

Curriculum Vitae

Kei Muto (武藤 慶)



Assistant Professor (講師 任期付)

Department of Applied Chemistry, School of Advanced Science,
Waseda University (The Junichiro Yamaguchi Group)

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Website: <http://www.jyamaguchi-lab.com>

Date of Birth

April 22, 1988

Citizenship

Japanese

Education

- | | |
|-----------|---|
| 2007–2011 | B.S. in Chemistry, Nagoya University, Japan
(Prof. Kenichiro Itami), <i>March 2011</i> |
| 2011–2013 | M.S. Graduate Student in Chemistry, Nagoya University, Japan
(Prof. Kenichiro Itami), <i>March 2013</i> |
| 2013–2015 | Ph.D. Graduate Student in Chemistry, Nagoya University, Japan
(Prof. Kenichiro Itami), <i>September 2015</i> |
| 2013–2015 | JSPS Research Fellowship for Young Scientists (DC1) |
| 2012 | Visiting Student (May–August), Wuhan University, China (Prof. Aiwen Lei) |

Academic Career

- | | |
|--------------|--|
| 2015–2016 | Postdoctoral Researcher, Institute of Transformative Bio-molecules, Nagoya University, Japan (Prof. Kenichiro Itami) |
| 2016–present | Assistant Professor, Waseda University (with Prof. Junichiro Yamaguchi) |

Awards and Honor

1. JXTG エネルギー優秀研究賞 (2018)
2. Inoue Research Award for Young Scientists (2017)
3. Reaxys PhD Prize Finalist (2016)
4. JSPS Ikushi Prize (日本学術振興会育志賞, 2016)
5. Nagoya University, Gakujutsu-Shorei Award (名古屋大学学術奨励賞, 2016)
6. CSJ Oral Student Presentation Award (Chemical Society of Japan 2014, The 94th Annual Meeting)
7. Annual Research Awards (Nagoya University Program for Leading Graduate Schools Annual Meeting 2013)
8. The 4th Otsu Conference Fellow (October 2013)
9. JSPS Fellowship for Young Scientist (DC1: 2013–2016)
10. Distinguished Master's Thesis Award 2012 in Department of Chemistry, Nagoya University (March 2013)
11. Nagoya University Graduate School of Science Award (March 2013)
12. Poster Award (The 59th Symposium on Organometallic Chemistry, Japan, September 2012)
13. Poster Award (The 29th Seminar on Synthetic Organic Chemistry, Japan, September 2012)
14. Poster Award (The 100th Symposium on Organic Synthesis, Japan, November 2011)

Media

[Chem-Station Spotlight Research](#)

