# Chemistry

Programme code: MSCHEM

### Learning outcomes

Candidates completing the international Master of Science program in Chemistry should aquire knowledge, general competence and analytical skills at an advanced level targeting future employment in research (i.e PhD), industry, teaching or public administration. During the program students will chose one of the following topics for specialisation and master thesis; Applied Theoretical Chemistry, Organic Chemistry or Structural Chemistry.

**Knowledge**
Upon completing the master's degree the candidate will have
- in-depth chemical knowledge and research experience within a specialised field of chemistry through a supervised master project
- advanced chemical knowledge approaching state of the art research
- knowledge on relevant methods applied for solving analytical and chemical problems within topical research fields
- knowledge about international state of the art research in a specialised field

**Skills**
Upon completing the master's degree the candidate will be able to
- develop and implement innovative solutions to advanced chemical problems
- master a selection of advanced theoretical methods or experimental techniques
- combine chemical knowledge with other specialty fields such as physics, mathematics or biology
- perform independent critical assessments of methods and results
- continously improve and develop their research qualifications
- correctly dispose of and handle chemical substances in accordance with current health and safety regulations
- carry out an independent scientific project from hypothesis to collecting, analysing and interprerating data and final presentation both written and orally

**General competence**
Upon completing the master's degree the candidate will
- be able to acknowledge the role of chemistry as a research field within societal and historical perspectives
- recognize topical issues within the field of specialization
- be able to locate and utilize relevant information resources and carry out critical evaluation of sources and contents
- be able to disseminate knowledge and results to both peers and non-specialists
- be able to evaluate personal contributions in project related teamwork
- be able to carry out advanced tasks and projects both individually and as part of a possible interdisciplinary team

### Learning outcome –specializations

Specific learning outcomes for each specialization add to the knowledge, skill and competence attained during the international master program in Chemistry.

**Applied theoretical chemistry**
Upon completing a master's degree the candidate will
- have profound knowledge about physical chemical principles and laws
- have advanced and research based knowledge of molecular modeling
- be able to analyze industrial situations and processes with background in physical chemical knowledge
- have profound knowledge about the laws of thermodynamics and how these can be used for system far from equilibrium.
- have profound knowledge about quantum chemistry methods and be able to apply these to simple molecular systems and determine properties of simple molecules.
- be able to carry out projects based using computational chemistry.
- be able to evaluate experimental results using chemometric and other physical chemistry methods.

**Organic chemistry**
Upon completing a master's degree the candidate will
- have theoretical knowledge of general reaction mechanisms in organic chemistry as well as practical skills in how to apply essential organic chemical reactions, including choice of reagents.
- be able to carry our advanced analysis to solve organic synthetic problems, including retro-synthesis, in order to make rational choices for synthesis strategy and reagents.
- be able to evaluate (H—M—S) aspects of practical operations and reagents.
- be able to plan and to carry out multi-step organic syntheses and optimization studies based on relevant mechanistic understanding.
- be able to find appropriate purification methods for diverse product mixtures, applying extraction, distillation, sublimation or chromatographic methods etc. for product isolation.
- be able to characterize and analyze products, mixtures of compounds and processes by different analysis techniques, such as spectroscopic (UV, IR, MS, NMR etc.) and chromatographic methods (GC, HPLC etc.)
- be able to extend knowledge in other relevant scientific fields, applying available literature, databases and net-based resources.

**Structural chemistry**
Upon completing a master's degree the candidate will
- have in depth knowledge about inorganic materials, their structure and applications
- be able to plan and carry out a parameter study for development of synthesis routes for functional materials
- be able to plan and carry out a characterization study of functional materials with main emphasis on spectroscopic techniques (XAS, FT-IR, UV-vis)
- be able to analyse and interpret spectroscopic data and relate results to the chemical structure
- have knowledge about some catalytic processes and their mechanism
- be able to deduce a structure activity relationship for inorganic functional materials

**Career prospects**

The goal of the MSc in Chemistry is to educate highly qualified chemists able to work independently with chemistry related issues at an advanced level. This will make you an attractive employee in a wide variety of fields.

