授業概要
COURSE SYLLABUS

東北大学理学部
Faculty of Science
Tohoku University
<table>
<thead>
<tr>
<th>Course</th>
<th>Semester/Credits</th>
<th>Instructor</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Introduction to Basic Chemistry (基礎化学序論)</td>
<td>2nd Semester 2 Credits</td>
<td>火原 彰秀</td>
<td>AMC course professors</td>
</tr>
</tbody>
</table>

**Course code/number**：SCH-OCH201E  
**Course Title**：Introduction to Basic Chemistry (基礎化学序論)  
**Purpose/Abstract**：  
This class is offered to freshmen enrolled in the AMC course. Fundamental knowledge and cutting-edge research in chemistry and materials science will be presented in the form of seminars in each laboratory. Throughout these seminars, the differences in high school-level and college-level chemistry will be emphasized, and students will be given motivation for their future studies.  
**Goal**：  
Understanding of the basic fields of university-level chemistry spread over a cross-section of each field, such as organic chemistry, inorganic chemistry, analytical chemistry, biochemistry and physical chemistry.  
**Contents**：  
Following the schedule distributed during the initial class, students will attend seminars and learn the importance of basic chemistry as well as cutting-edge research.  
**Books required/referenced**：  
Indicated by each instructor  
**Preparation and review**：  
Indicated by each instructor  
**Grading**：  
Class attendance, attitude and activity  
**Remarks**：  
主として実践的教育から構成される実務・実践的授業／Practical business

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<tbody>
<tr>
<td>Special Class in Basic Chemistry I (専門基礎化学Ⅰ)</td>
<td>3rd Semester 2 Credits</td>
<td>南後 恵理子 奥西 みさき</td>
<td>Quantum beam-based structural biology and chemistry</td>
</tr>
</tbody>
</table>

**Course code/number**：SCH-PCH211E  
**Course Title**：Special Class in Basic Chemistry I  
**Purpose/Abstract**：  
In this lecture, we try to understand fundamentals of the quantum mechanics and quantum chemistry that are required for advanced chemistry courses. Starting with a lecture of the early quantum mechanics, we learn how to formulate the Schrödinger equation, which is the basic equation of quantum mechanics. The basic concept of wavefunctions (= solutions of the Schrödinger equations) are presented to understand the wave nature of particles in atomic scale. Then the simple models for vibrational and rotational motions of molecules, and the electronic state of the hydrogen atom are treated quantum mechanically as the prototypes for more complex atoms and molecules.  
**Goal**：  
Gain the skill to solve simple Schrödinger equations using a problem of a particle in a box. Extend it to solve quantum mechanical problems of the harmonic oscillator and the rigid rotator of diatomic molecules, and the electronic motion of the hydrogen atom.  
**Contents**：  
This course will cover the following themes.  
1. Outline and introduction to elementary physical chemistry  
2. Dawn of the quantum theory  
3. The classical wave equation  
4. The Schrodinger equation  
5. A particle in a box  
6. General Principles of quantum mechanics  
7. The harmonic oscillator and the rigid rotator  
8. The hydrogen atom  
**Books required/referenced**：  
Physical Chemistry - a molecular approach by D.A.McQuarrie and J.D.Simon  
**Preparation and review**：  
Read the textbook before and after the lectures and try to solve the examples in the textbook.  
**Grading**：  
Attendance + Mid-term exam. + Final exam. (+Additional exam)  
**Remarks**：
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<tr>
<td>Special Class in Basic Chemistry II (専門基礎化学 II)</td>
<td>3rd Semester 2 Credits</td>
<td>BREEDLOVE BRIAN</td>
<td>Laboratory of Nanomaterials</td>
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</tbody>
</table>

**Course code/number**: SCH-INO211E  
**Course Title**: Special Class in Basic Chemistry II (AMC)  
**Purpose/Abstract**: This course builds from the basic electronic structure of atoms and molecules to bonding in compounds to structure and finally to the relationship between the structure and properties of compounds. It is my aim that students will develop tools needed to predict the properties from the electronic and physical structures of relatively simple compounds.  
**Goal**: The goal of this course is to learn the basics of electronic structures of atoms and molecules and bonding. In addition, students will be able to understand the relationship among those topics and the properties of compounds.  
**Contents**: Below is a tentative schedule and content for the course. The schedule may be changed due to time constraints or at the discretion of the professor.  
1. Elemental Origin and Atomic Composition  
2. Quantum Mechanics  
3. Periodic Table General Properties and Periodicity, Magnetic Properties  
4. Covalent Bonding, Lewis Structure, Molecular Orbital Method  
5. Atoms, Molecule, polyatomic molecules  
6. Valence bonding method, hybrid orbital, σ bond  
7. Molecular structure and polarity  
8. Symmetry and group theory  
9. Group theory molecular orbital, application to molecular vibration  
10. Crystal structure (1)  
11. Crystal structure (2)  
12. Ionic solids  
13. Metal and metal like  
14. Electric conduction, semiconductor, superconductivity  
**Books required/referenced**: Primary text: Inorganic Chemistry 6th Ed, General Chemistry 9th Ed. by Ebbing and Gammon and other texts  
**Preparation and review**: You should be reading the chapters and trying problems not assigned by the professor.  
**Grading**: Class attendance, homework, and two exams  
**Remarks**: email: breedlove.brian.h1@tohoku.ac.jp

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<tr>
<td>Special Class in Basic Chemistry III (専門基礎化学 III)</td>
<td>3rd Semester 2 Credits</td>
<td>和田 健彦</td>
<td>Laboratory of Nanobio Functional Materials/ Chemical Biology &amp; Supramolecular Photochirogenesis</td>
</tr>
</tbody>
</table>

