The report on a visit to the Aix Marseille Université

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I studied in Prof. Christophe Jouvet group in Aix Marseille Université for 2 weeks from 4th to 14th of November 2014 by JSPS (Japan Society for the Promotion of Science) Core-to-Core program.

Purpose

My main purpose of visit to Christophe's group was to learn their electrospray (ESI) machine. We are now developing an ESI machine in our laboratory, therefore I learned how to handle the machine. For example, sample preparation, controlling electrode voltage and so on.

We measured the electronic spectra of protonated adrenaline and noradrenaline this time. These two species are a kind of catecholamine neurotransmitters. In case of catecholamine, we assume that protonation occurs at the NH_2 group, and the charge may influence the orientation of catechol OH group or protonated amino group may directly interact with benzene ring. Therefore, it is possible that the excited state dynamics of protonated species is difference from that of the neutral. Our group measured the electronic spectra of protonated dopa and dopamine last year. If we measure protonated adrenaline and noradrenaline, spectroscopy on the series of protonated catecholamines are completed.

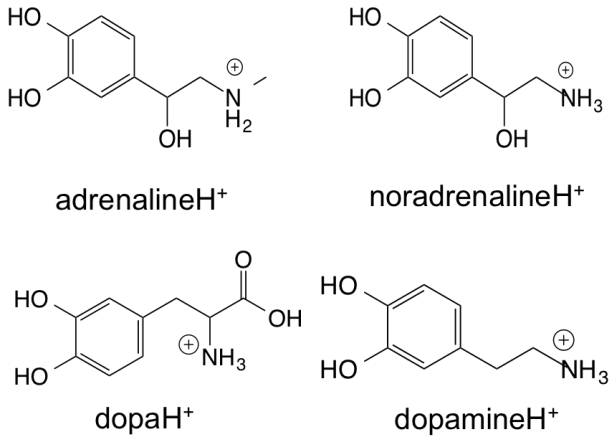


Fig 1. catecholamine neurotransmitters

Apparatus

Figure 1 shows a schematic view of the setup of the ESI machine in the Prof. Christophe Jouvet group. This apparatus adopts a linear configuration and consists of three parts, an ESI source, a cold quadrupole ion trap (QIT) and a time of flight mass spectrometer (TOF-MS).

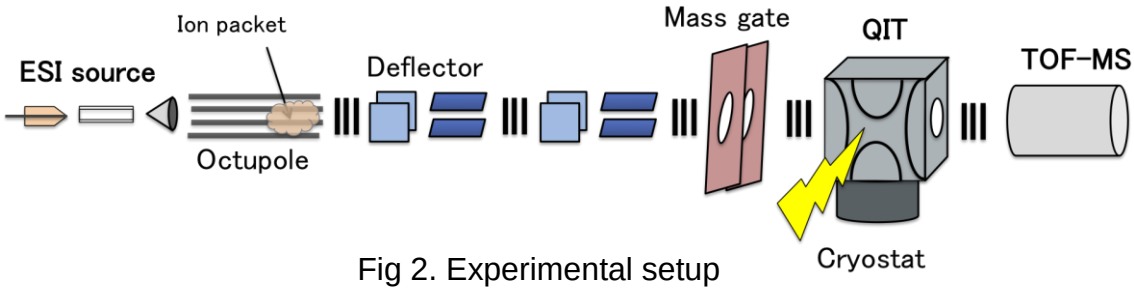


Fig 2. Experimental setup

The protonated ions are produced in the ESI source. At the exit of the capillary, ions are trapped in an octupole trap for 90 ms. They are extracted by applying a negative pulse and are further accelerated by a second pulsed voltage just after the exit electrode. This time sequence produces ion packets with a 500 ns–1 μs duration. A mass gate at the entrance of the trap allows selection of the parent ion. The ions are trapped in the Paul trap cooled by a cryostat and filled with He buffer gas injected with a pulsed valve. The ions are thermalized at a temperature around 40 K while they stay in the trap. After 60 ms, the pump UV laser is triggered to excite and dissociate the cold ions. After 30 ms, the fragments and remaining parent ions are extracted to the TOF-MS and are detected on a microchannel plate detector (MCP). In case of measuring the UV-UV HB spectroscopy, fragment ions from burn laser are removed from the trap by applying a RF voltage to the entrance endcap of QIT. The probe laser detects the depletion of fragment ions by the burn laser. Ions by the burn laser arrive at the detector earlier than ions by the probe. Therefore, we can distinguish ion signals produced by the burn laser and the probe laser. This method may be applicable to our ESI machine.