By majoring in chemistry, you obtain knowledge about several issues important in today's society, such as environmental issues or developing new sources of energy, which will can lead to exiting and meaningful jobs. Today we find chemists in many fields including; industry, research, central and local government administrations and in teaching covering a wide range of specified topics. Within research, you can work at universities, different kinds of research institutes like SINTEF or in industry.

Examples of jobs that would be relevant for you with an MSc in Chemistry:

- Research position at Statoil, Reinertsen Engineering, Forsvarets forskningsinstitutt, SINTEF, Borregaard, Chiron, Alpharma, GE Healthcare, Axis-Shield, Statens legemiddelverk
- Research positions at universities in Norway or international universities
- Product managers in Sigma-Aldrich and VWR
- Laboratory managers in Napro-Pharma and Norsk Hydro
- Laboratory positions in hospitals and pharmacy companies
- Consultant positions in companies like Norconsult and Rambøll
- Teachers in high schools and colleges

**Admission requirements**

In the following table you will find the admission requirements for NTNU BSc students. Compulsory courses are written in bold.

**BSc in Chemistry:**

| Year | Semester | | | | |
|---|---|---|---|---|---|
| 3 | 6. Spring | Elective course | Elective course | **TKJ4150 Organic Synthesis I** | **KJ20XX Bachelor project** |
| | 5. Autumn | **KJ1041 Chemical Bonds, Spectroscopy and Kinetics** | Elective course | Elective course | Elective course |
| 2 | 4. Spring | **KJ1042 Basic Thermodynamics with Laboratory** | **KJ2022 Spectroscopic Methods in Organic Chemistry** | **KJ2053 Chromatography** | **FY0001 Service Course in Physics** |
| | 3. Autumn | **Perspective Course** | **KJ2050 Analytical Chemistry, Basic Course** | **ST0103 Statistics with Applications** | **KJ2031 Inorganic Chemistry, Advanced Course** |
| 1 | 2. Spring | **TMT4130 Inorganic Chemistry** | **MA0002 Mathematical Methods B** | **KJ1020 Organic Chemistry** | |
| | 1. Autumn | **EXPH0001 Philosophy and Theory of Science** | **MA0001 Mathematical Methods A** | **KJ1000 General Chemistry** | |
| ECTS Credits: | | 7,5 | 7,5 | 7,5 | 7,5 |

*Students admitted to BSc in Chemistry, NTNU, before 2013 follows the relevant study plans from the year they were accepted (plan for 2010-2011, 2011-2012 or 2012-2013). Hence, this table applies for the classes from 2013 onwards. NTNU-students completing their BSc in Chemistry, specialization in applied theoretical chemistry, chemical structure and dynamics or organic chemistry with biochemistry according to the study plans from 2010-2011 or 2011-2012 are therefore qualified for admission autumn 2014.*

*NTNU BSc students under the regulations of the old study plan for BSc in Chemistry will also be qualified for admission until 2016-2017. Later, each applicant will be evaluated on an individually basis.*

For students with a bachelor's degree from outside NTNU, the following admission requirements apply:

Bachelor in Chemistry (minimum of 80 ECTS credits chemistry courses), including basic courses in general, organic, inorganic, physical and analytical chemistry. You must have

good practical skills in the chemistry lab, and sufficient knowledge of experimental methods relevant for your specialization (for example chromatography and/or spectroscopy). It's also important that you have experience with writing scientific reports. In addition, applicants must have basic knowledge in mathematics and physics. Background in statistics is recommended.

The specializations are:

- Organic chemistry
- Applied theoretical chemistry
- Structural chemistry

The admission process and subsequent area of specialization will be based on individual evaluation of your academic background.

## Information about the Master's Study

### Workload and structure

The programme requires two years of full-time study, beginning with the autumn term (medio August). The normal work load for a full-time student for one academic year is 60 ECTS credits.

