

Fluorescence Spectroscopy of Formaldehyde for Carbon-14 Isotope Separation

Yonghee KIM, Lim LEE, Taek-Soo KIM, Kwang-Hoon KO and Yongho CHA

Quantum Optics Research Division, Korea Atomic Energy Research Institute



Background

Carbon-14 waste recycling

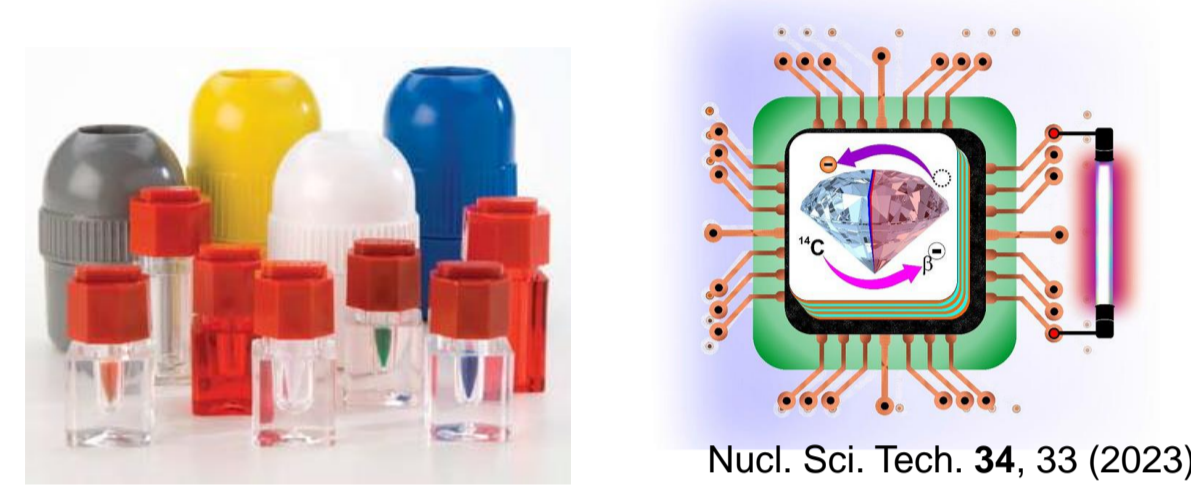
- C-14 waste in Nuclear Power Plants
- Irradiated graphite (as moderator in HTR)
- Spent ion-exchange Resin (in heavy water reactor)



C-14 Enrichment > 90~95 %

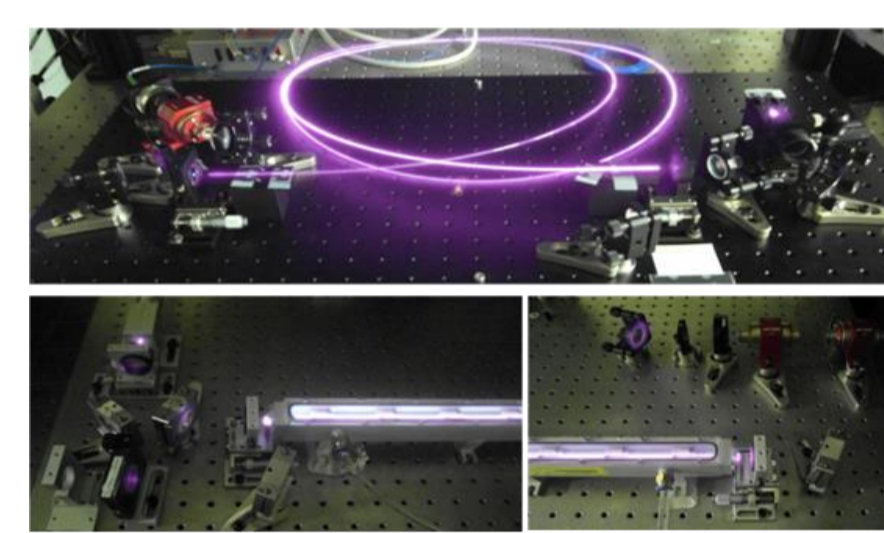
Radioactive waste reduction

C-14 labelled compounds
C-14 nuclear battery



ALSIS (Advanced Laser Stable Isotope Separation) Technology

- Unique original technology in KAERI
- High power fiber-laser system based method
- Using the selective photo-dissociation of formaldehyde (CH₂O)
- High isotope selectivity and energy efficiency
- Already demonstrate for C-13, O-17, O-18 → commercialize



