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**Nuclear data at work:
Tackling current and future challenges**



Behind every reactor, every safety decision and every expected radiation dose lies something many people have never heard of: nuclear data.

UKNNL is one of a small number of organisations globally with the expertise to build and maintain nuclear data libraries, and our work is shaping internationally recognised standards used across the world.

Challenge

Behind the delivery of every new nuclear reactor to power the UK's clean energy future lies a complex set of calculations.

These calculations are carried out using specialised computational modelling that simulates all aspects of the new system to ensure controlled working and that it meets rigorous safety standards.

At the root of these calculations stand the nuclear data, a set of information built mostly on experimental evidence, which provide the reaction probabilities to the modelling codes.

Building this knowledge into libraries of nuclear data that can be accessed worldwide is a process which takes decades, and these libraries need to be regularly revisited and updated if the future of the UK's nuclear sector is to be assured.

Simulating how nuclear fuel changes during reactor operation, calculating the thickness of the shielding needed to protect workers from radiation and assessing whether nuclear materials are being kept safely below the threshold in normal and unexpected operation modes are just a few of the critical tasks that depend entirely on accurate nuclear data.

Solution

UKNNL is a key player in the international nuclear data community. We ensure that the UK influences how nuclear data libraries develop and has the expertise to use them confidently. This is an ongoing process, as libraries are regularly being updated with new knowledge. Being a strong partner in the nuclear data community means we can steer priorities and have some control over what is inside the libraries and how these data are compiled.

We are an active member of the Joint Evaluated Fission and Fusion (JEFF) collaboration, working alongside partners from across Europe to produce the latest nuclear data libraries. UKNNL scientists focus on fission product yields, the data describing what materials emerge when nuclear fuel splits apart, because this information is crucial for reactor operations and spent fuel management.

Beyond JEFF, UKNNL participates in the Working Party on International Nuclear Data Evaluation Co-operation (WPEC), in close co-operation with the International Atomic Energy Agency (IAEA) connecting British expertise with programmes worldwide. This

“The IAEA Nuclear Data Section works with Member States and partner institutions worldwide to build the accessible, trusted nuclear data resources that researchers and decision-makers rely on. Our collaboration with UKNNL is one valuable example of that work, contributing to a nuclear data ecosystem that underpins scientific discovery and innovation across reactor systems, fusion and medical applications.”



Professor Tzanka Kokalova Wheldon
Director, Division of Physical
and Chemical Sciences,
IAEA

global network ensures that UKNNL scientists understand not just how to use nuclear data but also how these are produced, checked and validated.

The laboratory has also developed specialist tools that take advantage of nuclear data libraries to support the nuclear industry.

FISPIN,¹ a depletion and isotopic inventory code used in the UK nuclear industry since the 1970s, which has continued to be improved and developed over the years, calculates how material composition changes during and after irradiation.

This has been essential for supporting operations at Sellafield and across the wider fuel cycle. Meanwhile, the newly developed Computational Assessment of Radionuclide Production (CARP) helps optimise medical radioisotope production by calculating the best conditions for specific nuclear reactions.

Nuclear data in action: Powering developments in nuclear medicine

Hospitals increasingly rely on radioactive isotopes for diagnosing and treating diseases, particularly cancers. Traditionally, these isotopes were produced in nuclear reactors, but many of these facilities are ageing and expensive to replace.

New production methods, including particle accelerators, offer alternatives, but they require fine-tuning by scientists to calculate which nuclear

reactions, which energy ranges and which intensities will most efficiently produce the desired medical isotopes while minimising unwanted byproducts.

At UKNNL, we are currently co-leading a pioneering project with Medicines Discovery Catapult that uses an isotope called lead-212 to perform targeted alpha therapies. This is a new type of radiopharmaceutical treatment that can effectively target and

destroy cancer cells with minimal damage to healthy tissue.