**Course code/number**: SCH-ORG211E  
**Course Title**: Special Class in Basic Chemistry III (Basic Organic Chemistry I)  
**Purpose/Abstract**: Objective and Summary of Class  
(1) Structure and Bonding  
(2) Organic Compounds  
(3) Stereochemistry  
(4) Alkanes  
(5) Alkenes  
(6) Alkynes  
Intended for those students majoring in organic chemistry, this class will provide the broad fundamentals of organic chemistry needed to become a chemist. It is desirable to continue taking Chemistry C, Special Class in Basic Chemistry II, and General Organic Chemistry A, B and C as well as to take Exercises in Organic Chemistry A and Organic Chemistry I A and II A (class concerning spectroscopy)  
**Goal**:  
• To understand chemical bonds and structure of organic compounds.  
• To understand stereochemistry.  
• To understand the main reactions of alkenes via electron flow arrows.  
• To understand the main reactions of alkynes via electron flow arrows.  
**Contents**: During the class, chapters 1-8 of "Organic Chemistry, 8th ed." by McMurry will be studied. Basically, I will give quizzes for each chapter, so please do your best at preparation and review using the textbook.  
**Books required/referenced**: "Organic Chemistry 9th ed." by John McMurry  
**Preparation and review**: Preparation / review / tasks are instructed during lecture.  
**Grading**: Quiz and reports and a final exam. Quizzes will be given at the beginning of classes.  
**Remarks**: The office hours are basically from 10 am to 5 pm, from Monday to Friday.
### Course: Thermodynamics and statistical physics

**Course code/number:** SCH-PCH221E  
**Course Title:** Thermodynamics and statistical physics  
**Purpose/Abstract:**  
In this course, we study thermodynamics, statistical mechanics, and the properties of many-body systems at finite temperature. The course is intended for the understanding both of chemical physical phenomena appeared in material science. We will cover the classical thermodynamics, the relationship between the macroscopic phenomena and the microscopic properties (statistical mechanics), and the application of these ideas to the observed states of actual materials.  
**Goal:**  
Chemical energetics: entropy, work and reversibility; phase equilibria: solution properties; a statistical approach to chemical energetics and equilibria. Introduction to quantum chemistry: applications to the bonding and structure of molecules, materials and nanoparticles. Molecular properties and reactivity  
**Contents:**  
The following topics will be discussed, each of which takes two weeks.  
- Properties of ideal gases  
- Statistical thermodynamics principles  
- Statistical thermodynamics principles  
- Entropy accounting principles  
- Free-energy functions & the chemical potential  
- Application to multi-phase systems  
- Application to solids, surfaces & nanostructures  
- Fuel cell  
- Topics like as chemical reaction of fuel cells and spin ordering of magnetic materials are both included.  
**Books required/referenced:**  
Hand out materials based on Physical Chemistry - molecular approach by D.A. McQuarrie and J.D. Simon  
**Preparation and review:**  
Homeworks at adequate occasions  
**Grading:**  
Midterm and Final Examination, plus reports of several classes, and the attendance  
**Remarks:**
### Course: General Physical Chemistry B

**Course code/number**: SCH-PCH223E  
**Course Title**: General Physical Chemistry B  
**Instructor**: 篠木 保幸  
**Affiliation**: Laboratory of Nanobio Functional Materials/Chemical Biology & Supramolecular Photochirogenesis

**Purpose/Abstract**:  
The course deals with the introduction to the principles of quantum mechanics and their application to chemical systems. Topics include the formalism and mathematical tools of quantum mechanics: approximate methods; atomic structure; the chemical bond: valence bond; and molecular orbital theory.

**Goal**:  
The aim of this courses that students are able to:  
1. understand approximation methods, including the variational method and perturbation theory;  
2. explain the atomic structures and their spectroscopic properties;  
3. understand the quantum mechanical description of the chemical bond and molecular structures;  
4. be familiar with the concept of molecular orbital theory.

**Contents**:  
The contents and schedule are as shown in below:  
⑴ Introduction  
⑵ Approximation method in quantum mechanics: Variational method  
⑶ Approximation method in quantum mechanics: Perturbation theory  
⑷ Structure of the helium atom  
⑸ Multiple electron atoms and the Pauli principle  
⑹ Multiple electron atom:em symbol and atomic spectra  
⑺ Chemical bond:the hydrogen molecular ion  
⑻ Chemical bond: The molecular orbital method  
⑼ Chemical bond: the structure of diatomic molecules  
⑽ Bonding in polyatomic molecules  
⑾ Hybridization and molecular structure  
⑿ Conjugated pi-electron systems: The Huckel molecular orbital method  
⒀ Computational quantum chemistry

**Books required/referenced**:  
Physical Chemistry - a molecular approach by D.A. McQuarrie and J.D. Simon

**Preparation and review**:  
The session time is limited and therefore self-directed learning is important. Students are required to prepare and review for each class.

**Grading**:  
Students are evaluated on their class attendance, the midterm report, and the final examination.

**Remarks**:  
This class will be conducted in English.

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### Course: General Physical Chemistry C

**Course code/number**: SCH-PCH223E  
**Course Title**: General Physical Chemistry C  
**Instructor**: 荒木 保幸  
**Affiliation**: Laboratory of Nanobio Functional Materials/Chemical Biology & Supramolecular Photochirogenesis

**Purpose/Abstract**:  
Chemical kinetics, also known as reaction kinetics, is the study of the speed of chemical processes. A study of chemical kinetics includes investigations of how experimental conditions can influence on the speed of a chemical reaction. In this class, appropriate construction of mathematical models that can describe the characteristics of a chemical reaction will be discussed. Concept of “order of reaction” and “how to determine order of reaction along with integrated rate laws” are also the most important topics of this class. Moreover, the enzymatic reaction kinetics will be introduced to understand the specific examples of chemical reaction rate determination. Through the trial to solve the problems in the textbook, the establishment of the knowledge will be achieved.

**Goal**:  
The main goal is to teach principles of reaction kinetics and catalysis. Topics covered include the laws and theories governing reaction rates and mechanisms in gas, condensed phase and at the solid-liquid interface. Modern experimental approaches to study kinetics in complex chemical and biochemical systems and analysis of experimental data will be introduced. Computational approaches to estimate rates of chemical reactions and study the mechanism of catalysis will be discussed.

**Contents**:  
Contents and Progress Schedule of the Class: In this class, the contents from Chapter 27 to Chapter 31 of the textbook (Physical Chemistry - a molecular approach by D. A. McQuarrie and J.D. Simon) will be discussed.  
Chapter 27 / The Kinetic Theory of Gases  
Chapter 28 / Chemical Kinetics: Rate Laws  
Chapter 29 / Chemical Kinetics: Reaction Mechanisms  
Chapter 30 / Gas-phase Reaction Dynamics  
Chapter 31 / Solid and Surface Chemistry

**Books required/referenced**:  
Physical Chemistry - a molecular approach by D. A. McQuarrie and J.D. Simon

**Preparation and review**:  
Students who joins in this class is expected to keep prep.

**Grading**:  
Record and Evaluation Method: Class attendance (perfect attendance is 60 points), reports (perfect submission is 20 points) and scores of final examinations (full score is 20 points) are totally evaluated.  
Person who gains over 90 ponts gets AA score.