Results

[1] protonated adrenaline (adrenalineH$^+$)

Figure 3 shows the TOF mass spectra of adrenalineH$^+$ recorded with and without the UV laser. Without the UV laser, many mass peaks are observed. Those fragment ions are obtained by CID with the He buffer gas in the cold ion trap. With the UV laser, excited adrenalineH$^+$ produces a fragment ion at m/z= 139 u, which are assigned to the CH_2-NH_2-CH_3 loss.

We measured UV photodissociation (UVPD) spectra of adrenalineH$^+$ by measuring the intensity of fragment ions as shown in figure 4. UVPD spectra of adrenalineH$^+$ were obtained by monitoring five fragment channels (m= 135, 139, 163, 166 and 180 u) and the parent channel (m= 184 u).The m = 139 u ion is the dominant fragment.

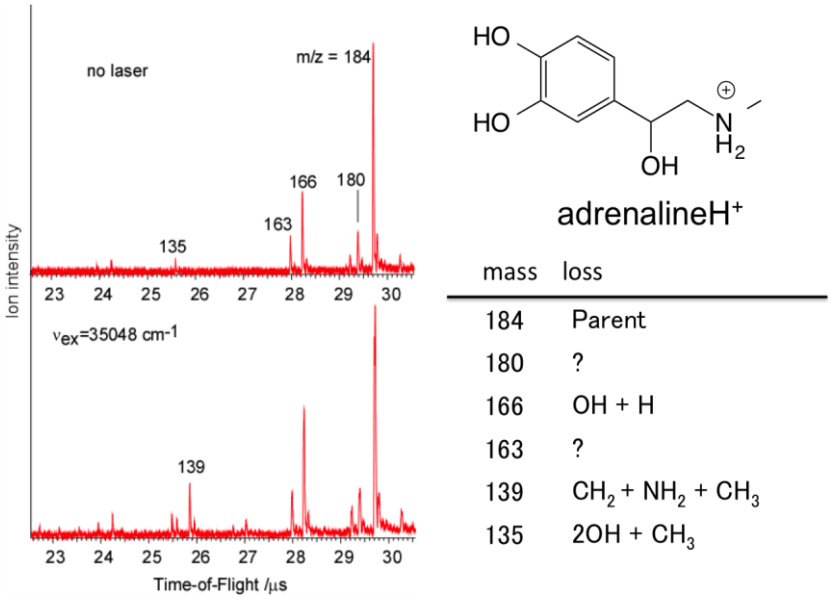


