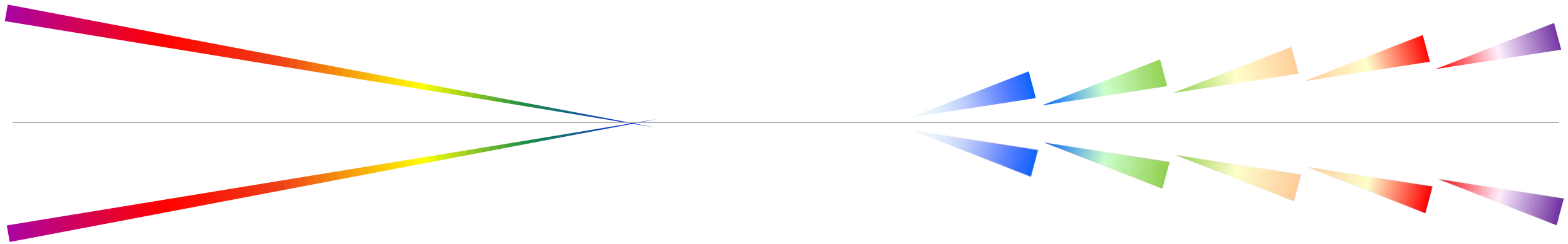




Recent highlights and perspectives on chemical deuteration activities in CROSS



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Comprehensive Research Organization for Science and Society (CROSS)

J-PARC Workshop 2022 -Deuterium Science Entering a New Phase-

January 19th, 20th, 2023



Number of participant: 55 (young researcher is 12). Thanks a lot!

Next J-PARC Workshop will be held in **October 2024** (tentative).
We look forward to your participation (especially for young researchers)!

J-PARC MLF Deuteration Laboratory

J-PARC MLF operates D-lab in cooperation with QST and CROSS.

Development/management of deuteration facility (MLF)

Synthesis

- Wet lab with fume hoods and clean bench
- High-pressure reactor
- Jar fermentor etc.

Characterization/analysis

- NMR (400 MHz)
- LC-MS/MS
- UV-Vis/FTIR spectroscopy
- QCM etc.



Development and expansion of facility

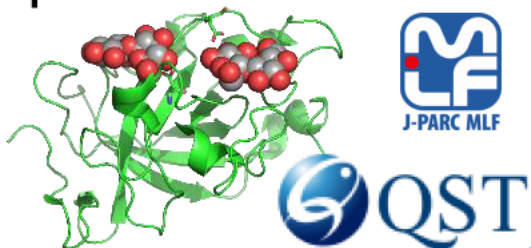
Development of preparation method

Development and expansion of facility

Development of preparation method

Biological deuteration (QST/MLF)

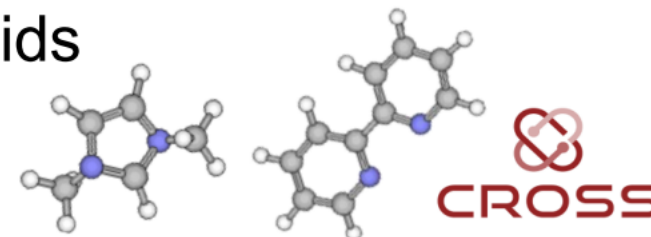
- Proteins and peptides
- DNA (Plasmid)
- E. coli cells



Chemical deuteration (CROSS)

Direct H-D exchange using H₂/2-PrOH

- Carboxylic acids
- Ionic liquids
- Amides, etc.



Current status of CROSS D-lab_1

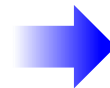
Since 2018, we have supplied some deuterated materials for neutron users.

Examples of chemical deuteration activities

- Synthesis of deuterated molecules for NR and inelastic neutron scattering for J-PARC MLF.
- Synthesis of deuterated molecules for SANS for JRR-3 (research reactor facility).
- Development of elemental analysis method for deuterated materials (in cooperation with JASCO Co.).
- Development of a new D₂O recycling technique (in cooperation with FC Development Co.).