**Remarks**:  
This class will be conducted in English.
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<tbody>
<tr>
<td>Experiments in Physical Chemistry A (物理化学演習A)</td>
<td>4th Semester 1 Credit</td>
<td>米田 忠弘 高岡 毅</td>
<td>Advanced Scanning Probe Microscopy &amp; Laboratories at Katahira Campus.</td>
</tr>
</tbody>
</table>

Course code/number : SCH-PCH251E  
Course Title : Exercises of problems and topics in physical chemistry A  
Purpose/Abstract :  
Through lectures of physical chemistry classes, fundamentals of physical and mathematical knowledge will be lectured. However, it is also necessary to solve actual problems in physical chemistry issues. Topics and exercises in special cases will be extended.  
Goal :  
In this course, we try to solve problems related to the issues discussed in AMC courses. The goal of this class is to require skills through these process.  
Contents :  
Part of this class will go along with ‘Problems and solutions to accompany Physical Chemistry - molecular approach by D.A. McQuarrie and J.D. Simon’ in which the problems shown in each chapter of the text book are analyzed.  
Books required/referenced :  
Indicated by each instructor.  
Preparation and review :  
Homework at adequate occasions  
Grading :  
class attendance, reports and scores of examinations  
Remarks :  

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Course code/number : SCH-PCH224E  
Course Title : Principles of spectroscopic methods in physical chemistry  
Purpose/Abstract :  
Starting from a lecture of the basic of spectroscopy, we try to survey modern spectroscopic methods used in physical chemistry.  
Goal :  
Gain the skill for the analysis of molecules, focusing on the understanding and application to the spectroscopic methods. We cover wide area of the spectroscopic methods, including optical absorprion/emission spectroscopy and magnetic resonance spectroscopy.  
Contents :  
1) molecular spectroscopy  
2) magnetic resonance NMR  
3) photochemistry, laser spectroscopy  
Books required/referenced :  
Textbook : Physical Chemistry - a molecular approach by D. A. McQuanie and J. D. Simon  
Preparation and review :  
Preparation and review  
Grading :  
Score: every week's attendance + Final exam  
Remarks :  
Katahira Campus - South Multidisciplinary Research Laboratory Building 1 "E02" Room303  
Email : tsuyoshi.takaoka.b1@tohoku.ac.jp  
Office hours : Mon - Fri, 9:00-17:00  
Closed : Saturdays and Sundays
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<tr>
<td>SCH-INO221E</td>
<td>5th Semester 1 Credit</td>
<td>来田 恵弘</td>
<td>Advanced Scanning Probe Microscopy &amp; Laboratories at Katahira Campus.</td>
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</table>

**Course code/number**: SCH-PCH252E  
**Course Title**: Exercises of problems and topics in physical chemistry B  

**Purpose/Abstract**: Through lectures of physical chemistry classes, fundamentals of physical and mathematical knowledge will be lectured. However, it is also necessary to solve actual problems in physical chemistry issues. Topics and exercises in special cases will be extended.  

**Goal**: In this course, we try to solve problems related to the issues discussed in AMC courses. The goal of this class is to require skills through these processes.  

**Contents**: Part of this class will go along with ‘Problems and solutions to accompany Physical Chemistry - molecular approach by D.A. McQuarrie and J.D. Simon’ in which the problems shown in each chapter of the text book are analyzed.  

**Books required/referenced**: indicated by each instructor  

**Preparation and review**: Homework at adequation occasions  

**Grading**: class attendance, reports and scores of examinations  

**Remarks**:  

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<tr>
<td>SCH-PCH252E</td>
<td>5th Semester 1 Credit</td>
<td>来田 恵弘</td>
<td>Advanced Scanning Probe Microscopy &amp; Laboratories at Katahira Campus.</td>
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</table>

**Course code/number**: SCH-INO221E  
**Course Title**: General Inorganic and Analytical Chemistry A  

**Purpose/Abstract**: Thermodynamics is a powerful tool to understand the equilibrium phase relationship that is needed for materials processing including materials synthesis and growth from the conventional to the most advanced one. It also gives an insight of the nonequilibrium process in terms of the deviation from the equilibrium state. It should be also noted that thermodynamics is a powerful mean to prove your developing theory. Although thermodynamics is one of the classic academics, it is not easy to learn. This is because the ‘practical state’ is often far different from the ‘ideal’ and only ideal-gas case with mathematical expressions are simply demonstrated in teaching without showing its applications to the ‘real world’. In this class, students will have an exciting learning experience of the thermodynamics through its practical applications with simple math forms. In addition, this class is linked to the ‘Exercises in Inorganic and Analytical Chemistry A’ and students will learn about the practical use of thermodynamics by solving a few kinds of problems associated with chemical equilibrium or chemical reactions.  

**Goal**:  
- Learn 1st law and 2nd law of Thermodynamics.  
- Learn different kinds of free energy and how they are related by the Legendre transformation.  
- Learn the basic concepts of Gibbs free energy, partial molar quantity.  
- Learn the derivation of chemical potentials to understand the phase relationship.  
- Learn how to read equilibrium phase diagrams.  
- To get the idea how to apply the thermodynamics to phase equilibria and reaction process in materials synthesis and growth process.  

**Contents**:  
I. Scope of Thermodynamics  
II. 1st law and 2nd law of Thermodynamics  
III. Equilibrium  
IV. Chemical Potentials and Activities  
V. Phase Diagrams  
VI. The Kinetics of Phase Transformations  

**Books required/referenced**: Handout will be given before the class begins.  

**Preparation and review**: Students are required to prepare for the assigned part of the designated textbook for each class. They are also required to make a thorough review, mainly by completing assignments.  