Fig 3. TOF spectra of adrenalineH$^+$

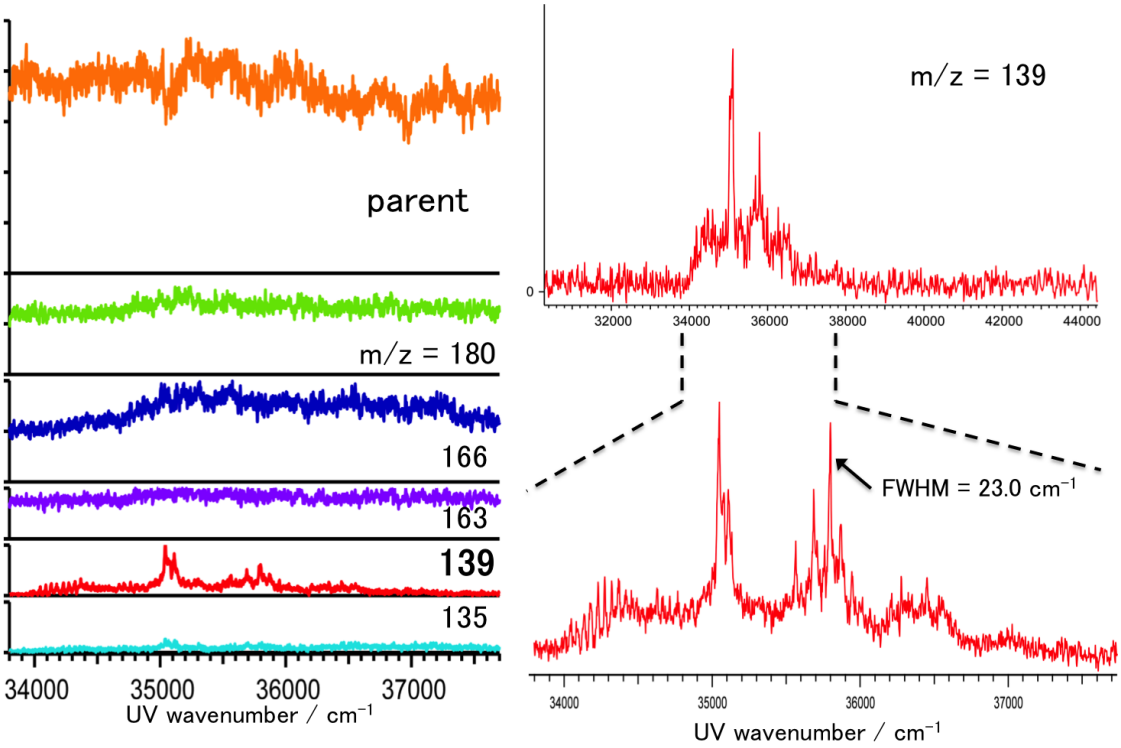


Fig 4. UVPD spectra of adrenalineH$^+$

The UVPD spectrum of adrenalineH$^+$ was very surprising, because the spectrum shows many sharp transitions while UVPD spectra of protonated dopa and dopamine are broad as shown in figure 5. Therefore, we initially expected the UVPD spectrum of adrenalineH$^+$ would be broad and UV-UV HB spectroscopy would be meaningless.

We tried to measure UV-UV HB spectra by fixing the probe laser at bands A to G as shown in figure 6. However, S/N ratio of the spectra is not high enough to assign their structures reliably. Therefore, we have to

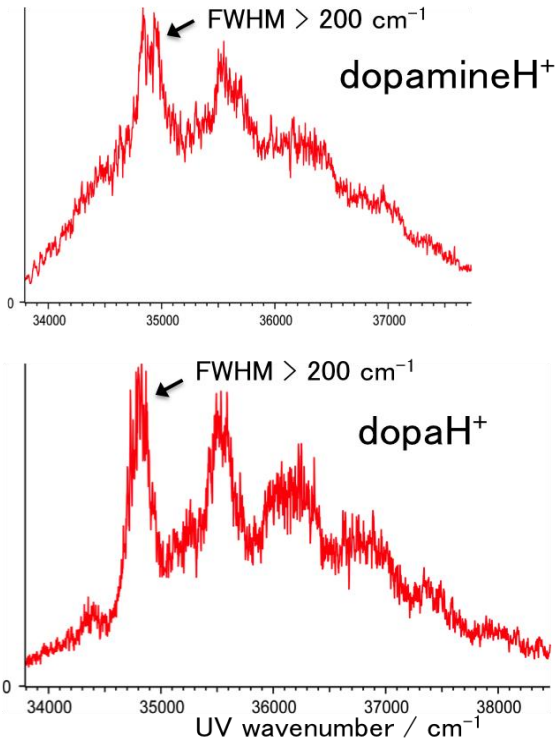


Fig 5. UVPD spectra of dopamineH$^+$ and dopaH$^+$

re-measure the HB spectra of adrenalineH$^+$.