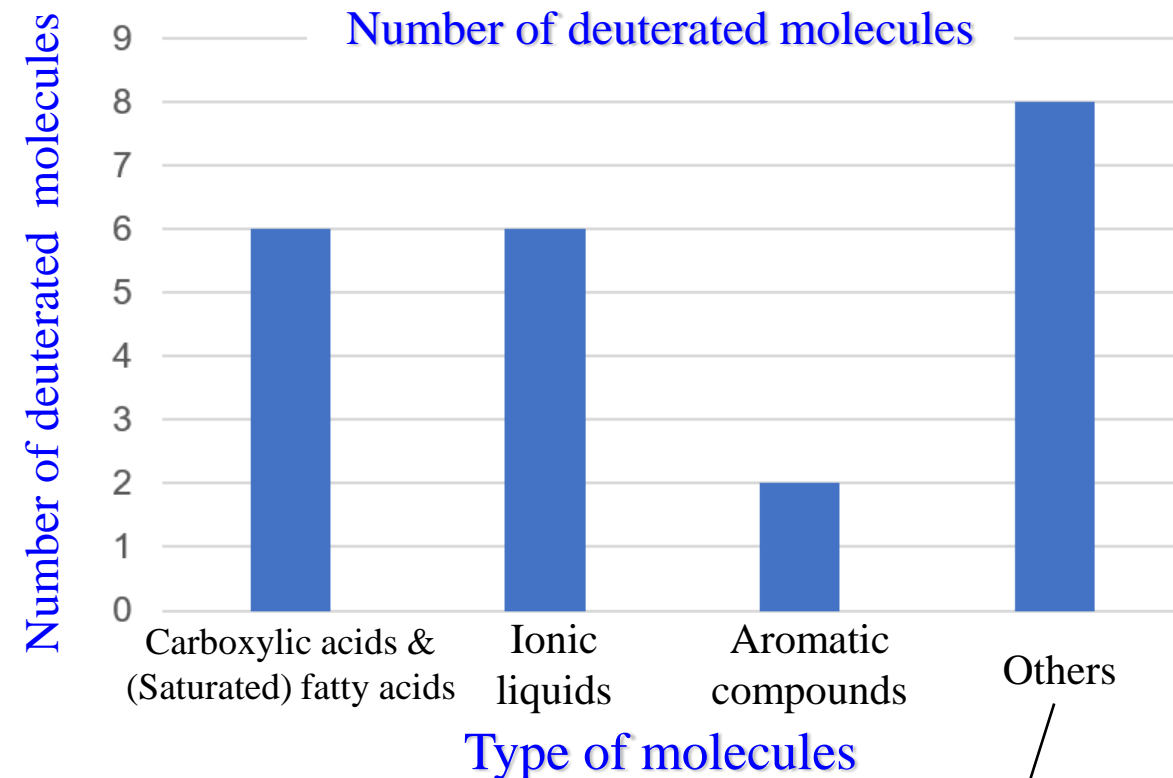
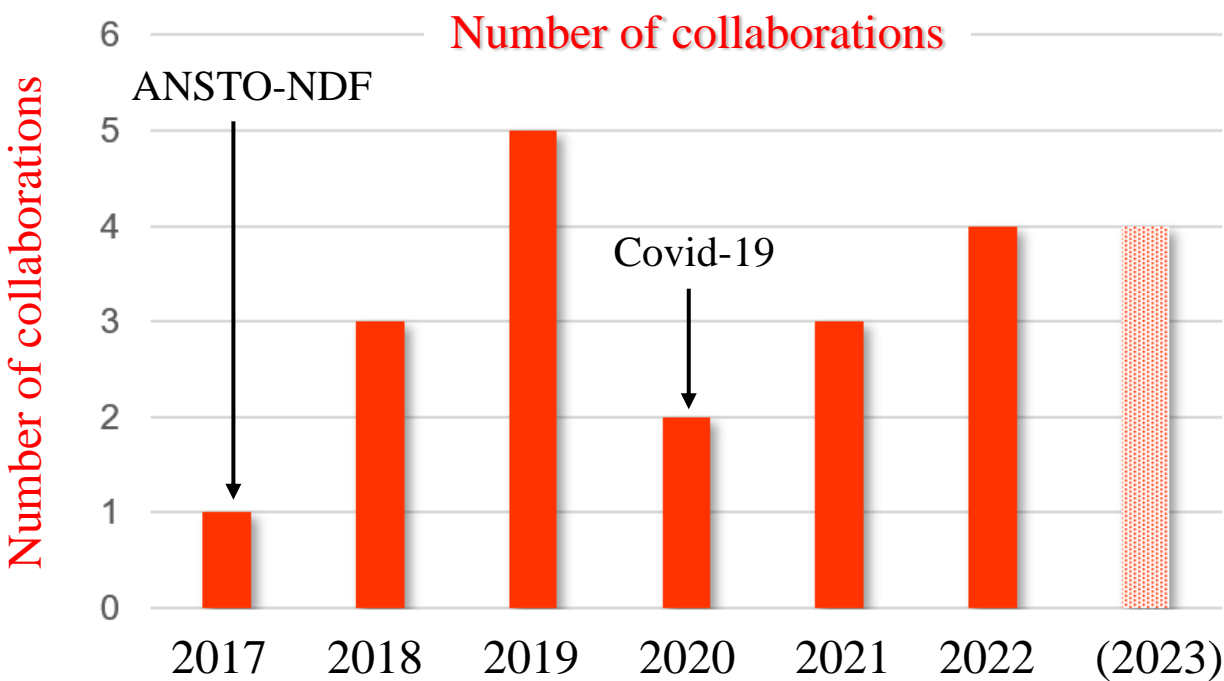
Number of collaborations on deuteration: 18
Number of deuterated molecules: 32
Number of publications: 8
Ratio (molecules:publications): 32 : 8 = 4 : 1 **25%**