**Grading**: Results of class attendance, quizzes and examination will be used for evaluation.  

**Remarks**: Contact address: uda@imr.tohoku.ac.jp Tel: 022-215-2100
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<tr>
<td>General Inorganic and Analytical Chemistry B (無機分析化学概論 B)</td>
<td>4th Semester 2 Credits</td>
<td>BREEDLOVE BRIAN</td>
<td>Laboratory of Nanomaterials</td>
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</table>

**Course code/number**: SCH-INO222E  
**Course Title**: General Inorganic and Analytical Chemistry B (AMC)  
**Purpose/Abstract**:  
This class is a survey of the general properties and reactivity of main group elements and transition metals. During the course, we cover chapters 9-22 in Shriver and Atkins' Inorganic Chemistry, 6th ed.  
**Goal**:  
The goal of this class is to learn the general trends in reactivity of the chemical elements.  
**Contents**:  

- Chemistry of main group elements  
- d-Block metals  
- Structure of d-block metal complexes  
- Basics of coordination chemistry  
**Books required/referenced**:  
Inorganic Chemistry 6th Ed. (formerly Shriver and Atkins)  
**Preparation and review**:  
read the chapters and do the problems  
**Grading**:  
Attendance and two exams  
**Remarks**:  
breedlove.brian.b1@tohoku.ac.jp

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<td>5th Semester 2 Credits</td>
<td>BREEDLOVE BRIAN</td>
<td>Laboratory of Nanomaterials</td>
</tr>
</tbody>
</table>

**Course code/number**: SCH-INO223E  
**Course Title**: General Inorganic and Analytical Chemistry B (AMC)  
**Purpose/Abstract**:  
The objective of this class is to introduce frontiers of inorganic chemistry. The aim of the class is to show how developments in inorganic chemistry impinge on the other disciplines, such as life science, condensed matter physics, and materials chemistry. We will discuss materials chemistry focusing on solid-state compounds, their structures, and electronic, magnetic, and optical properties. In addition, we will discuss nanomaterials and biosensors and introduce the area of catalysis.  
**Goal**:  
Students will gain an understanding of the properties of solid-state materials and nanomaterials and learn about f-block elements. In addition, you will learn basic concepts of catalysis and biosensors.  
**Contents**:  

- f-block elements  
- Introduction to catalysis  
- Homogeneous catalysis  
- Heterogeneous catalysis  
- Other catalytic systems (e.g., photocatalysis and electrocatalysis)  
- Biological inorganic chemistry  
- Biological inorganic processes  
- Band structures of solids and semiconductors  
- Magnetic properties of solids  
- Electronic properties of solids  
- Optical properties of solids  
- Solid-state and materials chemistry  
- Nanoscience  
- Biosensors  
**Books required/referenced**:  
Inorganic Chemistry 6th Ed.  
**Preparation and review**:  
reading  
**Grading**:  
Class attendance and two exams  
**Remarks**:  
breedlove.brian.b1@tohoku.ac.jp
Course Semester/Credits Instructor Affiliation

General Inorganic and Analytical Chemistry D (無機分析化学概論D)
6th Semester 2 Credits 火原 彰秀 Laboratory of Nano-Micro Chemical Measurements

Course code/number: SCH-INO224E
Course Title: General Analytical Chemistry: two-phase equilibrium, electroanalytical chemistry, and instrumental analysis
Purpose/Abstract:
In this course, students will understand various analytical methods based on the fundamental knowledge on analytical chemistry learnt in Special Class in Basic Chemistry IV.
Goal:
The purpose of this course is to help students explain principles, apparatuses, and applications of the analytical methods from the viewpoint of selectivity and sensitivity.
Contents:
This is a lecture-centered course with short quiz and homework report. The contents and schedule are as shon below:
1) Introduction
2) Electrochemistry
3) Potentiometry and coulometry
4) Ion selective electrode and other sensors
5) Two-phase equilibrium and extraction
6) Principle of chromatography
7) Partition chromatography
8) Ion chromatography and size exclusion chromatography
9) Review of electroanalytical chemistry, extraction, and chromatography
10) States of atoms
11) Atomic absorption spectroscopy
12) Inductively-coupled plasma optical emission and mass spectrosopies
13) X-ray generation and detection
14) X-ray fluorescence
15) Review of atomic and x-ray spectrosopies
Books required/referenced:
References are handed out at every class.
Preparation and review:
Students are expected to do homework (review).
Grading:
Quizzes in class, homework reports, and examination(s)
Remarks:
Bring your scientific calculator. E-mail: hibara@tohoku.ac.jp Lab homepage: http://www22.tagen.tohoku.ac.jp/lab/hibara/
Office hour: weekday 13:00-18:00, IMRAM West Building 1 RoomS211

Course Semester/Credits Instructor Affiliation

Exercises in Inorganic and Analytical Chemistry B (無機分析化学演習B)
5th Semester 1 Credit 高坂 亘 福山 真央 Laboratory of Solid-State Metal-Complex Chemistry Laboratory of Nano/Micro Chemical Measurements

Course code/number: SCH-INO252E
Course Title: Exercises in Inorganic and Analytical Chemistry: From Basic Inorganic Chemistry to Coordination Chemistry and Ligand-Field Theory
Purpose/Abstract:
Conduct exercises in inorganic and analytical chemistry, in particular an area from basic inorganic chemistry to coordination chemistry related to the solid-state molecular chemistry, by explaining their fields.
Goal:
To gain a deeper understanding of the course. And we hope that you may be interested in the field of the solid-state molecular chemistry.
Contents:
Conduct exercises and explanation for the fields.
• Basic of quantum chemistry
• Molecular orbital and Molecular electronic state
• Periodic table and crystal structure
• Acid-base and Oxidation-reduction
• Thermodynamics and crystal structure
• Molecular symmetry
• Ligand-field theory
• Crystal-field theory
• Coordination chemistry 1
• Coordination chemistry 2
• Analytical chemistry 1
• Analytical chemistry 2
• Analytical chemistry 3
Books required/referenced:
The problem set will be given at each class hour, but the following texts may be useful for your study: Shriver & Atkins’ Inorganic Chemistry, by P. Atkins et al., Oxford University Press. D- and F-Block Chemistry, by C. Jones, RSC, publisher.
Preparation and review:
The problems given at each class hour should be solved.
Grading:
Evaluation will be performed by your attendance records and results of the exercises.
Remarks:
w-kosaka@imr.tohoku.ac.jp 022-215-2033 maofukuyama@tohoku.ac.jp 022-217-5640
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<tbody>
<tr>
<td>General Organic Chemistry C</td>
<td>5th Semester 2</td>
<td>仙塚 和光</td>
<td>Synthetic Chemistry for Biofunctional Molecules</td>
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**Course code/number**: SCH-ORG223E

**Course Title**: General Organic Chemistry C (AMC, Chemistry of Carbonyl Compounds)

**Purpose/Abstract**:
- Learning the chemistry of carbonyl compounds - main reactions, methods of synthesis, reaction mechanisms and synthetic applications.