The Master's study consists of two parts:

1. A written thesis of the project (Master thesis). The extent of the assignment should correspond to a work load of 60 credits. The work on the thesis is time limited. The thesis has to be submitted within May 15$^{th}$ of the 2nd year.
2. An approved selection of courses, a minimum of total 60 credits, from what (at least) 30 credits must be courses at 3000-level (master level) (UTF§14.1).

### Master's agreement

Every master student has to make a Master's agreement. This agreement comprises your syllabus and master project together with regulations for the counseling given during the master's study. The subjects, compulsory or elective, stated as syllabus in your Master's agreement cannot be changed. If there for serious reason develops a need for change, the Master's agreement must be revised. The supervisor, the responsible Department and the student must agree upon the revision and the new agreement filed.

### The Master thesis

The Master thesis should be developed as your own original work (with some support from your adviser). Any quotation, use of data, information etc from other sources (including the scientifically literature and your fellow students) should therefore be carefully listed and included in the reference list of your thesis, according to best practice within your field of study.

### Submission and Examination

The student has to:

- Register for the final master's degree exam (through STUDWEB) within February the 15th of the 2nd academic year
- Apply for approval of your individual special syllabus. It is important that this is done well in advance of the examination. A study committee will evaluate the syllabus, and if it is not accepted, you must change it. Your supervisor must approve and sign the form. Hand in the thesis (within the deadline given, see below) for print through DAIM .The Department will give you 5 copies of the thesis. At the Department of Chemistry, the special syllabus exam (and similar special curriculum courses) can be arranged at the same day as the final master exam or within two weeks before the final master exam.

In addition to the judgment of thesis, the candidate will have an oral exam consisting of:

- A presentation ("defence") of the research assignment (the master thesis) followed by a conversation on the thesis and presentation
- Examination on the special syllabus of the advanced courses which has previously not been evaluated during the study (at least 7,5 credits, preferentially individual special syllabus). All exams, except the special syllabus (if any) have to be passed before the date of the final Master's Degree exam, unless otherwise stated in your Master's agreement.

A grade is given for every course/special syllabus that constitutes a part of the exam.

**Important deadlines**

- **15th of October (1st year)**: Decide on a Master's project in cooperation with the supervisor.
- **15th of October (1st year)** Register your Master's agreement in DAIM and hand in the signed agreement, a project description and risk assessment of the project.
- **15th of February (2nd year):** Deadline for registration for the final Master's Degree exam (through STUDWEB)
- **15th of May (2nd year)**. Deadline for the submission of the master thesis. If the thesis is not submitted within this date the grade "not passed" will be awarded, unless there is handed in an application for extension of the deadline in reasonable time before the deadline. The reasons given in the application must be in accordance with Supplementary Regulations for the Natural Sciences (UTF) § 20.3 and the Examination Regulations at NTNU, § 20. Alternatively such an application may be dealt with, taken into consideration The Supplementary Regulations for the Natural Sciences (UTF) § 7 and the Examination Regulations at NTNU, § 7. See below for further information regarding §7 and §23.3.
- **15th of June (**approximately**, 2nd year)**: is the date for the final Master's Degree exam. (Individual agreement with the respective Department, approximately four weeks after the thesis is submitted).

**Leave of absence from the Master Study (UTF § 7) (extract):**

a) Leave of absence from the master studies of two years of duration and from the two last year of master studies of five years of duration is normally not granted.
b) Leaves of absence may nevertheless be granted when applied for and compelling circumstances are present. Such circumstances might be illness (yourself or among close family member) etc.

**Prolongation of the study (UTF § 20.3) (extract):**
The master thesis is time limited. In case of illness, the deadline for handing in the thesis can be postponed equivalent to the time of absence due to illness. The illness must be documented by medical certificate.