The work is supported by nuclear-data-based calculations to accurately predict the outcome of the nuclear reactions involved in the radioisotope production and the composition of the target. This helps in making the best choices when tuning the instruments and feeding the information needed to the chemistry specialists.



Professor James Benstead
Theoretical Scientist,
AWE

“ Nuclear physicists from AWE and UKNNL interact regularly in the field of nuclear data, where UKNNL’s expertise is widely recognised. In recent years, these interactions have focused heavily on the sharing of knowledge and best practice within the field, including addressing capability gaps – such as in data evaluation – within the larger UK community. These exchanges will play an important role in strengthening the foundations of the UK nuclear sector during a key period of renewal. ”

¹ Spent nuclear fuel inventory code suite developed by UKNNL. It calculates the changes in the numbers of atoms of the nuclides of various species – heavy isotopes or actinides, fission products, and structural or activation materials – as a sample of material is subjected to periods of irradiation and cooling. It is a ‘point’ code: the whole sample is subject to the same irradiation conditions.

A case of priorities: Demystifying graphite irradiation

Advanced reactor development is a perfect example of the need for constant improvements in nuclear data. This development illustrates the importance of ensuring that we prioritise the data most likely to support the novel technologies needed for the UK’s energy transition.

Advanced reactor designs differ significantly from those of their predecessors, with different fuel types, moderators, structural materials, coolants, cladding and operating conditions, all of which results in additional nuclear data needs.

For example, high-temperature gas reactors (HTGR) operate at higher temperatures than current operating reactors, so there needs to be nuclear data available for this temperature range and for the materials used.

Specifically, the performance of the graphite, which makes up most of the materials in the core and is a large component of the coated particle fuel, has been noted to perform slightly differently in experiments compared with simulations.

Improved nuclear data based on new reactor-grade graphite measurements for HTGR operations are required to improve safety, reliability and economic viability. Owing to the competitive nature

“ The OECD Nuclear Energy Agency greatly values the deep technical expertise that UKNNL brings to international nuclear data development.

“ Recent UKNNL contributions include the provision of fission-yield data for the Joint Evaluated Fission and Fusion (JEFF-4.0) library, significantly enhancing the accuracy and consistency of fission-product inventory predictions across reactor applications, alongside the development of application-specific nuclear data libraries that underpin the development and safety assessment of nuclear systems.

“ Through UKNNL’s long-standing involvement in the JEFF library and the Working Party on International Nuclear Data Evaluation Co-operation (WPEC), UK experts provide high-value scientific contributions that strengthen the robustness and relevance of nuclear data for all NEA members and the wider international community. ”



Dr Tatiana Ivanova
Head of Division of Nuclear Science and
Education at the Nuclear Energy Agency (NEA)

of advanced reactor designs, it is important for the UK to have a voice in nuclear data communities, to push these measurements up the UK and international priority lists.

The interactions with the reactor core with part-per-billion (ppb) levels of corrosion products that are gradually released from circuit pipes is, at first glance, a subtle phenomenon.

However, owing to the extremely high mass transport in a pressurised water reactor, this effect can dominate the

production of operational radiological wastes and worker doses for commercial power plants. Mitigations are being developed by the industry to optimise their effectiveness and to support their application to new classes of material.

As well as experimental investigations, another key area is the numerical modelling of this effect on fuel deposit chemistry at microscopic scales. Enabling a link between experimental studies and simulation is a priority of the programme.

What the future holds

Nuclear data might remain invisible to most people, but its already strong relevance will only grow as the UK pursues its clean energy ambitions. Advanced reactors will push calculations into new fields not previously explored.

Decommissioning programmes will require precise predictions for materials never previously characterised. Medical applications will demand ever-more-targeted isotopes and more convenient production paths.

UKNNL's investment in nuclear data capability through international collaboration, tool development and training the next generation ensures that the UK will have the solid foundation and the tools needed to meet both today's and tomorrow's challenges.

A sound pyramid needs a solid base