**Goal**:
- Understanding the chemistry of carbonyl compounds.

**Contents**:
- Lectures based on the textbook, discussions in the class, tests
  - Chapter 19 Aldehydes and Ketones: Nucleophilic Addition Reactions
  - Chapter 20 Carboxylic Acids and Nitriles
  - Chapter 21 Carboxylic Acid Derivatives
  - Chapter 22 Carbonyl Alpha-Substitution Reactions
  - Chapter 23 Carbonyl Condensation Reactions

**Books required/referenced**:
- McMurry-Organic Chemistry: chapters 19-23

**Preparation and review**:
- Reading the textbook, self-training to understand reaction mechanisms

**Grading**:
- Attendance of the class, activity in the discussions, tests results

**Remarks**:
- of aromatic stability, heterocyclic aromatic compounds, the Hückel rule, and electrophilic substitution reactions.
- Chemical properties and reactivity of alcohols, phenols, epoxides, and thiols.

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<tbody>
<tr>
<td>General Organic Chemistry A</td>
<td>4th Semester 2</td>
<td>水上 進</td>
<td>Cell Functional Molecular Chemistry</td>
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**Course code/number**: SCH-ORG221E

**Course Title**: General Organic Chemistry A

**Purpose/Abstract**:
- Objective and Summary of Class:
  - This class is part of organic chemistry classes, including Special Class in Basic Chemistry III, and General Organic Chemistry A, C, and D. The lecture covers the following topics:
    1. Basic chemistry of organic halides.
    2. Nucleophilic substitution reactions and reaction theory
    3. Diene and allylic systems
    4. Conjugated and aromatic compounds
    5. Aromatic substitution reactions
    6. Properties of alcohols, phenols, ethers, and thiols.

This class will provide the broad fundamentals of organic chemistry that are essential for students to be a chemist.

**Goal**:
- Objective of Study:
  - To understand
  - Properties of alkyl halides and related compounds, synthetic methods, radical reactions, principles of the stability of allyl radicals, the characteristics of Grignard reactions
  - Reactions of organic compounds, especially the characteristics and reaction mechanisms of nucleophilic substitutions and aliphatic reactions
  - Stability of conjugated chains, electrophilic reactions, kinetic and thermodynamic control of reactions, and the characteristics of Diels-Alder reactions
  - Structure of benzene and its derivatives, the principles

---

**Contents**:
- This class will involve chapters 10, 11, and 14–18 of Organic Chemistry 9th Ed. by John McMurry. However, the parts in chapter 14 covering spectroscopy will be omitted.
  1. Introduction
  2. Organohalides (Chapter 10)
  3. Nucleophilic substitutions and eliminations
  4. Conjugated compounds (Chapter 14)
  5. Benzene and aromaticity (Chapter 15)
  6. Electrophilic aromatic substitution (Chapter 16)
  7. Alcohols and phenols (Chapter 17)
  8. Ethers and epoxides: Thiols and Sulphides (Chapter 18)

**Books required/referenced**:
- McMurry Organic Chemistry 9th Ed.

**Preparation and review**:
- Problem-solving exercise

**Grading**:
- Grading:
  - Evaluation will be performed on the basis of exams, class participation, and homework results.

**Remarks**:
### General Organic Chemistry D

- **Semester/Credits:** 5th Semester 2 Credits
- **Instructor:** 永次 史
- **Affiliation:** Synthesis Chemistry for Biofunctional Molecules

**Course code/number:** SCH-ORG224E  
**Course Title:** General Organic Chemistry D  
**Purpose/Abstract:**  
Objective and Summary of Class:  
This class is part of series of organic chemistry classes, including General Organic Chemistry A, C, and D.  
This lecture will concern the following topics:  
1. Basic chemistry of amines and heterocycles  
2. Chemistry of biomolecules  
   - 2-1 Carbohydrates  
   - 2-2 Amines, Peptides and Proteins  
   - 2-3 Lipids  
   - 2-4 Nucleic acids  
3. The organic chemistry of metabolic pathway  
4. Pericyclic reactions: electrocyclic reactions, cycloadditions and sigmatropic rearrangements  
**Goal:**  
- To understand the synthetic method of amines and reactions of amines  
- To understand the chemical properties and reactivity of heterocyclic amines  
- To understand the structures and biological functions of biomolecules (carbohydrates, amino acids, peptides, proteins, lipids and nucleic acids)  
- To understand the organic chemistry of metabolic pathway in the cells of living organisms  
- To understand the pericyclic reactions by molecular orbital theory  
**Contents:**  
The class will involve chapters 24–30 of Organic Chemistry by John McMurry.  
**Books required/referenced:**  
Textbook and References: Organic Chemistry 8th ed. by John McMurry  
**Preparation and review:**  
They should do the homework, which is assigned in the class. In addition, they should do the exercise in the textbook.  
**Grading:**  
Record and Evaluation Method: Evaluation will be performed on the basis of exam and the homework results.  
**Remarks:**

### Exercises in Organic Chemistry A

- **Semester/Credits:** 4th Semester 1 Credit
- **Instructor:** 永次 史
- **Affiliation:** Institute of Multidisciplinary Research for Advanced Materials

**Course code/number:** SCH-ORG251E  
**Course Title:** Exercises in Organic Chemistry A  
**Purpose/Abstract:**  
Objective and Summary of Class:  
Understanding of organic chemistry will be deepened by performing exercises based on the lecture contents of “Chemistry C” and “Special Class in Basic Chemistry III” and in parallel “General Organic Chemistry A” and “Laboratory Experiments in Chemistry A” (up to chapter 18 in McMurry, “Organic Chemistry”, 8th ed.)  
**Goal:**  
It will be possible to explain basic organic chemistry in real terms. In particular, organic reaction mechanisms can be described with arrows showing the movement of electrons.  
**Contents:**  
The problems at the end of each chapter of McMurry's “Organic Chemistry”, 8th ed. up to chapter 18 will be performed. Details will be explained during the 1st lecture.  
**Books required/referenced:**  
McMurry “Organic Chemistry”, 8th ed. and 9th ed. References will be introduced accordingly.  
**Preparation and review:**  
You should study the exercise in the McMurry’s “Organic Chemistry”, 8th ed. (chapters 1–18)  
**Grading:**  
Evaluation will be based on attendance and the number of exercise answers given. Additional points will be given for answers written on the blackboard.  
**Remarks:**  
主として実践的教育から構成される実務・実践的授業／Practical business
### General Biochemistry (生物化学概論)