If there is a valid reason for not handing in the thesis in time, one can apply for up to three months prolongation of the deadline. If the thesis is not handed in within the extended deadline, a new extension must be applied for, or else the candidate is regarded failed. Delay of deadline can only be applied for twice.

Valid reasons for postponement (in addition to illness) is teaching, organized student activity, social work and unmerited problems concerning the thesis. Written documentation or statement is required, in addition to a new plan of completion. The Faculty, or Department when given the assignment by the Faculty, determines the application. When the reason for delay is teaching, organized student activity or social work, the extended time given is according to the time spent on these activities.

The agreed delay has no influence on the evaluation of the thesis.

## Programme Structure and Specialisations

There are three areas of scientific specialisation in this Masters programme:

Applied Theoretical Chemistry
Organic Chemistry
Structural Chemistry

## Applied theoretical chemistry

Applied theoretical chemistry is a field that covers many different areas. Common to these areas within chemistry is that they employ theoretical models, simulations and calculations to describe and predict chemical phenomena. In basic research, theoretical models are important because many of the interesting aspects take place on a scale that prevents the use of experimental tools. For example in quantum chemistry, the developement of computational methods has reached a level where we can achieve higher accuracy in calculations, than what is possible in spectroscopic experiments.

Also in the industry, the interest for theoretical methods is significant. By using simulations and modelling one can achieve increased insight into chemical processes and systems that can be harnessed, while avoiding expensive and time-consuming experiments.

Working with applied theoretical chemistry, you will have the opportunity to investigate a broad range of chemical systems through a variety of methods and angles. Regardless of the branch of applied theoretical chemistry one belongs to, a theoretical investigation follows a relatively similar procedure:

Development of a mathematical model that describes the chemistry of interest
Implementation of the mathematical model on a computer
Applying the software to investigate a relevant system
Analyze and process the large amounts of data generated

Students in our group can choose to focus on one or more of the steps in this chain. The knowledge and skills acquired are valuable in industry and research within all fields of interest.

## Organic chemistry

Organic chemistry is the study of structures, properties, and reactions of organic compounds and organic materials. The range of applications of organic compounds is enormous and organic chemistry overlaps with many areas, including medicinal chemistry, biochemistry, organometallic chemistry, polymer chemistry and many aspects of materials science. Thus, in the modern society, knowledge within organic chemistry is required within a wide range of disciplines, as demonstrated by the fact that organic synthetic products serve as e.g. plastics, drugs, pharmaceuticals, pesticides, nano-molecular devices, food additives, pigments, flavorings, fibers, clothing, petrochemicals, explosives and paints. Additionally, organic chemistry deals with life and life processes, being associated with nearly every aspect of our existence. All the key molecules of life, such as DNA, proteins, lipids and carbohydrates, are organic compounds, furnishing the energy that sustains life.

Organic chemistry traditionally includes the chemistry of fuels. Currently, the activity is increasingly connected to energy related sciences, such as energy capture and storage. Due to environmental problems arising by unwanted consequences of organic chemicals

previously introduced to the environment, the development of environment-friendly (sustainable) processes has become an interesting and challenging field of organic chemistry.
Key subtopics presently covered by the activity at the Section of Organic Chemistry includes catalysis, organometallic chemistry, chemistry of polyenes, chemo- regio- and enantioselective synthesis, heterocyclic chemistry, fluoro-containing compounds and NMR. The application of analytical tools, such as advanced NMR and other spectroscopic and chromatographic techniques are important components of all these research activities.

Some current research projects are:

- Development of new cancer treatment agents by kinase inhibition;
- Synthesis of anti-bacterial agents based on marine natural products;
- Synthesis of polyenes, modification of polyenes, polyenes as gene carriers;
- Gold catalysed chemo-, regio- and enantioselective synthesis;
- Enzyme catalysed chemo-, regio- and enantioselective synthesis;
- New anti-inflammatory compounds from plant.

