

§10. Atomic and Molecular Processes with Lithium in Peripheral Plasmas

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Lithium has been proposed as a plasma-facing wall material because of its low nuclear charge, low induced radiation loss, and advantage on facilitating heat and particle exhaust¹⁻³. Many experiments have been performed in which Li was introduced into fusion devices by pellet injection⁴ and lithium aerosol injection⁵ aiming for improved confinement. Introduced lithium vapor would be transported to divertor plates along the magnetic field lines and would cover the plate. It is important to know the lithium behavior in divertor and peripheral regions for diagnostics of Li particles and we need to know atomic and molecular processes of lithium.

Lithium chemistry has examined for the early Universe (e.g. ref.6) and atomic and molecular data were evaluated and estimated for chemical network calculations. In this work we examine the lithium chemical network in peripheral plasmas⁷. The element components of the simple model for peripheral plasmas are similar to that of the early Universe and we can use the same atomic and molecular processes.

Here we make a lithium chemical network model with the simplest components, electron, Li, and H, to apply to peripheral plasmas. Figure 1 shows the reaction network considered in the model. In peripheral plasmas, photon induced processes are not included. Atomic and molecular processes for Li colliding with e, H, H⁺ and H⁻ are considered. Collisions with H₂ are not taken into account since there are not enough data of rate coefficients. Charge transfer process between Li ions and H⁰ are important, however, there are not cross section data for low collision energy region, less than 1eV.

We performed a time-dependent calculation of particle densities of Li, Li ions, LiH and LiH⁺ by solving rate equations

$$\frac{dn(i)}{dt} = \sum_j W(i,j)n(j) \quad (1)$$

where $n(i)$ is the number density of i -th component (Li, Li⁺, Li²⁺, Li³⁺, Li⁻, LiH, and LiH⁺) and $W(i,j)$ is reaction rate with which i -th component is produced from j -th component. All reactions in the chemical network in Figure 1 are considered. Here we assume plasma is uniform with uniform temperature and density and the effects of particle diffusion or particle production from wall materials are ignored for simplicity. As a simple case for a peripheral plasma model, we solve eq. (1) with $n_e = n_{H_2} = 2 \times 10^{12} \text{ cm}^{-3}$, $n_H = 3 \times 10^{10} \text{ cm}^{-3}$, $n_{H^+} = n_e$, $n_{H^-} = 4 \times 10^9 \text{ cm}^{-3}$, $T_e = 1 \text{ eV}$, which are picked up from the result of the 3 dimensional numerical simulation of neutral particle transports for peripheral region of LHD plasma⁸. Ion temperatures are

assumed to be the same as the electron temperature. Total number density of Li is assumed as 10^7 cm^{-3} . As an initial condition, we set all Li particles are neutral and there are no ions and no molecules. Figure 2 shows time evolution of fractional abundance of Li ions and LiH molecules as a function of time. All the fractional abundances reach steady state by 1s. The timescale for the decrease of the neutral Li number density can be estimated about $1.07 \times 10^{-5} \text{ s}$ with the rate coefficients of related reactions and this can roughly explain the behavior of the fractional abundance of neutral Li in Fig. 2. LiH molecules are produced from neutral Li at first, then from Li⁺. The final fractional abundance of neutral LiH is 1.99×10^{-5} at $t=1 \text{ s}$.

For more realistic model calculations of peripheral plasmas, we need to consider diffusion and particle production due to plasma-wall interaction in Eq. (1), and also need much more atomic and molecular data for the Li chemistry.

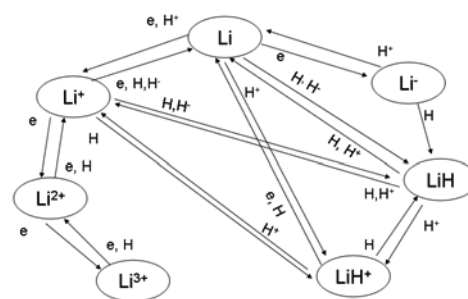


Fig. 1. Chemical reaction network for lithium.

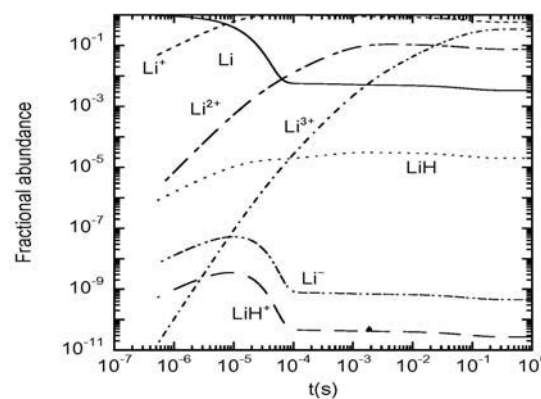


Fig. 2. Fractional abundance of Li ions and LiH molecules for low temperature plasma.

- 1) Hogan, J. T., et al., Nucl. Fusion **37** (1997) 705.
- 2) Pistunovich, V.I., et al., J. Nucl. Mater. **248** (1997) 85.
- 3) Evitikhin, V.A., et al., Plasma Phys. Control. Fusion **44** (2002) 955.
- 4) Kugel, H.W., et al., Phys. Plasmas **15** (2008) 056118.
- 5) Mansfield, D.K., et al., Nucl. Fusion **41** (2001) 1823.
- 6) Lepp, S., et al., J. Phys. B **35** (2002) R57.
- 7) Murakami, I. et al., Fusion Eng. Design **85** (2010) 854-857.
- 8) Sawada, K., Report on JSPS Grant-in-Aid for scientific research No.15540470 (Japanese), 2007.