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<thead>
<tr>
<th>Course code/number</th>
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<tbody>
<tr>
<td>Course Title</td>
<td>General Biochemistry (生物化学概論)</td>
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</table>
| Purpose/Abstract   | To study the basic knowledge of molecular biology, biochemistry and structural biology and to understand biological phenomena at the molecular level, students will learn the following contents.  
1) Structures and chemical properties of nucleic acids  
2) Structures and chemical properties of amino acids and proteins  
3) Biochemical methods for analyzing DNA sequence, amino acid sequence, protein structures and functions  
4) Mechanisms of enzyme catalysis |
| Goal                | Students will gain deep insights into structures and physiological functions of nucleic acids, proteins and other important biomolecules. Also, students will understand molecular mechanisms of several important enzymes. |
| Contents            | Lectures will follow a textbook indicated below. Especially, we will learn Chapters 1-9 of the textbook. |
| Books required/referenced | Berg, Tymoczko and Stryer, Biochemistry, 7th international edition. |
| Preparation and review | A short test will be given as a homework in the end of every class. |
| Grading             | Attendance, attitude in class and results of examinations will be taken into consideration for grading. |
| Remarks             | |

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<td>Exercises in Organic Chemistry B</td>
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<tr>
<td>Purpose/Abstract</td>
<td>Understanding of organic chemistry will be deepened by performing exercises based on the lecture contents of &quot;General Organic Chemistry C&quot; and &quot;General Organic Chemistry D&quot; (from chapter 19 up to chapter 29 in McMurry, &quot;Organic Chemistry&quot;, 8th ed.)</td>
</tr>
<tr>
<td>Goal</td>
<td>It will be possible to explain basic organic chemistry in real terms. In particular, organic reaction mechanisms can be described with arrows showing the movement of electrons.</td>
</tr>
<tr>
<td>Contents</td>
<td>The problems at the end of each chapter of McMurry’s &quot;Organic Chemistry&quot;, 8th ed. (chapters 19-29) will be performed. Details will be explained during the 1st lecture.</td>
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<tr>
<td>Preparation and review</td>
<td>You should study the exercise in the McMurry’s &quot;Organic Chemistry&quot;, 8th ed. (chapters 19-29).</td>
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<tr>
<td>Grading</td>
<td>Evaluation will be based on attendance and the number of exercise answers given. Additional points will be given for answers written on the blackboard.</td>
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<td>Course Title</td>
<td>General Biochemistry (生物化学概論)</td>
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| Purpose/Abstract   | To study the basic knowledge of molecular biology, biochemistry and structural biology and to understand biological phenomena at the molecular level, students will learn the following contents.  
1) Structures and chemical properties of nucleic acids  
2) Structures and chemical properties of amino acids and proteins  
3) Biochemical methods for analyzing DNA sequence, amino acid sequence, protein structures and functions  
4) Mechanisms of enzyme catalysis |
| Goal                | Students will gain deep insights into structures and physiological functions of nucleic acids, proteins and other important biomolecules. Also, students will understand molecular mechanisms of several important enzymes. |
| Contents            | Lectures will follow a textbook indicated below. Especially, we will learn Chapters 1-9 of the textbook. |
| Books required/referenced | Berg, Tymoczko and Stryer, Biochemistry, 7th international edition. |
| Preparation and review | A short test will be given as a homework in the end of every class. |
| Grading             | Attendance, attitude in class and results of examinations will be taken into consideration for grading. |
| Remarks             | |
Course code/number: SCH-OCH251E
Course Title: Laboratory Experiments in Basic Chemistry

Purpose/Abstract:
You learn experimental operations of basic inorganic chemistry, basic analytical chemistry, basic physical chemistry, and basic organic chemistry.

Goal:
You can make fundamental experiments of basic inorganic chemistry, basic analytical chemistry, basic physical chemistry, and basic organic chemistry.

Contents:
⑴ Basic operations
Calibration of volumetric measuring instruments

⑵ Titrations
Neutralization titration
Precipitation titration
Oxidation-reduction titration
Complexometric titration
Neutralization titration curves and acid dissociation constants of weak acids

⑶ Analyses of absorption spectra using UV-vis spectrophotometer

⑷ Measurement of enthalpy changes in neutralization and dissolving salts

⑸ Syntheses of organic compounds
Synthesis of 6,6-nylon from cyclohexene
Synthesis of Aspirin

Books required/referenced:
Textbooks (directions for the experiments) will be given in the class; other references are shown in the directions.

Preparation and review:
Read the textbook and draw a flow chart of the experiment, in advance.

Grading:
Evaluation will be performed by your attendance records and laboratory reports.

Remarks:
Telephone: 022-795-6606 (staff room) : E-mail: kozo.toyota.d3@tohoku.ac.jp
主として実践的教育から構成される実務・実践的授業／Practical business
<table>
<thead>
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<th>Affiliation</th>
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<tbody>
<tr>
<td>Laboratory Experiments in Chemistry A (化学一般実験A)</td>
<td>6th Semester 5 Credit</td>
<td>豊田 耕三</td>
<td>Laboratory of Fundamental Chemistry</td>
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<td>Course code/number</td>
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<tr>
<td>Course Title</td>
<td>Laboratory Experiments in Chemistry</td>
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<tr>
<td>Purpose/Abstract</td>
<td>You learn fundamental experimental operations of inorganic chemistry, analytical chemistry, and the related fields.</td>
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<tr>
<td>Goal</td>
<td>You can make fundamental experiments of inorganic chemistry, analytical chemistry, and the related fields.</td>
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</tbody>
</table>
| Contents               | (1) Inorganic experiments  
Synthesis of chemicals used for measurements 
Complex synthesis  
X-ray crystal structure analysis  
UV-visible absorption spectra of metal complexes  
Complex formation reaction rates  
Cyclic voltammetry of metal complexes  
(2) Analytical experiments  
Determination of the composition of an iron phenanthroline complex by using spectrophotometry  
Determination of fluoride ion contents by using an iron-selective electrode  
(3) Optional experiments and exercises |          |                                  |
| Books required/referenced | Textbooks (directions for the experiments) will be given in the class; other references are shown in the directions. |          |                                  |
| Preparation and review | Read the textbook and draw a flow chart of the experiment, in advance. |          |                                  |
| Grading                | Evaluation will be performed by your attendance records and laboratory reports. |          |                                  |
| Remarks                | Telephone: 022-795-6606 (staff room): E-mail: kozo.toyota.d3@tohoku.ac.jp |          |                                  |