Fiber laser system

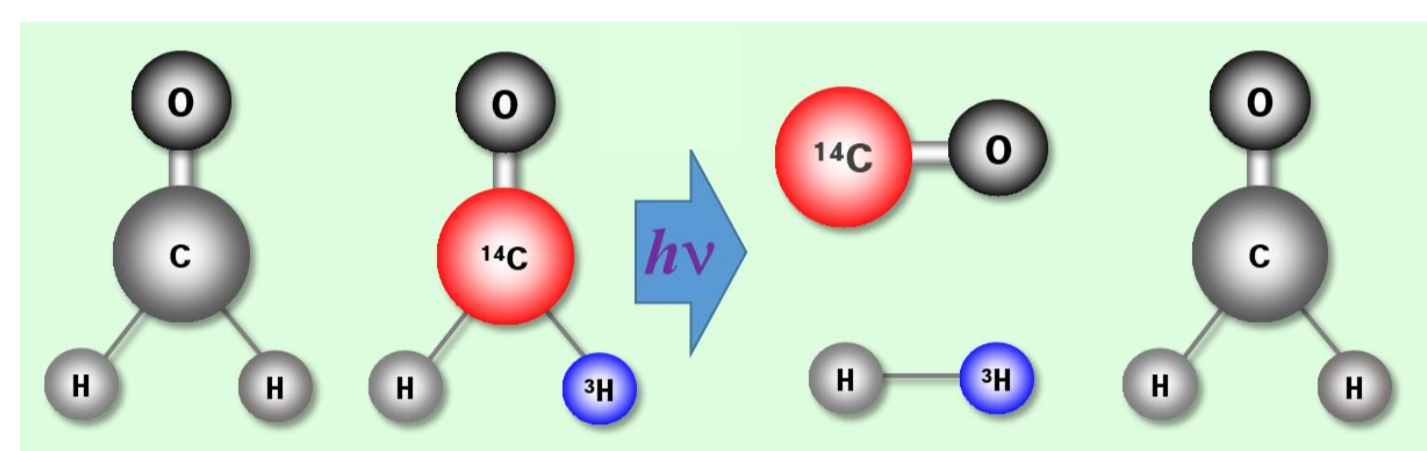


O-18 water

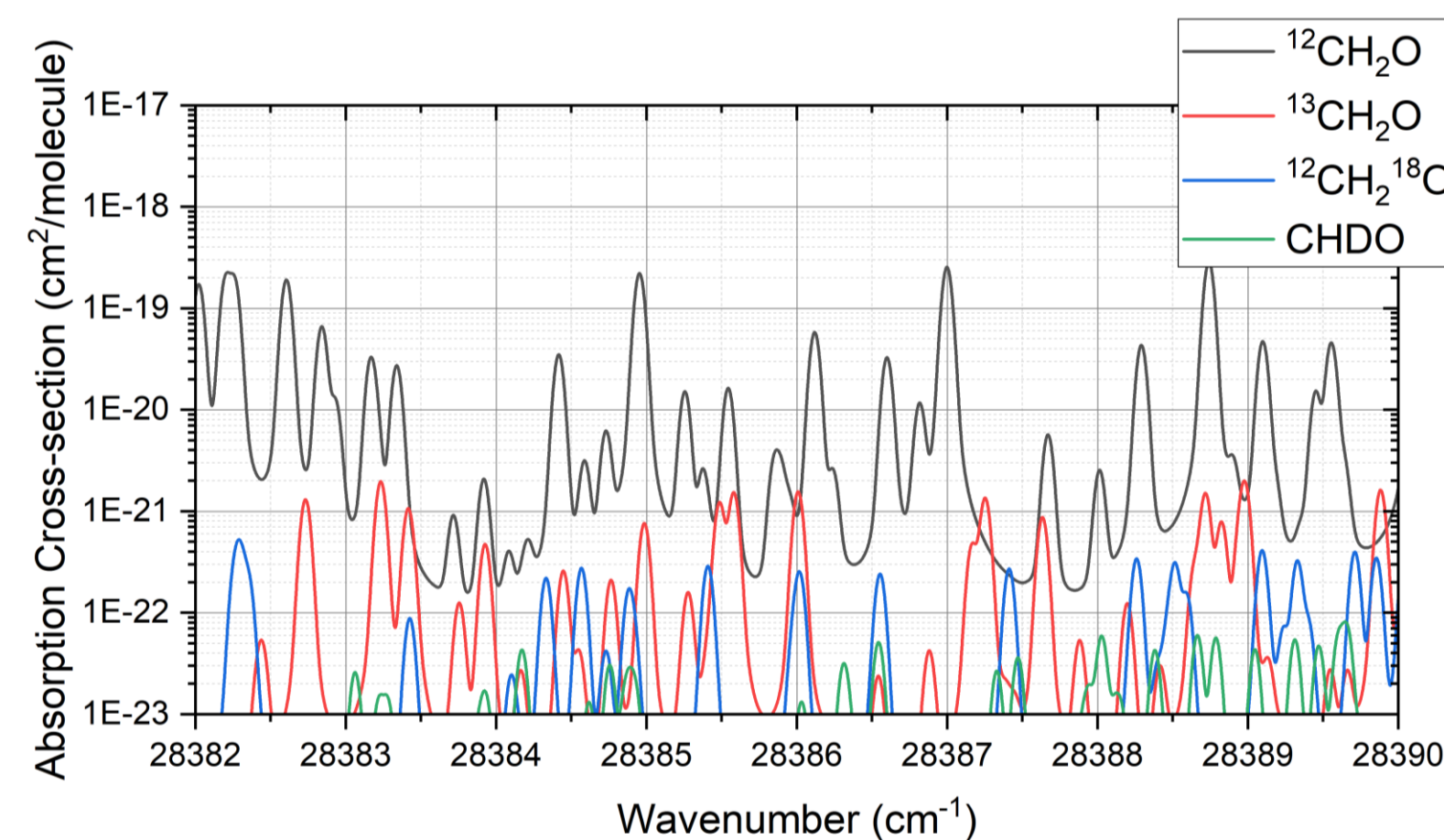
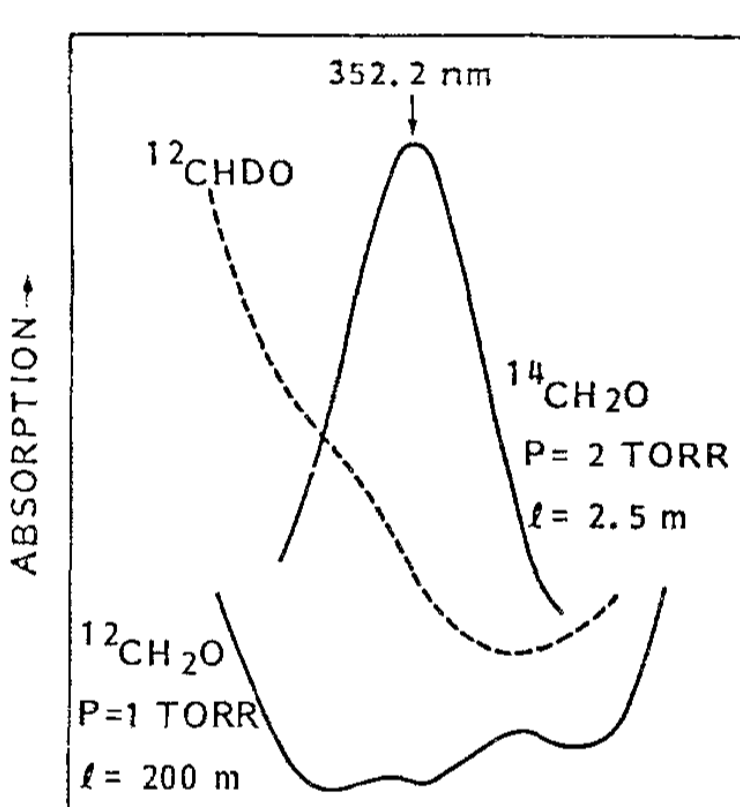
Experimental Design

* Goal

: Find the optimal wavelength for C-14 formaldehyde photo-dissociation



Appl. Phys. B 37, 79 (1985)



- Photo-dissociation of 14C-formaldehyde is reported at 1985.
- Resolution of reported spectrum is too low!

1. Need high resolution spectrum for ¹⁴CH₂O ~ few hundred MHz
2. Find the optimal wavelength.

* Problems

: C-14 formaldehyde is radioactive chemical.

