Hall thruster used as molecular gas dissociator

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Outlines

- Molecular Propellants
- HT used as gas dissociator
- H2 chemistry
- H/H2 gas Monte Carlo model in a frozen plasma
- Results
Why using alternative molecular propellants

Usually not an optimum choice in terms of thrust.

Nevertheless, potential applications include:
- the use/transformation of waste products in manned spacecraft
- the use of propellant residuals in chemically propelled spacecraft
- the use of propellants that are directly available in space (CO$_2$ from Mars/Venus atmosphere or from waste product of crewed missions and ISS)

Another possible reasons for investigating molecular propellant is to use HT as gas dissociator to:
- produce hot atoms for negative ion conversion on Caesiated grid
- produce atoms for Passive Hydrogen maser used as atomic clock
H₂ Chemistry: e-induced dissociation channels

H Atom e-induced production channels:
- dissociation \( e - H₂(v) \rightarrow H₂^* \rightarrow H(m) - H(n) \) \([E_H=3 \text{ eV}]\)
- dissociative ionization \( e - H₂(v) \rightarrow H(m) - H^+ \) \([E_H=0.5 \text{ eV}]\)

R. Celiberto et al., At. Data Nucl. Data Tables 77, 161 2001
H₂ Chemistry: dependance from initial vibrational level

H Atom e-induced production channels:
- dissociation  
  \[ e - H_2(v) \rightarrow H_2^* \rightarrow H(m) - H(n) \]  
  \[ E_H=3 \text{ eV} \]
- dissociative ionization  
  \[ e - H_2(v) \rightarrow H(m) - H^+ \]  
  \[ E_H=0.5 \text{ eV} \]
H$_2$ Chemistry: ion-induced dissociation channels

While the corresponding ion-induced vibrational excitation of molecules can be considered negligible in comparison to the electron-induced counterpart (adiabatic Massey parameter $P_{Ma} = \Delta E/h\nu$), the possible ion-induced dissociation processes

- **CX** $\text{H}^+ - \text{H}_2(v) \rightarrow \text{H} - \text{H}_2^+$
- **H$^+$-induced dissociation** $\text{H}^+ - \text{H}_2(v) \rightarrow \text{H}^+ - 2\text{H}$
- **H$_2^+$-induced dissociation** $\text{H}_2^+ - \text{H}_2 \rightarrow \text{H}^+ - \text{H} - \text{H}_2$

have cross sections 2 order of magnitude larger than electron-induced dissociation. Therefore, one can thing using electrons to creates vibrational excited molecules-precursors and ions to dissociate them.

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P. Krstic, PRA 66, 042717, 2002
Preliminary Results with a gas MC-frozen plasma code

- 3D Monte Carlo gas dynamics/kinetics in fixed plasma background
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![Graph showing gas density n (m^-3) vs. z (m) with different species and vibrational states.]
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![Graph showing electric potential and reaction rate coefficients](image)

- Anode
- Exit Plane

**SPT-100 (P=1.3 kW)**

**Electric Potential**

- molecular ionization
- dissociation
- dissociative ionization

**Reaction rate coefficient k (m³/s)**
Conclusions

- Importance of molecular propellants
- Numerical model able to resolve vibrational kinetics
- Plasma-gas coupling
- First results with a maxwellian plasma background