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<tbody>
<tr>
<td>Laboratory Experiments in Chemistry B (化学一般実験B)</td>
<td>7th Semester 6 Credit</td>
<td>豊田 耕三</td>
<td>Laboratory of Fundamental Chemistry</td>
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<tr>
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<tr>
<td>Course Title</td>
<td>Laboratory Experiments in Chemistry</td>
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<tr>
<td>Purpose/Abstract</td>
<td>You learn fundamental experimental operations of physical chemistry, organic chemistry, and biochemistry.</td>
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<tr>
<td>Goal</td>
<td>You can make fundamental experiments of physical chemistry, organic chemistry, and biochemistry.</td>
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</tr>
</tbody>
</table>
| Contents               | (1) Physical chemistry experiments  
Optics and molecular spectroscopy  
Molecular spectroscopy in solutions  
Electronics  
Computer calculation experiments  
(2) Organic experiments  
Basic procedures for the organic chemistry experiments  
Grignard synthesis of triphenylmethanol  
Benzoin condensation and synthesis of hexaphenylbenzencene  
Molecular modeling and various spectroscopic measurements  
(3) Biochemical experiments  
Enzyme Reaction kinetics  
Basic gene cloning |          |                                  |
| Books required/referenced | Textbooks (directions for the experiments) will be given in the class; other references are shown in the directions. |          |                                  |
| Preparation and review | Read the textbook and draw a flow chart of the experiment, in advance. |          |                                  |
| Grading                | Evaluation will be performed by your attendance records and laboratory reports. |          |                                  |
| Remarks                | Telephone: 022-795-6606 (staff room): E-mail: kozo.toyota.d3@tohoku.ac.jp |          |                                  |
**Course Code/Number:** SCH-INO303E  
**Course Title:** Electronic Properties of Inorganic Materials  
**Purpose/Abstract:**  
Properties of solid are mainly dominated by an electronic structure of material. In this class, we will learn how to understand the atomic bonds, which form a crystal structure, and electric properties such as electrical conductivity of materials based on the electronic structure.  
**Goal:**  
The goal of this class is to understand the relationship between electronic structure and atomic bond/electrical conductivity of solid. One will understand the classification of atomic bonds and the definition of metal and insulator based on an electronic structure.  
**Contents:**  
1. Introduction (crystal structure, X-ray diffraction)  
2. Bonding character in crystal (Relationship between atomic bonding character and crystal structure)  
3. Quantum-mechanical treatment of atomic bond (Molecular orbital, LCAO-approximation, Hückel method)  
4. Band Theory (Expansion of molecular orbital to crystal)  
**Books Required/Referenced:**  
The Electronic Structure and Chemistry of Solids (P. A. Cox, OXFORD), Transition Metal Oxides (P. A. Cox, OXFORD), Electronic Structure and The Properties of Solids (W. A. Harrison, Dover), etc.  
**Preparation and Review:**  
The session time is limited and therefore self-directed learning is important. Students are required to review for each class.  
**Grading:**  
Class attendance and examination  
**Remarks:**
Course code/number: SCH-PCH303E
Course Title: Physical Chemistry II A

Purpose/Abstract:
This course focuses on physical chemistry hidden in life sciences. Biomolecules function obeying some rules based on physical chemistry. These physical chemistry bases are deeply discussed.

Goal:
This course is designed to help students understand what kind of physical chemistries are utilized in the life sciences.

Contents:
The contents are as follows.
1. Introduction
2. Nucleic Acid and Protein Structure
3. Evolutionary Variation in Proteins
4. Energy and Intermolecular Forces & Molecular Dynamics Simulation
5. Molecular Recognition
6. Diffusion and Transport
7. Fidelity in DNA and Protein Synthesis
8. Current Progress of Physical Chemistry for Life Sciences

This course is centered on a lecture as well as a short questions and answers session.

Books required/referenced:

Preparation and review:
The session time is limited and therefore self-directed learning is important. Students are required to review for each class.

Grading:
Attendance in each class is evaluated. Also, a report is evaluated.

Remarks:
Questions are accepted at any time (in or after class).
<table>
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<tr>
<th>Course</th>
<th>Semester/Credits</th>
<th>Instructor</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Polymer Chemistry I</td>
<td>6th Semester</td>
<td>和田 健彦</td>
<td>Laboratory of Nanobio Functional Materials/Chemical</td>
</tr>
<tr>
<td>（高分子化学 I）</td>
<td>1 Credit</td>
<td></td>
<td>Biology &amp; Supramolecular Photochirogenesis</td>
</tr>
</tbody>
</table>

Course code/number: SCH-OCH301E
Course Title: Polymer Chemistry I

Purpose/Abstract:
The category of polymer (or macromolecular) materials is so wide, for example, familiar fiber (or textile), rubber, plastics, and photo-resist to fabricate semiconductor integrated circuit (IC). Protein and nucleic acid are also a kind of polymer, so-called biopolymer.

In this lecture, synthesis, structure, and properties of polymers will be first introduced, which is considerably different from the case of ordinary organic low-molecular weight compounds. Next, high-performance and functional polymers, and hybrid polymer materials will be explained in detail. In addition, biopolymer will be summarized from the viewpoint of biophysics.

Goal:
Aiming at making the backbone in the specific fields of advanced materials science in nano-science and nano-technology through basic understanding for polymer material chemistry.

Contents:
(1) Basic Principles
(2) Molecular Weight and Polymer Solutions.
(3) Chemical Structure and Polymer Morphorogy
(4) Chemical Structure and Polymer Properties
(5) Evaluation, Characterization and analysis of Polymers.

Books required/referenced:

Preparation and review:
The session time is limited and therefore self-directed learning is important. Students are required to review for each class.

Grading:
Attendance and regular examination

Remarks:

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<th>Instructor</th>
<th>Affiliation</th>
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<tr>
<td>Organic Chemistry I A</td>
<td>6th Semester</td>
<td>理学部化学科教官</td>
<td>AMC Course</td>
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<td>（有機化学 I A）</td>
<td>1 Credit</td>
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Course code/number: SCH-ORG301E
Course Title: Spectral identification of organic compounds

Purpose/Abstract:
Learning to elucidate structures of organic compounds from the data of MS, IR and NMR spectroscopy

Modern spectral techniques make possible elucidation of structures of organic compounds from spectral data. These skills will be trained via lectures on the principles of the spectral methods and practical exercises for solving the structures.

