Czechoslovakia proved that the reagent can also be used for the isolation of palladium and **actinides**.

The main features of the processes based on the use of **dicarbolyde** of cobalt are:

the possibility to extract **cesium**, strontium from solutions of a relatively high nitric acid concentration  
high selectivity of separation (**Cs/Na, Ba/Sr, Sr/Ca**)  
low losses of the reagent in the aqueous phase

exceptionally high chemical and **radiolytical** stability of the reagent the possibility to use the voluminous anion to extract several components (Cs, Sr, **actinides**, Ba, etc).

The main problems which were solved to a certain degree the difficulty with achieving an effective concentration of the elements separated in the final aqueous phase the toxicity of nitrobenzene as an important component of the organic phase in some schemes.

The main sources of information on work performed up to now are listed separately [15 to 21].

During the period 1987 - 1989, the activity of the research group of 3 to 5 co-workers at the NRI (**Rez**) was financed by the Radium Institute in Leningrad due to the fact that the high level radioactive wastes from reprocessing exist in the USSR, but not in **CSFR**. The financing of the activities in 1990 is ensured by a grant from **Czechoslovak** basic research funds .

Starting by the year 1991 the activities of the research group involved in the research described cannot be financially supported using the previous types of funds and NRI would be interested to perform research work in the field of **actinide** partition under the condition of attaining a contract with the framework of the **programme** of a more complex nature. The activity could include laboratory research in the field of solvent extraction of **actinides** or fission products using reagents such as the **dicarbolyde, polyethyleneglycols, crowns, bidentate phosphororganic** extractants according to the general or specific request of the complex **programme**. One of the promising directions could be based on preliminary positive results obtained in studying synergetic effects obtained with the simultaneous use of the **dicarbolydes** and the above **phosphororganic** reagents of crowns. In case of interest work in ion-exchange separation both with organic and inorganic ion exchangers could also be carried out using highly experienced professional staff.

#### PROPOSAL FOR **INTERNATIONAL** COOPERATION

1. The IAEA might function as a mediator between the OECD states research efforts and those of **non-OECD** states (exchange of information, etc.)
2. The mutual information about activities occurring in the **non-OECD** states is highly desirable.
3. The inclusion of the problems of **PT** (such as **radiochemical** research, nuclear data, reactor physics and design aspects) into existing IAEA forms of co-ordination whenever possible. Information of countries whose specialists cannot participate in the respective meetings.
4. The **IAEA** should organize an international symposium on **actinide** burning.
5. IAEA might encourage pooling of financial means of the OECD states and those which are not members of OECD with the objective of establishing suitable projects (semi-industrial pilot plants etc). oriented to partitioning or transmutation. The incentive for governments be devote financial means for these purposes might be the possibility to attain waste from reprocessing without **actinides** or long-lived fission products.

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Comments and Remarks on the Contents of the OMEGA Project.

## 1. Physical and Chemical Properties of Elements Generated in the Nuclear Fuel Cycle

Mechanical properties should also be included.

The relevant data should be provided with the same accuracy as those of uranium and plutonium isotopes. Experimental benchmarks should be carried out and sensitivity analyses be performed.

## 1.1 Chemical properties and behaviour of the actinide species in aqueous and organic solution

Include in the studies other separation systems such as ion exchange and precipitation methods.

## 1.2 Analytical techniques and methods

If the techniques are meant to be used during partitioning, they should be incorporated under 2 (i.e. between 2.2. and 2.3). Other techniques should be included like new developments in on-line techniques and improvements in **radiometric** analysis. Software for computerized process and analyses should be developed.

## 1.3 Physical and chemical properties of various actinide compounds

Add metallurgical in title. Study also **stoichiometrical** properties and phase transitions.

## 1.4 Collection and evaluation of nuclear and thermodynamic data of relevant elements

Add ( $\beta$ ,  $\beta_{eff}$ ) after delayed neutron data. Cross-section data for fission reactors are required for the whole fission energy range.

study of thermodynamics for prediction of multi-phase (such as solid-liquid, liquid-liquid and solid-organic-liquid) and multi-component equilibrium included in high level waste systems.

## 2. Partitioning technology

The necessity of minimizing the arising of secondary wastes and the reduction of the waste volume should be stressed. Systematic studies should also be included on:

the distribution ratios and separation factors of **actinides**, fission products and other components in **multicomponent** systems for the solvent extraction technologies  
degradation and third phase formation of solvents  
extraction and re-extraction kinetics.

## 2.1 Partitioning of high-level liquid waste with wet and dry processes

It is suggested not to limit separation into "four groups" but into "several preliminary groups". Subsequent separation of individual elements should be provided.

Comparative evaluations of proposed partitioning processes should be carried out with respect to technical performance, cost effectiveness and environmental aspects.

In the future, efforts should be oriented to the separation of the unburnt or newly produced elements in the **actinide** burner.

## 2.2 Recovery of Platinum group metals-recovery technology

No comments

## 2.3 Fabrication technology of the fuel and target materials

Fabrication should be done into high integrity and intrinsically safe fuel or targets exhibiting high retention of the most hazardous components. The technology of handling the highly radioactive materials should be improved and the conditions of safeguards fulfilled.

Properties of all possible fuel matrices should be examined and tested.

Attention should also be paid to the following powder characteristics: size distribution, fluidity, compatibility, hardness, porosity, and **sinterability**.

## 2.4 Partitioning in the reprocessing process

No comments

## 3. Transmutation

Nuclear reactor chains of (higher) actinides and fission products should be included.

Based on the approach (i.e. selected system) the need for specific data (nuclear, physical, chemical) should be defined and also investment and operation costs estimated.

### 3.1 Transmutation with (FBRs)

Include the development of fuel assemblies, the equation of state for these **actinides** in the safety calculations and risk assessment analyses.

### 3.2 Transmutation with TRU burner reactors

Irradiation tests of fuel assemblies containing actinides should be **performed** in sub-critical and critical facilities.

### 3.3 Transmutation with proton accelerators

Not only experiments on lead and uranium targets, but also on **actinide** and fission product targets should be performed.

### 3.4 Transmutation with electron accelerators

no comments

### 3.5 Comparative Analysis

Comparative analysis of above and of other transmutation systems should be carried out.

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