Publications

- (32) Pd-Catalyzed Dearomative Three-Component Reaction of Bromoarenes with Diazo Compounds and Allylborates
Komatsuda, M.; Kato, H.; Muto, K.; Yamaguchi, J.
ACS Catal. **2019**, *9*, 8991–8995.
DOI: [10.1021/acscatal.9b03461](https://doi.org/10.1021/acscatal.9b03461)
Most Read Article
- (31) Pd-Catalyzed Denitrative Intramolecular C–H Arylation
Asahara, K. K.; Okita, T.; Saito, A. N. Muto, K.; Nakao, Y.; Yamaguchi, J.
Org. Lett. **2019**, *21*, 4721.
DOI: [10.1021/acs.orglett.9b01593](https://doi.org/10.1021/acs.orglett.9b01593)
- (30) Pd-Catalyzed Dearomative Allylation of Benzyl Phosphates
Komatsuda, M.; Muto, K.; Yamaguchi, J.
Org. Lett. **2018**, *20*, 4354–4357.
DOI: [10.1021/acs.orglett.8b01807](https://doi.org/10.1021/acs.orglett.8b01807)
Most Read Article
- (29) “Synthesis of A Heptaaryloisoquinoline: Unusual Disconnection for Constructing Isoquinoline Frameworks”
Asako, T.; Suzuki, S.; Itami, K.; Muto, K.; Yamaguchi, J.
Chem. Lett. **2018**, *47*, 968.
DOI [10.1246/cl.180429](https://doi.org/10.1246/cl.180429)
Highlights Editor’s Choice
- (28) “Dibenzofuran Synthesis: Decarbonylative Intramolecular C–H Arylation of Aromatic Esters”
Okita, T.; Komatsuda, M.; Saito, A. N.; Hisada, T.; Takahara, T. T.; Nakayama, K. P.; Isshiki, R.; Takise, R.; Muto, K.; Yamaguchi, J.
Asian J. Org. Chem. **2018**, *7*, 1358. DOI [10.1002/ajoc.201800207](https://doi.org/10.1002/ajoc.201800207)
- (27) “Decarbonylative Methylation of Aromatic Esters by a Nickel Catalyst”
Okita, T.; Muto, K.; Yamaguchi, J.
Org. Lett. **2018**, *20*, 3132. DOI [10.1021/acs.orglett.8b01233](https://doi.org/10.1021/acs.orglett.8b01233)
- (26) “Pd-Catalyzed Decarbonylative C–H Coupling of Azoles and Aromatic Esters”
Matsushita, K.; Takise, R.; Hisada, T.; Suzuki, S.; Isshiki, R.; Itami, K.; Muto, K.; Yamaguchi, J.
Chem Asian. J. **2018**, Accepted publication. DOI: [10.1002/asia.201800478](https://doi.org/10.1002/asia.201800478)
- (25) “Decarbonylative Coupling Reaction of Aromatic Esters”
Isshiki, R.; Okita, T.; Muto, K.; Yamaguchi, J.
J. Synth. Org. Chem. Jpn. **2018**, *76*, 300. DOI: [10.5059/yukigoseikyokaishi.76.300](https://doi.org/10.5059/yukigoseikyokaishi.76.300) (Review, Japanese)
- (24) “Decarbonylative Aryl Thioether Synthesis by Ni Catalysis”
Ishitobi, K.; Isshiki, R.; Asahara, K. K.; Lim, C.; Muto, K.; Yamaguchi, J.
Chem. Lett. **2018**, *47*, 756 DOI: [10.1246/cl.180226](https://doi.org/10.1246/cl.180226)
- (23) “Synthesis of Fully Arylated (Hetero) arenes by Coupling Reaction”
Asako, T.; Muto, K.; Yamaguchi, J.
J. Synth. Org. Chem. Jpn. **2018**, *76*, 98–110. DOI: [10.5059/yukigoseikyokaishi.76.98](https://doi.org/10.5059/yukigoseikyokaishi.76.98) (Review, Japanese)