It is necessary to increase the productivity of publications per deuterated molecules!!

Current status of CROSS D-lab_2

Since 2018, we have supplied some deuterated materials for neutron users.



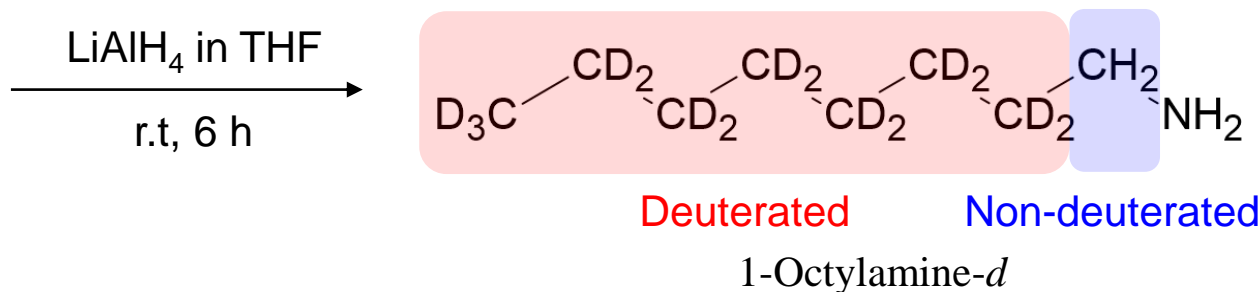
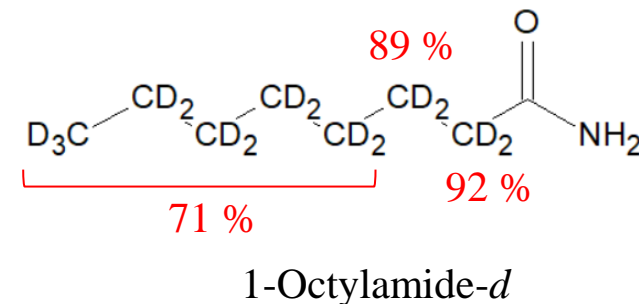
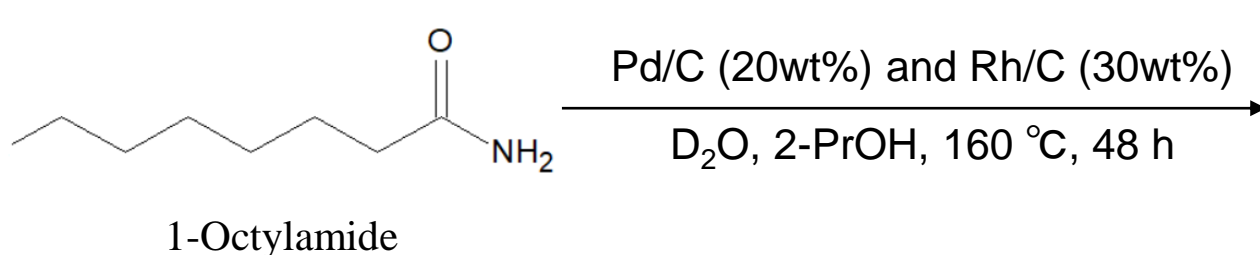
- J-PARC MLF: 12 (+ 1)
- JRR-3 (Reactor) : 3 (+ 2)
- Others: 3 (+1) → Elemental analysis, NMR, and D₂O recycling