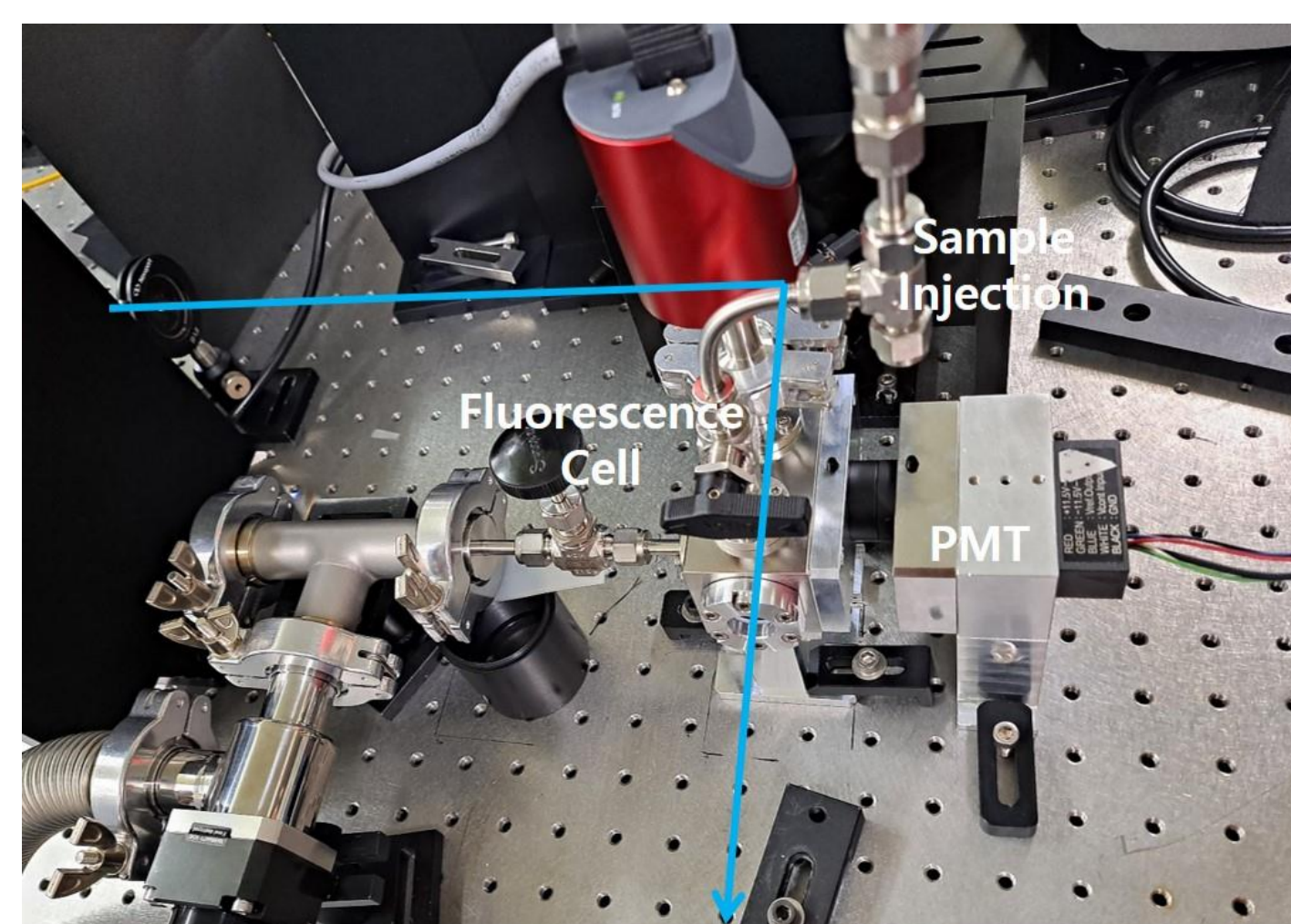
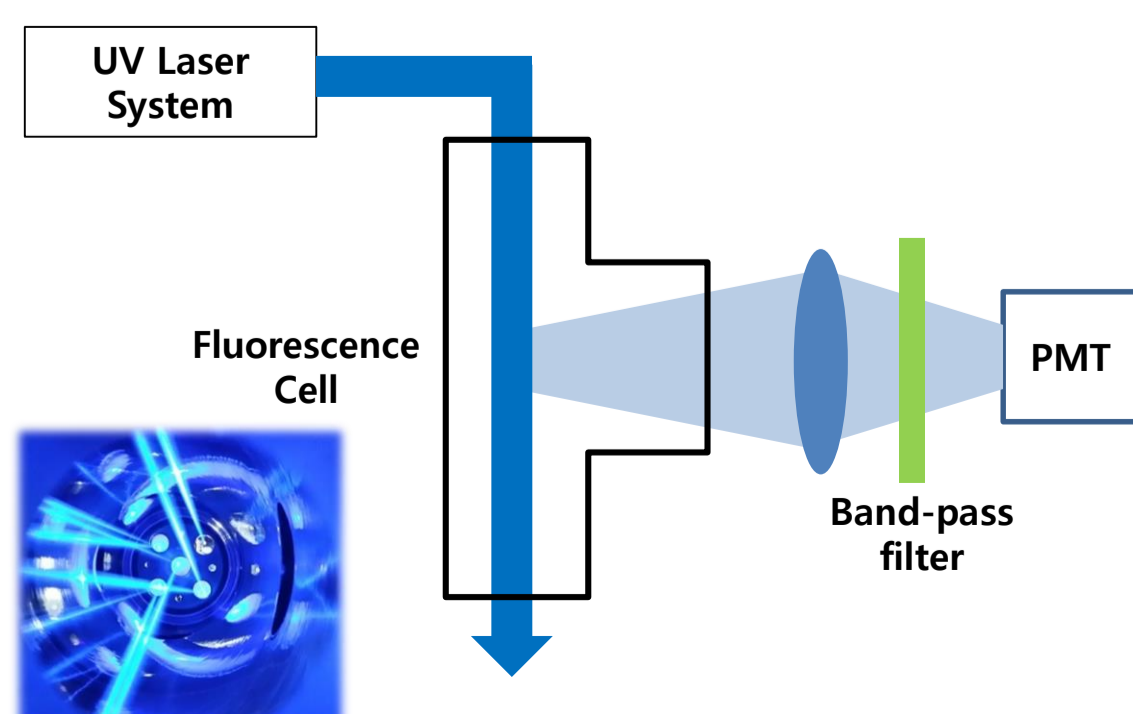
- Regulation and license for use
- Restriction for sample amount and concentration
 - Aqueous solution of C-14 formaldehyde (from ARC (USA))
 - 1mCi/ml = 0.048 wt.% C-14 formaldehyde
 - Max. amount for regulatory exemption = 250 μl
- Consider the waste