- (22) “Decarbonylative C–P Bond Formation using Aromatic Esters and Organophosphorus Compounds”
Isshiki, R.; Muto, K.; Yamaguchi, J.
Org. Lett. **2018**, *20*, 1150. DOI: [10.1021/acs.orglett.8b00080](https://doi.org/10.1021/acs.orglett.8b00080)
- (21) “Catalytic α -Arylation of Ketones with Heteroaromatic Esters”
Isshiki, R.; Takise, R.; Itami, K.; Muto, K.; Yamaguchi, J.
Synlett **2017**, *28*, 2559. DOI: [10.1055/s-0036-1589120](https://doi.org/10.1055/s-0036-1589120)
- (20) “Cross-coupling of aromatic esters and amides”
Takise, R.; Muto, K.; Yamaguchi, J.
Chem. Soc. Rev. **2017**, *46*, 5864. (Review) DOI: [10.1039/C7CS00182G](https://doi.org/10.1039/C7CS00182G)
Inside Back Cover DOI: [10.1039/C7CS90100C](https://doi.org/10.1039/C7CS90100C) **Highly cited paper (Web of Science)**
- (19) “Synthesis of Multiply Arylated Pyridines”
Asako, T.; Hayashi, W.; Suzuki, S.; Amaike, K.; Itami, K.; Muto, K.; Yamaguchi, J.
Tetrahedron **2017**, *73*, 3669, (Invited contribution). DOI: [10.1016/j.tet.2017.03.095](https://doi.org/10.1016/j.tet.2017.03.095)
- (18) “Decarbonylative Diaryl Ether Synthesis by Pd and Ni Catalysis”
Takise, R.; Isshiki, R.; Muto, K.; Itami, K.; Yamaguchi, J.
J. Am. Chem. Soc. **2017**, *139*, 3340. DOI: [10.1021/jacs.7b00049](https://doi.org/10.1021/jacs.7b00049)
Highly cited paper (Web of Science)
- (17) “触媒的なアルケンのエナンチオ選択的ジハロゲン化反応” (Catalytic Enantioselective Dihalogenation Reaction of Alkene) (Review)
武藤慶
有機合成化学協会誌、2016, 74, 1225–1226. DOI: [10.5059/yukigoseikyokaishi.74.1225](https://doi.org/10.5059/yukigoseikyokaishi.74.1225)
- (16) “Palladium-Catalyzed Decarbonylative Alkynylation of Aromatic Esters”
Okita, T.; Kumazawa, K.; Takise, R.; Muto, K.; Itami, K.; Yamaguchi, J.
Chem. Lett. **2016**, *46*, 218. DOI: [10.1246/cl.161001](https://doi.org/10.1246/cl.161001)
- (15) “Palladium-Catalyzed Decarbonylative Cross-Coupling of Azinecarboxylates with Arylboronic Acids”
Muto, K.; Hatakeyama, T.; Itami, K.; Yamaguchi, J.
Org. Lett. **2016**, *18*, 5106. DOI: [10.1021/acs.orglett.6b02556](https://doi.org/10.1021/acs.orglett.6b02556)
- (14) “Nickel-Catalyzed Aromatic C–H Functionalization” (Review)
Yamaguchi, J.; Muto, K.; Itami, K.
Top Curr Chem, **2016**, *374*, 55. DOI: [10.1007/s41061-016-0053-z](https://doi.org/10.1007/s41061-016-0053-z)
- (13) “C–H Arylation and Alkenylation of Imidazoles by Nickel Catalysis: Solvent accelerated Imidazole C–H Activation”
Muto, K.; Hatakeyama, T.; Yamaguchi, J.; Itami, K.
Chem. Sci. **2015**, *6*, 6792–6798. DOI: [10.1039/C5SC02942B](https://doi.org/10.1039/C5SC02942B)
- (12) “C–H Activation Generates Period Shortening Molecules Targeting Cryptochrome in the Mammalian Circadian Clock”
Oshima, T.; Yamanaka, I.; Kumar, A.; Yamaguchi, J.; Nishiwaki-Ohkawa, T.; Muto, K.; Kawamura, R.; Hirota, T.; Yagita, K.; Irle, S.; Kay, S. A.; Yoshimura, T.; Itami, K.
Angew. Chem., Int. Ed. **2015**, *54*, 7193. DOI: [10.1002/anie.201502942](https://doi.org/10.1002/anie.201502942)
- (11) “Decarbonylative Organoboron Cross-coupling of Esters by Nickel Catalysis”
Muto, K.; Yamaguchi, J.; Musaev, D. G.; Itami, K.
Nature Commun. **2015**, *6*, 7508. DOI: [10.1038/ncomms8508](https://doi.org/10.1038/ncomms8508)
Highlighted in Nature Asia.
Highly cited paper (Web of Science)