The number of acceptable collaborative research project is 4 or 5 per year.

Carboxylic acids and ILs are in high demands. Recently, the demand for **deuterated amines** has been increasing.

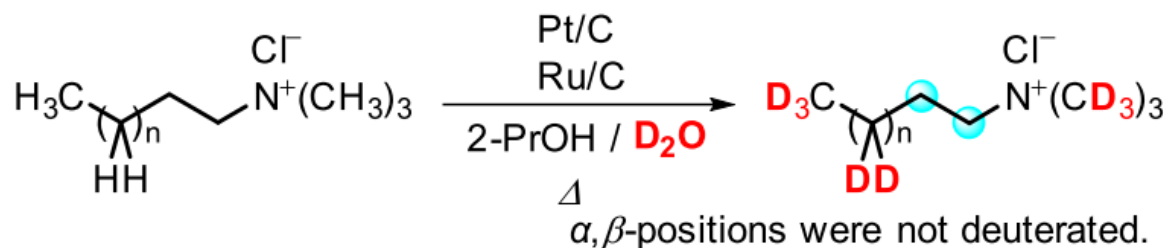
Chemical Deuteration

To increase chemical deuteration activities... ➡ A new synthetic route for **deuterated amines**



➡ Mean deuteration level: ~71 %

◇ New method from H. Sajiki's group*



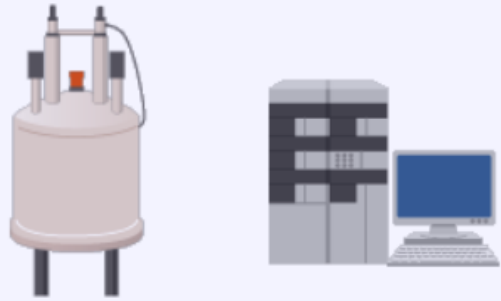
➡ Mean deuteration level: ~50 %

*Y. Sawama et al., Asian J. Org. Chem. In Press.

We will use these deuteration methods as needed.

Analytical Techniques_qNMR_1

Development of new method for analyzing the chemical purity of deuterated compounds



Analyses of deuterated molecules

Deuteration level analysis: ^1H , ^2H , ^{13}C -NMR, MS
Chemical purity analysis: ??

Quantitative NMR (qNMR) analysis is an answer!?*

*The qNMR method was developed for determination of concentration and purity of drugs and medicines.

Development of ^1H and ^2H qNMR techniques is the best answer to analyze the isotopic and chemical purity of deuterated compounds!

