Applications of nuclear data to fusion material engineering

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Nuclear data, describing particle (including neutron) interactions, reaction probabilities (cross sections) and decay behaviour, and the inventory and transport codes that use them, are critical to the design and operation of fusion experiments and future fusion power plants. For materials, predictions of transmutation, including gas production, and neutron-induced displacement damage rates, are part of the integrated modelling needed to understand performance evolution, degradation and lifetimes.

Nuclear data and codes are most often used to predict radiation fields and materials activation because these are needed to plan the safe operation, maintenance and decommissioning of nuclear devices. For example, simulations with inventory codes such as FISPACT-II are routinely utilised to support the prediction of ex-vessel gamma doses and radioactive waste arising for designs of EU-DEMO, often driving changes in material selection and shielding configurations. Similarly, nuclear simulations are providing the radiation field predictions needed to plan the decommissioning of JET. These same simulations can also support predictions of material failure mechanisms, such as embrittlement due to gas generation, changes in properties due to build-up of transmutation impurities. Gas generation quantification plays directly into designs for novel microstructures where precipitate phases absorb gas products inter- and intra-granularly. Meanwhile, the same nuclear reaction data used in inventory and transport simulations can also be employed to probe structural damage evolution, including being used to predict gamma-induced damage evolution and provide the source terms – as energy distributions of primary knock-on atoms or PKAs – for modelling of irradiation cascades.

In this presentation, we discuss these critical applications of nuclear data and simulations to fusion material development and selection, and fusion reactor engineering. We also discuss how the validation and uncertainty quantification in nuclear data and code predictions is an ongoing challenge, despite notable successes, requiring further effort within the community.

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