The inductively coupled plasma etcher shown below is used to etch silicon. Your assignment is to determine the power required to obtain an etch rate of 1 μm per minute. The input feed gas is 1 mtorr of CF₄, and plasma species are pumped out of the chamber through a 10 cm diam. pump port. For this exam, you may assume that any particle that enters the pump port is removed from the plasma.

The important species in this plasma are shown in the figure above. The rate constants for their generation are:

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\begin{align*}
&\text{e} + \text{CF}_4 \rightarrow \text{CF}_3^+ + \text{F} + 2\text{e} & K_{i2} = 1.5\times10^{-8} \exp(-16/T_e) \text{ cm}^3\text{s}^{-1} \\
&\text{e} + \text{CF}_4 \rightarrow \text{CF}_3 + \text{F} + \text{e} & K_{D3} = 2\times10^{-9} \exp(-13/T_e) \text{ cm}^3\text{s}^{-1} \\
&\text{e} + \text{CF}_4 \rightarrow \text{CF}_2 + 2\text{F} + \text{e} & K_{D2} = 5\times10^{-9} \exp(-13/T_e) \text{ cm}^3\text{s}^{-1} \\
&\text{e} + \text{CF}_4 \rightarrow \text{CF}_2^* + \text{e} & K_{ex} = 2\times10^{-9} \exp(-12/T_e) \text{ cm}^3\text{s}^{-1} \\
&\text{e} + \text{CF}_4 \rightarrow \text{CF}_4 + \text{e} & K_{el} = 1\times10^{-7} \text{ cm}^3\text{s}^{-1} \\
&\text{CF}_3^+ + \text{CF}_4 \rightarrow \text{CF}_3^+ + \text{CF}_4 & \sigma_i = 3\times10^{-14} \text{ cm}^2
\end{align*}
\]

As usual, ions and electrons recombine only at the reactor surfaces. Assume that CF₃ and CF₂ stick to all surfaces with unity probability. F atoms stick to the wafer with unity probability, but are reflected from the walls of the reactor. Because the gas pressure is low, 3-body recombination may be ignored.

Use a simple etch model similar to that of eqs. (15.3.16) and (15.3.17). These equations will need to be modified to account for the existence of CF₂ and CF₃ in the plasma!