Through a master in Organic Chemistry, you will get an excellent knowledge of modern theoretical and experimental organic chemistry. Your master project will give you a solid background for planning and applying a variety of organic synthetic methods in experimental research projects. You will gain experience in how the outcome, yields and selectivity of your reactions may be improved by optimization of reaction conditions. Additionally, your investigations will give you important mechanistic understanding of the theoretical basis of organic processes.

Today, NTNU is the university in Norway educating most organic chemists, being regarded as skillful synthetic chemists and well trained within analytical organic chemistry. Organic chemists from NTNU work within industry, research and administration both in Norway and abroad.

**Structural chemistry**

In inorganic Structural Chemistry, we study the structure of advanced materials and their many interesting applications for important processes in today's society. At the Department of Chemistry we have focused our activities within what is commonly referred to as Materials Science, and relevant topics for a master thesis are structural studies of advanced functional materials. This means that we produce new materials such as the super-hydrophobic aerogels, currently used in space suits, or hierarchical zeotypes with mesopores functioning as super highways to transport gas molecules to micro-reactors inside the material. The structures of these materials give them unique properties as molecular sieves with functional surface or metal sites interesting for catalytic processes. We are currently studying new materials for catalytic conversion of diesel exhaust such as copper aerogels, and the use of bimetallic copper and gold nanoparticles in hierarchical zeotypes for the industrial process of selectively oxidization of propene.

Our goal is to develop synthesis routes for new exciting materials and then characterize these systems to obtain a fundamental understanding of the structure, and then explore their behavior during realistic working conditions. The materials are therefore characterized using a range of techniques, which you will be trained in. Our research lab houses an FT-IR coupled to a GC-MS and a catalysis rig for fundamental studies of these materials.

Our group is experienced in X-ray absorption spectroscopy, a technique which requires synchrotron radiation. We frequently travel to the European Synchrotron Radiation Facility (ESRF) in Grenoble – an international state of the art research facility supported and shared

by 18 countries. Synchrotron techniques represent an important tool-kit for studying nanoparticles and functional materials under operating conditions and the techniques available at the Swiss - Norwegian beamlines (SNBL) at ESRF are crucial for our projects. Previous MSc candidates in this group often continue with research at Universities or Institutes such as SINTEF, or start working in industries such as Life Technologies, Reinertsen, Statoil and GE Healtcare.

Below you will find a table and lists of courses that describe the programme structure for each of these specialisations. The final structure of the course will be individually selected by each student allowing you to create the study programme most suited to your interests and skills. Advice will be given by the course administrators if required, and all study plans must be approved by the respective department.

You will find the course descriptions at the following web sites:
**http://www.ntnu.no/studies/courses**

The programme requires two years of full-time study, beginning with the autumn term (mid August). The normal workload for a full-time student for one academic year is 60 ECTS credits.

| Year | Semester | Course | Course | Course | Course |
|---|---|---|---|---|---|
| **2** | **Spring 4. semester** | **KJ3091 Special syllabus** | | | |
| | **Autumn 3. semester** | Elective course | **Master's Thesis** | **Master's Thesis** | **Master's Thesis** |
| **1** | **Spring 2. semester** | **Experts in Teamwork** | Elective course | Elective course | |
| | **Autumn 1. semester** | Elective course | Elective course | Elective course | |
| | | **7,5 ECTS** | **7,5 ECTS** | **7,5 ECTS** | **7,5 ECTS** |

**There are two main components to the Masters programme:**

- Masters thesis (60 ECTS credits)
- Theoretical and methodological courses, some compulsory and some elective (60 ECTS credits)

**Compulsory courses:**

- Experts in team work (7,5 credits, spring)
- KJ3091 Special syllabus for Master's degree (7,5 credits, last semester)

**Elective courses:**

There are recommended elective courses for each specialization. At least 30 ECTS credits of courses must be at the master level (3000-level), and the courses are chosen in

collaboration with the academic supervisor and the administration at the Department of Chemistry.