* Experimental Design

- Available sample → over 300 m path length for absorption spectroscopy

- Fluorescence spectroscopy

- Extremely sensitive
- Hard to calibrate



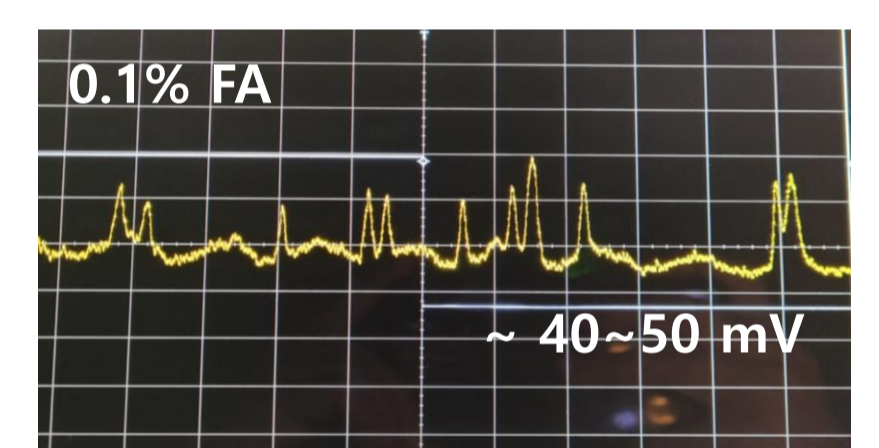
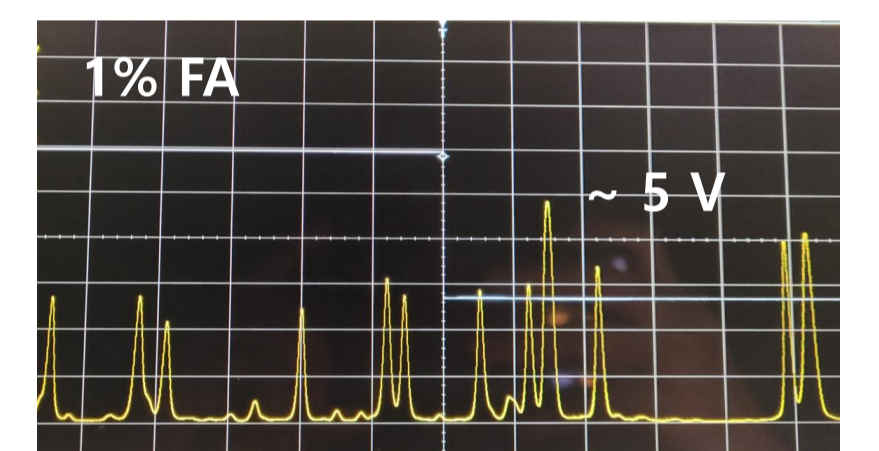
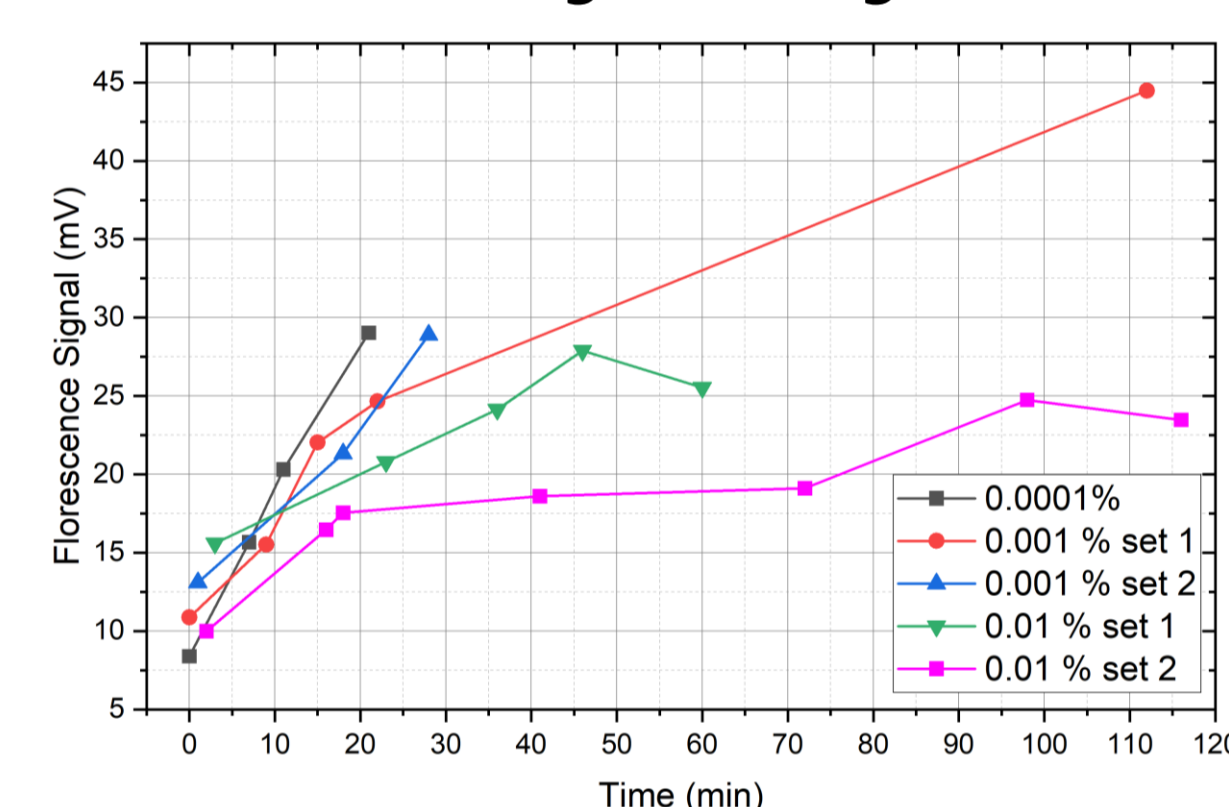
Experimental Results

