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The role of atomic and molecular physics for dissipative divertor operation in helium and deuterium plasmas[1]

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Recent experiments in DIII-D helium plasmas are examined to resolve the role of atomic and molecular physics in major discrepancies between experiment and modeling of dissipative divertor operation. Helium operation removes the complicated molecular processes of deuterium plasmas that are a prime candidate for the inability of standard fluid models (SOLPS, UEDGE) to reproduce dissipative divertor operation, primarily the consistent under-prediction of radiated power. With helium fueling, a high-recycling divertor was established with divertor densities increasing to $\mathrm{n}_{e,div} \geq 3 \times 10^{20} m^{-3}$ and temperatures decreasing to $\mathrm{T}_{e,div} \leq 2$ eV as measured by divertor Thomson scattering (DTS). The electron pressure, $p_{e,div}$ decreased gradually with increasing density to less than 30% of the low density value. However, the ion flux to the divertor target did not decrease until the highest densities and lowest temperatures, $\mathrm{T}_{e,div} \leq 2$ eV. In contrast, with deuterium operation, increasing density leads to a rapid transition from $\mathrm{T}_{e,div} \geq 10$ eV to $\mathrm{T}_{e,div} \leq 3$ eV, though both $p_{e,div}$ and ion flux do not decrease until $\mathrm{T}_{e,div} \leq 2$ eV. These differences indicate an important role for molecular and atomic physics in the dynamics of divertor dissipation. Initial SOLPS modeling has reproduced n_e and T_e profiles at the midplane and divertor target, as well as the spatial structure of radiation patterns measured in moderate density helium plasmas. However, the modeled divertor radiation is less than measured, similar to deuterium simulations, suggesting processes more universal than species-specific atomic or molecular physics may be the source of radiation deficit. Detailed assessments of n_e, T_e profiles in the divertor volume, uniquely determined at DIII-D using DTS, are made along with analysis of measured and modeled line radiation to shed more light on these intriguing findings.

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