- (10) “Key Mechanistic Features of Ni-catalyzed C-H/C-O Biaryl Coupling of Azoles and Naphthalen-2-yl Pivalates”
 Xu, H.; Muto, K.; Yamaguchi, J.; Zhao, C.; Itami, K.; Musaev, D. G.
J. Am. Chem. Soc. **2014**, *136*, 14834. DOI: 10.1021/ja5071174
- (9) “Nickel-Catalyzed α -Arylation of Ketones with Phenol Derivatives”
 Takise, R.; Muto, K.; Yamaguchi, J.; Itami, K.
Angew. Chem., Int. Ed. **2014**, *53*, 6791. DOI: 10.1002/anie.201403823
- (8) “Isolation, Structure, and Reactivity of an Arylnickel(II) Pivalate Complex in Catalytic C-H/C-O Biaryl Coupling”
 Muto, K.; Yamaguchi, J.; Lei, A.; Itami, K.
J. Am. Chem. Soc. **2013**, *135*, 16384. DOI: 10.1021/ja409803x
- (7) “C–H Alkenylation of Azoles with Enols and Esters by Nickel Catalysis”
 Meng, L.; Kamada, Y.; Muto, K.; Yamaguchi, J.; Itami, K.
Angew. Chem., Int. Ed. **2013**, *52*, 10048. DOI: 10.1002/anie.201304492
- (6) “Nickel-Catalyzed Direct Coupling of Heteroarenes”
 Yamaguchi, J.; Muto, K.; Amaike, K.; Yamamoto, T.; Itami, K.
J. Synth. Org. Chem. Jpn. **2013**, *71*, 576.
- (5) “New Cross-coupling Reactions through Nickel Catalysis”
 Yamaguchi, J.; Amaike, K.; Muto, K.; Itami, K.
Catalysts and Catalysis **2013**, 624.
- (4) “Recent Progress in Nickel-Catalyzed Biaryl Coupling” (MicroReview)
 Yamaguchi, J.; Muto, K.; Itami, K.
Eur. J. Org. Chem. **2013**, 19. DOI: 10.1002/ejoc.201200914
Highly cited paper (Web of Science)
- (3) “Decarbonylative C–H Coupling of Azoles and Aryl Esters: Unprecedented Nickel Catalysis and Application to Synthesis of Muscoride A”
 Amaike, K.; Muto, K.; Yamaguchi, J.; Itami, K.
J. Am. Chem. Soc. **2012**, *134*, 13573. DOI: 10.1021/ja306062c
Highly cited paper (Web of Science)
- (2) “Nickel-Catalyzed C–H/C–O coupling of Azoles with Phenol Derivatives”
 Muto, K.; Yamaguchi, J.; Itami, K.
J. Am. Chem. Soc. **2012**, *134*, 169. DOI: 10.1021/ja210249h
Most Read Articles in JACS during December 2011
Highlighted as Synstory in Synform Highlighted in Newspapers (Chunichi, Yomiuri, Yahoo! News, Mynavi News and so on...)
Nagoya University Press Release
Highly cited paper (Web of Science)
- (1) “Nickel-Catalyzed C–H Arylation of Azoles with Haloarenes: Scope, Mechanism, and Application to the Synthesis of Bioactive Molecules”
 Yamamoto, T.; Muto, K.; Komiyama, M.; Canivet, J.; Yamaguchi, J.; Itami, K.
Chem. Eur. J. **2011**, *17*, 10113. DOI: 10.1002/chem.201101091

Others

- (3) Otsu Conference 2017 Reports 第9回大津会議 有機合成の夢を語る
 Ikemoto, K.; Muto, K.; Nogi, K. *J. Synth. Org. Chem. Jpn.* **2018**
- (2) “Lewis 酸でヒドリドを引き抜く 触媒的 FLPs 形成による C–H 変換反応” (Japanese)

武藤慶, 化学 (化学同人), 2019 年 1 月号

- (1) Otsu Conference 2017 Reports 第 8 回大津会議 有機合成の夢を語る
Morita, M.; Ikemoto, K.; Muto, K. *J. Synth. Org. Chem. Jpn.* **2018**

