Radiative losses of alpha particles on tungsten impurities in thermonuclear plasmas

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A new channel of radiative losses related to collisions of fast alpha particles with tungsten impurity ions is under consideration. The standard plasma radiative losses channel is connected with electron-impurity ions collisions. The large tungsten nuclear charge withholds the significant number of bound electrons up to high plasma temperature values (20-30 keV for ITER plasma condition). The high energy of alpha particle makes possible the effective collisional excitation of multielectron tungsten impurity ions. The radiative losses of electrons \(Q_e\) and alpha particles \(Q_\alpha\) and their ratio \(R^{(1)}\) are expressed in terms of electrons and alpha particles densities as well as reduced losses per one impurity ion and per one impact particle as following.

\[
Q_\alpha = N_\alpha N_w q_\alpha \\
Q_e = N_e N_w q_e \\
R^{(1)} = \frac{Q_\alpha}{Q_e} = \frac{q_\alpha}{q_e} \frac{N_\alpha}{N_e}
\]  

(1)

The alpha particle velocity \(v\) distribution function is determined by the total power in d-t reaction \(P_{dt}\) and relaxation time \(\tau_s\) (taken for typical ITER plasma conditions [1])

\[
f_\alpha = \frac{p\tau_s}{v' + v_s}, \quad p = P_{dt} / E_\alpha(3.5\text{MeV}) \approx 0.5 (\text{MW/m}^3) / 3.5 (\text{MeV}) \approx 10^{18} \text{m}^{-3} \text{s}^{-1}
\]

(2)

The \(Q_\alpha\) calculations were made in the frame of the atomic statistical model [2]. The comparison between the electron and alpha particle radiative losses is presented in fig 1. It is shown that the alpha particle radiative losses can be comparable with electron ones.

References

[1] A. Polevoi, ITER IDM, ITER_D_2WBNP5 v1.0