Executive Summary

The OECD Nuclear Energy Agency Information Exchange Meeting on Actinides and Fission Products Partitioning and Transmutation, organised since 1990, is a forum for experts to present and discuss the state-of-the-art development in the field of P&T. Thirteen meetings have been organised so far and held in Japan, the United States, France, Belgium, Spain, the Republic of Korea and the Czech Republic. This 13th meeting was hosted by Seoul National University (Seoul, Republic of Korea) and was organised in co-operation with the International Atomic Energy Agency (IAEA) and the European Community (EC).

The meeting covered strategic and scientific developments in the field of P&T such as: fuel cycle strategies and transition scenarios, the role of P&T in the potential evolution of nuclear energy as part of the future energy mix; radioactive waste management strategies; transmutation fuels and targets; advances in pyro and aqueous separation processes; P&T specific technology requirements (materials, spallation targets, coolants, etc.); transmutation systems: design, performance and safety; impact of P&T on the fuel cycle; fabrication, handling and transportation of transmutation fuels.

A total of 103 presentations (39 oral and 64 posters) were discussed among the 110 participants from 19 countries and 2 international organisations. The meeting consisted of one plenary session where national and international programmes were presented followed by 5 technical sessions:

- Fuel Cycle Strategies and Transition Scenarios.
- Transmutation Systems and Infrastructures.
- Waste Management for P&T Scenarios.
- Advanced Nuclear Fuel Recycling (Aqueous and Pyroprocessing).
- Transmutation Fuels and Targets.

Opening Session

The meeting opened with a welcome address by Professor Il-Soon Hwang from Seoul National University and Jim Gulliford, Head of the NEA Division of Nuclear Science followed by the Honourable Dr Han-Py Kim, member of the National Assembly, Committee on Trade, Industry and Energy of Korea.

D. Warin (CEA, France) gave an introductory lecture on the benefits and challenges of P&T for a sustainable nuclear energy. P&T can help reduce the burden of long-term waste management and improve related public acceptance. As a result, many countries are increasing R&D efforts on P&T technologies for a wide range of fuel cycle concepts.

Session 1: National and International Programmes

J. Gulliford (NEA) summarised the on-going activities of NEA related to P&T. Most work is carried out within the Nuclear Science programme of work. Current activities involve MA bearing fuel performance benchmark studies, an international review of separation processes, minor actinides management and recycling.

An overview of the IAEA activities on P&T was given by ***U. Basak*** (IAEA) ***and S. Monti*** (IAEA)**.** The framework of the IAEA activities is carried out by several Nuclear Energy sections and technical

working groups (TWG) and is implemented through co-ordinated research projects (CRP). An assessment of partitioning processes was performed and the trends in advanced pyroprocessing were reviewed. Transmutation activities focus on fast neutron systems such as fast reactors (FR) and accelerator-driven systems (ADS).

J-H. Lee (ROK) presented the status of the back-end of the nuclear fuel cycle in Korea. No decision has yet been made regarding spent fuel management strategy in Korea. A public engagement commission (PECOS) was set up to survey public opinion. Currently the spent fuel is kept in an interim storage. In the meantime, R&D programmes on pyroprocessing and SFR are on-going with the objective of operating a close fuel cycle in the near-term. For partitioning, the PRIDE facility (*PyRoprocessing Integrated inactive DEmonstration facility*) is in operation and engineering scale demonstration on surrogates is expected. A prototype SFR was designed for transmutation. Current R&D activities focus on the 3S (safety, safeguards and security) requirements.

P. Paviet (US) gave an overview of actinide partitioning research in the US. The US is currently operating a once-through nuclear fuel cycle but is evaluating advanced (closed) fuel cycle for potential deployment around mid-century. A comprehensive Nuclear Fuel Cycle Evaluation and Screening Study has been completed and showed that continuous recycle of U/Pu or U/TRU (transuranic) is among the most promising fuel cycle. The US Fuel Cycles Technologies programme is performing R&D on advanced partitioning technologies for potential fuel cycles. Investigations support both homogeneous and heterogeneous approaches and focus on more robust and simpler processes. Both aqueous and electrochemical technologies are being developed.

