EFTC 2017
17th European Fusion Theory Conference
9 - 12 October 2017, Athens - Greece

Impurities in a Reactor

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In a future fusion reactor the occurrence of plasma impurities pose a challenge as they lead to dilution and increased energy losses via radiation. However, for power exhaust the impurity radiation including that in the main plasma may be a crucial ingredient. The fact that impurities may be beneficial and detrimental for the plasma implies that in a reactor a compromise needs to be found.

In order to evaluate the appropriate impurity level, an important ingredient is a set of high quality atomic data, which can be used to evaluate the cooling efficiency, i.e. the cooling factor L_Z, of an impurity. For the present work, a unique set of cooling factors for 35 elements from hydrogen ($Z = 1$) to bismuth ($Z = 83$) was available. All data has been calculated using the same codes and approximations for all elements. On these grounds the ensemble may be labelled 'consistent'.

Using these data, the optimal impurity level is evaluated with four reactor models varying in complexity. The simplest model is a 0D power balance and is quickly applicable to all sorts of fusion reactors. The most complex model is focusing on the EU DEMO1 2015 design. The comparison between the models yields insights into the effect of various simplifications and demonstrates the following:

- The consideration of plasma profiles instead of a 0D model (Lawson criterion) always reduces the concentration of the optimal impurity level.
- The radial profiles of impurities and electrons including the divertor compression are sensitively influencing the operational window of a reactor.
- Low-Z impurities - intrinsic or seeded - should be avoided because the related dilution is significantly diminishing the performance of a power plant.
- For core temperatures above 20 keV, the cooling factors of high-Z radiators support optimized power exhaust at good core performance.
- The transport and confinement of helium may reduce the fusion yield of a reactor plasma and requires attention.

Following the discussion of the above models, modifications of the operational window due to impurity transport are discussed. For comparison, experimental findings on impurity transport in today's fusion experiments are extrapolated to a reactor plasma.