» **This project is in progress.**

Analytical Techniques_qNMR_2

◇ $^1\text{H}/^2\text{H}$ qNMR method is currently under development by



NMR standard reference:
1,4-BTMSB- d_4

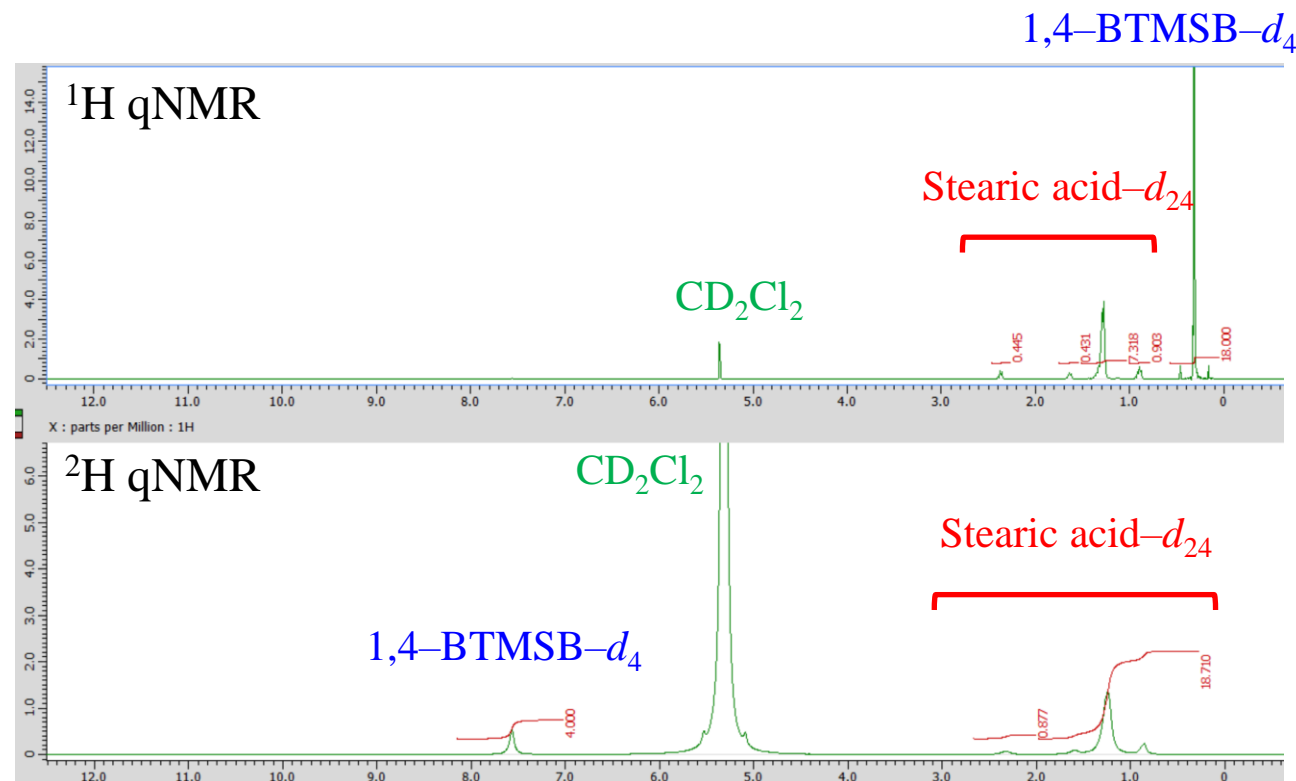
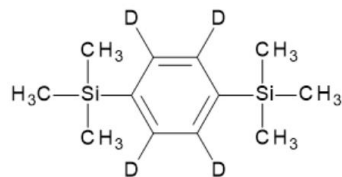


Fig. $^1\text{H}/^2\text{H}$ qNMR data of round robin sample with NMR standard.

Device error, including operator error, is within $\pm 1.0\%$.

We will provide you with more details on our new qNMR method in the near future.

Outcome_Neutron Studies

Study on the Electric Double Layer Structure (J-PARC BL17)* Aggregate structure of Pd-extractant (JRR-3 SANS-J)**

*K. Tamura et al, *ECS Advances*, 1, 020503 (2022).