Z. Hodgson (UK) outlined the status of nuclear energy development in the United Kingdom. The current UK policy is to operate an open fuel cycle and reprocessing plants are planned to be shut down in the near future. The UK roadmap focuses on keeping scenario options open and training the next generation of nuclear scientists. Importance is given to actinide separation processes in particular advanced reprocessing and MA partitioning.

D. Warin (France) illustrated the R&D programmes for the management of Pu and minor actinides in France. Sustainability of the fuel cycle will be reached by operating a closed fuel cycle through systematic recycle and fast reactors. Minor actinides recycling in fast reactors will provide a solution to waste management. The 2013-2023 R&D programmes focus on (1) Pu multirecycling; (2) partitioning Am and (3) transmuting Am. The sodium cooled prototype reactor ASTRID aims at demonstrating MA transmutation.

M. Alyapykev (Russian Federation) summarised the R&D programmes on partitioning in the Russian Federation. Primary programmes concentrated on the separation of Cs and Sr but the current priority is given to Am. New ligands and modification of existing aqueous processes are being investigated to optimise the separation of Am from spent fuel.

H. Oigawa (Japan) highlighted the new energy plan issued after the review of the Japan R&D programme carried out by the government. Two fuel cycle options are considered for P&T: homogeneous recycle in FBR and transmutation in ADS. Transmutation of minor actinides (MA) is the main focus and will be conducted in Monju. A transmutation experimental facility (TEF) will be built in J-PARC. Future R&D plan involves partitioning of MA and transmutation in ADS. The importance of international collaboration (i.e. MYRHHA) was mentioned.

Session 2: Fuel Cycle Strategies and Transition Scenarios

F. Alvarez-Velarde (on behalf of NEA/EG AFCS) presented the results of a benchmark study on uncertainties analysis of input parameters on nuclear fuel cycle scenario carried out within the NEA Expert Group on Advanced Fuel Cycle Scenarios (EGAFCS). The objectives of the international study were to provide guidance on which input parameters are important to be investigated thoroughly, and which components can be less well-known, given the objectives of a particular study. Twenty-two magnitudes were estimated by the codes and 17 sensitivity studies were calculated. A first estimation on which input parameters impact significantly (given the objectives of a particular study) was obtained. These results and conclusions will be included in an NEA report expected to be published in 2015.

The results of the study of the environmental impact of different nuclear fuel cycle were explained by ***S. Bourg*** (France). The simulation tool NELCAS was developed and a twice-through fuel cycle and a once-through fuel cycle were studied. Comparison to other sources of energy showed the low impact of nuclear energy. Simulations also demonstrated the significant contribution of the front-end activities on the global impact. In addition, the beneficial effects on the overall footprint of recycling processes were demonstrated.

T. Kim (US) described the Evaluation and Screening study (E&S) carried out in the United States in order to strengthen the basis for the implementation of a nuclear energy R&D programme. This presentation focused on the comparison of mass flow data analysis for different fuel cycles options. The conclusions of this study showed that natural resource utilisation is generally lower than 2% for fuel cycle options that require enriched uranium fuel, but could be improved by avoiding enriched uranium fuel support. The mass of spent nuclear fuel and high level waste (SNF+HLW) can be reduced by continuously recycling nuclear fuel. Mass of DU (depleted uranium) is a major fraction of the DU+RU+RTh mass for fuel cycle options that require enriched uranium.

The decision to phase out electric energy production in nuclear power plants in Germany has led to a number of questions regarding the future of P&T research. The Federal Ministry for Economic Affairs and Energy and the Federal Ministry of Education and Research have launched a study managed by the National Academy of Science and Engineering to answer these questions on a broad scientific basis. The objective was to evaluate scientific and technological as well as socio-economic challenges and opportunities of the P&T technology with a view to the phase-out decision, both in a national and an international context. The scientific and technological aspects of P&T were analysed with respect to a possible contribution to the management of nuclear waste. The outcomes of the study and recommendations were presented by ***B. Merck*** (Germany).