Goal:
Train students to identify organic compounds from spectra

Contents:
Lectures, discussions in the class, joint solution of problems, tests.

- MS spectroscopy
- GC spectroscopy
- 1H and 13 NMR spectroscopy
- Multinuclear NMR spectroscopy
- 2D NMR spectroscopy

Books required/referenced:
Silverstein. Spectroscopic identification of organic compounds

Preparation and review:
Self-training in solving problems

Grading:
Attendance of the class, activity in the discussions, tests results

Remarks:
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<tr>
<th>Course</th>
<th>Semester/Credits</th>
<th>Instructor</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Biochemistry II A</td>
<td>6th Semester</td>
<td>松井 敏高</td>
<td>Cell Functional Molecular Chemistry</td>
</tr>
<tr>
<td>(生物化学Ⅱ A)</td>
<td>1 Credit</td>
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</table>

**Course code/number**: SCH-BIC301E  
**Course Title**: Biochemistry of nucleic acid and protein synthesis.  
**Purpose/Abstract**:  
To learn the biological phenomena at the molecular level and to gain a deeper understanding of biochemistry, molecular biology and biophysics.  
It is desirable to consistently attend the discussions in Biochemistry II B concerning the photosynthesis, protein turnover and protein trafficking.  
**Goal**:  
Students will gain an understanding of the various biological phenomena related to synthesis of nucleic acids and proteins.  
**Contents**:  
The lectures will cover chapters 28 to 32 of the textbook.  
1st class DNA replication, repair and recombination  
2nd class DNA replication, repair and recombination  
3rd class RNA synthesis and processing  
4th class RNA synthesis and processing  
5th class Protein synthesis  
6th class The control of gene expression in prokaryotes  
7th class The control of gene expression in eukaryotes including practical approach for heterologous protein expression  
**Books required/referenced**:  
Berg, Tymoczko and Stryer, Biochemistry (Freeman and Co. NY). The 8th edition is available but the chapter numbers are based on the 7th edition.  
**Preparation and review**:  
Students are required not only to submit class assignments but also to review each class using handouts. If there remain any parts they cannot understand, they should ask questions in the next class.  
**Grading**:  
The results of examinations and attendance will be taken into consideration for evaluation.  
**Remarks**:  
The contact addresses of Toshitaka Matsui are as follows:  
Office: South Multidisciplinary Research Laboratory Building 1, room 607 (Katahira Campus).  
Office hour: Tuesday from 1:00pm to 3:00pm. Email: toshitaka.matsui.d5@tohoku.ac.jp

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<th>Affiliation</th>
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<td>Biochemistry II B</td>
<td>6th Semester</td>
<td>門倉 広</td>
<td>Laboratory of Structural Biology</td>
</tr>
<tr>
<td>(生物化学Ⅱ B)</td>
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</tbody>
</table>

**Course code/number**: SCH-BIC302E  
**Course Title**: Biochemistry II B  
**Purpose/Abstract**:  
To learn the biological phenomena at the molecular level and to gain a deeper understanding of biochemistry, molecular biology and biophysics.  
**Goal**:  
Students will understand the principles and basic mechanisms of photosynthesis, protein turnover and protein trafficking.  
**Contents**:  
1. Light reactions of photosynthesis  
2. Light reactions of photosynthesis  
3. Calvin cycle and the pentose phosphate pathway  
4. Protein turnover and amino acid metabolism  
5. Intracellular compartments and transport  
6. Intracellular compartments and transport  
7. Final exam  
The lectures will be interactive.  
**Books required/referenced**:  
Handouts will be provided. For further studies, use the following text books:  
**Preparation and review**:  
Some assignments may be given for better understanding.  
**Grading**:  
The final grade in this course will be based on the final exam, quizzes, attendance, and active participation.  
**Remarks**:  
The contact address of Hiroshi KADOKURA  
Office: Laboratory of Biomolecular Structure, IMRAM  
South Multidisciplinary Research Laboratory Building I, Room 508, Katahira Campus  
Email: hirosi.kadokura.b3@tohoku.ac.jp
Course code/number : SCH-OCH302E
Course Title : Polymer Chemistry II

Purpose/Abstract :
The category of polymer (or macromolecular) material is so wide, for example, familiar fiber (or textile), rubber, plastics, and photo-resist to fabricate semiconductor integrated circuit (IC). Protein and nucleic acid are also a kind of polymer, so-called biopolymer.

In this lecture, synthesis, structure, and properties of polymers will be first introduced, which is considerably different from the case of ordinary organic low-molecular weight compounds. Next, high-performance and functional polymers, and hybrid polymer materials will be explained in detail. In addition, biopolymer will be summarized from the viewpoint of biophysics.

Goal :
Aiming at making the backbone in the specific fields of advanced materials science in nano-science and nano-technology through basic understanding for polymer material chemistry.

Contents :
1. Free Radical Polymerization
2. Ionic Polymerization
3. Vinyl Polymerization with Complex Coordination Catalysts
4. Step-reaction and Ring-opening Polymerization

Books required/referenced :

Preparation and review :
The session time is limited and therefore self-directed learning is important. Students are required to review for each class.

Grading :
Attendance and regular examination

Remarks :
List of Frequently Used Academic Terms

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<th>Department</th>
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<tr>
<td>物理学</td>
<td>Physics</td>
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<tr>
<td>宇宙地球物理学</td>
<td>Astronomy and Geophysics</td>
</tr>
<tr>
<td>化学</td>
<td>Chemistry</td>
</tr>
<tr>
<td>地球環境科学</td>
<td>GeoEnvironmental Science (a division of Earth Science)</td>
</tr>
<tr>
<td>地球惑星物質科学</td>
<td>Earth and Planetary Materials Science (a division of Earth Science)</td>
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<tr>
<td>生物学</td>
<td>Biology</td>
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<th>Professor</th>
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<td>准教授</td>
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<tr>
<td>講師</td>
<td>Lecturer</td>
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<td>助教</td>
<td>Assistant Professor</td>
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<td>授業</td>
<td>Course, Class</td>
</tr>
<tr>
<td>時間割</td>
<td>Schedule, Timetable</td>
</tr>
</tbody>
</table>