We carried out geometry optimization of adrenalineH$^+$. The optimized structures of the eight conformers are presented in figure 7. However, we cannot determine how many conformers exist from the HB spectra. Therefore, it is difficult to determine which conformaters are responsible for the spectrum of adrenalineH$^+$ at this

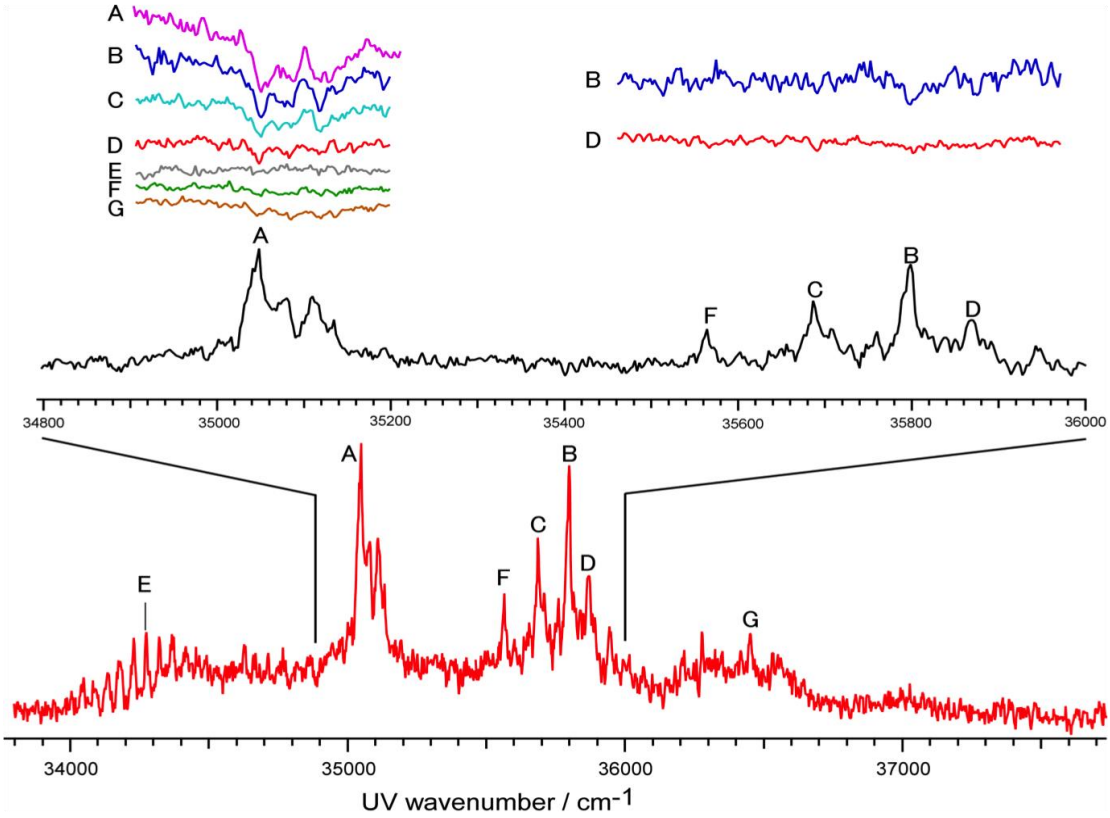


Fig 6. UV-UV HB spectra of adrenalineH$^+$

stage.