Session 3: Transmutation Systems and Infrastructures

H. Aït Abderrahim (Belgium) gave an invited presentation on the MYRRHA project (Multipurpose hYbrid Research Reactor for High-tech Application) and explained its role in the European strategy for P&T. One option to solve the issue of treatment of High Level Waste (HLW) is the transmutation of waste in accelerator driven systems such as MYRRHA. This reactor initiative is part of the European Sustainable Nuclear Industrial Initiative (ESNII) and is supported through international and bilateral collaborations. This reactor should replace the currently operating material test reactor BR2 and is planned to be fully operational by 2026. MYRRHA would be used for testing Gen-IV, for demonstrating P&T technology, and for the production of radioisotopes.

A. Saturnin (France) presented the studies carried out on minor actinide transmutation scenarios. The recycling of minor actinides in sodium-cooled fast neutron reactors has been studied, in homogeneous or heterogeneous modes or in a dedicated ADS stratum (Accelerator-Driven System). The transport of minor

actinides loaded elements is one of the technical issues under analysis: the feasibility of this operation was examined, pointing out all associated difficulties and uncertainties and the annual transport requirements in routine conditions were evaluated.

T. Taiwo (United States) summarised the US Nuclear Fuel Cycle Evaluation and Screening study. This study covered all aspects of the nuclear fuel cycle from mining to disposal. Different fuel cycle options were listed in order to identify the potential challenges and benefits as well as the most promising options. It also allowed ascertaining R&D needs.

T. Sasa (Japan) described the J-PARC Transmutation Experimental Facility (TEF) designed to support ADS design and technology. This new facility will consist of two buildings, an ADS target test facility 5TEF-T) and a transmutation physics experimental facility (TEF-P). The work carried out at TEF will be part of a joint roadmap with MYRRHA.

V. Ignatiev (Russian Federation) summarised the progress made on molten salt reactor technology for transmutation. The results of a benchmark study involving codes and experimental data on MOSART and MSFR were presented.

Fuel cycle options for on-going/regional and phasing out scenario with ASTRID-like burners were investigated. ***B. Vezzoni*** (Germany) discussed the performances of both types of burners and explained that the results of the study showed that the burners allowed the use of all TRU compositions foreseen in the fuel cycle with a proper choice of the MAs/Pu ratios and of the U/TRU fractions.

J. Lim (Belgium) gave an overview of the experimental facility MEXICO designed to support the engineering and licensing of MYRRHA. The main purpose of MEXICO is to study LBE coolant chemistry, specifically, to develop oxygen control systems and purification technology. Highly accurate oxygen control was achieved by both oxygen control systems during the first experimental campaign.

Session 4: Waste management for P&T scenarios

J. Cobos (Spain) presented the solubility studies carried out at CIEMAT on ThO_2(cr) and irradiated Th-MOX fuels. The fabrication and characterisation of the fuel pellets was described as well as the experimental results of leaching tests in different conditions.

H. Ju (Republic of Korea) presented some studies on the impact of potential inadvertent human intrusion on geological repository. Seven scenarios were considered to see the impact of partitioning ratio and loading of the waste in term of safety and radiation dose.

Session 5: Advanced Nuclear Fuel Recycling

On behalf of members of the OECD Nuclear Energy Agency Expert Group on Fuel Recycling Chemistry, ***S. Cornet*** (NEA) summarised the state-of-the-art report on progress in separation chemistry, minor actinide separation and perspective for future R&D currently in preparation. This report reviews the status of separation processes related to current and future nuclear fuel cycles. Technological readiness of various reprocessing techniques was described.

5a: Aqueous Processes

S. Bourg (France) described the ExAm process developed at CEA for the recovery of americium. This process was demonstrated in a hot lab in April 2010 and, since then experiments have been performed to improve several aspects of the process and define an optimised process flowsheet using the PAREX code.

Activities on minor actinide partitioning and lanthanide-actinide separation at the Indira Gandhi Centre for Atomic Research were summarised by ***R. Kumaresan*** (India). Different extractants are being considered and two-cycle process involving TRUEX solvent and HDEHDGA was demonstrated. Research is currently focusing on the development of a single cycle approach.