Presentations

International

- (8) "Development of Catalytic Decarbonylative Coupling of Aromatic Esters"
Kei Muto, Ryosuke Takise, Ryota Isshiki, Toshimasa Okita, Kazushi Kumazawa, Kenichiro Itami, Junichiro Yamaguchi
The 19th OMCOS (PP2-48) · ICC Jeju, Korea 6 月 28 日
- (7) "Ni-Catalyzed C–H/C–O Couplings: Catalyst Development and Mechanistic Studies"
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
XXVI International Conference on Organometallic Chemistry (ICOMC 2014), Royton Sapporo, Hokkaido, Japan, July 17, 2014. (Poster)
- (6) "Ni-Catalyzed C–H/C–O Couplings: Development and Mechanistic Studies"
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
Core to Core/IRTG Meeting Programs on Elements Function for Transformative Catalysis and Materials
Nagoya University, Aichi, Japan, June 13, 2014. (Oral)
- (5) "Direct C–H Coupling through Nickel Catalysis"
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
4th Otsu Conference 2013
Otsu Prince Hotel, Shiga, Japan, October 23, 2013. (Oral)
- (4) "Ni-Catalyzed C–H/C–O Coupling of Azoles with Phenol Derivatives: Development, Mechanistic Studies, and Applications"
Kei Muto, Junichiro Yamaguchi, Aiwen Lei, and Kenichiro Itami
17th IUPAC International Symposium on Organometallic Chemistry Directed Towards Organic Synthesis
Lincoln Center, Colorado, USA, July 29, 2013. (Poster)
- (3) "Direct C–H Arylation of Heteroarenes by Nickel Catalyst"
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
3rd International Symposium on Molecular Activation
Sheraton Steamboat Resort, Colorado, USA, July 27, 2013. (Oral)
- (2) "Nickel-Catalyzed C–H Arylation of Azoles with Haloarenes"
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The 10th Joint Seminar University of Münster
Nagoya University, Aichi, Japan, October 4, 2011. (Poster)
- (1) "Nickel-Catalyzed C–H/C–X Arylation of Heteroarenes"
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The 4th Global COE in Chemistry Annual Symposium
Nagoya University, Aichi, Japan, June 15, 2011. (Poster)

Domestic

- (17) "Catalyst Design toward Selective Dearomative Functionalizations" (Invited)
Kei Muto
The Chemical Society of Japan 2019, 99th Annual Meeting-Special Program Lecture-, Konan Univ., Mar 19, 2019.
- (16) 「C–O 結合切断を起点とする新奇触媒反応の開発」 (Invited)
武藤慶
第二回産総研化学研究シンポジウム・産総研 10 月 12 日, 2018 年
- (15) "Pd-catalyzed Dearomative C–C Bond Formation of Benzyl Alcohols"(ポスター)
武藤慶
第 2 回大津会議合同研究発表会・びわ湖大津プリンスホテル 9 月 11 日, 2017 年
- (14) 「分子触媒による新奇分子連結反応の開発」 (口頭)
武藤慶
平成 29 年度育志賞研究発表会・大阪大学中之島センター 9 月 5 日, 2017 年

- (13) 「エステル切断を軸とする新規カップリング反応の開発」
武藤慶
第三回中分子戦略若手シンポジウム・京都 3月7日
- (12) “Decarbonylative Suzuki–Miyaura Coupling by Nickel Catalysis”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The Chemical Society of Japan 2015, 95th Annual Meeting
Nihon University, Chiba, Japan, March 27, 2015. (Oral)
- (11) “Decarbonylative Cross-Coupling of Phenyl Esters and Arylboronic Acids with Ni Catalyst”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
IGER Annual Meeting
Nagoya University, Aichi, Japan, December 18, 2014. (Poster)
- (10) “Nickel-Catalyzed C–H/C–O Biaryl Coupling: Catalyst Developments and Mechanistic Studies”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The Chemical Society of Japan 2014, 94th Annual Meeting
Nagoya University, Aichi, Japan, March 27, 2014. (Oral)
- (9) “Ni-Catalyzed C–H coupling of Heteroarenes: Development, Mechanism, and Applications”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
IGER Annual Meeting
Nagoya University, Aichi, Japan, January 8, 2014. (Oral)
- (8) “Nickel-Catalyzed C–H Arylation of Heteroarenes”
Kei Muto, Kazuma Amaike, Junichiro Yamaguchi, and Kenichiro Itami
The 46th Meeting for Young Scientists in Organometallic Chemistry
Zao Royal Hotel, Miyagi, Japan, July 9, 2013. (Poster)
- (7) “Nickel-Catalyzed Direct C–H Arylation of Heteroarenes”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The Improvement of Prominent Graduate School Meeting for Young Scientists
Kyoto University, Kyoto, Japan, March 14, 2013. (Poster)
- (6) “Nickel-Catalyzed Direct Arylation of Heteroarenes”
Kei Muto, Kazuma Amaike, Junichiro Yamaguchi, and Kenichiro Itami
59th Symposium on Organometallic Chemistry
Osaka University, Osaka, Japan, September 14, 2012. (Poster)
- (5) “Nickel-Catalyzed Direct Arylation of Heteroarenes”
Kei Muto, Kazuma Amaike, Junichiro Yamaguchi, and Kenichiro Itami
The 29th Seminar on Synthetic Organic Chemistry
Convention Arts Center, Shizuoka, Japan, September 6, 2012. (Poster)
- (4) “Ni-Catalyzed C–H/C–O Coupling of Azoles and Phenol Derivatives”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The Chemical Society of Japan 2012, 92th Annual Meeting
Keio University, Kanagawa, Japan, March 28, 2012. (Oral)
- (3) “Ni-Catalyzed Direct C–H Arylation of Heteroarenes”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The 100th Symposium on Organic Synthesis
Waseda University, Tokyo, Japan, November 11, 2011. (Oral)
- (2) “Ni-Catalyzed Direct C–H Arylation of Heteroarenes”
Kei Muto, Junichiro Yamaguchi, and Kenichiro Itami
The 100th Symposium on Organic Synthesis
Waseda University, Tokyo, Japan, November 11, 2011. (Poster)
- (1) “Ni-Catalyzed C–H/C–X Coupling of Heteroarenes”
Kei Muto, Takuya Yamamoto, Masato Komiyama, Junichiro Yamaguchi, and Kenichiro Itami
The Chemical Society of Japan 2011, 91th Annual Meeting
Kanagawa University, Kanagawa, Japan, March 28, 2011. (Oral)

