Theory-based integrated modelling of impurity transport: from the validation on ASDEX Upgrade experiments to ITER predictions

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Impurities play important roles in fusion plasmas, from the beneficial impurity seeding to dissipate excess power at the edge to the deleterious fuel dilution and radiative cooling in the core. The recent plan of ITER to transition to a full tungsten (W) wall highlights the importance of predicting the behavior of impurities.

A theory-based integrated modelling framework for the coupled evolution of tokamak plasmas with multiple impurities and their radiation [1] is presented. It includes all relevant effects presently identified in local quasi-linear turbulent and neoclassical impurity transport theories. The ASTRA transport suite [2] couples the STRAHL impurity code [3] to TGLF-SAT2 [4] and FACIT [5], the models used to calculate turbulent and collisional transport.

This workflow is validated against ASDEX Upgrade experiments, including L-modes with and without impurity seeding and H-modes with electron and ion cyclotron heating power ramps. Emphasis is placed on impurity-related features that will be important for reactor operation, such as strongly seeded plasmas [6] and the application of central wave heating to prevent core W accumulation [7]. Simulations of ITER scenarios are then performed, to assess how the transport and control of impurities will differ in the confined plasma of a fusion device with such different characteristics as current machines. Predictions of W transport in the baseline 15 MA H-mode scenario at different levels of central electron cyclotron heating are presented, along with the behavior of W during the current ramp-up in L-mode, and reduced current and field in H-mode. Differences and similarities between the transport regimes of ITER and present devices, and the different phases of an ITER discharge, are discussed in the context of impurity physics. Several missing elements which are still present and produce uncertainties in the predictions are pointed out.

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