M. Nilsson (United States) presented some of the main results from an on-going project studyingthe connection between extraction synergy and micro-emulsions. The study investigated synergistic extraction of trivalent lanthanides and uranyl combining TBP and HDBP. Data obtained from EXAFS, XANES and thermodynamic studies of the metal extraction point towards the existence of two different metal-ligand complexes. The aggregates might not participate directly in the metal ion extraction, although it is quite possible that it strongly affects system behaviour.

T. Matsamura (Japan) mentioned the MA separation process currently being investigated. This process consists of a two-step extraction, the first one being the co-extraction of An(III)/Ln(III) with N,N,N',N'-tetradodecyldiglycolamide (TDdDGA). The second step separates An from Ln. New extractants are being explored.

A. Wilden (Germany) presented the results of the development of two innovative partitioning processes i-SANEX and 1-cycle SANEX. These separation processes are based on solvent extraction studies which benefit from the experience gained over the last 15 years in European collaborative projects. Both spiked processes showed excellent performance for the recovery of An (III) from simulated HAR solution. The 1-cycle SANEX and innovative SANEX processes demonstrated the possibility of separating An(III) directly from HAR solution in a single cycle.

5b: Pyrochemical Processes

S. Bourg (France) gave an overview of the work carried out at CEA on the Direct Oxide Solubilisation (DOS) process, an optimised process for head-end steps and liquid/liquid extraction. This study investigated the capability of fluoride salts for direct oxide dissolution preventing the use of HF gas. A theoretical approach coupled with experimental data was carried out on several simulated fission product and actinide oxides with promising results. The process was validated on an oxide mixture representative of irradiated fuel.

The use of Laser Induced Breakdown Spectroscopy (LIBS) to carry out quantitative measurement of molten salt composition was described by ***S-H. Kim*** (ROK).

S-M. Woo (United States) presented the development of a model for Pu mass accountancy in Pyroprocessing. A method to quantitatively evaluate the probability of error in the determination of Pu to Cm-244 ratio was proposed. As a first step, numerical recipes were developed for the deterministic evaluation of spent fuel composition. Uncertainties associated with the spent fuel composition were then quantitatively evaluated by a random-sampling approach.

J-H Jang (Republic of Korea) summarised the study of the separation of adhered salt in uranium deposits generated from an electrorefiner. Salt distillation with multilayer porous crucibles were tested and proved to be effective.

Session 6: Transmutation fuels and targets

V. Royet (France) gave an overview of the recent outcomes on the development of AmBB (Americium bearing blankets) fuels. Promising results were achieved for the conversion and fabrication of these types of fuel at laboratory scale. In addition, collaborative irradiation programmes and PIE examination are on-going. A database on MABB is planned to be generated by 2020.

M. Kato (Japan) described the relationship between mechanical and thermal properties in MA bearing fuels. The heat capacity and thermal conductivity were analysed in order to contribute to the development of Pu-burning MOX fuels.

An innovative route called calcined resin microsphere pelletisation (CRMP) for the development of mixed oxide fuel pellets was mentioned by ***M. Caisso*** (France). The main goal of this study was to point out and interpret the key-steps of weak acid resin (WAR) spherical precursor mineralisation into oxide through structural in-situ characterisations.

R. Kennedy (United States) reported the progress of R&D programmes carried out at Idaho National Laboratory (INL) regarding the development of actinides bearing alloy metallic fuels. In particular, demonstration of the fabrication of fuels under remote (hot cell) conditions; the chemical sequestration of lanthanide fission products to mitigate fuel-cladding-chemical-interaction (FCCI); and transmission electron microscopy (TEM) and atom probe tomography (APT) studies on the as-cast microstructure of the metallic fuel alloys were mentioned.

M. Ohta (Japan) discussed the results of irradiation tests of minor actinide bearing metal fuels with different burn-ups. Based on the chemical analysis results, the burn-ups were evaluated. The MA transmutation performance of U-Pu-Zr-MA alloys with medium burn-up was mentioned.

F. Delage (on behalf of GIF) presented the progress status of the Sodium Fast Reactor Advanced Fuel Project within the Generation IV International Forum. The project includes research on remote fuel fabrication & material manufacturing techniques as well as performance under irradiation.

Poster Session

64 posters were presented covering all areas of P&T. Among them, 10 posters were related to ADS and 21 to reprocessing.