Lecture in charge 担当講義

2019 (@Waseda Univ)

1. 理工基礎実験 1A (春) (ナイロン合成)
2. 理工基礎実験 2B (秋) (酸化チタン合成と評価)

3. 有機化学実験 (秋) (Wittig 反応)
4. 応用化学基礎演習 A(有機化学) (春)
5. 応用化学基礎演習 D(物理化学) (春)
6. 上級有機化学 A (春)
7. 機器分析演習 (秋)
8. 応用化学総論 (春)
9. Introduction to Industrial Chemistry (国際コース) (春)
10. Introduction to Applied Chemistry (国際コース) (秋)
11. ナノスケール科学ジョイントセミナー (春)
12. マテリアルデザイン科学ジョイントセミナー (春)

2018 (@Waseda Univ)

1. 理工基礎実験 1A (春) (水の分析)
2. 理工基礎実験 2B (秋) (酸化チタン合成と評価)
3. 有機化学実験 (秋) (Wittig 反応)
4. 応用化学基礎演習 A(有機化学) (春)
5. 応用化学基礎演習 D(物理化学) (春)
6. 上級有機化学 A (春)
7. 機器分析演習 (秋)
8. 応用化学総論 (春)
9. Introduction to Industrial Chemistry (国際コース) (春)
10. Introduction to Applied Chemistry (国際コース) (秋)
11. ナノスケール科学ジョイントセミナー (春)
12. マテリアルデザイン科学ジョイントセミナー (春)

2017 (@Waseda Univ)

1. 理工基礎実験 1A (春) (ナイロン合成)
2. 理工基礎実験 2B (秋) (酸化チタン合成と評価)
3. 有機化学実験 (秋) (Wittig 反応)
4. 応用化学基礎演習 C(有機化学) (春)
5. 応用化学基礎演習 D(物理化学) (春)
6. 上級有機化学 A (春)
7. 機器分析演習 (秋)
8. 応用化学総論 (春)
9. Introduction to Industrial Chemistry (国際コース) (春)
10. Introduction to Applied Chemistry (国際コース) (秋)
11. ナノスケール科学ジョイントセミナー (春)
12. マテリアルデザイン科学ジョイントセミナー (春)

2016 (@Waseda Univ)

1. 理工基礎実験 1A (春) (ナイロン合成)
2. 理工基礎実験 2B (秋) (酸化チタン合成と評価)
3. 有機化学実験 (秋) (Wittig 反応)
4. 応用化学基礎演習 C(有機化学) (春)
5. 応用化学基礎演習 D(物理化学) (春)
6. 上級有機化学 A (春)
7. 機器分析演習 (秋)
8. 応用化学総論 (春)
9. Introduction to Industrial Chemistry (春)
10. Introduction to Applied Chemistry (秋)