**M. Cyril et al, *Solv. Extr. Ion Exch.*, 1-20 (2023).

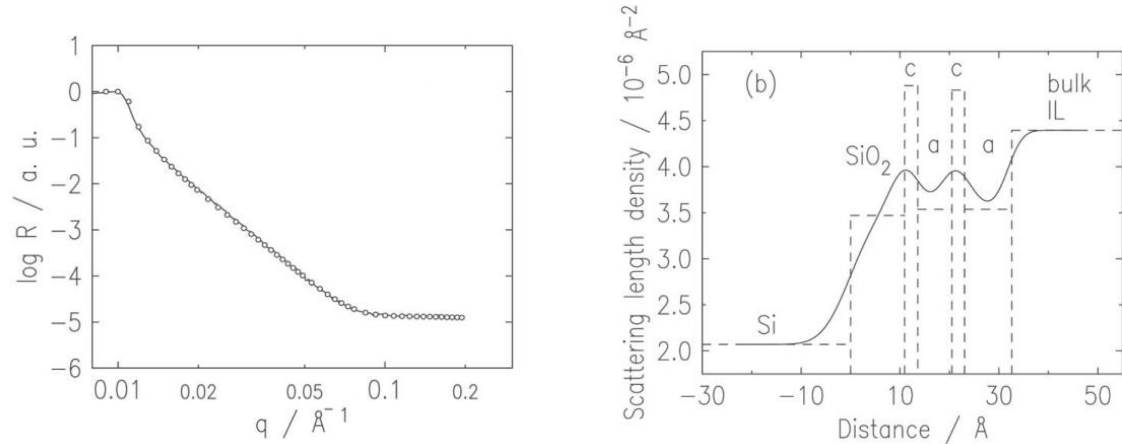


Fig.1 NR profile (left) and the SLD profile elucidated by parameter fitting (right).

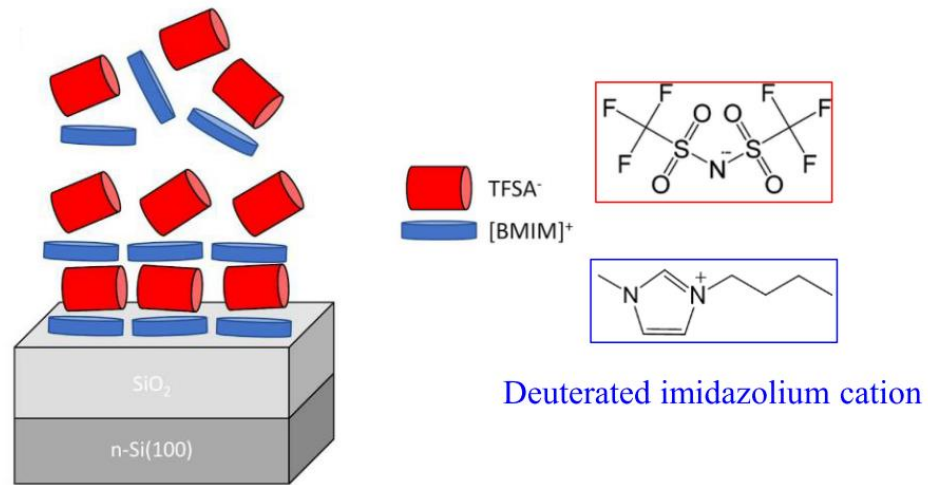
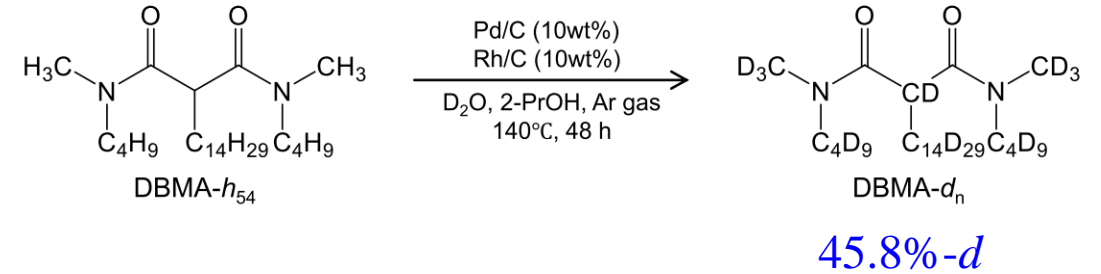


Fig.2 EDL structure obtained by parameter fitting.



Scheme 1 Direct deuteration reaction of DBMA.