* Fluorescence Signal Measurement

: Simulation experiment using natural CH₂O

- 40~100 times smaller signal than we expected
- No consistent results over repeated measurements

Fluorescence signal change over time

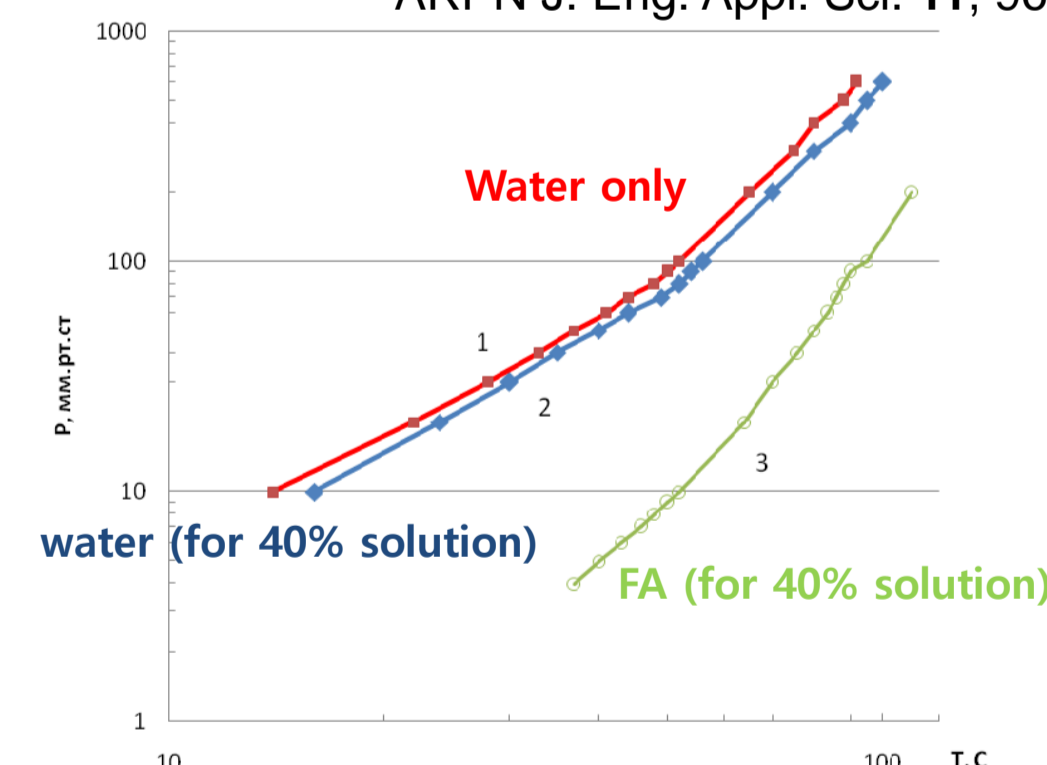