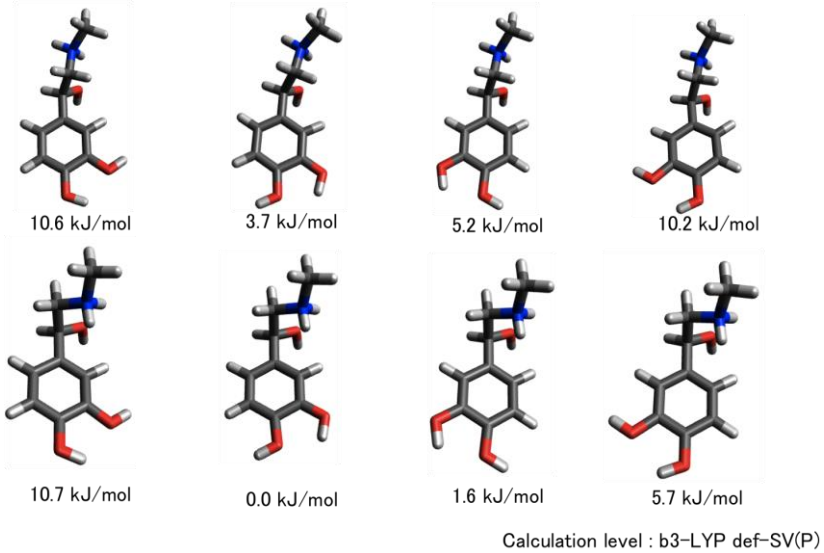
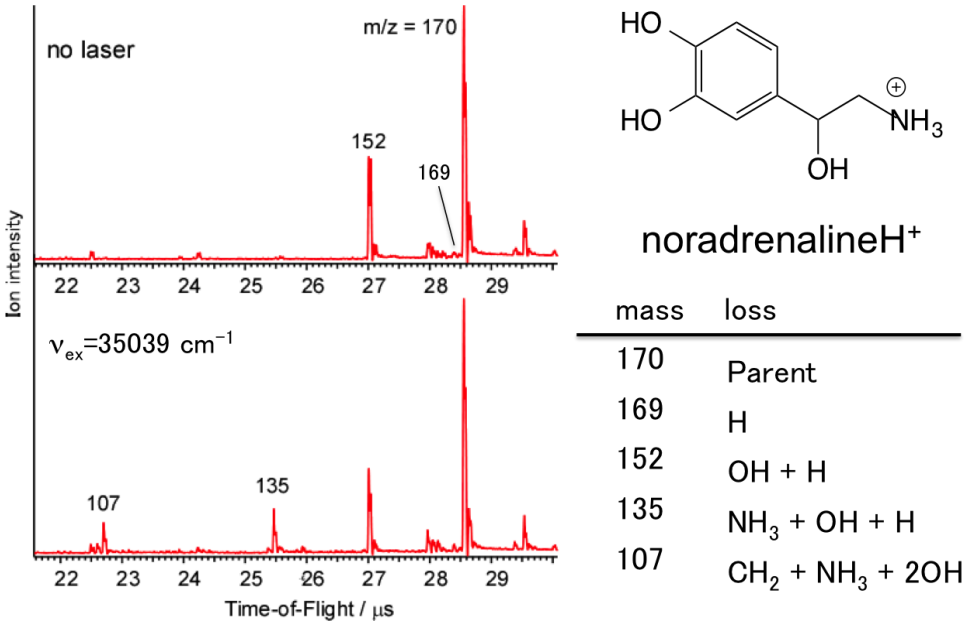


Fig 7. Most stable structures of adrenalineH$^+$

[2] protonated noradrenaline (noradrenalineH$^+$)

We also measured TOF mass spectra of noradrenalineH$^+$ recorded without and with the UV laser as shown in figure 8. With the UV laser, noradrenalineH$^+$ produces two fragment ions at m/z= 107 and135 u, which are assigned to the NH_3-OH-H loss and CH_2-NH_3-2OH loss.

