Studies of interaction between Ion and atom/molecule at Fudan University

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Outline

➢ Experimental setup at Fudan University

➢ Experiment result

➢ New Project: Cross section measurement
Experimental setup
**Experimental setup**

H, C, N, O and inert gas beams could be supplied.

Beam energy: 5~150 qkeV.

Beam current: nA ~ μA.
Experimental setup

1. ECR ion source
2. Magnetic analyzer
3. Faraday cup
4. Slit
5. Deflectors
6. Movable Faraday cup
7. Cold gas target
8. TOF spectrometer
9. Position-sensitive detector
10. Electrostatic analyzer
Experimental setup

$x, y \rightarrow$ 横向动量
TOF $\rightarrow$ 纵向动量

Recoil Ion

trajectory

Extraction Field

Beam

Detector

$x, y$

TOF
Experimental setup
Experiment with HCl

120 keV Ar$^{8+}$ - CH$_4$
Experiment with HCl

\[ \text{CH}_4^{2+} \rightarrow \text{CH}_2^+ + \text{H}^+ + \text{H} \]

\[ \rightarrow \text{CH}_3^{+*} + \text{H}^+ \rightarrow \text{CH}_2^+ + \text{H}^+ + \text{H} \]

\[ \rightarrow \text{CH}_2^+ + \text{H}_2^{+*} \rightarrow \text{CH}_2^+ + \text{H}^+ + \text{H} \]

Synchronous concerted

Two Step

No CH$_3^{2+}$ in TOF Spectrum.
Then no reaction related CH$_3^{2+}$. 
Experiment with HCl

\[ \text{CH}_4^{2+} \rightarrow \text{CH}_2^+ + \text{H}^+ + \text{H} \]
Experiment with HCl

\[ \text{CH}_4^{2+} \rightarrow \text{CH}_3^{+*} + \text{H}^+ \]

\[ \rightarrow \text{CH}_2^{+} + \text{H} + \text{H}^+ \]
Experiment with HCl

\[ \text{CH}_4^{2+} \rightarrow \text{CH}_2^+ + \text{H}_2^+ \]

\[ \rightarrow \text{CH}_2^+ + \text{H}^+ + \text{H} \]
Experiment with HCl

$$\text{CH}_4^{2+} \rightarrow \text{CH}_2^+ + \text{H}^+ + \text{H}$$

The momentum of H depends on the fragmentation mechanism.
Experiment with HCI

Experiment with HCl

\[ \text{Ar}^{8+} - \text{C}_2\text{H}_2 \rightarrow \text{Ar}^{r+} + \text{C}_2\text{H}_2^{2+} \rightarrow \text{C}_2^+ + \text{H}^+ + \text{H} \]
Experiment with HCl

\[ \text{Ar}^{8+} - \text{C}_2\text{H}_2 \rightarrow \text{Ar}^{r+} + \text{C}_2\text{H}_2^{2+} \rightarrow \text{C}_2^+ + \text{H}^+ + \text{H} \]
Experiment with HCI
Experiment with HCI
Experiment with HCI

120 keV Ar$^{8+}$ - CH$_4$
Experiment with HCI

120 keV Ar$^{8+}$ - C$_2$H$_2$

H$^+$

C$_2$H$^+$

C$^+$ + CH$_2^+$

CH$^+$ + CH$^+$

H$^+$ + C$_2$H$^+$

CH$^+$ + CH$^+$

C$^+$ + CH$_2^+$
Experiment with $e^-$

$100 \text{ eV } e^- - C_2H_4$

$C_2H_3^+$
$C_2H_2^+$
$C_2H^+$
$C_2^+$

$H^+$
$H_2^+$
$H_3^+$
Proton migration

Ultrafast Extreme Ultraviolet Induced Isomerization of Acetylene Cations

Steering Proton Migration in Hydrocarbons Using Intense Few-Cycle Laser Fields

Ultrafast proton migration and Coulomb explosion in intense laser fields

Pan Ma, Chungheng Wang, Xiaokai Li, Xitao Yu, Xu Tian, Wei and Dajun Ding

Institute of Acids and Molecular Physics, Shanghai University, Shanghai, China.

Proton migration

Two-step mechanism

I. A long-lived neutral moiety of $\text{H}_2$ is formed.

II. The $\text{H}_2$ moiety abstracts a proton to form $\text{H}_3^+$. 

Potential-energy diagram
Given by Prof. C. Yang
Experiment with e⁻
Experiment with $e^-$

100 eV $e^-$ - NH$_3$
Cross section
Measurement of Absolute Single and Double Charge Exchange Cross Sections for Si(7–10)+ at 0.88–2.50 KeV/u Impacting He and H₂

PHYSICAL REVIEW A 96, 052703 (2017)

Single- and double-electron transfer in low- and intermediate-energy C⁴⁺ + He collisions

J. W. Gao,¹,²,* Y. Wu,¹ N. Sisourat,² J. G. Wang,¹ and A. Dubois²
Cross section

- Absolute single and double electron capture cross section

\[ \sigma_{q,q-j} = \frac{kT}{PL} \frac{qI_{q-j}}{(q-j)I_q} \]

Diagram:
- Analyzing Magnet
- Deflectors
- Gas Cell
- Analyzer
- Faraday Cup
- Slit1
- Slit2
- Detector

A\(^q^+\) beam from Accelerator
Cross section
Cross section

150 keV $\text{Ar}^{10+} \rightarrow \text{Ar}$

0.02 mTorr

0.1 mTorr
Cross section

7 kV O$^{5+}$ - CO$_2$

7 kV O$^{6+}$ - CO$_2$

7 kV O$^{7+}$ - CO$_2$

Ref I, PRA-75-032704, Ref II, PRA-63-062707
## Cross section: Experimental uncertainties

<table>
<thead>
<tr>
<th>T</th>
<th>Cell temperature change</th>
<th>0.10%</th>
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<tbody>
<tr>
<td>T</td>
<td>Temperature different about guage and cell center</td>
<td>1%</td>
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<tr>
<td>P</td>
<td>Accuracy of Capacitive manometer (MKS 627D) reading</td>
<td>0.25%</td>
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<tr>
<td>P</td>
<td>Pressure attenuation causes systematic correction errors</td>
<td>2%</td>
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<tr>
<td>P</td>
<td>Pressure fluctuation</td>
<td>3%</td>
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<tr>
<td>L</td>
<td>The efficient length of gas cell</td>
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<tr>
<td>L</td>
<td>Background particle (10^{-5}torr——10^{-7}torr)</td>
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</tr>
<tr>
<td>n</td>
<td>Relative Detection efficiency of different Position</td>
<td>6%</td>
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<tr>
<td>n</td>
<td>Statistical errors</td>
<td>2%</td>
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<tr>
<td></td>
<td>Total errors</td>
<td>9%</td>
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</tbody>
</table>
Cross section

![Graph showing cross sections with theoretical and experimental data points. The graph plots cross sections (10^-6 cm^2) against energy (E(keV/u)). Theoretical and experimental results are compared with data from various researchers such as Crandall, Phaneuf, Hansen, Ishii, Kimura, Zwally, Errea, Iwai, and Dijkkamp.]
Cross section

The absolute charge exchange cross section for HCl interaction with atom and molecule will be measured in an international collaboration.

Xinwen Ma and his Group

Hongqiang Zhang, Ximeng Chen

Linfan Zhu

Michae Roy Fogle

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科技部
复旦大学
上海市重点学科

Thanks for your attention!