- Can not measure ~0.01% (~C-14 target concentration) sample

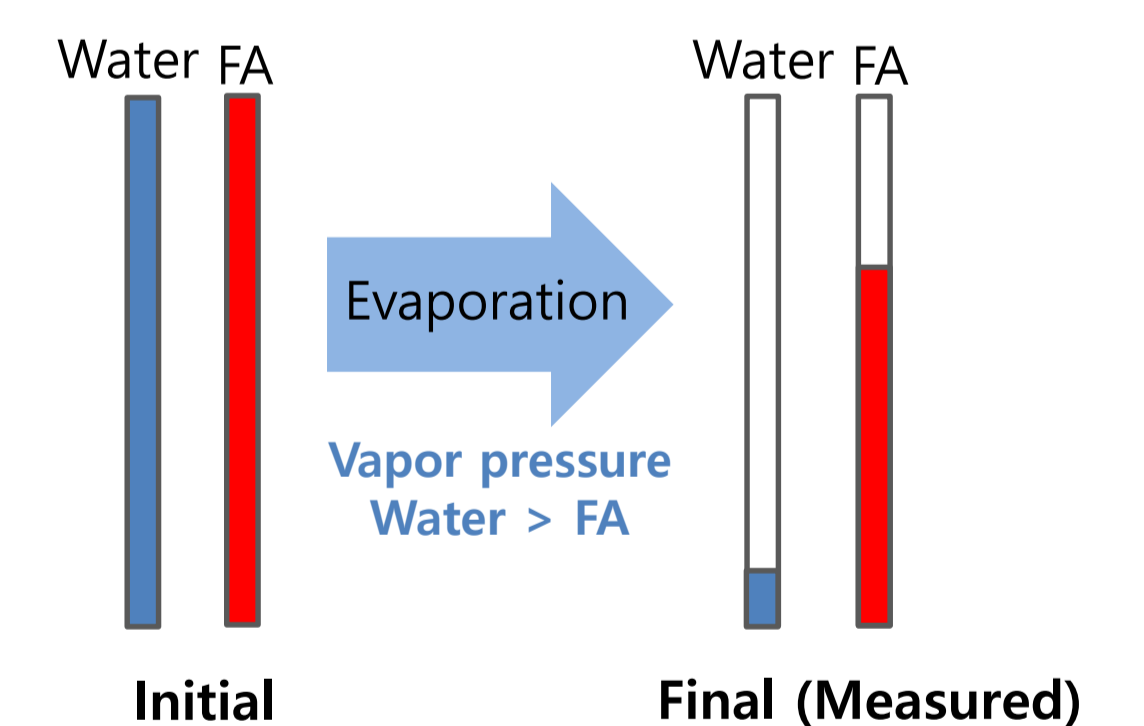
Water / Formaldehyde Solution vaporization problem

Water/Formaldehyde vapor pressure

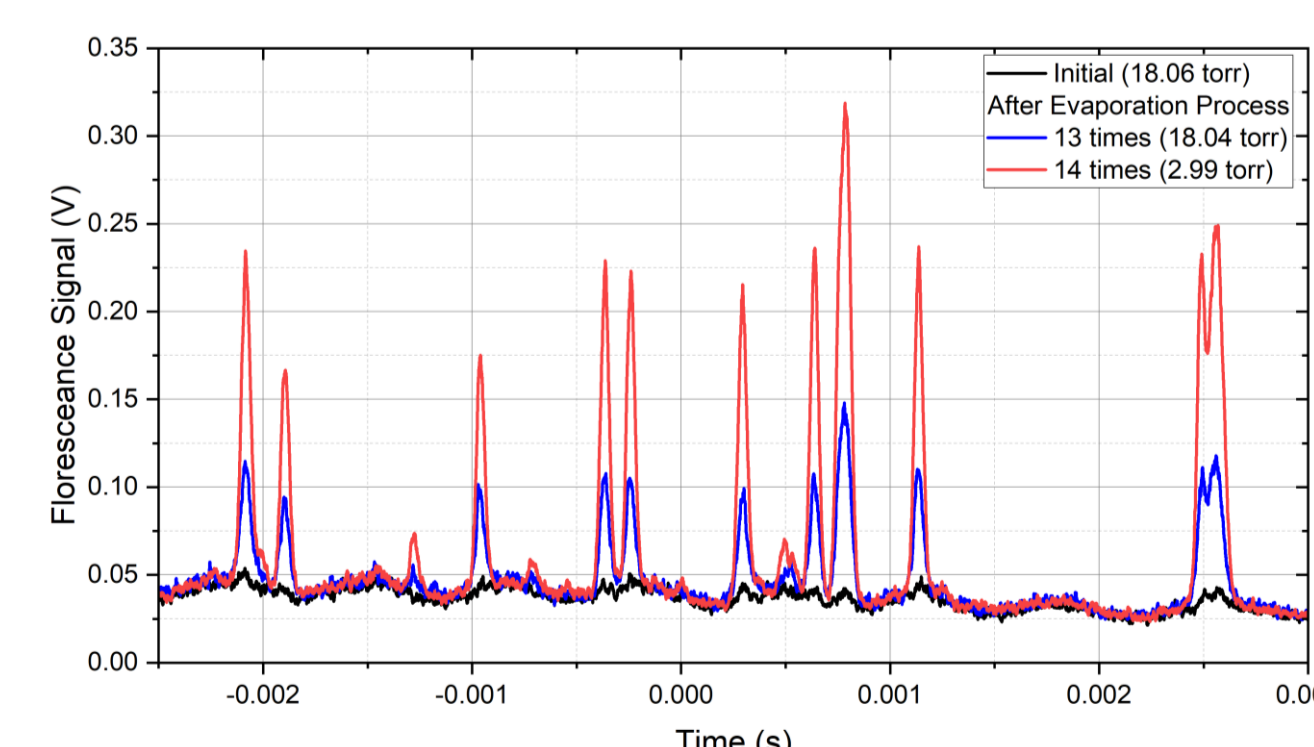
ARNP J. Eng. Appl. Sci. 11, 9655 (2016)