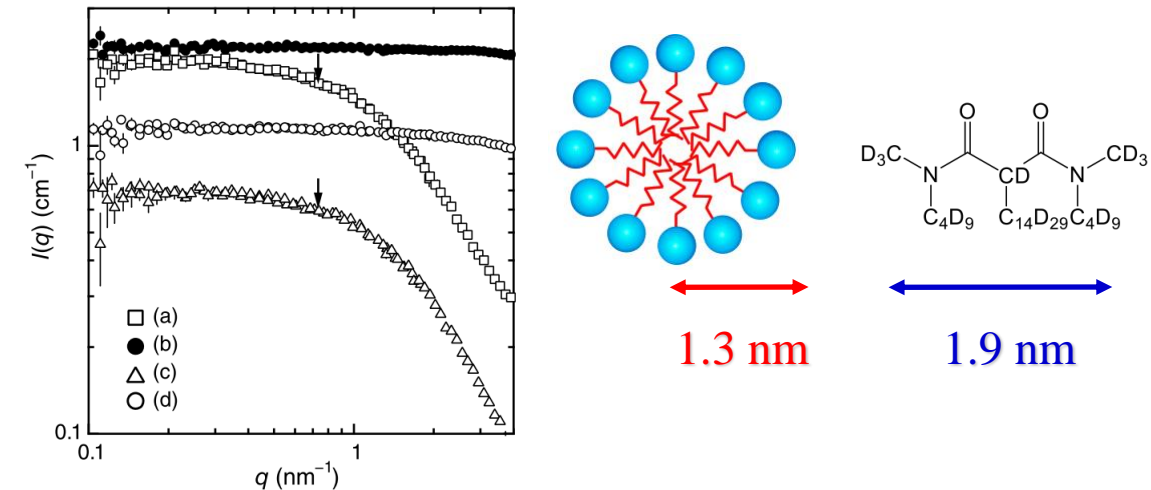


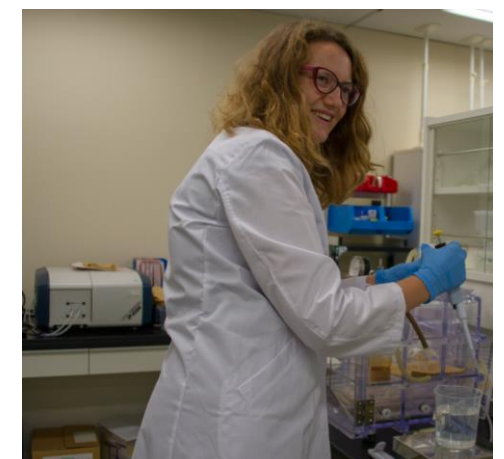
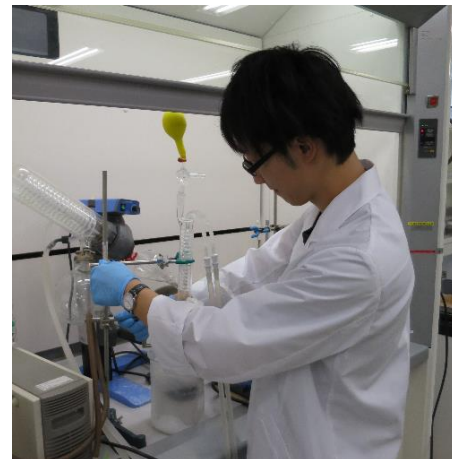
Fig.3 SANS profiles obtained for the four DBMA in *n*-heptane solutions.

Summary

★ Perspectives on chemical deuteration activities

- 1) To increase the productivity of publications, easy and cost-effective synthesis method for deuterated amines is developing now.
- 2) The quantitative $^1\text{H}/^2\text{H}$ NMR technique for the analysis of deuterated molecules will be well developed in the near future..
- 3) The number of acceptable collaborative research activities is 4 or 5 per year.
 - ➔ For enhancing our deuteration activities, we need to find strong collaborators or employ a staff of deuteration chemist.

- ◇ For your information
J-PARC&CROSS accept internship (or special research) students from various universities including overseas!



Acknowledgement

- ◇ ANSTO-NDF

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- ◇ JAEA/CROSS/QST

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