Figure 9 shows UVPD spectra of noradrenalineH$^+$, which were obtained by monitoring four fragment channels (m= 107, 135, 152 and 169 u) and the parent channel (m = 170 u). The m= 135 u ion is the dominant fragment. The bandwidth of the UVPD spectrum of noradrenalineH$^+$ is sharper than that of adrenalineH$^+$.



mass	loss
170	Parent
169	H
152	OH + H
135	NH_3 + OH + H
107	CH_2 + NH_3 + 2OH

Fig 8. TOF spectra of noradrenalineH$^+$

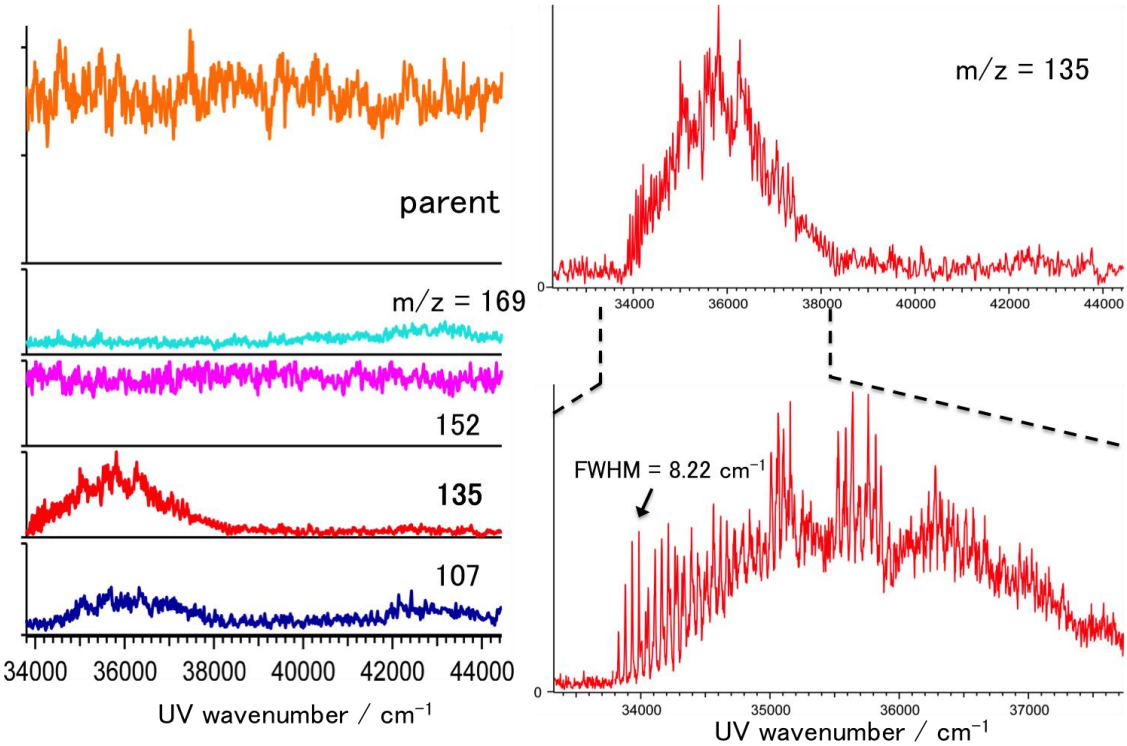


Fig 9. UVPD spectra of noradrenalineH$^+$

In protonated tryptophan, the UVPD spectrum is very broad, and Kang and coworkers measured lifetime of the excited state is 380 fs [1]. On the other hand, bands in the UVPD spectrum of protonated tyrosine is very sharp, and they measured the lifetime is 22.3 ps [1]. From those results, Ishiuchi and coworkers assumed the lifetime of protonated dopa and dopamine are from 0.1 to 10 ps [2] .In the similar way, I assumed that the lifetime of adrenalineH$^+$ and noradrenalineH$^+$ are from a few ps to several tens of ps.

Conclusion

We learned how to handle the ESI machine and measured the UVPD spectra of adrenalineH$^+$ and noradrenalineH$^+$. From the UV-UV HB spectroscopy and quantum chemical calculations, we tried to assign to conformers. However, quality of the HB spectra was not high enough to determine number of stable conformations of the protonated adrenaline. Therefore, we have to re-measure HB spectra again probably in our lab. using the new ESI apparatus that we are now constructing.

References

[1] H. Kang et al., PCCP **7** (2005) 394.

[2] Ishiuchi et al., The 8th annual meeting of Japan society for molecular science (2014) 4P014.