To Increase the FA vapor pressure



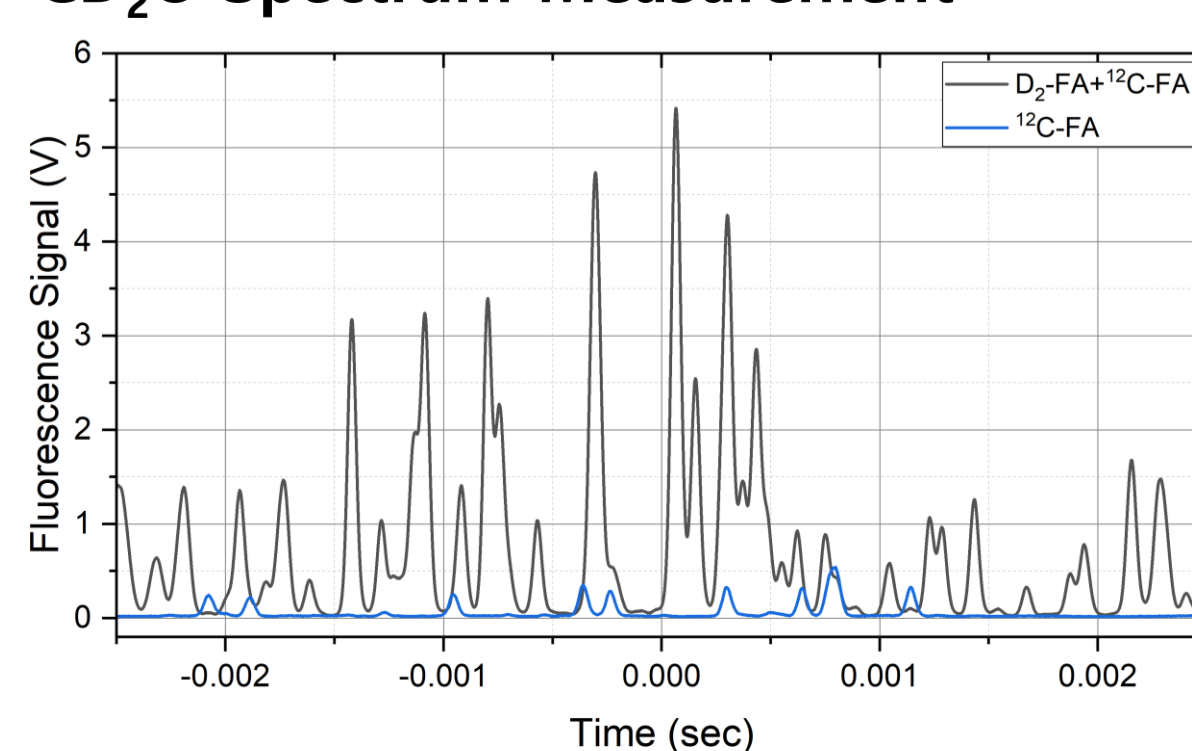
Measurement Result after Evaporation Process



- 0.01 wt.% sample measurement
- Equivalent to C-14 available sample
- Sample concentration cannot define.
 - hard to obtain absorption cross-section
- Peak position determination OK

Conclusion and Future Works

CD₂O Spectrum Measurement



- We construct the experimental setup for fluorescence spectroscopy of C-14 formaldehyde.
- We verified the system performance using non-radioactive isotopologues.
- We are preparing the experiment in radiation controlled area for C-14 treatment.