Recommended courses Applied theoretical chemistry:

| | |
|---|---|
| TKJ4170 Quantum chemistry | (7,5 credits, spring) |
| TKJ4175 Chemometrics | (7,5 credits, spring) |
| TKJ4200 Irreversible thermodynamics | (7,5 credits, autumn) |
| TKJ4205 Molecular modelling | (7,5 credits, autumn) |
| TKJ4215 Statistical thermodynamics in chemistry and biology | (7,5 credits, spring) |
| KJ3021 Nuclear magnetic resonance spectroscopy | (7,5 credits, autumn) |
| KJ3053 Analytical methods for industrial and env. monitoring | (7,5 credits, autumn) |
| TKP4175 Thermodynamic methods | (7,5 credits, spring) |
| TFY4205 Quantum mechanics II | (7,5 credits, autumn) |
| TFY4210 Quantum theory of many-particle systems | (7,5 credits, spring) |
| TFY4235 Computational physics | (7,5 credits, spring) |
| TFY4255 Materials physics | (7,5 credits, autumn) |
| TFY4275 Classical transport theory | (7,5 credits, spring) |
| TFY4280 Signal processing | (7,5 credits, spring) |
| TFY4292 Quantum optics | (7,5 credits, autumn) |
| TFY4340 Mesoscopic physics | (7,5 credits, spring) |
| TFY4345 Classical mechanics | (7,5 credits, spring) |
| TMA4145 Linear methods | (7,5 credits, autumn) |
| TMA4205 Numerical linear algebra | (7,5 credits, autumn) |
| TMA4300 Computer intensive statistical methods | (7,5 credits, spring) |

Recommended courses organic chemistry:

| | |
|---|---|
| KJ3021 Nuclear Magnetic Resonance Spectroscopy | (7,5 credits, autumn) |
| TKJ4155 Organic synthesis II | (7,5 credits, autumn) |
| TKJ4180 Physical organic chemistry | (7,5 credits, autumn) |
| TKJ4175 Chemometrics | (7,5 credits, spring) |
| KJ3059 Chromatography, advanced course | (7,5 credits, autumn) |
| TKJ4205 Molecular modelling | (7,5 credits, autumn) |
| TBT4135 Biopolymers | (7,5 credits, autumn) |
| TKP4110 Chemical reaction engineering | (7,5 credits, spring) |
| TKP4115 Surface and colloid chemistry | (7,5 credits, autumn) |
| TKP4155 Reaction kinetics and catalysis | (7,5 credits, autumn) |

Recommended courses structural chemistry:

| | |
|---|---|
| TKP4155 Reaction kinetics and catalysis | (7,5 credits, autumn) |
| TMT4320 Nanomaterials | (7,5 credits, autumn) |
| TKP4190 Fabrication and applications of nanomaterials | (7,5 credits, spring) |
| TKP4515 Catalysis and petrochemistry, specialization course | (7,5 credits, autumn) |
| KJ3021 Nuclear magnetic resonance spectroscopy | (7,5 credits, autumn) |
| TKJ4175 Chemometrics | (7,5 credits, spring) |
| TKJ4200 Irreversible thermodynamics | (7,5 credits, autumn) |
| TKJ4205 Molecular modelling | (7,5 credits, autumn) |
| TMT4145 Ceramic engineering | (7,5 credits, autumn) |
| TMT4285 Hydrogen technology, fuel cells and solar cells | (7,5 credits, spring) |
| TKP4130 Polymer chemistry | (7,5 credits, spring) |
| TKP4150 Petrochemistry and oil refining | (7,5 credits, spring) |

**Contact information and counselling**

Address: NTNU, Faculty for Natural Sciences and Technology, 7491 Trondheim, Norway
Telephone: 73 59 41 97
E-mail: studier-nt@nt.ntnu.no
URL: http://www.ntnu.no/nt/english
http://www.ntnu.edu/studies/msenvitox

**Study advisors:**

Kristin Omre +47 73 59 34 01
Siri Bremdal +47 73 59 45 52